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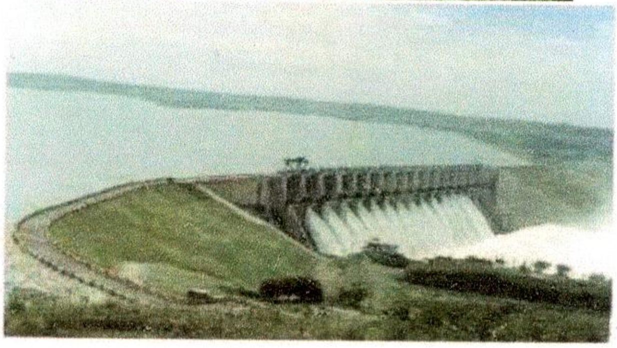
# "ESTIMATION OF SEDIMENT-DISCHARGE OF JWALAMUKHI SITE USING ARTIFICIAL NEURAL NETWORK"



NATIONAL INSTITUTE OF HYDROLOGY

राष्ट्रीय जल विज्ञान संस्थान

आपो हि ष्ठा मयोभुवः

**NATIONAL INSTITUTE OF HYDROLOGY**

**ROORKEE 247 667**

**A summer internship report on the topic "Estimation of Sediment-Discharge of Jwalamukhi site using artificial neural network"**


**Supervised by:** **Dr. Rama Mehta**
**Scientist**
**National Institute Of Hydrology**
**IIT ROORKEE**

**Submitted by:** **Pinki**
**M.Sc. (Ind. Maths & Informatics)**
**IIT ROORKEE**
**En.No.-14614009**

**A Report Submitted BY**

**Pinki**

**(Enrolment No: 14614009)**

**Under the Supervision of**

**Dr. Rama Mehta**

**(Scientist)**

**DEPARTMENT OF MATHEMATICS**

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

**ROORKEE-247667 (INDIA)**

# DECLARATION

I hereby declare that the work presented in this project entitled "Estimation of Sediment-Discharge of Jwalamukhi site using Artificial Neural Network" in partial fulfillment of the degree M.Sc Industrial Mathematics & Informatics at Indian Institute of Technology, Roorkee is an authentic work of my own done under the guidance of Dr. Rama Mehta , Scientist, National Institute of Hydrology, Roorkee.

Date: 13|10|15
Place: Roorkee

Pinki
Pinki

# TO WHOMSOEVER IT MAY CONCERN

It is certified that Ms. **Pinki**, (enrollment No. 14614009), student of M.Sc. Industrial Mathematics & Informatics, Indian Institute of Technology Roorkee, did an internship project from May 2015 to July 2015 under my supervision

Date: 13|10|15

(Dr. RAMA MEHTA)
Project Guide

Place: Roorkee

# INTRODUCTION

Sediment-discharge measurements usually are available on a discrete or periodic basis. However, estimates of sediment transport often are needed for unmeasured periods, such as when daily or annual sediment-discharge values are sought, or when estimates of transport rates for unmeasured or hypothetical flows are required. Selected methods for estimating suspended-sediment, bed-load, bed- material-load, and total-load discharges have been presented in some detail elsewhere in this volume. The purposes of this contribution are to present some limitations and potential pitfalls associated with obtaining and using the requisite data and equations to estimate sediment discharges and to provide guidance for Selecting appropriate estimating equations. Records of sediment discharge are derived from data collected with sufficient frequency to obtain reliable estimates for the computational interval and period. Most sediment discharge records are computed at daily or annual intervals based on periodically collected data, although some partial records represent discrete or seasonal intervals such as those for flood periods. The method used to calculate sediment discharge records is dependent on the types and frequency of available data. Records for suspended-sediment discharge computed by methods described by Porterfield (1972) are most prevalent, in part because measurement protocols and computational techniques are well established and because suspended sediment composes the bulk of sediment discharges for many rivers. Discharge records for bed load, total load, or in some cases bed-material load plus wash load are less common.

## SEDIMENT-DISCHARGE RELATIONSHIP

Suspended sediment discharge relationship of the form Ss = aQ^b, where Ss is suspended sediment, Q discharge, and a and b are best fit estimated parameters. In regions where seasonal variation in erosion processes and source areas are controlled by floods generated by both spring snowmelt and summer storms, seasonal variation in sediment yield may mask any relationship with discharge. The relationship between sediment and discharge and the character of suspended sediment transport have been investigated for individual hydrological events. Variations in sediment concentration have been attributed to exhaustion and replenishment of the sediment supply, differences in travel distance between source areas and the locations of the measuring station, the location of sediment source areas and the existence of a time lag between sediment concentration and discharge peaks. Williams (1989) developed models for sediment rating relationships (linear and curved) for individual hydrological events by comparing sediment concentration and discharge ratios at a given discharge on the rising and falling limbs of discharge hydrographs. Although he summarized the physiographical and hydrological reasons for the existence of each type of relationship associated with sediment rating curves, only partial understanding of the controlling factors exists.

Artificial Neural Network (ANN) can be applied to predict the monthly, weekly and daily suspended sediment in the catchment by relating it to average rainfall, temperature, rainfall intensity and water discharge. Generally hydrological modeling using artificial neural network has adopted simple trained-and-tested procedure to find the best ANN structure. Sometimes due to inadequate data set, ANN structure is decided by this simple trained-and-tested procedure that provides biased testing. Cross validation procedure has been used for estimating the generalized performance for during smaller data set. Although suspended sediment load can be predicted using numerous developed equations their results often differ from each other and from measured data due to complexity of sediment transport nature.

Many researchers have studied the application of Artificial Neural Networks in vital topics of hydrology and hydraulics such as prediction of sediment load, rainfall-runoff modeling, flow prediction etc. Dr.Rama Devi Mehta in PH.D thesis of shri A.K.lohani ,Dept of Hydrology,IIT Roorkee and Cigizoglu (2002) made a comparison between ANNs and SRC for suspended sediment estimation and found that the estimations obtained by ANN's were significantly superior to the corresponding classical sediment rating curve ones.

The application of ANNs to sediment concentration Estimation is, however, not available in the literature. In this study, initially, ANNs are used to forecast the present or future sediment value using the past sediment values as input.

## STUDY AREA

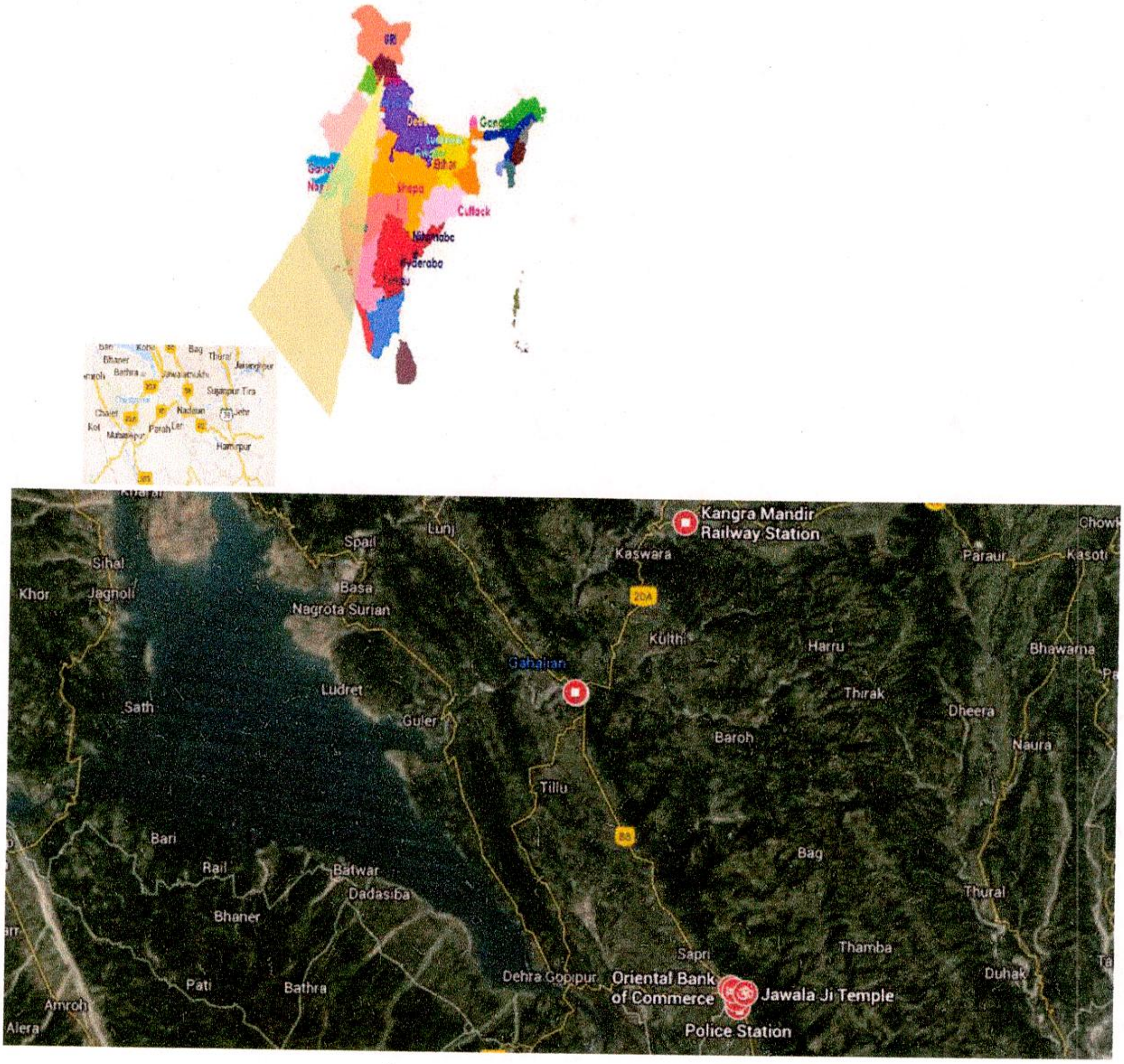



**Fig.:** *Location of Nadaun or Jwalamukhi in Himachal Pradesh*

In the present study, the study area is Nadaun or Jwalamukhi in the Beas basin. Beas basin of Himachal Pradesh (Indian Himalaya) is selected as a study area, from where the Beas River originates. Thus being a catchment area of a river it is important to monitor the snow cover as it has lot of applications. Climatically, this area falls in the lower Himalayan zone (Sharma and Ganju 2000) and characterized by moderate temperature as mean minimum temperature −1.6◦C, lowest minimum −12◦C and mean maximum 7.7◦C during winter (November to April) and high precipitation as mean standing snow 165 cm and mean cumulative snowfall 363 cm in the month of January (Singh and Ganju 2006). Due to moderate temperatures, the winter period remains short and the snow cover changes into 528 H S Negi et al 0◦C isothermal. The average altitude of this zone is between 2000 and 4000 m. However, middle Himalayan zone is characterized by cold temperature, mostly glaciated and altitude varies from 3500 to 5300 m and the upper Himalayan zone is extremely cold, receives dry snow and highly glaciated which is somewhat close to continental snow conditions, and altitude more than 5000 m.

As the study area receives high precipitation and significant changes in the snow characteristics due to moderate temperature, it also receives lot of avalanche activities along Manali–Leh highway, which is very important highway to the population of Ladhak, as it connects Ladhak division with rest of the country.
In addition to catchment areas of Beas river,snow cover distribution was carried out because the areal extent of snow significantly changes in summer due to melting. This provides ample opportunity to validate snow indices under different melting conditions. This area also covers vegetation (pine trees),
The total area of the basinis approximately 347 $km^2$

# DATA ANALYSIS

- **DATA USED**

In this present study, we have monthly data of discharge and sediment of Nadaun/Jwalamukhi site from 1987 to 2009.that is collected by National Institute of Hydrology (NIH). Then we divided that data into monsoon and non-monsoon seasons. As we consider June to October in monsoon and November to May in non-monsoon, where the discharge is in Cumec and sediment is in mg/lit

