Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 3 [Special Issue V] 2014: 128-134

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE

Comparison of three methods of ANN, ANFIS and Time Series Models to predict ground water level: (Case study: North Mahyar plain)

Zohreh Alipour [1] , Ali Mohammad Akhund Ali[2], Feraydoun Radmanesh[3] , Mahmoud Joorabyan[4]
1- College of Water Recourse engineering of Shahid Chamran University, Iran.
2- Hydrology & Water Resources Group of Shahid Chamran University, Iran.
3- Hydrology & Water Resources Group of Shahid Chamran University, Iran.
4- Electrical Engineering & Artificial Intelligence Group of Shahid Chamran University, Iran.
Email Address: ALIPOUR 777@GMAIL.COM

ABSTRACT
Investigation of the level of water supplies is considered as a very significant and prominent procedure in basin area programs. Studying the groundwater resources is much more important in regions suffering from the lack of surface waters.In this study, three methods of artificial neural networks, Adaptive Neuro-Fuzzy Inference System and Time Series havebeen assessed in order to find the best way to predict ground water levels in North Mahyar plain, Isfahan. The rainfall, temperature, relative humidity, the operation wells and aquifer fed by the near aquifer are considered as input data, and groundwater levels of 14 observed wells are considered as output. The results showed that the Adaptive Neuro-Fuzzy Inference System can give more accuracy for predicting groundwater level than Time Series analysis and artificial neural network.
Keywords: Ground water level, Prediction, Artificial Neural Networks, Adaptive Neuro-Fuzzy Inference System, Time Series analysis

Received 09.06.2014 Revised 30.07.2014 Accepted 25.08. 2014

INTRODUCTION

Groundwater is the largest reserve of fresh water available on the earth. In areas where surface water resources are limited, ground water, distributed widely around the earth, can be applied to provide water requirements. Ground water management is taken into account as a critical issue due to reduced rainfall, drought and consequently water short ages in the country in the last decade. In order to employ an appropriate management, it is necessary to identify, model and predict water level fluctuations of the plain's aquifers which enables long-term planning and more efficient utilizing of plains water. Different factors such as climate variables (temperature, precipitation, evaporation, and relative humidity) and the rate of aquifer charging and discharging affect the groundwater level, which makes analyzing this phenomenon difficult. The most common methods for the analysis of ground water level fluctuations are physical -conceptual models, regression models and time series analysis. The main concept of the most of predicting methods is a kind of simulation of current status of the system, which is called modeling. Statistical models apply for the relationship between time series data. Recently, adaptive methods have been appeared to predict the relationship between effective parameters in groundwater fluctuations. Mathematical model is one of these methods, which has been immensely spread due to vast computer growth. However, the main challenge of this method is that accurate information and many inputs are required. Moreover due to expand calculations, mathematical model takes too much time to be implemented in any management scenario [6]. Today novel methods such as neural networks and fuzzy systems have been considered as effective ones. Lalahm et al. [14] evaluated the level of groundwater in limestone aquiferusing artificial neural networks. The results showed that the MLP algorithm with a minimum of central neuronsis the best approach in the short-term. Coppola et al. [8] and Dalyakapulus et al. [7] used artificial neural network to predict time fluctuations of groundwater level. They utilized variables such as rainfall, maximum temperature, and minimum and average temperature and evaporation variables-reference evapotranspiration. According to the hydrogeology characteristics of the aquifer and measured values for some parameters aquifer, Purtabary and et al presented a developed ground water model by using dynamic neural networks; underground water level changes for scheduling equations [12].Dehghani et al. compared three methods of artificial neural networks, and Adaptive Neuro-Fuzzy Inference System and geostatistics to interpolate groundwater level. The results showed that the Adaptive Neuro-Fuzzy Inference System with the high correlation coefficient and the less mean square error, has greater accuracy in estimating groundwater level in unknown points in the aquifer rather than two other methods [1]. Izadi et al. while predicting the water table with an artificial neural network concluded that the structure of recurrent neural network trained by CD algorithm has not satisfactory results [2].Mirzaei and his colleague studied the ability of neural networks with different structures to predict groundwater level. They showed that the artificial neural network with LM algorithm, with minimum errors, presented the best results [3]. Nakhaeet al. investigated the neural-wavelet network in predicting the groundwater level, and the results showed that this model can provide more appropriate responses rather than numerical ones [10].Furthermore Kholghi and Hosseini compared the three methods of geostatistics, artificial neural network and Adaptive Neuro-Fuzzy Inference System in interpolation of transfer coefficient. The results showed that the Adaptive Neuro-Fuzzy Inference System has more interpolation accuracy in comparison to the other methods [11].According to the literature, it can be noticed that the researches dedicated to the prediction of ground water level with artificial neural networks and Adaptive Neuro-Fuzzy Inference System are not enough. In this work, three methods of artificial neural networks, Adaptive Neuro-Fuzzy Inference System and time series are employed to predict groundwater level of northern Mahyar plain aquifer in order to evaluate and compare the results.

