Suspended Sediment Simulation Using ANN Based MLP and MLR Technique for Narmada River in Hoshnagabad Station.

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Abstract— Rainfall runoff sediment modelling is good one of the most important topics in water resources planning development and management on sustainable basis. The Multilayer Perceptron MLP and Multiple linear regression MLR . This study was undertaken to develop and evaluate the applicability of the MLP and MLR models by way of training and testing of developed models during monsoon period June to September for Narmada River in Hoshngabad station. Daily data of rainfall-runoff and suspended sediment were used in the study for monsoon season. The daily data were splite into two set a training data set 2006 to 2010 and testing data in 2011 to 2012 for Narmada River. The Neurosolution 5.0 software and Microsoft excel were used in analysis and the performance evaluation indices for developed models. respectively .The best input combination of rainfall, runoff and suspended sediment were identify using the input output combination for simulation of suspended sediment. 10 best models for sediment were selected out of 31 models. The predicted suspended sediment using MLP and MLR models were found to be the performing models for Narmada River but MLP model the predicted suspended sediment best performing models for Narmada River. It was clearly evident MLR models fit very poorly for the dataset under study. The current day's suspended sediment can be simulated using the data of rainfall and runoff of previous one day MLP-5.

Keywords: ANN, MLP, MLR

I. INTRODUCTION

Today, the soil conservation is one of the development fundamentals in the world, while the main problems resulted from the soil erosion and more specifically the water and soil loss by extra runoff is not considered efficiently. On the other hand, awareness of the amount and severity of erosion and sediment yield for efficient and optimized strategies of preventing the soil losses have been attended by researchers to be able to predict the sediment location and erosion based on them. In order to implement the sediment yield estimation programs, and also the precise calculating and designing the dam's capacity in building the reservoir dams, the simulation and evaluation of the amount of produced sediment behind the sediment-retention dams is necessary. Different approaches have been used so far to estimate the sediment amount in small basins and sediment-retention dams. Using the simulators, physical models, mathematical models, statistical distributions and computer based models are of those cases used for predicting and modelling the hydrologic phenomena. The empirical and regression approaches are common extensively for having the simple structure, simple mathematical calculations and the ability of working with the limited input data set. Thus, the linear or non-linear common regression models can present the sediment loads with relative precision of the simple empirical-calculative models' accuracy (Morgan, 1996).

River sediment discharge determination is one of the crucial problems in water resources engineering. Several techniques including ANN have been successfully applied for estimation and prediction of suspended sediments around the world. Predict the amount of River daily suspended sediment discharge which occurs in the suspended sediment modelling is required to provide basic information for monitoring the water quality related to the river management problem and catchments area is very important as an indicator to assess the level of erosion hazard, management of the water resources, water quality, hydrology project management (dams, reservoirs, and irrigation) and to determine the level of damage in the catchment area. Prediction of sediment suspension using ANN has been widely carried out in the catchments area with the exact result.

II. MATERIAL AND METHOD

The main purpose of the present study is development, validation and performance evaluation of ANN models to estimate concentration of suspended sediment on daily basis for the Narmada river at Hoshngabad station located at the outlet of the Narmada river basin falling in the state of M..P. India and comparison of best selected model with the physical based models such as MLP and MLR basis on the MSE CE and r.

This chapter deals with the study area data acquisition and methodology adopted SUSPENDED SEDIMENT SIMULATION USING ANN FOR NARMDA REGION OF HOSHAGABAD MP INDIA procedure used for calibration and validation of the model and various criteria for evaluating performance of the model are also discussed here

A. Study Area: -

Hoshngabad district lies between north latitudes 22º 15' and 23º 00' and east longitudes 77º 15' and 78º 42' in part of survey of India toposheet Nos, 55F & 55J. Hoshngabad is the district headquarters and Itarsi, Sohagpur, Piparia, Pachmarhi and Bankheri are some of the major towns. Itarsi is a very important railway Junction lying on Delhi-Chennai, Delhi-Bangalore and Patna Mumbai railway routes. National Highway No. 69 and State Highway No. 21 and 22 pass through the district. The villages in the district are approachable by fair weather motorable tract .the catchment area in Narmada river in Hoshngabad station is 44,548 km^2 .s

B. CLIMATE

The climate of Hoshngabad district is characterized by a hot summer and general dryness except during the south west monsoon season. The year may be divided into four seasons. The cold season, December to February is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the southwest monsoon season. October and November form the post monsoon or transition period.

