XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

COMPARISON OF DRAINMOD AND ARTIFICIAL NEURAL NETWORK FOR PREDICTING WATER TABLE DEPTH AND DRAIN DISCHARGE IN A SUBSURFACE DRAINAGE SYSTEM

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CSBE100087 – Presented at ASABE's 9th International Drainage Symposium (IDS)

ABSTRACT Drainage is an effective way to control water table in the farm fields with high groundwater level in the north of Iran. This study is carried out in the Ran Behshahr field under subsurface drainage system. Artificial Neural Network and DRAINMOD model were evaluated for predicting water table depth in midpoint between two laterals designated as S3PD14 and S3PD15 and drain discharge. Depth of water table and drain discharge were measured for rainfall seasons of 2004 and 2006 years. In this study the feed-forward back propagation model of ANN was used in MATLAB Software. For evaluation of these two models, the value of absolute error (AE), standard error (SE) and R2 were calculated. For the best ANN model, these values were obtained 4.4cm, 5.8cm, and 0.57 for prediction of water table depth and 0.08 mm/day, 0.1 mm/day and 0.59 for drain discharge, respectively. For DRAINMOD model, these values were obtained 15.6 cm, 18.1 cm and 0.42 and 0.27 mm/day, 0.32mm/day and 0.71, respectively. Results indicated that the accuracy of ANN model is better than DRAINMOD model in prediction of water table depth and drain discharge in this case study.

Keywords: Artificial Neural Network, DRAINMOD, Drain discharge, Subsurface Drainage, Water Table.

INTRODUCTION Water table management is one of the main solutions to create appropriate condition for soil. It is necessary to have quick and correct methods to design subsurface drainage systems optimally for simulating water table and drain discharge. To reach this purpose, different models have been developed. Some of these models are time-series, tentative and physical models. But, some of these models had not accurate result in dynamic behaviour of hydrological systems (Bierkens, 1998). Also physical models require intricate input parameters for long term simulation (Nayak et al, 2006). Furthermore, these models do not respond accurately to meteorological rapidly changing condition, such as heavy rainfall, in real time (Yang et al., 1996, 1998). Artifical neural networks have been used frequently in engineering sciences recent years. These models are a good alternative and have been applied to various hydrological problems (Yang et al., 1996; 1998). In this way, a set of implicit relationships between inputs and outputs is eventually defined and accepted. Yang et al. (1996; 1998) applied ANNs to accurately

simulate real-time fluctuations of water table depths and drain outflows in the Canadian regions of southwestern Quebec, eastern Nova Scotia, and eastern Ontario, based on daily precipitation and evapotranspiration. Strobl and Forte (2007) concluded that Artificial Neural Network (ANN) model is the best way for exploration of a environmental factors for a drainage network. Another widely used model is DRAINMOD developed by Skaggs (1978). This model employs the concept of macroscopic water balance in a vertical soil column at the midpoint between parallel drains. The model is simple enough and has been used by experts throughout the USA as well as in other parts of the world. Though DRAINMOD has been successfully used for different soil, water and crop conditions (Chang et al., 1983; Fouss et al., 1987; Breve et al., 1998; Helweig et al., 2002; Wang et al., 2006), Sinai et al. (2005) reported a dramatic disagreement between observed water table heights from a test field in the Jordan Valley and those predicted by DRAINMOD. Skaggs et al. (1987) concluded that the effect of nonuniform boundary conditions diminishes at distances greater than 30–100 m in drained fields.
The primary goal of this study was to compare DRAINMOD and Artificial Neural Network for predicting water table depth and drain discharge in a subsurface drainage system located in northern Iran.

