ANN and MLR Based Stage-Discharge Models for Dehli Gauging Station of Kim River, Gujarat

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ABSTRACT

Stage-discharge predication is increasingly used to predict and forecast water resource variables and its mitigation. In this work stage-discharge models has been developed using ANN (Artificial Neural Network) and MLR (Multiple Linear Regression) techniques. Daily data of stage and discharge of Kim River during monsoon season are used as inputs in the development of models. Yearly stage discharge models are developed apart from a model developed using data of decadal discharge.

The ANN model is developed using two layer Feed forward network, Sigmoid transfer function and Levernberg – Marquardt and Scaled conjugate as learning rule. Multiple Linear Regression curve is developed using MS - Excel. The time – scale Model also developed using the same techniques with same network and learning rules. From the above model an optimal model performance and a meaningful comparison between different models are done.

Keywords: Artificial Neural Network, Feed Forward Network, Multiple Linear Regression, Scaled conjugate, Stage and Discharge.

1. INTRODUCTION

For any hydrological structure discharge predictions should be taken into account prior to go for any building of structure component to safe disposal of excess inflows. A small change in velocity changes the stage and discharge [1]. The setting up of a stage-discharge curve is an important part of the processing of stream flow data [2]. Since stream flow monitoring on a regular basis is time consuming and expensive, a common practice is to measure the river stage regularly.

Discharges are typically estimated from recorded stages and a rating curve [3]. Rating curve is a graph of stage versus discharge also known as stage discharge curve [4]. Advancement in artificial neural network gives better results in modeling stage-discharge relations than conventional rating curves from the studies carried at previously [5].

2. ARTIFICIAL NEURAL NETWORKS

From few past decades, Artificial Neural Network (ANN's) has been used for forecasting in many areas of engineering [6]. Artificial neural networks are highly simplified mathematical models of biological neural networks [8]. An ANN is a network of parallel, distributed information processing systems that relate an input vector to an output vector. It consists of a number of information processing elements called neurons, which are grouped in layers [7]. Artificial neural networks can roughly be divided into two types, depending on the connection patterns of the layers and the arrangement of neurons.

1) Feed-Forward Networks,
2) Feed-Back (Recurrent) Networks.

Feed forward networks produce set of output signals from a given set of input. The desired input-output transformation is usually determined by external supervised adjustment of the system parameters. Here the input data only flows forward from one layer to another layer through the network. Figure 1 given below shows a typical feed-forward network. Every neuron in a given layer receives inputs from layers below its own and sends output to the layers above its own.

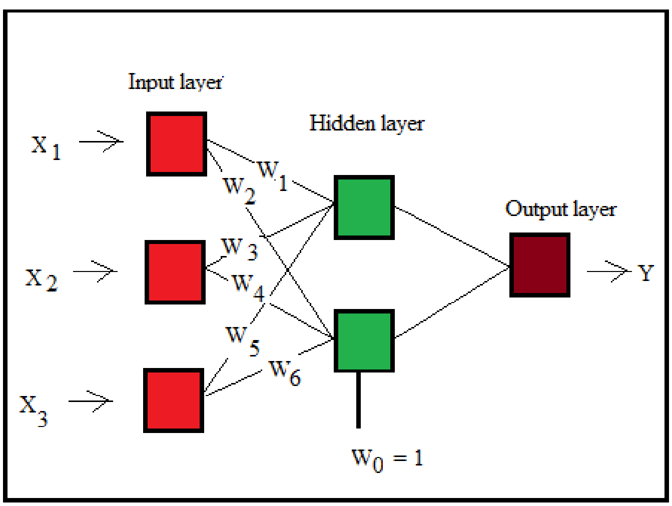

Figure 1. A feed-forward neural network

In a feed- forward network, the input values are feed into input nodes, which in turn pass them on the hidden layer nodes after multiplying by a weight. A hidden layer node adds up the weighted input received from each input node, associates it with a bias, and then passes the result on through a nonlinear transfer function. The output nodes do the same operation as that of a hidden node. Before its application to any problem, the network is first trained, where by the target output at each output node is compared with the network output and the difference (error) is minimized by adjusting the weights and biases though training algorithms [9]. A feed-forward network is a standard type of neural network and might be used for such applications as control systems and pattern identifiers. Perceptron, multilayer perceptrons (MLPs), and radial-basis function networks are three variations of feed-forward networks.

