e-ISSN: 2455-5703

Rainfall Runoff Analysis of Daman Ganga Basin by using Artificial Neural Network

[1]Ashvin Vaghani [2]Pradeepsinh Chauhan [3]Margi Sheth
[1,2,3]Assistant Professor
[1,2,3]Department of Civil Engineering
[1,2,3]S.S.A.S.I. T, Surat, Gujarat, India

Abstract

Rainfall, runoff is highly non-linear and complicated phenomena in nature which requires modeling and simulation for the accurate prediction. The tool used to predict the rainfall-runoff pattern is by formulating the model using artificial neural network. The general application of artificial neural networks (ANNs) act as 'black-box' models of rainfall-runoff processes. The ANNs have been applied to both real and theoretical catchments with both measured and synthetically-generated rainfall-runoff data. The ANN tool has become an attractive alternative to the traditional statistical methods. This review considers the application of artificial neural networks (ANNs) to rainfall–runoff modeling. The effects of the number of layers are studied on the observed data and the result so obtained is compared with the observed values. Validation of the models is also discussed in the study. Different types of ANN Networks are compared with their architectures and based on their model performances. The present work involves Rainfall-Runoff modeling using Artificial Neural Network Using ANN software tool Neuro-solution, Linear Regression by least squares method using Microsoft office tool Excel is done also. The eight years' data from 2001-2008 is utilized for analysis. The Rainfall-Runoff model is developed by applying Multilayer perceptron (MLP) and Linear Regression (LR) to predict daily Runoff as a function of daily rainfall for the catchment area under consideration of Damanganga basin. Neural network architecture is established for daily rainfall-runoff relationship for monsoon season data and yearly data. A linear regression model is also formulated. The seasonal data gives a better fit in comparison to yearly data and it gives higher value of coefficient of determination.
Keyword- Rainfall-Runoff, Prediction, ANN, Least Mean Square, Linear Regression

---

I. INTRODUCTION

1) Rainfall: The quantity of water, usually expressed in millimeters or inches, that is precipitated in liquid form in a specified area and time interval. Rainfall is often considered to include solid precipitation such as snow, hail, and sleet as well.
2) Runoff: Quantity of water discharge in surface stream. Runoff include not only the water that over the land surface and through channels to reach a stream but also interflow, the water that infiltration the soil surface and travel by means of gravity toward a stream channel.

Rainfall being the predominant form of precipitation causing stream flow, especially flood flow in majority of rivers in India. The relationship of rainfall-runoff is known to be highly non-linear and complex. The rainfall-runoff relationship is one of the most complex hydrologic phenomena to understand because of various reasons such as uncertainty in the rainfall, uneven pattern of rainfall, variations with respect to space and time, etc. Parametric models use mathematical transfer functions (such as multiple linear regression equations) to relate meteorological variables to runoff.

Therefore, the present study was undertaken in order to develop rainfall-runoff models that can be used to provide reliable and accurate estimates of runoff and the linear regression and multiple linear regression carried out. Modelling is done by using rainfall data of eight years of rain-gauge station Madhuban dam, Nani Palsan, Ozarkheda, Mokheda and Dindore runoff data for the same catchment areas of Damanganga basin.

II. OBJECTIVES AND SCOPE

The following are the main objectives of study:
- To study rainfall-runoff using artificial neural network.
- To develop the rainfall-runoff models using artificial neural network.
- To validate the developed models.
- To check the performance evaluation of developed models using suitable performance criteria.

Development of rainfall-runoff models for the set of available data only. The proposed study is limited to five catchment areas of Damanganga basin. Selection of the artificial neural network architecture and configuration is purely based on trial and error.

III. METHODOLOGY

Main objective of the present study is to carry out Linear Regression by Least Squares Method and Rainfall Runoff based Modelling. The Artificial Neural Network (ANN) Models are developed for daily rainfall-runoff analysis of catchment area named Damanganga. Model development is discussed in details in the following sections.

Linear Regression by least squares method are developed using built-in features of Microsoft Office Excel. Microsoft Office Excel facilitates the use of readily available built-in programs for developing Linear Regression. Rainfall-Runoff relationship can be easily developed using various functions in Microsoft Office Excel. Other theoretical backgrounds are discussed earlier.

