

Monthly Suspended Sediment Load Estimation Using Artificial Neural Network and Traditional Models in Krishna River Basin, India

Arla Rama Krishna, Arvind Yadav, Thottempudi Bhavani, Penke Satyannarayana

Abstract: *The measurement of sediment yield is essential for getting the information of the mass balance between sea and land. It is difficult to directly measure the suspended sediment because it takes more time and money. One of the most common pollutants in the aquatic environment is suspended sediments. The sediment loads in rivers are controlled by variables like canal slope, basin volume, precipitation seasonality and tectonic activity. Water discharge and water level are the major controlling factor for estimate the sediment load in the Krishna River. Artificial neural network (ANN) is used for sediment yield modeling in the Krishna River basin, India. The comparative results show that the ANN is the easiest model for the suspended sediment yield estimates and provides a satisfactory prediction for very high, medium and low values. It is also noted that the Multiple Linear Regressions (MLR) model predicted an many number of negative sediment outputs at lower values. This is entirely unreality because the suspended sediment result can not be negative in nature. The ANN is provided better results than traditional models. The proposed ANN model will be helpful where the sediment measures are not available.*

Keywords : *Back propagation algorithm, Suspended sediment yield, Krishna river, Artificial Neural Network.*

I. INTRODUCTION

In streams and rivers the transport of suspended sediment is most important. The quantity of sediment transported during the waterway provides the necessary information for its morphodynamics, its catchment basin geophysics and, subsequently, for operations between the river in terms of erosion and sedimentation operations in the water system. Sediments transferred from continents to sea through rivers.

Revised Manuscript Received on January 05, 2020

* Correspondence Author

Arvind Yadav, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India

Arla Rama Krishna, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India

Thottempudi Bhavani, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India

Penke Satyannarayana, Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram-522502, AP, India.

Rivers are one of the most significant mechanisms that regulate the stability of the river bank, the formation of soil, water quality, geochemical sections of aquatic ecosystems and the host of specific processes related to the earth. Due to changes in place in the continent throughout the earth's history, river flow and sediment masses together have shown differences across completely different periods of time. However, a high-flow stream's high sediment carrying capacity can only increase sedimentary suspension if a further sediment is offered. During all days of high discharge, the provision is made through the erosion from the land surface and suspension of particles such as clay sand, etc. that has settled down in ancient times in the body of water. Several sediment loads, factors such as relief, canal paths, rain seasonality and tectonic activities, are very important factors. Most models are designed to model the suspended sediment load, which is difficult to obtain and expensive, physically and conceptually dependent. In empirical models, the suspended sediment yield calculable by relating the characteristics like voidance, topography, land and climate. These are used due to their straightforward structure and numerical methods.

Some researchers have used traditional mathematical models, such as the, Multiple Linear Regression(MLR) and Sediment rating curve (SRC) for sediment load estimation and have found that these models are unable to capture sediment load changes. Artificial intelligence techniques and other mathematical models were used successfully by various researchers to solve complex non-linear worldwide problems in hydrology and other domains (Chakravarti and Jain 2014; Chakravort et al 2017a; Chakravort and Das 2017b;Kebed et al. 2017; Chaube 2017, Yadav et al. 2017, 2018a; Chaube 2018a,b; Patel et al. 2018; Patel et al. 2019a,b. Yadav 2019a, Yadav and Satyannarayana 2019b). Various researchers have been used artificial intelligence for sediment load estimation in river basin system (Kebed and Chakravarti 2017;Yadav et al 2018b). One common intelligence-driven technique is the ANN, and various researchers have successfully used it to measure sediment load and it have provided a better result. the traditional SRC and MLR methods (Jain 2001; Bhattacharya, et al.,2007; Zhu et al.,2007;Rajae et al., 2009;Melesse et al., 2011, Yadav et al., 2017,2018). In terms of floods and water production capacity, the Krishna River is one of the important Indian rivers. In order to forecast floods in Indian Krishna river basin and precipitation, ANN has been successfully implemented.