3. MULTIPLE LINEAR REGRESSIONS

Regression analysis study the relationship, called the regression function, between one variable 'A', called the dependent variable, and several other called the independent variables [10]. Regression function also involves a set of unknown parameters. Multiple linear regressions are the expansion of linear regression which is also called deterministic type of model .Deterministic models make use of available historical records in predicting/ forecasting of future flow sequences. The multiple linear or simple linear regressions are widely used modelling techniques in many fields. However, deterministic techniques are not capable of modelling nonlinear relationship between input and output variables. In hydrological application, stage is considered as dependent variable and discharge is considered as independent variable. The general multiple linear regression models are as under equation no 1.

$$A = X_0 + X_1B_1 + X_2B_2 + \dots X_i B_i \qquad (1)$$

Where, A - Dependent variable (predicted by a regression model) Intercept (or constant) X_0; X_1, X_2……… X_i - unknown parameters; i - Number of independent variables (number of coefficients); B_1, B_2…….. B_i - independent variables

4. STUDY AREA AND DATA COLLECTION

Kim River is west flowing rivers in Gujarat state. It starts from Saputara hill ranges and end in Gulf of Khambhat near village Kantiajal in Hansot taluka of Bharuch district after flowing south west direction for a length of 107 km. The river Kim, for the first 80 kilometre of its course passes through Rajpipala and Valia talukas. For the remaining the river flows in a western direction between Ankleshwar and Olpad taluka of Surat District. The main tributaries of Kim River are Ghanta River and Tokri River. The river basin extends over an area of 1286 square kilometre. The catchment areas up to the site Dehli is 117.9 square kilometre and Motinaroli is 804 square kilometre. The silent features of Kim river basin is presented in Table.1. The necessary data for predication of stage-discharge curve (rating curve) of Kim River was collected from W.R.I. Circle no. 1, R G subdivision, Vadodara and the Gauging station was at Dehli Bridge near Bharuch. The data were collected from years 2001 to 2010. The data is collected for monsoon season i.e. From June to October.

Table 1:- Silent Features Of Kim River Basin

Location	Latitude 21° 19' to 21° 38' North Longitudes 72° 40' to 73° 27' West
Shape	Fern shaped
Size	The catchment area is 1286 sq. km
Soils	Sandy loam to Gravelly sandy
Slope	1V:713.33H
Drainage	Open roadside ditches and pipe systems
Temperatures	27° C to 44° C and 26° C to 10° C

5. METHODOLOGY

In this analysis data of 2001 to 2010 are used to develop ANN model using MATLAB (version 6.11) where discharge is taken as input and stage as target. To develop these networks Levenberg Marquardt Learning Rule, Generalized Feed Forward Network and Sigmoidal axon Transfer Function were used. Fig 3 and 4 shows the output of 10 daily and yearly models of combined data from 2001 to 2010. In another set of analysis same data were used to develop ANN model using MATLAB (version 6.11) where discharge is taken as input and stage as target. To develop this model Scaled conjugate Learning Rule, Generalized Feed Forward Network and Sigmoidal Axon Transfer Function were used. Figure 5 and 6 shows the output of 10 daily and yearly models.