Artificial Neural Network Models are developed using built-in features of Neuro-solutions. Neuro-solution facilitates the use of readily available built-in programs for developing Artificial Neural Network model. Several options are available for working with different networks architecture. Rainfall-Runoff model can be easily developed using various functions in Neuro-solutions functions. Models development, architecture selection and other theoretical background are discussed. Rainfall-Runoff modelling using ANN model are discussed in subsequent sections.

Artificial Neural Network Models are used in simulation of the given rainfall runoff values after a set of training. As discussed in earlier, ANN models map the given input-output patterns with different weights and bias values used between layers of the network. Simulation plots of rainfall-runoff data and performance statics of the model developed is shown below. In the present work yearly data is been taken for annual data model development and as well as data of monsoon (June to September) is been taken for seasonal data model development. Here 80% of the data are used for training and remaining 20% are used for testing.

IV. RESULTS AND DISCUSSION

A. Results of Linear Regression (LR) by method of Least Squares

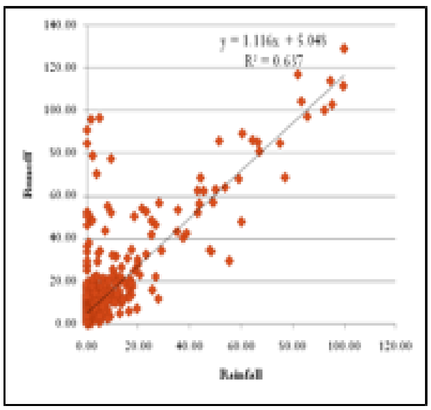

Fig. 1: Scatter Diagram of Rainfall-Runoff (year: 2001-2007)

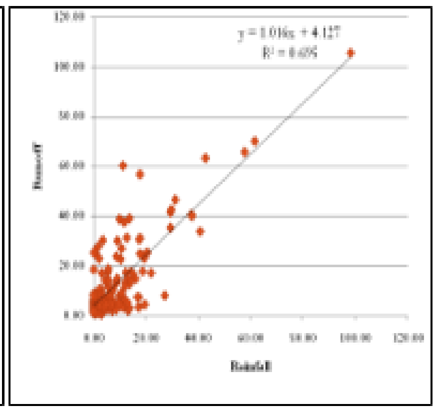

Fig. 2: Scatter Diagram of Rainfall Runoff (year: 2007-2008) for validation

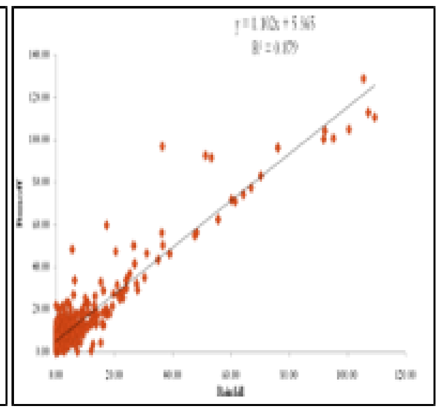

Fig. 3: Scatter Diagram of Rainfall-Runoff of Seasonal data

B. Results of Linear Regression (LR) by ANN

1) Result of Annual Data Model

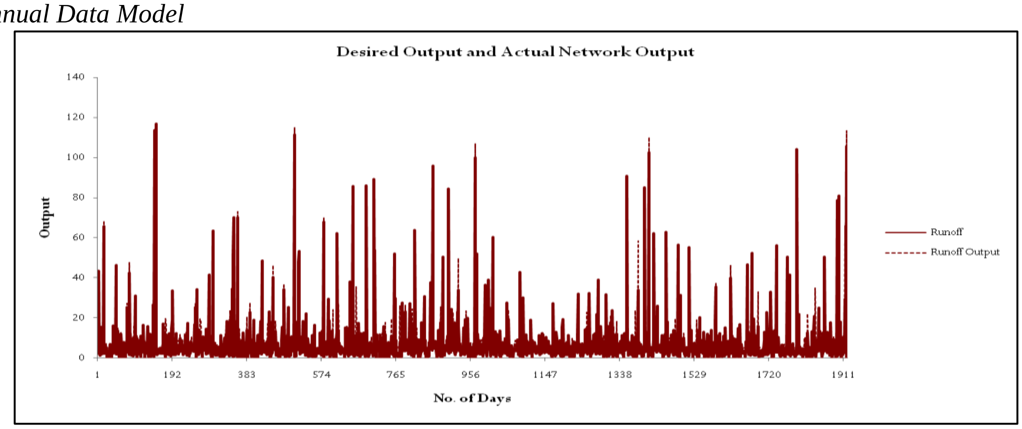

Fig. 4: Day wise simulated and observed runoff of annual data of LR

Performance	Runoff
MSE	48.57837145
NMSE	0.357452309
MAE	3.649146117
Min Abs Error	0.000471131
Max Abs Error	89.27703796
r	0.801590725