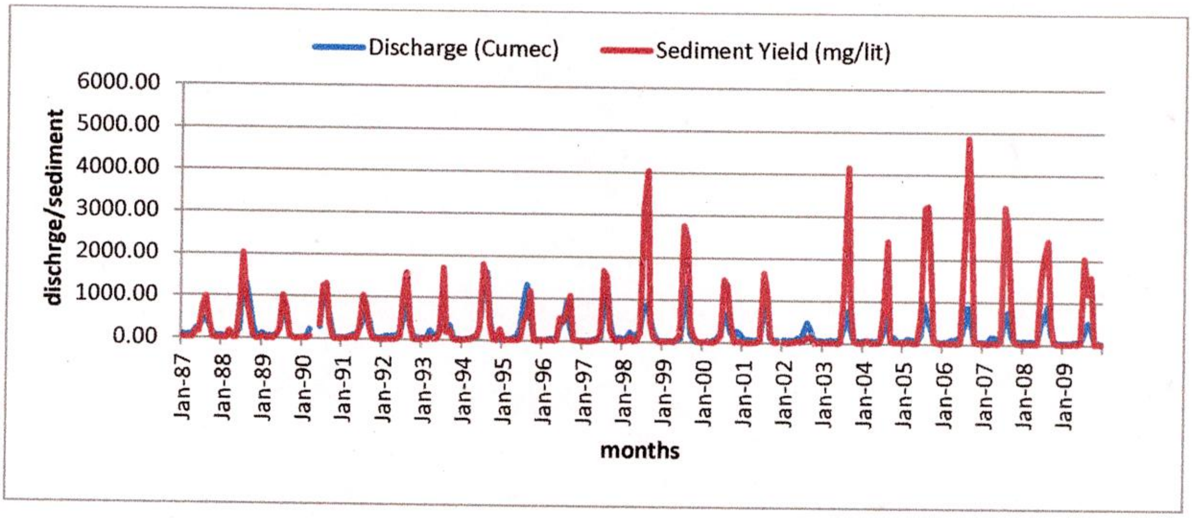



Fig.: *Sediment and discharge monthly data of Nadaun/Jwalamukhi (1987-2009)*

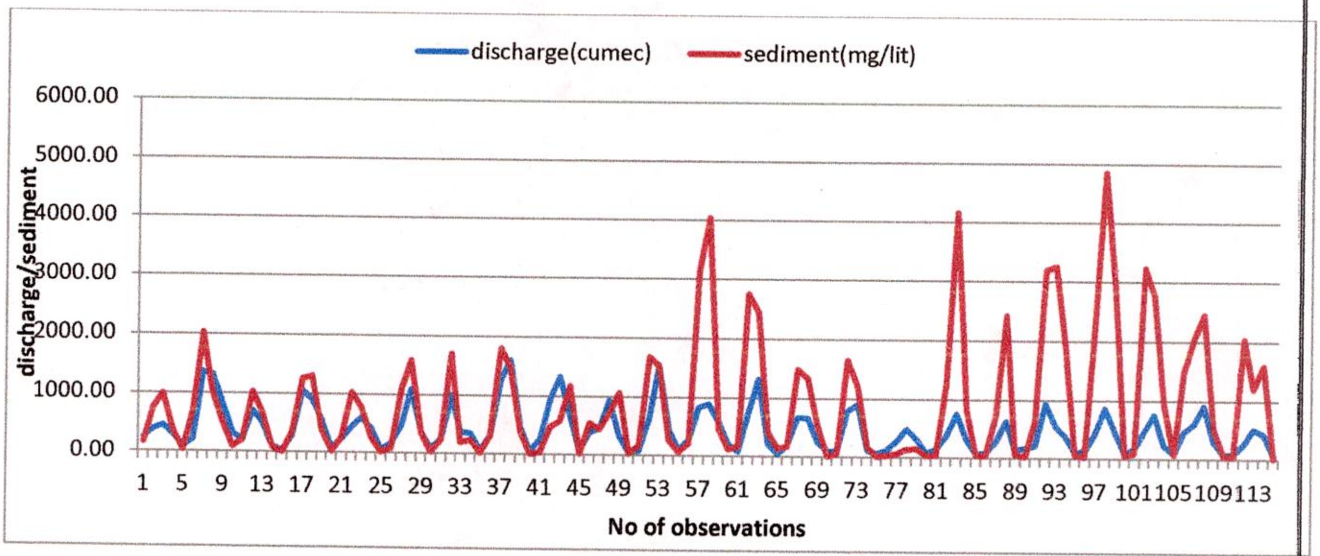



Fig.:*sediment and discharge data during monsoon season of Nadaun/Jwalamukhi (1987-2009)*

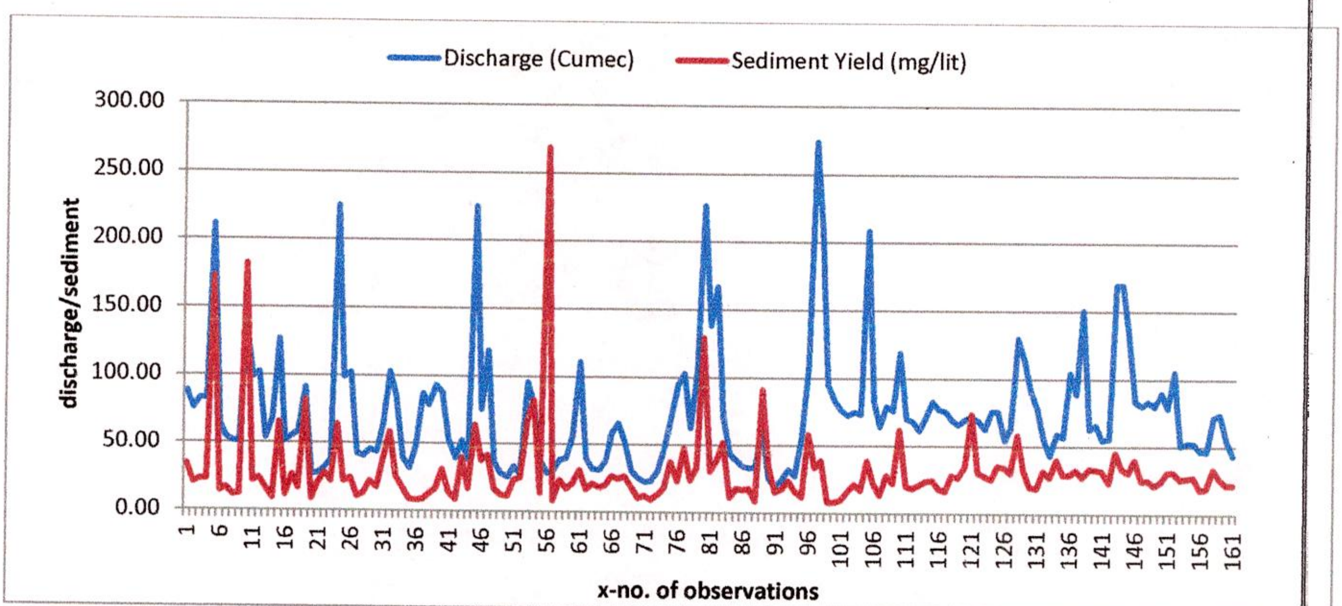



Fig.: *Sediment and discharge data during non-monsoon season of Nadaun/Jwalamukhi (1987-2009)*

- # DESCRIPTIVE STATISTICAL ANALYSIS

### Table1: MAXIMUM AND MINIMUM DISCHARGE

| Maximum and Minimum Discharge Year | Maximum Discharge (cumec) | Maximum Sediment (mg/l) | Minimum Discharge (cumec) | Minimum Sediment (mg/l) |
|---|---|---|---|---|
| 1987 | 608.63 | 993.0452 | 54.53 | 14.27333 |
| 1988 | 1366.25 | 2034.881 | 51.24 | 9.112903 |
| 1989 | 710.00 | 1028.716 | 27.71 | 8.79 |
| 1990 | 1059.88 | 1312.374 | 32.24 | 10.78667 |
| 1991 | 604.10 | 1037.613 | 31.89 | 8.6 |
| 1992 | 1092.01 | 1589.248 | 39.37 | 8.322581 |
| 1993 | 1006.21 | 1713.7 | 28.44 | 12.41613 |
| 1994 | 1606.09 | 1807.739 | 25.46 | 11.37419 |
| 1995 | 1333.36 | 1176.537 | 30.42 | 8.464516 |
| 1996 | 939.75 | 1070.387 | 25.49 | 10.79355 |
| 1997 | 1550.52 | 1683.006 | 22.79 | 9.625 |
| 1998 | 895.73 | 4050.403 | 43.53 | 11.49677 |
| 1999 | 1326.31 | 2753.258 | 19.73 | 8.666667 |
| 2000 | 670.19 | 1487.126 | 24.94 | 11.86667 |
| 2001 | 906.28 | 1655.752 | 73.02 | 8.4 |
| 2002 | 489.16 | 151.4333 | 64.5 | 13.48714 |
| 2003 | 753.64 | 4164.012 | 61.78 | 16.65806 |
| 2004 | 643.69 | 2428.294 | 54.46 | 25.44516 |
| 2005 | 944.58 | 3259.555 | 43.46 | 18.98387 |
| 2006 | 872.01 | 4866.555 | 56.88 | 27.77097 |
| 2007 | 758.13 | 3237.639 | 54.62 | 23.25714 |
| 2008 | 909.31 | 2455.232 | 50.92 | 21.10345 |
| 2009 | 517.92 | 2040.961 | 43.86 | 18.11429 |

| | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Discharge (cumec) | 232.03 | 303.4122388 | 19.73 | 1606.09 |
| Concentration (mg/l) | 389.7866487 | 797.8968635 | 8.322580645 | 4866.554839 |

**TABLE2. STATISTICAL DESCRIPTION**

# METHODS AND METHODOLOGY

## Observed value:

It is the value of given monthly data of discharge and sediment.as we used it in further procedure.

## Sediment rating curve:

The sediment rating curve is a relation between the river discharge and sediment load.Such curves are widely used to estimate the sediment load being transported by a river.Generally, a sediment-rating curve may be plotted showing average sediment concentration or load as a function of discharge averaged over daily, monthly, or other ne periods. Using the rating curve, the records of discharge are transformed into records of sediment concentration or load. Mathematically, a rating curve may be constructed by log-transforming all data and using a linear least square regression to determine the line of best fit. The relationship between sediment concentration and discharge is of the form:

$$S = aQ^b .$$

The log-log transformation of equation is:

$$\log S = \log a + b\log(Q)$$

where, $S$ and $Q$ are suspended sediment concentration (or load) and discharge respectively. $a$ and $b$ are regression constants.

A typical sediment-rating curve is a straight-line plot on log-log paper and a regression equation minimizes the sum of squared deviations from the log-transformed data. This is not the same as minimizing the sum of squared deviations from the original dataset. Therefore, this transformation introduces a bias that underestimates the sediment concentration (or load) at any discharge and it may result in underestimation by as much as 50% (Ferguson, 1986). Ferguson and others have suggested bias correction factors, but their appropriateness is uncertain . Further, depending upon the channel characteristics, two or more curves may be fitted to the data. A major limitation of this approach, however is that it is not able to take into account the hysteresis effect that gives a loop rating curve . Therefore, as such, the conventional rating technique is not adequate in view of the complexity and importance of the problem and, hence, there remains a scope for further improvement.

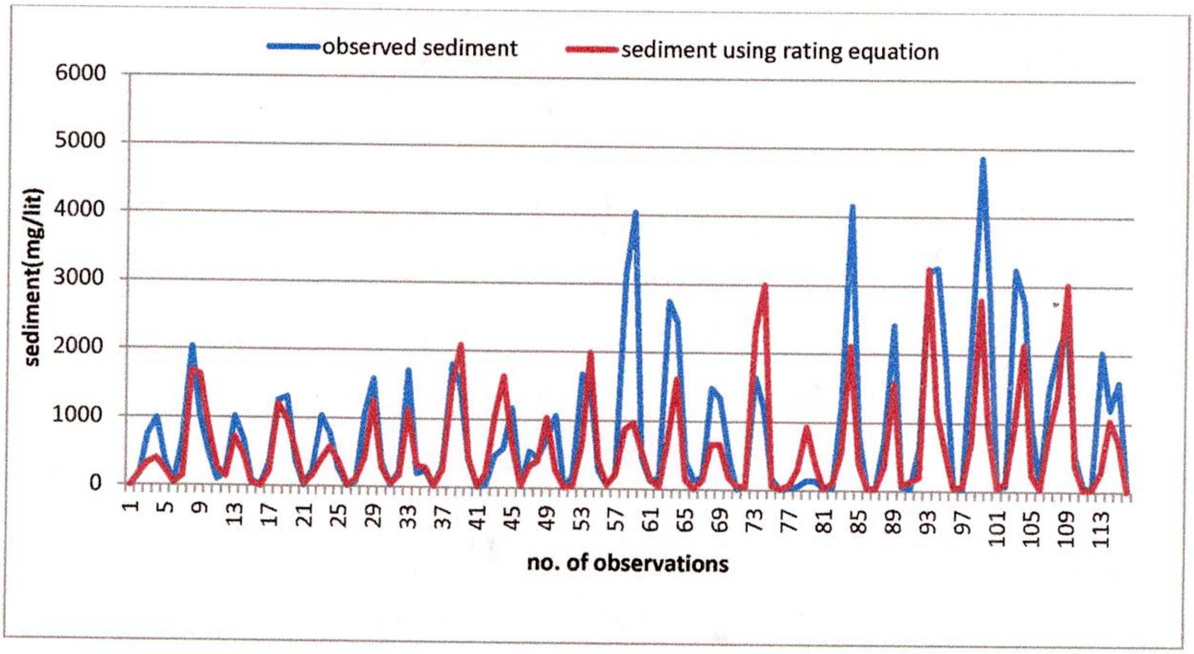



Fig.:*Comparision of observed value of sediment to sediment obtained by rating equation.*

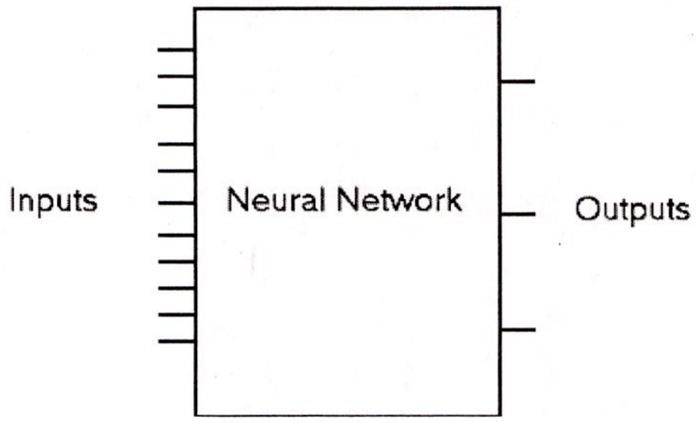
ROOT – MEAN- SQUARE ERROR(RMSE) =

√ (OBSERVED- RATING SEDIMENT)^2/N =761.4826

## ANN TECHNIQUE

An artificial neural network is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system. The computing world has lot to gain from neural networks, also known as artificial neural network or neural net. The neural network s have the ability to learn by example, which makes them very flexible and powerful.