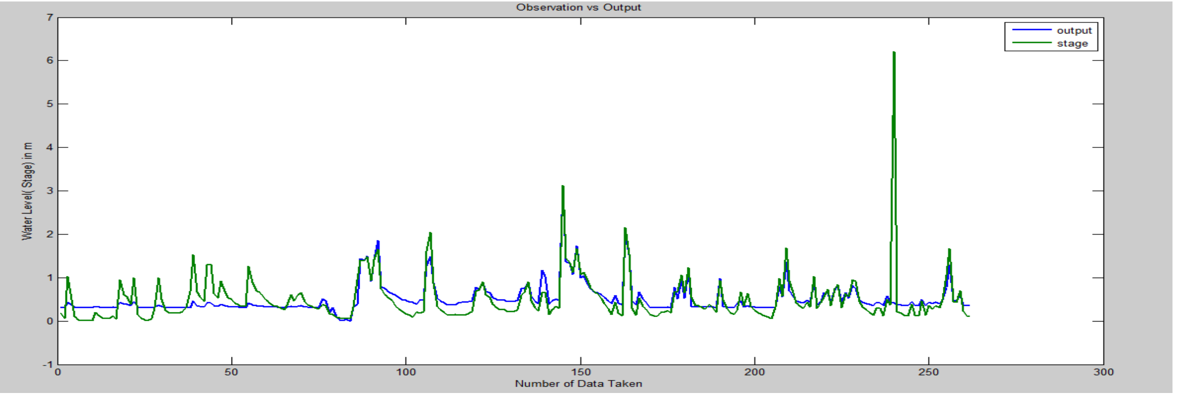

Figure 3.Actual vs simulated stage for 10 daily models.

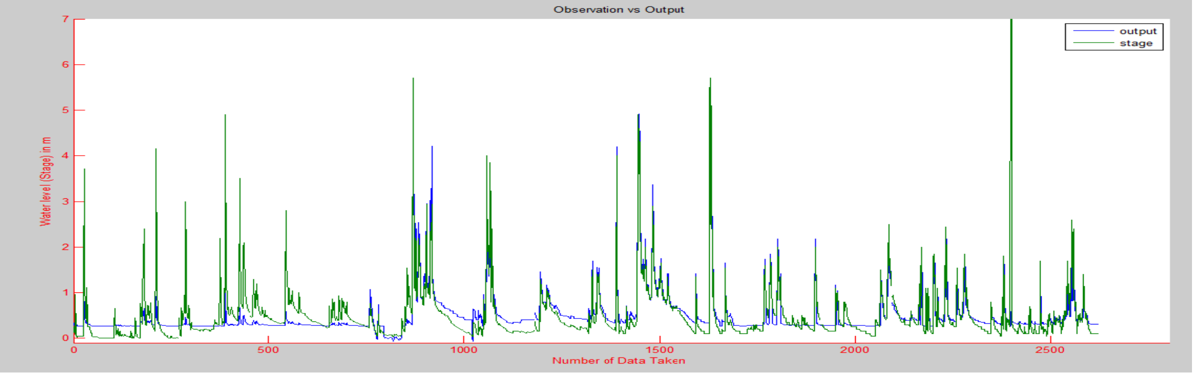

Figure 2. Actual vs simulated stage for yearly model.

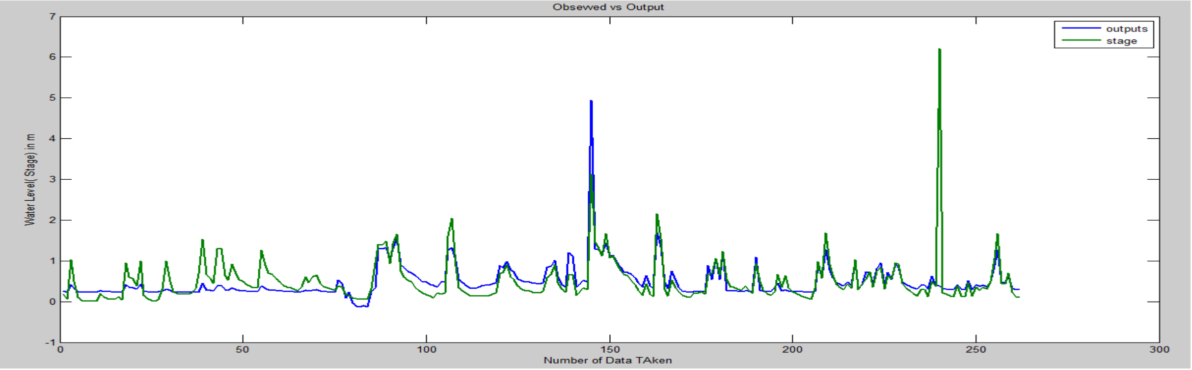

Figure 3. Actual vs simulated stage for 10 daily.