MATERIALS AND METHODS

Case study This study was conducted on a site in Behshahr, a city located in northern part of Iran. The drainage network is located in the southern border of Miankale bay (Figure 1). The area of drained fields is 840 ha in the Mazandaran province lying between 53° 40′ to 53° 41′ E longitude and 36° 45′ to 36° 48′ N latitude. This zone has a semi-Mediterranean climate with an average annual rainfall of 577 mm and an average annual temperature of 16 ◦C. According to previous studies, installation of drainage system was necessary in the area due to the rise of water table, and high salinity of groundwater and soil. To prevent water logging and soil salinization 125 mm diameter drains were installed at a depth of 1.5 m. The basic design criteria for water table depth and drainage coefficient were 1 m and 1.5 mm/d, respectively. Corrugated perforated PVC pipes with rice husk envelope were spaced at 75 m with 440 m length. The rice husk envelope was placed with more compaction underneath the drain pipes than the envelope above drain pipes. The drainage system consists of open earth collector drains with an outlet to Miankale bay (Nashtak Consulting Engineers, 2002). The surplus water to be drained was from excessive rain, as the field was under dry farming and was not being irrigated. Barley, as a salt tolerant crop, has been the major crop in this area.

Experimental field and data collection The pilot area was located between two subsurface drains designated as S3PD14 and S3PD15. The drains were connected to earth canal (SD3). The total area of experimental site was about 3.3 ha. The texture of soils for 0-40, 40-100 and 100-150 cm layers were found to be loamy sand, silty loam and silty clay, respectively. Some of soil physical characteristics of experimental field are shown in table 1. The depths of S3PD14 and S3PD15 drains were 1.4 and 1.5 m, respectively. Subsurface drainage system was monitored in rainfall season in 2006 and 2007 (22 November to 19 March). Parameters such as daily water table fluctuations and drain discharge rate were recorded. Water levels in the piezometer tubes were measured with a scaled rod. Drain discharge was measured in both drains for the duration of four months. This site was also monitored in autumn season in 2004 (23 September to 21 December) by Nashtak Consulting Engineers. In this assessment, daily water table fluctuations and drain discharge rate were measured.

Figure 1. Map of Iran and position of Miankale bay and subsurface drainage system.

Table 1. Selected soil physical characteristics of the experimental field.

Layer	Soil texture	Thickness (cm)	Saturated moisture	Wilting moisture	Hydraulic conductivity (m/day)
1	Loamy sand	40	0.39	0.05	3
2	Silty loam	60	0.44	0.09	1.3
3	Silty clay	60	0.48	0.17	0.4

Artificial Neural Networks Artificial Neural Networks (ANNs) have emerged as one of the useful artificial intelligence concepts used in the various engineering applications. Due to their massively parallel structure and ability to learn by example, ANNs can accommodate nonlinear modeling for which an accurate analytical solution is difficult to obtain. Artificial Neural Networks consist of the large number of processing elements with their interconnections. ANNs are basically parallel computing systems similar to biological neural networks. They can be characterized by three components: nodes, weights (connection strength), an activation (transfer) function. ANNs modeling is a nonlinear statistical technique; it can be used to solve problems that are not amenable to conventional statistical and mathematical methods. Usually neural networks are trained so that a particular set of inputs produces, as nearly as possible, a specific set of target outputs. The feed-forward back propagation model of ANN was used in MATLAB Software for this study (MathWorks, 2006).

DRAINMOD DRAINMOD was developed at North Carolina State University in the mid 1970's (Skaggs, 1978). It is based on a water balance in the soil profile and uses climatological records to simulate the performance of drainage and water table control systems. The model was developed specifically for shallow water table soils. Approximate methods are used to quantify the hydrologic components: subsurface drainage, subirrigation, infiltration, evapotranspiration (ET) and surface runoff. As explained previously, the model has been filed-tested in many parts of the world for different soils, climates, and crops. DRAINMOD version 5.1 was used in this paper.

Evaluation of models To evaluate the performance of these models in daily water table depth and drain discharge estimates, between the predicted and measured, several criteria were used including regression coefficient (R^2), standard error (SE), absolute error (AD), CRM and were calculated.

$$R^2 = \frac{\left[\sum_{i=1}^{n}(O_i - \overline{O})(P_i - \overline{P})\right]^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2 \times \sum_{i=1}^{n}(P_i - \overline{P})^2} \tag{1}$$

$$S.E = \sqrt{\frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n}} \tag{2}$$

$$A.D = \frac{\sum_{i=1}^{n}\left|O_i - P_i\right|}{n} \tag{3}$$

$$CRM = \frac{\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} O_i} \tag{4}$$

Where n is the number of observations; O_i is the ith value of observed measurement; P_i is the ith value of predicted measurement; $\overline{O}$ is mean of the observed values and $\overline{P}$ is mean of the predicted values.

