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ESTIMATING THE FLUCTUATIONS OF SOIL SALINITY AND WATER DRAINAGE IN UNDERGROUND DRAINAGE AND IRRIGATION NETWORKS OF MIANDUAB USING DRAINMOD 6.0 MODEL

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Abstract

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Computerized models are used widely in different sciences since they have the capability to reduce the costs and shorten the time required for a scenario to achieve the results of implementation on a system. Drainage networks are usually placed in semiarid lands under irrigation in order to control soil marsh and salinity. Because of the complexity of water travel and salt transfer in soil, simulation models are used to interpret the water management systems performance which may include underground, surface and irrigation drain. One of the models is Drainmod which simulates travel and storage of water in soil. In this research, the efficiency of Drainmod 6.0 model in predicting the soil salinity and water drain of underground drainage system in Mianduab Plain, is evaluated. To do so, an alfalfa field, was selected. The rate of salinity of soil and the drain of the waters extracted from lateral located in it was measured during August 2012. Then, the information required for the model, including meteorological, soil, drainage, irrigation and plant parameters, were collected and the model was implemented, and the obtained results were compared with the measured values. To quantitatively evaluate the performance of the model, the statistical parameters of Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and coefficient of residual mass (CRM) were used. The results showed that the model can simulate the salinity of soil and the waters drain with a high accuracy in the region. The values of RMSE, MAE, CRM obtained for the salinity of water drain were 0.51, -0.24 and 5.82, respectively. And the same values obtained for the soil salinity were 1.06, 0.06, 0.14, respectively.

Key words: estimating, Drainmod 6.0, Mianduab plain, salinity

Introduction

Iran, meteorologically, is an arid and semi-arid region and like many other parts of the world, the only way for optimal exploitation of the wide lands in the country most of which lack a drainage network and are saline, is to fortify and build surface and underground drainage networks. The ways of designing and evaluating the water management systems should be capable of considering atmospheric changes and interpreting the system performance during the periods with similar conditions. For the complexity of water management system, using the simulation models to design and interpret the performance of these systems is necessary (Marlow and Willey, 2001).

Design and implementation of irrigation and drainage networks requires the simulation of water flow regime in the soil profile. Some of these models are available and are employed for the purpose (Skaggs, 1999). Certainly, with the complexity of the problems, simulation of the models is a useful way for better understanding the processes by comparing different strategies and suggesting a solution and predicting long-term logical results (Borin et al., 2000). These models are highly effective in evaluating drainage networks (Bahceci et al., 2006). The common criteria to design and management of drainage networks are salinity control and keeping the water table level in low (to ventilate the surrounding of the plant root). Releasing the drain of nitrate-polluted waters, residues

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of herbicides and pesticides and element such as selenium, boron, arsenic and a variety of salts in environment cause new environmental problems and consequently, another criterion, environmental protection, is added to the conventional criteria. Thus, it is essential to revise the conventional criteria of design and management sot that the environmental aspects be included in them. Managing the systems designed by the conventional criteria and designing new drainage networks should be so that the volume of waters drain and the density of elements and salts in it become as low as possible (Darbandi, 2001). One of the computerized simulation models capable of analyzing the parameters of water quality for the lands with underground drainage is Drainmod model (Helving et al., 2000).

Drainmod model is evaluated and examined for a wide range of soils, plants and different climate conditions including hot or semi-arid (Maurizio et al., 2000; Yang, 2008; Ale et al., 2010), humid conditions (Evans and Skaggs, 1996), and cold weather (Yang et al., 2007; Dayyani et al., 2009). Besides the good performance of Drainmod as an independent set, the model is capable of playing an important role as a part of the wider studies on the relation of water, soil and plant (Gayle et al., 1987). This model was first introduced by Skaggs in 1978 and then, developed by him and other researchers. Shirmohammadi (1997) presents the results obtained from implementing the model in some regions of America and emphasizes the necessity of using Drainmod model in Iran. Rahbari et al. (2006) simulated the density of nitrate in the development and propagation center of Haraz, Mazandaran using DRAINMOD-N model. And gained the average error, model efficiency and correlation coefficient, as 0.61 mg/l, 0.97 and 0.99, respectively, and reported that the model can be used as a capable model in prediction and a tool for water management and pollution in the region of drainage in order to reduce the environmental dangers of rice fields. Luo et al. reported that evaluating the effects of designing the underground drainage networks and their management on the quality of water and hydrology in Minsuta central region by Drainmod NII model shows that management and design of drainage networks as a choice can reduce nitrate loss without a significant reduction in the product amount.

The aim of the current research is to evaluate Drainmod 6.0 model for predicting the changes in the rate of soil salinity and waters drain in the underground drainage network of Mianduab Plain.

Description of Drainmod Model

Drainmod is used to simulate the water table level, output water drain, number of days the land is ready for work, soil salinity and drain of water coming out of the river drains. Balancing in this model is divided into two parts:

Surface balancing

The model does runoff and surface maintenance in order to estimate the surface water balancing. The surface water balance, in any time interval Δt, is:

$$P = f + \Delta s + Ro \qquad (1)$$

where P is precipitation amount (cm), f is penetration rate (cm), Δs is the change in surface maintenance (cm) and R_0 is the surface runoff (cm).