Monthly Suspended Sediment Load Estimation using Artificial Neural Network and Traditional Models in Krishna River Basin, India

Nevertheless, no attempt was made at the Wadenpalli Gauge Station to estimate the suspended production in the Krishna River. Nevertheless, due to complex processes like deposition and erosion, the estimation of the suspension in sediment yield was not a simple task. In recent years, the techniques of the artificial neural network (ANN), in particular in the area of pattern recognition and functional estimation provide excellent performance in a reversal of regression.

II. STUDY AREA

Krishna River is chosen for the analysis of sediment yield. Krishna River is the fourth largest river in India after the Ganga, Godavari and Brahmaputra River in terms of water flows and river basin size. The river has a length of approximately 1400 kilometers. The river is also known as Krishna veni. It is one of Maharashtra, Mysore, Telangana and Andhra Pradesh's main irrigation reservoirs. It is one of Bharat's longest flows. Roughly 1,400 kilometers long is the Krishna River. Krishna Rivers Information Office is located at Mahabaleswar near the village on the east seacoast of Hamsaladevi (near Koduru) in Andhra Pradesh, on the east side of the island of Taluka, the satar district, Mae West, and Maharashtra. The Krishna River formed at approximately 1300 meters above sea level in Western Ghats near Mahabaleswar, in Central India's Maharashtra state. The river delta has been the home of the Satavahana Antediluvian dynasty and of the Ikshvaku Sun King and one of the most fertile regions in India. Vijayawada is the Krishna River's largest city Centre.

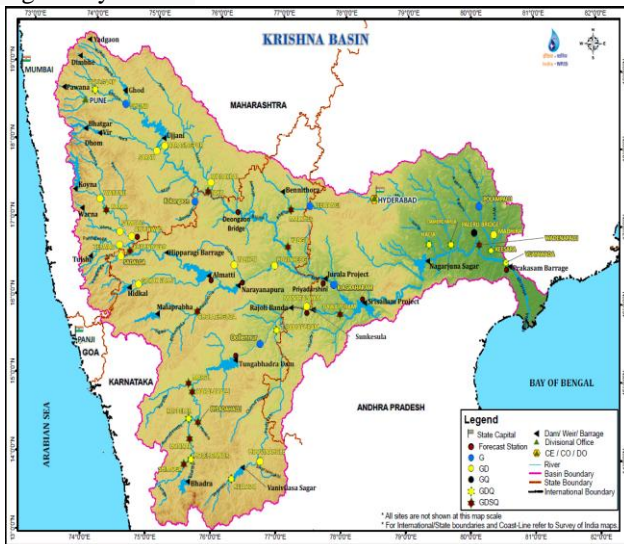


Figure 1. Location map of the Krishna basin showing main streams and Wadenpalli gauge station

The study collected the monthly discharge of water from Wadenpalli and the suspended sediment production data for the period of 40 years from 1981 to 2010, to develop a sediment outcome forecast. The gage station Wadenpalli is located at 80°04' longitude and 16°48' latitude. Figure 1 shows the location map of the Wadenpalli gage station in Krishna river.

III. METHODOLOGY

A. Artificial neural network (ANN)

The Artificial Neural Network (ANN) is commonly known as the neural computing network which is theoretically based on biological neural network structures and functions. The method, receiving and passing data in Synonyms / Hypernyms (ordered by approximate frequency) of noun terms in computer science is like an artificial human nervous network. The ANN is a popular, non-linear statistical class of artificial intelligence which is capable of learning complex nonlinear. There were three different levels s features in the neural network as shown in Figure 2. These are Input layer, in which all the remarks are rendered in the template through this layer, Hidden layer, and it is possible to use more than one hidden layer to process the inputs obtained through the input layer and finished output layer

