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Application of Soft Computing Techniques - A Case Study of Reservoir

Qamar Sultana[1], Asma Sultana[2]

[1]Associate Professor, Civil Engineering Dept., Muffakham Jah College of Engg. & Tech, Hyd., India,
[2]Assistant Professor, Civil Engineering Dept., Muffakham Jah College of Engg. & Tech, Hyd., India,

ABSTRACT

The sediment accumulation takes place continuously in the reservoirs, which occupies the useful space which is meant for storage of water, which is a huge loss for mankind. Various methods such as hydrographic surveys have been applied to know the sediment retaining in reservoirs. In this study, various soft computing techniques have been applied to determine the sediment volume retained in reservoir using MATLAB software. It is determined using the artificial neural technique (ANN) with the feed forward back propagation network (FFBP) and Fuzzy Logic model (FL). The input data considered for the ANN modelling is the annual inflows, annual outflows and annual rainfall for the simulation of volume of sediment retained in the reservoir for a period of thirty one years. The developed model has been applied for the Sriramsagar reservoir of Godavari basin.

Key Words*: *Reservoir Sedimentation, Artificial Neural Networks, Fuzzy Logic.

1. INTRODUCTION

The problem confronting the project planner is to estimate the rate of deposition and the period of time before the sediment will interfere with the useful function of the reservoir. The replacement cost of storage lost due to sediment accumulation in American reservoirs amounts to millions of dollars annually (Chow, 1964). There are a series of basic steps to follow in studying the sedimentation processes in reservoirs. First, sediment transported by the upstream river system into a reservoir is deposited and/or transported at a reduced rate further into the reservoir, the distance being dependent on the decreased water velocities. As sediment accumulates in the reservoir, storage capacity is reduced. The continued deposition develops distribution patterns within the reservoir which are greatly influenced by both operations of the reservoir and timing of large flood inflows. Deposition of the coarser sediments occurs in the upper or delta reaches while finer sediments may reach the dam and influences the design of the outlet works

2. STUDY AREA AND DATA AQUIREMENT

The sediment retained in the reservoir is determined for Sriramsagar reservoir (SRSP). It was earlier known as the Pochampadu irrigation project which is constructed on Godavari River. The Godavari River is one of the

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major peninsular rivers in southern India. This irrigation 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 200 km from Hyderabad city. The data of inflows, outflows, rainfall and capacity was acquired from Sriramsagar Reservoir Camp Office-I, the sediment data was collected from Central Water Commission and the volume of sediment retained in the reservoir was taken from the then A.P and now Telangana State Engineering and Research Labs.

3. DATA ANALYSIS

The annual rate of siltation was calculated using the sediment data from the surveys conducted by the then A.P and now Telangana State Engineering and Research Labs during the years 1979, 1981, 1983, 1984, 1994 and 2014, which is shown in the Table 1. The parameters annual inflows, annual outflows and annual rainfall for a period of thirty one years are used as inputs for the ANN model and sediment volume retained in the reservoir is used as the output parameter.

Table 1 Annual rate of siltation of Sriramsagar reservoir

Year	Water level in reservoir (m)	Original capacity at given w.r.l (Mcum)	Capacity as per survey (Mcum)	Total volume of sediment (Mcum)	Annual volume of sediment (Mcum)	Annual rate of siltation (%)
Dec. 1979	322.478	606.451	380.56	226	22.6	0.71
Nov. 1981	322.478	606.451	338.0	268.451	22.37	0.7
Jan. 1983	326.136	1184.59	942.36	242.23	17.3	0.545
Dec. 1984	332.537	3172	2377.37	794.63	52.97	1.67
Dec. 1994	332.537	3172	2557.25	614.75	25.61	0.807
Jan. 2014	332.537	3172	2266.26	905.74	20.585	0.648

