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Research Paper

Comparison of Multiple Lenear Regression & Artificial Neural Network for Reservoir Operation – Case Study Of Gosikhurd Reservoir

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ABSTRACT:- In recent years, artificial intelligence techniques like Artificial Neural Networks (ANN) have arisen as an alternative to overcome some of the limitations of traditional methods .The most important advantage of ANN is that it can effectively approximate a nonlinear relationship between input and output parameters.

A case study of Gosikhurd a major multipurpose project Is considered. Simulation model is developed for the Gosikhurd Reservoir for forty seven years historical data with 10 daily interval. Using the simulation results mathematical model for multiple linear regression and for Artificial Neural Network are formulated and the results are also compared.

The results demonstrates that ANN is a effective and powerful tool in mapping hydrologic parameters i.e. input and output and is an excellent alternative for deriving reservoir operating policy.

Keywords:- *Simulation, Multiple Linear regression, Artificial Neural Network, Reservoir operation.*

I. INTRODUCTION

Once the structural facilities like dams, barrages and distribution network etc. are constructed, the benefits that could be received depends to a large extent, upon how well these facilities are operated and managed. The objective of the present work is to study the applicability of Artificial Neural Network (ANN) in modelling reservoir operation. For this research study Gosikhurd a major project perhaps the largest reservoir of Vidarbha region, is considered.

The objective is attained through the following steps:

1. Hydrological data like inflow, irrigation and non-irrigation demands, and physical features of the reservoir like Area, Capacity relation with elevation, FRL. MDDL and evaporation were collected from the project authority. Reservoir simulation was carried out for Forty seven years with 10 daily intervals.
2. Using the simulation analysis mathematical model using i) Multiple Linear Regression(MLR) and ii) Artificial Neural Networks (ANN) are developed . Which gives the functional relationship between output (closing capacity/ water levels / closing area) and inputs (initial storage/level, Inflow, demands & evaporation).
3. Performance of i) multiple regression analysis and ii) Artificial Neural Networks (ANN) are compared.

II. APPLICATION OF ANN IN RESERVOIR OPERATION

Since the early 1990’s there has been a rapidly growing interest among engineers & scientist to apply ANN in diverse field of water resources engineering. Raman and Chandramouli (1996) used artificial neural networks for deriving better operating policy for the Aliyer dam in Tamil Nadu. General operating policies were derived using neural network model from the DP model. The results of ANN with dynamic programming algorithm provided better performance than the other models. Jain, Das and Shrivastava(1999) used artificial neural network for reservoir inflow prediction and the operation for upper Indravati Multipurpose Project, Orissa. They developed two ANN to model the reservoir inflows and to map the operation policy. They found

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that ANN was suitable to predict high flows. They concluded that ANN was a powerful tool for input output mapping and can be used effectively for reservoir inflow forecasting & operation. Chandramouli et al (2002), Cancelliere et all (2002), Oscar Dollins and Eduardo Varas (2004) , Haddad and Alimohammadi (2005), Farid Sharifi, Omid Haddad and Mahsoo Naderi (2005), Paulo Chaves and Toshiharu Kojiri (2007) , Paulo Chaves & Fi John Chang (2008), Yi min Wang at all (2009) , Amir Ali Moaven Shahid (2009),Paresh Chandra Deka and V. Chandramouli (2009), El Shafie A at all (2011), Sabah S Fayaed at all (2011), T. S. Abdulkadir at all (2012) are among the others successfully studied the application of ANN in optimal operation of reservoir system. They concluded and recommended that forecasting using ANN is very versatile tool in reservoir operation.

III. CASE STUDY

To develop and compare the application potential of the Artificial Neural Network model in attaining the reservoir operational objectives one major irrigation project " Gosikhurd project" of Bhandara district is taken as a case study. The Gosikhurd project is located in Eastern Vidarbha region. Project envisages Reservoir across Vainganga River a major river near village Gosi. in Pauni tahasil of Bhandara district. This is a multipurpose project and is intended to cater the irrigation of 190000 hector annually as well as domestic and industrial water demands to the tune of 124 Mm^3 annually. It augments about 229 Mm^3 annually to an existing tank Asolamendha during monsoon. Expected annual utilisation is about 1613.10 Mm^3 . The Reservoir has two main canals one on each bank.

Salient features of Gosikhurd Reservoir are shown below.

Sr.No.	Particulars	Gosikhurd Storage
1	Location :- Village/Tahasil/Districr	Gosi/Pauni/Bhandara
2.	River :-	Vainganga river
3.	Catchment area :- Gross/Free	34862Sq.Km./5902 Sq.Km.
4.	Avg. Annual Rainfall	1200 mm
5.	Water availability :- i) at 75 % dependability ii) at 90 % dependability	3407.688 Mm^3 (Year 1966) 2987.411 Mm^3 (Year 1996)
6.	Storage capacity :- Live	1146..080 Mm^3
7.	FRL Level / MDDL Level :-	245.50 / 241.290 m
8.	FRL Area / MDDL Area :-	222.965 Mm^2 / 102.822 Mm^2
9.	FRL Capacity / MDDL Capacity :-	1146.08 Mm^3 / 376.092 Mm^3
10.	Annual Water demand :- i) Irrigation ii)Water Supply iii)Feeding to existing Asola Tank iv) Evaporation	911.414 Mm^3 123.69 Mm^3 229.00 Mm^3 348.996 Mm^3 } 1613.10 Mm^3

IV. RESERVOIR SIMULATION

Reservoir simulation for 10 daily intervals from year 1960 to 2006 i.e. for forty-seven years is carried out. The demands that can be fulfilled with 100 % success i.e. 100 out of 100 years the demand is fulfilled are arrived by trial and error by adjusting the reservoir releases. With these demands the simulation is repeated and the demands are readjusted in such a way that all forty-seven years we as successful years. I.e. the contemplated demands will be fulfilled.

The table indicates the abstract of simulation study.

Sr.No.	Year	Inflow at Dam Site in Mm^3.	Total with-drawal in Mm^3.	Spillover in Mm3.	Defecit in Mm^3.	Remarks
1	2	3	4	5	6	7
1	1960	8659.671	1638.0611	7000.41637	0.000	Success
2	1961	22924.428	1680.0185	20920.8123	0.000	Success
3	1962	5265.237	1631.0699	4089.54895	0.000	Success
4	1963	7381.389	1604.3668	5687.75594	0.000	Success

5	1964	7057.660	1666.6153	5401.8014	0.000	Success
6	1965	2126.345	1632.1663	739.736279	0.000	Success
7	1966	3407.688	1609.1428	1734.52484	0.000	Success
8	1967	6346.889	1598.2782	4597.5141	0.000	Success
9	1968	7319.847	1635.3465	5644.94399	0.000	Success
10	1969	8474.269	1661.8839	6773.99105	0.000	Success
11	1970	13070.585	1691.2407	11249.3698	0.000	Success
12	1971	3735.683	1683.8566	2382.35453	0.000	Success
13	1972	2898.823	1619.5789	1335.00724	0.000	Success
14	1973	10024.953	1594.1999	8122.73624	0.000	Success
15	1974	3361.811	1634.5859	1993.73695	0.000	Success
16	1975	9718.211	1562.2785	7899.66541	0.000	Success
17	1976	5945.324	1621.1621	4459.19713	0.000	Success
18	1977	7599.320	1646.9898	5887.85445	0.000	Success
19	1978	4419.888	1616.4769	2953.92336	0.000	Success
20	1979	3962.426	1592.4092	2390.89628	0.000	Success