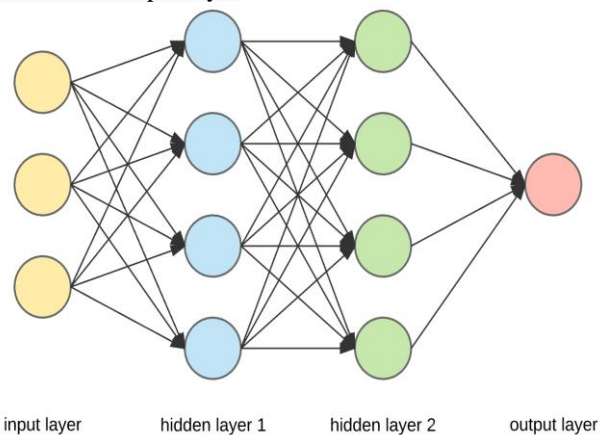


Figure 1 Artificial Neural Network block diagram.

B. Multiple Linear Regression(MLR)

The MLR aims of forming a linear relationship between the explanation variables (independent) and the response variable (dependent). Essentially, multiple regression is an extension of the traditional less-square regression which involves more than one explanatory variable Traditionally MLR models are the most frequently used methods for sediment production by using linear inputs. The sediment output of the same data set has been analysed for MLR. The MLR equation is required

$$S_{(t)} = a + bQ_{(t)} + cL_{(t)} \quad (1)$$

Here a, b and c are defined MLR equation regression coefficients. $L_{(t)}$ is the precipitation, $Q_{(t)}$ is the discharge of water and $S_{(t)}$ is the charge of the sediment at the given time. The values a, b and c were calculated with the inputs and observations using a method of least square regression.

The independent variables such as water level and water discharge have not been interacted.

C. Sediment Rating Curve (SRC)

In all sediment rating curves, there is the most common power function ratio describing the average ratio of streamflow t o suspended sediment concentration (SSC) for a certain location. The sediment rating curve equation is given as

$$S = aQ^b \quad (2)$$

Here Q is the water discharge and S is the sediment load. a and b are the coefficient of SRC. Water discharge information is used as input to estimate SRC sediment production, which is interpreted as the relationship between power function. Sustained sediment concentrations are SSC (g / m^3) and SL (g / s) are the load of sediment.

IV. RESULTS AND DISCUSSION

A. Levenberg-Marquardt algorithm in feed-forward back-propagation artificial neural network model

In this research, Levenberg Marquardt (LM) algorithm, which converges quickly and trains neural network significantly faster rate than the usual gradient descent The ANN model was used for the back propagation process. The ANN has been used to predict the suspended load in Wadenpalli guage station, Krishna river. There may be a change in the number of hidden neurons, where the Levenberg-Marquardt system has played a significant part with the use of ANN models. However, the optimum neuron count in the hidden layer was demonstrated 12. As an activation function for both the cache and the output layers, the tan-sigmoid activation function was optimally chosen. In the model LM algorithm a value of 20 was selected for optimized combination (μ) coefficient value. Figure 2 shows the variation of the ANN model learning parameter.

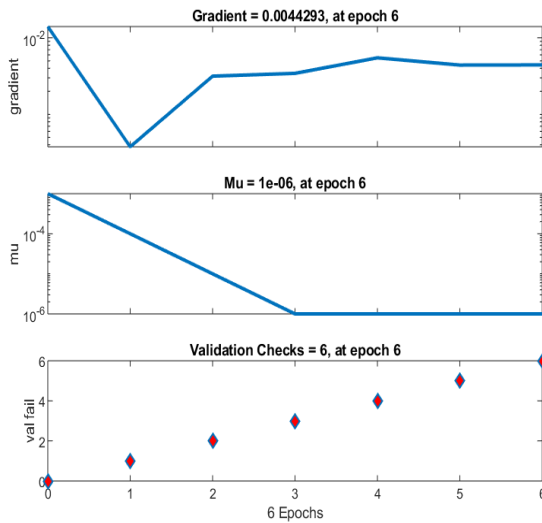


Figure 2. Variation of learning parameters in training phase

Figure 3 shows that the sediment yields measured and found are very similar. From the scattered plots (Figure 4 and Figure 5) it is also clear that the actual and ANN model predicted sediment values are closer than 45 degree (1:1) (observed sediment values are the same as the expected values) in the validation, practice and test datasets.

