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Estimation of Suspended Sediment Yield using Artificial Neural Network Model

Manikanta Pajjuri, Arvind Yadav, Kondapanani Lakshmi Tanuja, Pendurathi Nagarjuna, Penke Satyannarayana

Abstract: ***Estimation of the suspended sediment yield is important for the planning and management of water resources and protection of the environment. Environmental change influences sediment generation and the transport and the consequent sediment load in river. In this study, artificial intelligence-based technique like the artificial neural network (ANN) is proposed for sediment yield estimation in the Godavari river basin, India. The ANN is one of the appropriate data-mining techniques that help model the complex phenomenon of sedimentation. In this study the prediction of the suspended sediment load is done using the ANN techniques by using the water discharge and water level data from 1970 to 2015 as inputs at Polavaram gauge station in Godavari river basin, India. The results demonstrate that the ANN shows a satisfactory performance based on the root mean squared error (RMSE), mean square error (MSE), mean absolute error (MAE) and correlation coefficient (r) error statistics and provided more accurate results.***

Keywords*: Suspended sediment yield, Artificial neural, network, water discharge, Godavari river.*

I. INTRODUCTION

Estimation of suspended sediment yield is always a key factor during the evaluation of Dam filling, protection of fish, hydroelectric equipment longevity, wildlife habitats and understanding of flood capacity. The information of the quantity of sediment present in a river can lead for understanding of flood capacity in reservoirs and help control flooding. Most of the floods cause loss of human life and property losses.

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***** Correspondence Author
Arvind Yadav*, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India. Email: arvindyadav@kluniversity.in
Manikanta. Pajjuri, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India. Email: 160050161@kluniversity.in
Kondapanani Lakshmi Tanuja, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India. Email: 160050116@kluniversity.in
Pendurathi Nagarjuna, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India. Email: 160050167@kluniversity.in
Penke Satyannarayana, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India. Email:satece@kluniversity.in

Moreover, sediment can itself be a major part of disaster which affects direct or indirect way to the lives and properties of people, and the deterioration of the environment, through a movement of soil and rock. There are many approaches which are used to estimate sediment yield using empirical models, numerical simulations, physically based models, utilizing remote detecting and Geographic Information Systems (GIS) strategies. Mathematical models are generally utilized in examining soil erosion and sediment transportation made definite surveys on the models. The functionality of river system is affected by the sediment loads of a river. The sediment load plays major role in channel morphology, delta improvement, geochemical cycling of components, water quality, the oceanic biological systems and environments pollutions. In river basin system, the relationship between sediment load and water discharge is complex. The estimation of sediment is difficult using traditional regression approaches due to complex behavior of sedimentation. Mismanagement of the catchment territory contribute greater sediment burden to the stream. Numerous Indian repositories have their capacity limits decreased due to sedimentation. Sediment deposition on riverbeds and banks causes extending of flood fields during floods. If in a present capacity of storage reservoirs is lost due to sedimentation, neither the present nor the anticipated populace and economic activity can be supported. Prediction of water level utilizing time arrangement information in the Ramganga river was studied. The linear models have a limited in hydrological and natural information to catch non-linearities. A noteworthy obstacle in precisely sediment load would that be the spatial of heterogeneity and of the different physical, hydro-meteorological and geomorphological properties that the waterway bowls and the non-straight connection between the components and the sedimentation procedure. The utilization of a physical and a hypothetical model required for explicit topographic, geological information and eco hydro-climatological information.

The usage of physical and applied models requires point by point topographic, Eco hydro-climatological and geophysical information. The preparation of such information for sediment load in any river like Godavari will be problematic and costly. Artificial intelligence techniques were used successfully by various researchers to solve complex non-linear worldwide problems in hydrology and other domains (Chakravorti and Das 2017; Yadav et al. 2017, 2018a; Yadav 2019a; Yadav and Satyannarayana 2019b). Numerical models are extensively used in examining sediment transportation. Under-fitting causes a poor framework display with a training dataset,

while overfitting prompts poor performance in the testing dataset in any model. Thus, optimum model parameter selection is very important for avoiding overfitting and underfitting problems in artificial neural network (Yadav et al 2018).