Sr.No.	**Year**	**Inflow at Dam Site in Mm^3.**	**Total with-drawal in Mm^3.**	**Spillover in Mm3.**	**Defecit in Mm^3.**	**Remarks**
21	1980	5236.435	1612.1969	3555.74978	0.000	Success
22	1981	9281.757	1659.2779	7463.5755	0.000	Success
23	1982	3200.712	1626.0243	1835.85265	0.000	Success
24	1983	9061.437	1618.3413	7189.27253	0.000	Success
25	1984	3823.319	1607.6203	2442.60485	0.000	Success
26	1985	3584.341	1574.9845	2012.51944	0.000	Success
27	1986	3909.868	1559.7612	2344.02594	0.000	Success
28	1987	2367.553	1569.3123	869.535902	0.000	Success
29	1988	4602.015	1548.7985	2939.01549	0.000	Success
30	1989	2949.216	1588.5495	1451.00491	0.000	Success
31	1990	5985.780	1562.4623	4254.1487	0.000	Success
32	1991	3165.514	1591.5275	1737.59852	0.000	Success
33	1992	3599.793	1583.6274	1988.01048	0.000	Success
34	1993	7639.139	1619.4257	5829.33812	0.000	Success
35	1994	19985.717	1639.9313	18033.0205	0.000	Success
36	1995	3899.033	1641.7097	2742.49788	0.000	Success
37	1996	2987.411	1605.7791	1420.92026	0.000	Success
38	1997	4890.133	1596.6214	3197.32053	0.000	Success
39	1998	12896.004	1666.7905	10959.8729	0.000	Success
40	1999	8932.268	1655.9951	7387.07659	0.000	Success
41	2000	3196.757	1561.2142	1892.25826	0.000	Success
42	2001	3659.643	1553.1762	2072.32318	0.000	Success
43	2002	3576.713	1590.7572	1959.12625	0.000	Success
44	2003	9622.491	1631.2218	7738.37081	0.000	Success
45	2004	2316.623	1621.4485	1019.51363	0.000	Success
46	2005	11039.965	1611.7384	9060.04134	0.000	Success
47	2006	5860.152	1500.507	4558.93098	0.000	Success
	Average	**6488.728**	**1613.160**	**4877.007**	**0.000**	

The table indicates percentage success as 100% i.e. the simulation study is giving acceptable results. The large amount of spill over is because of the inflow during monsoon season is concentrated mainly in July & August and cannot be stored due to Level constraints and downstream commitments. The simulation study thus forms the basis for multiple regression modelling as well as Artificial Neural Network (ANN) modelling.

V. MULTIPLE LINEAR REGRESSION MODEL (MLR):-

The degree of relationship existing between three or more variables is called multiple regression. Regressions models are formulated using IBM SPSS 20 software. The 47 years 10 daily simulation study is used to perform multiple linear regression. Three regression models are developed. One each for Closing capacity, closing water level and closing area of reservoir at the end of 10 days interval i.e. Multiple linear regression model for final storage (MLR Cap.), final area (MLR Area) and final levels (MLR Level) are developed. Initial storage/area/level , irrigation demands, non-irrigation demands and evaporation are considered as independent variables. The summary of MLR models is given below-

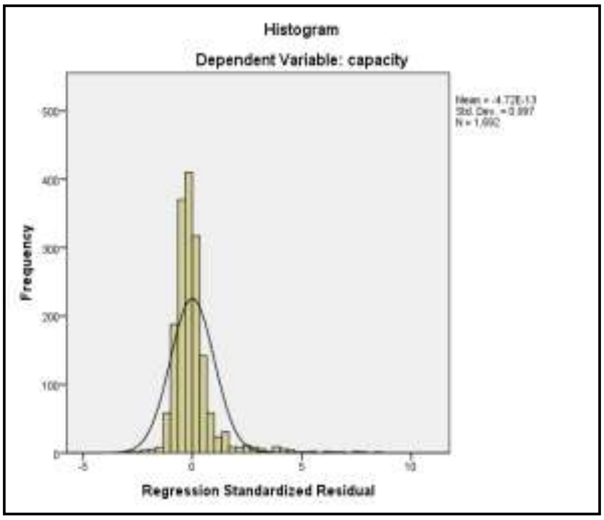
ANOVA summary

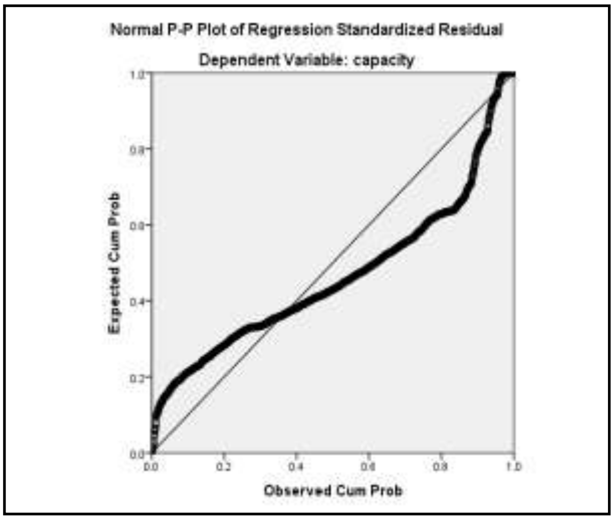
Model		**Sum of Squares**	**df**	**Mean Square**
MLR(Cap.)	**Regression** **Residual**	**79601664.48** **6382408.48**	**9** **1682**	**8844629.38** **3794.53**
MLR (Level)	**Regression** **Residual**	**2660.991** **215.075**	**9** **1682**	**295.666** **0.128**
MLR (Area)	**Regression** **Residual**	**2327402.078** **185739.445**	**9** **1682**	**258600.231** **110.428**

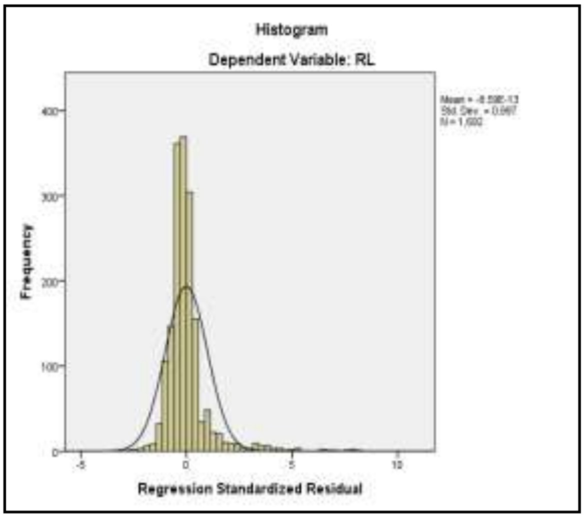
Model summary

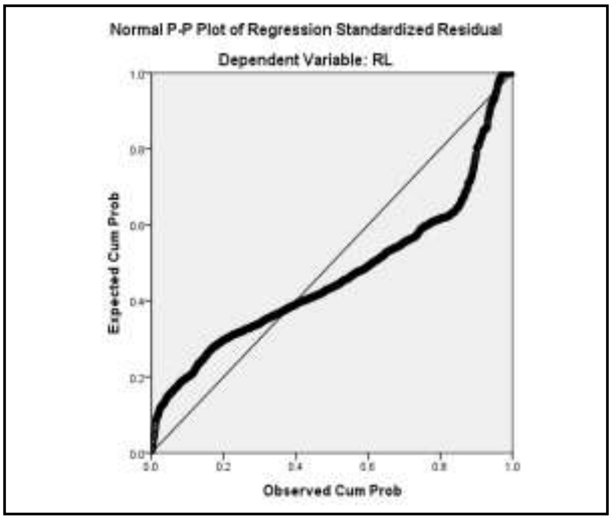
Model	(R^2)	Adjusted (R^2)	F	Sig. F	Std. error of estimate
MLR(Cap.)	0.926	0.925	2330.886	0.000^b	62.599
MLR (Level)	0.925	0.925	2312.260	0.000^b	0.3576
MLR (Area)	0.926	0.926	2341.805	0.000^b	10.508