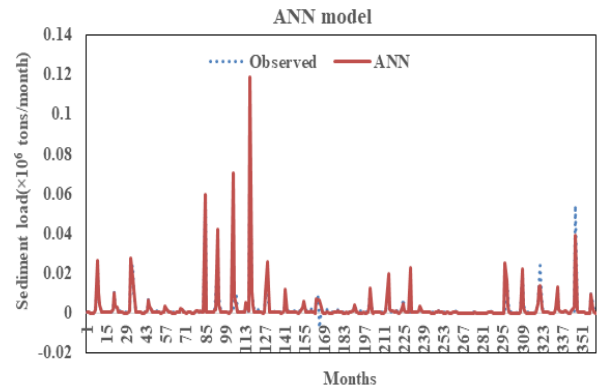


Figure 3. Comparison between observed and estimated suspended sediment load of ANN model

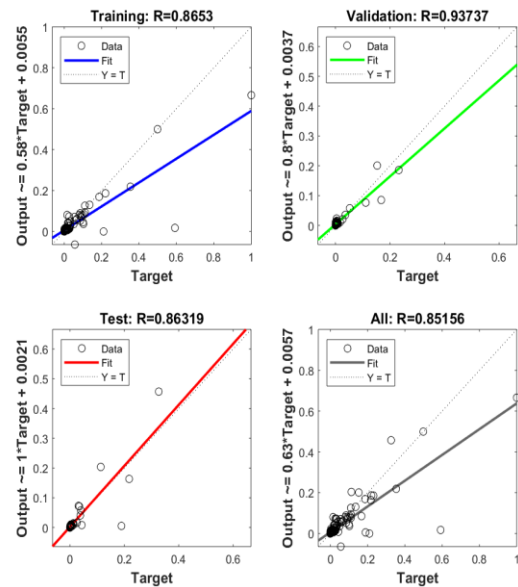


Figure 4. Scatter plots of normalized observed and estimated suspended sediment yield of ANN model

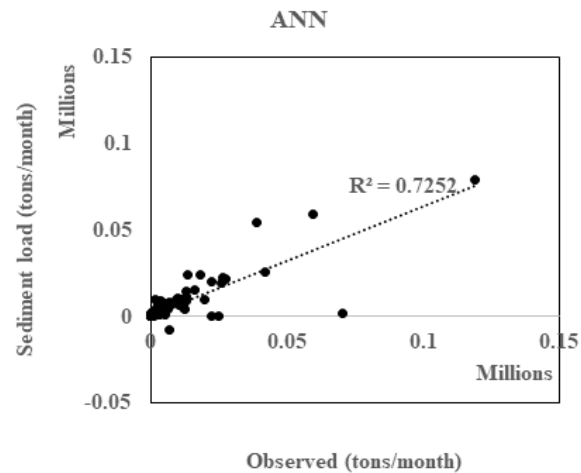


Figure 5. Scatter plots of observed and predicted suspended sediment yield of ANN model

Monthly Suspended Sediment Load Estimation using Artificial Neural Network and Traditional Models in Krishna River Basin, India

B. Multiple linear regression (MLR) model

The multi-linear regression (MLR) method was conducted using the combined data set validation and learning. No validation data set for the linear sample is therefore required. The same run data used for neural network models' test designs. The MLR model inputs are selected according to the forward selection method, by adding a parameter at one time.