Table 1: Performance Table of Linear Regression Network of annual data

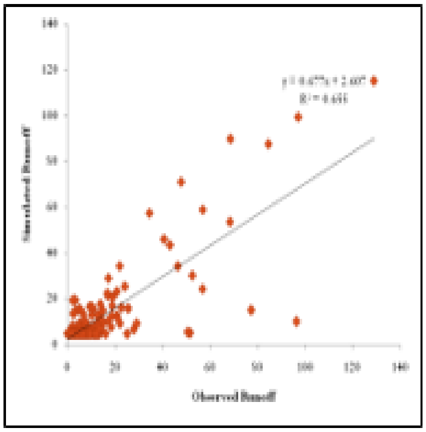

Fig. 5: Scatter Diagram of Observed flow vs. simulated flow of annual data of LR

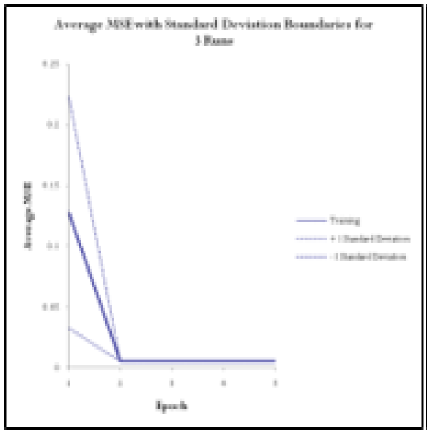

Fig. 6: Plot of Average MSE vs. Epoch of annual data of LR

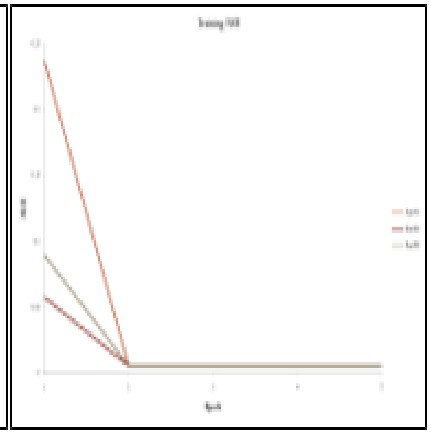

Fig. 7: Plot of MSE vs. Epoch of annual data of LR

Best Network	Training
Run #	1
Epoch #	3
Minimum MSE	0.005756677
Final MSE	0.005756677

Table 2: Best Performance of Network of 3 runs of annual data of LR

2) Result of Seasonal Data Model

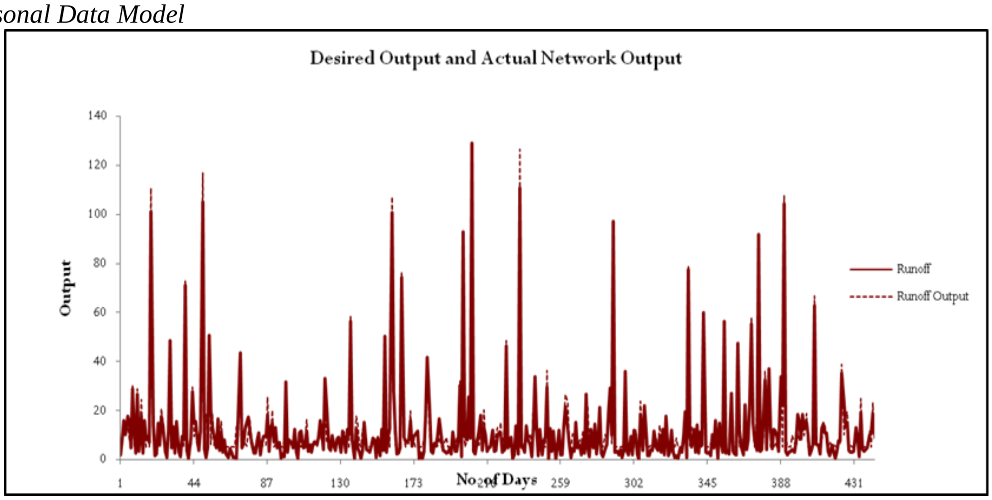

Fig. 8: Day wise simulated and observed runoff of Seasonal data of LR

Performance	Runoff
MSE	40.35327772
NMSE	0.133122047
MAE	4.270239507
Min Abs Error	0.074584605
Max Abs Error	51.3996237
r	0.931062809

