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Groundwater Level Prediction Using Artificial Neural Network Model

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A B S T R A C T

Forecasting of stream flow and ground water level changes became an important component of water resources system control and challenging task for water resources engineers and managers. The ground water level data and rainfall data of twenty years from 1996 to 2015 were collected. Artificial neural network (ANN) is used to predict water resources variable. The model was trained, validated and tested for randomly divided samples. The regression analysis shows good correlation between each other within the range 0.12 to 0.97 of Abhanpur block. The performance evaluation of ANN model showed highest value of correlation coefficient (R) as 0.9781 during training for the month March/April/May of Abhanpur block. Thus it can be determined that ANN provides a feasible method in predicting groundwater level in Raipur district of Chhattisgarh state.

Introduction

Groundwater is a highly valuable resource. Measurement and analysis of groundwater level is needed for maintaining groundwater availability. The accurate prediction of groundwater levels is essential for sustainable utilization and management of vital groundwater resources. The consumption of water increases every day with the growth in population. The ground water level is going down day by day. In India, groundwater serves about 80% of rural population, 50% of urban population and about 60% of agricultural area. For management of groundwater level a model is required which can predict the groundwater level in future with the current available information. The ANN technique has been found to be very much suited to the modelling of non-linear and dynamic systems such as water resources systems (ASCE 2000b; Maier and Dandy 2000).

The main advantage of the ANN technique over traditional methods is that it does not require the complex nature of underlying processes to be explicitly described in mathematical form. After proper training, ANN models can yield satisfactory results for many prediction problems in the field of hydrology (ASCE 2000a, b).

In this paper artificial neural network model were developed. The present paper considers the development of ANN model for prediction of GWL (Cobaner *et al.*, 2016).

Materials and Methods

Study area

The area Abhanpur block is located at the Raipur District of Chhattisgarh State, India. Raipur is situated in East Central part of Chhattisgarh at latitude of 22º33 N to 21º14 N, longitude 82º6 E to 81º38 E and altitude 289.5m above mean sea level and district covers 226 km^2 (87 Sq. m.) areas. The study area comes under sub-tropical type of climate. Maximum temperature reaches to 41ºC and minimum temperature reaches 10-15ºC. Ground water level data for 1996-2015 was obtained from Central Ground Water Board (CGWB), Raipur district of Chhattisgarh state and Rainfall data from the Department of Agro-meteorology, College of Agriculture, IGKV, Raipur (C.G.).

Levenberg-Marquardt Training algorithm

The Levenberg-Marquardt method is a modification of the classic Newton algorithm for finding an optimum solution to a minimization problem. The update rule of the Gauss-Newton algorithm is presented as

$$X_{k+1} = X_k - [J^T J]^{-1} J^T e \ldots (1)$$

In order to make sure that the approximated Hessian matrix $J^T J$ is invertible, Levenberg-Marquardt algorithm introduces another approximation to Hessian matrix:

$$H = J^T J + \mu I \ldots (2)$$

It uses and approximation to the Hessian matrix in the following Newton-like weight update

$$X_{k+1} = X_k - [J^T J + \mu I]^{-1} J^T e \ldots (3)$$

Where x the weights of neural network, J the Jacobian matrix of the performance criteria to be minimized, μ a scalar that controls the learning process and e the residual error vector. Levenberg-Marquardt has great computational and memory requirements and thus it can only be used in small networks (Kumar, Indian and Khan 2013).

Performance evaluation criteria

To judge the prediction performance of a network, MSE, and correlation coefficient (R) between network output and network target outputs in three training, testing and validation groups were used and calculated as follows:

$$\mathbf{MSE} = \frac{\sum_{i=1}^{n}\left((yi-\overline{yi})^2\right)}{n} \quad \ldots (4)$$

$$\mathbf{R} = \sqrt{1 - \frac{\sum\left((yi-\overline{yi})^2\right)}{\sum yi^2 - \frac{\sum \overline{yi}^2}{n}}} \quad \ldots (5)$$

Where, yi is actual data and $\overline{yi}$ is calculated data by network. Zero is the best condition for MSE and one is the most desirable condition for R. (Kumar, Indian and Khan 2013)

Results and Discussion

This chapter deals with the results related to development of optimized ANN MODELs for Groundwater level prediction. Table 1 shows the calculated values of mean, standard deviation, skewness and variance for different months.

Figure 2 to 5 shows the relation between Actual Groundwater level and Normalised groundwater level for different months of Abhanpur block of Raipur District of Chhattisgarh State.