While ANNs have been standard choice for sediment transport of models, simply obliged examinations which have so far and been driven a surveying supply sedimentation which using the ANN's. This paper evaluates an artificial neural systems approach for estimation of sediment yield using the water discharge and water level data in Godavari river basin, India. It is found that the ANN model has more generalization capability to estimate the suspended sediment load in Godavari river basin, India.

II. STUDY AREA

The Godavari is India's second longest river after the Ganga. Godavari River is located at a latitude of 16.708548, longitude of 82.118683 and with degrees minutes seconds (DMS) Lat of 16° 42' 30.7728" N and DMS Long of 82° 7' 7.2588" E. India. Its source is in Trimbakeshwar, Maharashtra. It flows towards the east for 1,465 KM depleting the conditions of Maharashtra, Telangana, Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Odisha, and Karnataka releasing into the Bay of Bengal through its wide arrangement of tributaries. The Godavari River bowl gets normal yearly rainfall of around 1132 mm, out of which practically 84% of the complete precipitation falls in the monsoon season. With respect to, a catchment of an area from discharge, the Godavari stream is the greatest in peninsular India. It has a catchment area which around 312812 Sq.km. It has average water resource potential (MCM) is 110540. The location on map of a Godavari basin showing the main part of the streams, Polavaram gauge station is given in Figure 1.

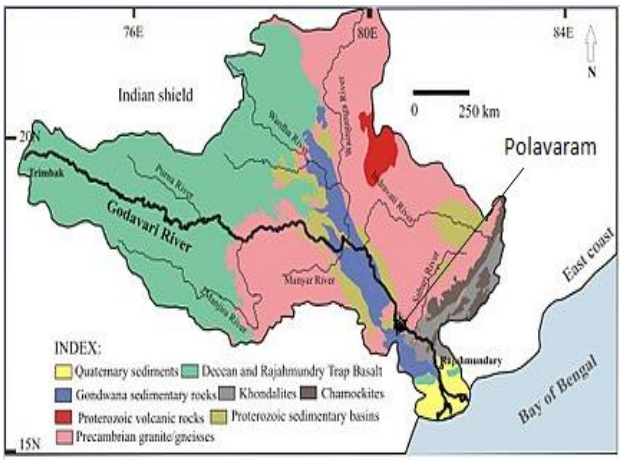

Figure 1. location on map of a Godavari basin which showing the main rivers, the Polavaram gauge station.

III. METHODOLOGY

A. Artificial neural network (ANN)

The ANN is a mathematical tool which is made up of artificial neurons arranged in layers. It established the relationship between the input variable and output variables through proper learning. The ANN analyzed the input and output dataset and find the correlation them. In a typical ANN architecture (Figure 2), the artificial neuron receives a set of inputs or set of signals (x), uses the summation function and weights(w) to calculate a weighted average of them, and then uses some activation function(f) to generate an output. The simulations took water discharge as a single variable source. In order to produce sedimentation as its output, tangent sigmoidal functions have been used as the transfer functions. The ANN models allowed the suspended sediment estimation accuracy better than the traditional models. It has been found that multi-layer perceptron based artificial neural network is performed superior to a traditional measurable technique like multi linear regression (MLR) and sediment rating curve (SRC).

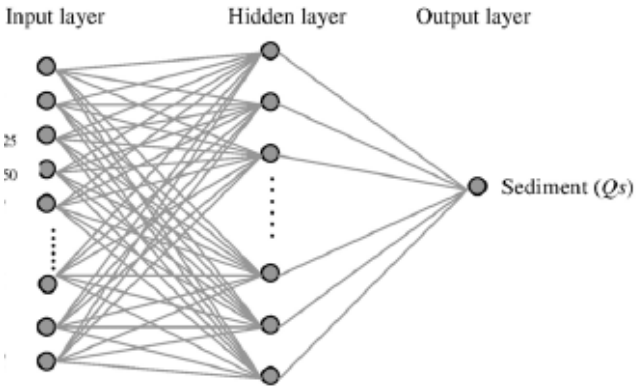

Figure 2 The architecture of multi-layer perceptron Artificial neural network.