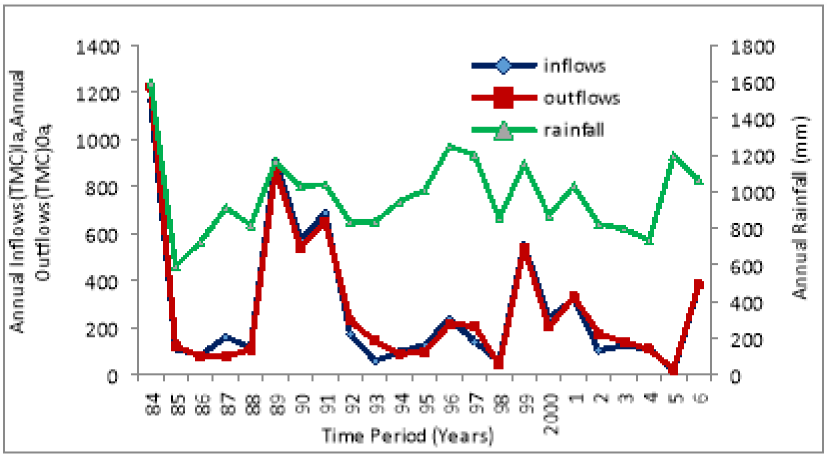

Figure 1 Time series plot of annual inflows, outflows and rainfall

The variations of annual inflows, outflows and rainfall over a period of time are shown in the Fig. 1. From the figure it can be seen that the inflows and outflows are following the same trend over a period of time. The correlation analysis of the input and output parameters is conducted which is shown in the Table 2. From the values of correlation coefficients, it is seen that the rainfall parameter correlates with the output parameter, sediment volume better when compared to the correlation of inflows and outflows with the sediment volume.

Table 2 Correlation analysis of available data

Parameter	R_a	I_a	O_a	S_v
R_a	1			
I_a	0.6846022	1		
O_a	0.99033	0.99033	1	
S_v	0.5359399	0.2917768	0.30042	1

4. MODELS APPLICATION

4.1 ANN Model

To simulate volume of sediment retained in the reservoir, the artificial neural network (ANN) model developed is a multi-layered perceptron (MLP). A three layered back propagation network model trained by Levenberg Marquardt optimization algorithm with the feed forward back propagation (FFBP) network is used.

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Table 3. Mean square error and coefficient of determination values-sediment retained

No of hidden neurons	Mean Square Error (MSE)			Coefficient of Determination (R^2)			
	Training	Validation	Testing	Training	Validation	Testing	Overall
5	0.0100	0.06540	0.04086	0.9795	0.87233	0.9666	0.95316
6	0.00264	0.00234	0.00444	0.9945	0.9981	0.9754	0.981
7	0.01088	0.00140	0.00478	0.9767	0.9938	0.9924	0.9675
8	0.02172	0.00303	0.00415	0.9476	0.9544	0.9173	0.941
9	0.00258	0.00207	0.01228	0.9988	0.974	0.933	0.9638
10	**0.00054**	**0.00640**	**0.00202**	**0.9991**	**0.9564**	**0.9844**	**0.9775**
11	0.01202	0.00267	0.00917	0.97188	0.9808	0.90358	0.9516