Table.1 Statistical Analysis of Groundwater Level of Abhanpur

	Jan	Mar	Aug	Nov
Mean	2.4575	3.0367	0.476	1.166
SD	0.6622	2.0600	0.2644	0.2862
Skewness	0.1781	0.5958	0.9293	1.1911
Variance	0.4386	4.2437	0.0699	0.0819

Table.2 Optimized ANN Model for Abhanpur

Month	ANN model
January (Post Monsoon Rabi)	P1*X+P2=0.7*0.151+0.02
March/April/May (Pre Monsoon)	P1*X+P2=0.77*1.162+0.02
August (Monsoon)	P1*X+P2= 0.23*0.108+0.03
November (Post Monsoon Kharif)	P1*X+P2= 0.21*0.104+0.11

Table.3 Regression Values of Abhanpur Block

Samples	Jan	Mar	Aug	Nov
Training	0.6657	0.9781	0.8484	0.3518
Validation	0.8667	0.9951	0.9032	0.77373
Testing	0.17581	0.9545	0.76495	0.85017

Fig.2 Relation between Observed G.W.L. and Normalized G.W.L. of Abhanpur for January Month

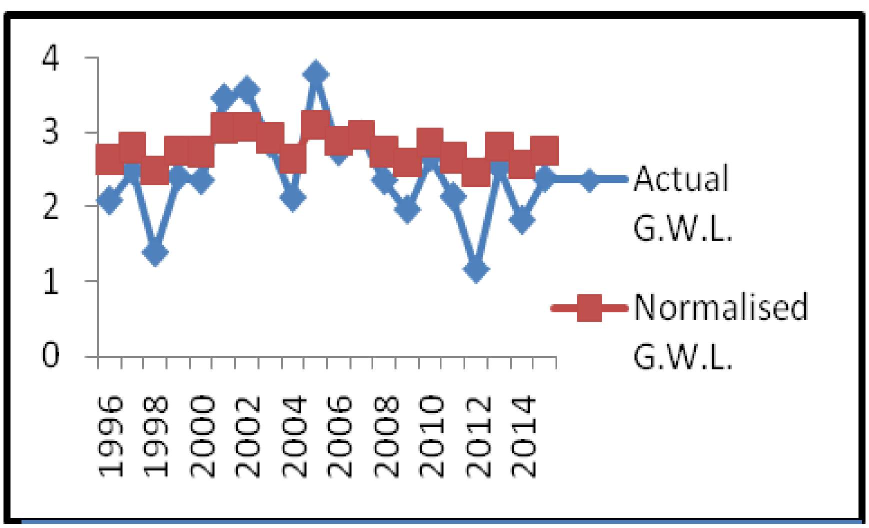


Fig.3 Relation between Observed G.W.L. and Normalized G.W.L. of Abhanpur for March/April/May Month

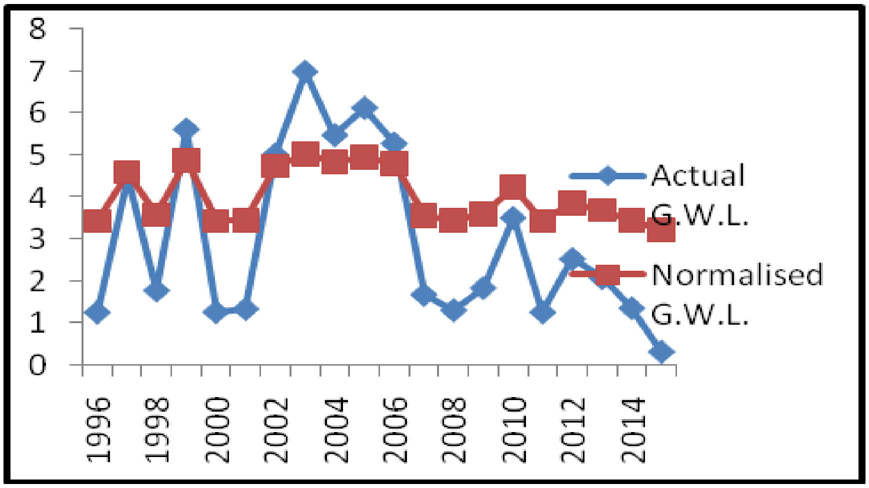


Fig.4 Relation between Observed G.W.L. and Normalized G.W.L. of Abhanpur for August Month