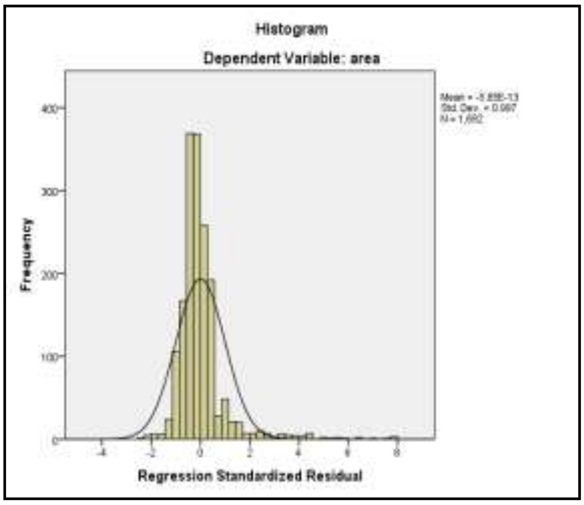
Interpretation of model for all basic variables and all readings: Of primary interest is the R Square and adjusted R square values, which are ranging from 0.925 and 0.926, respectively. We learn from these that the weighted combination of the predictor variables explained approximately 92 to 93 % of the variance of R.L. The prediction model is statistically significant, Sig.F < .001, and accounted for approximately 92 to 93 % of the variance. (R^2= 0.925, Adjusted R^2= 0.926). In the normal plots the residuals look very normal and thus the predictors mentioned in the model explained better variation in the data. Figure also depict the distribution of observed residuals matches up nicely with the distribution we would expect under normality, then residuals should fall along a straight line, as they more or less do in the plot mentioned. As deviation is substantially less from a straight line, it suggests a fewer potential deviation from normality. Histogram and normal probability plot for regression residuals for all three models are presented below-

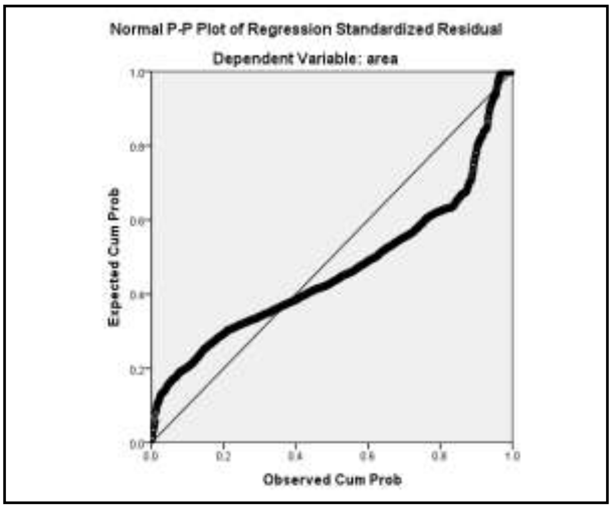












VI. ARTIFICIAL NEURAL NETWORK MODEL (ANN)

Three ANN models are developed. One each for Closing capacity, closing water level and closing area of reservoir at the end of 10 days interval i.e. ANN model for final storage (ANN Cap.), final area (ANN Area) and final levels (ANN Level) are developed. Initial storage/area/level, irrigation demands, non-irrigation demands and evaporation are considered as independent variables.

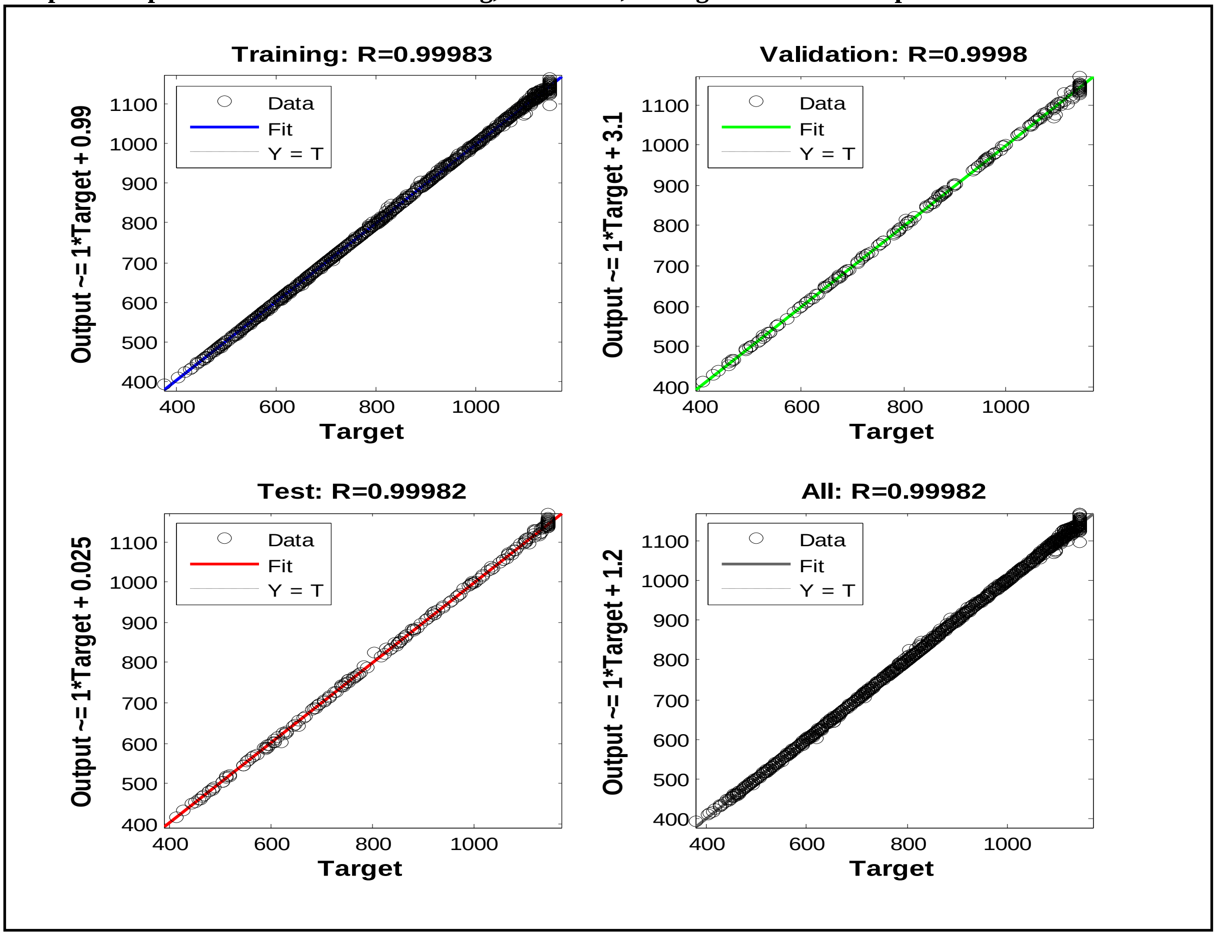
The Forty seven years 10 daily simulation study is used to develop ANN Model. The standard network that is used for function fitting is a two-layer feed forward network, with a sigmoid transfer function in the hidden layer and a linear transfer function in the output layer. We have tried various topologies and out of that the best results are achieved using 12-15-1 topology. Training algorithm used to train the neural network is Levenberg-Marquardt (trainlm) which is recommended for most problems by various researchers. Software Matlab along with IBM SPSS 20 used for ANN modelling.

