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Research Article

RESERVOIR SEDIMENT PREDICTION IN DUHOK DAM USING ARTIFICIAL NEURAL NETWORK AND CONVENTIONAL METHODS

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ABSTRACT
Estimating soil erosion and sediment yield in watershed can play an important role for study on dams and reservoirs. Because of complicated and nonlinear process of sediment load and the lack of data in hydrological stations, it's difficult to measure exact sediment yield. However, the classic methods usually cannot handle the problem as well. In this study, Artificial Neural Network (ANN) as a non-linear black box model is used for modeling sediment yield in the dam of Duhok, located in Duhok, Kurdistan region, Iraq. The ANN is becoming a strong tool for providing environmental engineers and hydrological process with sufficient details for design purposes and management practices. For this aim, Observed time series of water discharge at current and previous time steps are used as input to a three-layered back-propagation feed-forward neural network model and the output will be the estimated sediment yield. The best architecture of the ANN method is obtained by try and error. The obtained results are compared with the results of two conventional methods (i.e., linear regression model and rating curve method) by using model efficiency factor (E) in order to approve the efficiency and ability of the proposed method. Results indicated ANN model performed better than conventional methods.

Keywords: *Artificial Neural Network, Linear Regression, Curve Number, Sediment Load*

INTRODUCTION
Aims:
The main objectives of this research consist of:
1. Measuring sediment yield of Duhok dam, Kurdistan region, Iraq,
2. Estimating sediment yield by conventional methods such as sediment rating curve and linear regression methods,
3. Using Artificial Neural Network as an intelligent method to predict sediment yield,
4. Comparison the obtained results of ANN model with two conventional approaches, sediment rating curve and linear regression methods.

Background
According to limited and non-uniform spatial and temporal distribution of water and soil resources, as well as increasing water pollution, land degradation, population, urban development and industrial and agricultural activities, an exact planning and managing in soil and water natural resources is inevitable. Therefore estimating and simulation the rate of runoff and sediment yield due to insufficient data in hydrological stations is so important for watershed management and soil conservation (Avarideh et al, 2001). Exact determination of sediment yield is so crucial for main purposes such as reservoir and channel design, sediment transportation, estimating water pollution and assessment the effects of watershed management. There are two basic methods for estimating suspended sediment load in rivers: a) Empirical methods which is based on physical concepts and hydrodynamic properties of sediment. This method partly doesn't have precise result because of insufficient and accurate data. b) Regression method wherein one or more curve is fitted on sediment data. However, one the current approaches is rating curve method using the following equation;

$Q_s = aQ_w^b$ (Agrawal *et al.*, 2006)

Where Q_s is sediment discharge, $Q_w$is water discharge, *a* and *b* are constant parameters. Most of available methods needs different data which is not measured in rivers also needs to solve complicated mathematical equations. In the other hand regression relationship between sediment and water discharge

don't have enough precision and accuracy. Nowadays most of researchers focused on modern methods to solve the problems with empirical models. One of the useful approaches in different fields of engineering is artificial neural network (ANN). This technique has been used successfully for predicting runoff and sediment yield process also for estimating daily suspended sediment (Cigizoglu, 2004). Only a few researches have been done by ANN model for the prediction sediment yield by using time series data of water discharge. In one research by the relationship between discharge and sediment load was established by ANN model. The result was shown that ANN model has high accuracy and more precision than conventional methods (Jain, 2001). Developed model by artificial neural network was applied to estimate suspended sediment load by using time series of water discharge in Talkherood River in Iran. The results approved the efficiency and ability of ANN model comparing to rating curve method and linear regression model (Nourani, 2009). In one study suspended sediment yield estimation was used by ANN model, range-dependent neural network (RDNN) and rating curve method. Results were shown that RDNN gives better estimates than other techniques (Kisi, 2007). In another research, generalized regression neural network and feed forward back propagation had high capability to estimate event-based suspended sediment concentration in comparison to classical regression models (Wang and Traore, 2009).Two intelligent model, Artificial Neuro-Fuzzy Inference Systems (ANFIS) and ANN was applied using measured data of water discharge in Ekbatan reservoir sub basin, Iran. The result was compared with rating curve method and was shown that ANFIS and ANN are more accurate than rating curve method (Asadinia *et al*, 2010).

ANN is a nonlinear method that is able to catch the complex temporal variations in time series data also between input and output parameters. This method consists of different layers and each layer contains of number of neurons. The first layer in general is known as input layer, the intermediate layers are hidden layer and the last layer is output layer.Hence, the main objective of this research is focused on applying ANN method as a parallel distributed processing system to estimate suspended sediment yield and comparing the results with conventional method for obtaining the priority method in sediment load prediction with high accuracy and precision.

