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Groundwater Level Simulation Using ANN for Gandhinagar District

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***Abstract*- In this research, Artificial Neural Network is used to predict groundwater level in Gandhinagar district. Model considers precipitation, maximum and minimum temperature, humidity, and Evaporation data as input parameter and groundwater levels as an output parameter. The past 09 year data was utilized for modeling. The dataset was divided into different training, testing and validation ratio to find the best model. The efficiencies of the Levenberg-Marquardt (LM), the Bayesian regularization (BR) and the scaled conjugate gradient (SCG) algorithms are compared. The model efficiency and accuracy were measured based on Mean square error (MSE) and correlation coefficient (R). Multiple Linear Regression (MLR) technique is also used to prepare a model. The performance of MLR model is determined using Correlation coefficient (R) and coefficient of determination (R2). The results revealed that the best model is composed of the feedforward networks, trained by the Levenberg-Marquardt algorithm.**

Index Terms- Rainfall, Maximum and Minimum temperature, Humidity, Evaporation, MATLAB and M.S. EXCEL.

I. INTRODUCTION

Groundwater is among the Nation's most precious natural resource. Groundwater is the largest source of fresh water on earth, and was little used until recently. Ground-water level (GWL) is the level below which the subsoil and rock masses of the earth are fully saturated with water. Groundwater level is an indicator of groundwater availability, groundwater flow, and the physical characteristics of an aquifer.

What is ANN?

An Artificial Neural Network (ANN) is a computational method. ANN represent highly idealized mathematical model of our present understanding of such complex system. One of the characteristics of the neural networks is their ability to learn using past historical data.

II. STUDY AREA

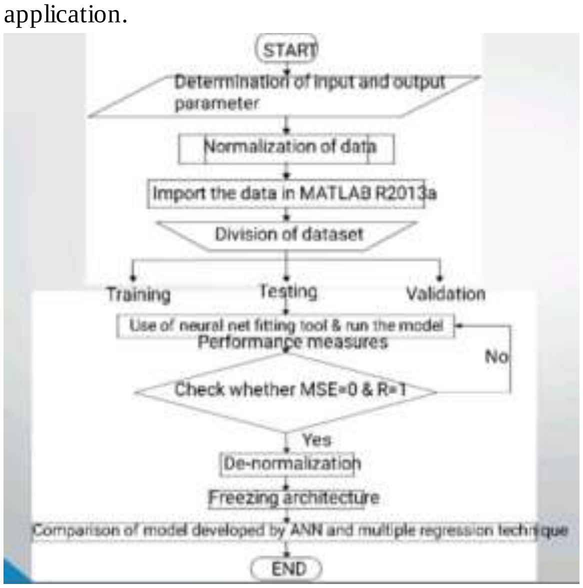
Gandhinagar district of Gujarat is selected as study area. Gandhinagar district is one of the most developed districts of Gujarat State. Gandhinagar district has the area of 2137.6 Sq km and is located in centre part of Gujarat State. It lies between north latitude 23.2156° and east longitudes 72.6369°. There are 04 Administrative units/ talukas in Gandhinagar district viz. Gandhinagar, kalol, Dehgam, Mansa. Groundwater is the main source of irrigation in this area. The major sources of draft are dugwells and tubewells.

III. DATA COLLECTION

Sr.No.	Data	Sources
1	Rainfall, Temperature, Humidity, Evaporation	State water data center, Gandhinagar
2	Piezometric groundwater levels	Groundwater investigation department, Unit-2, Kherva