METHODOLOGY

The studied area is the northern Mahyar plain located in 20 kilometers from Isfahan-south, between the latitudes 50º 41' 20"to51º 53' Eastern and Longitude 32º 15' 30" to32º 26' Northern. The location of the studied area is depicted in Figure 1. Two sets of North West-SouthEast mountains surroundthe region. Kolahghazi, Mah-dasht, and Lashotor mountains are located in the East of the plain. Lorsag, shotor, Barike and Tak-Tak heights are located in the West of the plain. South Mahyar Plain and Dehsorkh plain are located in south-east and north-west of North Mahyar plain, respectively.

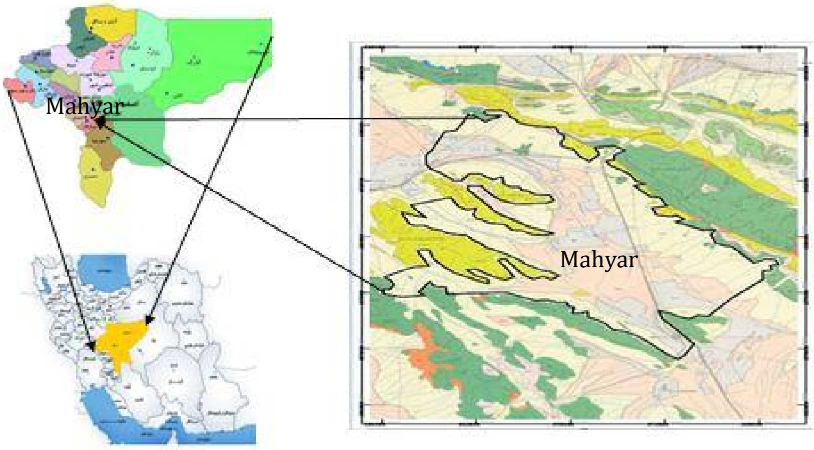

Figure 1 - Location of the study area relative to the country

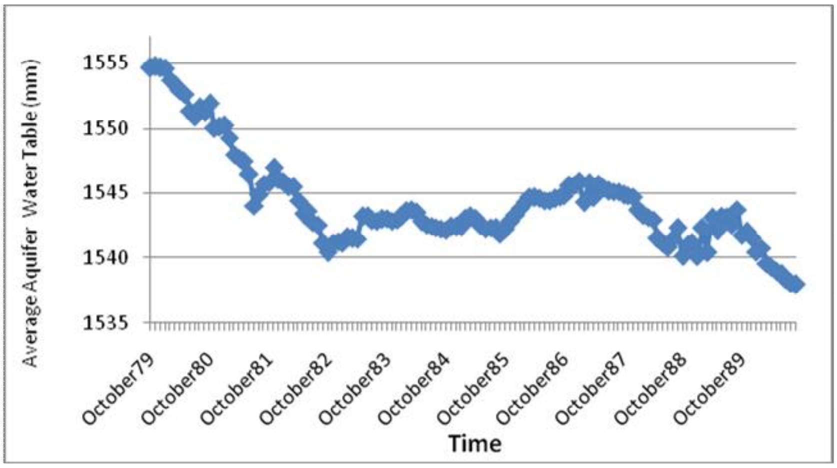

Figure 2 - Unit hydrograph of northern Mahyar plain

Artificial Neural Network (ANN)

These are mathematical and flexible models which can be applied in complex systems modeling. Also, these networks are able to present a nonlinear transformation between inputs and outputs by appropriate selection of the number of layers and neurons. In neural networks, processing is performed by many processing units called neurons. Each neuron in each layer is attached to all elements of next and previous layer by series of weights. Overall ability of ANN is first to explore nonlinear relationship between the data and then to generalize the results to the other data [13]. One of the neural networks widely used in water engineering is the back-propagation network which is a kind of regulatory net works. MATLAB 7.6Software is utilized for ANN.

