ESTIMATION OF TRAP EFFICIENCY OF RIHAND RESERVOIR USING ANN MODELLING

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Submitted by

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CANDIDATE'S DECLERATION

I, Abdul Waheed, Roll No. 2K17/HFE/01, student of M.Tech (Hydraulics and Water Resources), hereby declare that the project Dissertation "Estimation of Trap Efficiency of Rihand Reservoir Using ANN modeling" is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirements for the award of the degree of Master of Technology. The content of this thesis is original and not copied from any source without proper citation. This work has not previously formed the basis for award of any Degree, Diploma Associates, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the project Dissertation titled "Estimation of Trap Efficiency of Rihand Reservoir Using ANN Modeling" which is submitted by Abdul Waheed, Roll No. 2K17/HFE/01, Department of Civil Engineering, Delhi Technological university, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by him under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Deposition of sediments in the reservoirs is a major critical issue in today's scenario. The sediments flowing along river gets deposited in reservoir as velocity gets reduced in vicinity of reservoir. Practically it is very difficult to estimate the volume of sediments retained in a reservoir and the trap efficiency of reservoir. Trap efficiency of a reservoir is the percentage of sediments that are retained in a reservoir. There are many conventional methods that were developed to estimate the trap efficiency of reservoir. Some of the conventional methods that are used to estimate the trap efficiency of reservoir are Brown's (1944), Churchill's (1948), Brune's (1953), Dendy's (1974), Gill's (1979), Heinemann (1981), etc. They all have given their empirical relations that can be used to estimate the trap efficiency of reservoir except Brown (1944). Brown has given the empirical equation relating the Ratio of capacity and watershed ratio. They all shows the relationship between capacity – inflow ratio and trap efficiency of reservoirs. Brune's is the only method which is widely used all over world.

In this present study Artificial Neural Network model was developed to estimate the trap efficiency of Rihand Dam located in Uttar Pradesh. Annual Rainfall, Age of Reservoir, Capacity and Inflow were taken as inputs. Using these inputs, the trap efficiency of reservoirs was estimated by ANN model. The model Developed has 5 and 10 hidden neurons for four and three inputs respectively. The data sets were trained using Levenberg Marquardt process. The MSE was 0.01 when the training was stopped. The average Trap Efficiency from ANN using four and three input parameter is 96.18% and 96.01% respectively. The outputs from ANN model was validated by the empirical equation developed by Jothiprakash and Vaibhav Garg. This equation has age of reservoir as a constraint in it unlike other equation. The average observed TE from Brune's (1953) and Jothiprakash and Garg (2008) for Rihand Reservoir was found to be 96.11% and 96.03 respectively%.

The results got validated and it shows that ANN model gives better results than conventional method. It is simple, easy and can solve complexity very easily. ANN model is not time consuming as well. ANN model gave best results with four inputs which were very close to Jothiprakash and Vaibhav Garg developed equation and other conventional method.

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ABBREVIATION

ANN = Artificial Neural Network

TE = Trap Efficiency

S.I = Sedimentation Index

C = Storage Capacity

I = Annual Average Inflow Rates

C/I = Capacity Inflow Ratio

W = Watershed Area

A = Watershed Area

T_e = Trap Efficiency

g = Acceleration due to gravity

f = Sigmoid function

X = Input vector

Y = Output vector

w = weights

E = Error

k = coefficient of Sedimentation Index

CHAPTER 1

INTRODUCTION

1.1 General

Reservoir sedimentation is a major issue in today's scenario. Sediments flow along the river due to soil erosion which takes place at the edge of the reservoir and at the bed of the reservoir. These sediments are deposited in the reservoir due to reduction in the velocity of the flow of river. Velocity of flow is reduced due to obstruction that occurred by dams present along the way of the flow of river. Deposition of sediments decreases the capacity of reservoir. This is one of the major issues that had to be looked after. As the deposition of sediments takes place, capacity of reservoirs get decreased. The capacity that is lost annually varies 1-2% of the total storage capacity (Mahmood 1987; Yoon 1992; Yang 2003).

As we all know that India is an agricultural country and its population is around 1 billion. As agriculture is the largest economic sector of India. All the agricultural lands have to be harnessed by water which are being supplied by more than 4000 dams and thousands of small dams [Central Water Commission (CWC) 2001; Durbude and Purandara 2005]. Deposition of sediments is the cause of reduction in capacities of reservoirs. For example, Nizam Sagar Reservoir which is situated in Andhra Pradesh, was constructed in 1930 and had a initial capacity of $841.18 * 10^6$ m^3. It has lost its 60.74% capacity by 1992 (CWC 2001). CWC in 2001 reported that the sedimentation rate in Indian Reservoirs is higher than the design rate taken at the stage of planning. Many reservoirs out of these reservoirs are losing their capacity at a rate of 0.2 – 1.0% annually (CWC 2001). Shangle (1991) has done the analysis of 43 reservoirs. There were major, medium and minor reservoirs. The analysis concluded that the rate of sedimentation of major reservoirs vary between 0.34 – 27.85 ha.m/100 km^2/year. The rate of sedimentation of medium reservoir vary between 0.15 – 10.65 ha.m/100 km^2/year. Likewise the rate of sedimentation of minor reservoir vary between 1.0 – 2.3 ha.m/100 km^2/year. Table 1.1 shows sedimentation rates of few reservoirs.

Table 1.1 Rate of sedimentation of few Reservoirs of India

Reservoir	River	Catchment Area (Km^2)	Initial Storage Capacity (10^6 m^3)	Average Sedimentation Rates (ha.m/100 km^2/year)
Linganamakki	Sharavathi	2176	4435.35	24.00
Ramganga	Ramganga	3134	2449.60	22.94
Pong	Beas	12562	8578.99	21.10
Malaprabha	Malaprabha	2176	1064.04	19.00
Konar	Konar	997	281.23	17.50
Idukki	Periyar	649	1998.57	15.92
Gandhisagar	Chambal	23025	7740.00	8.96
Aliyar	Aliyar	195	109.40	8.48
Ukai	Tapi	62224	8510.00	8.13
Hirakud	Mahanadi	83395	8105.00	6.35
Bhakra	Satluj	56980	9868.00	6.10
Jayakwadi	Godavari	21774	2909.04	4.78
Matatila	Matatila	20720	1132.70	4.69
Sriram Sagar	Godavari	91751	3171.94	2.80

Note: Data from CWC (2001).

Sedimentation takes place in mostly in every reservoir and decreases the capacity of reservoir. As the capacity of reservoir is decreased hence, it affects the life of reservoir. Life of reservoir is decreased. The Life of reservoir differ from the life of reservoir at the planning stage due to sedimentation. Siltation in reservoir can be responsible for many hazardous problems. It is very necessary to study about sedimentation and siltation rate so that these hazardous problems can be avoided. There was practice in vogue before eighties was that a dead storage should be provided to accommodate 100 years of sedimentation. According this it was assumed that sediments are only deposited in dead storage at the bottom of reservoir. Later, it was found that it was invalid and analysis of surveys showed that sedimentation took place throughout the reservoir.

1.2 Effect of Sedimentation on the Life of Reservoir

Reservoir sedimentation decreases the storage capacity and available water storage and destruct the sustainable water resource management. Reservoir is just like an artificial lake that is made by human and all of these reservoirs are going through severe problem of loss of storage capacity due to deposition of sediments. The capacity of reservoir is diminishing daily without any instant damage. The damage can be there but it would happen after a long time. As we can observe, reduction in capacity of reservoir is also affecting the life of reservoir. The reservoir would be not useful as designed.

Reservoir sedimentation and its effect can be observed by loss of available storage due to deposition of sediments and it can also be felt due to the increased evaporation taking place over the years. There is depletion of water storage due to sedimentation and due to this it won't satisfy the needs for which it was built. Available water supply is also affected due to evaporation because deposition of sediments changes area – capacity relation which can increase evaporation.

Therefore, it is necessary to observe the reservoir on monthly basis. Available storage should be noted and volume of sediments is to be quantified. Trap efficiency has to be calculated. Necessary step should be taken so that life of reservoir can be conserved. Percentage of water loss should be recorded. Siltation rate has also to be taken care of. Siltation rate is reduced when there is no sediments incoming in the reservoirs. It is important to note the effects of sedimentation on reservoir.

1.3 Classification of Reservoir

There are many classification of reservoir but in this present study we will only talk about classification based on CCA (Cultural Command Area).

1.3.1 Major Reservoir

The CCA to be covered by these reservoirs should be greater than 10000 hectare. The size of the reservoir is large with its large storage capacity so that it could fulfill the needs. They are often used for multi purposes such as hydro electric power plant, irrigation etc.

1.3.2 Medium Reservoir

The CCA to be covered by these reservoirs should be in between 2000 – 10000 hectare. The size of reservoir is sufficient fulfill the needs. It can also be used for multipurpose such as hydro electric power plant, irrigation etc.

1.3.3 Minor Reservoir

The CCA to be covered by these reservoirs is less than 2000 hectare. The size of reservoir is enough to fulfill the needs. They cannot be used for multipurpose. They are used for individual purpose like Baspa Reservoir in Himachal Pradesh. The following table 1.2 shows the some of major reservoirs of India.

Table 1.2: Some major Reservoirs of India

Name	River	State	CCA, ha	Year of completion
Bhakra Nangal	Satluj	Himachal Pradesh	4000000	1963
Hirakud	Mahanadi	Orissa	1000000	1957
Malprabha	Malprabha	Karnataka	218191	1972
Kangsabati	Kangsabati	West Bengal	348477	1956
Mayurakshi	Mayurakhshi	West Bengal	240000	1956

These all reservoirs are very large and a huge cost had been put to construct them. It is very necessary to prevent all these reservoirs from damages. It can be done if we know the siltation rates and amount of sediments depositing in the reservoir. By doing so Trap

Efficiency could be estimated. There were many conventional methods that were developed to estimate the trap efficiency of reservoir. In present study I am going to develop an ANN model for the estimation of trap efficiency of reservoir. ANN model is a Artificial Neural Network that just work like brain.

1.4 Remedies to prevent sediments

Different remedies have to be used to prevent sedimentation. Prevention of sedimentation will help to keep useful life of reservoir as designed life of reservoir. The climatic factors due to which sedimentation takes place are given below

- Amount of Rainfall
- Intensity of rainfall
- Distribution of rainfall
- Wind
- Temperature
- Evaporation

The remedies that have to be taken are given below.

- Highly degraded areas should be treated in the catchment upstream of the reservoir.
- Vegetation has to be grown along the river and at the catchment upstream of a reservoir.
- Waste lands should to be developed specifically which are coming in the catchment areas of project.
- Construction of check dam in the catchment area.
- There should be a bypass for diverting the water which has the high concentration of silt in it.
- Regularly dredging should be done to remove silts from the reservoir.
- Regular flushing of reservoir should be done for the removal of sediments.

