Hydraulic Head Forecasting Using Artificial Neural Networks (Case Study: Debal Khazaie Sugarcane Plantation)

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Abstract: Forecasting the ground water level fluctuations is an important requirement for planning conjunctive use in any basin. Artificial neural network have been used as a robust instrument for this subject. In this study, Artificial Neural Networks (ANN) is used to predict hydraulic head. For this purpose, field R9-11 of the Debal Khazaei sugarcane plantation is selected and a number of piezometers were installed in different depth and distance from collector Hydraulic head changes in Piezometers, the volume of irrigation water and drainage flow were measured from November 2013 to October 2014 on a daily basis. The volume of irrigation water and drainage flow measured in this period were this period measurements were introduced as inputs to the neural network. The results showed that the artificial neural networks method has a high accuracy in predicting hydraulic head. So that the average RMSE in different depths between measured and predicted with ANN model obtained as 0.109, and the average of determination coefficient R2 in different depths for ANN model obtained as 0.964 respectively.
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1. Introduction

Groundwater is the largest resource 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. Given the importance of forecasting groundwater level from different points of view, finding the right way is important in this regard. Today novel method such as neural networks have been considered as effective ones [1]. Hydrologic models may be divided into two general categories: physical models, and abstract models [2]. Physical models include scale models which represent the system on a reduced scale. Abstract models, on the other hand, represent the system having properties similar to those of the prototype. Abstract models may be further divided into black box or white box models. Artificial neural network (ANN) models are examples of “black box” models with unique properties which make them greatly suitable for dynamic nonlinear modeling [3]. Concepts and applications of ANN models in hydrology have been discussed by many researchers [4,5]. 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. Coppola et al. showed that ANN has potential in accurately predicting of groundwater level fluctuations in an unsteady state of an aquifer influenced by pump and different weather conditions. They noted that predicted results of ANN are more accurate than quantitative models and also showed that ANN models are good at simulating karstic and leaky aquifers where other numerical models are weak in such cases. In another study by Taiyuan et al. the effects of hydrological, weather and humidity conditions on groundwater level were simulated by neural networks in lower part of Shenyang river basin, North West of China. ANN model was able to predict groundwater level with the average error of 0.37 m or lower with the high accuracy. In this study, Artificial Neural Networks (ANN) is used to predict hydraulic head. For this purpose, field R9-11 of the Debal Khazaei sugarcane plantation is selected and number of piezometers were installed in different depth and distance from collector. Piezometers hydraulic head changes, the volume of irrigation water and drainage flow were measured from November 2013 to October 2014 on a daily basis.

2. Material and Methods

Seven different sugarcane plantations have been established in Khuzestan province recently which cover an area of about 100,000□□ all together, namely Imam Khomeini, Amir Kabir, Mirza Kochakkhan, Debal Khazaie, Salman Farsi, Hakim Farabi and Dehkhoda. This study was conducted in

Debal khazaie Sugarcane Plantation with an area of around 12000 ha. Figure 1 shows location of the field study in Khuzestan province.

The Debal Khazaie longitude 48 degrees 35 minutes latitude and 31 degrees 8 minutes and covers an area of about 12,000 hectares of land 25 km south of East Road East Karun River in Ahvaz - Abadan is located.

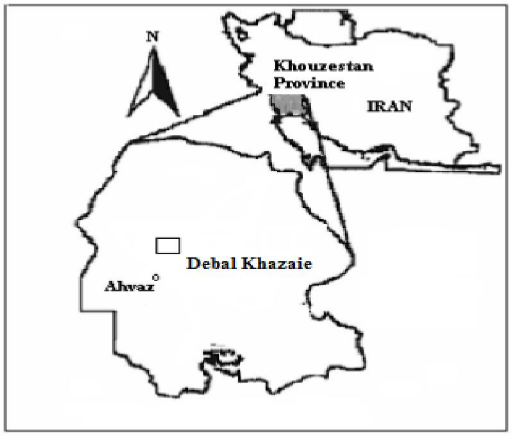

Figure 1. Location of the study area in Khuzestan province of Iran

Installation of Piezometers: in seven categories piezometer pipe piezometers at different depths of 2.2, 3, 4 and 5 yards over half the farm (500 m) are characterized picker drainage has been installed. As the first batch at a distance of five meters, the second at a distance of 30 meters, third at a distance of 50 meters, fourth in the 200 meters, right fifth in the 250 meters, sixth category in the 300 meters and finally categories seventh at 400 m from the of effluent were. Figure 2 respectively show Aerial photo piezometers pipes placed between two drain pipes.