C. Rainfall

The normal rainfall of Hoshangabad district is 1225.9 mm. It receives maximum rainfall during southwest monsoon period. About 92.8% of the annual rainfall received during monsoon seasons and only 7.2 % of the annual rainfalls take place during October to May period Rainfall forms the sole source of natural recharge to grpound water regime and the rain water is available mainly during the southwest monsoon period only. The maximum rainfall received in district at Pachmarhi i.e. 2122 mm and minimum at Hoshangabad i.e. 1302.3 mm

Temperature

The normal maximum temperature received during the month of May is 42.1oC and minimum during the month of January is 11.7oC. The normal annual means maximum and minimum temperature of Hoshangabad district is 32.8^{0c} and $19.8\ ^{0C}$ During the southwest monsoon season the relative humidity generally exceeds 91% (August month). In rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less than 33%. April is the driest month of the year. The wind velocity is higher during the pre-monsoon period as compared to post monsoon period. The maximum wind velocity 7.7 km/hr observed during the month of June and is minimum 2.9 km/hr during the month of December. The average normal annual wind velocity of Hoshngabad district is 5.0 km/hr.

D. Economy

The economy largely depends on agriculture. Hoshngabad is one of the largest producers of Soya Bean. The land is quite fertile and farmers have good canal irrigation facilities from the Tawa reservoir throughout the year. The farmers employ rotation of crops and their major income depends on soya bean and wheat.

E. Cropping pattern

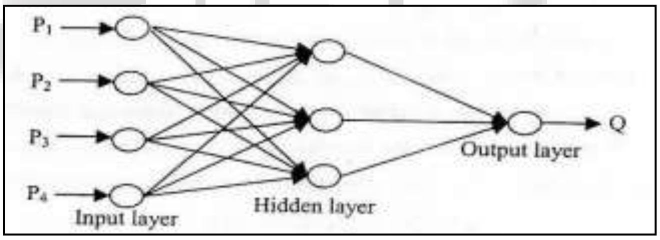
District is very rich in the field of agriculture due to good sources of irrigation and fertile alluvial soil. Wheat and gram are the main crops grown during Rabi season. Soybean, Mustard, Til and Groundnut are the main oilseeds produced here. The farmers have started the production of Sunflowers.

F. Data Acquisition

The daily rainfall, runoff and sediment data of monsoon season (1 June to 30th September during the years 2006 to 2012 at Narmada basin in Hoshngabad station were obtained from CWC (Central water commission Bhopal) and metrological department.

1) ANN: -

Artificial Neural Networks (ANNs) are inspired by the structure of human brain that is well suited for complicated task such as runoff prediction, rainfall-runoff modelling, river flow prediction etc., in hydrologic systems. These neurons were presented as models of biological neurons and as conceptual components that could perform conceptual task. ANN has been proven to provide better solutions for simulations and forecasting. Before looking at the structure of ANN, we need to understand the structure of biological neurons.



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a) The back propagation algorithm