RESULTS AND DISCUSSION

Artificial Neural Network The daily data during the measurement period (seven months) such as precipitation (P), pan evaporation (E_p), potential evapotranspiration (ET_0), wind velocity (V_{wind}), relative humidity (RH), sunshine hours (hr_{sun}), water table depth (W) and drain discharge (Q) were used for training and testing the Artificial Neural Network. Six months and one month of total data were chosen for training and testing, respectively. In this research three types of input parameter models were used for the prediction of water table depth and drain discharge shown in tables 2 and 3. The results of statistical analysis for the evaluation of these models were showed in tables 4 and 5 for predicting the water table depth and drain discharge, respectively. Figure 2 shows the difference between the observed and predicted water table depths and drain discharges.

Table 2. ANN models with different input parameters for predicting water table depth.

Model	Input Parameters	Output
1	$P+ET_o+W_{i-1}$	W_t
2	$P+E_{pan}+W_{i-1}$	W_t
3	$P+T+RH+V_{wind}+hr_{sun}+W_{i-1}$	W_t

Table 3. ANN models with different input parameters for predicting drain discharge.

Model	Input Parameters	Output
1	$P+ET_o+Q_{i-1}$	Q_t
2	$P+E_{pan}+Q_{i-1}$	Q_t
3	$P+T+RH+V_{wind}+hr_{sun}+Q_{i-1}$	Q_t

Each of the three ANN models had the same results. Nevertheless the model 3 had the best results so that values of R^2, SE, and AD were 0.57, 4.4 cm and 5.8 cm for water table depth and 0.59, 0.08 mm/d and 0.1 mm/d for drain discharge predictions, respectively. Having many input parameters, the model 3 had the best performance in prediction of variation of water table depth and drain discharge. In general, the results of ANN models had good agreements with the observed data except for the 7th and 29th days. The main reason of low performance in these days was rapid fluctuations of water table and drain discharge due to intensive rainfall. These results show that ANN models have low accuracy for intensive rainfall conditions. The model 2 requires fewer input parameters that it is an advantage for evaluating the performance of ANN models. Moreover the difference between performances of three models was slight so the model 2 was suggested for prediction of water table depth and drain discharge.

Table 4. Results of ANNs models evaluation for predicting water table depth.

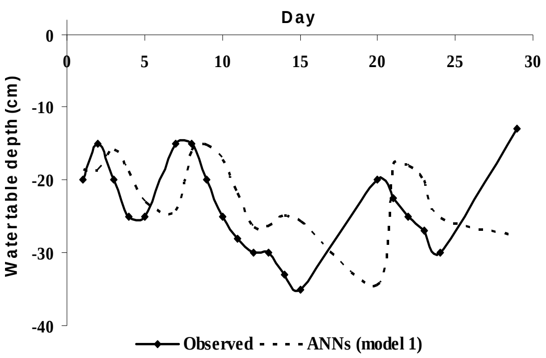
Case[1]	PEs[2]		Transfer function	Statistic evaluation		
	First layer	Second layer		R^2	S.E (cm)	A.D (cm)
1	1	3	Tangent Hyperbulic	0.53	7.1	6.1
2	1	3	Tangent Hyperbulic	0.67	6.2	4.6
3	1	2	Sygmoid	0.57	5.8	4.4

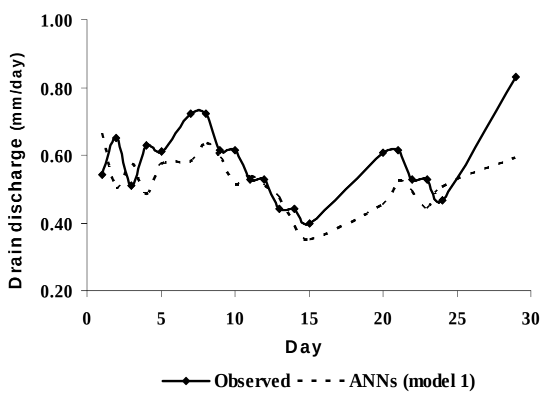
Table 5. Results of ANNs models evaluation for predicting drain discharge.