Figure 2. Aerial photo piezometers pipes placed between two drain pipes

Artificial Neural Networks (ANN): The general structures of the artificial neural networks were driven from human neural networks. These structures are like biological neural system but in smaller size and dimensions. By processing the available data they transfer and preserves the hidden rule behind the network structure, because this, they have been called Intelligent. For the first time, a basic artificial neural network model was presented by [10]. From that time up to now, about 30 models of neural network with different structure were suggested. Artificial neurons send their signals "forward", and then the errors are propagated backwards. The network receives inputs by neurons in the input layer, and the output of the network is given by the neurons on an output layer. There maybe or more intermediate hidden layers. The back propagation algorithm uses supervised learning, which means that algorithm with examples of the inputs and outputs are provided to network to compute, and then the error (difference between actual and expected results) is calculated. The idea of the back propagation algorithm is to reduce this error, until the ANN learns the training data. The training begins with random weights, and the goal is to adjust them so that the error will be minimal. In forward networks, processors nodes are located in hidden layers. Every network can have several hidden layers and every hidden layer can have several nodes. In general, a neural network is made up of three layers shown in Figure 3.

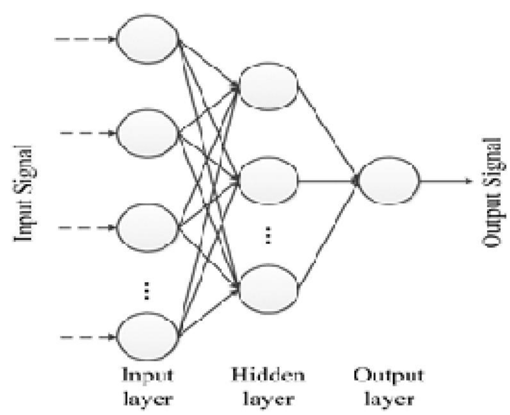

Figure 3. Outline of an artificial neural network

Input parameters for model: Hydraulic head changes, the volume of irrigation water and drainage flow were measured from November 2013 to October 2014 on a daily basis and then volume of irrigation water and drainage flow measurements in this period were introduced as inputs to the neural network.

Performance evaluation: A large number of statistical criteria are available to compare the goodness/adequacy of any given model. In this research, we used from Root Mean Square Error

(RMSE), Mean Absolute Error (MAE) and determination coefficient (R^2). These parameters have been determined using the following equations [11].

$$RMSE = \sqrt{\frac{1}{n}\sum (y_{observed} - y_{predicted})^2}$$

$$MAE = 100 * \frac{1}{n}\sum | y_{observed} - y_{predicted} |$$

$$R^2 = 1 - \frac{\sum (y_{predicted} - y_{observed})}{\sum y_{predicted}^2 - \frac{\sum y_{observed}}{n}}$$

$y_{predicted}$ is the predicted values and $y_{observed}$ is the observed data and n is the number of data. If the values of the MAE and RMSE are closer to zero and the amount of R^2 is closer to one, the forecasting results will be more accurate.

3. Results and discussion

A comparison between the average hydraulic head measured and predicted by neural network at various depths shown in Figure 4.

According to figure 4, there was a good agreement between predicted and observed values. The coefficient of determination (R^2), RMSE and MAE values for all depths shown in Table 1.