Multy Layer Perceptron ANN model for final storage (ANN Cap.), final area (ANN Area) and final levels (ANN Level) are developed. Hyperbolic tangent activation function is used. Out of Forty seven years data 33 years data is used for training and remaining data is used for testing and validation. The summary of ANN models is given below-

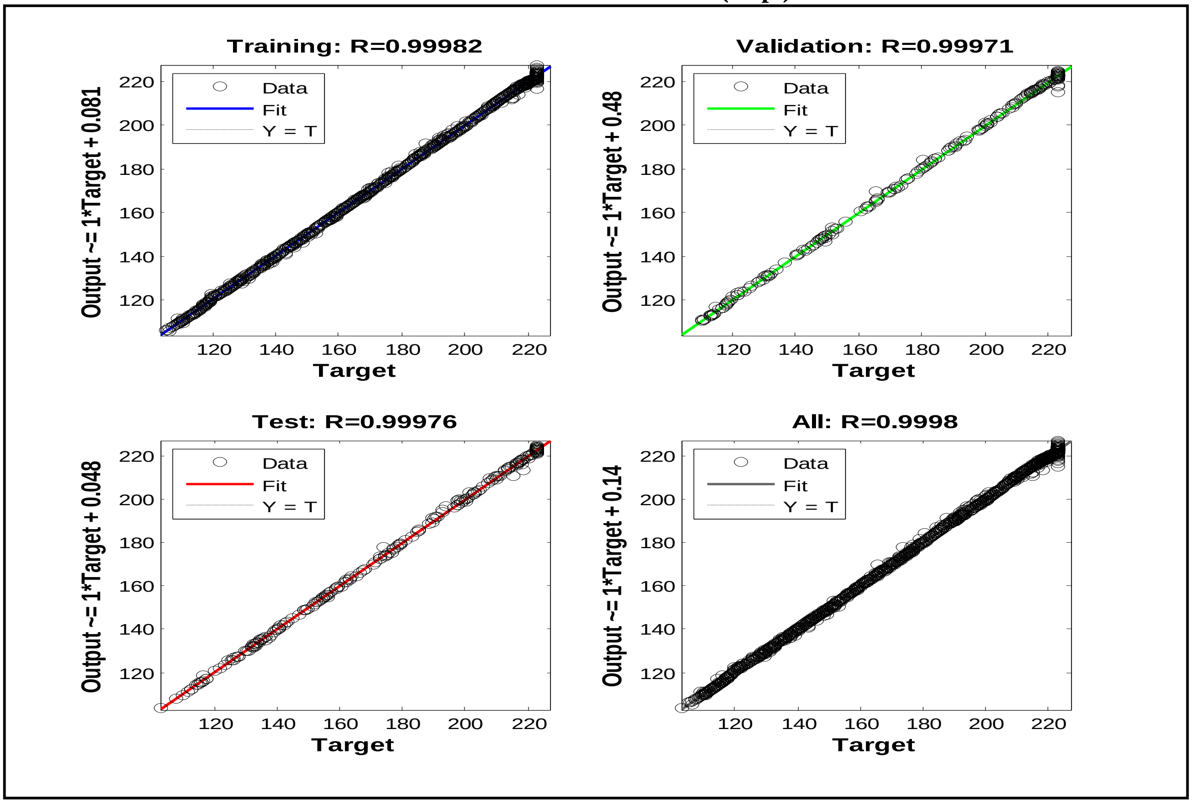
Model summary

Model	Topology	Overall R	MSE
ANN (Cap.)	**12-15-1**	**0.99**	**23.15 at epoch 12**
ANN (Level)	**12-15-1**	**0.99**	**0.00118 at epoch 28**
ANN (Area)	**12-15-1**	**0.99**	**0.9071 at epoch 25**

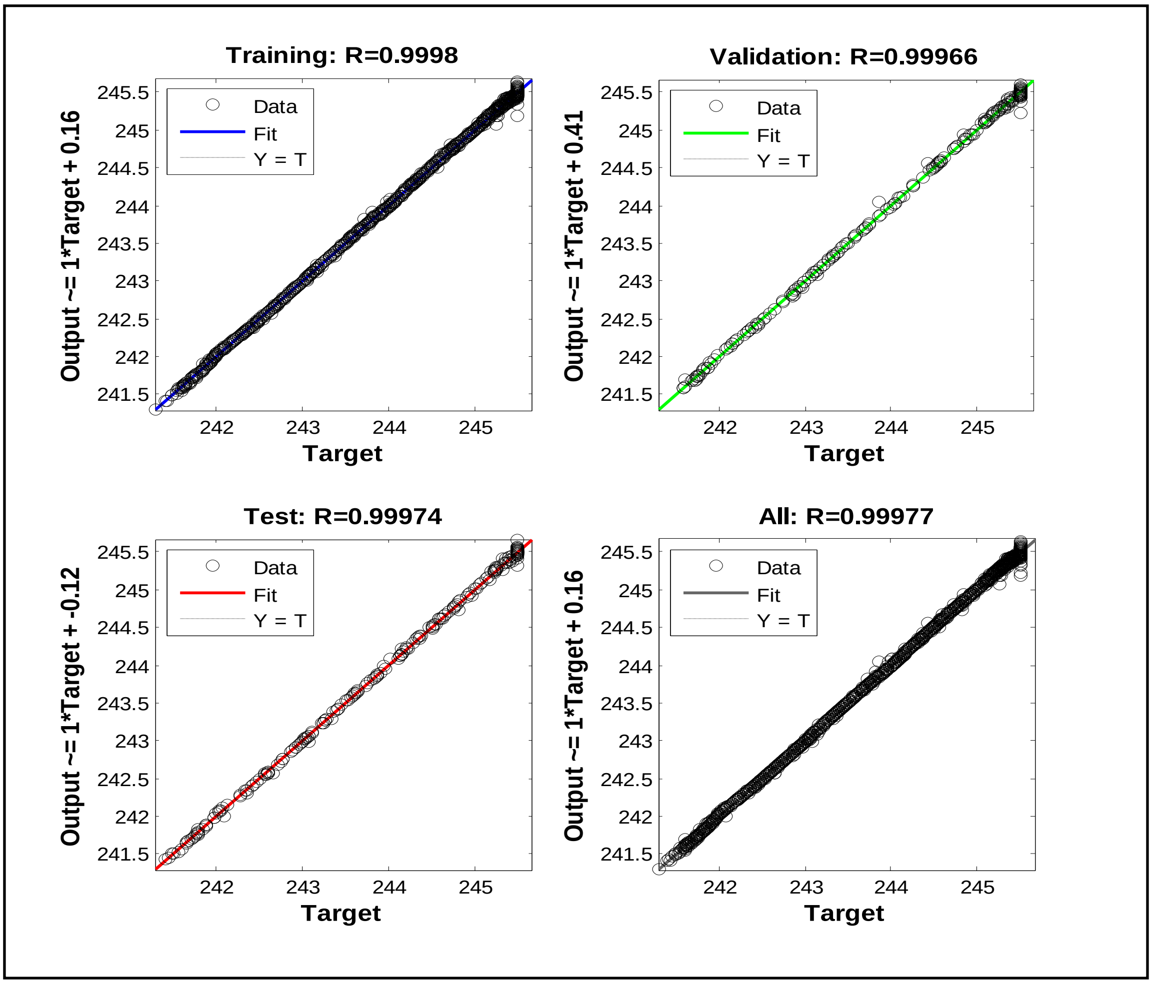
Graphical representation of R for Training, validation, testing and overall r is presented below-



Values of R for model ANN (Cap.)

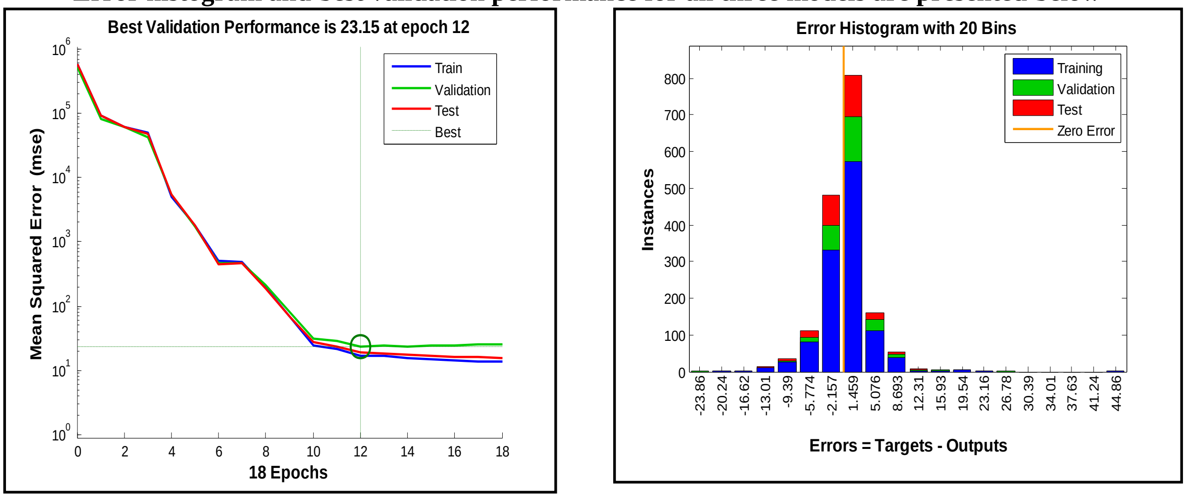


Values of R for model ANN (Area)