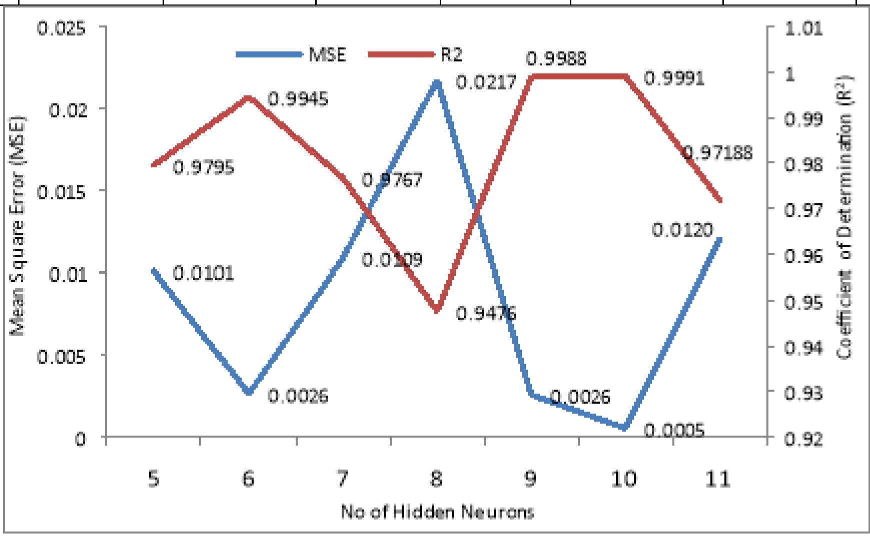

Figure 2. Plot of mean square error and coefficient of determination values

The number of parameters to be given as input in the ANN model was determined on basis of parameters causing and affecting the underlying process and which are also easily measurable at the reservoir site. For selecting the number of hidden neurons, the data was trained for the selected inputs and target for different numbers of hidden neurons. The values of mean square error (MSE) and coefficient of determination (R^2) for different numbers of hidden neurons were determined and the number of hidden neurons with the least MSE and the maximum R^2 was selected for the network. Table 3 shows the mean square error and coefficient of determination values for different values of hidden neurons. In the present study, the network with ten hidden neurons has the least mean square error and the maximum coefficient of determination value which is shown in the Fig. 2 and hence is selected for the simulation of volume of sediment retained in the reservoir.

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The architecture of 3-10-1 is selected which means the network uses three input parameters, ten hidden neurons and one output parameter. The annual data of inflows, outflows and rainfall as input parameters and volume of sediment retained in the reservoir as output parameter for thirty one years were used, out of which 70% (21 years) is used for training and 30%(10) is used validation and testing. The input data is normalised between 0 and 1. For training purpose, the back propagation training algorithm was used along with TRAINLM (Levenberg-Marquardt) - training function, TRAINGDM (gradient descent momentum) - learning function and TANSIG (Logistic Sigmoid) - transfer function. Once the training process was satisfactorily completed, the network was saved, the test and validation data sets recalled, and values predicted by the model were compared with the observed values. The performance of the models was tested through statistical indicators such as the coefficient of correlation (R), coefficient of determination (R^2), root mean square error (RMSE), Nash Sutcliffe's model efficiency coefficient (E_{NS}), mean absolute error (MAE) and difference in peak (DP).

4.2 Fuzzy Logic Model

For the simulation of the values of volume of sediment retained in reservoir, the Fuzzy Logic model is developed using Matlab fuzzy editor, with the Mamdani fuzzy inference system. The input variables (annual rainfall and annual inflows) and output variable (annual sediment retained volume) are divided into subsets with triangular membership functions with equal base widths. These subsets are very low (VL), low (L), medium (M), high (H), very high (VH), extreme high (EH). Accordingly, thirty six fuzzy rules that express a linguistic relationship between the inputs and output are formulated. The performance of the models was tested through statistical indicators such as the coefficient of correlation (R), coefficient of determination (R^2), root mean square error (RMSE), Nash Sutcliffe's model efficiency coefficient (E_{NS}), mean absolute error (MAE) and difference in peak (DP).

5. RESULTS AND DISCUSSION

The results of the application of the various models for the simulation of the reservoir sediment are discussed below. The various techniques applied are the empirical, ANN and the fuzzy logic. The discussion for the estimation of trap efficiency by empirical method is presented along with the results of the estimation of the useful life of reservoir. The results of the simulation of volume of sediment retained in reservoir and trap efficiency of reservoir by ANN and fuzzy logic techniques are discussed along with the prediction of trap efficiencies using the ANN technique for the future period. The comparison of results of the ANN and Fuzzy Logic models for the simulation of sediment volume retained in reservoir and trap efficiency of reservoir are discussed along with the discussions of the limitations of the models.

5.1 ANN Model

The volume of sediment retained in the Sriramsagar reservoir has been simulated considering the annual rainfall, inflows and outflows as the factors affecting the sediment accumulated in the reservoir. The data used

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and analysed for the simulation are given in the chapter five. The simulation has been done by using the artificial neural network technique (ANN), with the feed forward back propagation network, the methodology of which has been presented in the chapter three. The volume of sediment retained in the reservoir is considered as the target which is supplied to the model during the analysis stage. The simulated values by the ANN model are shown in the Table 4 along with the observed values of the sediment retained and Fig. 3 shows plot of it.