IV. METHODOLOGY

The dataset have been divided into three sets: training, testing and validation. The training set will be used to adjust connection weights, whereas the testing set will be used to check the performance of the model at various stages training and to determine when to stop training to avoid over fitting. The validation set will be used to estimate the performance of trained network in the deployed environment. Rainfall/Precipitation, Maximum and Minimum Temperature, Humidity, Evaporation data can be used to develop the various Groundwater level prediction models. The data forms are available in the watershed and they will be divided into three sets: Training (60%), testing (20%), Validation (20%). Depending upon the required results this division can be varied such as 70%, 15%, 15% and 80%, 10%, 10%. Artificial neural network with one input layer, one output layer and one hidden layer is taken into consideration. For selection of appropriate network architecture with optimum numbers of hidden layer neuron, many trials have to be carried out. The different training algorithm such as Levenberg-Marquardt algorithm (LM), the Bayesian regularization (BR) and the scaled conjugate gradient (SCG) algorithm has also been used to train the model. Different trials involve variation in numbers of hidden layer neurons and in training algorithms. The performance of a model can be evaluated in terms of accuracy refers to the ability of the model to reduce calibration error consistency is used for representing the characteristics of the model whereby the level of accuracy and estimate of the parameters values persists through different samples of data. A versatile model is defined as the model which is accurate and consistent when used for different application.



V. RESULT

- R – Values and MSE values [Training (60%), Testing (20%) and Validation (20%)]

Model Architecture	Training	Testing	Validation	All	MSE values
M-1-5-8-1	0.38029	0.29157	0.46565	0.3924	0.093674
M-1-5-9-1	0.53113	0.15779	0.49067	0.41916	0.041036
M-1-5-10-1	0.11598	0.54087	0.1501	0.18904	0.10282
M-1-5-11-1	0.67087	-0.13977	0.68166	0.53742	0.042867
M-1-5-12-1	0.48226	0.89146	0.40554	0.55619	0.06313
M-1-5-13-1	0.60658	0.57458	0.5771	0.59172	0.038033

- R-values and MSE values [Training (70%), Testing (15%) and Validation (15%)]

Model Architecture	Training	Testing	Validation	All	MSE values
M-2-5-8-1	0.35238	0.43502	0.45707	0.3924	0.083859
M-2-5-9-1	0.24195	0.37939	0.7237	0.37909	0.044739
M-2-5-10-1	0.092493	0.6609	0.23862	0.18904	0.092064
M-2-5-11-1	0.71978	-0.22647	0.36964	0.5712	0.070487
M-2-5-12-1	0.4547	0.89828	0.6297	0.55619	0.052874
M-2-5-13-1	0.77561	0.26386	0.59215	0.64872	0.041642

- R-values and MSE values [Training (80%), Testing (10%) and Validation (10%)]

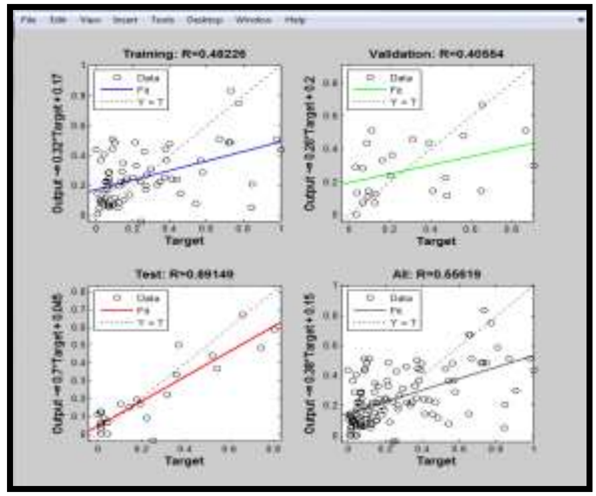
Model Architecture	Training	Testing	Validation	All	MSE values
M-3-5-8-1	0.60072	0.26149	0.68773	0.58086	0.032748
M-3-5-9-1	0.32117	0.12117	0.79283	0.37909	0.050216
M-3-5-10-1	0.6941	0.18398	0.62669	0.63684	0.035168
M-3-5-11-1	0.75712	-0.97379	0.3748	0.63053	0.055376
M-3-5-12-1	0.46484	0.88969	0.95449	0.55619	0.0038411
M-3-5-13-1	0.59794	0.55721	0.65326	0.59172	0.06028