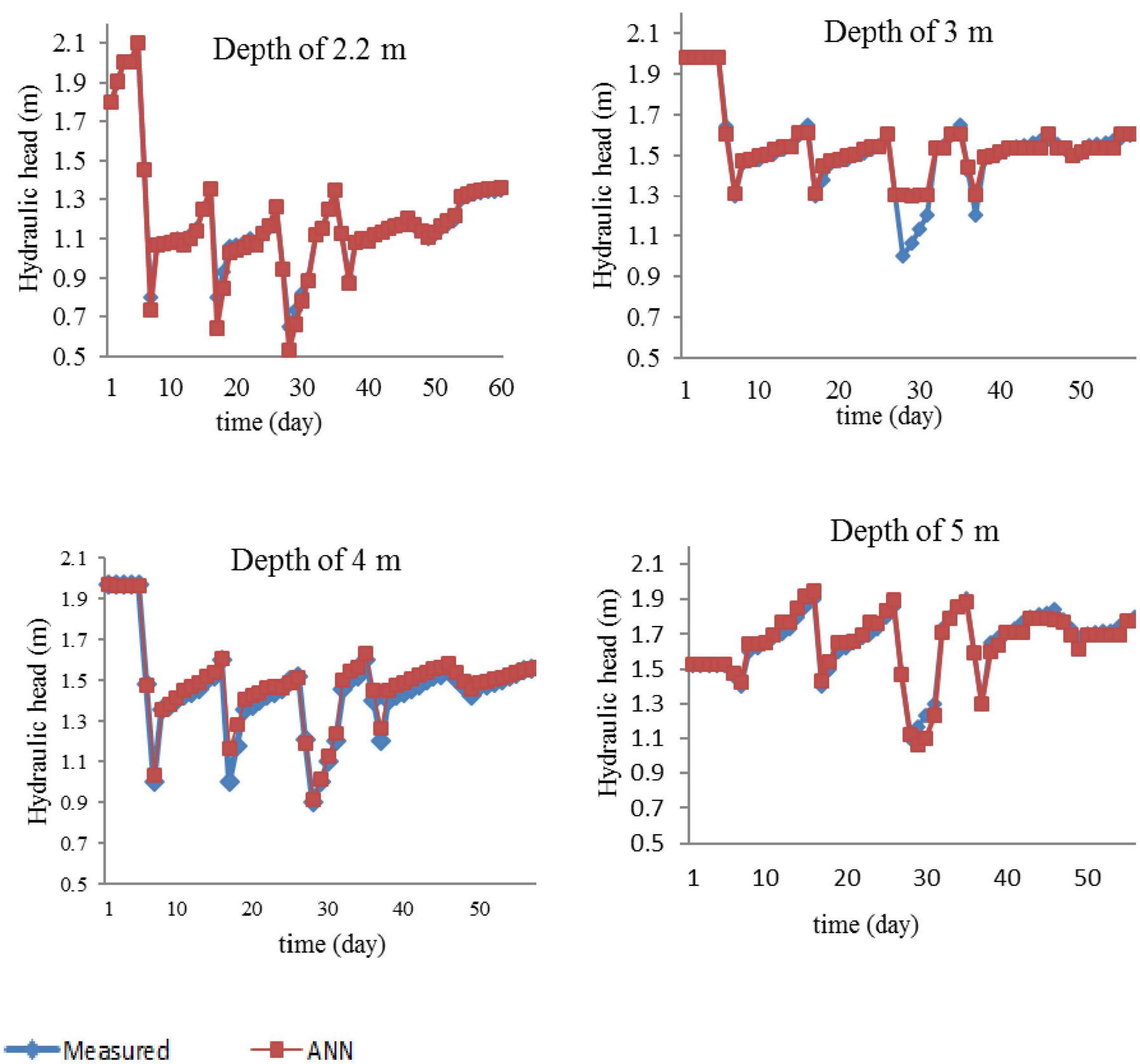

Figure 4: Mean hydraulic head comparing in different depth

Table 1. Statistical indicators calculated between predicted and observed hydraulic head

Depths (m)	Average of RMSE	Average of MAE	Average of R^2
2.2	0.02	1.43	0.991
3	0.02	1.21	0.925
4	0.38	1.02	0.984
5	0.019	1.6	0.957

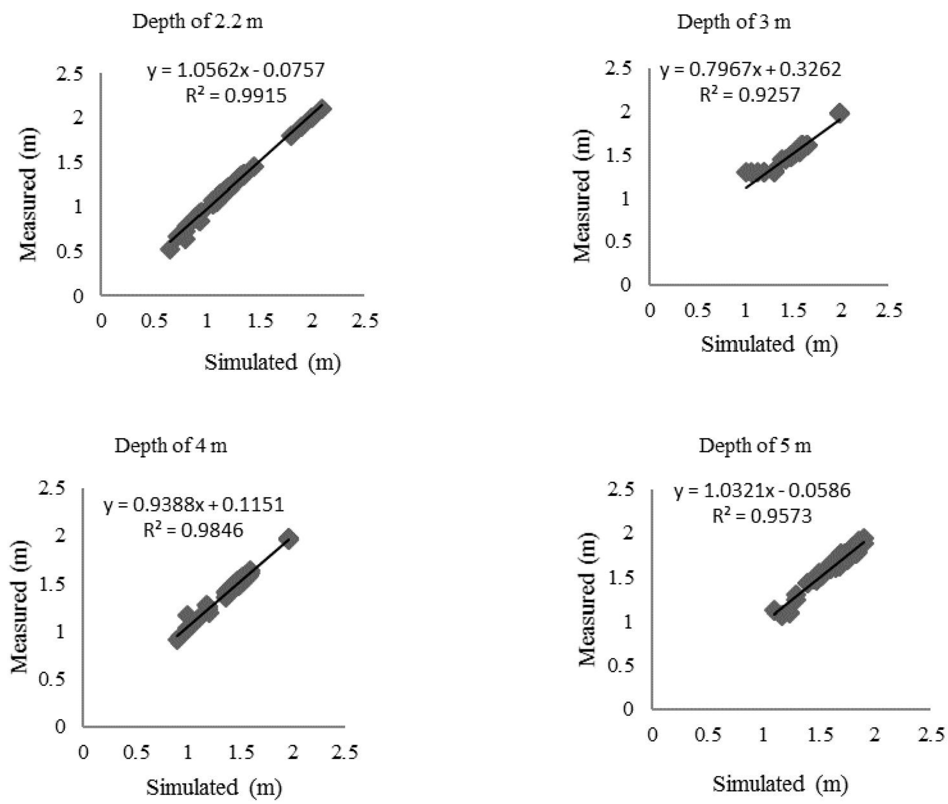

Figure 5. Relation between predicted and observed hydraulic head at different depths

4. Conclusion

The goal of this study was to evaluate the neural network as a possible tool for prediction of hydraulic head in Debal khazaie sugarcane plantation, Khuzestan province, south- west Iran. The results showed that the artificial neural networks method has a high accuracy in prediction of hydraulic head. So that the average of RMSE in different depths between observed and predicted with ANN obtained as 0.109 and the average of determination coefficient (R^2) in different depths was 0.964.

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