1.5 Factors affecting Trap Efficiency of Reservoir

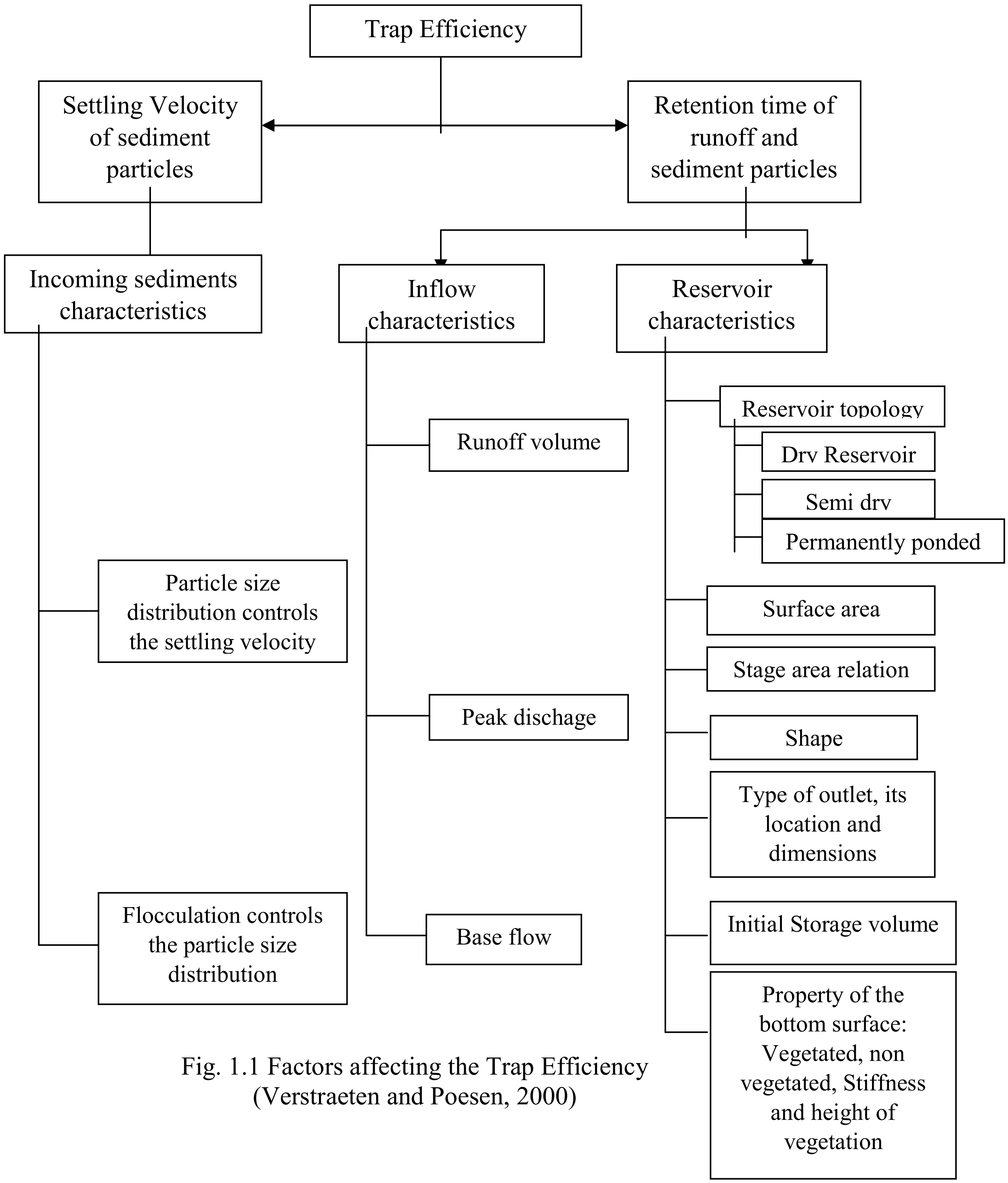


Fig. 1.1 Factors affecting the Trap Efficiency
(Verstraeten and Poesen, 2000)

Fig. 1.1 shows the flow chart explaining the factors affecting Trap Efficiency of Reservoir. Capacity and inflow are the major factors affecting trap efficiency of the reservoir.

1.6 Conventional Methods

These methods are being used from years and years. There were different methods that showed the different empirical relation. These methods were used to estimate the trap efficiency of reservoir. The empirical relation shows the relation between capacity – inflow ratio and trap efficiency. There were no methods which were developed to deal with theoutflow. This is because it is very difficult to install gauges at downstream to measure outflow. It is very costly to install gauges at downstream but t is very easy and cheaper to install gauges at upstream since India is a developing country, many of the reservoirs do not have gauges at downstream to measure outflow.

1.6.1 Brune's Method

Brune's method is mostly and widely used all over the world. It gives the relationship between capacity – inflow ratio and trap efficiency of reservoir. Brune (1953) has given a curve which shows the relationship between capacity – inflow ratio and trap efficiency of reservoir. It is the simplest method of all conventional methods. It is more accurate, versatile due to its simplicity. There were only two parameters which are considered in formulation are capacity and average inflow rates. No other parameters which affect the sedimentation were considered. Later Brune was found accurate mainly because sedimentation was affected by inflow rates.

1.6.1.1 Brune's Curve

Brune's curve is the curve which shows a empirical relation between capacity – inflow ratio and trap efficiency. This curve that gives the trap efficiency of primarily highly flocculated and coarse grained sediment envelope curve, median curve, primarily colloidal and dispersed fine grained sediment envelope curve. This graph gives the estimated trap efficiency of reservoir and it is very simple and fast to get. There is no complexity in this method that is the reason this is the most accurate, versatile method.

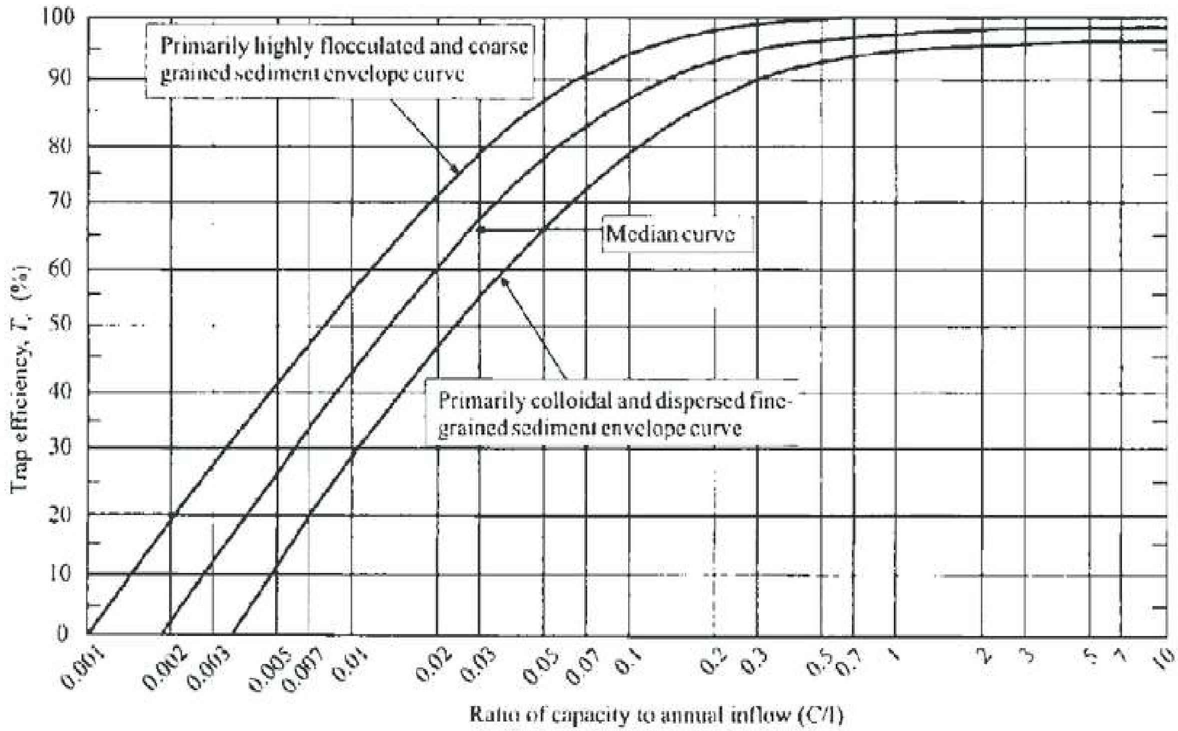


Fig. 1.2 Brune's Curve

1.6.2 Churchill Method

Churchill (1948) gave a graph relating Release Efficiency (R.E) and Sedimentation Index (S.I) which is shown in Fig. 1.3. (100 – T_e) is called as release efficiency. Release efficiency is also called as sediment flushed by the reservoir in percentage. He considered more parameters than Brune. The parameters that were considered by Churchill were detention time and mean velocity. All other parameters were neglected. Trimble et.al (2005) had concluded that Churchill (1948) gives more accurate estimated trap efficiency.

Verstraeten et.al (2000) had said Churchill may give better results than Brune (1953) method for the estimated trap efficiency but the complexity in estimating trap efficiency by Churchill's curve is more than Brune method. Therefore, Brune method is widely used over Churchill method.

1.6.2.1 Churchill's Curve

The Churchill's curve gives the relationship between Release efficiency and sedimentation index shown in Fig. 1.3 and Trimble revised curve in Fig. 1.4.

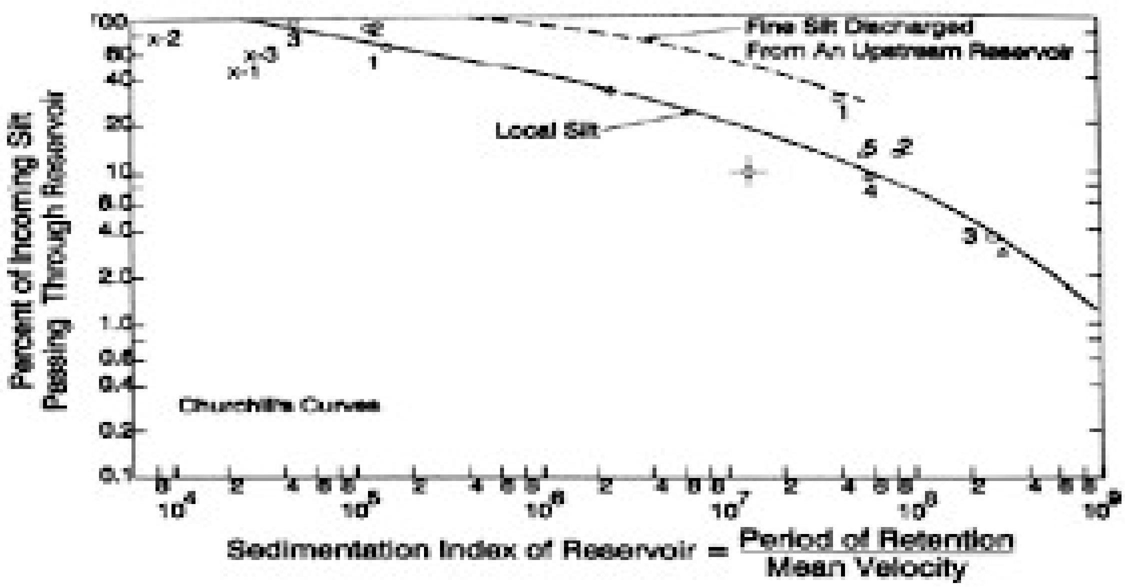


Fig. 1.3 Churchill's curve

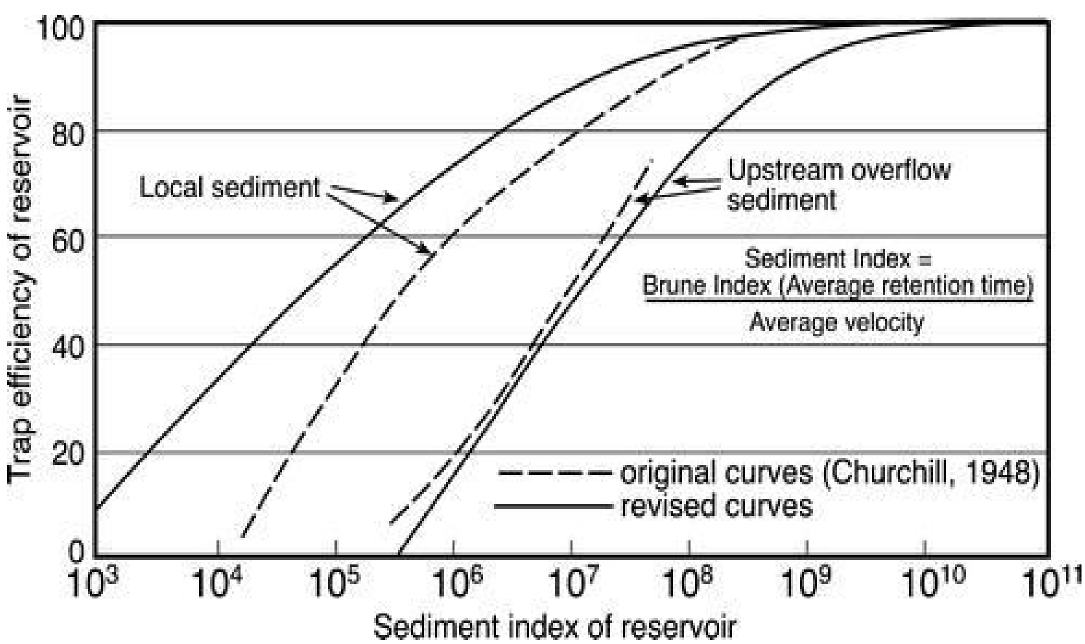


Fig. 1.4 Revised curve of Churchill's curve by Trimble et.al

The equation given by Churchill's is given below:

Sedimentation can be given as

$$S.I = \frac{Detention\ time}{Mean\ velocity} \qquad (1.1)$$

$$S.I = \frac{Reservoir\ capacity^2 * g}{Reservoir\ inflow^2 * Reservoir\ Length} \qquad (1.2)$$

1.6.3 Brown's Method

Brown (1944) gave the empirical relation between T_e in percentage and the ratio of reservoir capacity (in acre – feet) and the watershed area (in Square miles). This curve is shown in Fig. 1.5 below. Brown had considered only reservoir capacity and watershed area only leaving all other factors that affect the sedimentation. The empirical Equation given by Brown is shown in equation below (Gill, 1979; USACE, 1989; Campos, 2001).

$$Te = 1 - \frac{1}{1 + k\frac{C}{A}} \qquad (1.3)$$

Where k is a coefficient and varies from 0.046 to 1.0. C is the storage capacity of reservoir. A is the watershed area.

According to USACE (1989), k increases with increase in retention time, increase in average grain size and for reservoir operations that prevents release of sediment through sluicing or movement of sediment towards the outlets by pool elevation regulation. The recommended value of k for average conditions is 0.1 and the value of k for coarse grained is 1.0, 0.1 for the medium and 0.046 for fine sediments (Gill, 1979).

Later USACE (1989) considered the relationship given by Brune as more accurate than Brown. Brune method considered inflow rates and capacity of reservoir instead of watershed area. Later Brune equation was developed by Dendy (1974); Gill (1979); Heinnemann (1981) and Jothiprakash and Garg (2008).

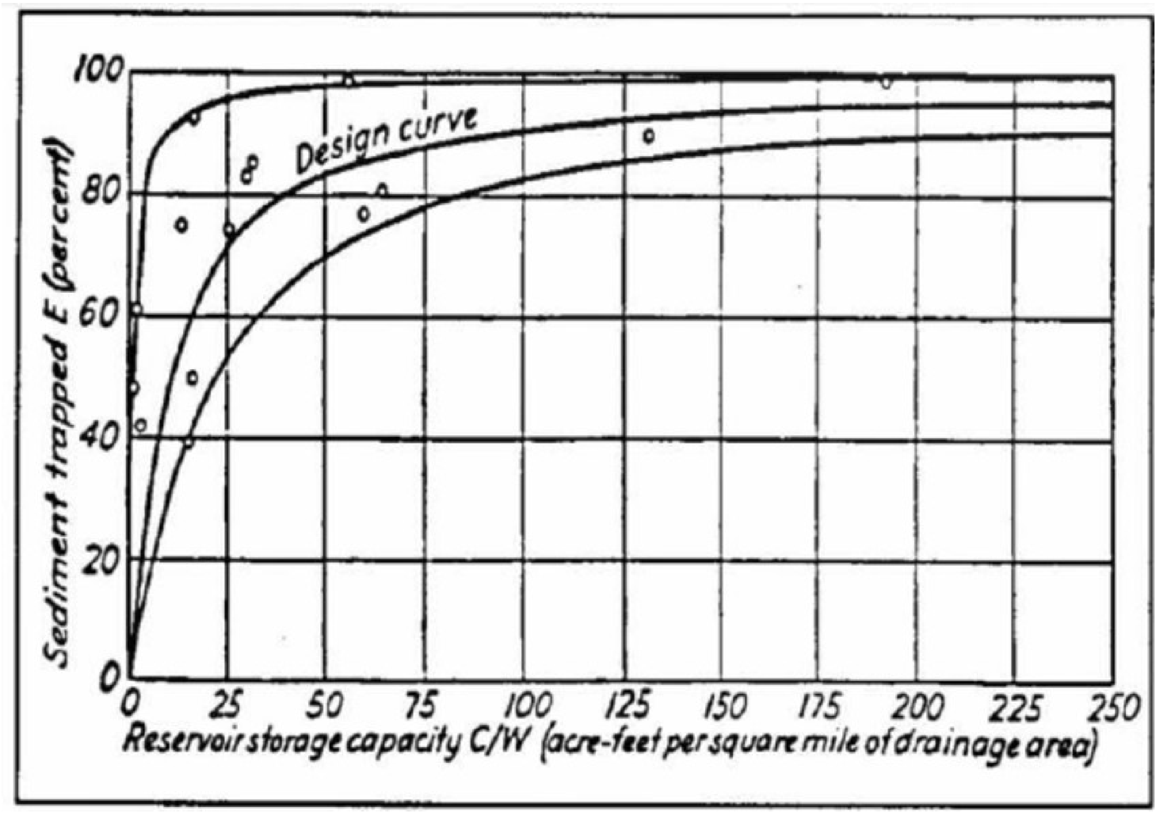


Fig. 1.5 Brown's Curve

1.6.4 Development and modification of Brune's Method

There were several people who developed the Brunes's method were Dendy (1974), Gill (1979), Heinemann (1981), Jothiprakash and Garg (2008). Their empirical equation are given below.

1.6.4.1 Development by Dendy (1974)

Dendy (1974) took more parameters and developed a empirical equation to estimate the trap efficiency for the median curve as:

$$Te = 100 * \ 0.97^{0.97^{log_I^C}} \text{ ......(1.4)}$$

1.6.4.2 Development by Gill (1979)

Gill (1979) has also developed the Brune's method. The equation given by Gill gives nearly the same result to the curves proposed by Brune.

Primarily Highly flocculated and coarse grained sediments:

$$Te = \frac{(C/I)^2}{0.994701(^C/_I)^2 + 0.006297(^C/_I)^2 + 0.3*10^{-5}} \quad \text{..........(1.5)}$$

Median Curve for Medium Sediments:

$$Te = \frac{^C/_I}{0.012 + 1.02\,^C/_I} \quad \text{..........(1.6)}$$

Primarily Colloidal and Dispersed Fine Grained Sediments:

$$Te = \frac{(^C/_I)^3}{1.02655(^C/_I)^3 + 0.02621(^C/_I)^2 - 0.133*10^{-3} * ^C/_I + 0.1*10^{-5}} \quad \text{..........(1.7)}$$

1.6.4.3 Development by Heinemann (1981)

Development (1981) developed the Brune's method and the empirical equation given by him is given below:

$$Te = 100 * \frac{k}{0.012 + 1.02k} \quad \text{..........(1.8)}$$

Where k = SI * g,

$$SI = \frac{(^C/_I)^2}{L} \quad \text{..........(1.9)}$$

Where L is length of reservoir, which is taken as a distance between the centre of dam axis and the extreme water spread point.

The empirical equations given by Dendy (1974) and Heinnemann (1981) have restrictions in their equations because they both have taken small reservoirs.

1.6.4.4 Jothiprakash and Garg (2008) development of Brune's Method

Jothiprakash and garg (2008) has also developed the Brune's Method for coarse grained and medium sediment.

Developed empirical equation for coarse grained sediments:

$$Te = \frac{8000- \quad *({}^{C}/_{I})^{-0.78}}{78.85+({}^{C}/_{I})^{-0.78}} \ldots\ldots(1.10)$$

Developed empirical equation for medium sediment incorporating age of a reservoir:

$$Te = \frac{(\frac{C}{I})}{0.00025 \quad .01*\frac{C}{I}+0.0000045a*\sqrt{\frac{C}{I}}} \ldots\ldots(1.11)$$

1.7 ANN model

ANN model works same as human brain. Like as human brain ANN also has neurons to take input. Synapsis in ANN model transfers the signal and also output neuron which gives us output. An ANN is huge parallel distributed information processing system which has several working features resembling biological neural networks of the human brain (Haykin, 1994). ANN models are the mathematical representation of neural biology.
Their development is based on the following rules:

- The processing of information occurs at nodes known as unit cells or neurons.
- Nodes pass the signals between them through connection link.
- Each connection link is associated with weights that represents the strength of connection.
- A non linear transformation known as activation function is applied to its net input to get the output signal.

A neural network is characterized by its architecture which shows the pattern of connection between nodes, its method of determining the connection weights and activation function (Fausett, 1994). Neural Networks can be classified by the number of layers: single (Hopfield nets); bilayer (Carpenter/Grossberg adaptive resonance networks); and multilayer (back propagation networks). There are different other ways to classify neural networks. One of these is the classification according to the direction of flow of information. Feed forward network is a type of it. In feed forward network there are several layers in sequence starting from input layer and ending at output layer. The sequence can have hidden layers also. Each layer can have one or more number of neurons. Input layer passes the information to the hidden layer and from hidden layer to the output layer. Each neuron is connected to the neuron of other layer with the associated weights. Neuron in a layer cannot be connected to the other neuron in the same layer. Associated weight represents the strength of connection. The number of neurons in hidden layer is found out by trial and error procedure. The Fig. 1.6 given below is showing the feed forward back propagation network.

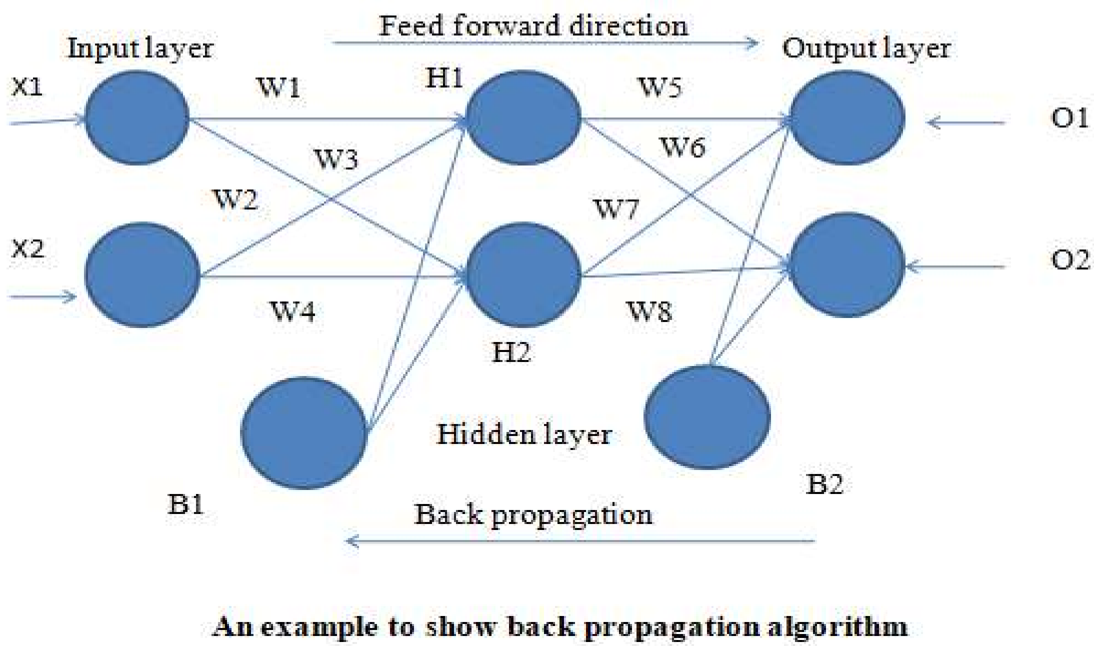


Fig 1.6 Feed Forward Back Propagation ANN network

1.7.1 Numerical Aspects

Fig. 1.7 shows a schematic diagram of a *k*th node. kth node get the inputs from the set input layer. All the inputs are in the form of vector i.e vector X = (X_1, X_2,

X_3……………..X_n). The sets of associated weights to each input are shown by W vector i.e vector W_k = (W_{1k}, W_{2k}, W_{3k}………………………W_{ik}). W_{ik} is a vector which shows the strength of connection from this node to each input.