Adaptive Neuro-Fuzzy Inference System (ANFIS)

The structure of neural-Fuzzy network is formed by combination of neural networks and fuzzy systems. Hence this structure utilizes both the trainable property of the neural networks and the inference ability of fuzzy systems which increases the power and accuracy in uncertain situations. Recently, Fuzzy systems are proposed for modeling of the reservoir management and solving their ambiguous features. Although neural network which is able to be trained by the environment, arrange its structure and adapt its interaction, the fuzzy system is lack of a cinematic process to design a fuzzy controller. To this end, Jang et al. presented ANFIS model with the ability to combine two above methods [9].

A fish as a great potential in training, making and classification. It also allows the extraction of fuzzy rules from numerical data or expert knowledge. ANFIS structure consists of five layers with several input variables and each input has two or more membership functions. In the first layer (input), the amount of allocation of each input to different fuzzy ranges is determined by the user. The rules weight in the second layer can be obtained by multiplying the input values in each node. In the third layer, the relative rule weights are calculated. The fourth layer is the rule layer which is the result of operations on the input signals to this layer.The final layer is the output layer of the network which aims to minimize the difference between the obtained output and the actual one. The network is trained by the monitored learning. So the goal is to train adaptive networks which can be able to approximate unknown functions obtained from training data, and find accurate values for above parameters. Appropriate ANFIS structure is determined according to the input data, kind of input and output membership functions, rules and the number of membership functions. To solve the first part of the fuzzy rules, there are two methods of Grid Partitioning and Sub-Clustering. In this work, the Sub-Clustering method is applied [8].

Time Series Models

One of the advanced methods of simulation and prediction of hydrological data is to discover their long-term and seasonal variations. Time series models are the powerful tools in such field and AR, MA, ARMA and ARIMA are the most well-known time series models. In order to model and simulation, the numeric values of observed data and error valuesat the previous time steps are employed in the AR and MA models, respectively [4].ARIMA (p, d, q) model is the most general time series model which p, d and q are respectively the coefficient of the AR model, the coefficient of the MA model and the seasonal difference operator.The mathematical equation of the ARIMA (p, d, q) model assuming t equal to Y_t-Y_{t-1}isas follows:

$$\nabla^d Y_t = \sum_{i=1}^{p} \emptyset_i Y_{t-1} + \varepsilon_t - \sum_{i=1}^{q} \theta_i \varepsilon_{t-1} \qquad (1)$$

Which Y_t is the time series and ε_t is the t^{th} member of the volatility series.First,the ACF and PACF graphs of time series are plotted for modeling.In general,ACF and PACF show stagnation and order of the model, respectively. In case of non-static, first the time series become static by subtracting or using the seasonal model. Then the ARIMA process is identified. The most important step in time series modeling is estimation of parameters of p, d and q and application of the fit test .In this test, normality and independence of residuals and the principle of parsimony (the model which has the lowest parameter)are investigated. In order to model using the time series, R programming language is applied. Risa mathematic programming language, which is better than S-plus and is designed for statistical analysis.