Table 4. Simulation of sediment retained in the reservoir by ANN model

	Year	Observed Volume	Volume of
1	1983	17.3	17.30
2	1984	52.97	52.97
3	1985	25.61	23.99
4	1986	25.61	26.19
5	1987	25.61	21.27
6	1988	25.61	25.87
7	1989	25.61	25.64
8	1990	25.61	28.20
9	1991	25.61	25.03
10	1992	25.61	26.01
11	1993	25.61	23.51
12	1994	25.21	21.01
13	1995	20.58	20.585
14	1996	20.58	16.01
15	1997	20.58	20.01
16	1998	20.58	20.52
17	1999	20.58	21.15
18	2000	20.58	18.25
19	2001	20.58	20.90
20	2002	20.58	21.18
21	2003	20.58	21.76
22	2004	20.58	27.40
23	2005	20.58	20.42
24	2006	20.58	18.52
25	2007	20.58	22.49
26	2008	20.58	21.87
27	2009	20.58	26.99
28	2010	20.58	21.33
29	2011	20.58	20.99
30	2012	20.58	23.42
31	2013	20.58	20.65
AVERAGE		22.98	23.21

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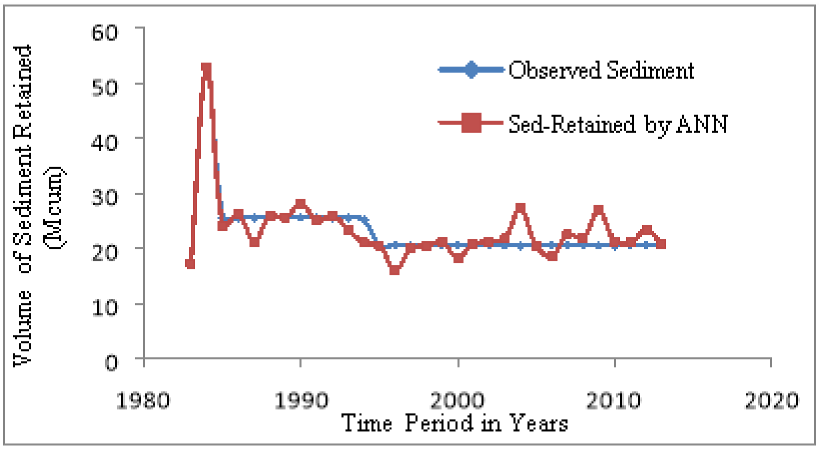

Figure 3. Plot of observed and simulated sediment retained by ANN

The performance of the ANN model for the simulation of the sediment volume is tested by the statistical parameters such as the correlation coefficient (R), coefficient of determination (R^2), root mean square error (RMSE), Nash Sutcliffe's model efficiency coefficient (E_{NS}), mean absolute error (MAE) and difference in peak (DP) which are shown in the Table 5. The correlation coefficient for the ANN technique is 0.95914, the model efficiency values are 0.8322.The efficiency of ANN model is nearing to 1 which means that the performance of this model is very good. The difference in peak values of ANN simulated value and the observed data is zero.

Table 5. Performance statistics of the ANN model-Sediment Retained

Statistical Parameter	ANN Model
R - Correlation Coeff	0.95914
R2 - Coeff of Determination	0.91995
RMSE - Root Mean Square Error	2.496
E - Nash-Sutcliffe Model Efficiency Coeff	0.8322
MAE - Mean Absolute Error	-0.1433
DP - Difference in Peak	0

The Fig. 4 and Fig. 5 show the scatter plot of the observed and simulated data by ANN model and their normalised values. The plots show a close scatter and a good coefficient of determination (R^2) value of 0.8585 and 0.9888.