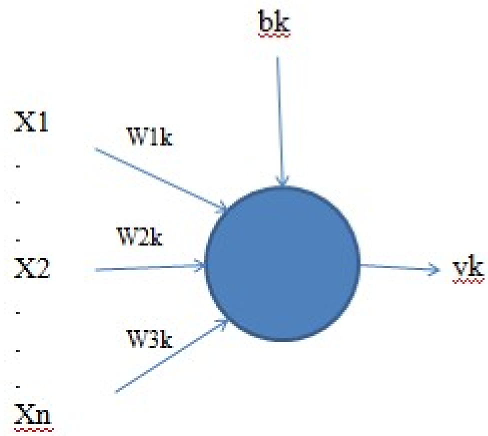


Fig. 1.7 Schematic diagram of node *k*

The inner product of vectors weights and inputs are multiplied by activation function f(t) to get the output $Y_{k.}$ b_j in above figure is known as bias. The sigmoid function gives the non linear response. The function is non decreasing. The sigmoid function is given below.

$$f(t) = \frac{1}{1+e^{-ayk}} \quad \text{……………………………………………………………....(1.12)}$$

The output is given by below equation:

$$Y_t = f\,(X * W_k - b_j) \quad \text{……………………………………………………………....(1.13)}$$

1.7.2 Network training

A training process is done by ANN known as learning to generate a output vector Y = (y_1, y_2………..y_n) which is very close to desired target vector T = (t_1,

t_2,……………………t_n). A training process is done to find out optimized weight matrix and bias function V, with minimized error.

$$E = \sum_Q \sum_q [y(t) - t(t)^2] \text{..} (1.14)$$

Here, t_t is output desired component; y_t is in correspondence with ANN output; q = number of output nodes; Q = number of training patterns. In the process of training, the connection weights are automatically simulated through continuous process by the environment the network is embedded. The main goal of training is to optimize the weights and reduce the error so that the output by ANN should be equal to or very close to the target value. These are mainly two types which are supervised and unsupervised. A supervised training process requires a guide. In this type of training process, a large number of data sets are required for testing and validating of data. In this process of training, the results are iterated and adjusted to get the optimized weights and threshold value for each node. In unsupervised training process, no external guide is required. A set of input is provided to ANN and it automatically cluster the set of data into class of same properties and optimizes the weights. Once training is completed, now ANN model can be provided with set of data which will produce the required output.

1.7.3 Applications of ANN

The usage of ANN model is widely increased in 20^{th} century. There are several application of ANN model which are explained as follows.

1.7.3.1 Rainfall – Runoff modeling

Determination of rainfall – runoff is major issue for engineers. Rainfall - runoff information is required to determine the relationship. As we know the data of rainfall is very complex and non linear. Initially simulation models were used to determine the relationship. Nowadays, rainfall runoff relationship can be determined using ANN. Halff et.al (1993) designed MLP feed forward ANN network using the rainfall hyetographs as inputs and hydrographs recorded US geological Survey (USGS) at Bellvue, Washington as outputs.

1.7.3.2 Water Quality modeling

ANN can also be used in water quality modeling. From literatures it is found that it is being used in water quality modeling. There are many factors which affect the water quality such as flow rate, contaminated load, medium of transport, water levels, initial conditions, and other site specific parameters. The data for water modeling is very complex and nonlinear. ANN makes the water modeling easy, simple and less time consuming.

Discussion on application of ANNs is to estimate the salinity at the Muray bridge on the river Murray in South Australia. This was done by Maier and Dandy (1996). Rogers (1992) and Rogers and Dowla (1994) developed an ANN model which was trained by a solute transport model, for the optimization studies of ground water remedies.

CHAPTER 2

LITERATURE REVIEW

Brown (1944) gave the relationship between T_e in percentage and watershed area. He developed a curve relating these two quantities. He had also given empirical equation related trap efficiency in percentage and the ratio of capacity - watershed area. The watershed area was in acre – feet per square mile of drainage area. He was the first one who gave a relationship between trap efficiency of reservoir and the ratio of storage capacity - watershed area. He gave curves for coarse sediment, medium sediments, fine sediments.

Churchill (1948) has developed a curve relating release efficiency in percentage and sedimentation index. He had given curves for the fine sediments which is coming from upstream of reservoir and local silt i.e. sediments originated in the catchment. He has also omitted many factors that affect trap efficiency. He used sedimentation index which is the ratio of detention time and mean velocity. His method to estimate the trap efficiency was more accurate but very complex.

Brune, (1953) has developed brune's curve which is still recognized as the accurate, simple and versatile. He gave a curve relating trap efficiency of reservoir in percentage and the ratio of storage capacity-inflow. He did survey on 44 reservoirs. He considered only two factors that were storage capacity and average inflow rates. His method was better and accurate that Brown (1944) because watershed area changes at the time of rainfall. He also gave trap efficiency three curves that were curve for primarily highly flocculated and coarse grained, curve for primarily colloidal and dispersed fine grained sediment and median curve.

Borland (1971) included more data from de silting basins and semi dry reservoirs to Churchill's curve. He observed that his data and Churchill's were close to each other except one dry reservoir which was also there in Brune's study. The trap efficiency of this reservoir was estimated same by Borland as well as Churchill curve but was out of range in Brune's curve. He concluded that for de silting basins and dry reservoirs Churchill's curve predicted accurate trap efficiency while Brune's curve did not.

Heinemann (1981) developed Brune's empirical relation of trap efficiency capacity – inflow ratio. He surveyed 20 ponded reservoir which had the catchment area between 0.8 – 36.3 km^2 and capacity was between ($3 * 10^6$ - $4 * 10^6$) m^3. His conclusion after doing this was the trap efficiency of normally ponded surface discharge reservoirs was less than the trap efficiency in Brune's curve.

Trimble and Carey (1990) have compared the both curves of Churchill as well as Brune for 27 reservoirs in the Tennessee River Basin. Sediment yield based on two trap efficiency curve and sediment accumulation was calculated by both of them. The results of trap efficiency of Brune curve were similar or higher than that of Churchill curve. From there they concluded that Churchill curve gives more appropriate results.

ASCE (American Society of Civil Engineers) Task committee (2000) discussed the role of Artificial Neural Networks in hydrology. This paper gives the introduction to ANN modeling which describes the various aspects of ANNs and some guidelines on their usage.

ASCE (American Society of Civil Engineers) Task Committee (2000) also discussed the application of ANN modeling in Hydrology. It is found that ANNs are robust tool for modeling many of the non linear hydrologic processes such as rainfall-runoff, stream flow, ground water management, water quality simulation and precipitation.

Hikmet Kerem Cigizoglu (2000) used ANN model for estimation and forecasting of sediment concentration values. The ANN model provided the Sediment concentration in no time with better results. He compared the results with classical regression models but ANN found to be the superior one.

Hikmet Kerem Cigizoglu (2000) made a comparison between ANN and Sediment Rating Curves for two rivers with very similar catchment areas and characteristics in the North of England. He concluded that in particular, an ANN approach can give information about the event of structure of events (e.g hystereis in the sediment concentration, water discharge relationship) which is impossible to achieve in sediment rating curves.

Licznar and Nearing (2002) compared the results of ANN model and WEPP model. They used ANN model to predict the soil loss and runoff volumes. They took data of 2879 erosion event from different 8 locations in the United States were used. They developed ANN model which comprised of eight input parameters and for complete data set 10 input parameters. The conclusion they gave was that ANN works better than WEPP model.

A. Sarangi and A. K. Bhattacharya (2005) predicted the sediment loss using ANN model and compared the results with Regression model developed earlier. The sudies were carried Banha Watershed in the upper Damodar valley in Jharkhand state of India. They concluded that ANN predicted better with highest coefficient of determination 0.98 than regression model with coefficient of determination of 0.94.

N.S. Raghuwanshi, R. Singh and L.S. Reddy (2006) developed ANN modeling for the accurate prediction of runoff and sediment yielding on a daily and weekly basis, for a small agricultural watershed. This paper has a comparison between conventional method and ANN modeling. ANN modeling gives better results than conventional method.

Yuan Lee et. al. (2006) used ANN model for the quantitative estimation of reservoir sedimention from three typhoon events. They compared the studies of a numerical model, Hydrological Simulation Program Fortran (HSPF), developed by USEPA. The collected data of discharge and suspended sediment from the three typhoon events occurred in Shihmen reservoir watershed was used. HSPF was used for the simulation of the sediment yield. Some collected data was used in ANN for testing and remaining data was used for validating the data. The conclusion showed that ANN is easy and fast to use.

Jothiprakash and Garg (2008) used conventional methods such as Brown and Brune to estimate the trap efficiency of Pong Reservoir at Beas Dam on the Beas River in Kangra district of Himachal Pradesh, India. There were certain modifications done in the empirical equation to estimate T_e trap efficiency of reservoir.

Jothiprakash and Garg (2008) developed the regression equation of Brune, Brown and other equations of Brune to estimate the trap efficiency of the Gobindsagar Reservoir situated at Bhakra Dam on Satluj River in Bilaspur district Himachal Pradesh, India and was compared with other. The developed equation of Brune in this present study gave better results unlike other methods.

Jothiprakash and Garg (2008) estimated the rate of sedimentation and useful life of a reservoir using trap efficiency of reservoir. They modified the empirical equation of Brune(1953) to estimate T_e and Gill (1979) to estimate the useful life of reservoir according to Gobindsagar Reservoir situated at Bhakra Dam on Satluj River in Himachal Pradesh, India. The sediments were found to be coarse according to Brune (1953). According to Bhakra Beas Management Board (BBMB), the dead storage would fill up in 142 years but the estimated life in the present study concluded to be three fourth of the period.

Seyed Ali and Ghasemizade (2010) compared two models, one was SWAT and the other one was ANN for the uncertainty in sediment load modeling. Monthly observed discharge and sediment data was used for the calibration and certainty analysis through the application of SUFI-2 procedure. In ANN model the uncertainty was accounted by training the models again and again to get minimized error. It was found that SWAT model was better in estimating the uncertainty in sediment loads than ANN model.

Rewel et. al (2015) estimated the sediment trap efficiency using Experimental setup. He set up a small laboratory to estimate T_e. He conducted the series of experiment varying inflow, outflow rates, sediment concentration and capacity. His results does not match with any of the methods previously given by other researchers. He only used d_{50} size particles so there was not much to say about size of particle.

2.1 Objectives of the Present Study

- To estimated the TE of Rihand Reservoir.
- To estimated the TE of Rihand Reservoir by Conventional methods
- To estimate the TE of Rihand Reservoir by ANN model.
- To compare the results of Conventional method with the results of ANN model.
- To check the suitability of ANN model.