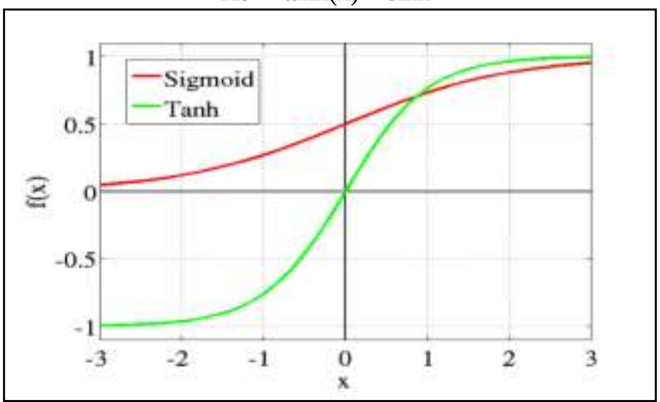
The back propagation algorithm (Rumelhart and McClelland, 1986) is used in feed –forward ANNs. This means that artificial neurons are organized in layers and send their signals “forward” and then the error are propagated backwards. The network receives inputs by neurons in input layer and the output of network is given by the neurons on an output layer. There may be one or more intermediate hidden layers. The back propagation algorithm uses supervised learning, which means that provides the algorithm with examples of inputs and outputs we want the network to compute, and then the error (difference between actual and expected results) was calculated. The idea of back propagation algorithm was to reduce this error, until the ANN learns the training data. The training begins with random weights, and the goal was to adjust them so that the error will be minimum. The activation function of artificial neurons in ANNs implementation the back propagation algorithm is a weighted sum (the sum of inputs X multiplied by their respective weights w)

b) Tanh or hyperbolic tangent Activation Function

tanh is also like logistic sigmoid but better. The range of the tanh function is from (-1 to 1). tanh is also sigmoidal (s - shaped). The activation function (also called transfer function) is used to transfer the activation level of a unit (neuron) input and output signal. It is a mathematical representation in terms of spatial or temporal frequency of the relation between the input and output .The activation function is usually has a sigmoid shape, but it may also take the form of other non-linear function, piecewise linear function, or shape function.

A number of activation function such as sigmoid Tanh, linear, softmax, linear, bias and axon, can be used to identify the best one is depicting the non-linearity of the modelled natural ststem .The best architecture of the network was determind by trial and error. In fact the optimal network architecture for each model was model selected from the one which resulted in minimum errors .in fact the optimal network architecture for each model was selected from the one which resulted in minimum errors and best correlation in the data set. Table 3.2 summarizes the types of transfer function that are available in NeuroSolution for Excel Release 5.0 software produced by NeuroDimension, Inc. Florida. first five function are non-linear of which only the Tanch and sigmoid are commonly used. for most problems. the recommended Tanh (Hyperbolic tangent) activation function is used fig 3.3 and same is used in this study. The Tanh is normally employed as hidden and hyperbolic tangent (Tanh) function to each neuron in the layer, thus outputting values within the range of -1 to +1 for each neuron . The Hyperbolic tangent (Tanh) function is expressed.

As tanh(x) = sinx



Transfer function	Output range	Description
Linear Tanh	-1 to 1	Piecewise linear
Tanh	-1 to 1	Hyperbolic tangent
Sigmoid	0 to 1	Sigmoid
Linear sigmoid	0 to 1	Piecewise linear
Softmaax	0 to 1	Sum to one
Bias	Infinite	Add a bias
Linear	Infinite	Add a bias and scales
Axon	Infinite	Stores input

Table 3.2: Details of various types of activation function

c) Multiple Linear Regressions

In multiple linear regression (MLR) equation, relationship between dependent variable and several independent variable by fitting in a linear equation. Regression analysis is commonly used to describe quantitative relationships between a dependent variable and one or more independent variables (Shirsath and Singh, 2010). MLR are used to model linear variables based on a least squares technique. However, MLR present some shortcomings and drawbacks in predicting nonlinear situations, given their nature of capturing strictly Linear Relations.

$$\boldsymbol{Y = b_0 + b_1 x_1 + b_2\ x_2 + \ldots + b_n x_n}$$

Where,

Y is the dependent variable, $\boldsymbol{b_1}$, $\boldsymbol{b_2}$……$\boldsymbol{b_n}$are the regression co-efficient for the linear equation. And $\boldsymbol{x_1}$,$\boldsymbol{x_2}$…..$\boldsymbol{x_n}$ are the independent variable.

d) Training and testing of MLP and MLR model.

The daily data of rainfall, runoff and suspended sediment were split into two set a training data set 2006 to 2010 and attesting data set from 2011-2012 for narmda river . the input pairs in training data set were applied to the network of a selected architecture and training was performed using back propagation algorithm of mlp model.