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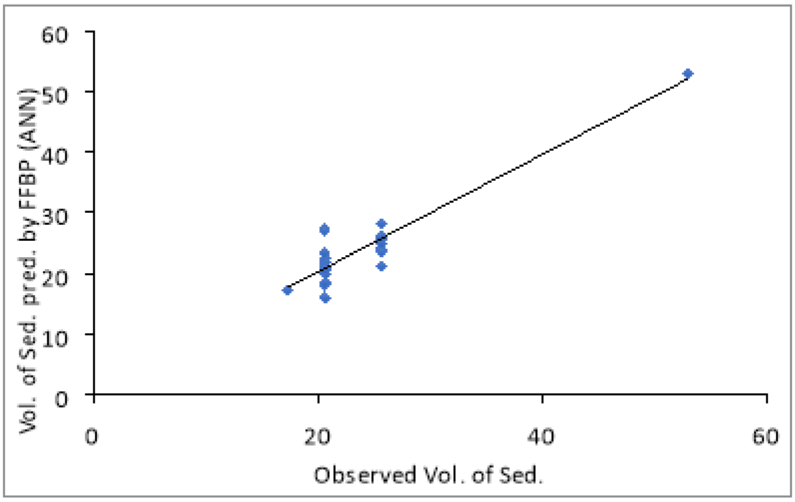

Figure 4. Scatter plots of the observed and simulated data using ANN technique

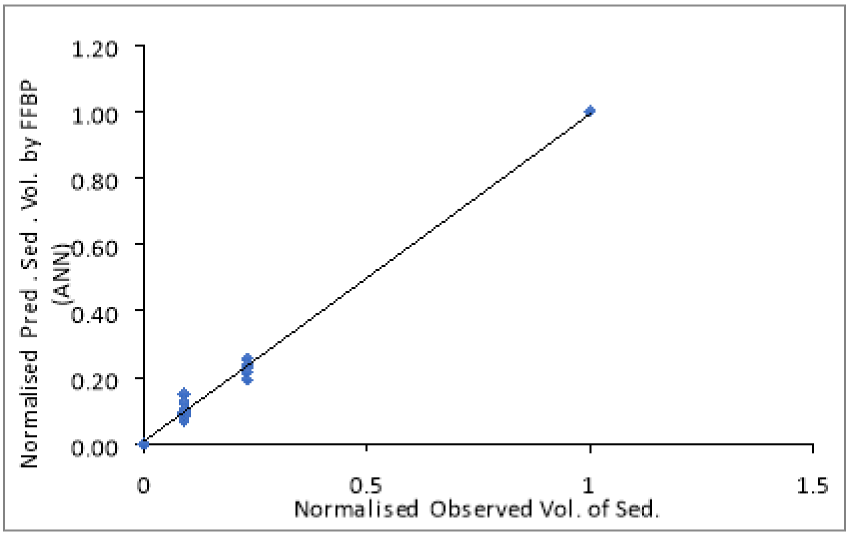

Figure 5. Scatter plots of normalised observed and simulated data using ANN technique

5.2 Fuzzy Logic Model

For the application of fuzzy logic technique, the input parameters (annual inflows and annual rainfall) and output parameter (annual sediment retained) are divided into subsets with triangular fuzzy memberships. These subsets are very low (VL), low (L), medium (M), high (H), very high (VH), extreme high (EH). Thirty six fuzzy rules were formulated. The sediment retained values, simulated by the fuzzy logic model after assigning the membership functions and formulating the fuzzy rules are shown in the Table 6 and the plot of it is shown in Fig. 6.

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Table 6. Volume of sediment retained- simulated by using Fuzzy Logic