B. MultI Layer Perceptron (MLP)

A Feed-Forward MLP arrangement consisting of a input layer, hidden layer and output layer with artificial neurons. In the middle of the input and the output layers, there is at least one hidden layer. In this current study, an MLP with log sigmoidal function is used as a transfer function and backpropagation algorithm as a training algorithm. In some of studies it states that the MLP based ANN models simulated far better than the traditional mathematical models. In MLP ANN there are associations between neurons of different layers, whereas there are no such associations within a similar layer between neurons. Using the MATLAB method, the MLP based ANN organizes development models consisting of three layers. The number of nodes in hidden layers was selected in the range of 1-32. The Levenberg Marquardt training algorithm is used for development of the ANN model.

C. Data processing

The normalization of information is imperative, and it should help in changing the input scope of every factor. Hence, after gathering of the hydrometeorological information, standardization was accomplished for every factor viz., daily mean water discharge and sedimentation. the correlation coefficients in the Godavari waterway at Polavaram Station was determined. Input and yield factors are pre-handled by scaling them in the range of 0 and 1 to wipe out their dimensions and to guarantee that all factors get equivalent consideration while preparing the models. This affirmed quick preparing and assembly while preparing which limited prediction errors (Rojas 1996).

For suspended sediment load (SSC) variable with least and greatest estimations of Smin and Smax separately the scaled esteem Sn is determined as pursues:

$$S_n = \frac{S - S_{min}}{S_{max} - S_{min}} \quad (1)$$

Where Sn, S, Smax, Smin are normalized estimation of the observed variable, original variable, the greatest estimation of the variable and the base estimation of the variable respectively. To create summed up and strong models for anticipating sediment yield, the information is isolated between training, validation and testing. Training information is used for the train of the neural system, while validation information is used to avoid overfitting.

IV. RESULTS AND DISCUSSION

4.1. Artificial Neural Network Model

The feed-forward back-propagation artificial neural network model was developed with input and output layers along with hidden layers. Levenberg–Marquardt (LM) training algorithm is used for training the artificial neural network (ANN).

Table 1. Training, validation and testing data error statistics of ANN model

RMSE	MSE	MAE	VAR	R
0.040 7	0.001 7	0.018 4	0.001 6	0.870 6

The LM-based MLP neural network models were built by single-hidden-layers inputs, outputs and neurons. In this ANN analysis, the value of μ ranges between 0.001 and 10×10^9; and the value μ of increase and decreases by a factor of 10 and 0.1 respectively. The number of which neurons in a secret layer ranges between 1 and 32 which to reduce the processing time and the complexity of a network (Yadav et al 2018;Yadav 2019a;Yadav and Satyanarayana 2019b). Lower the complexity of the model makes it easier to understand the interpretability of the machine learning model. The design began with an initialized μ value, that continues to change with each epoch to improve performance. The Figure 3 shows that the minimum RMSE value (0.00460) was provided by the ANN method. in the training data when the optimum value of hidden neurons and μ are 10 and 0.06 respectively. Therefore, this combination of ANN structure is considered as the best one. The RMSE, mean square error (MSE), error variance (VAR), mean absolute error (MAE) and correlation coefficient (r)) are widely used to calculate model output through statistical parameters. error statistics of the model training, validation and testing datasets of are calculated using standard formulas. The generalization capability and the performance evaluation ANN model is carried out with the test data set. To assess the accuracy of the model various error statistical parameters for training, validation and testing data are used and given in Table 1. It is observed that RMSE, MSE, MAE is very low), and correlation coefficient (r) is very high.