- R-values and MSE values [Training (80%), Testing (10%) and Validation (10%)] trained with different algorithms

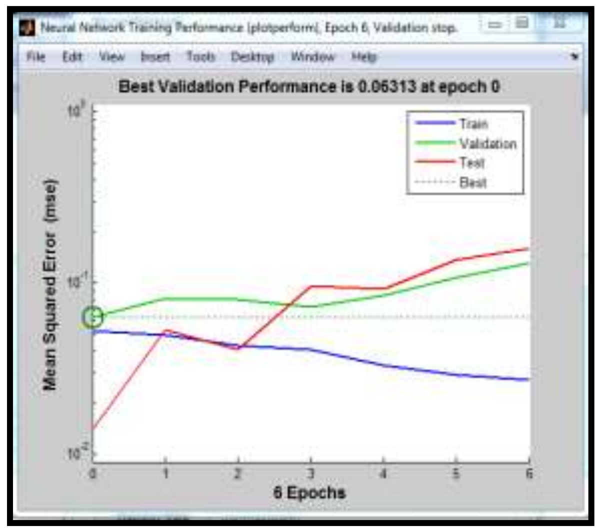
Algorithm	Model Architecture	Training	Testing	Validation	All	MSE values
LM	M3-5-11-1	0.75712	-0.097379	0.3748	0.63053	0.05376
LM	M3-5-12-1	0.46484	0.88969	0.95449	0.55619	0.0038411
BR	M3-5-11-1	0.49113	-0.34243	0.29301	0.3751	0.022514
BR	M3-5-12-1	0.40546	0.88349	0.80067	0.48614	0.015383
SCG	M3-5-11-1	0.19044	0.25672	-0.25884	0.17708	0.032048
SCG	M3-5-12-1	0.31282	0.85222	0.81729	0.40164	0.019589