RESULTS AND DISCUSSION

To evaluate the relationship among the input parameters together and water table of plain, statistical analysis was performed. Therefore, the correlation coefficient of input data were compared together and with data of three selected wells from fourteen wells of the plains, which are output. The correlation coefficient between discharge operations with water-table of plain is maximum in all. After that, the rainfall parameter shows maximum correlation. Thus, the discharge of operation wells is introduced the most influential factor on the water table of Mahyar plain. However, correlation coefficient values among all input and output parameters is not very high.In this study, the network's designed structure is a back-propagation network. Transfer function from the input layer to the first hidden layer and from the first hidden layer to the second one is the log Zygmueid function. According to the structure of the back-propagation networks, the transfer function from the hidden layer to the output is a linear function. Moreover, learning function employed in the network is Learned. Each kind of ANN has lots of training algorithm. However the LM algorithm was employed in this work according to use of the network. In this study, the effectiveness of each training algorithms such as LM, RP, SCG and GDM for input data were evaluated in a similar situation. The following figure is shown comparing the performance of each training algorithms such as GDM, RP, SCG and LM for the input data.

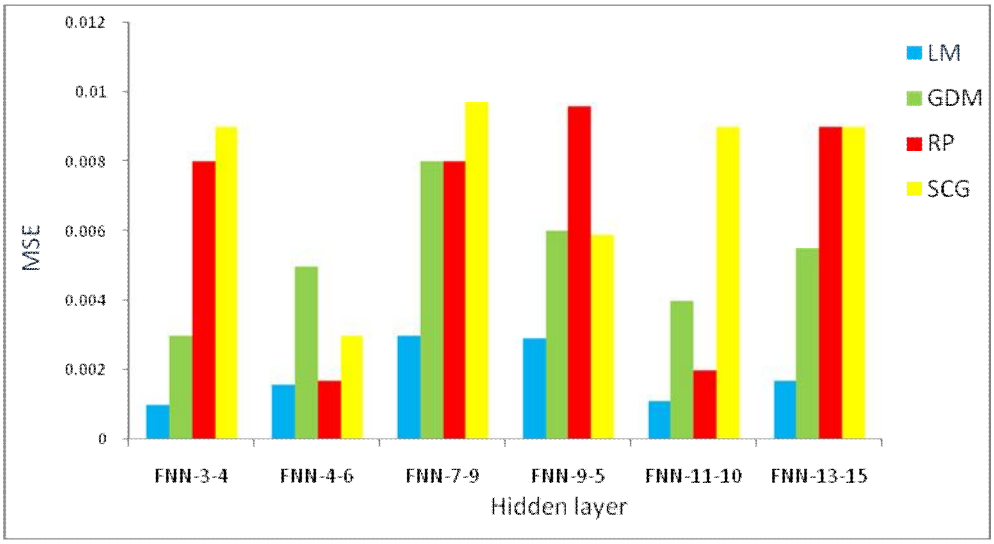

Figure (3) comparing the performance of each training algorithms such as GDM, RP, SCG and LM for data

Using the LM algorithm while all terms are held constant, the best values for learning rate, the number of iteration and hidden layers are obtained respectively as 0.5, 300 and 2. The reported and calculated average water level coefficients obtained by the present model are shown in Table 3.To perform ANFIS section of study, first the data are normalized. Then, water level of plain wells is calculated by indicating input and output membership functions and the number of membership functions considered for input data in ANFIS edit in MATLAB 7.6 software.Also Hybrid algorithm is employed for the training. The reported and calculated average water level coefficients are shown in Table 3.The membership functions and defuzzification such as trimf, trapmf, gaussmf, gauss2mf, gbellmf, dsigmf, psigmf, pimf, smfand zmf were examined. Finally, gaussmf membership function, using the formula provided the best results.

$$f(x,\sigma,c) = e^{\frac{-(x-c)^2}{2\sigma^2}} \qquad (2)$$

This function has two parameters (C & σ) that are to be determined.

Table (1) comparing results of using different defuzzification

Defuzzification **Function**	**R2**	RMSE
Trimf	0.88	0.53
Trapmf	0.83	0.68
Gaussmf	**0.97**	**0.21**
Gauss2mf	0.92	0.33
Gbellmf	0.91	0.45
Dsigmf	0.84	0.65
Psigmf	0.88	0.55
Pimf	0.84	0.64
Smf	0.89	0.66
Zmf	0.83	0.64

To determine the most suitable numbers of membership functions of fuzzy, the numbers such as 2, 3, 4, 5 membership functions were considered for each input, the results is given in Table (2).