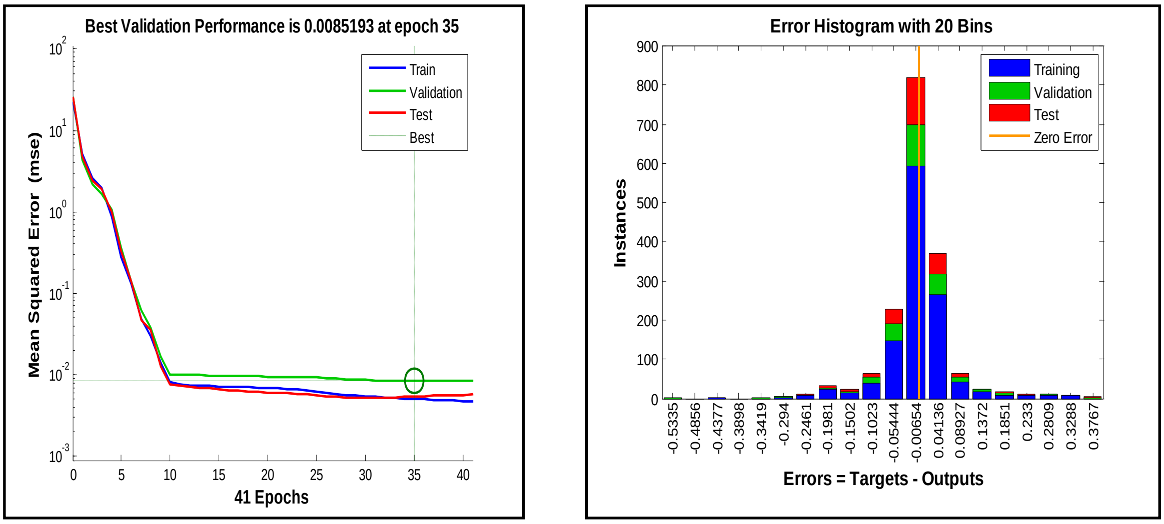


Values of R for model ANN (Level)

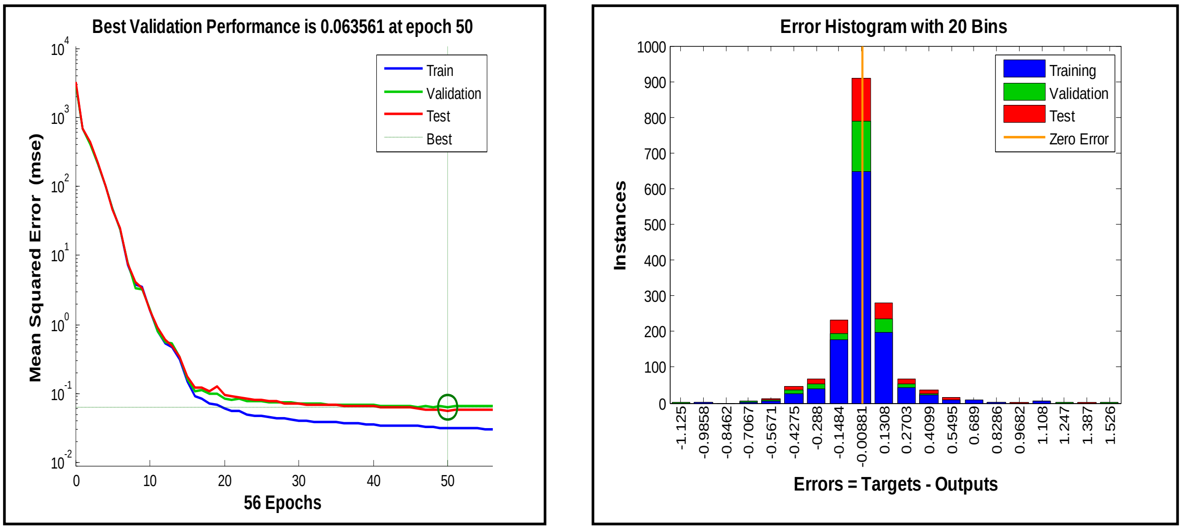
Error histogram and best validation performance for all three models are presented below –



ANN (Cap)

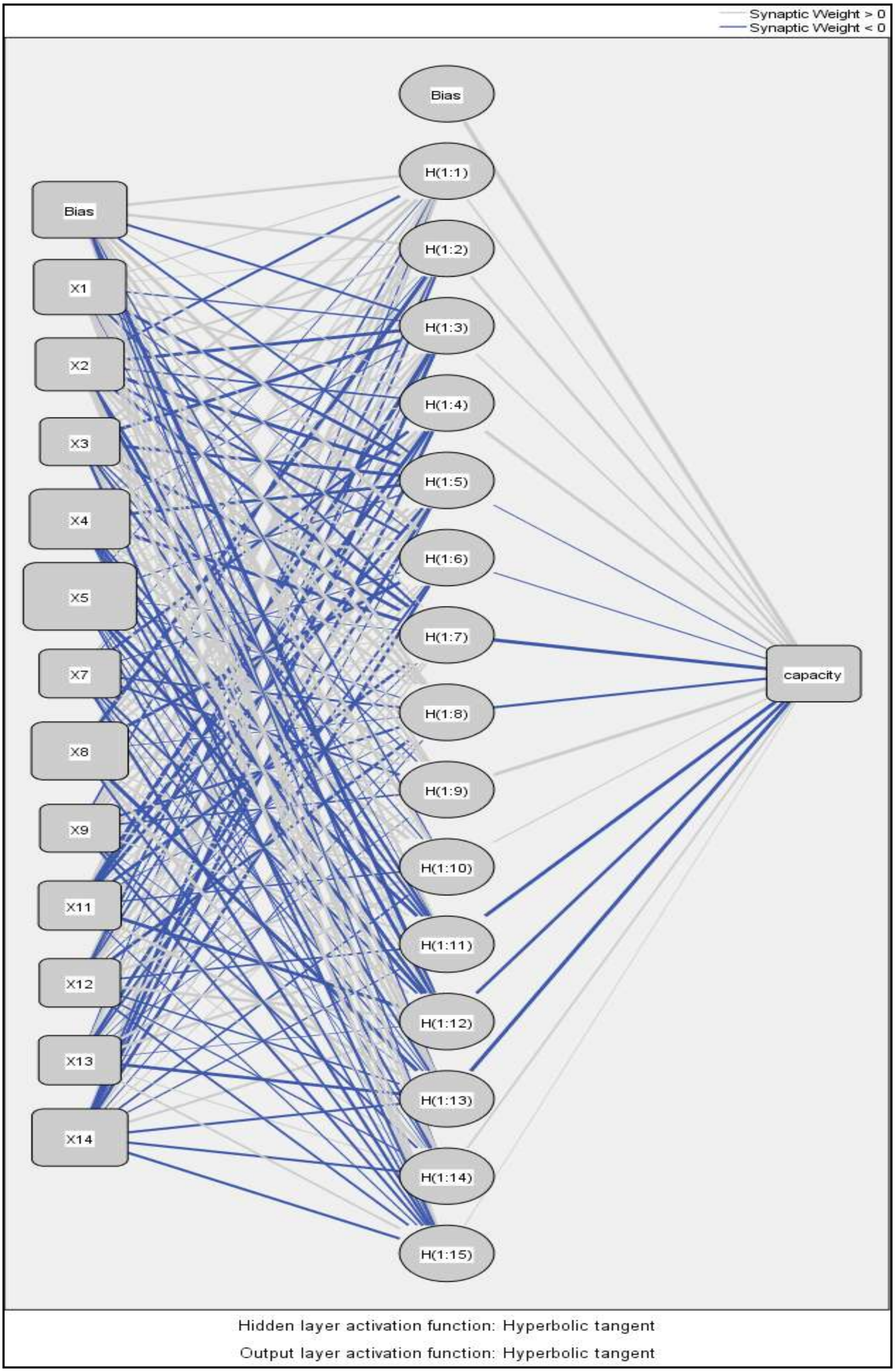


ANN(Level)