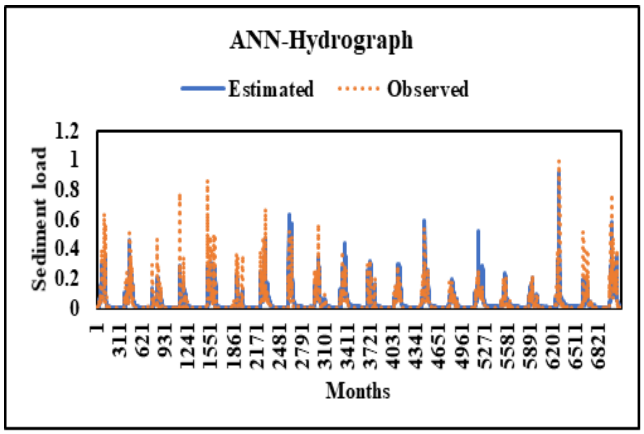

Figure 3. Hydrograph between and observed and which predicted Sediment yield of a ANN model

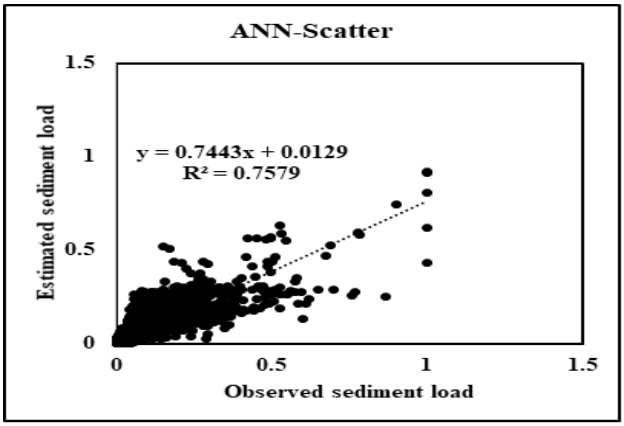

Figure 4. Scatter between and observed and a predicted Sediment yield of a ANN model