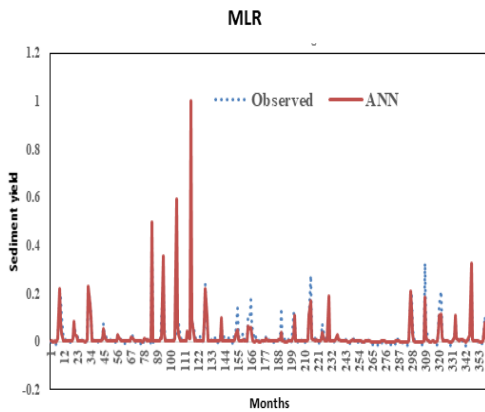


Figure 6. Comparison between observed and predicted suspended sediment yield of MLR model

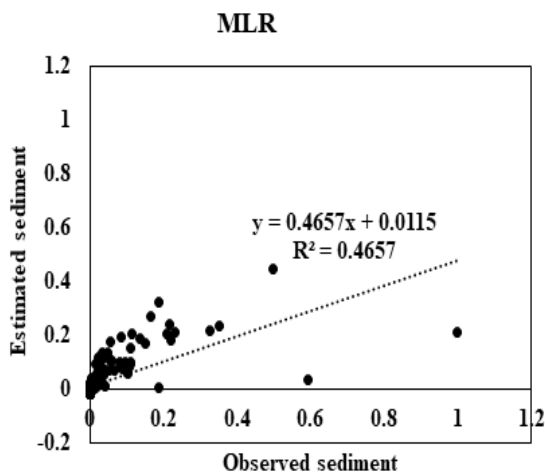


Figure 7. Scatter plots of observed and predicted suspended sediment yield of MLR model

The MLR position shows that some dispersion points are less than 45 degrees line and at places where a sediment has negative values is very low from Figure 6 and Figure 7. It shows that data are extremely non-linear in the field of small samples. The non-linearity that results in negative estimated values is failure to capture this linear good example. The resolution states that the MLR method generates negative sediment yield values. Moreover, sediment levels can not in fact be negative.

C. Sediment Rating Curve(SRC) model

The SRC-based nonlinear regression (NLR) model was fitted with the combined data sets of training and validation. No input parameter extract algorithm was used since we used one input, namely water discharge. The model for this is the least square method in general. The Power Relationship model (PR) is obvious, i.e. The SRC model generates a higher R^2

and higher root mean square error (RMSE) value. The lower coefficient of determination (R^2) and RMSE during the testing phase during the training phase. R^2 and RMSE therefore did not give the same direct relationship pattern.

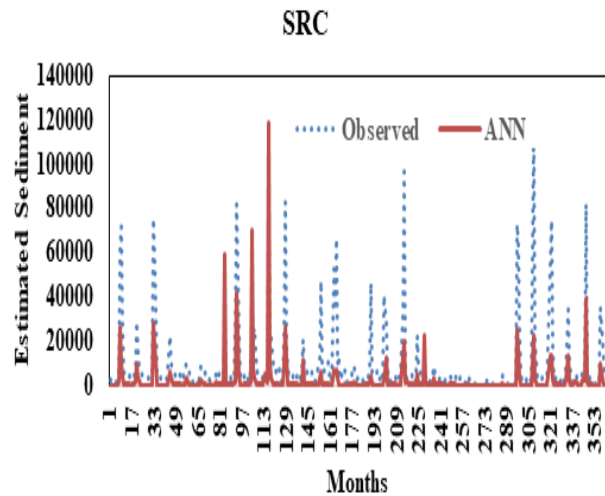


Figure 8. Comparison between observed and predicted suspended sediment yield of SRC model