- ANN is a black box performing transformation.




For neural networks, there is no need to devise an algorithm to perform a specific task/work i.e. there is no need to understand the internal mechanism of hat task. These network are well suitable for real time systems because of their fast response and computational times.

Artificial Neural Network is an information processing system that tries to replicate the behavior of a past through their learning systems with input output data and it is appreciably applicable for sediment modelling. Artificial neural networks are able to imprecise nonlinearities in the data. ANN is data driven self-adaptive method based on multivariate nonlinear nonparametric statistical analysis for real world complex problem.

An artificial neural network is a type of biologically inspired computational model, which is based loosely on the functioning of the human brain.it is more useful to think of a neural network as performing an input-output mapping via a series of simple processing nodes or neurons. The task of each individual neuron is twofold: it integrates information from an external source or from other neurons, often via a linear function, and it outputs this value via transfer function, such as sigmoid. The ability to map a function is derived via the configuration of these neurons into a set of weighted, interconnected layers, where the neurons in the first and last layers have a one-one correspondence to the input and output values respectively. Between these two external layers are one or more interconnected, hidden layers. Which is the key to learning the relationships in **the data.**

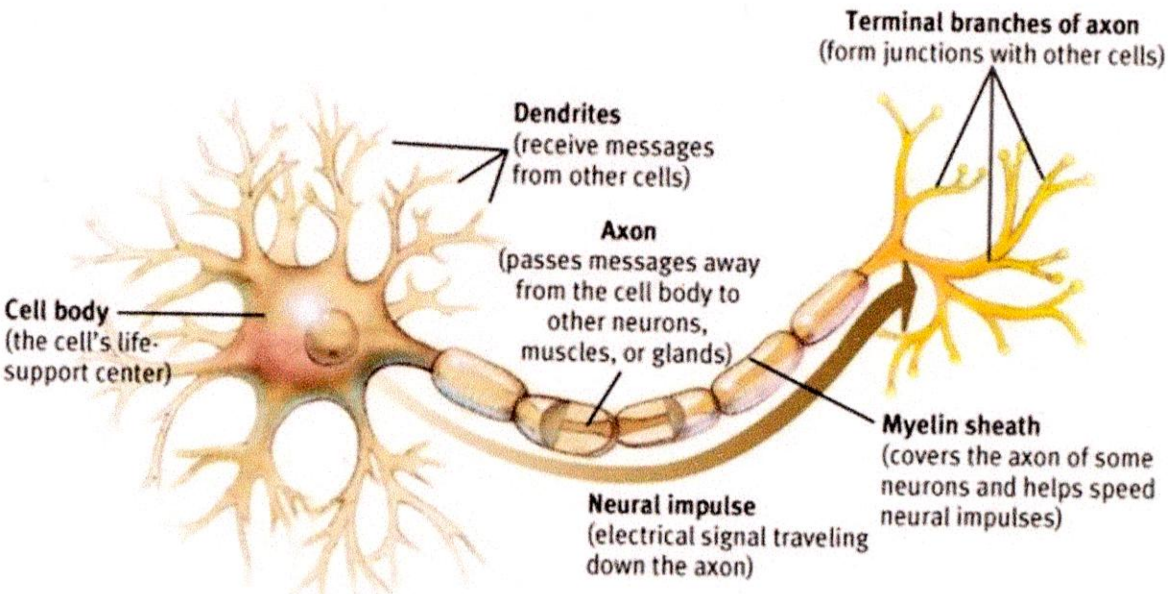



Fig*: Diagram of neuron in human brain*

## Advantages of neural network

Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, could be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques

ADAPTIVE LEARNING: an ANN is endowed with an ability to learn how to do tasks based on the data given for training or initial experience.

SELF ORGANISATION: an ANN can create its own organization or representation of the information it receives during learning time.

REAL TIME OPERATION: ANN computations may be carried out in parallel .special hardware devices are being designed and manufactured to take advantage of this capability of ANN's.

Adaptively (understands new ideas).

Evidential response (notice easily).

VLSI (very large scale integrated) implements ability.

A neural network can perform tasks that a linear program cannot.

When an element of neural network fails, it can continue without any problem ,a neural network learns and does not need to be reprogrammed.

And so on……

## Disadvantages

It needs training to operate.

Requires high processing time for large neural networks.

The architecture of a neural network is different from the architecture of microprocessors therefore needs to be emulated.

## Basic model of artificial neural network

The models of ANN are specified by the three basic entities namely:

i) The model synaptic interconnections in ANN consists a set of highly interconnected neurons or processing elements such that each neuron output is found to be connected through weights to neurons or to itself; delay, lead and lag –free connections are allowed. The arrangements and the geometry of their interconnections are essential for ANN. The point where the connection originates and terminates are noted.
The arrangements of neurons to form layers and the connection pattern within and between the layers is called network architecture. There exist five basic types of network architecture.

a) Single layer feed forward network
b) Multilayer feed forward network
c) Single node with its own feedback.
d) Single layer recurrent network.
e) Multi-layer recurrent network.

i) Training or learning rules adopted for updating and adjusting the connection weights;

ii) Their activation functions.

## Activation functions:

Activation function acts as a squashing function, such that the output of the neuron in a neural network is between certain values (usually 0 and 1, or -1 and 1)

When a signal is fed through a multilayer network with linear functions, the output obtained is remain same as that could be obtained using a single layer network. Due to this reason nonlinear functions are widely used in multilayer networks compare to linear functions.

List of linear activation functions:

i) Identity function: f(x)=x  for all x

The input function uses identity function for single layer network and output remains the same as input.

ii) Binary step function: f(x)= 1 if x>=theta
0 if x< theta

Here, theta represents the threshold value. This function is used in single layer network to convert net input to an output i.e. binary (1 or 0). It is also known as threshold function,

iii) Bipolar step function: f(x)= 1 if x>= theta
-1 if x< theta

Where, theta represents the threshold value. This function is also used in single layer network to convert net input to an output that is bipolar (+1 or -1).

iv) Piecewise –linear function: this function again can take on the values of 0 or 1, but can also take on values between that depending on the amplification factor in a certain region of linear operation.

Phi (v) =1  v>=1/2
V,  -1/2 >v>1/2
0  v<= -1/2

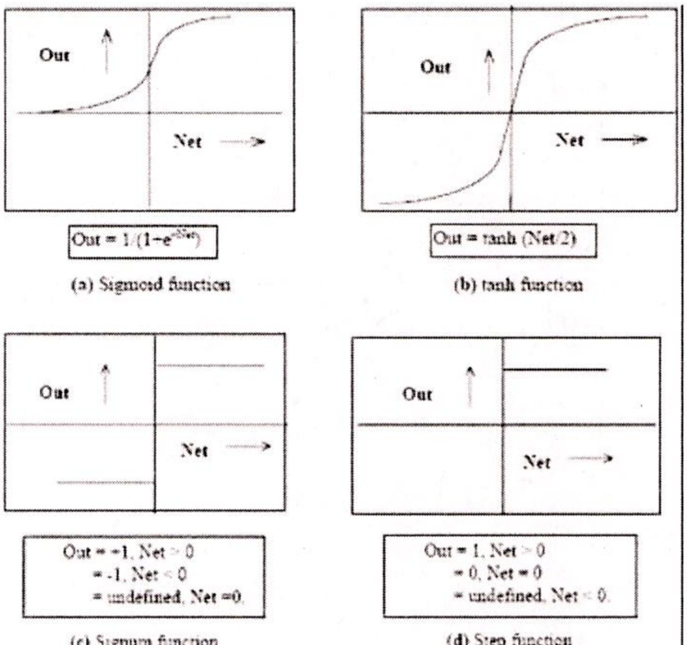
# Nonlinear functions

These functions are used to achieve the advantages of a multilayer network from single layer network.

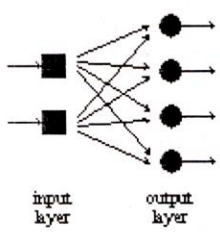
i) Sigmoidal function: it is the hyperbolic tangent function.
Phi (v) = tan (v/2) =1-exp(-v)/1+exp(-v)

And other functions are:-

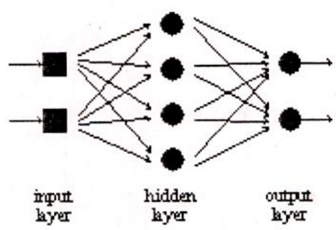
i) Sigmoid
ii) Tan(h)
iii) Signum
iv) Step




Common non-linear functions used for synaptic inhibition. Soft non-linearity: (a) Sigmoid and (b) tanh; Hard non-linearity: (c) Signum and (d) Step.




a) Single layer network




b) Multi layer network

## Neural network topologies

It focuses on the pattern of connections between the units and the propagation of data. for this pattern of connections, the main distinction is between:

i) Feed forward neural network: where the data from input to output units is strictly feed forward .the data processing can extend over multiple (layers of) units, but no feedback connections are present, i.e. connections extending from outputs of units to inputs units in the same layer or previous layer.

ii) Recurrent neural network: that do contain feedback connections.

We have given data of monthly discharge and sediment of Nadaun. We use excel file to plot the calibration and validation data where calibration data contains 70% of the observations and validation has only 30%.and which is further divided into training 15% and testing 15%. Then the above graph is of calibration and validation of monthly data where we have regression line and coefficients as well.

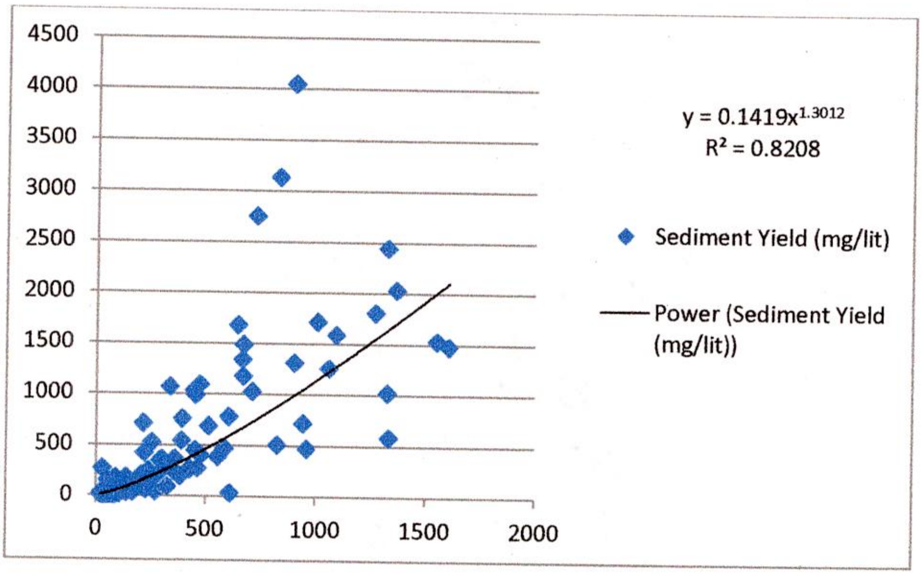



**Fig.:** *Sediment discharge during at nadaun (Calibration)*

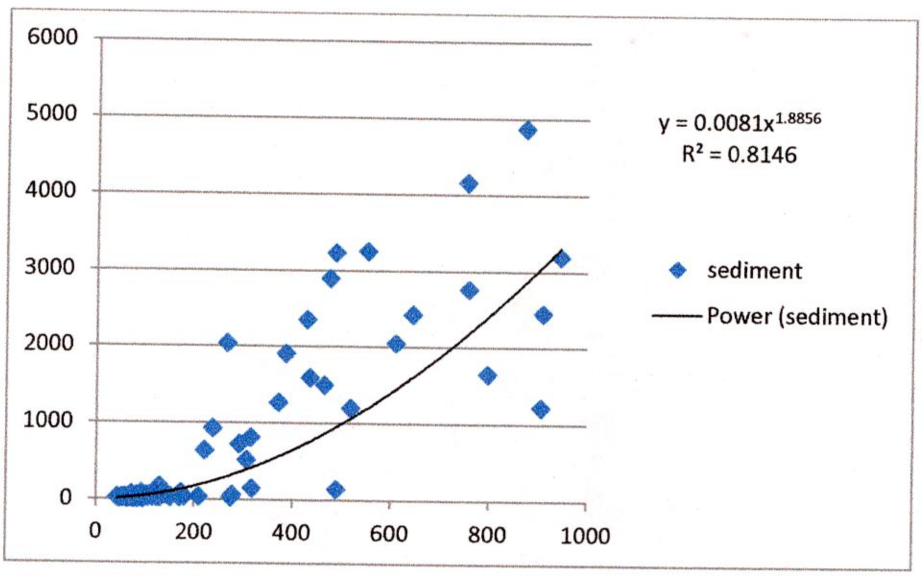



**Fig.:** *Sediment discharge at nadaun (Validation)*

Then we classified that monthly data of discharge and sediment of nadaun (Jwalamukhi) from 1987-2009 in monsoon and non-monsoon seasons.

Here, R^2 is the regression coefficient.