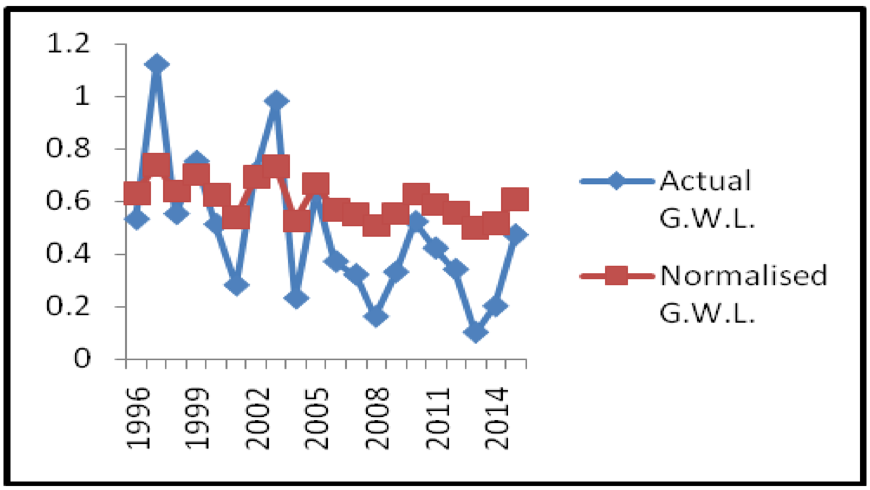


Fig.5 Relation between Observed G.W.L. and Normalised G.W.L. of Abhanpur for November Month

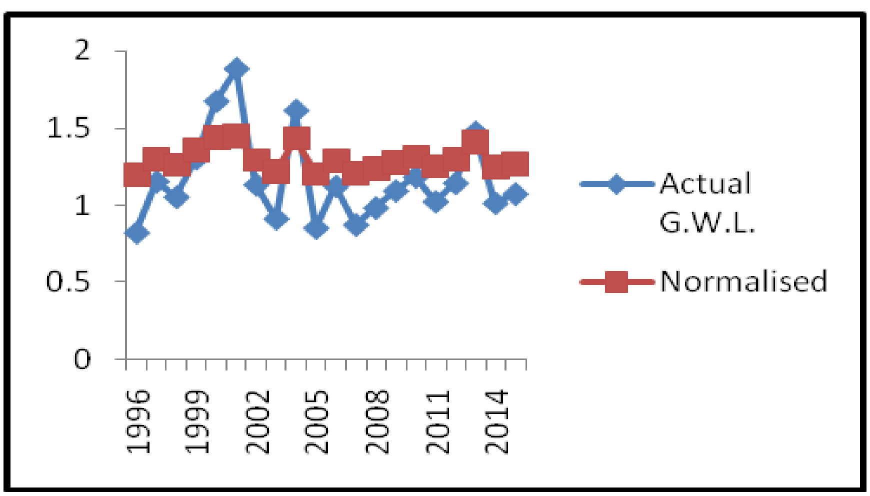


Fig.6 Shows the optimized Artificial Neural Network Model. Trend line shows that the groundwater level increases in the month of January, August and November. Groundwater level decreases in the month of March/April/May.