Training variables	Assigned values for MLP
MFs per input	2-10
Activation function	Tanh
Learning rule	Delta-Bar-Delta
Epoch	1000
Training threshold	0.001

Table training variables and their assigned value for MLP model.

e) Correlation coefficient (r):-

The correlation is an indicator of degree of closeness between observed and predicted values. if observed and predicted values are completely independent the correlation coefficient will be zero (mutreja 1992).

$$r = \frac{\sum_{i=1}^{N}(X_{oi} - \overline{X_o})(Y_{pi} - \overline{Y_p})}{\sqrt{\sum_{i=1}^{N}(X_{oi} - \overline{X_o})^2 \sum_{i=1}^{N}(Y_{pi} - \overline{Y_p})^2}}$$

x = mean observed values

Y =mean of observed value

The correlation coefficient is described in Equation-4. The correlation coefficient measures how well each observed discharge value correlates with the simulated discharge. The value is between -1 and 1. The value of one means perfect correlation, whereas zero means that there is no correlation. This criterion can be used to measure the agreement between the overall shape of the observed and simulated hydrographs.

f) Coefficient of efficiency (CE) :-

Coefficient of efficiency (CE) has been recommended by many researchers in the field of hydrology for evaluating the model performance (Mutreja, 1992 and Basu, 1993). They reported that the value of CE should be least 80% or so for a model to be accepted .A negative efficiency represent that the predicted values are less than the observed mean . The value of CE is determined by the following equation.

$$CE = \left[1 - \frac{\sum_{i=1}^{N}(X_{oi} - Y_{pi})^2}{\sum_{i=1}^{N}(X_{oi} - \overline{X_o})^2}\right]$$

g) Mean square error (MSE):-

The mean square error (MSE) is determined to measure the prediction accuracy. It always produces positive values by squaring the errors. The MSE is zero for perfect fit and increased values indicate higher discrepancies between predicted and observed values (wilks, 1995). The Mean Square Error between observed and predicted values is determined by the following equation..

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_{oi} - X_{pi})^2}$$

III. RESULT AND DISCUSSION

This chapter deals with the development and application of ANN and MLR model to simulate daily sediment for Narmada River on Hoshngabad station in M.P. India. The daily data of rainfall, runoff and sediment of Narmda river of monsoon period (1^{st} June to 30 september) The subsequent use in training and testing during years 2006-2010 (610 days) were used for the training or calibration of the model ,whereas the data of years 2011-2012 (244 days) were used for verification or testing of the development model.

The performance of the development model were evaluated qualitatively and quantitatively by the visual observation and based on various statistical and hydrological indices such as Correlation coefficient (r), Coefficient of efficiency (CE), Mean square error (MSE).The thirty one model having lower value of MSE and high value of r, and CE, is considerd as the better fit model.

A. *Model Performance*

S.NO	MODEL	Structure	Training			Testing		
			MSE	CE	r	MSE	CE	R
1	MLP-5	2-6-1	0.0084	0.3634	0.5900	0.0023	0.8654	0.9429
2	MLP-7	2-2-1	0.0088	0.3404	0.5399	0.0025	0.8530	0.9249

Table 4.1: Statistical indices for select MLP sediment model during training and testing

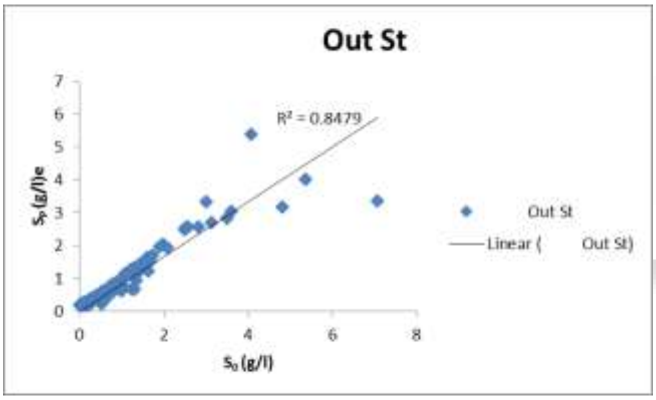


Fig. 4.1.1: Correlation between observed and predicted sediment by MLP model -5 neuron 6 during the validation period..