# MONSOON SEASON

## The data is given as follows:

| Year | Discharge (Cumec) | Observed Sediment Yield (mg/lit) | rate of equation | ANN |
|---|---|---|---|---|
| Jun-87 | 253.05 | 167.25 | 188.707 | 257.0219 |
| Jul-87 | 392.14 | 760.9387 | 333.6491 | 858.4846 |
| Aug-87 | 452.93 | 993.0452 | 402.4511 | 922.8399 |
| Sep-87 | 300.91 | 360.0033 | 236.4134 | 327.3393 |
| Oct-87 | 91.74 | 33.96129 | 50.40718 | 24.80968 |
| Jun-88 | 213.85 | 712.5733 | 151.6014 | 190.8259 |
| Jul-88 | 1366.25 | 2034.881 | 1692.56 | 1384.506 |
| Aug-88 | 1327.68 | 1021.671 | 1630.664 | 1419.408 |
| Sep-88 | 824.50 | 507.4467 | 877.3758 | 2316.528 |
| Oct-88 | 323.55 | 94.95484 | 259.8046 | 427.9309 |
| Jun-89 | 208.13 | 209.0653 | 146.3456 | 173.583 |
| Jul-89 | 710.00 | 1028.716 | 722.2838 | 2203.051 |
| Aug-89 | 512.18 | 688.7677 | 472.2506 | 930.0939 |
| Sep-89 | 105.05 | 85.48 | 60.12352 | 14.07953 |
| Oct-89 | 34.98 | 18.94839 | 14.37826 | -12.605 |
| Jun-90 | 291.41 | 347.57 | 226.7436 | 303.5325 |
| Jul-90 | 1059.88 | 1259.67 | 1216.405 | 1495.949 |
| Aug-90 | 900.71 | 1312.374 | 984.3134 | 2314.352 |
| Sep-90 | 554.56 | 387.1067 | 523.7199 | 948.1812 |
| Oct-90 | 77.93 | 22.58065 | 40.76732 | 29.82871 |
| Jun-91 | 237.32 | 250.03 | 173.596 | 239.2393 |
| Jul-91 | 444.90 | 1037.613 | 393.1962 | 920.817 |
| Aug-91 | 604.10 | 779.9161 | 585.3803 | 1083.87 |
| Sep-91 | 426.38 | 268.1733 | 372.0359 | 912.2074 |
| Oct-91 | 57.03 | 22.98387 | 27.15995 | 20.22048 |
| Jun-92 | 174.60 | 82.8 | 116.4451 | 50.90421 |
| Jul-92 | 472.10 | 1092.439 | 424.7575 | 925.7117 |
| Aug-92 | 1092.01 | 1589.248 | 1264.592 | 2714.526 |
| Sep-92 | 358.56 | 365.7367 | 296.9695 | 687.2881 |
| Oct-92 | 91.11 | 30.95806 | 49.95643 | 25.19941 |
| Jun-93 | 244.34 | 231.8567 | 180.3013 | 248.0859 |
| Jul-93 | 1006.21 | 1713.7 | 1136.892 | 1071.314 |
| Aug-93 | 382.69 | 197.1129 | 323.2211 | 825.7363 |

| | | | | |
|---|---|---|---|---|
| **Sep-93** | 353.91 | 246.3333 | 291.9592 | 652.49 |
| **Oct-93** | 61.71 | 24.89677 | 30.09383 | 24.32728 |
| **Jun-94** | 323.64 | 321.5633 | 259.8982 | 428.4739 |
| **Jul-94** | 1270.53 | 1807.739 | 1539.938 | 1764.735 |
| **Aug-94** | 1606.09 | 1481.858 | 2088.935 | 1499.268 |
| **Sep-94** | 476.20 | 403.6383 | 429.5534 | 926.1354 |
| **Oct-94** | 62.58 | 19.18065 | 30.64671 | 24.9661 |
| **Jun-95** | 269.81 | 42.88 | 205.1251 | 272.5102 |
| **Jul-95** | 958.97 | 472.0903 | 1067.938 | 2093.456 |
| **Aug-95** | 1333.36 | 584.9613 | 1639.747 | 1410.515 |
| **Sep-95** | 668.75 | 1176.537 | 668.1663 | 1846.735 |
| **Oct-95** | 75.81 | 29.50903 | 39.33154 | 29.86039 |
| **Jun-96** | 389.55 | 544.3667 | 330.7822 | 850.5801 |
| **Jul-96** | 453.48 | 450.2742 | 403.0943 | 922.9547 |
| **Aug-96** | 939.75 | 721.4419 | 1040.185 | 2253.694 |
| **Sep-96** | 333.76 | 1070.387 | 270.5262 | 496.2263 |
| **Oct-96** | 56.04 | 31.99355 | 26.54696 | 19.20873 |
| **Jun-97** | 92.93 | 175.28 | 51.25881 | 24.03794 |
| **Jul-97** | 642.11 | 1683.006 | 633.7482 | 1466.576 |
| **Aug-97** | 1550.52 | 1533.194 | 1995.403 | 1397.53 |
| **Sep-97** | 462.84 | 273.64 | 413.9457 | 924.5655 |
| **Oct-97** | 109.98 | 70.84065 | 63.82092 | 9.366367 |
| **Jun-98** | 283.88 | 219.4633 | 219.1494 | 289.9542 |
| **Jul-98** | 828.22 | 3137.178 | 882.5274 | 2316.683 |
| **Aug-98** | 895.73 | 4050.403 | 977.2349 | 2315.486 |
| **Sep-98** | 585.36 | 472.08 | 561.8664 | 1002.6 |
| **Oct-98** | 219.82 | 128.5613 | 157.1271 | 206.4632 |
| **Jun-99** | 85.89 | 172.6333 | 46.27087 | 27.8818 |
| **Jul-99** | 725.09 | 2753.258 | 742.3217 | 2254.513 |
| **Aug-99** | 1326.31 | 2444.658 | 1628.466 | 1421.86 |
| **Sep-99** | 219.88 | 425.1233 | 157.1823 | 206.608 |
| **Oct-99** | 52.34 | 149.9774 | 24.28998 | 14.99808 |
| **Jun-00** | 210.14 | 177.0467 | 148.184 | 179.8868 |
| **Jul-00** | 670.19 | 1487.126 | 670.0387 | 1865.482 |
| **Aug-00** | 664.85 | 1344.103 | 663.1084 | 1794.167 |
| **Sep-00** | 254.32 | 526.0133 | 189.9442 | 258.2073 |
| **Oct-00** | 105.81 | 24.45484 | 60.69431 | 13.36535 |
| **Jun-01** | 109.77 | 62.447 | 56.15242 | 9.569668 |
| **Jul-01** | 796.98 | 1655.752 | 2356.789 | 2314.3 |
| **Aug-01** | 906.28 | 1225.19 | 3002.798 | 2312.435 |
| **Sep-01** | 128.88 | 176.3167 | 75.99518 | -6.54469 |

| | | | | |
|---|---|---|---|---|
| **Oct-01** | 76.10 | 22.33548 | 28.15088 | 29.8688 |
| **Jun-02** | 127.88 | 31.82667 | 74.8869 | -5.95831 |
| **Jul-02** | 276.98 | 69.50323 | 321.4537 | 280.4301 |
| **Aug-02** | 489.16 | 145.7935 | 939.098 | 927.3478 |
| **Sep-02** | 317.06 | 151.4333 | 414.7119 | 391.8171 |
| **Oct-02** | 81.28 | 39.98065 | 31.87088 | 29.34974 |
| **Jun-03** | 151.42 | 45.66667 | 102.9754 | -2.30716 |
| **Jul-03** | 370.23 | 1272.845 | 555.4654 | 764.2423 |
| **Aug-03** | 753.64 | 4164.012 | 2121.012 | 2297.969 |
| **Sep-03** | 314.16 | 817.9933 | 407.5778 | 377.6407 |
| **Oct-03** | 82.68 | 55.25161 | 32.91175 | 28.99983 |
| **Jun-04** | 90.66 | 38.88667 | 39.15874 | 25.46956 |
| **Jul-04** | 290.66 | 729.0487 | 352.0266 | 301.9972 |
| **Aug-04** | 643.69 | 2428.294 | 1575.618 | 1488.774 |
| **Sep-04** | 141.46 | 69.6 | 90.57547 | -9.03647 |
| **Oct-04** | 178.91 | 35.2129 | 141.0344 | 65.86125 |
| **Jun-05** | 220.95 | 643.4967 | 209.941 | 209.1494 |
| **Jul-05** | 944.58 | 3199.91 | 3246.478 | 2228.628 |
| **Aug-05** | 550.98 | 3259.555 | 1175.238 | 945.195 |
| **Sep-05** | 385.04 | 1908.413 | 598.0852 | 834.919 |
| **Oct-05** | 114.70 | 72.24194 | 61.00125 | 4.817908 |
| **Jun-06** | 122.87 | 33.35333 | 69.45132 | -2.41906 |
| **Jul-06** | 427.85 | 2353.245 | 729.5864 | 913.1819 |
| **Aug-06** | 872.01 | 4866.555 | 2792.381 | 2317.319 |
| **Sep-06** | 474.50 | 2899.443 | 886.7305 | 925.9641 |
| **Oct-06** | 102.16 | 61.07097 | 49.04787 | 16.72713 |
| **Jun-07** | 171.98 | 93.26333 | 130.9113 | 42.42048 |
| **Jul-07** | 486.19 | 3237.639 | 928.3573 | 927.0734 |
| **Aug-07** | 758.13 | 2765.761 | 2144.883 | 2301.292 |
| **Sep-07** | 236.74 | 931.43 | 239.109 | 238.4195 |
| **Oct-07** | 92.51 | 82.55161 | 40.67858 | 24.31553 |
| **Jun-08** | 464.22 | 1499.503 | 850.8849 | 924.7585 |
| **Jul-08** | 609.10 | 2055.777 | 1419.811 | 1115.804 |
| **Aug-08** | 909.31 | 2455.232 | 3021.784 | 2310.996 |
| **Sep-08** | 306.14 | 524.7733 | 388.1879 | 344.5199 |
| **Oct-08** | 89.91 | 64.61613 | 38.54621 | 25.90424 |
| **Jun-09** | 91.30 | 50.31 | 39.68218 | 25.08327 |
| **Jul-09** | 265.57 | 2040.961 | 296.9315 | 268.4148 |
| **Aug-09** | 517.92 | 1204.687 | 1045.87 | 931.1462 |
| **Sep-09** | 433.65 | 1599.433 | 748.3313 | 916.4554 |
| **Oct-09** | 69.58 | 29.21935 | 23.77787 | 28.67274 |

## Simulation result

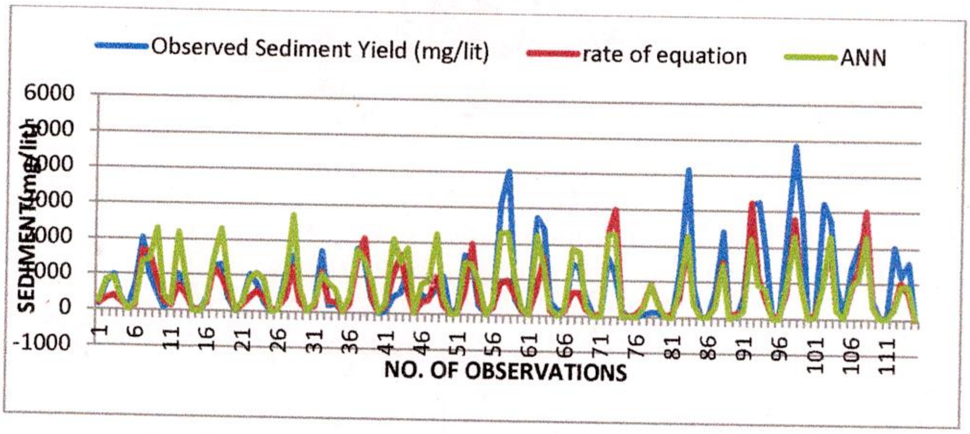



**Fig. :**<u>*comparision of sediment between observed and calculated using rate equation or using ANN.*</u>

Now, we use matlab software, to estimate sediment using ANN . In tools of matlab artificial neural network is inbuilt function and we use that for train the network by providing inputs, and further steps shown by these above screen shots.