Case	PEs		Transfer function	Statistic evaluation		
	First layer	Second layer		R^2	S.E (mm/day)	A.D (mm/day)
1	2	0	Tangent Hyperbulic	0.70	0.12	0.10
2	1	3	Tangent Hyperbulic	0.81	0.12	0.09
3	1	4	Sygmoid	0.59	0.10	0.08

1.Case of ANN training.

2. PEs: Number of PEs in the hidden layer.





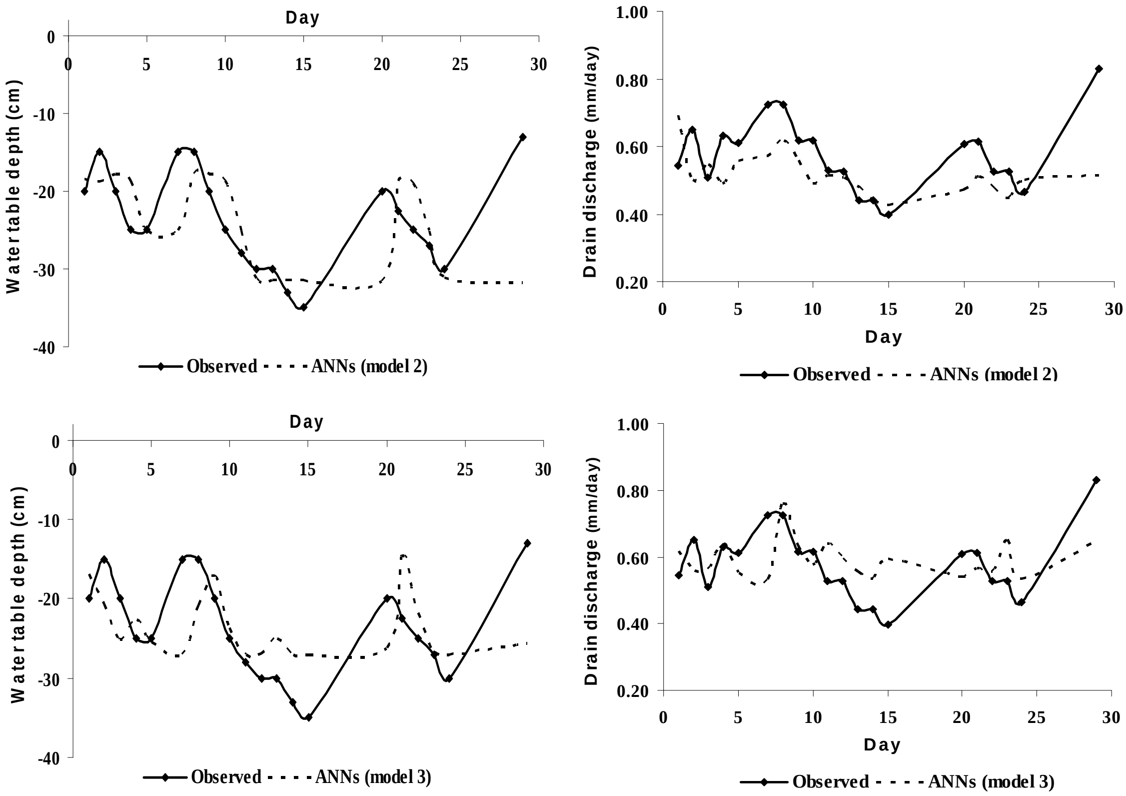


Figure 2. Comparison of observed water table depths and drain discharges with simulation by three ANN models.