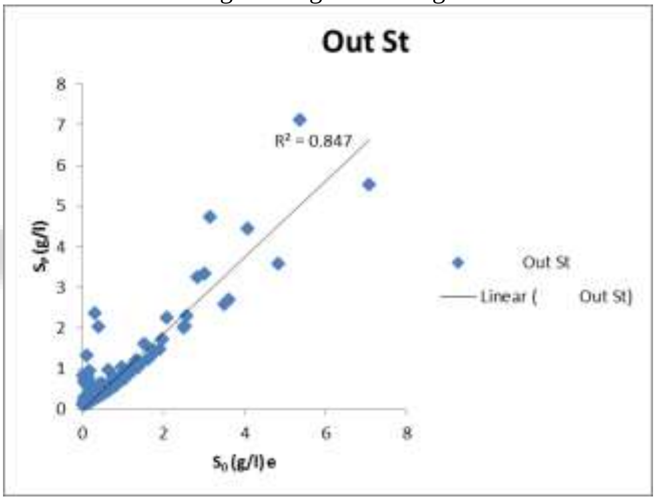
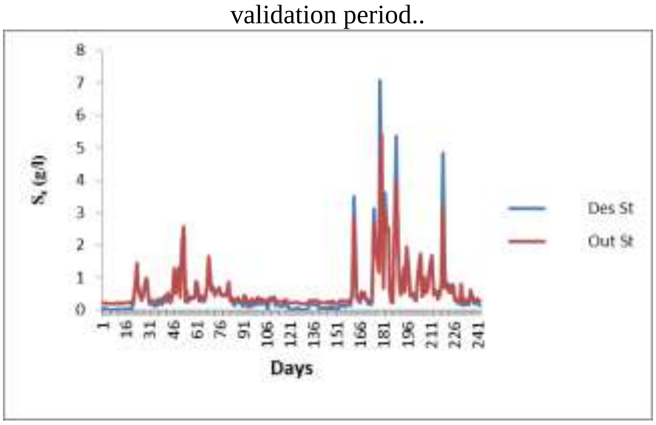


Fig. 4.1.2: Correlation between observed and predicted sediment by MLP -7 neuron 2 during the validation period.



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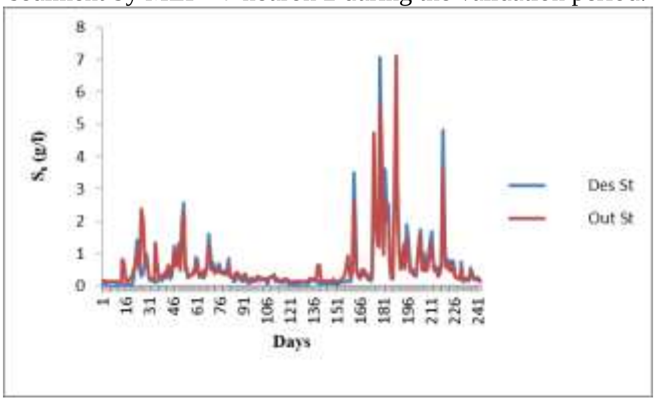

Fig. 4.1.2: Comparison of observed and predicted sediment by model 7 neuron 2 during validation period.

Model no.	Regression equation	Testing		
		MSE	CE	r
MLR-31	S_t $S_t=a_{31}+b_{24}R_t+b_{24}R_{t-1}+c_{24}Q_t+c_{24}Q_{t-1}+d_{16}\ S_{t-1}$	0.2983	0.6177	0.7860
MLR-30	$S_t=a_{30}+b_{23}R_t+$ $+c_{23}Q_t+c_{23}Q_{t-1}+d_{16}$ S_{t-1}	0.3001	0.6154	0.7845

Table 4.2: MLR sediment model during the testing period (2011-2012)

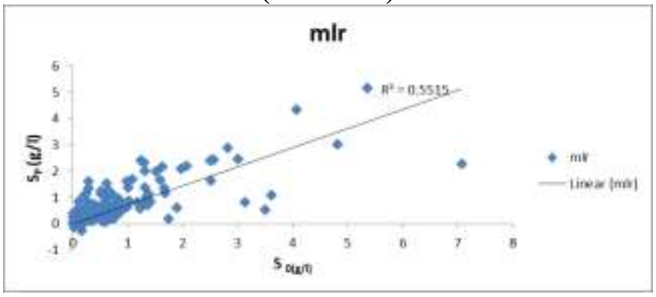

Fig. 4.2.1: Correlation between observed and predicted sediment by MLR model 31 during the validation period.