Table 3: Performance Table of Linear Regression Network of Seasonal data

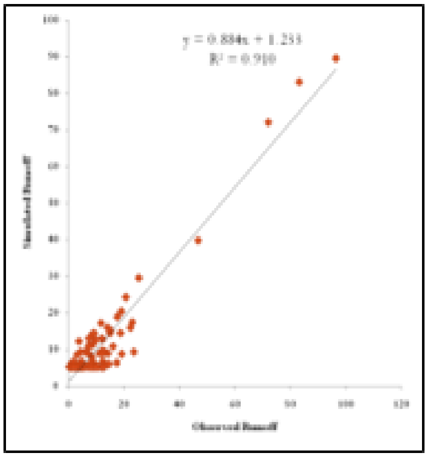

Fig. 9: Scatter Diagram of Observed flow vs. simulated flow of Seasonal data of LR

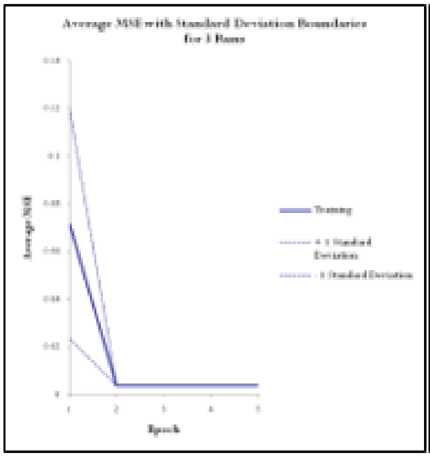

Fig. 10: Plot of Average MSE vs. Epoch of Seasonal data of LR

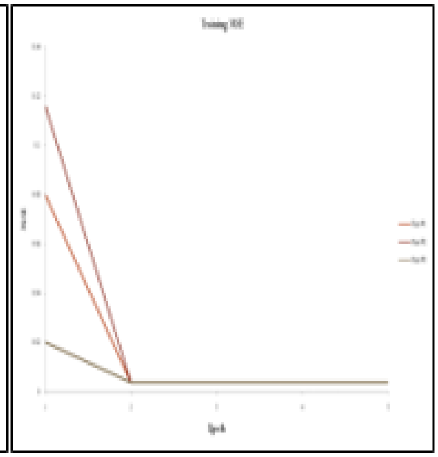

Fig. 11: Plot of MSE vs. Epoch of Seasonal data of LR

Best Network	Training
Run #	1
Epoch #	3
Minimum MSE	0.003938108
Final MSE	0.003938108

Table 4: Value of Average MSE for Seasonal Data of LR

C. Discussion of Models of LR

The results shown in the table (1 & 3) shows the performance of the annual data model and seasonal data model respectively by calculating MSE and MAE of the network using LR, the value of which are 48.57 & 3.54, 40.35 & 4.27 respectively that means network performance is well accepted.

The scatter diagram is generated between observed runoff and simulated runoff for annual data model shown in figures (5), which gives the value of coefficient of correlation (R2) equal to 0.6559 which is not fit good.

The scatter diagram is generated between observed runoff and simulated runoff for seasonal data model shown in figure (9), which gives the value of coefficient of correlation (R2) equal to 0.9102 which is nearly to 1, which indicates the goodness of fit of the model. (R2) having the value of 1.0 indicates that the regression line perfectly fits the data.

Moreover, Plot of Average MSE vs. Epoch and MSE vs. Epoch is generated and shown in Figures (6, 7 & 10, 11) for annual data and for seasonal data model respectively shows the decrease in the value of MSE indicating that the network is well trained and is having good performance.

Table(2 & 4) gives the value of MSE is 0.005 & 0.003 for annual data model and seasonal data model respectively of best of 3 runs of 1000 iterations indicates the good performance of the network.