ANN (Area)

ANN network and important graphs for ANN model for closing capacity (ANN Cap.) are shown below-



Network Diagram Topology 12-15-1

Interpretation of model for all basic variables and all readings: The regression plots display the network outputs with respect to targets for training, validation, and test sets. For a perfect fit, the data should fall along a 45 degree line, where the network outputs are equal to the targets. For this model, the fit is exceptionally good for all data sets, with R values in each case of 0.999 or above. If even more accurate results were required, retraining the network might be possible. Retraining will change the initial weights and biases of the network, and may produce an improved network after retraining. The error histogram obtains additional verification of network performance. The blue bars represent training data, the green bars represent validation data, and the red bars represent testing data. The histogram can give an indication of outliers, which are data points where the fit is significantly worse than the majority of data. In this model, one can see that while most errors fall between 12.31 and -13.01, there is a training point with an error of 44.86 and validation points with errors of -23.86 and -20.24. These outliers are also visible on the testing regression plot. It is a good idea to check the outliers to determine if the data is bad, or if those data points are different than the rest of the data set. If the outliers are valid data points, but are unlike the rest of the data, then the network is extrapolating for these points. There is no significant evidence of influence of outliers on error histogram and the errors are almost normally distributed which indicates better fitting of the Neural network model.

COMPARISION OF RESULTS : Results of Forty seven years simulation accompanied by Multiple Regression model and ANN model indicates fairly equal results for all three output i.e. dependent variables namely Closing area, closing levels and closing capacity at the end of each 10 days period. Further the results for high flows (50% probability), normal flows (75% probability) and low flow (90% probability) are also compared. The results are tabulated and also presented in graphs below.

Reservoir Parameters for 75% , 50% & 90% dependable year

		75% Dep- Year 1966					
Sr.No.	**Month**	**Yc Capacity Regression**	**Yc Capacity ANN**	**Yc RL Regression**	**Yc RL ANN**	**Yc Area Regression**	**Yc AREA ANN**
1	Jun-01	460.706	473.000	241.646	241.620	111.283	109.970
2	Jun-02	446.213	473.450	241.611	241.610	110.702	109.540
3	Jun-03	453.216	494.460	241.655	241.710	112.031	112.010
4	Jul-01	601.485	648.280	242.419	242.770	133.613	138.270
5	Jul-02	766.294	964.450	243.332	244.600	157.292	192.470
6	Jul-03	996.705	1119.320	244.763	245.380	198.274	218.720
7	Aug-01	1142.426	1144.540	245.474	245.510	222.266	222.540
8	Aug-02	1154.032	1136.830	245.543	245.490	224.320	222.560
9	Aug-03	1148.791	1135.450	245.513	245.460	223.428	222.130
10	Sep-01	1165.430	1136.670	245.609	245.500	226.276	222.730
11	Sep-02	1157.709	1137.480	245.564	245.500	224.943	222.710
12	Sep-03	1149.122	1133.930	245.516	245.430	223.493	221.730
13	Oct-01	1136.929	1140.720	245.462	245.490	221.549	222.020
14	Oct-02	1126.038	1127.980	245.400	245.420	219.689	219.650
15	Oct-03	1122.933	1114.640	245.382	245.350	219.165	217.750
16	Nov-01	1096.063	1109.090	245.248	245.310	214.694	217.090
17	Nov-02	1082.508	1101.710	245.181	245.280	212.445	216.140
18	Nov-03	1069.079	1092.970	245.114	245.230	210.218	215.050
19	Dec-01	986.948	1055.060	244.656	245.080	196.417	208.210
20	Dec-02	1022.694	1016.150	244.887	244.940	202.574	203.180
21	Dec-03	992.656	977.570	244.728	244.750	197.526	196.920
22	Jan-01	955.852	928.510	244.533	244.440	191.374	188.060
23	Jan-02	922.867	884.580	244.361	244.160	185.831	179.090
24	Jan-03	881.766	849.370	244.141	243.870	178.912	169.540
25	Feb-01	807.129	806.380	243.709	243.510	166.127	159.760
Sr.No.	**Month**	**Yc Capacity Regression**	**Yc Capacity ANN**	**Yc RL Regression**	**Yc RL ANN**	**Yc Area Regression**	**Yc AREA ANN**

26	Feb-02	802.750	739.310	243.645	243.240	164.814	153.910
27	Feb-03	762.930	691.090	243.373	243.000	157.463	147.810
28	Mar-01	680.644	666.040	242.842	242.710	142.812	140.480
29	Mar-02	697.038	631.850	242.917	242.550	145.296	134.510
30	Mar-03	673.970	605.470	242.761	242.390	141.056	130.490
31	Apr-01	619.135	602.140	242.417	242.280	131.419	127.520
32	Apr-02	626.748	579.210	242.445	242.170	132.475	124.380
33	Apr-03	608.084	561.980	242.319	242.070	129.055	121.870
34	May-01	512.652	536.860	241.751	241.940	112.703	119.720
35	May-02	558.341	519.980	242.042	241.870	121.427	117.680
36	May-03	547.469	510.830	242.011	241.810	120.820	115.630
		50% Dep-	**Year 1999**				
Sr.No.	**Month**	**Yc Capacity Regression**	**Yc Capacity ANN**	**Yc RL Regression**	**Yc RL ANN**	**Yc Area Regression**	**Yc Area**
1	Jun-01	859.663	835.170	244.020	243.590	175.257	166.150
2	Jun-02	831.094	880.810	243.826	243.930	169.988	176.160
3	Jun-03	890.040	1024.080	244.190	245.020	180.311	203.770
4	Jul-01	1020.305	1125.380	244.882	245.420	202.192	219.590
5	Jul-02	1159.838	1133.850	245.595	245.480	225.496	221.520
6	Jul-03	1161.527	1134.410	245.583	245.480	225.655	222.300
7	Aug-01	1162.771	1145.020	245.589	245.510	225.722	222.910
8	Aug-02	1156.591	1142.420	245.556	245.510	224.717	222.850
9	Aug-03	1153.873	1138.610	245.542	245.500	224.279	222.700
10	Sep-01	1223.779	1141.580	245.937	245.510	236.129	222.970
11	Sep-02	1208.408	1143.870	245.849	245.510	233.498	222.960
12	Sep-03	1168.399	1139.380	245.624	245.510	226.747	222.910
13	Oct-01	1176.588	1145.620	245.685	245.510	228.250	222.940
14	Oct-02	1137.136	1144.180	245.462	245.510	221.563	222.580
15	Oct-03	1126.450	1129.840	245.402	245.430	219.759	219.940
16	Nov-01	1124.700	1128.550	245.391	245.420	219.449	219.830
17	Nov-02	1124.700	1128.550	245.391	245.420	219.449	219.830
18	Nov-03	1124.700	1128.550	245.391	245.420	219.449	219.830
19	Dec-01	1050.185	1117.160	244.966	245.370	206.889	217.000
20	Dec-02	1112.393	1108.530	245.332	245.350	217.451	216.470
21	Dec-03	1102.773	1103.890	245.284	245.330	215.857	215.720
22	Jan-01	1085.440	1083.230	245.197	245.200	213.006	211.470
23	Jan-02	1065.237	1058.570	245.104	245.080	209.687	208.190
24	Jan-03	1035.893	1029.730	244.959	244.950	204.822	204.110
25	Feb-01	972.226	1004.040	244.609	244.800	194.121	199.170
26	Feb-02	981.240	943.550	244.675	244.570	195.684	193.120
27	Feb-03	947.376	906.370	244.494	244.340	189.982	186.190
28	Mar-01	870.254	896.110	244.049	244.320	176.837	184.710
29	Mar-02	901.641	882.780	244.238	244.110	182.176	177.540
30	Mar-03	881.628	859.450	244.131	243.990	178.805	173.120