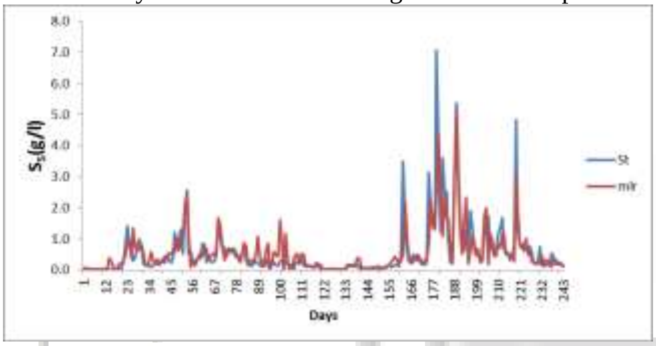

Fig. 4.2.1: Correlation between observed and predicted sediment by MLR-31 during the validation period.

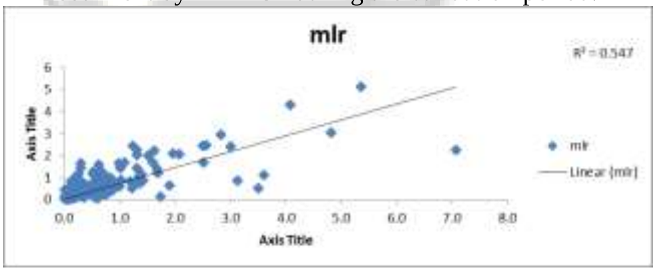

Fig. 4.2.2: Correlation between observed and predicted sediment by MLR model -30 during the validation period..

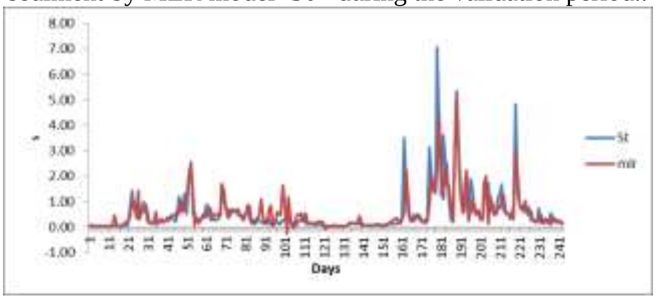

Fig. 4.2.2: Correlation between observed and predicted sediment by MLR-30 during the validation period.

IV. CONCLUSION

In this paper, the MLP and MLRg, are used prediction daily suspended sediment discharge in Narmada River in Hoshngabad station.

The artificial neural network (ANN) models show good capability to model hydrological process. They are useful and powerful tools to handle complex problems scompared with the MLRg, technique in this study, the results obtained show clearly that the artificial neural networks are capable prediction daily suspended sediment.

Total 31 model structures were developed, each one with different number of neurons in 2, 4, 6, 8, 10, the hidden layer to investigate the probability impacts of enabling rainfall-runoff and sediment. Out of 31 model structure, 10 best suitable models were selected based on statistical performance. Out of 10 ANN model, the MLP- 5 2-6-1 as best model configuration and indicated that 6 neuron in hidden layer fitted best on testing data and shows high degree of accuracy with training data set than other ANN architectures.

The performance of ANN MLP-5 2 -6-1 architecture in estimation of runoff from rainfall data was checked statistically, Hence, this ANN 2-6-1 architectures can be adopted to estimate suspended sediment from Narmada river with rainfall and runoff as input.

ANN model with MLP-5 2-6-1 architecture is found to be better which gives 31 model Mean squre error (MSE) 0.023 correlation coefficient 0.9429 coefficient of efficiency (CE) 0.865.

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