D. Results of Multilayer perceptron (MLP)

1) Result of Annual Data Model

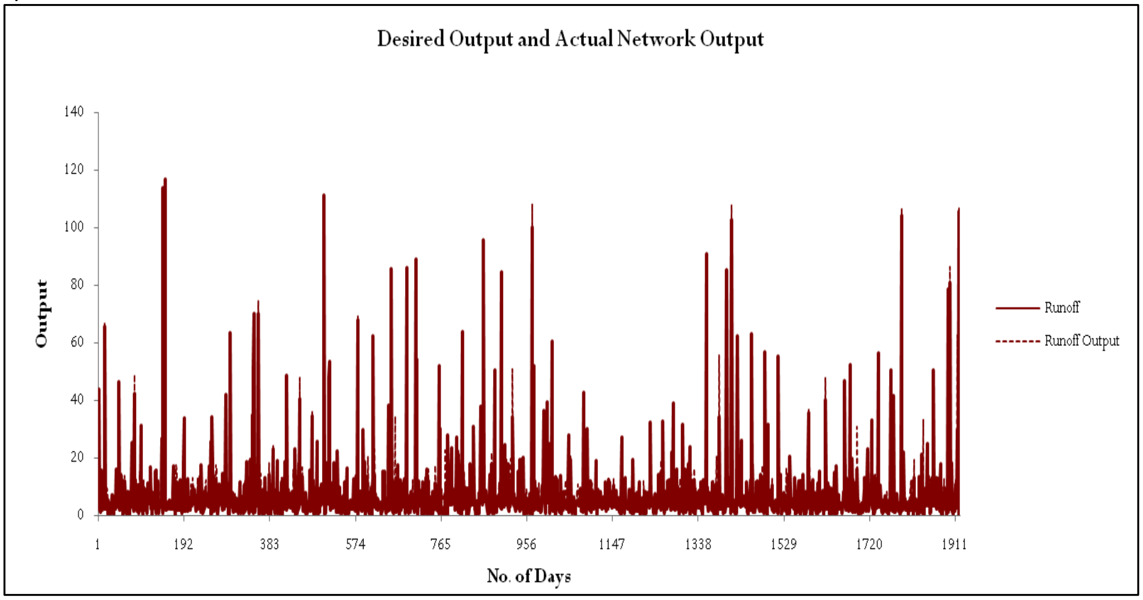

Fig. 12: Day wise simulated and observed runoff of annual data of MLP

Performance	Runoff
MSE	47.60461448
NMSE	0.350287152
MAE	3.612211628
Min Abs Error	0.003595983
Max Abs Error	87.70460196
r	0.806050991

Table 5: Performance Table of Multilayer Perceptron Network of annual data

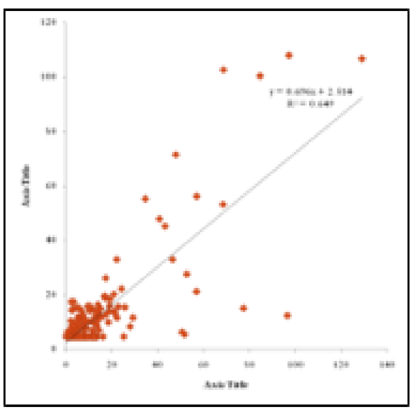

Fig. 13: Scatter Diagram of Observed flow vs. simulated flow of annual data of MLP

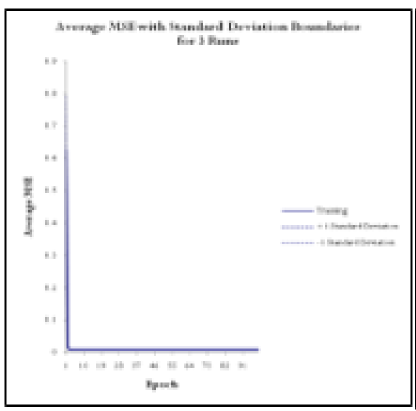

Fig. 14: Plot of Average MSE vs. Epoch of annual data of MLP

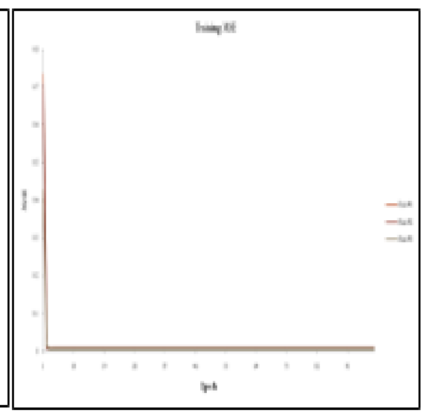

Fig. 15: Plot of MSE vs. Epoch of annual data of MLP

Best Network	Training
Run #	3
Epoch #	21
Minimum MSE	0.006919485
Final MSE	0.006919485