Table 2: Comparing the results of using variable number of fuzzy membership functions for each input

Number of MF	R2	RMSE
2	0.94	025
3	**0.96**	**0.19**
4	0.93	0.29
5	0.9	0.34

According to the above table, Three membership function for each input is the most appropriate fuzzy structure. It should be noted that the number of fuzzy membership function for each input is less; the running time of model is reduced. Thus, and the structure obtained is quite good.

Based on data presented monthly in Time series model, data are seasonal with a period equal to 12 [4]. Consequently, to form static data, first seasonal model and in the next step, subtraction procedure is applied on data. Then, the appropriate model for data is indicated based on the ACF and PACF curves.

While the parameters are estimated, the fit test is applied to the model. Finally, the ARIMA (1, 0, 1) (0,1,0) $_{12}$modelis selected as the optimum model.

The simulation results obtained from the three models and the reported ones are compared in Figure 4.

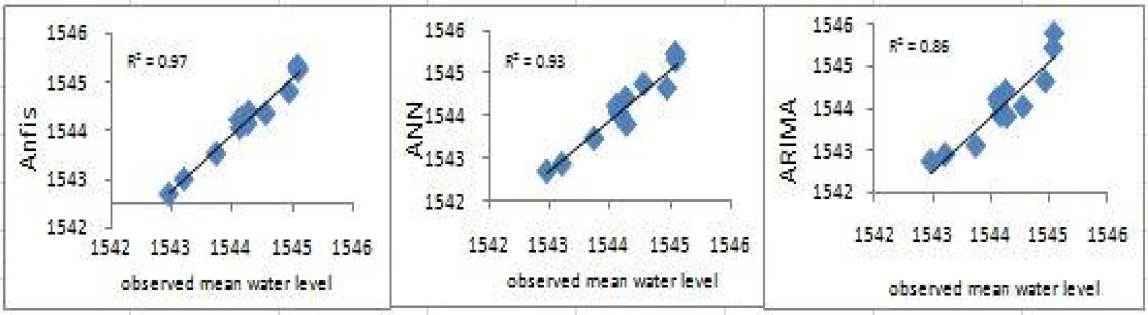

Figure 4: R^2values for the three methods of modeling compared to the observed mean water level

The characteristics and performance of the models in prediction of groundwater level are presented in Table3.

Table3: Characteristics of the three models and the determination coefficient for the predicted results

MODEL	Specifications	R^2
ANFIS	Hybrid method	0.97
ANNs	LM Algorithm	0.93
ARIMA	$ARIMA_{12}(1,0,1)(0,1,0)$	0.86

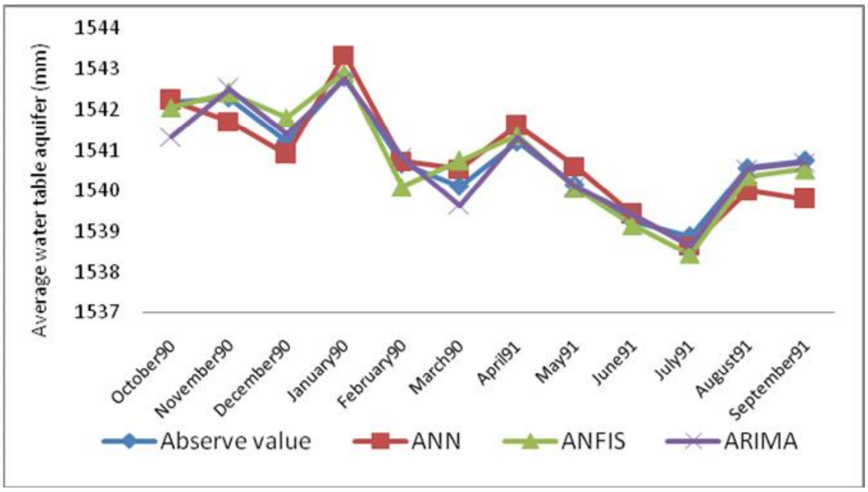

Figure 5: Comparing the calculated values using the three methods and the average actual values

CONCLUSION

In this work, three methods of ANN, the adaptive neural fuzzy inference system (ANFIS) and Time Series (TS) are applied to predict the ground water level on the northern Mahyar plain. Comparing the Correlation Coefficient values obtained from these three methods and indicate that the Anfis provides the most accurate predictions. ANFIS and ANN utilize the data of rainfall, temperature, relative humidity, recharging and discharging of the aquifer to predict the average ground water level of plain for the next twelve months. However, modeling of time series due to statistical using of groundwater level and neglecting other effective parameters provides less accurate results.