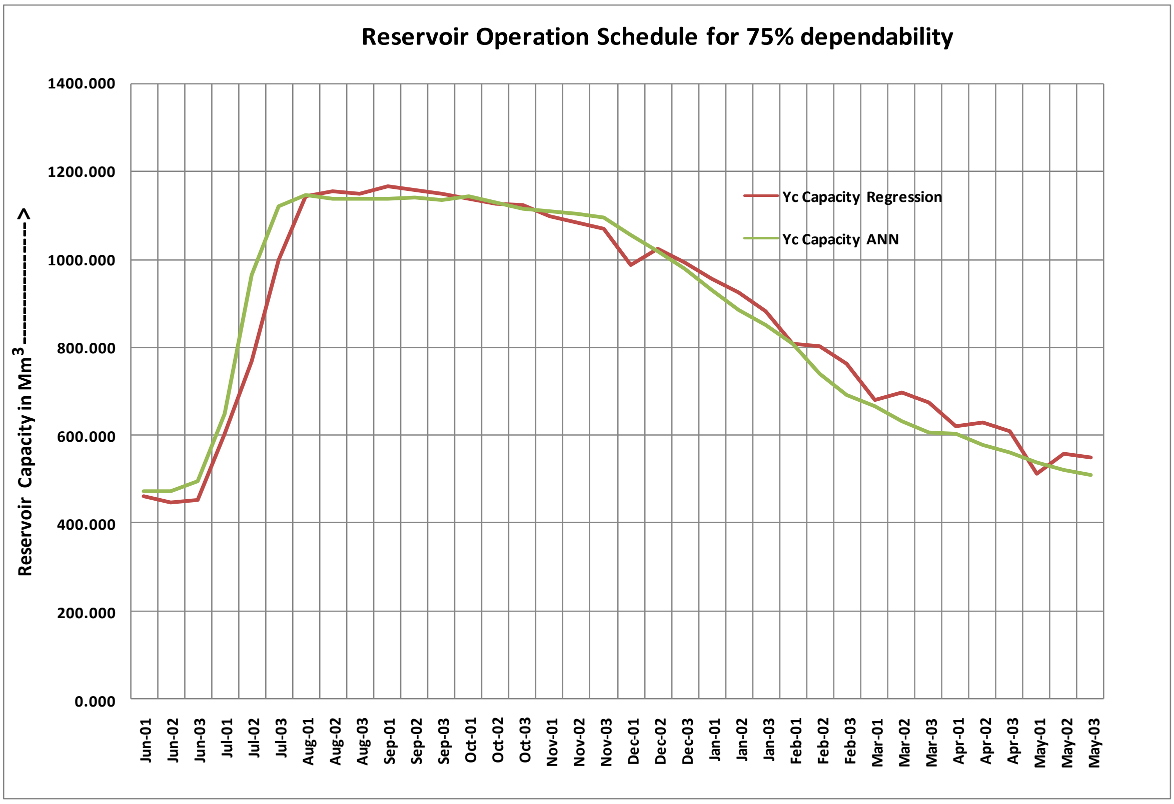
Sr.No.	Month	Yc Capacity Regression	Yc Capacity ANN	Yc RL Regression	Yc RL ANN	Yc Area Regression	Yc Area
31	Apr-01	829.375	825.860	243.833	244.000	169.952	173.880
32	Apr-02	847.358	819.610	243.932	243.850	172.888	169.850
33	Apr-03	830.466	802.780	243.818	243.730	169.792	166.320
34	May-01	735.793	804.070	243.255	243.550	153.567	160.960
35	May-02	794.111	779.100	158.528	163.254	158.260	243.422
36	May-03	772.332	755.210	154.551	159.288	153.740	243.276

90% Dep- Year 1996

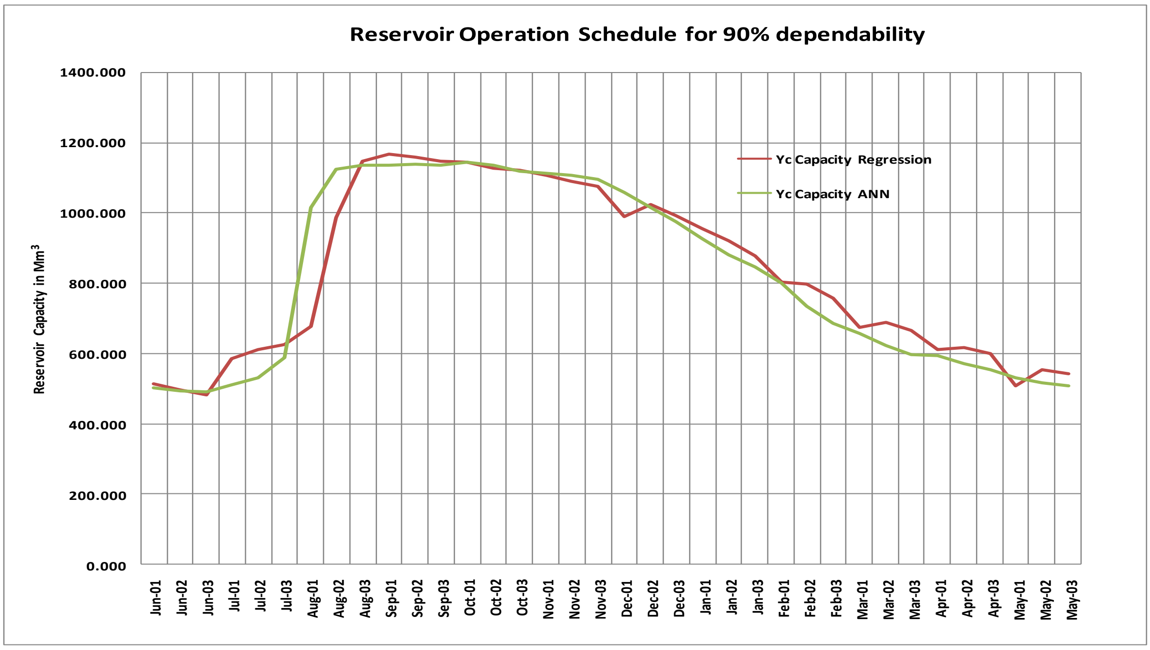
Sr.No.	Month	Yc Capacity Regression	Yc Capacity ANN	Yc RL Regression	Yc RL ANN	Yc Area Regression	Yc AREA ANN
1	**Jun-01**	**514.825**	**502.430**	**241.816**	**241.820**	**114.899**	**116.200**
2	**Jun-02**	**495.549**	**492.810**	**241.758**	**241.750**	**113.705**	**113.830**
3	**Jun-03**	**482.505**	**490.140**	**241.723**	**241.720**	**113.072**	**112.880**
4	**Jul-01**	**584.680**	**509.210**	**242.325**	**241.780**	**130.843**	**114.350**
5	**Jul-02**	**612.034**	**531.460**	**242.435**	**242.130**	**133.651**	**119.300**
6	**Jul-03**	**624.970**	**586.340**	**242.446**	**241.800**	**134.019**	**120.820**
7	**Aug-01**	**677.075**	**1014.900**	**242.695**	**244.590**	**140.501**	**200.980**
8	**Aug-02**	**987.385**	**1124.390**	**244.693**	**245.440**	**196.511**	**220.530**
9	**Aug-03**	**1147.409**	**1135.280**	**245.505**	**245.450**	**223.190**	**222.020**
10	**Sep-01**	**1168.584**	**1136.820**	**245.626**	**245.500**	**226.812**	**222.790**
11	**Sep-02**	**1159.851**	**1137.970**	**245.576**	**245.500**	**225.304**	**222.790**
12	**Sep-03**	**1149.913**	**1134.470**	**245.520**	**245.440**	**223.627**	**221.920**
13	**Oct-01**	**1146.541**	**1144.160**	**245.516**	**245.510**	**223.178**	**222.710**
14	**Oct-02**	**1128.458**	**1136.260**	**245.414**	**245.460**	**220.098**	**221.000**
15	**Oct-03**	**1123.953**	**1118.910**	**245.388**	**245.370**	**219.337**	**218.330**
16	**Nov-01**	**1108.001**	**1113.740**	**245.307**	**245.340**	**216.672**	**217.710**
17	**Nov-02**	**1091.849**	**1105.830**	**245.227**	**245.300**	**213.993**	**216.670**
18	**Nov-03**	**1075.873**	**1096.070**	**245.148**	**245.250**	**211.345**	**215.450**
19	**Dec-01**	**990.859**	**1057.830**	**244.675**	**245.090**	**197.064**	**208.670**
20	**Dec-02**	**1025.136**	**1016.490**	**244.899**	**244.950**	**202.979**	**203.410**
21	**Dec-03**	**993.454**	**975.610**	**244.732**	**244.740**	**197.661**	**196.810**
22	**Jan-01**	**954.976**	**925.810**	**244.529**	**244.420**	**191.226**	**187.670**
23	**Jan-02**	**920.860**	**881.220**	**244.350**	**244.130**	**185.492**	**178.410**
24	**Jan-03**	**878.656**	**845.340**	**244.125**	**243.840**	**178.388**	**168.610**
25	**Feb-01**	**803.515**	**800.480**	**243.684**	**243.470**	**165.458**	**158.810**
26	**Feb-02**	**798.120**	**732.760**	**243.613**	**243.200**	**163.961**	**152.960**
27	**Feb-03**	**757.683**	**684.230**	**243.337**	**242.970**	**156.495**	**146.900**
28	**Mar-01**	**674.654**	**657.790**	**242.801**	**242.650**	**141.706**	**139.120**
29	**Mar-02**	**690.207**	**623.200**	**242.871**	**242.500**	**144.041**	**133.200**
30	**Mar-03**	**666.721**	**597.080**	**242.711**	**242.330**	**139.724**	**129.210**
31	**Apr-01**	**611.337**	**593.530**	**242.364**	**242.230**	**129.987**	**126.240**
32	**Apr-02**	**618.308**	**570.990**	**242.388**	**242.120**	**130.929**	**123.180**
33	**Apr-03**	**599.845**	**554.200**	**242.263**	**242.020**	**127.540**	**120.760**
34	**May-01**	**507.857**	**531.560**	**241.739**	**241.910**	**112.478**	**118.590**
35	**May-02**	**553.033**	**515.270**	**242.026**	**241.840**	**121.129**	**116.630**
36	**May-03**	**541.934**	**506.480**	**241.995**	**241.780**	**120.494**	**114.680**