Table 6: Best Performance of Network of 3 runs of annual data of MLP

E. *Result of Seasonal Data Model*

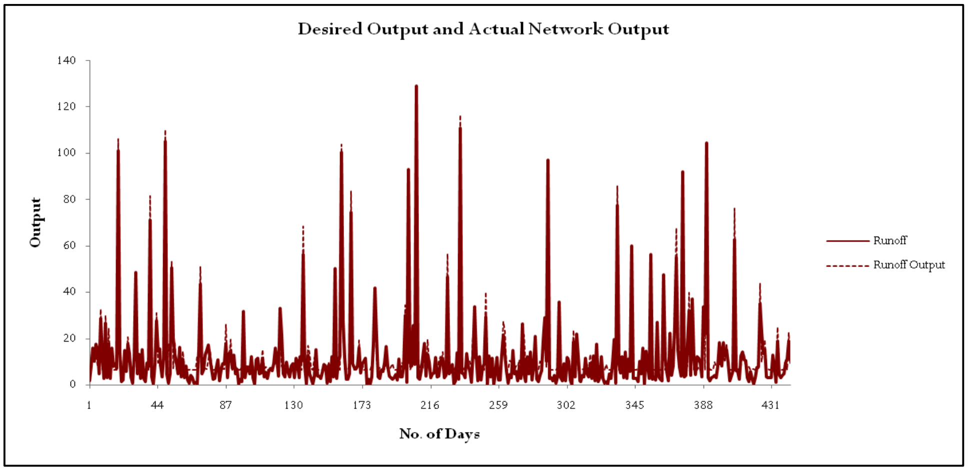

Fig. 16: Day wise simulated and observed runoff of Seasonal data of MLP

Performance	Runoff
MSE	38.56470531
NMSE	0.127221698
MAE	4.489269345
Min Abs Error	0.000270061
Max Abs Error	43.99850953
r	0.935177734

Table 7: Performance Table of Multilayer Perceptron Network of Seasonal data

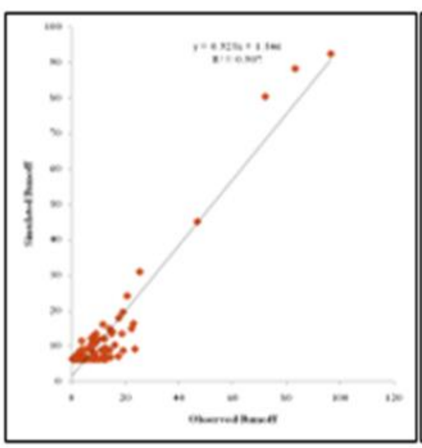

Fig. 17: Scatter Diagram of Observed flow vs. simulated flow of Seasonal data by MLP.

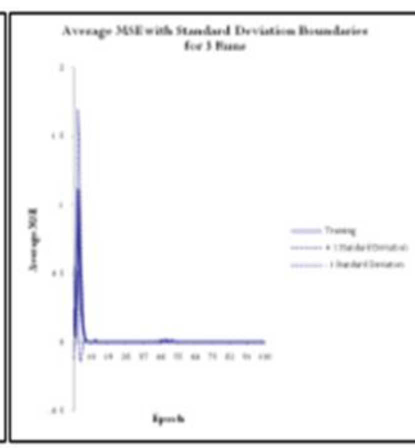

Fig. 18: Plot of Average MSE vs. Epoch of Seasonal data of MLP

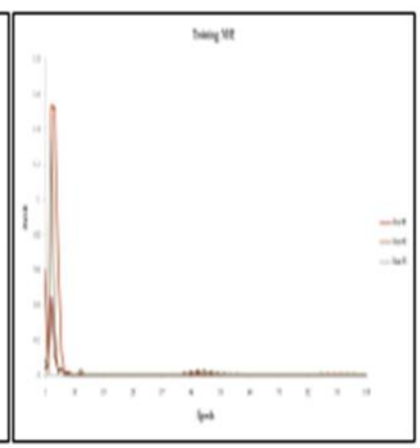

Fig. 19: Plot of MSE vs. Epoch of Seasonal data of MLP

Best Network	Training
Run #	1
Epoch #	99
Minimum MSE	0.00357509
Final MSE	0.004575141