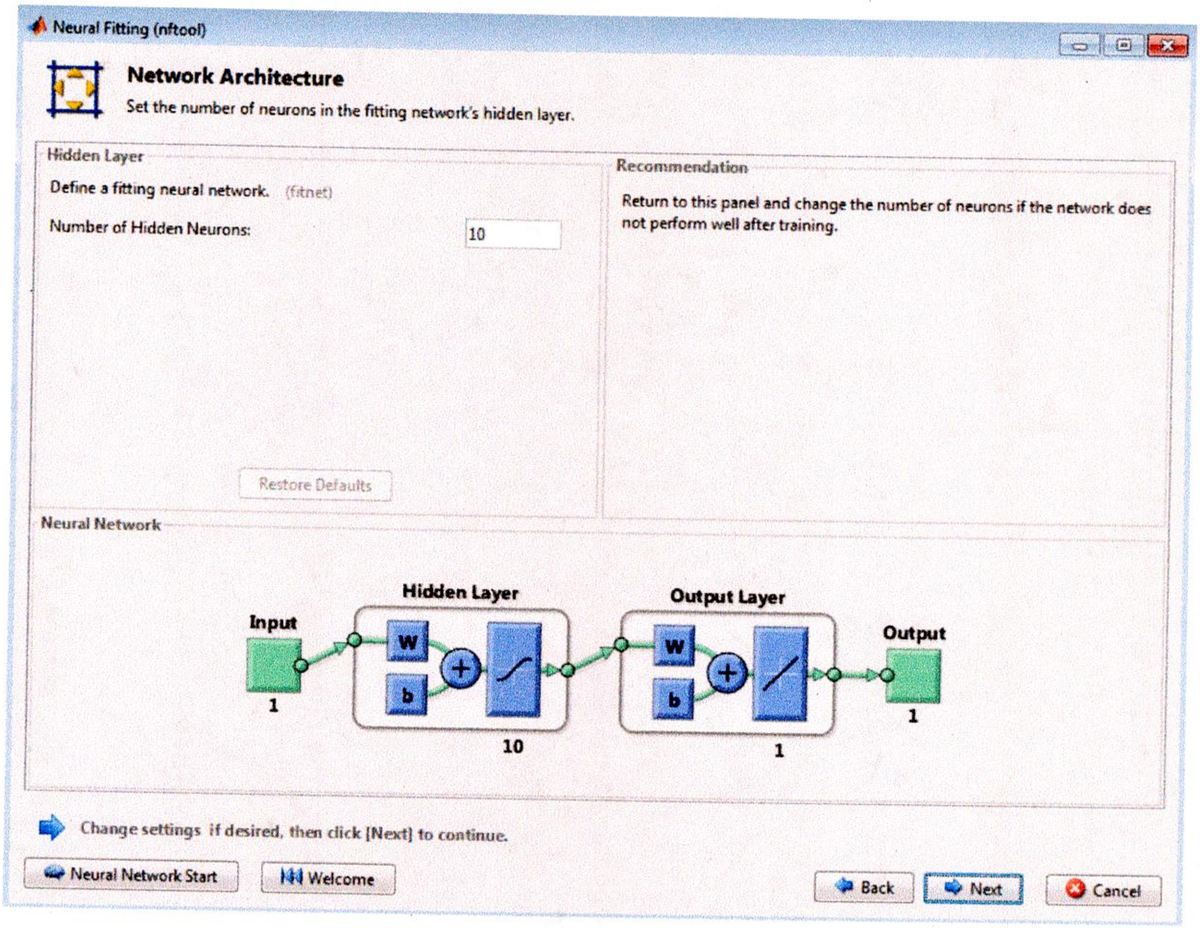



**Fig:** *DATA NETWORK* .

This shows the network is of this type and no. of neurons is 10.

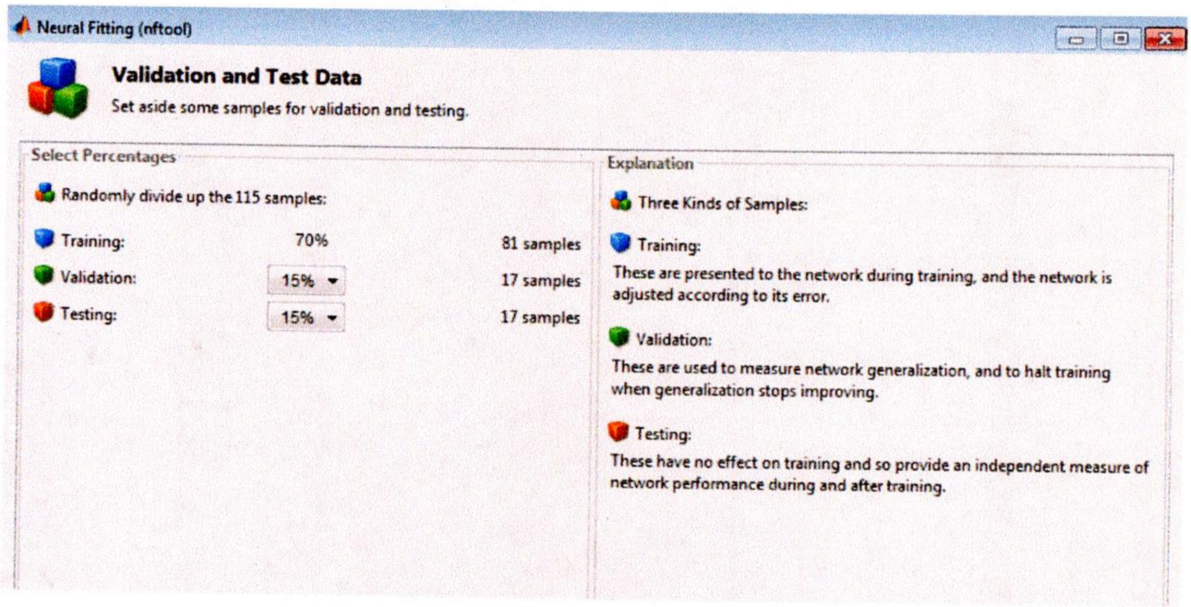



**FIG.:** *DATA SELECTION FOR MONSOON PERIOD*

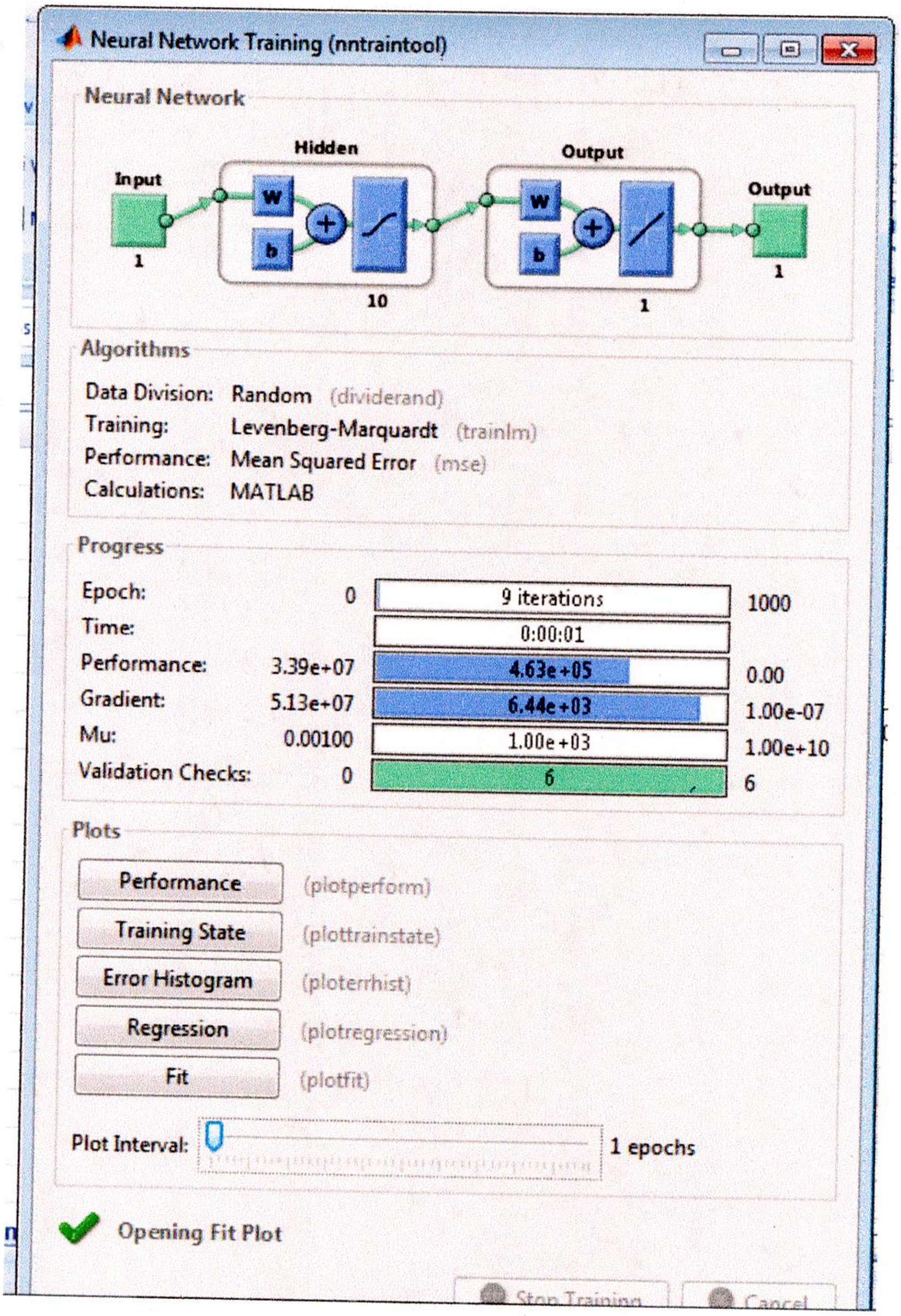
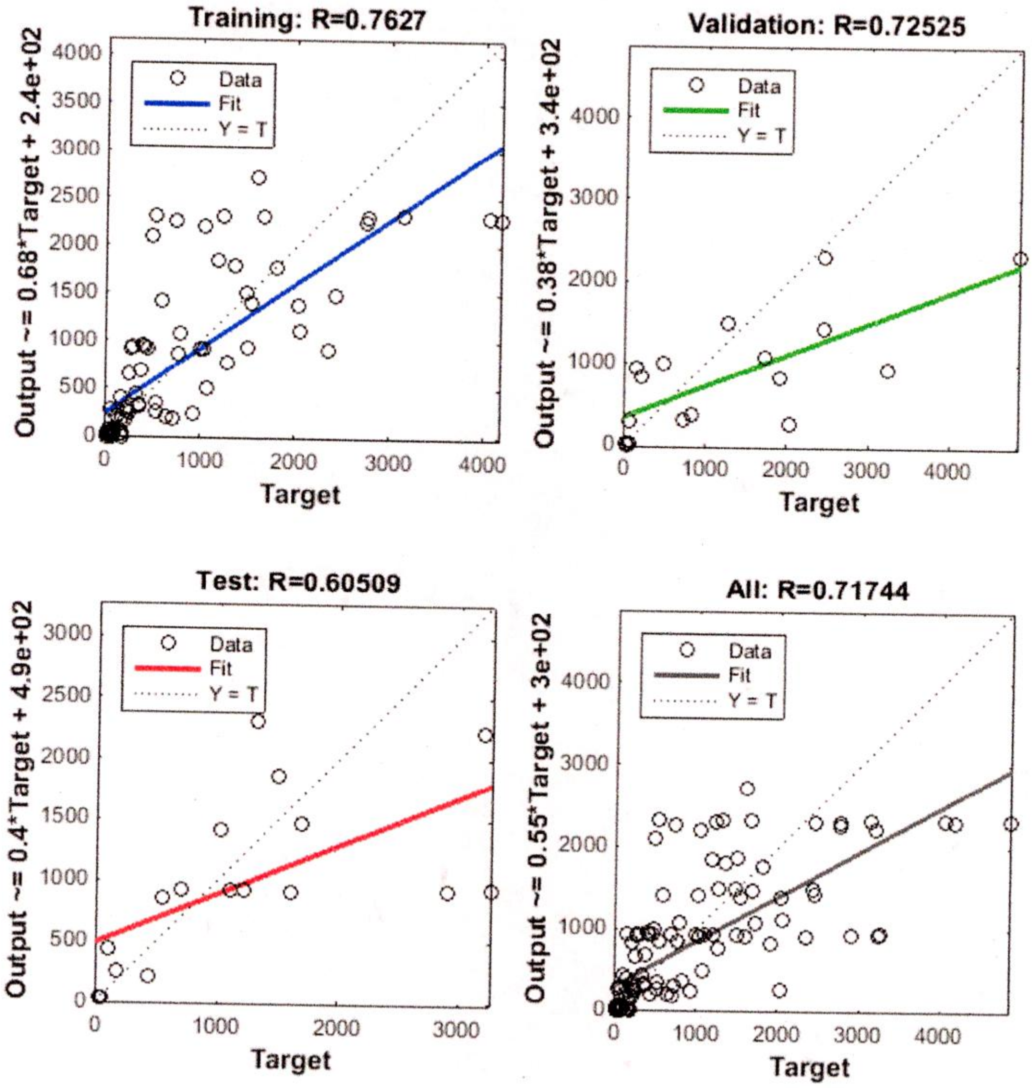



**Fig:** ***NEURAL NETWORK TRAINING***

**REGRESSION PLOT**

**The regression plot obtained from the trained network for monsoon is shown below:**



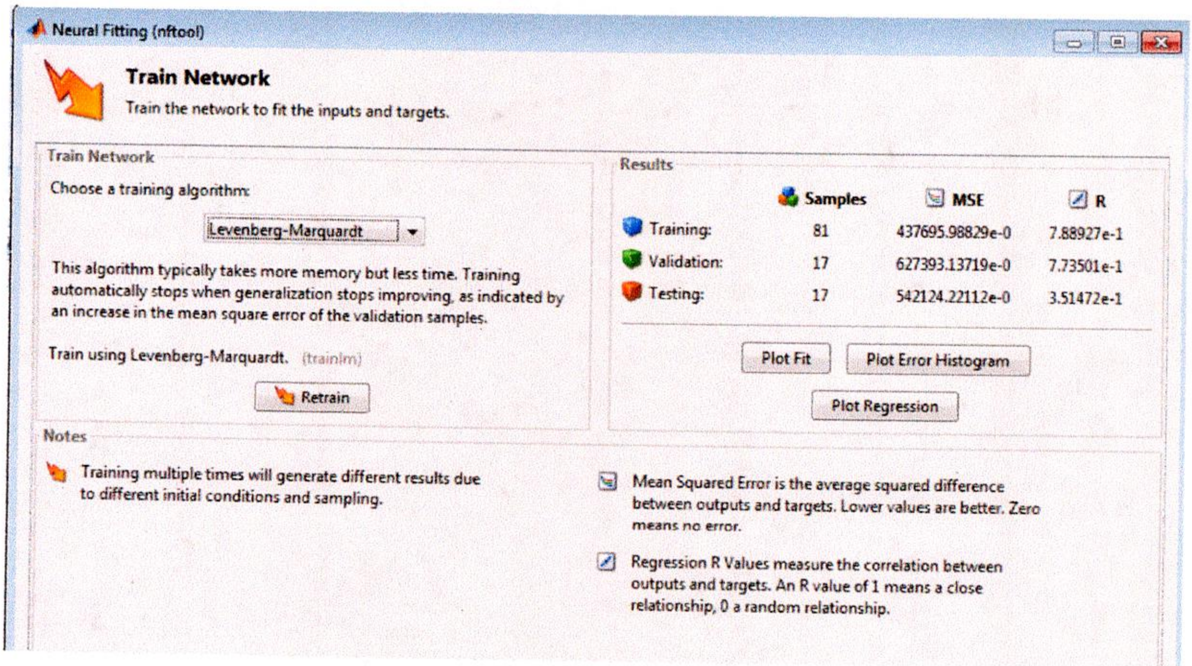



Fig*: TRAIN NETWORK*

In this ,mean square error (MSE)and R is shown for validation, training and testing i.e. shown in the screen shot. This training continues up to when either the errors are less or epochs are finished.