MATERIALS AND METHODS

Duhok dam reservoir belongs to the Zargross mountain region. It is located at the head water of the main stream passing through the city of Duhok. It is bounded by parallels N36^{o} 87.110$'$ and N37^{o} 01.015$'$ and meridians E42^{o} 84.055$'$ and E 43^{o} 06.010$'$, with an area about of 134.4 km^{2} (Fig. 1). The mean monthly temperature vary from 5^{oC} in January up to 32.8^{oC} in July with annually average of 19.4^{oC}.Mean annual rainfall is about 560mm of which more than 90% occurs between December and April.

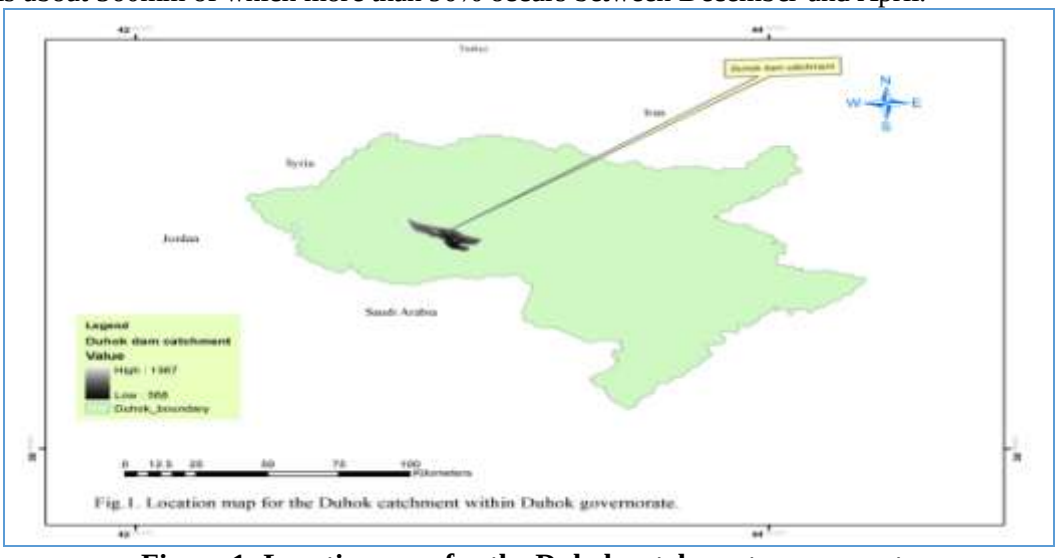

Figure 1: Location map for the Duhok catchment governorate

Time series data of daily water discharge and suspended sediment yield was used in this research which was obtained through 2010-2011.The samples were measured by point integrating method. According to this method, the sample was lowered quickly to half of the depth of flow at each sub-section to give the best estimate of the average sediment concentration. After that, the remaining sections were sampled nearly at the same time. About 270 sediment measurements have been recorded for this period. Time series data divided into two sets: the first 70% of total data was used for training and the second 30% was applied for testing. In the present research ANN model as an intelligent method was used. The network in this model is Multi-Layer Feed Forward network with standard back propagation algorithm. In ANN model parameters should be identified which is consist of number of hidden layer, number of neurons for each hidden layer, kind of activation function, input and output data. Therefore by using MATLAB R2013 software, design of ANN structure was determined. The numbers of neurons in input layer varies based on the value of water discharge (Q_{wt}) at the same current day, one day (Q_{wt-1}) and two days before (Q_{wt-2}) of the observed sediment yield. The parameter, suspended sediment discharge, is considered as output layer, therefore only one neuron was used in the output layer. The Levenbreg Marquardt training algorithm was applied for training the Multi-Layer Feed Forward network. For normalization data between 0 to 1 before entering to the ANN model, equation (1) was used.

$$n = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (1)$$

Where n is the normalized value, X_i is the real value, X_{min} and X_{max} are the minimum and maximum of all used values, respectively.

Rating curve method is another model was used in this study which is related to conventional models based on sediment (Q_s) and water (Q_w) discharge (Eq. 2)that can be used for estimation sediment yield (Cobaner *et al*, 2009).

$$Q_s = aQ_w^{\ b} \quad (2)$$

Where Q_s is suspended sediment yield (tone/day), Q_w is water discharge (m^3/s), a and b parameters are constant and relate to soil properties.

Linear regression model is another experimental method which was used in this research with dependent parameter, Q_w, and the independent variable,Q_s (suspended sediment load).

The performance of applied models was evaluated using statistical technique which was model efficiency factor (E) expressed by the following equation;

$$E = 1 - \frac{\sum_{i=1}^{N}(Pi - Qi)^2}{\sum_{i=1}^{N}(Qi - \bar{Q})^2} \quad (3)$$

Where E is determination coefficient, N number of observation, Pi predicted data, Qi observed data and $\bar{Q}$ is mean observed data.