CHAPTER 3

METHODOLOGY

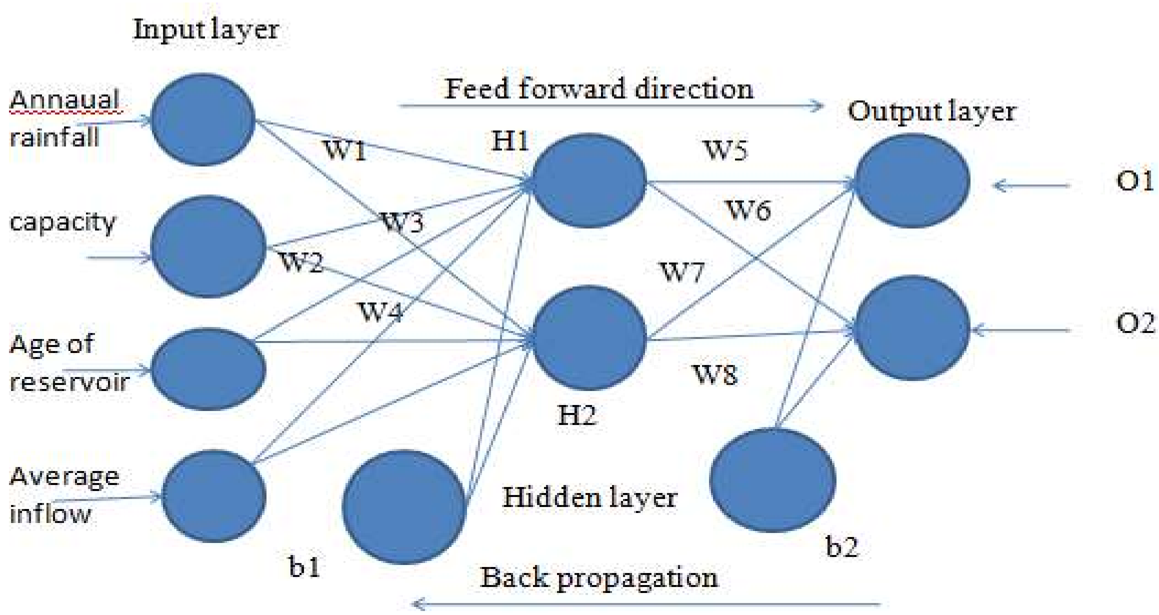
3.1 ANN model

The usage of ANN model is increased in 20th century. According to ASCE (2000) task committee, ANN model can be used to estimate volume of sediments retained in a reservoir. It can also be used to estimate the trap efficiency of reservoir. A try was made to estimate the trap efficiency of reservoir through ANN model. It was seen that ANN model was very fast and accurate to give the results of $T_{e.}$

There are already many research with development of ANN model. They have proved the utility of ANN model to its best. Yuan Lee et. al. (2006) used ANN model for the quantitative estimation of reservoir sedimentation from three typhoon events. They compared the studies of a numerical model, Hydrological Simulation Program Fortran (HSPF), developed by USEPA. The collected data of discharge and suspended sediment from the three typhoon events occurred in Shihmen reservoir watershed was used. HSPF was used for the simulation of the sediment yield. Some collected data was used in ANN for testing and remaining data was used for validating the data. The conclusion showed that ANN is easy and fast to use. Cigizoglu (2004) developed a MLP ANN model to forecast daily suspended sediment in a stream. Cigizoglu (2002a) developed ANN model to forecast and estimate the concentration suspended sediments in a river. He used the observed data of flow rates of river and previous observed values in a nearby river as input. Cigizoglu (2002b) compared the data of two rivers with similar catchment characteristics in England by ANN and Sediment Rating Curves. Sarangi et al. (2005) predicted the surface runoff and sediment loss by developing ANN model and regression model. N.S. Raghuwanshi, R. Singh and L.S. Reddy (2006) developed ANN modeling for the accurate prediction of runoff and sediment yielding on a daily and weekly basis, for a small agricultural watershed.

This paper has a comparison between conventional method and ANN modeling. ANN modeling gives better results than conventional method.

In present study a feed forward back propagation MLP ANN model was developed. Rainfall, storage capacity, inflow rates and age of reservoir are used as input parameters. There are no rules to develop ANN model because there can be many layers such as input layer, one or more hidden layer, output layer. Inputs layer can have one or more neuron as per input. Neurons of hidden layer are set by trial and error procedure. There are 5 neurons for 4 input parameter and 10 neurons for 3 input parameter in my present study. The network developed is shown in Fig. 3.1 below. In the present study data of Rihand Dam located in Sonbhadra district Uttar Pradesh, India. I used the data of Rihand Dam. I used the data of 21 years.



. 3.1 A feed forward back propagation ANN architecture

From the data available 70 % of data was used for the testing of data and 30 % was used for validation of data. The Sigmoid and Hyperbolic Tangent (tanh) transfer function were used as activation function. Back propagation (BP) algorithm was used along with Momentum, Conjugate Gradient (CG) and Levenberg – Marquardt (LM) as learning rules for training process. When Mean Squared Error reaches 0.01, the training process is terminated. Once the training is terminated, the network is saved, as per the input the model developed predicted the estimated value.

In Fig. 3.1 given above the architecture shows the input layer and the output layer. It has hidden layer with 5 and 10 neurons for different input data. The input layer has four neurons with different four input parameters. Each neuron of input layer is connected with hidden layer with associated weights. This is structure of the ANN model developed. Given below in section 3.2, there is a small example showing the working of BP algorithm. It explains the manual calculation of BP algorithm.

3.2 Back Propagation Algorithm

Here is an example of showing the manual calculation of Back Propagation algorithm (BP). I have taken a small example to show the working of Back Propagation algorithm. The example shows input as $X_1 = 0.05$, $X_2 = 0.10$ with biases $b_1 = 0.35$, $b_2 = 0.60$.

H1 = w1*x1 + w2*x2 + b1

Activation function is sigmoid

Sigmoid =

Output of H1 =

inputs and bias are

x1 = 0.05 , x2 = 0.10 , b1 = 0.35 , b2 = 0.60

Weights can be any value between 0 and 1, let us assume weights

w1 = 0.15, w2 = 0.10, w3 = 0.25, w4 = 0.30, w5 = 0.40, w6 = 0.45,

w7 = 0.50, w8 = 0.55

Targets are:

T1 = 0.01, T2 = 0.99

H1 = w1*x1 + w2*x2 + b1

From above given data

H1 = 0.05 * 0.15 + 0.10 * 0.20 + 0.35

H1 = 0.3775

Output of H1 =

Placing the values in the equation

Output of H1 = 0.593269992

In same way we get H2

Output of H2 = 0.596884378

Now for calculating O1

O1 = output of H1 * w5 + output of H2 * w6 + b2

O1 = 0.593269992 * 0.4 + 0.596884378 * 0.45 + 0.6

O1 = 1.105905967

Output of O1 =

Output of O1 = 0.75136507

In the same way output of O_2

O_2 = 0.772928465

Calculating the total error

$$Error = \frac{\sum(target - output)^2}{2}$$

$$Error = \frac{\sum(0.01 - 0.75136507)^2 + (0.99 - 0.772)}{2}$$

Error = 0.238371109

To update we do backward pass

Considering w_5

$$w5 = \frac{\delta E}{\delta w5}$$

$$\frac{\partial E}{\partial w5} = \frac{\partial E}{\partial outO1} * \frac{\partial outO1}{\partial O1} * \frac{\partial O1}{\partial w5}$$

$$\frac{\partial E}{\partial outO1} = 0.74136507$$

$$\frac{\partial outO1}{\partial O1} = 0.186815602$$

$$\frac{\partial O1}{\partial w5} = 0.593269992$$

$$\frac{\partial E}{\partial w5} = 0.082167041$$

Updating w_5

$$w5 = w5 - \eta * \frac{\partial E}{\partial w5}$$

$W_5 = 0.35891648$

Similarly,

w6 = 0.408666186	w1 = 0.149780716
w7 = 0.511301277	w2 = 0.19956143
w8 = 0.061370121	w3 = 0.24975116

3.3 Conventional Methods

In these days different conventional techniques are used to estimate the trap efficiency of reservoir. The techniques that are used are Brune's (1953) method and Jothiprakash and garg (2008). Brune (1953) gave the 3 curves of trap efficiency of primarily flocculated fine grained sediments, primarily colloidal and dispersed fine grained sediments and median curve. He related percentage of trap efficiency with Capacity-Inflow ratio. Jothiprakash and Garg (2008) developed the Brune's curve by adding age of reservoir parameter affecting trap efficiency.

3.3.1 Brune's method

Brune (1953) developed an empirical relation after surveying 44 reservoirs. Out of 44 reservoir, 40 were normal ponded reservoir, two were de silting reservoirs and two were dry semi reservoir. After the survey he developed a relationship between the percentage of trap efficiency and the Capacity-Inflow ratio. He took the parameters that affect the trap efficiency such as reservoir capacity, average annual flow rates, shape of reservoir, type of outlets and methods of operation. He did survey of reservoirs with suspended measurement downstream for measuring annual sediment collected in a reservoir and the sediments which was passing over the dam, he took it for sampling sediments. He also had surveys of reservoir measuring upstream and downstream sediments for estimating the percentage of suspended sediments. The total rate of sedimentation was provided by Bed Load.

More of this suspended load up and downstream with no reservoir survey was done to get a measure of total sediments. The sediments measured at downstream show that proportion of sediment passes the dam. The difference between these two gives the trapped sediments in reservoir.

3.3.2 Jothiprakash and Garg method (2008)

Jothiprakash and Garg in their paper published in 2008 developed an equation for the median curve of Brune. The equation developed had age of reservoir in it. As age of the reservoir is one of the parameter that affect the trap efficiency of reservoir. They both have done the regression analysis to include the age of reservoir in the equation of Brune's method for median curve. The equation 3.1 shows the equation given below.

$$Te = \frac{C/_I}{0.00025 + 0.01 * (C/_I) - 0.0000045 * at * \sqrt{\frac{C}{I}}} \text{..} (3.1)$$

The above equation 3.1 is used to estimate the percentage of trap efficiency of both the reservoir and the results from ANN model are validated with this equation.

3.4 Study Area

In present study The Rihand reservoir has been taken to estimate the trap efficiency of reservoir. The Rihand Dam located in Sonbhadhra district of Uttar Pradesh.

3.4.1 Rihand Dam

Rihand Dam is a largest dam of India by volume. It is also known as Govind Ballabh Pant Sagar. The reservoir of Rihand dam is located at largest artificial lake. It is a concrete dam that is located on Rihand River, a tributary of Son River in Pipri, Sonbhadra district of Uttar Pradesh. The border of Reservoir extends in Uttar Pradesh as well Madhya Pradesh. The catchment area of this dam extends over Uttar Pradesh, Madhya Pradesh & Chhattisgarh whereas it supplies irrigation water in Bihar located downstream of the river.

Govind Ballabh Pant Sagar is the largest manmade lake in India. Rihand dam is a concrete gravity dam with a length of 934.45 m. The maximum height of the dam is 91.46 m and was constructed during period 1954-62. The dam consists of 61 independent blocks and ground joints. The powerhouse is situated at the toe of the dam, with installed capacity of 300 MW (6 units of 50 MW each). The Intake Structure is situated between blocks no. 28 and 33. The Dam is in distress condition. It is proposed to carry out the rehabilitation works in the dam and the powerhouse. The F.R.L. of the dam is 268.22 m and it impounds 8.6 Million Acre ft of water. The construction of the dam resulted in forced relocation of nearly 100,000 people.