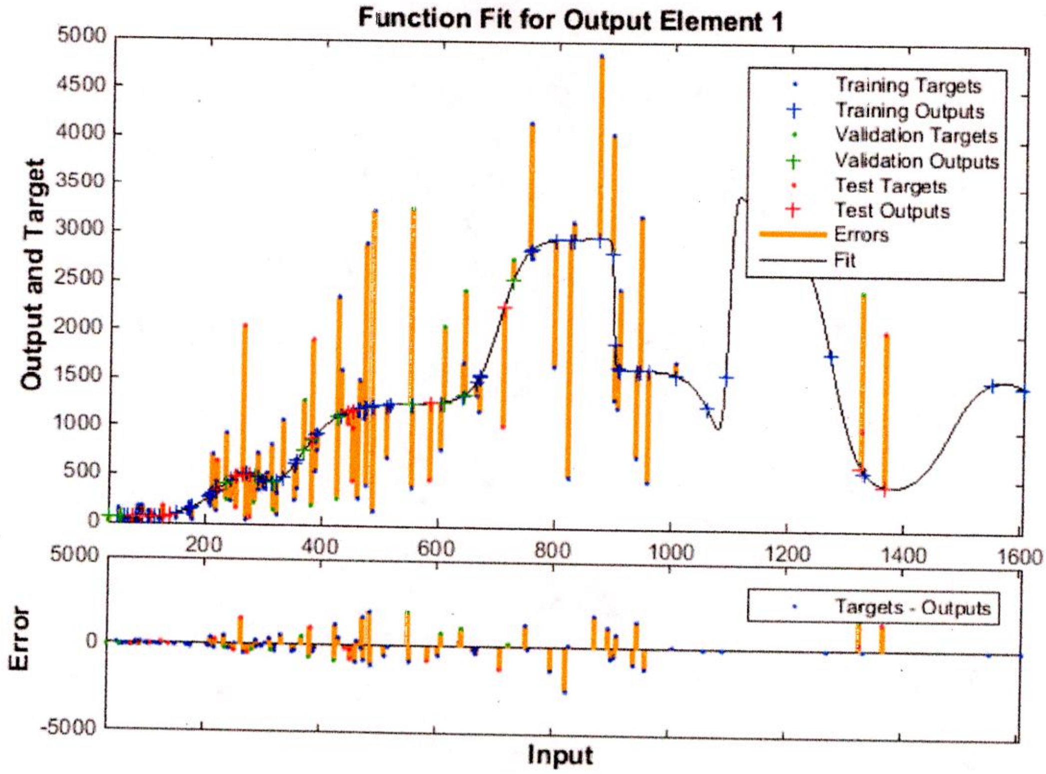
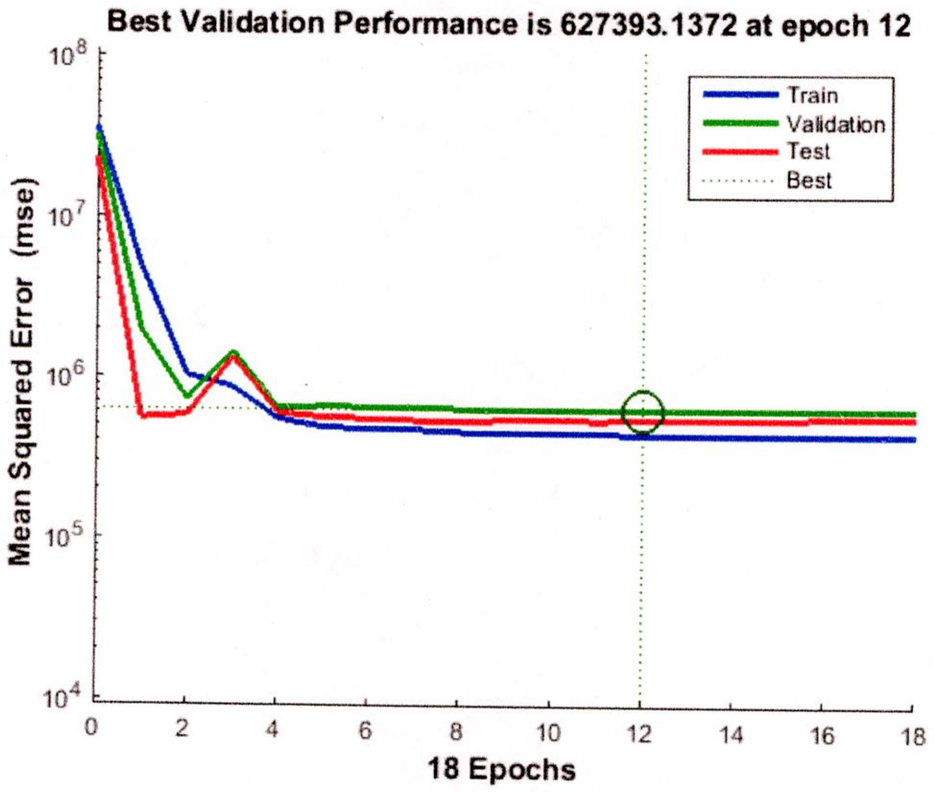



**Fig:** *BEST ERROR FITTING CURVE*

In this graph, best curve is fitted with taking care of errors

PERFORMANCE PLOT OF THE MODEL:



# NON MONSOON SEASON

## The data is given is as follows:

| Year | Discharge (Cumec) | Sediment Yield (mg/lit) | rate of equation | ANN |
|---|---|---|---|---|
| Jan-87 | 88.28 | 34.32903 | 47.94971 | 29.52261 |
| Feb-87 | 75.90 | 20.94643 | 39.39202 | 21.36797 |
| Mar-87 | 83.22 | 23.14839 | 44.40189 | 23.24337 |
| Apr-87 | 83.16 | 23.09333 | 44.36173 | 23.16804 |
| May-87 | 211.21 | 172.929 | 149.1644 | 41.3345 |
| Nov-87 | 64.70 | 14.27333 | 32.00667 | 28.79811 |
| Dec-87 | 54.53 | 17.34839 | 25.62186 | 23.82886 |
| Jan-88 | 51.24 | 11.52903 | 23.63027 | 22.39434 |
| Feb-88 | 51.46 | 12.54483 | 23.75885 | 22.5048 |
| Mar-88 | 138.75 | 182.2871 | 86.35245 | 76.21914 |
| Apr-88 | 99.16 | 21.75 | 55.77391 | 38.57096 |
| May-88 | 102.31 | 24.29355 | 58.0899 | 40.40632 |
| Nov-88 | 53.68 | 16.79 | 25.10369 | 23.50135 |
| Dec-88 | 68.52 | 9.112903 | 34.48244 | 30.51288 |
| Jan-89 | 127.00 | 65.82258 | 76.95772 | 49.55262 |
| Feb-89 | 51.52 | 11.52857 | 23.79727 | 22.53457 |
| Mar-89 | 55.70 | 26.76129 | 26.33829 | 24.24491 |
| Apr-89 | 58.38 | 16.72 | 27.99746 | 25.1863 |
| May-89 | 91.41 | 82.51935 | 50.17614 | 32.72491 |
| Nov-89 | 27.71 | 8.79 | 10.61769 | 18.23903 |
| Dec-89 | 27.81 | 20.58065 | 10.67033 | 18.26729 |
| Jan-90 | 32.24 | 28.35806 | 12.93132 | 18.60206 |
| Feb-90 | 38.30 | 21.89643 | 16.18131 | 17.25712 |
| Mar-90 | 225.12 | 64.12258 | 162.0683 | 129.0619 |
| Apr-90 | 99.16 | 21.75 | 55.77391 | 24.24491 |
| May-90 | 102.31 | 24.29355 | 58.0899 | 25.1863 |
| Nov-90 | 42.54 | 10.78667 | 18.54716 | 17.78227 |
| Dec-90 | 40.57 | 13.08065 | 17.43677 | 17.29129 |
| Jan-91 | 45.71 | 21.97097 | 20.36531 | 19.26176 |

| | | | | |
|---|---|---|---|---|
| **Feb-91** | 43.60 | 17.47857 | 19.15206 | 18.20085 |
| **Mar-91** | 64.74 | 39.08065 | 32.03254 | 28.82574 |
| **Apr-91** | 103.19 | 58.52333 | 58.74473 | 40.88049 |
| **May-91** | 85.22 | 25.65806 | 45.79685 | 25.81342 |
| **Nov-91** | 39.41 | 16.63333 | 16.79018 | 17.20241 |
| **Dec-91** | 31.89 | 8.6 | 12.74716 | 18.64389 |
| **Jan-92** | 47.63 | 8.322581 | 21.48684 | 20.36942 |
| **Feb-92** | 87.05 | 8.6 | 47.08299 | 28.09359 |
| **Mar-92** | 78.87 | 12.7 | 41.40883 | 19.52888 |
| **Apr-92** | 93.24 | 16.9 | 51.48584 | 34.3329 |
| **May-92** | 87.98 | 31.07742 | 47.73492 | 29.18286 |
| **Nov-92** | 53.23 | 14.36667 | 24.83012 | 23.31668 |
| **Dec-92** | 39.37 | 8.664516 | 16.7686 | 17.20207 |
| **Jan-93** | 52.42 | 39.6129 | 24.33742 | 22.96234 |
| **Feb-93** | 38.28 | 16.6 | 16.16631 | 17.25928 |
| **Mar-93** | 225.12 | 64.12258 | 162.0683 | 129.0619 |
| **Apr-93** | 75.43 | 37.72 | 39.0751 | 22.0511 |
| **May-93** | 119.00 | 41.94258 | 70.71561 | 47.35989 |
| **Nov-93** | 36.36 | 16.6 | 15.12328 | 17.6199 |
| **Dec-93** | 28.44 | 12.41613 | 10.98691 | 18.42666 |
| **Jan-94** | 25.46 | 11.37419 | 9.508902 | 17.42121 |
| **Feb-94** | 33.47 | 23.33571 | 13.57543 | 18.37746 |
| **Mar-94** | 27.64 | 24.9129 | 10.58288 | 18.21877 |
| **Apr-94** | 95.96 | 67.96667 | 53.44993 | 36.43549 |
| **May-94** | 79.30 | 82.9 | 41.7017 | 19.63206 |
| **Nov-94** | 38.44 | 13.87 | 16.25587 | 17.24313 |
| **Dec-94** | 28.69 | 268.6 | 11.11055 | 18.48053 |
| **Jan-95** | 30.42 | 8.464516 | 11.98859 | 18.69339 |
| **Feb-95** | 38.48 | 23.50357 | 16.27698 | 17.2395 |
| **Mar-95** | 39.73 | 17.26774 | 16.9673 | 17.21164 |
| **Apr-95** | 56.53 | 21.05667 | 26.84754 | 24.52794 |
| **May-95** | 111.05 | 30.93871 | 64.6338 | 44.52699 |
| **Nov-95** | 39.52 | 16.57 | 16.85457 | 17.20428 |
| **Dec-95** | 31.81 | 21.18387 | 12.70964 | 18.6519 |
| **Jan-96** | 31.44 | 18.14194 | 12.51392 | 18.68124 |