Where:
1. Yc Capacity, Yc Area & Yc Rl indicates reservoir's closing capacity in Mm^3, closing Area in Mm^2 and closing water Level in m at the end of 10 daily periods. Further Regression and ANN indicates results for regression model and ANN models.
2. June-01 = June 1 to 10
June- 02 = June 11 to 20 &
June -03 = June 21 to 30: And so on for remaining months.

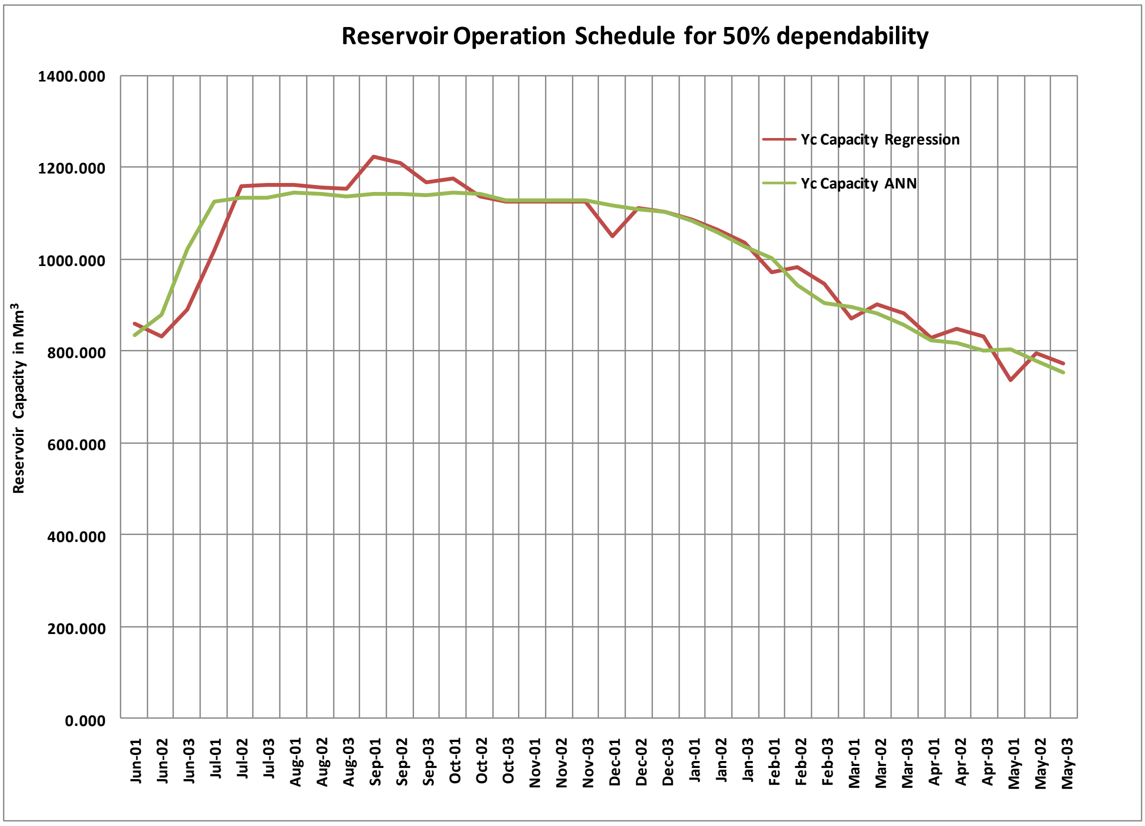
Comparison of MLR & ANN model for closing capacity



Yc Capacity indicates the capacity of reservoir at the end of 10 daily period.



Yc Capacity indicates the capacity of reservoir at the end of 10 daily period.



Yc Capacity indicates the capacity of reservoir at the end of 10 daily period.

VII. CONCLUSION

The objective of this study was to develop ANN model for operation of reservoirs and assess its application potential in attaining the objectives of reservoir operation. For Gosikhurd reservoir the optimal releases for 10 daily periods were arrived at by trial and error and simulating the reservoir opening and closing conditions for 10 days intervals. Historic data of inflow for 47 years were used for simulation. Mathematical model for Multiple Linear Regression(MLR) as well as Artificial Neural Network(ANN) was developed using the 47 years simulation study.

The research shows that the results by MLR and ANN model were fairly similar. Real time forecast can be done. However, ANN has predicted comparatively higher values for reservoir filling (storage built up) periods whereas the MLR has predicted comparatively higher values for reservoir depletion period. ANN presents very smooth curve fitting indicating uniform variation of capacity which is very convenient and desirable by the operator. Whereas MLR presenting instantaneous and rapid variations in capacity which is very inconvenient for the operator. The ANN procedure to derive the general operating policy for reservoir operation gives better and robust performance. This is because the ANN approach allows more complex modelling than the MLR approach. ANN is able to produce suitable degree of nonlinearity to match the considered pattern as closely as possible, indicating that ANN has a great potential for deriving optimal operating policy for reservoir.

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