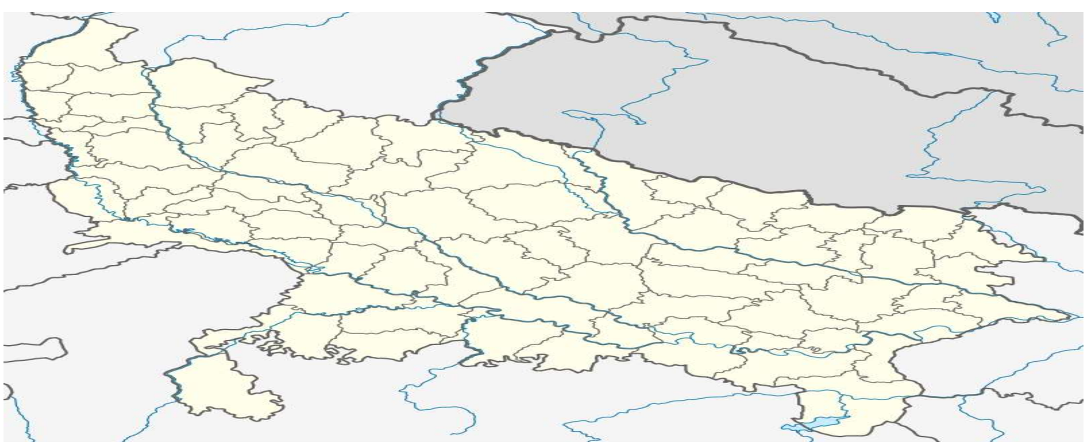


Fig. 3.2 Catchment area of Rihand Dam

Fig. 3.3 Location of Rihand Dam

Fig. 3.4 Front view of Rihand Dam

3.5 Data of Rihand Reservoir located in Pipri Sonbhadra district of Uttar Pradesh

Table 3.1 Data of Rihand Reservoir

Year	Age of reservoir (years)	Inflow (m^3/sec)	Capacity (Mm^3)	Rainfall (m)
1998-1999	1	569.89	8099.42	0.137
1999-2000	2	682.31	8753.92	0.141
2000-2001	3	529.73	7726.17	0.130
2001-2002	4	554.93	8050.10	0.132
2002-2003	5	408.23	7232.78	0.113
2003-2004	6	499.44	7383.88	0.126
2004-2005	7	330.31	5886.95	0.099
2005-2006	8	384.16	6643.12	0.099
2006-2007	9	474.39	6660.65	0.095
2007-2008	10	311.85	6093.58	0.109
2008-2009	11	384.76	6931.03	0.075
2009-2010	12	272.96	6171.65	0.120
2010-2011	13	282.14	5904.08	0.070
2011-2012	14	697.77	7992.07	0.215
2012-2013	15	575.78	7327.29	0.124
2013-2014	16	411.38	6521.80	0.099
2014-2015	17	367.74	6665.45	0.068
2015-2016	18	361.81	6572.23	0.069
2016-2017	19	402.96	8095.00	0.292
2017-2018	20	356.89	7453.18	0.081
2018-2019	21	351.81	7378.05	0.878

Note – Data of Rihand Reservoir from Irrigation Department, Uttar Pradesh

3.6 Future Work

More work can be done in this field. Trap efficiency of the reservoir is the percentage of sediments that retained in a reservoir. It means that the difference in the inflow of sediments and the outflow of sediments give the total sediments retained in a reservoir. Till now there are many conventional methods such as Brune (1953, Brown (1944), Gill (1979), Heinemann (1981), Jothiprakash and Garg (2008) as well as new techniques such as ANN modeling that can be used to estimate the Trap efficiency of the reservoir. These all methods gave the empirical equation that is only dependent on Capacity- inflow ratio. Brown (1944) is dependent on Capacity-Watershed ratio. There are many other factors that affect trap efficiency of reservoir. Jothiprakash and Garg (2008) developed an equation that included age of the reservoir as one of the factor affecting Trap Efficiency. The further work that can be done is that new equation can be developed which would comprise more factors that affect the trap efficiency of reservoir such as rainfall, runoff, evaporation etc.

Experimental work can also be done in this field. Experimental work had been done before but they did not give the successful results. This is also a good area where a reservoir can be simulated in the lab or experimental setup can be used to estimate the trap efficiency of reservoir.

Experimental work can be validated with conventional methods as well as software such as ANN modeling, fluent.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results of Trap efficiency of Rihand reservoir

Table 4.1 Observed and Estimated Trap efficiency of Rihand Reservoir

Year	Age of Reservoir (years)	Inflow (m^3/sec)	Capacity (Mm^3)	C/I ratio	Observed Trap Efficiency %(Brune curve)	Trap efficiency (Jothiprakash and Garg equation) %
1998-1999	1	569.89	8099.42	0.450	94.80	94.79
1999-2000	2	682.31	8753.92	0.407	94.35	94.29
2000-2001	3	529.73	7726.17	0.462	95.10	94.98
2001-2002	4	554.93	8050.10	0.460	94.92	95.08
2002-2003	5	408.23	7232.78	0.562	96.25	95.94
2003-2004	6	499.44	7383.88	0.465	95.65	95.25
2004-2005	7	330.31	5886.95	0.565	96.40	96.05
2005-2006	8	384.16	6643.12	0.548	96.20	95.97
2006-2007	9	474.39	6660.65	0.445	94.90	95.04
2007-2008	10	311.85	6093.58	0.620	96.80	96.54
2008-2009	11	384.76	6931.03	0.571	96.50	96.26
2009-2010	12	272.96	6171.65	0.717	97.35	97.13
2010-2011	13	282.14	5904.08	0.664	96.65	96.91
2011-2012	14	697.77	7992.07	0.636	96.55	96.80
2012-2013	15	575.78	7327.29	0.403	94.20	94.76
2013-2014	16	411.38	6521.80	0.503	96.15	95.92
2014-2015	17	367.74	6665.45	0.575	96.70	96.54
2015-2016	18	361.81	6572.23	0.576	96.85	96.83
2016-2017	19	402.96	8095.00	0.637	97.25	97.02
2017-2018	20	356.89	7453.18	0.662	97.29	97.20
2018-2019	21	351.81	7378.05	0.665	97.50	97.46

The average of observed Trap Efficiency from Brune's (1953) curve in above table is 96.11%.

The average of estimated Trap efficiency from Jothiprakash and Garg (2008) is 96.03 %.

4.1.1 Graphs showing the trap efficiency observed with Brune Curve (1953) and Estimated by Jothiprakash and Garg (2008)

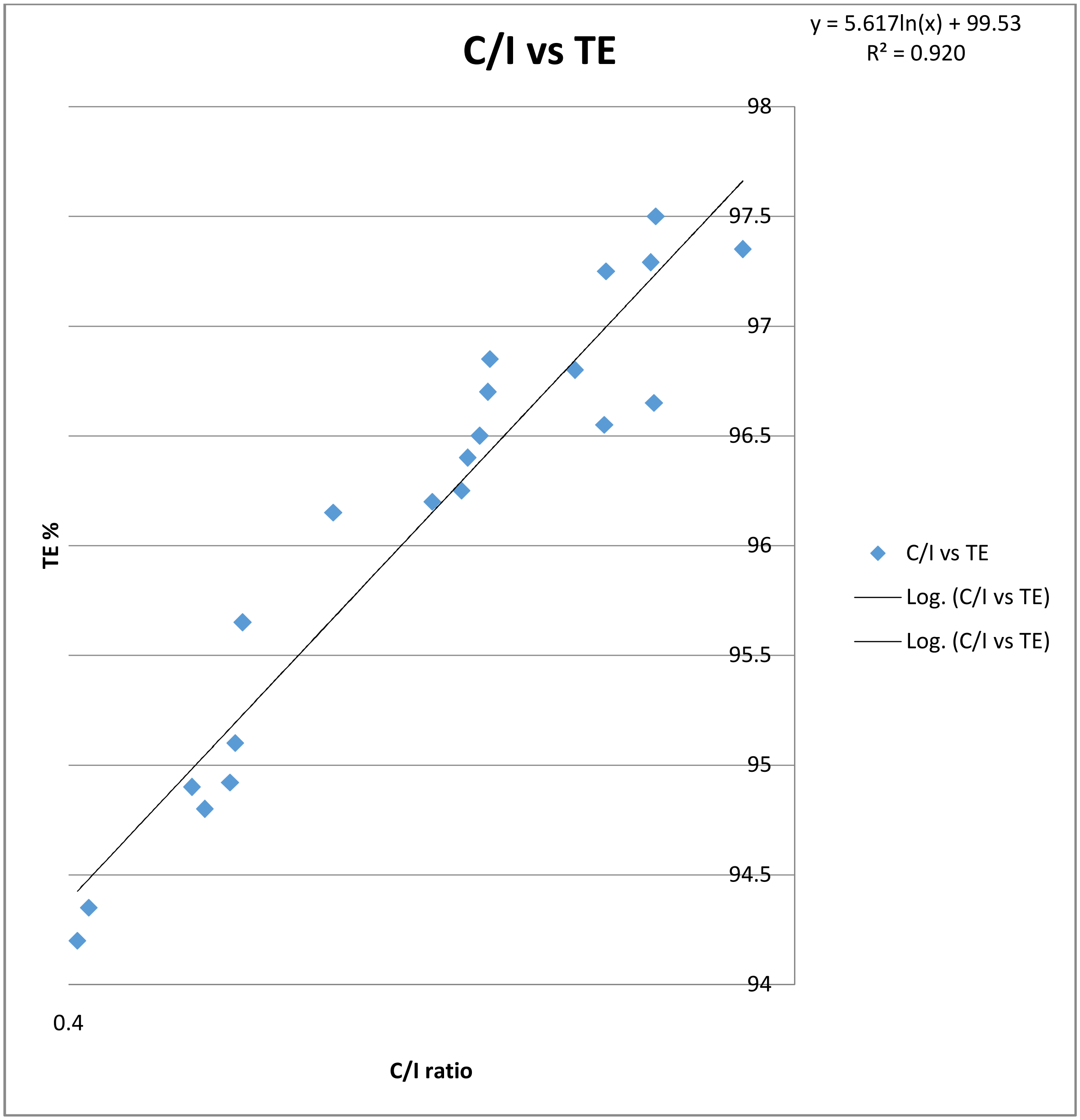


Fig. 4.1 (a) Graph showing TE observed

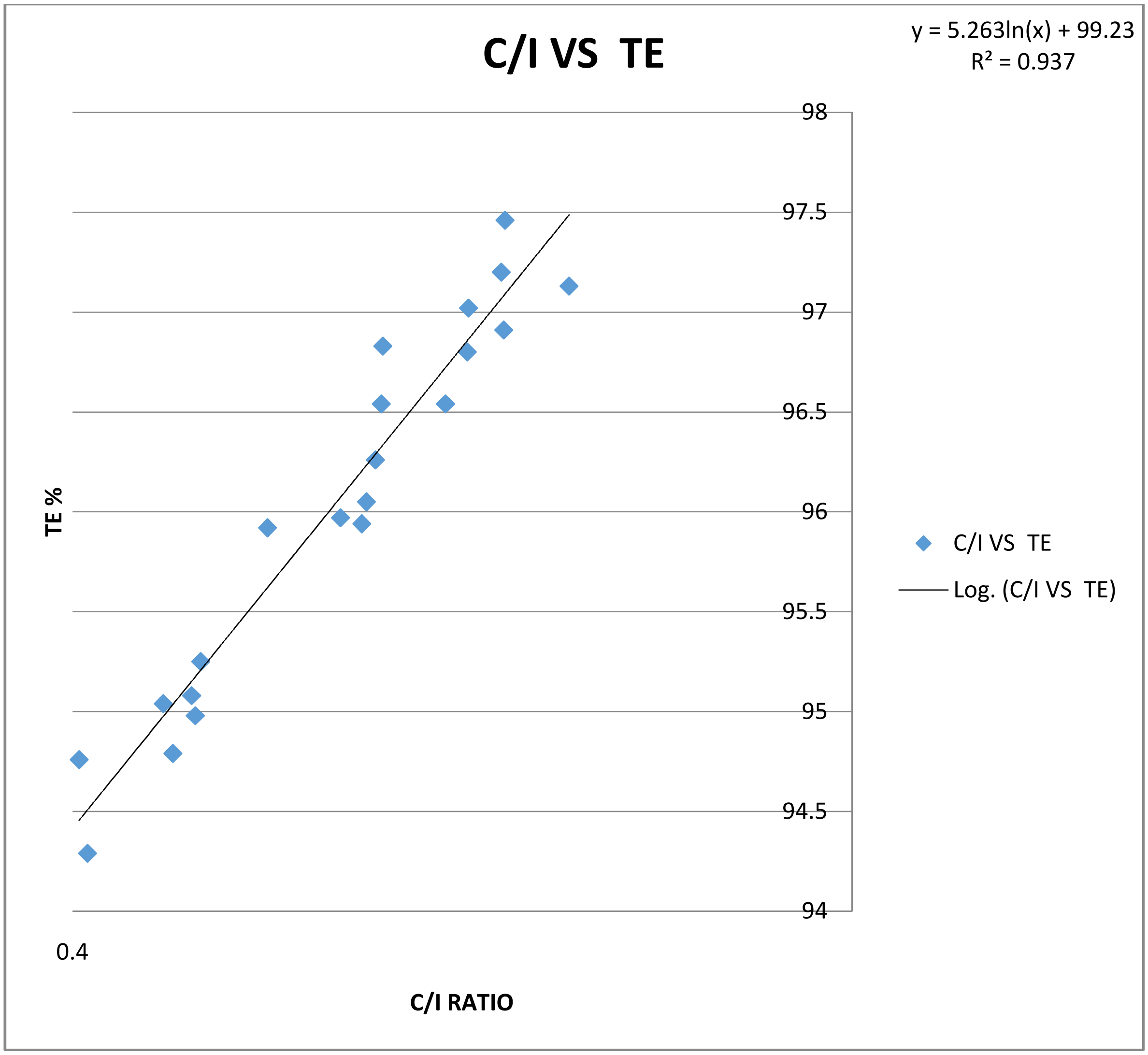


Fig. 4.1 (b) TE estimated by Jothiprakash and Garg (2008)