❖ Regression and Mean square error graph

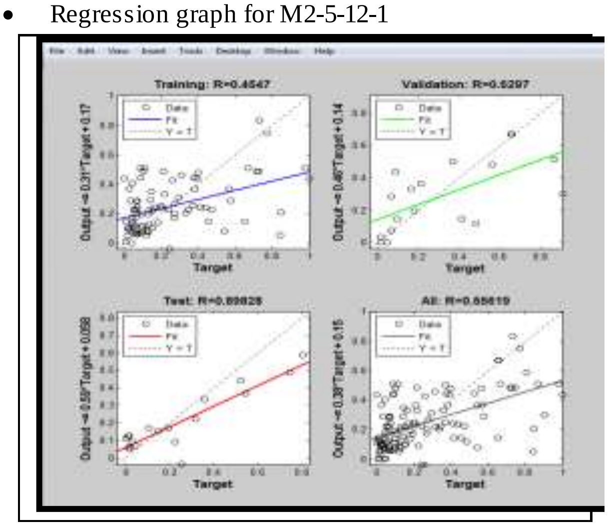
- Regression graph for M1-5-12-1



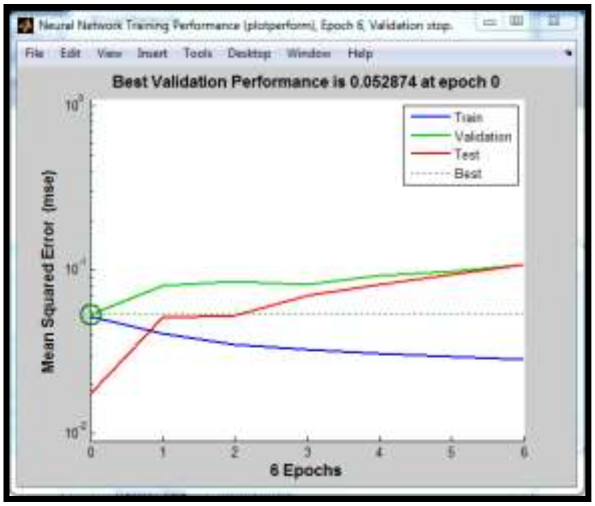
- MSE chart for M1-5-12-1



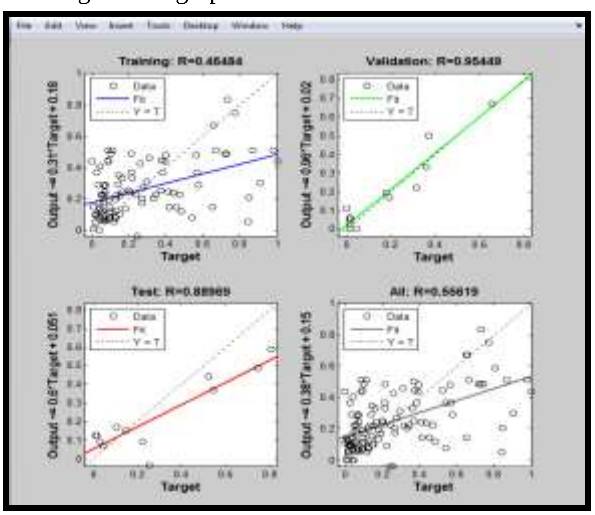
- Regression graph for M2-5-12-1



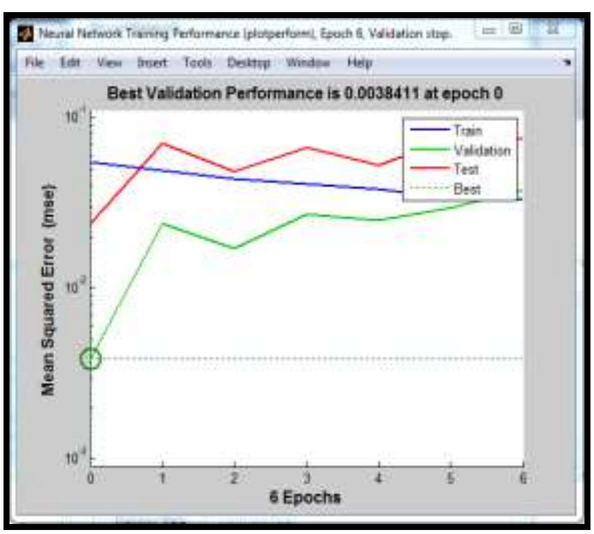
- MSE chart for M2-5-12-1



- Regression graph for M3-5-12-1



- MSE chart for M3-5-12-1



- MULTIPLE LINEAR REGRESSION (MLR) MODEL

Regression statistics of MLR model

Multiple R	0.435679093
R square	0.189816272
Adjusted R square	0.171234077
Standard error	0.168084632
Observations	224

Where , Multiple R = Gives correlation between dependent & independent variable,
R^2 = coefficient of determination,
Adjusted R^2 = used if more than one variable, Standard Error = Standard Error of the regression, Observations = Number of data used for regression.

VI. DISCUSSION

- While carrying out analysis it is observed that Groundwater levels are very complex to predict and also the software i.e. MATLAB R2018a takes more time for training. In this problem, the algorithm has been modified so that data set can be divided into training, testing and validation as desired. The different training algorithm such as Levenberg-Marquardt algorithm (LM), the Bayesian regularization (BR), and the scaled conjugate gradient (SCG) algorithm has also been used to train the model. But the LM algorithm proved to be more accurate amongst other algorithm.
- The regression analysis carried out for MLR model shows that the correlation between input variables and the output variable is 0.435679093 which is very poor.

VII.CONCLUSION

In this study, it is observed that Artificial Neural Networks (ANN) performs better than Multiple Linear Regression (MLR) technique for simulating groundwater levels. The most suitable model architecture for this study is proved to be M3-5-12-1 trained with Levenberg-Marquardt (LM) algorithm. From the results obtained it can also be observed that LM algorithm is more appropriate for this problem. In general, the result of this study observes that

Artificial Neural Networks can be a useful tool for simulating groundwater levels.

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