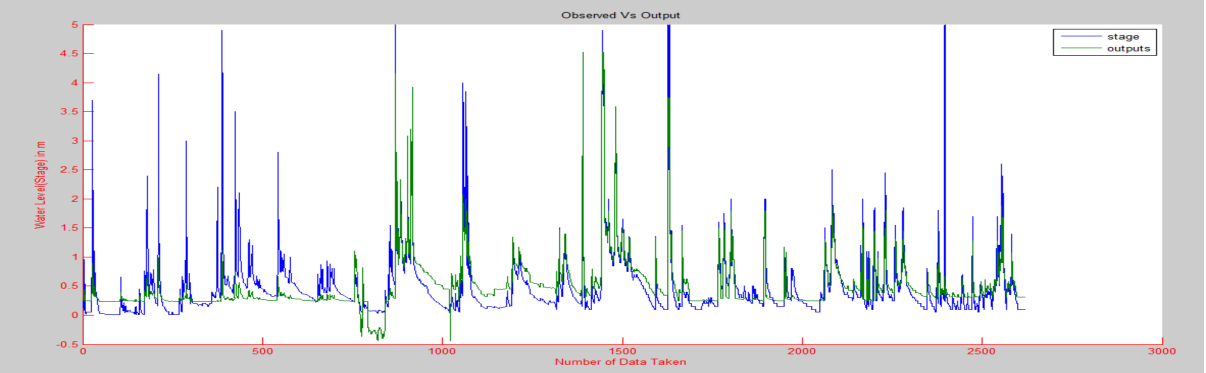

Figure 4. Actual vs simulated stage for yearly model.

A spread sheet of MS- Excel is used for multiple linear regression models. Regression plots are developed to display the network outputs with respect to targets for training, validation, and test sets. For a perfect fit, the data should fall along a 45 degree line, where the network outputs are equal to the targets. Figure 7 and 8 shows the output of 10 daily and annual models.