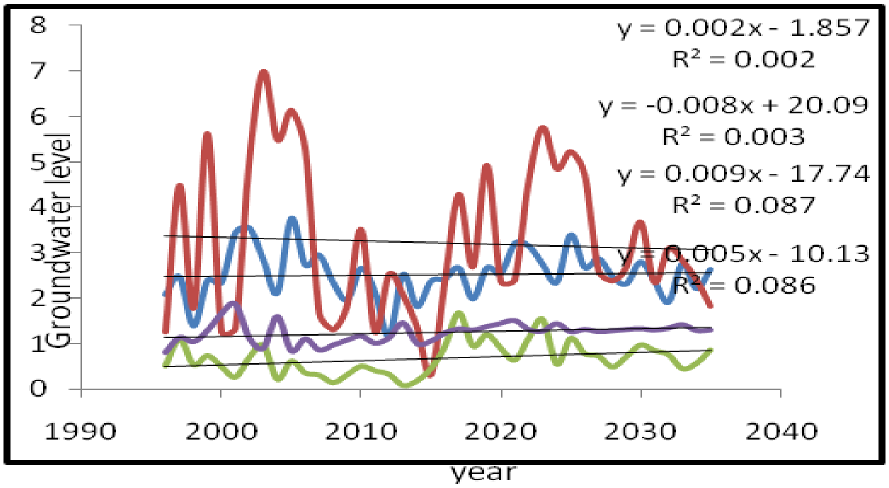
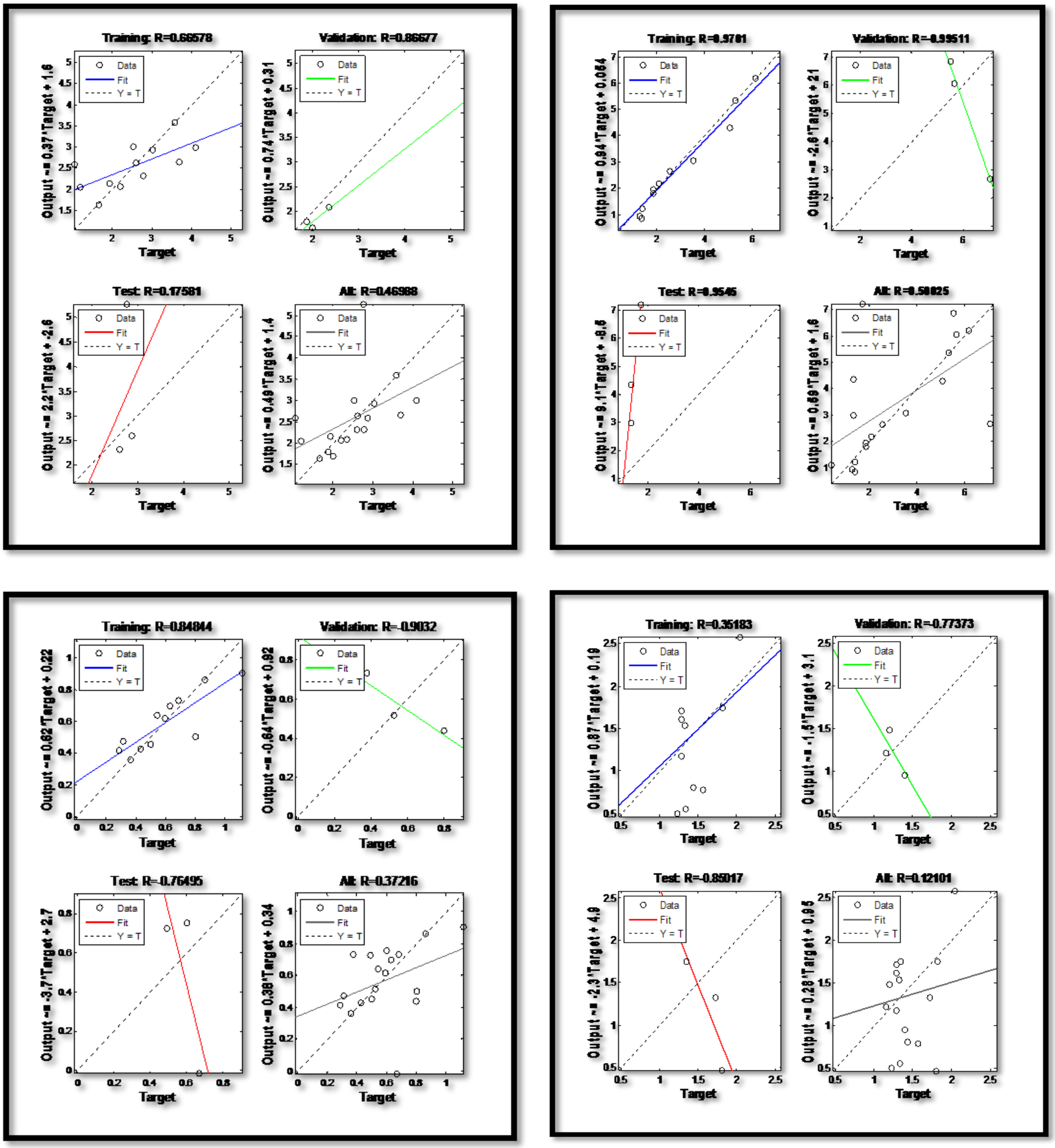


Fig.7 Map of Raipur district of Chhattisgarh state, India

Fig.8 Regression Line of Outputs and Targets for January, March, August and November Month of Abhanpur Block



Development of optimized Artificial Neural Network Model

Table 2 shows the optimised ANN model generated for different months viz. January, March/April/May, August and November of Abhanpur block.

Regression analysis

The regression analysis is done to determine the values of parameters for a function causing the function to best fit a set of data observation. Regression is used to analyzed the relation between two continuous (scale) variables. Table 3 shows the regression values of different month viz. January, March/April/May, August and November.

Figure 8 shows the regression line of outputs and targets for different months of Abhanpur block.

The developed models were then validated and tested using ANN for the further accuracy in the model generated. The regression value of training, testing and validation varies between 0.9781 to 0.12101 which shows the good correlation between the output and target data set.

The following conclusions were drawn from the present study as enumerated below:

The performance evaluation of ANN model showed highest value of correlation coefficient (R) as 0.9781 during training for the month March/April/May of Abhanpur block of Raipur District (C.G.).

The regression analysis shows good correlation between each other within the range 0.12 to 0.97 of Abhanpur block.

The optimized ANN models were developed successfully resulting best fit curve.

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