Table 8: Best Performance of Network of 3 runs of Seasonal data of MLP

F. Discussion of Models of MLP

The results shown in the table (5 & 7) shows the performance of the annual data model and seasonal data model respectively by calculating MSE and MAE of the network using MLP, the value of which are 47.60 & 3.61 and 38.56 & 4.48 respectively that means network performance is well accepted.

The scatter diagram is generated between observed runoff and simulated runoff for annual data model shown in figure (13), which gives the value of coefficient of correlation (R2) equal to 0.6498 which is not fit good, which indicates the goodness of fit of the model.

The scatter diagram is generated between observed runoff and simulated runoff for seasonal data model shown in figure (17), which gives the value of coefficient of correlation (R2) equal to 0.9076 which is nearly to 1, which indicates the goodness of fit of the model.

(R2) having the value of 1.0 indicates that the regression line perfectly fits the data. Moreover, Plot of Average MSE vs. Epoch and MSE vs. Epoch is generated and shown in Fig (14 & 15) for annual data model and shown in Fig (18 & 19).for seasonal data model respectively shows the decrease in the value of MSE indicating that the network is well trained and is having good performance.

Table (6 & 8) gives the value of MSE is 0.006 & 0.004 for annual data model and seasonal data model respectively of best of 3 runs of 1000 iterations indicates the good performance of the network.

V. CONCLUSION

Following are the conclusions drawn based on the study carried out:

A linear regression model and ANN architecture is fitted for the daily data of monsoon season and daily data of year for data set of eight years. Seasonal data model gives a better fit with (R2) values higher than the (R2) values of Annual data model for both regression model and ANN model.

Results of coefficient of Determination (R2) of Annual data model for Damanganga reflect that the Linear Regression (LR) models by ANN display a better performance as compared the Linear Regression (LR) models by least square method.

Results of coefficient of Determination (R2), Mean square error (MSE), and Mean absolute error (MAE) of Annual data model and as well as Seasonal Data model for Damanganga reflect that the Linear Regression (LR) models display a better performance as compared to Multilayer perceptron (MLP) model.

The Advantage of LR is that it can be trained much faster than the MLP.

The convergence obtained by training network takes much time in case of Multilayer Perceptron (MLP), while it converges quickly in case of Linear Regression (LR).

REFERENCES

[1] McCulloch, W. S.; Pitts, E. (1943), "A logical calculus of the ideas imminent in nervous activity", Bulletin of Mathematical Biophysics: 541–544.
[2] Hebb, D.O. (1949), the organization of behavior. New York: Wiley & Sons
[3] Rosenblatt, Frank (1957), The Perceptron--a perceiving and recognizing automaton. Report 85 460-1, Cornell Aeronautical Laboratory.
[4] Minsky M. L. and Papert S. A. (1969),Perceptrons, Cambridge, MA: MIT Press.
[5] Widrow and Hoff (1960), Adpative Switching circuits, in 1960 IRE WESCON Convention record, part 4, New York: IRE, pp. 96-104.
[6] Minsky, M.; S. Papert (1969), An Introduction to Computational Geometry. MIT Press, ISBN 0-262-63022-2.
[7] Rosenblatt (1962), Principles of Neurodynamics. Washington, DC:Spartan Books.
[8] Pal et al. (2002), MLP based forecasting model for Dum station, www.iasri.Res .in/ebook/EB_SMAR/e-book.../3-ANN.pdf.network vs linear discriminant analysis in credit ratings forecast: A comparative study of prediction performances, Review of Accounting and Finance, Volume 5, Issue 3, 2006, pp. 216-227.
[9] Lin and Chen (2005), Application of an artificial neural network to typhoon rainfall forecasting, Hydrological Process, 19, 1825–1837 (2005) Wiley Inter Science (www.interscience.wiley.com)