In addition, according to the seasonal trends of groundwater level, it can be realized That the main reason of variations are the amount of rainfall and excessive water harvesting of plain resources. Moreover, any fluctuation can have a significant impact on the future of the series.These changes can be due to the natural or human resources. Hence, by taking actions such as artificial recharge, the decreasing trends of series can be prevented.

REFERENCES

1. A, Dehghani. M,Asgari. & A,Mosaedi. 2009. Compared three methods of artificial neural networks, Adaptive Neuro-Fuzzy Inference System and geostatistics to interpolate groundwater level . (case study : Gazvin plain) . Journal of Agricultural Sciences and Natural Resources. 1(16):88-101.
2. A,Izadi. K,Davari. A, Alizadeh. B,Ghahraman. &S,Haghayeghi Moghadam. 2007. Prediction of water table usingArtificial Neural Network. Journal of Irrigation and Drainage.2(1):59-70.
3. A, Mirzei & A.Nazemi. 2010. Perediction of water table using Artificial Neural Network. Resources management of surface water. First National Conference on Surface Water Resources Management, Water Resources and Agricultural Sciences, University of Surrey, Department of Water Engineering.
4. A, Salajeghe. A,Fath Abadi.& M,Najafi Hajifar.2008. Compared artificial neural networks and time series for Prediction of drought in Khorasan plain. Journal of Science and Watershed Engineering of Iran.(4):74-77.
5. F.J, Chang & Y.T, Chang. 2005. Adaptive neuron-fuzzy inference system for prediction of water level in reservoir. Advance in Water Resources, 291 (1):1-10.
6. Gh, Rahmani.2011. Simulationof groundwater sources in Aghili's plain using artificial neural networks method. Master thesis, Shahid Chamran University, Ahvaz.
7. I. N, Daliakopoulos. P, Coulibaly. & I. K, Tsanis. 2005 .Ground water level forecasting using artificial neural networks. Journal of Hydrology. 309(4): 229-240.
8. Jr, Coppola. E, Szidarovszky. F, Poulton. & E, Charles. 2003. Artificial neural network approach for predicting transient water levels in a multilayered groundwater system under variable state , pumping , and climate condition . J. of Hydrology Engineering , 21(1): 115-123.
9. J.S.R, Jang. C.T, Sun. & E, Mizutani. 1997. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. Prentice-Hall International. New Jersey.112p.
10. M.Nakhaee. A,Saberi Nasr.& R,Faraj zade. 2011. Iinvestigated the neural-wavelet network in predicting the groundwater level. Fourth Conference on Water Resources Management, Amirkabir University of Technology, Tehran.
11. M, Kholghi. & S.M, Hosseini. 2009. Comparison of groundwater Levels Estimation Using Neuro-fuzzy and Ordinary Kriging. Journal of Enviromental Modelingand Assessment,14(6): 729-753.
12. M.R, Purtabari. T, Ebadi.&R,Maknoon.2010.Presentedadeveloped groundwater model by using dynamic neural networks, under ground water level changes for scheduling equations. Journal of Water-Science and Sewage.(4):70-80.

13. N.B, Karayiannis. & A.N, Venetsnaopoulos. 1993. Artificial Neural Network: Learning Algorithms, Performance Evaluation, and Application. Kluwer Academic Publisher, Boston.
14. S, Lallahemea. J, Maniaa. A, Hania. and Y, Najjarb. 2005. On the use of neural networks to evaluate groundwater levels in fractured media. Journal of Hydrology, 307(92):102- 111.

CITATION OF THIS ARTICLE
Zohreh A , Ali M A A, Feraydoun R , Mahmoud J. Comparison of three methods of ANN, ANFIS and Time Series Models to predict ground water level: (Case study: North Mahyar plain). Bull. Env. Pharmacol. Life Sci., Vol 3 [Spl Issue V] 2014: 128-134