| | | | | |
|---|---|---|---|---|
| **Feb-96** | 37.26 | 19.83448 | 15.61176 | 17.41715 |
| **Mar-96** | 58.50 | 26.72903 | 28.07235 | 25.23269 |
| **Apr-96** | 66.09 | 24.59833 | 32.90127 | 29.69984 |
| **May-96** | 52.56 | 26.43387 | 24.42187 | 23.02566 |
| **Nov-96** | 30.87 | 18.62667 | 12.2186 | 18.70069 |
| **Dec-96** | 25.49 | 10.79355 | 9.523555 | 17.43407 |
| **Jan-97** | 22.79 | 12.64194 | 8.234871 | 16.1361 |
| **Feb-97** | 22.96 | 9.625 | 8.313169 | 16.22433 |
| **Mar-97** | 30.65 | 12.90645 | 12.10581 | 18.69964 |
| **Apr-97** | 47.53 | 18.41667 | 21.42378 | 20.31054 |
| **May-97** | 68.46 | 37.33548 | 34.44656 | 30.51263 |
| **Nov-97** | 94.72 | 22.99 | 52.54954 | 35.51491 |
| **Dec-97** | 103.17 | 47.7 | 58.73176 | 40.86988 |
| **Jan-98** | 63.03 | 24.14516 | 30.93219 | 27.64018 |
| **Feb-98** | 103.61 | 33.26071 | 59.05451 | 41.10146 |
| **Mar-98** | 226.95 | 129.4968 | 163.7849 | 150.4883 |
| **Apr-98** | 138.66 | 30.89333 | 86.27604 | 76.20141 |
| **May-98** | 167.34 | 38.73226 | 110.1879 | 39.9148 |
| **Nov-98** | 72.11 | 52.18667 | 36.85524 | 27.78498 |
| **Dec-98** | 43.53 | 11.49677 | 19.10856 | 18.1704 |
| **Jan-99** | 39.23 | 18.04516 | 16.69372 | 17.20227 |
| **Feb-99** | 34.59 | 17.28214 | 14.16919 | 18.09674 |
| **Mar-99** | 33.25 | 17.70645 | 13.46049 | 18.42543 |
| **Apr-99** | 33.70 | 8.666667 | 13.69671 | 18.32431 |
| **May-99** | 63.80 | 91.60645 | 31.42885 | 28.16991 |
| **Nov-99** | 25.49 | 34.55 | 9.523555 | 17.43407 |
| **Dec-99** | 19.73 | 15.36774 | 6.82641 | 14.47735 |
| **Jan-00** | 24.94 | 17.77097 | 9.257967 | 17.19158 |
| **Feb-00** | 32.17 | 23.94138 | 12.89673 | 18.61129 |
| **Mar-00** | 27.68 | 16.4 | 10.60291 | 18.23039 |
| **Apr-00** | 57.89 | 11.86667 | 27.69161 | 25.00298 |
| **May-00** | 110.72 | 58.30935 | 64.38078 | 44.39251 |
| **Nov-00** | 274.18 | 34.07333 | 315.3436 | 34.03459 |
| **Dec-00** | 209.02 | 39.26129 | 189.0737 | 38.33901 |
| **Jan-01** | 95.58 | 8.4 | 43.26215 | 36.15959 |

| | | | | |
|---|---|---|---|---|
| **Feb-01** | 83.29 | 8.4 | 33.37545 | 23.33155 |
| **Mar-01** | 76.67 | 9.958065 | 28.5535 | 20.45613 |
| **Apr-01** | 73.02 | 15.91 | 26.04202 | 26.2863 |
| **May-01** | 74.95 | 21.29032 | 27.3537 | 22.82759 |
| **Nov-01** | 73.44 | 17.2 | 26.32193 | 25.53557 |
| **Dec-01** | 209.02 | 39.26129 | 189.0737 | 18.26729 |
| **Jan-02** | 84.14 | 22.36129 | 34.01701 | 24.41947 |
| **Feb-02** | 64.50 | 13.48714 | 20.61257 | 28.65927 |
| **Mar-02** | 79.52 | 28.03871 | 30.58694 | 19.71631 |
| **Apr-02** | 76.37 | 22.54667 | 28.34035 | 20.77802 |
| **May-02** | 118.74 | 62.2871 | 65.11756 | 47.27862 |
| **Nov-02** | 70.53 | 19.86667 | 24.39212 | 29.68109 |
| **Dec-02** | 68.49 | 18.72903 | 23.08076 | 30.51291 |
| **Jan-03** | 61.78 | 21.04516 | 19.00162 | 26.83836 |
| **Feb-03** | 71.44 | 24.11786 | 24.98978 | 28.71642 |
| **Mar-03** | 83.13 | 24.47097 | 33.2553 | 23.13046 |
| **Apr-03** | 77.14 | 18.26667 | 28.87753 | 20.04393 |
| **May-03** | 75.91 | 16.65806 | 28.01727 | 21.35439 |
| **Nov-03** | 69.54 | 28.42667 | 23.75002 | 30.30631 |
| **Dec-03** | 66.19 | 26.72258 | 21.6403 | 29.75745 |
| **Jan-04** | 69.81 | 34.78065 | 23.92932 | 30.17935 |
| **Feb-04** | 72.16 | 74.06552 | 25.4665 | 27.70887 |
| **Mar-04** | 69.13 | 30.87097 | 23.48861 | 30.43938 |
| **Apr-04** | 62.86 | 27.87667 | 19.63677 | 27.52612 |
| **May-04** | 76.23 | 25.44516 | 28.24012 | 20.94317 |
| **Nov-04** | 75.86 | 35.54333 | 27.98487 | 21.42269 |
| **Dec-04** | 54.46 | 34.13548 | 14.98513 | 23.80284 |
| **Jan-05** | 63.73 | 30.2871 | 20.15085 | 28.12112 |
| **Feb-05** | 130.39 | 58.27143 | 77.68744 | 51.06217 |
| **Mar-05** | 115.03 | 32.44194 | 61.33501 | 46.03852 |
| **Apr-05** | 91.63 | 19.86667 | 39.95094 | 32.92767 |
| **May-05** | 79.33 | 18.98387 | 30.44868 | 19.64234 |
| **Nov-05** | 56.20 | 31.77333 | 15.89574 | 24.41576 |
| **Dec-05** | 43.46 | 27.23871 | 9.790835 | 18.14031 |
| **Jan-06** | 59.53 | 40.11613 | 17.7213 | 25.66112 |

| | | | | |
|---|---|---|---|---|
| **Feb-06** | 56.88 | 29.20714 | 16.26117 | 24.64736 |
| **Mar-06** | 104.55 | 28.90968 | 51.22934 | 41.5841 |
| **Apr-06** | 89.37 | 32.70333 | 38.11103 | 30.70794 |
| **May-06** | 150.81 | 27.77097 | 102.1965 | 77.76324 |
| **Nov-06** | 62.76 | 33.21 | 19.57845 | 27.45966 |
| **Dec-06** | 66.20 | 32.80645 | 21.65043 | 29.76314 |
| **Jan-07** | 54.62 | 31.62581 | 15.06814 | 23.8621 |
| **Feb-07** | 56.33 | 23.25714 | 15.96865 | 24.45995 |
| **Mar-07** | 169.42 | 45.68387 | 127.2624 | 33.20871 |
| **Apr-07** | 169.68 | 33.68 | 127.633 | 32.99111 |
| **May-07** | 131.25 | 30.92903 | 78.65717 | 52.51318 |
| **Nov-07** | 84.09 | 39.96667 | 33.98055 | 24.35491 |
| **Dec-07** | 80.56 | 24.4 | 31.33959 | 20.36554 |
| **Jan-08** | 83.28 | 25.17419 | 33.36904 | 23.31894 |
| **Feb-08** | 79.94 | 21.10345 | 30.88835 | 19.93155 |
| **Mar-08** | 89.96 | 24.19355 | 38.59125 | 31.31762 |
| **Apr-08** | 78.90 | 31.09333 | 30.13507 | 19.53333 |
| **May-08** | 105.47 | 31.14194 | 52.0814 | 42.04121 |
| **Nov-08** | 50.92 | 26.08667 | 13.20155 | 22.23013 |
| **Dec-08** | 52.91 | 26.74839 | 14.18993 | 23.18014 |
| **Jan-09** | 52.70 | 27.52258 | 14.08391 | 23.0881 |
| **Feb-09** | 47.05 | 18.11429 | 11.37341 | 20.02863 |
| **Mar-09** | 46.69 | 19.23871 | 11.20757 | 19.81884 |
| **Apr-09** | 71.85 | 33.45667 | 25.26388 | 28.16667 |
| **May-09** | 74.01 | 26.24516 | 26.71313 | 24.49463 |
| **Nov-09** | 54.77 | 22.06333 | 15.14432 | 23.91695 |
| **Dec-09** | 43.86 | 21.73548 | 9.964964 | 18.31713 |

## Simulation results:

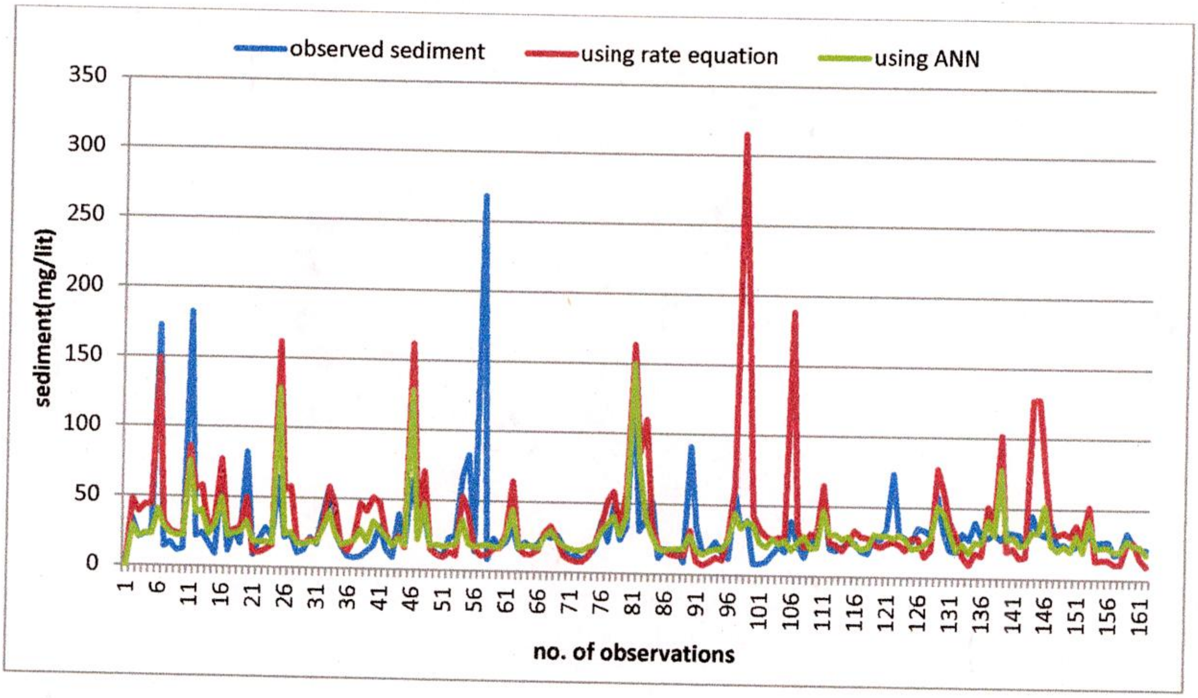



**Fig.:** *<u>Comparision of sediment between observed and calculated using rate equation or using ANN for non monsoon season</u>*

Now, similar procedure for training the network and same data network as above.

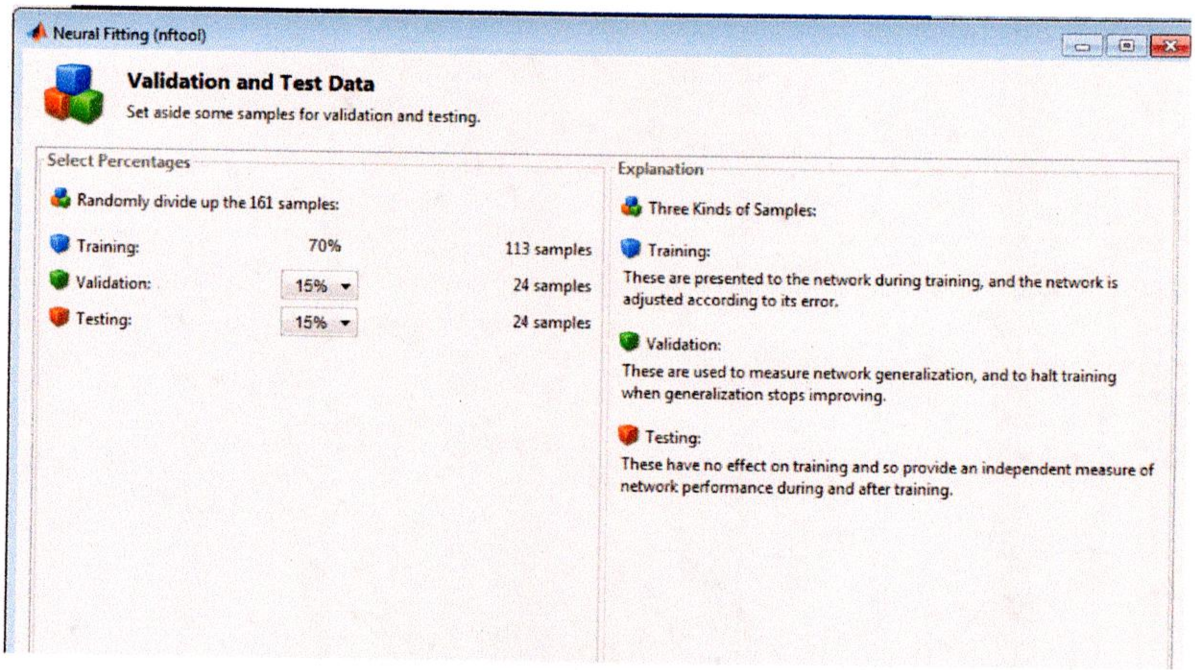



Fig.: *Data classification for non monsoon period*

In this screenshot, training, validation and testing data is classified. i.e. here,161 samples, for training 113 samples, validation 24 samples and for testing 24 samples.