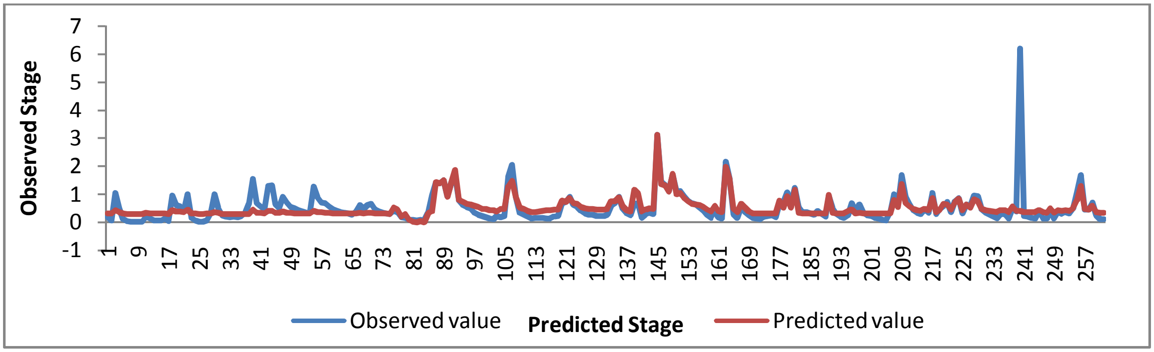

Fig. 5. Predicted Stage Vs Observed Stage for 10 daily 2001-2010

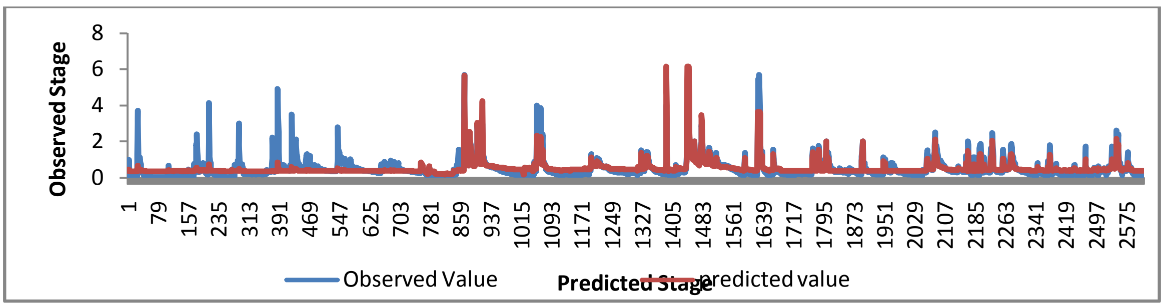

Fig. 6. Predicted Stage Vs Observed Stage for annual models 2001-2010

6. RESULTS

Table no 2 shows the Co-efficient of co-relation for the data used to carry out MLR analysis.

Table 2: Co-efficient of co-relation for developed models using MLR.

S.No	Year	Input data	Output data	Approach	R^2(Power)
1	2001	Discharge	Stage	Multiple linear regression	0.99
2	2003	Discharge	Stage	Multiple linear regression	0.79
3	2004	Discharge	Stage	Multiple linear regression	0.28
4	2005	Discharge	Stage	Multiple linear regression	0.93
5	2006	Discharge	Stage	Multiple linear regression	0.96
6	2007	Discharge	Stage	Multiple linear regression	0.71
7	2008	Discharge	Stage	Multiple linear regression	0.73
8	2009	Discharge	Stage	Multiple linear regression	0.89
9	2010	Discharge	Stage	Multiple linear regression	0.93
10	2001-2010	Discharge	Stage	Multiple linear regression	0.91
11	2001-2010	Discharge	Stage	Multiple linear regression	0.88

Table no 3: Co-efficient of co-relation for developed models using ANN

Sr no.	Year	Input data	Output data	Transfer function	Network	Levenberg-Marquardt Learning rule (R^2)	Scaled Conjugate Learning rule (R^2)
1	2001	Discharge	Stage	Sigmiod	Feed Forward	0.99	0.81
2	2003	Discharge	Stage	Sigmiod	Feed Forward	0.66	0.69
3	2004	Discharge	Stage	Sigmiod	Feed Forward	0.95	0.93
4	2005	Discharge	Stage	Sigmiod	Feed Forward	0.99	0.94
5	2006	Discharge	Stage	Sigmiod	Feed Forward	0.99	0.48
6	2007	Discharge	Stage	Sigmiod	Feed Forward	0.94	0.72
7	2008	Discharge	Stage	Sigmiod	Feed Forward	0.98	0.74
8	2009	Discharge	Stage	Sigmiod	Feed Forward	0.81	0.78
9	2010	Discharge	Stage	Sigmiod	Feed Forward	0.99	0.85
10	2001-2010	Discharge	Stage	Sigmiod	Feed Forward	0.83	0.45
11	2001-2010	Discharge	Stage	Sigmiod	Feed Forward	0.64	0.59

Table no 3 show the value of Co-efficient of co-relation were two different learning rules has been used namely Levenberg – Marquardt learning rule and Scaled conjugate learning rule.

CONCLUSION

The following findings are summarized from the present study:

1. Based on performance results of ANN & MLR models for 10 daily and yearly models for decadal data it is found that MLR model performs better than ANN.
2. For yearly models, ANN models perform better than MLR models.
3. When performance is compared with reference to learning rule used, Levenberg – Marquardt learning rule gives better results than Scaled conjugate learning rule.
4. With rigorous exercises on different aspects such as selection of an appropriate algorithm, transfer function, number of hidden layers, number of neurons in each hidden layers, number of epochs, artificial neural network models performance can be further improved.

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