RESULTS AND DISCUSSION

In this research by ANN model, according to the previous investigation of (Rajaee *et al*, 2009), parameters like number of hidden layer (one layer) and output layer neurons (one neuron), also activation function (tansig) were supposed as the constant. The best model in this study based on the numbers of optimized number of training epochs and number of neurons in input and hidden layer. So, the relationship between error and replication by trial and error for both training and testing data was obtained. Results for the best ANN structure is obtained based on coefficient efficiency for training and testing data also RMSE for testing data. The best structure of ANN model is shown in table 1 which is consist of (Q_{wt}) at the same current day, one day (Q_{wt-1}) and two days before (Q_{wt-2}) as input layer, 2 neurons in hidden layer and sediment concentration as output layer. Also, figures 2 and 3 are illustrated

the Scatter-plot of observed and computed suspended sediment yield and Normalized observed and predicted water discharge in time series in Duhok dam reservoir respectively.

Table 1: Best structure of ANN model to estimate suspended sediment yield

ANN structure	3.2.1
Activation function	Sigmoid
Epoch	25
Network learning function	TRAINLM
E training	0.98
E testing	0.97
RMSE testing	0.021

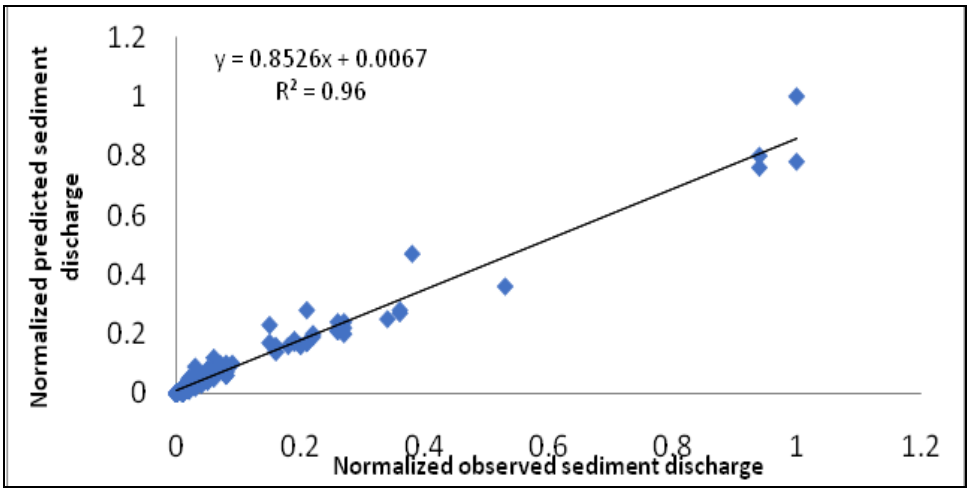

Figure 2: The scatter-plot of normalized observed and computed suspended sediment yield using ANN model

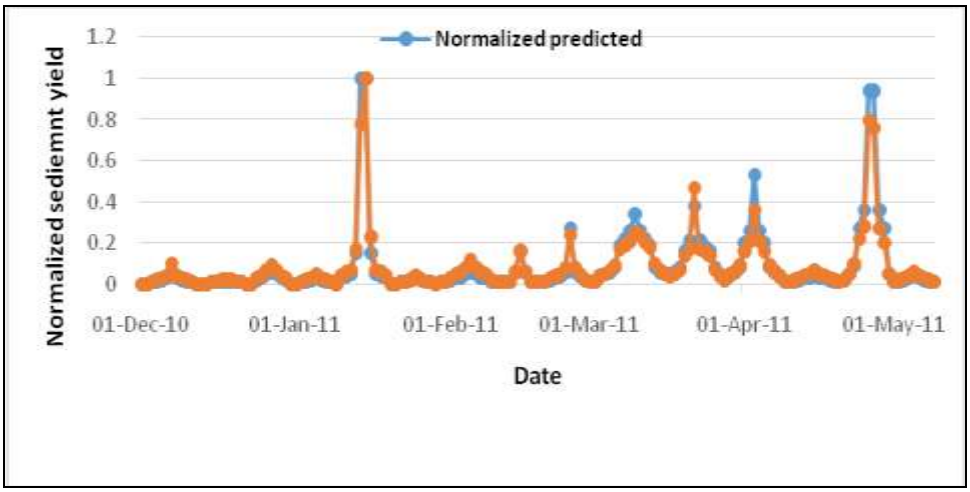

Figure 3: Comparison between observed and predicted suspended sediments yield by using ANN network RBF Neural Network

In rating curve method the values of a and b were calibrated by using training data set which is obtained 0.28 and 1.21 respectively. The result of E value was 0.95 which is illustrated in figure (4). The efficient coefficient of the model obtained from water discharge at same current day, one day and two days before.