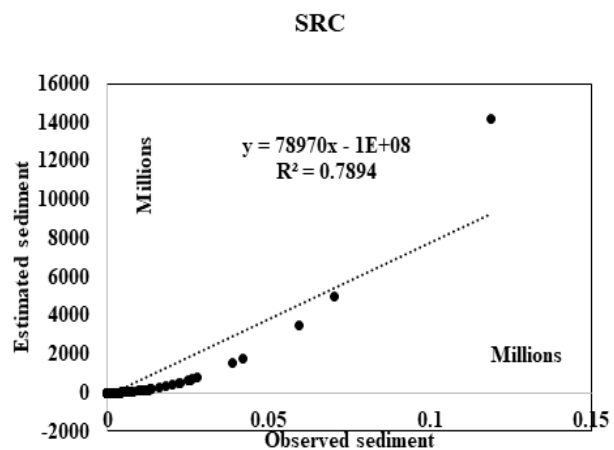


Figure 9. Scatter plots of observed and predicted suspended sediment yield of SRC model

Figure 8 shows that the predicted and observed sediment yields differ widely. The scatter points are not in the 45 degree line as shown in a scattering plot (Figure 9). Rajaee et al. (2009) also estimated very significant deviations in sediment yields from Predicted suspended sediment values using the SRC model when reporting data from Little Black River and Salt River, USA, showed significant variations in the sediment yield values predictable to observed. Due to poor non-linear functionality, the larger deviation in the SRC model was. These bad results show also that other variables like temperature, rainfall etc. are also importance.

V. COMPARATIVE EVALUATION OF THE DIFFERENT MODELS ON TESTING DATA

After the development of ANN, MLR and SRC models, the performance of the models was examined using the test dataset.

Table1. Comparing the Performances of ANN, MLR and SRC models for the testing period.

Models	RMSE	MSE	R2
ANN	0.0435	0.0019	0.725
MLR	0.3964	0.1571	0.466
SRC	0.3053	0.0932	0.789

The observed error statistics during testing phase using the ANN, MLR and SRC models are given in Table 1. It is found that the ANN performed better in terms of minimizing the root mean square (RMSE) and mean square error (MSE) than the traditional MLR and SRC models. However, although R^2 is very high (0.725) for the ANN is still next to SRC model, which has a maximum R^2 value (0.7894). Based on only R^2 , it is not always possible to demonstrate the capability of any model (Legates and McCabe 1999, Yadav et al. 2018).

VI. CONCLUSION

The suspended sediment yield were calculated at Wadenpalli gauge station of the Krishna basin by MLR, SRC and ANN models with water discharge and water level. The most important parameters are observed as water and water discharge for suspended sediments in the Krishna River. The ANN model developed is highly generalized than SRC and MLR models. The ANN model includes appropriate sediment load estimates at the Krishana River basin gage station in Wadenpalli. The ANN is compared with other conventional regression model such as MLR and SRC. It is found that ANN model has a high generalization power as compare to others.

This hydrological modeling work will be beneficial in this case if estimates of sediment values are not available. Sediment estimates will contribute to the efficient management of watersheds. This method would lead to a better management of downstream water resources and also for the design of pipes, reservoirs, bridges, canals, processes in the field of water treatment and stream geomorphology in the Krishna River, India and the assessment of water quality issues.

REFERENCES

1. Chakravarti, A., Joshi, N., and Panjjar, H., 2015. Rainfall runoff modeling using artificial neural networks. *Indian Journal of Science and Technology*, Vol. 8(14), pp 1-7, ISSN – 0974-5645.
2. Chakravorti, T., and Dash, P.K., 2017b. Multiclass power quality events classification using variational mode decomposition with fast reduced kernel extreme learning machine-based feature selection." *IET Science, Measurement & Technology* 12, no. 1, 106-111
3. Chakravorti, Tatiana, Rajesh Kumar Patnaik, and Pradipta Kishore Dash. "Detection and classification of islanding and power quality disturbances in microgrid using hybrid signal processing and data mining techniques." *IET Signal Processing* 12.1 (2017): 82-94.
4. Chaubey, Abhay Kumar, Ajay Kumar, and Anupam Chakrabarti. "Novel shear deformation model for moderately thick and deep laminated composite conoidal shell." *Mechanics Based Design of Structures and Machines* 46.5 (2018): 650-668.
5. Chaubey, Abhay Kumar, Ajay Kumar, and Anupam Chakrabarti. "Vibration of laminated composite shells with cutouts and concentrated mass." *AIAA Journal* 56.4 (2017): 1662-1678.