The upper graph in Fig. 4.1 shows observed TE of Rihand Reservoir. Seeing the graph we can say that estimated trap efficiency is nearly equal to Trap efficiency estimated from Jothiprakash and Garg (2008) developed equation. The observed trap efficiency were taken from Brune's curve. Seeing both the trap efficiency Jothiprakash and Garg (2008) gave better results because they incorporated one more parameter that affect the trap efficiency. They incorporated age of reservoir in their empirical equation. The results show little bit variation because of the extra factor that they incorporated in the equation. The results of Jothiprakash and Garg (2008) are better because of the R^2 value is 0.937 compared to R^2 value from Brune method is 0.920.

4.2 Results of TE of Rihand Dam from ANN model.

Table 4.2 TE from ANN model

Year	Age of Reservoir (years)	Inflow (m^3/sec)	Capacity (Mm^3)	C/I ratio	Observed Trap Efficiency %(Brune curve)	Trap efficiency (Jothiprakash and Garg equation) %	TE ANN model (4 inputs)	TE ANN model (3 inputs
1998 - 1999	1	569.89	8099.42	0.450	94.80	94.79	94.82	94.56
1999 - 2000	2	682.31	8753.92	0.407	94.35	94.29	94.36	94.35
2000 - 2001	3	529.73	7726.17	0.462	95.10	94.98	95.10	95.11
2001 - 2002	4	554.93	8050.10	0.460	94.92	95.08	94.93	94.93
2002 - 2003	5	408.23	7232.78	0.562	96.25	95.94	96.11	96.51
2003 - 2004	6	499.44	7383.88	0.465	95.65	95.25	95.64	95.00
2004 - 2005	7	330.31	5886.95	0.565	96.40	96.05	96.35	96.40
2005 - 2006	8	384.16	6643.12	0.548	96.20	95.97	96.20	96.18
2006 - 2007	9	474.39	6660.65	0.445	94.90	95.04	95.52	94.45
2007 - 2008	10	311.85	6093.58	0.620	96.80	96.54	96.78	96.80
2008 - 2009	11	384.76	6931.03	0.571	96.50	96.26	96.53	96.50

2009 - 2010	12	272.96	6171.65	0.717	97.35	97.13	97.34	97.06
2010 - 2011	13	282.14	5904.08	0.664	96.65	96.91	96.67	96.66
2011 - 2012	14	697.77	7992.07	0.636	96.55	96.80	96.56	96.53
2012 - 2013	15	575.78	7327.29	0.403	94.20	94.76	94.62	94.20
2013 - 2014	16	411.38	6521.80	0.503	96.15	95.92	96.15	95.13
2014 - 2015	17	367.74	6665.45	0.575	96.70	96.54	96.77	96.71
2015 - 2016	18	361.81	6572.23	0.576	96.85	96.83	96.82	96.86
2016 - 2017	19	402.96	8095.00	0.637	97.25	97.02	97.50	97.24
2017 - 2018	20	356.89	7453.18	0.662	97.29	97.20	97.50	97.48
2018 - 2019	21	351.81	7378.05	0.665	97.50	97.46	97.50	97.49

The average of observed trap efficiency of Rihand Dam from Brune's curve is 96.11%. The average of estimated Trap efficiency from Jothiprakash and Garg (2008) is 96.03%. The average of estimated TE from ANN model using 4 input parameters is 96.18% and the average of estimated TE from ANN model using 3 input parameters is 96.01%.

All methods gave nearly same results but ANN can solve the complexity with any number of input parameter. Jothiprakash and Garg empirical equation gives better results than Brune curve. Brune had only considered only capacity and inflow in estimating the trap efficiency whereas Jothiprakash and Garg (2008) incorporated age of reservoir in their equation.

4.2.1 Graph showing the Estimation of TE by ANN model using 4 and 3 inputs

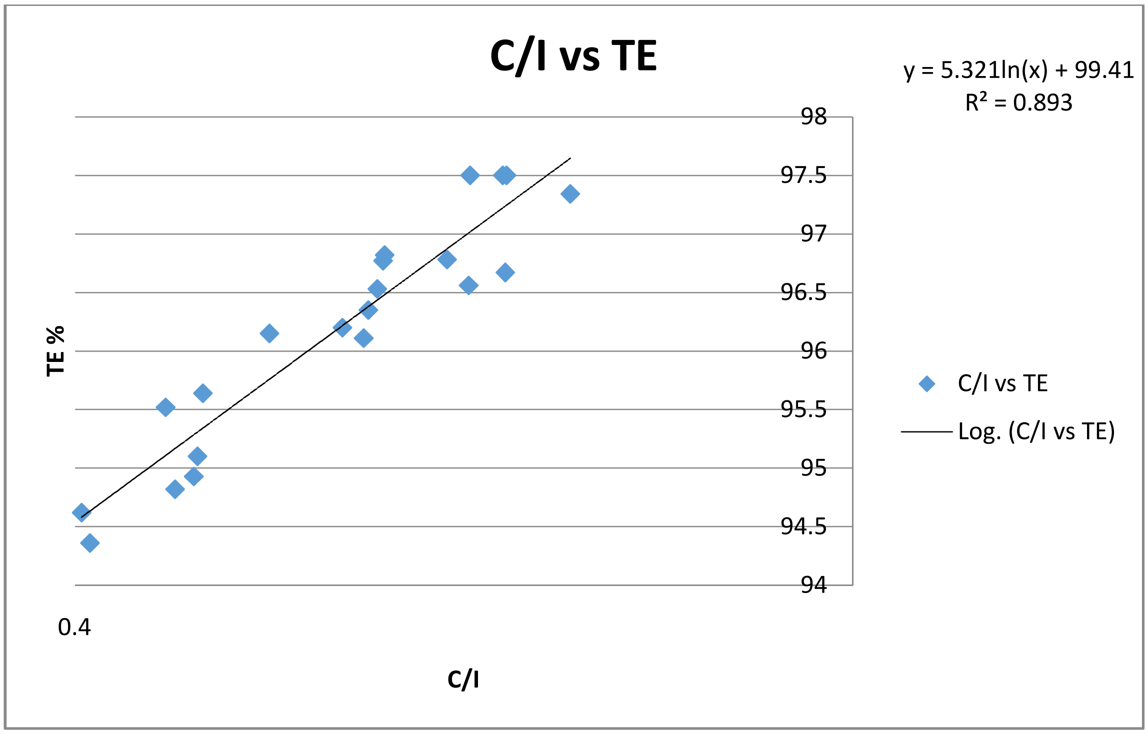


Fig. 4.2 (a) TE estimated by ANN model using 4 inputs

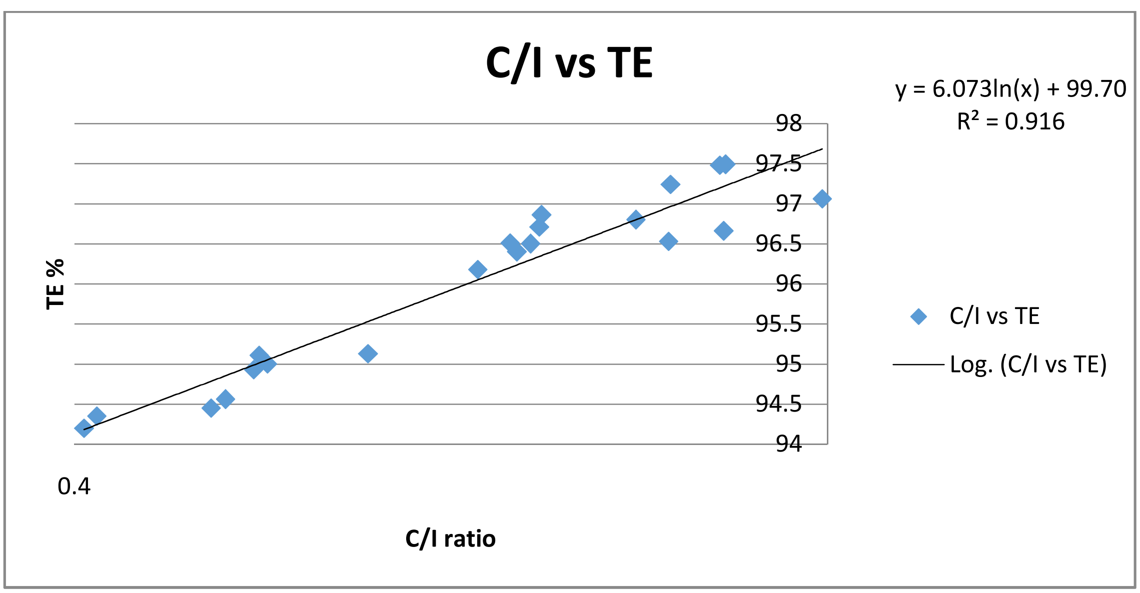


Fig. 4.2 (b) TE estimated by ANN model using 3 inputs

The above graph given in Fig. 4.2 (a) and (b) shows the value of estimated Trap efficiency of Rihand Reservoir. There is not much difference in average Trap efficiency of Rihand reservoir in all methods. The graph given above in Fig. 4.2 (a) and (b) shows estimated Trap efficiency of Rihand Reservoir using four inputs namely rainfall, capacity, inflow, age of reservoir. The average TE from ANN modeling using 4 inputs is 96.18 %. The average TE of Rihand Reservoir estimated by ANN modeling using 3 inputs is 96.01 As the input parameters is increased it is difficult to estimate trap efficiency by conventional method's proposed by Brune (1953), Brown (1944), Gill (1979) etc. ANN modeling technique can easily solve the increased complexity easily and in a less time. ANN gives better results.

4.3 ANN diagrams

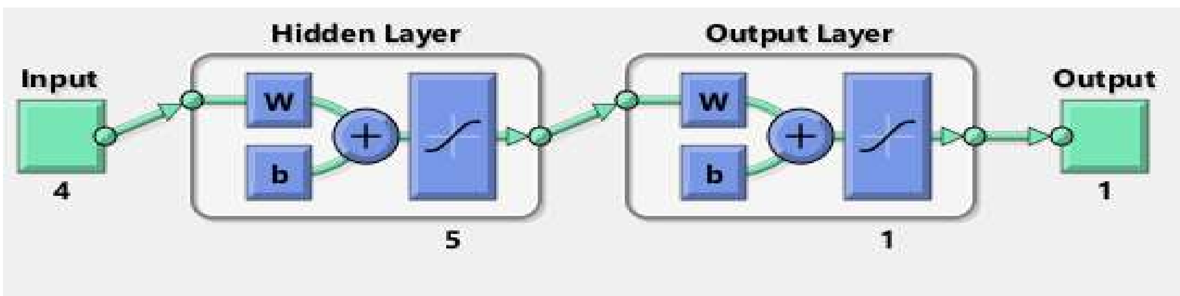


Fig. 4.3 Neural Network Diagram with four inputs

The above diagram in fig. 4.3 shows the ANN diagram which has a set of four input parameters namely rainfall, age of reservoir, capacity, annual average inflow rates. The three layers are input layer, hidden layer and output layer and the output. The hidden layer has 5 neurons for the optimization of weights.