In linear regression model the correlation relationship was established between suspended sediment load and water discharge. Figure (5) is presented the scoter plot for observed and estimated sediment yield using linear regression method. The result for the best performance by using training data was obtained with 0.92 efficiency factor.

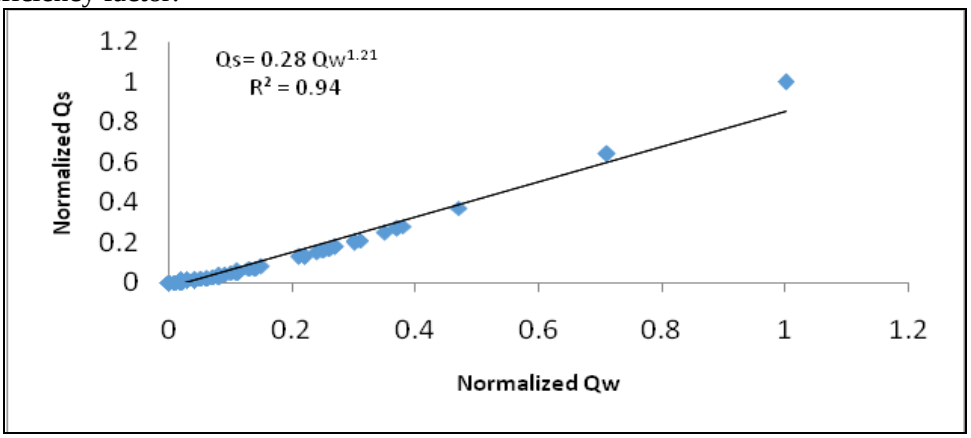

Figure 4: The scatter-plot of normalized observed and computed suspended sediment in rating curve method

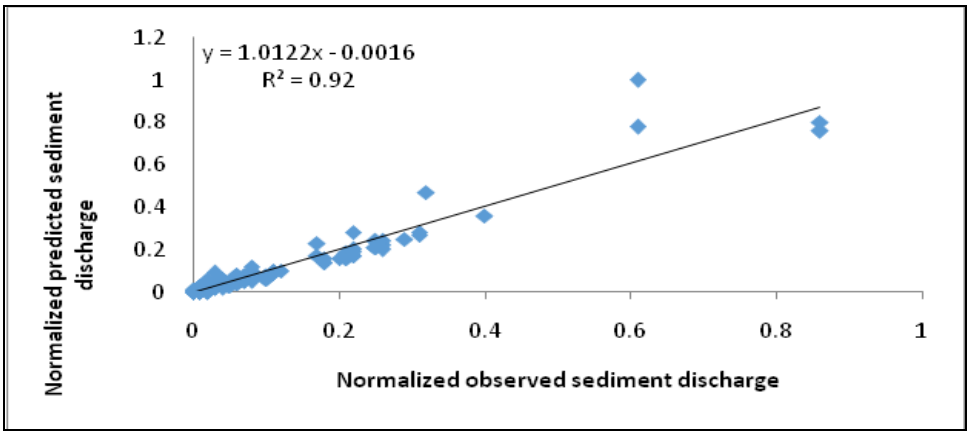

Figure 5: The scatter-plot of normalized observed and computed suspended sediment using linear regression method

Table 2 is showing the values of efficiency factor (E) for the mentioned three methods. It is clear that ANN model could perform better and present proper Evalues for both training and testing steps. Also, rating curve method performance is much better than linear regression model.

Table 2: Results of applied methods to estimate suspended sediment yield

Method	E training	E testing	Equation
ANN	0.98	0.97	3.2.1
Rating curve method	0.96	0.94	$Qs= 0.28\ Qw^{1.21}$
Linear regression method	0.94	0.92	$y = 1.0122Q_w - 0.0016$

Conclusions

In this study, ANN model with two conventional methods, rating curve and linear regression methods, were used to estimate suspended sediment yield in Duhok dam reservoir, Kurdistan region, Iraq. Results were demonstrated that intelligent model, artificial neural network (ANN), with standard back propagation algorithm and Multi-Layer Feed Forward network has more accuracy and high precision

comparing to conventional methods. These results are compatible with those researchers, Agrowal *et al* (2006), Avarideh *et al* (2001) and Mirbagheri and Rajaei (2006). Modeling with ANN method can be useful for real time prediction in short duration and high intensity rainfall when the previous time series of water discharge are known. However, in linear regression method, in contrast, was found the worst prediction in respect of other comparing criteria. This research is suggested for improving ANN model in upstream of Duhok dam, hydrological and morphological parameters should be considered, also duration of training and testing the network should be extended. Also, the importance application to other watersheds and reservoir dams could be mentioned to strengthen the approaches of ANN model for suspended sediment yield.

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