S.No	Year	Annual Rainfall (mm)	Annual Inflows (Mm^3)	Observed Volume of Sediment	Sediment Retained by Fuzzy
1	1983	1184.207	32887.36	17.3	19
2	1984	591.9661	3159.214	52.97	22.7
3	1985	728.8235	2425.04	25.61	22.1
4	1986	767.237	4585.372	25.61	23.5
5	1987	3828.964	43137.58	25.61	50.7
6	1988	818.203	3215.825	25.61	22.8
7	1989	1166.993	25900.39	25.61	38.5
8	1990	1028.219	16351.96	25.61	30.2
9	1991	1040.547	19509.94	25.61	33.6
10	1992	833.747	4863.1	25.61	23.6
11	1993	835.416	1666.596	25.61	23
12	1994	947.891	2775.153	25.21	23.7
13	1995	1008.65	3586.791	20.58	23.9
14	1996	1248.731	6815.24	20.58	22.9
15	1997	1201.493	4049.052	20.58	24.4
16	1998	853.921	1583.046	20.58	23.1
17	1999	1150.78	15672.72	20.58	29.8
18	2000	872.886	6815.07	20.58	24.1
19	2001	1031.159	9185.724	20.58	24.7

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20	2002	823.496	2947.728	20.58	22.9
21	2003	798.663	3505.653	20.58	22.9
22	2004	733.1	3147.254	20.58	22.7
23	2005	1197.8	541.1578	20.58	24.4
24	2006	1066.6	10622.35	20.58	26.2
25	2007	917.6	14625.44	20.58	28.6
26	2008	959.3	2920.039	20.58	23.7
27	2009	689.7	3707.051	20.58	23
28	2010	1192.7	1061.095	20.58	24.4
29	2011	962.9	8848.575	20.58	24.4
30	2012	845.4	4896.577	20.58	23.6
31	2013	609.4444	418.4686	20.58	20
Average				23.12871	25.58387

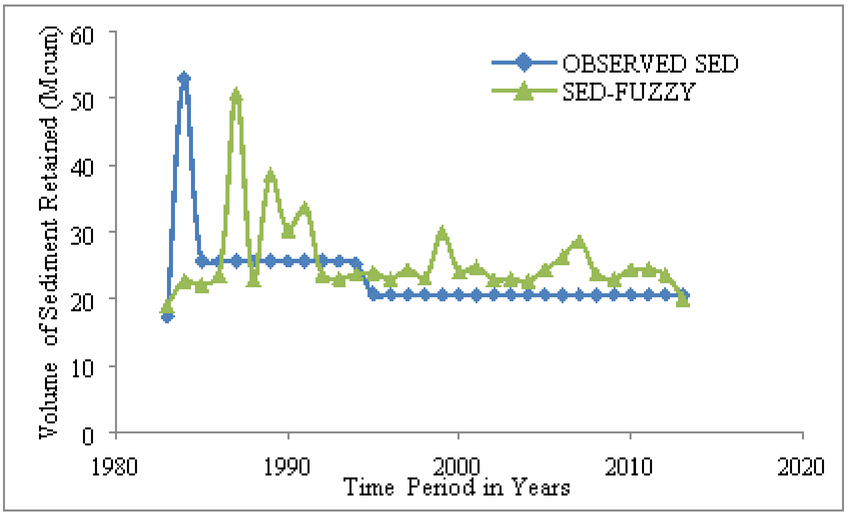

Figure 6. Plot of Observed and simulated sediment retained by fuzzy logic

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The performance statistic parameters of the fuzzy logic model are shown in the Table 7. The correlation coefficient value is 0.8932 for the total period and is reasonably good but the efficiency value of the model is very less, but closer to zero, which indicates that it is just below average efficient model. The difference in peak values of the observed and the simulated trap efficiencies is 2.22, which shows that there is a variation in the peak values of the observed and the simulated values.

Table 7. Performance Statistics of Fuzzy Logic Model-sediment retained

Statistical Parameter	Fuzzy Logic Model
R - Correlation Coeff	0.8932
R2 - Coeff of Determination	0.7979
RMSE - Root Mean Square Error	8.412
E - Nash-Sutcliffe Model Efficiency Coeff	-0.9807
MAE - Mean Absolute Error	-2.635
DP - Difference in Peak	2.27

5.3 Comparison of Models.

The sediment retained in reservoir simulated by the ANN and fuzzy logic model are shown in the Table 8 along with the observed data and the plot of it is shown in the Fig. 7. The average values generated by the ANN and Fuzzy Logic models are 23.21 Mcum and 25.58 Mcum respectively, which are seen from the Table 8. The ANN model simulates the average value closer to the observed value which is 22.98 Mcum.