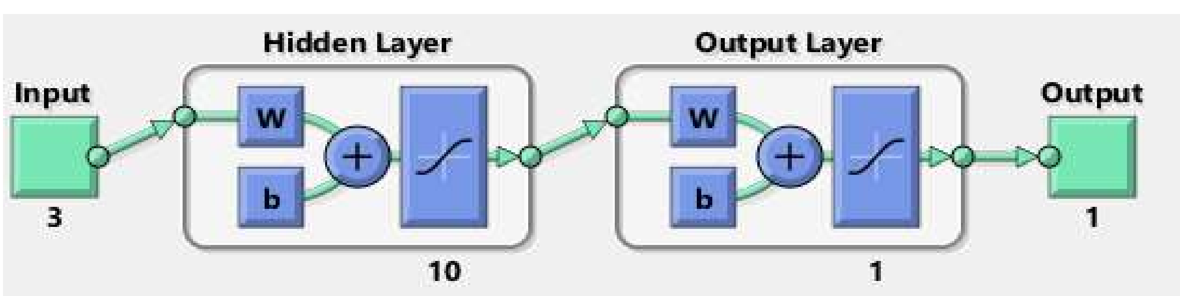


Fig. 4.4 Neural Network diagram with 3 inputs

The above diagram in fig. 4.4 shows the ANN diagram which has a set of three input parameters namely rainfall, age of reservoir, capacity, annual average inflow rates. The three layers are input layer, hidden layer and output layer and the output. The hidden layer has 10 neurons for the optimization of weights.

4.3.1 Graphs of relation coefficient R input and target in ANN model

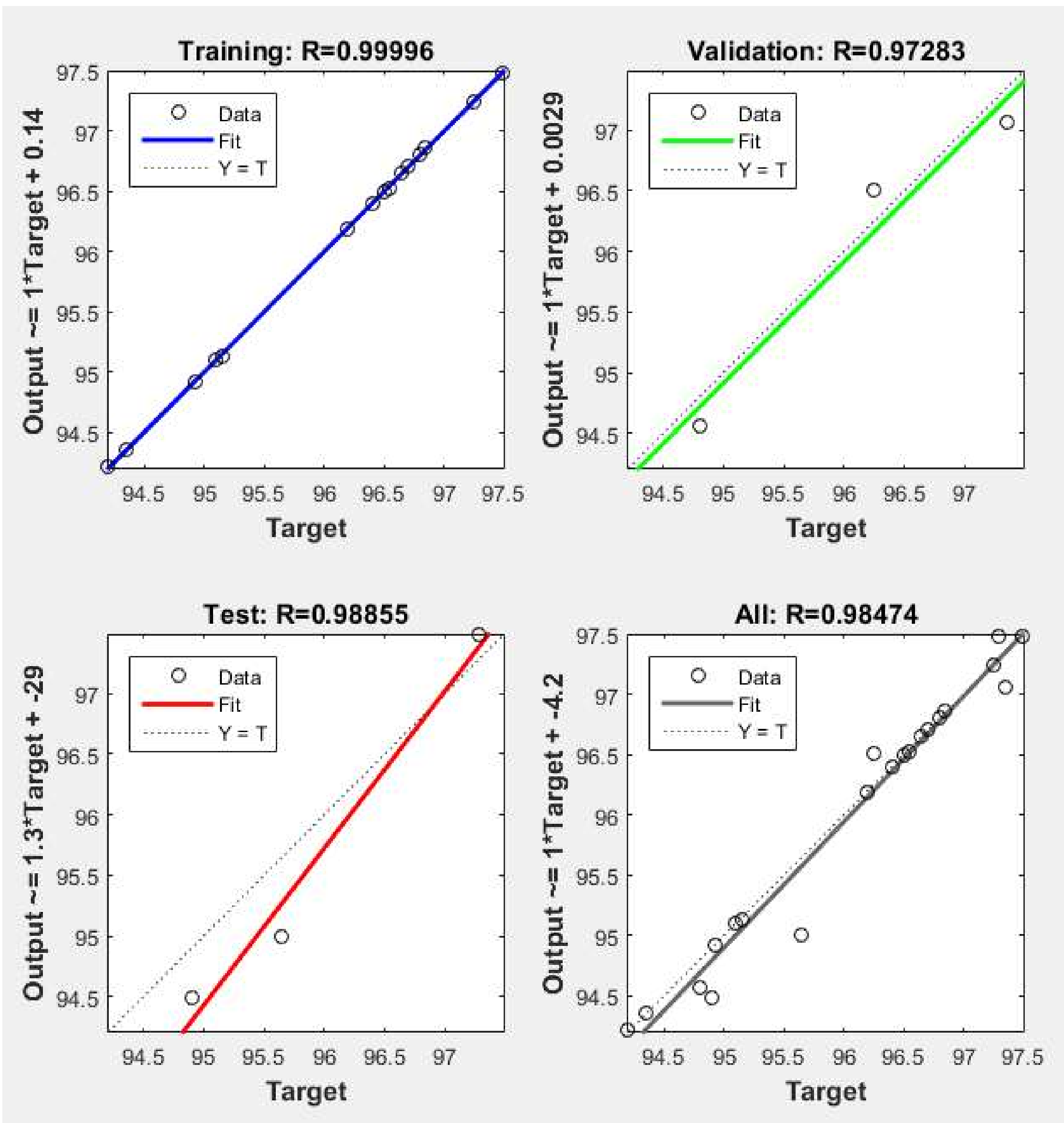


Fig. 4.5 (a) Regression Coefficient R (3 inputs)

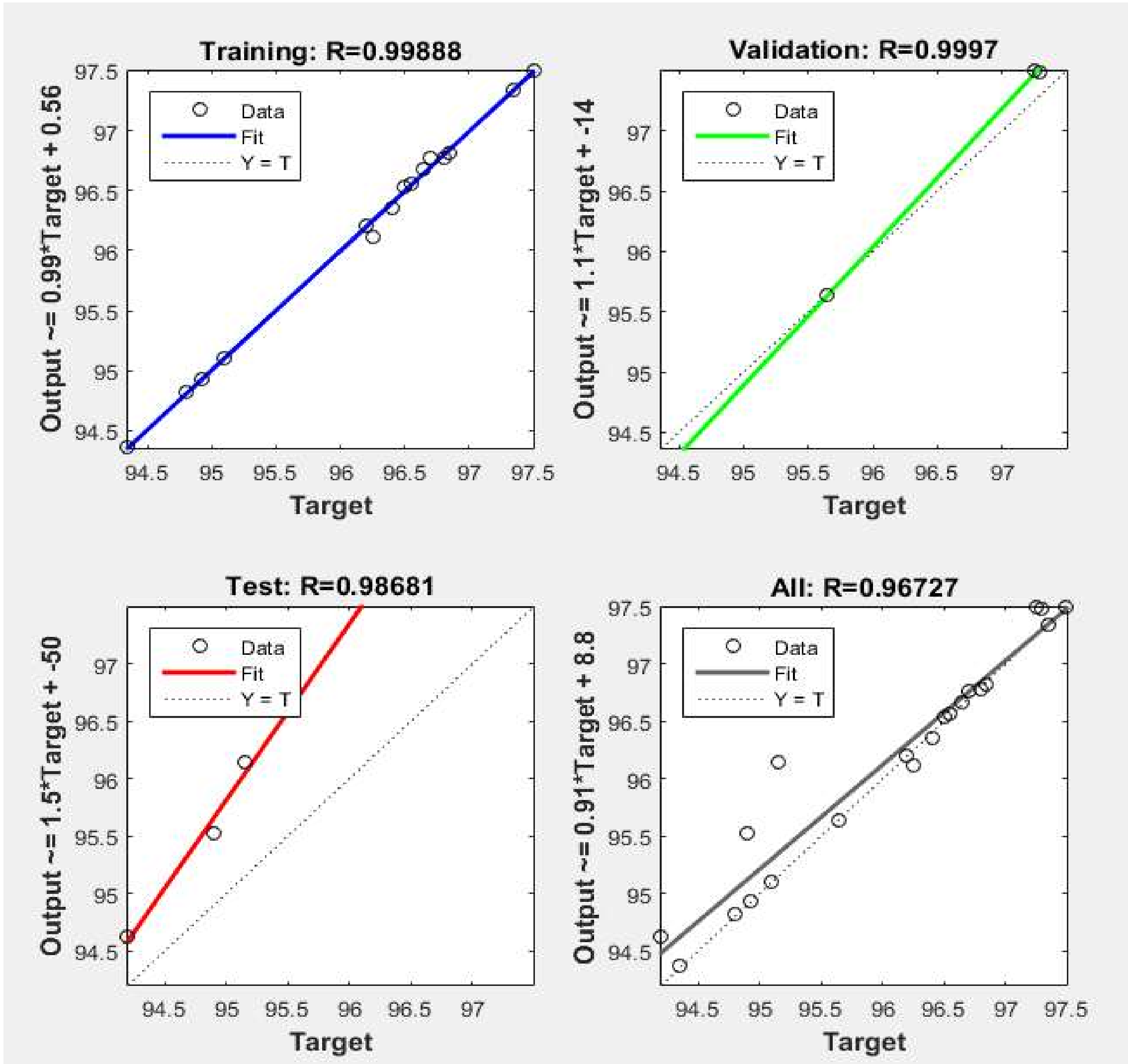


Fig. 4.5 (b) Regression Coefficient (4 inputs)

Above fig 4.5 (a) shows the relation of R with target data that I used in the present study. Graphs shows the relationship between output and target value. Fig. 4.5 (a) is a where there were four input parameters and Fig 4.5 (b) where there three input parameters.

CHAPTER 5

CONCLUSION

Brune's (1953) method is most widely used conventional technique to estimate the trap efficiency of a reservoir. Brune gave relationship between trap efficiency in percentage with capacity-inflow ratio. Brown (1944) was the first person to estimate the trap efficiency of a reservoir using watershed area. Later, his studies were replaced by Brune's method because his method was more accurate. Watershed area can change due to many factor such as rainfall. Capacity- inflow ratio should be used instead of capacity-watershed area ratio. All the developments in the Brune curve used Capacity-Inflow ratio. Churchill's method is more accurate than Brune but is more complex.

Jothiprakash developed Brune's equation incorporating age of reservoir in it. They were the first who developed the Brune curve which incorporated the age of reservoir. The equation developed gave better results than Brune. ANN can also be used for the estimation of trap efficiency. ANN gives better results than Brune and other conventional methods. ANN is faster and can solve as many input parameters to estimate trap efficiency.

The average trap efficiency of Rihand reservoir from Brune (1953) curve is 96.11%. The average trap efficiency of Rihand reservoir from Jothiprakash and Garg (2008) is 96.03%. The average trap efficiency of Rihand reservoir from ANN using 4 input parameters is 96.18%. The average trap efficiency of Rihand reservoir from ANN using 3 input parameters is 96.01%. The average Trap efficiency of all methods are nearly equal. The results got validated with all methods. ANN model was faster and accurate with more no of input parameters. The values of TE of each methods followed Brune Curve.

From present study it is very clear that ANN model can be used to estimate the Trap Efficiency of reservoir. It is fast, more accurate, can solve complexity very easily.

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