DRAINMOD The DRAINMOD model was calibrated with six months of data. The performance of subsurface drainage system was simulated with the input parameters such as weather, soil, and drainage design data. The water table depth and drain discharge fluctuations were predicted and compared with the observed data of the final month. The results of the statistic analysis for evaluation of the model are presented in table 6. Also Comparison of predicted and observed data is showed in figure 3. The results indicated there was good agreement between the observed and predicted data. The values of absolute error (AE), standard error (SE) and R^2 were calculated for the DRAINMOD model. The values obtained were 15.6cm, 18.1cm, and 0.42 for prediction of water table depth, respectively. For drain discharge, the error measures obtained were 0.27 mm/day, 0.32 mm/day and 0.71, respectively. These values were in agreement with the other researches reported formerly.

Table 6. Results of DRAINMOD model evaluation for predicting water table depth (in cm) and drain discharge (in mm/day).

Parameter	S.E	A.D	R^2
Water table depth	18.1	15.6	0.42
Drain discharge	0.32	0.27	0.71

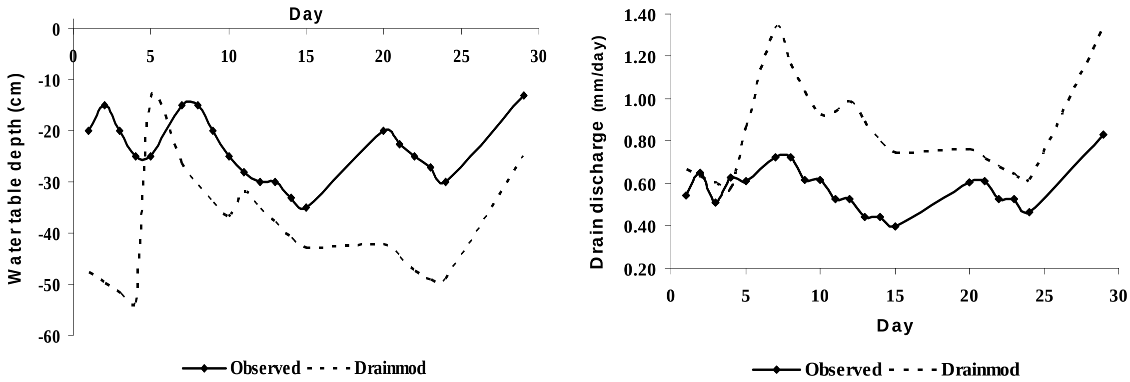


Figure 3. Comparison of observed water table depths and drain discharges with simulation by DRAINMOD model.

CONCLUSIONS This study was conducted to compare the performances of the ANN models and the DRAINMOD model for the Ran subsurface drainage system located in the northern part of Iran. The values obtained for AE, SE, and R^2, for the best ANN model were 4.4cm, 5.8cm, and 0.57 for water table depth and 0.08 mm/day, 0.1 mm/day and 0.59 for drain discharge, respectively. The results showed that the ANN models can predict fluctuations of water table depth and drain discharge in subsurface drainage system very well without having many input parameters. For the DRAINMOD model, the error values obtained were 15.6 cm, 18.1 cm and 0.42 for water table depth and 0.27 mm/day, 0.32mm/day and 0.71 for drain discharge, respectively. The results also indicated that the DRAINMOD model over-predicted both the observed water table depth and drain discharge. Ebrahimian (2007) reported there was an envelope clogging around drain pipes in this area. This phenomenon caused the reduction of the water table depth and drain discharge in the field. Therefore it is necessary to determine the envelope clogging effect for simulating the performance of subsurface drainage system.
The results showed the performances of ANN models in prediction of water table depth and drain discharge were better than the DRAINMOD model. Because the ANN models were trained based on the observed data and fewer input parameters. However DRAINMOD model need more input parameters and its accuracy depends on the accuracy of input parameters. Input parameters such as soil characteristics, envelope clogging, and seepage are difficult to measure accurately in field conditions.

Acknowledgement

This research was supported by The Center of Excellence for Evaluation and Rehabilitation of Irrigation and Drainage Networks in University of Tehran.

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