Now, after that similar procedure for train the network

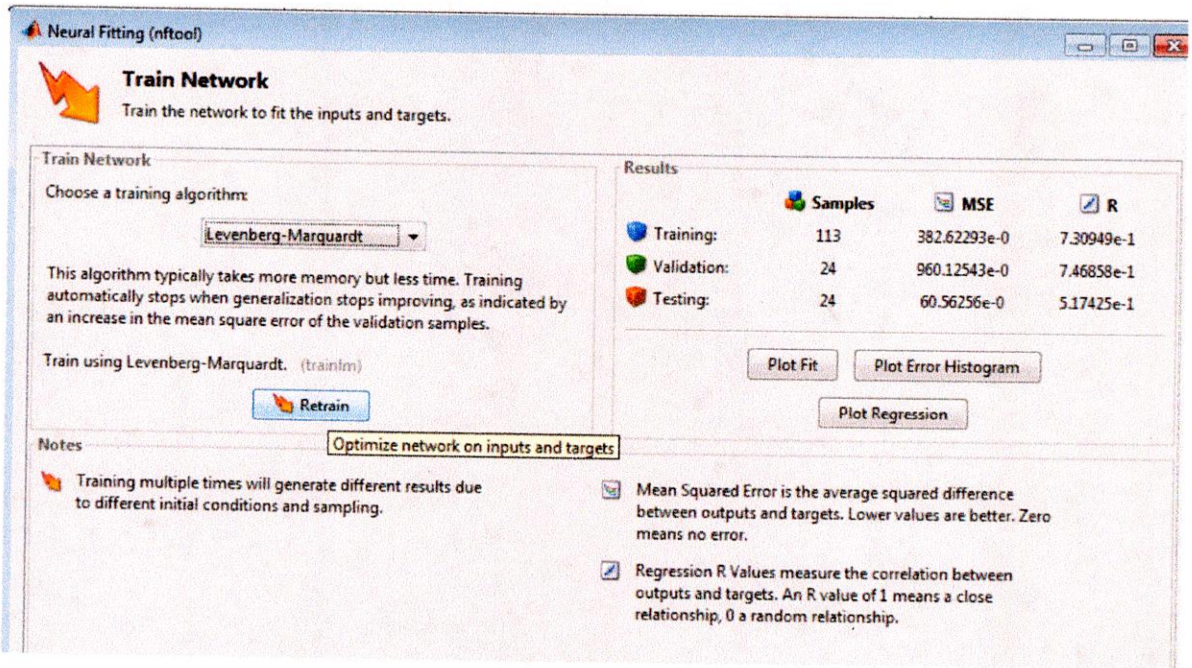
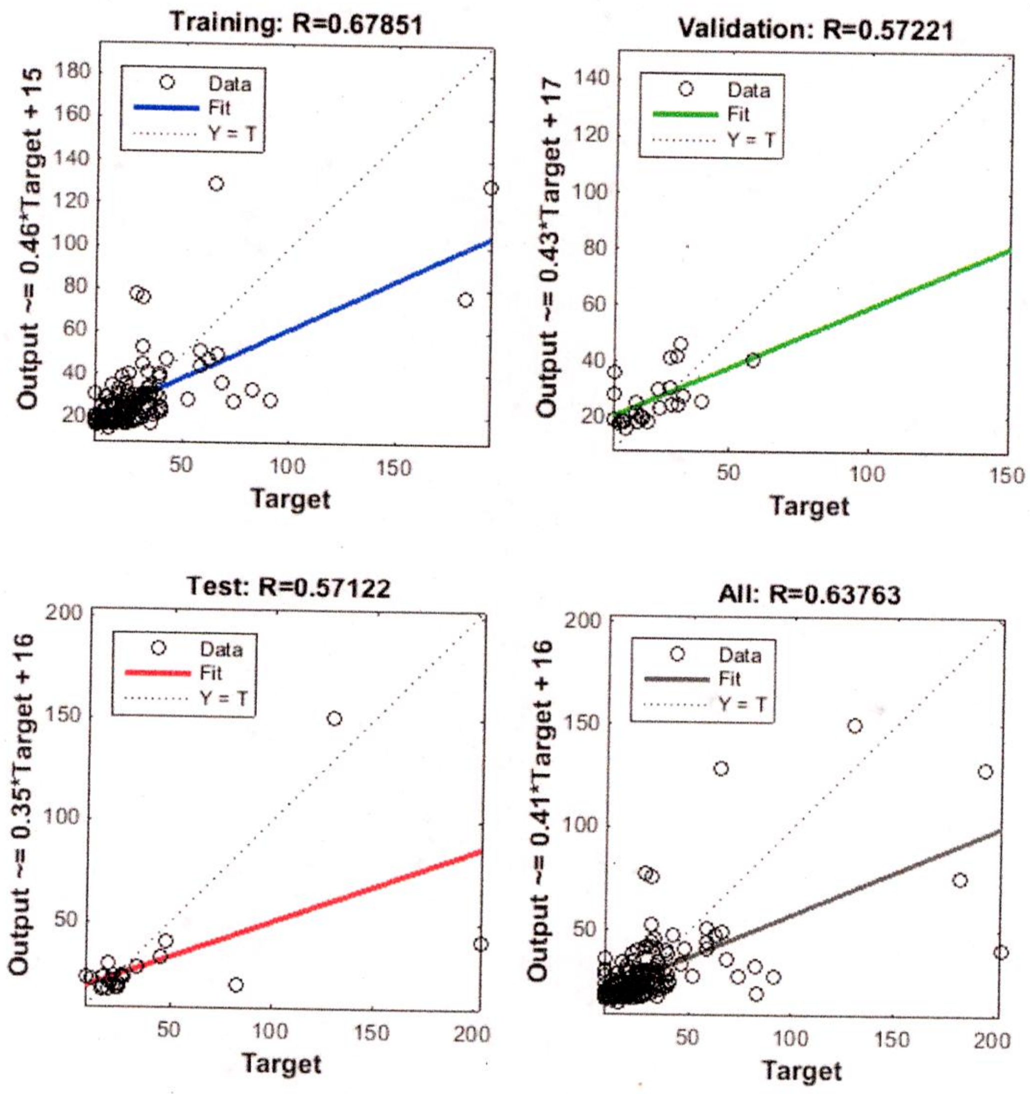



Fig.: ***TRAIN NETWORK***

The above screen shot is showing errors for non-monsoon period of training, validation and testing data. And the values is displayed in the above screenshot.

**REGRESSION PLOT**

**The regression plot obtained from the trained network for non -monsoon is shown below:**



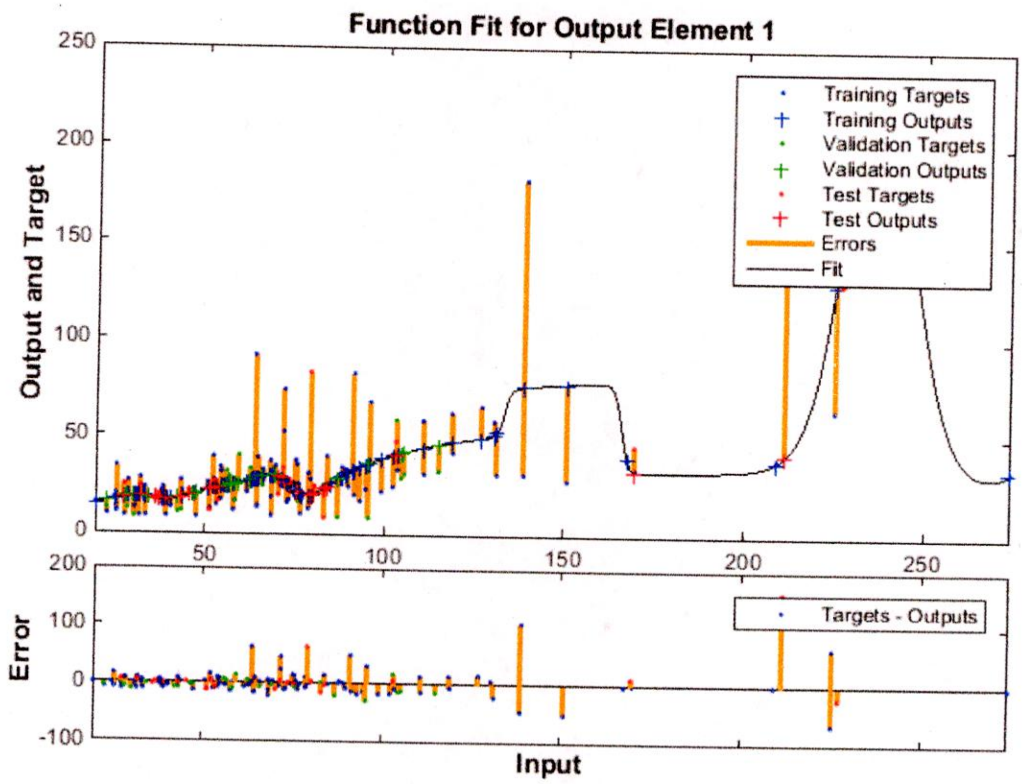
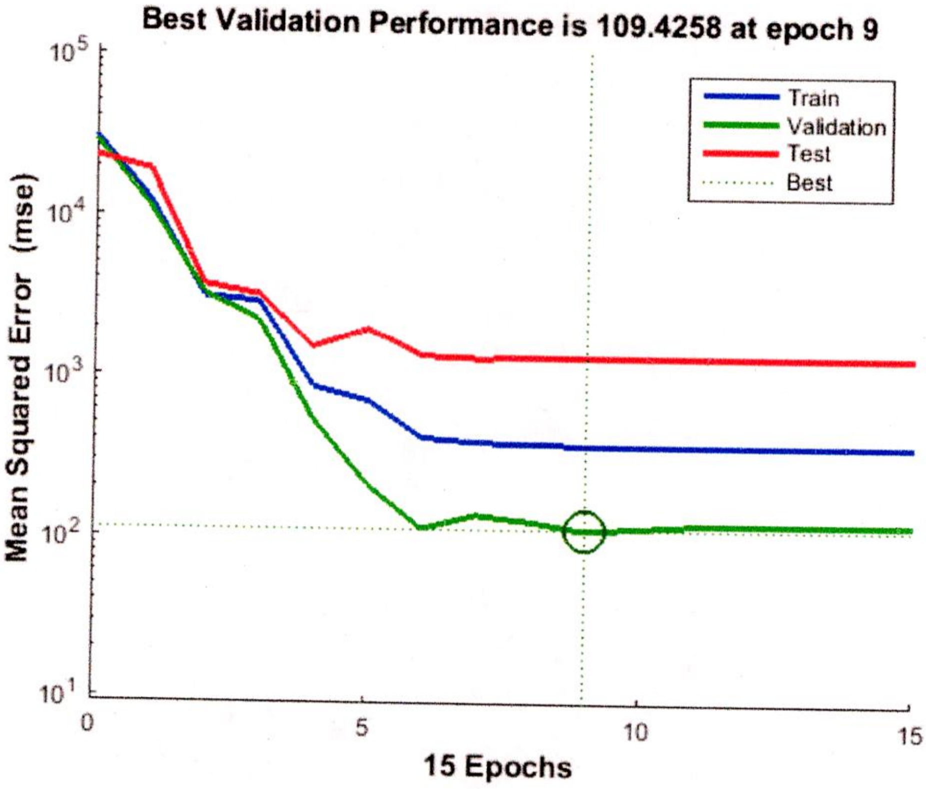



Fig.: <u>*BEST ERROR FITTING CURVE*</u>

In this graph, best curve is fitted with taking care of errors.

## PERFORMANCE PLOT OF THE MODEL:



# RESULT ANALYSIS

1. On the basis of simulation result of both monsoon period and non-monsoon period . i.e.(in fig.).It is observed that the peaks are almost the same for observed sediment and obtained sediment using rating equation as well as using ANN.
   Or,The curve obtained by using ANN lies between observed value of sediment and rating equation .so, ANN is use in future to estimate the sediment (mg/lit).

2. Secondly ,on the basis of performance indices table (6.1 &6.2) the RMSE value, in monsoon period the value is more in comparison with the non-monsoon season .so, the results are better in non –monsoon season in the both the cases i.e. by using rating equation or by ANN..
3. In monsoon season, the correlation coefficient on the basis of regression plot of monsoon season, shows that the value of R =0.7627 in training,0.72525 in validation,0.60509 in testing &0.71744 overall and which is more in comparison to the non-monsoon season i.e. having value R=0.67851 in training=0.57221 in validation,0.57122 in testing and 0.63763 overall. So, results are far better to estimate sediment in non –monsoon season using ANN.
   So, by this, it is observed that ANN is used to estimate sediment in future...

**Equations for performance evaluation indices**

1. Root –mean –square error(RMSE)=
   √∑((Y(observed)-y(cal))^2)/n
2. Sum squared error(SSE) =
   ∑(Y(obs)-Y(cal))^2
3. Mean bias error(MBE)=
   1/n(∑(Y(cal)-Y(Obs)))
4. Mean absolute error(MAE)=

1/N(∑(abs(Y(cal)-Y(Obs))))

## Performance indices:

Table 6.1 (Monsoon season)

| ERROR | For Rating Equation | For ANN |
|---|---|---|
| RMSE | 761.48266 | 733.3318 |
| SSE | 66683421 | 61844186 |
| MAE | 445.96017 | 461.93748 |
| MBE | -273.36174 | -98.73826 |

Table 6.2( Non Monsoon season)

| ERROR | For Rating Equation | For ANN |
|---|---|---|
| RMSE | 42.41046 | 27.76484 |
| SSE | 289582.2 | 124112.7 |
| MAE | 7.63296 | 1.26814 |
| MBE | 20.88191 | 12.36399 |

# CONCLUSIONS

According to the simulation result, the peak of sediment using ANN lies between the observed sediment and sediment using rating equation .

By performance indices Table(6.1 )&(6.2),it is observed that RMSE value is less in Non-Monsoon season data using ANN while correlation coefficient(R) is high for Monsoon data.All the performance indices using ANN are giving better performance for both Monsoon and Non-Monsoon data.so,it is observed that ,in future ANN can be used for further analysis of suspended sediment.

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OZGUR KISI
Hydraulics division, civil department, engineering faculty, erciyes university,38039 kayseri ,turkey
kisi@erciyes.edu.tr