6. Chaubey, Abhay Kumar, et al. "Dual-axis buckling of laminated composite skew hyperbolic paraboloids with openings." *Journal of the Brazilian Society of Mechanical Sciences and Engineering* 40.10 (2018): 490.
7. Kebede, M., Chakravarti, A. and Adugna, T., 2017. Stream flow and land use landS cover changes in Finchaa Hydropower, Blue Nile river basin, Ethiopia" *International Journal of Civil, Structural, Environmental, Infrastructures Engineering, Research & Development (IJCSSEIERD)*, 7, 1-12, ISSN:2249-7978.
8. Patel, Ashok Kumar, Snehamoy Chatterjee, and Amit Kumar Gorai. "Development of a machine vision system using the support vector machine regression (SVR) algorithm for the online prediction of iron ore grades." *Earth Science Informatics* 12.2 (2019): 197-210.
9. Patel, Ashok Kumar, Snehamoy Chatterjee, and Amit Kumar Gorai. "Development of an expert system for iron ore classification." *Arabian Journal of Geosciences* 11.15 (2018): 401.
10. Patel, Ashok Kumar, Snehamoy Chatterjee, and Amit Kumar Gorai. "Development of an expert system for iron ore classification." *Arabian Journal of Geosciences* 11.15 (2018): 401.
11. Patel, Ashok Kumar, Snehamoy Chatterjee, and Amit Kumar Gorai. "Development of a machine vision system using the support vector machine regression (SVR) algorithm for the online prediction of iron ore grades." *Earth Science Informatics* 12.2 (2019): 197-210.
12. Patel, Ashok Kumar, Snehamoy Chatterjee, and Amit Kumar Gorai. "Effect on the Performance of a Support Vector Machine Based Machine Vision System with Dry and Wet Ore Sample Images in Classification and Grade Prediction." *Pattern Recognition and Image Analysis* 29.2 (2019): 309-324.
13. Patel, Ashok Kumar, Snehamoy Chatterjee, and Amit Kumar Gorai. "Effect on the Performance of a Support Vector Machine Based Machine Vision System with Dry and Wet Ore Sample Images in Classification and Grade Prediction." *Pattern Recognition and Image Analysis* 29.2 (2019): 309-324.
14. Yadav, A. Estimation and Forecasting of Suspended Sediment Yield in Mahanadi River Basin: Application of Artificial Intelligence Algorithms, Ph.D. Thesis, National Institute of Technology, Rourkela, India. (2019a).
15. Yadav, Arvind, Snehamoy Chatterjee, and Sk. Md. Equeenuddin. Prediction of suspended sediment yield by artificial neural network and traditional mathematical model in Mahanadi river basin, India. *Sustainable Water Resources Management* 4.4 (2017): 745-759.
16. Yadav, Arvind, Snehamoy Chatterjee, and Sk. Md. Equeenuddin. Suspended sediment yield estimation using genetic algorithm-based artificial intelligence models: case study of Mahanadi River, India. *Hydrological sciences journal* 63.8 (2018): 1162-1182.
17. Yadav, A. and Satyanarayana, P.. Multi-objective genetic algorithm optimization of artificial neural network for estimating suspended sediment yield in Mahanadi River basin, India. *International Journal of River Basin Management* (2019b), pp.1-21. DOI:10.1080/15715124.2019.1705317.

AUTHORS PROFILE



Arla. Rama Krishna: 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

Monthly Suspended Sediment Load Estimation using Artificial Neural Network and Traditional Models in Krishna River Basin, India

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.



Thottempudi Bhavani: 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.