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Table 8. Simulated sediment retained in reservoir by different models

S.No	Year	Observed Volume of sediment (Mcum)	Volume of sediment by ANN Model (Mcum)	% Error for ANN Model	Volume of sediment by Fuzzy Logic Model (Mcum)	% Error for Fuzzy Logic Model
1	1983	17.3	17.30	0	19	9.82659
2	1984	52.97	52.97	0	22.7	-57.1456
3	1985	25.61	23.99	-6.32565	22.1	-13.7056
4	1986	25.61	26.19	2.26474	23.5	-8.23897
5	1987	25.61	21.27	-16.9465	50.7	97.96954
6	1988	25.61	25.87	1.015228	22.8	-10.9723
7	1989	25.61	25.64	0.117142	38.5	50.3319
8	1990	25.61	28.20	10.11324	30.2	17.92269
9	1991	25.61	25.03	-2.26474	33.6	31.19875
10	1992	25.61	26.01	1.56189	23.6	-7.8485
11	1993	25.61	23.51	-8.19992	23	-10.1913
12	1994	25.21	21.01	-16.6601	23.7	-5.98969
13	1995	20.58	20.585	0.024295	23.9	16.13217
14	1996	20.58	16.01	-22.206	22.9	11.27308
15	1997	20.58	20.01	-2.76968	24.4	18.56171
16	1998	20.58	20.52	-0.29155	23.1	12.2449
17	1999	20.58	21.15	2.769679	29.8	44.80078
18	2000	20.58	18.25	-11.3217	24.1	17.10398
19	2001	20.58	20.90	1.554908	24.7	20.01944
20	2002	20.58	21.18	2.915452	22.9	11.27308
21	2003	20.58	21.76	5.733722	22.9	11.27308
22	2004	20.58	27.40	33.13897	22.7	10.30126
23	2005	20.58	20.42	-0.77745	24.4	18.56171
24	2006	20.58	18.52	-10.0097	26.2	27.30807
25	2007	20.58	22.49	9.280855	28.6	38.96987
26	2008	20.58	21.87	6.268222	23.7	15.16035
27	2009	20.58	26.99	31.14674	23	11.75899
28	2010	20.58	21.33	3.644315	24.4	18.56171
29	2011	20.58	20.99	1.992225	24.4	18.56171
30	2012	20.58	23.42	13.79981	23.6	14.67444
31	2013	20.58	20.65	0.340136	20	-2.81827
AVERAGE		22.98	23.21	0.996953	25.583	13.90176

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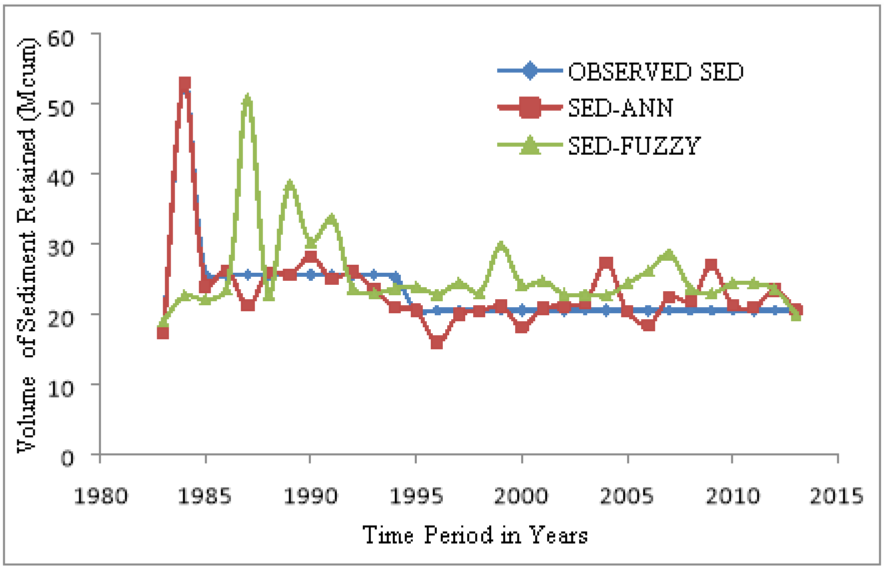