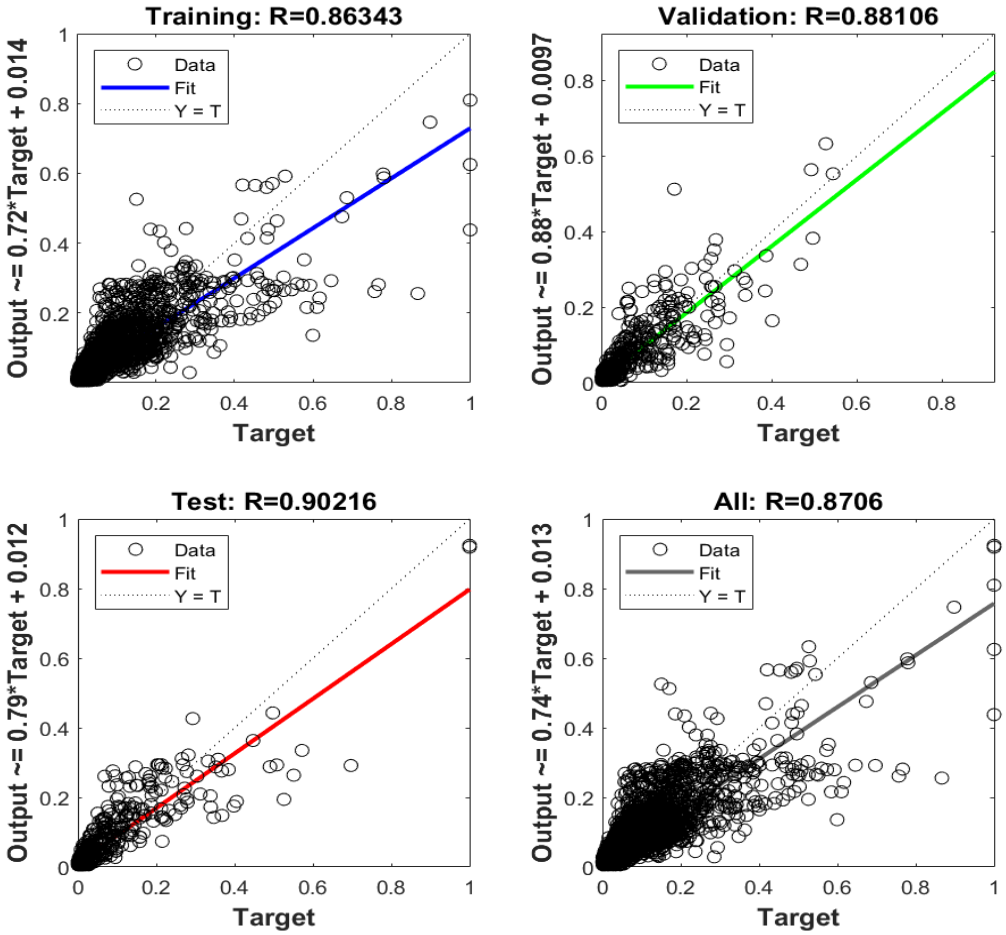

Figure 5. Scatter plots of a observed which estimated suspended Sediment yield of a ANN model

It is clear from the Figure 3 and Figure 4 that estimated and observed sediment yield are very close to each other. It should also clear that from this scatter plots (Figure 5)that in learning, validation and test dataset the real and the Model values of the ANN Model predicted that the more points are similar to the 45-degree line where the sediment values observed were equal to the predicted values.

VI. CONCLUSION

In this study, the suspended sediment yield was estimated by the ANN Model utilizing the water discharge and water level data at Polavaram station in the Godavari river basin. It was found that the water discharge and water level are the major controlling parameter of the sediment suspended in the River Godavari. The ANN model is provided sensitive prediction of large high and/or low estimations of a suspended sediment. It is demonstrated that the ANN model is the most reasonable substitute for traditional methods. The proposed ANN model predicts the sediment yield as data that is reasonably well-using water discharge and water level. It is very interesting finding that the ANN model is provided positive sediment for low, medium and high sediment load. Many methods are provided negative sediment values at low sediment, but this proposed model is provided positive sediment at low values. The proposed ANN model has more generalization capability. It is provided satisfactory performances. In this study ANN model parameters is selected using trial and error methods. In future model parameter will be select by global search algorithm. The proposed model is very beneficial where measurement of sediment load is not available.

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AUTHORS PROFILE

Manikanta. Pajjuri, I am a student of KL University studying final year belongs to Department of ECM, B-Tech. I have done my specification in Artificial Intelligence Technologies. I have worked on application of artificial intelligence in river basin system as my project.

Dr. Arvind Yadav, I am Dr. Arvind Yadav, Assistant Professor, Electronics and Computer Engineering Department, KL university Vijayawada. I have completed Ph.D. from National Institute of Technology (NIT) Rourkela. Artificial Intelligence Techniques are applied in interdisciplinary fields. Recently, I have published the "Prediction of suspended sediment yield by artificial neural network and traditional mathematical model in Mahanadi river, India" paper in Springer. Recently, I have also published SCI free journal paper "Suspended Sediment Yield Estimation using Genetic Algorithm-based Artificial Intelligence Models in Mahanadi River "of impact factor 2.3 in Taylor & Francis and others in river basin system. Many other papers which are based on application of artificial intelligence-based techniques in interdisciplinary domains are under review in SCI journals. I have qualified GATE exam.

Kondapanani Lakshmi Tanuja, I am a student of KL University studying final year belongs to Department of ECM, B-Tech. I have done my specification in Artificial Intelligence Technologies. I have worked on application of artificial intelligence in river basin system as my project.

Pendurathi. Nagarjuna, I am a student of KL University studying final year belongs to Department of ECM, B-Tech. I have done my specification in Artificial Intelligence Technologies. I have worked on application of artificial intelligence in river basin system as my project.

Dr. Penke Satyannarayana, Professor, Electronics and Computer Science, Koneru Lakshmaiah University, Vaddeswaram, India. Ph.D JNTU. AP, India.