Figure 7. Plot of sediment retained values simulated by different models

The performance statistics of both the ANN and fuzzy logic models is presented in the Table 9. The coefficient of determination (R^2) of ANN model is 0.91995 which is higher when compared to that of Fuzzy Logic model which is 0.7979 which indicates that the values generated by ANN model are better correlated with the observed sediment values when compared to that of the values generated by fuzzy logic model. The root mean square error (RMSE) value by the ANN and the fuzzy logic model are 2.496 and 8.412 respectively, which indicates that the ANN model simulates the trap efficiency values with less error, when compared to that of the fuzzy logic model values. The model efficiency value for the ANN model is positive with a value of 0.8322 (83.22 %) where as it is negative for the fuzzy logic model, which indicates that the efficiency of the ANN model is much better than that of fuzzy logic model.

Table 9. Performance Statistics of ANN and Fuzzy Logic-sediment retained

Statistical Parameter	ANN Model	Fuzzy Logic Model
R - Correlation Coeff	0.95914	0.8932
R2 - Coeff of Determination	0.91995	0.7979
RMSE - Root Mean Square Error	2.496	8.412
E - Nash-Sutcliffe Model Efficiency Coeff	0.8322	-0.9807
MAE - Mean Absolute Error	-0.1433	-2.635
DP - Difference in Peak	0	2.27

6. CONCLUSIONS

- It is found from the results of simulation of sediment retained in reservoir using ANN model of Table 8, that the percentage error between the observed and simulated values varies within a range of -22% to +33%.
- From the results of simulation of sediment retained using fuzzy logic, it is seen that the percentage error between the observed and simulated values varies within a range of -57% to +50%.
- From the Table 9, the coefficient of determination (R^2) value for the sediment retained in reservoir is found to be 0.9199 for ANN model and 0.7979 for fuzzy logic model, which shows the better accuracy of the ANN model.
- Based on the simulation results and the statistical parameters, it can be concluded that the developed ANN model is more suitable for this reservoir.

REFERENCES

1. Agarwal, A., Rai, R.K., Upadhyay, A. (2009). "Forecasting of Runoff and Sediment Yield Using Artificial Neural Networks", *J. Water Resources and Protection, 1(5),* 368-375.
2. Bowden, G.J., Dandy, G. C., and Maier, H.R. (2005a). "Input determination for neural network models in water resources applications, Part-I- Background and methodology." *Journal of Hydrology,* 75-92.
3. Chow, yen Te. (1964). Handbook of Applied Hydrology, McGraw-Hill,New York, N.Y.
4. Hundecha, Y., Bardossey, A., and Theisen, H.W. (2001). "Development of fuzzy logic based rainfall runoff model*", J. Hydrol. Sc., 46(3),* 363–376.
5. Jothiprakash, V. and Garg, V. (2009). "Reservoir Sedimentation Estimation Using, Artificial Neural Network", *J. of Hydrologic Engg. ,14 (9).*
6. Kisi, O. (2004). "Daily suspended sediment modelling using a fuzzy differential evolution approach", *Hydrological Sciences Journal, 49(1).*
7. Kothari, M. and Gharde, K.D. (2015), "Application of ANN and fuzzy logic algorithms for streamflow modelling of Savitri catchment", *J. Earth Syst. Sci. 5(124), 933*–943.
8. Sultana Q., Gopal Naik M. (2015). "Estimation of Sediment Retained in Sriramsagar Reservoir using Artificial Neural Technique and Conventional Method", Proc. National Conference on "*World, Environment and Society(NCWES-2015)*", July 30th -31st, Vol.1, pp. 580-586.
9. Zadeh, L.A (1973). "Outline of a new approach to the analysis of complex systems and decision processes". *IEEE Trans. Systems, Man and Cybernetics, 3: 28–44.*
10. Zadeh, L.A. (1965). "Fuzzy sets", Information and Control, 8 (3), 338–353.