Subsurface balancing

The model calculates the water balance for a thin section of soil located between two drains. Subsurface water balance in any time interval Δt is:

$$\Delta V_a = D + ET + D_s - F, \qquad (2)$$

where, ΔVa is the changes in the amount of pores empty of water (cm), D is the depth of drainage water or the depth of water supplied by irrigation water (cm), ET is evaporation and transpiration (cm), Ds is depth leakage (cm) and F is collective penetration (cm) (Yang, 2008).

Drainmod-S model is one of the submodels of Drainmod presented by Kandil et al. to simulate the salt in the soil and waters drain (Kandil et al., 1992). For this purpose, they solved the advective-dispersive equation of salts via finite element method:

$$\frac{\partial \Theta C}{\partial t} = \frac{\partial}{\partial Z}\left(\Theta D_{hz}\frac{\partial C}{\partial Z}\right) - q_z\frac{\partial C}{\partial Z} + \Gamma_C \qquad (3)$$

where, θ is the volume moisture of soil, t is time (day), C is the density of salt in liquid phase (gr/m^3), D_{hz} is the dispersibility coefficient (m^2/day), Z is downward axis (m), q_z is the intensity of water flow (m/day), Γ_C is salt supply or evacuation (gr/m^3/day).

Kandil and colleagues used the entries of the moisture within the DRAINMOD model to solve the salt transfer equation (Liaqat and Kaviani, 2005).

Materials and Methods

Introducing the studied region and explanation of the experiments

The project zone was located in West Azerbaijan province; East-Southern part of Urmia Lake and near Mianduab city and, indeed, it is located in the crossroad of Kermanshah-Tabriz and Kermanshah-Urmia main roads. The project zone is distanced 155 km from the capital of West Azerbaijan province and 180 km from the capital of West Azerbaijan province.

The project zone is located between 36.50 and 37.15 northern latitudes and 45.50 and 46.15 eastern longitudes. Mianduab city is at the center of this plain.

To do the research, a field with completed drainage operations was selected in which the drains were working properly, and the required parameters for the model were collected.

Model inputs

The required inputs for the implementation of Drainmod model are:

Meteorological parameters

These include the potential daily height of precipitation and evaporation and transpiration. If the evaporation and transpiration data are not available, the model receives the maximum and minimum of daily temperatures from the user and estimates the potential amount of evaporation and transpiration by Thornwaite method (Liyaqat and Kavyani, 2005). The parameters from Poldasht meteorological station, the nearest station to the project place.

Soil properties

This includes the Hydraulic drive of soil and moisture indicator curve (Liyaqat and Kavyani, 2005).

For this purpose, the required information about the soil properties was determined by a soil-scientific standard profile dig in the field and transferring it to the laboratory. RETC model of Van Genuchten-Mualem method was used to determine the hydraulic drive of saturation and moisture indicator curve.

Van Genuchten model (van Genuchten, 1980) is as follows:

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{[1+(ah)^n]^{1-1/n}} \quad (4)$$

$$S_e = \frac{\theta(h)-\theta_r}{\theta_s-\theta_r} = [1+(\alpha h)^n]^{1/n-1} \quad (5)$$

$$K(S_e) = K_o S_e^L \left\{1-\left[1-S_e^{n/(n-1)}\right]^{1-1/n}\right\}^2 \quad (6)$$

,

where S_e is relative saturation, θr and θs *are the residual and saturated water contents;* K_O is hydraulic drive of saturation (cm/day), *1* is the parameter related to the pores connectivity, *h* is suction (cm), $K(S_e)$ is hydraulic drive (cm/day) and *α, n, m* are empirical constants defining the shape of the curves (m=1-1/n , n>1).

The properties of field soil and coefficients of Van Genuchten model are shown in Tables 1 and 2.

Drainage network parameters

These include the depth and distance of drains, management type of the drains, implementation gradients of drains, the most depth of surface maintenance, the initial depth of water table and equivalent depth (Liyaqat and Kavyani, 2005). These parameters are extracted from the planning reports presented in Table 3.

Table 1
Soil properties

Depth, cm	Sand, %	Silt, %	Clay, %	Soil Texture	Bulk density, gr cm^{-3}	EC, ds m^{-1}	$\theta_{fc,}$ $cm^3\ cm^{-3}$
0-30	10	34	56	Clay	1.22	5.68	0.381
30-60	14	28	58	Clay	1.33	8.29	0.376
60-90	10	28	62	Clay	1.39	7.11	0.393

Table 2
Parameters of Van Genuchten model

Depth, cm	i	n	Ks, cm hr^{-1}	α, cm^{-1}	θs, $cm^3\ cm^{-3}$	θr, $cm^3\ cm^{-3}$
0-30	0.5	1.2330	1.31	0.0229	0.5216	0.0987
30-60	0.5	1.2239	1.04	0.0227	0.4866	0.0977
60-90	0.5	1.1996	0.646	0.0224	0.4736	0.0988

Irrigation management

These include the depth of irrigation water, the day and month of beginning irrigation, irrigation cycle, the time of start and end of irrigation every day, the probable precipitation depth during the irrigation and the quality of water (Liyaqat and Kavyani, 2001). Table 4 shows the amounts and time of irrigation and precipitation and Table 5 shows the average amount of the parameters of the water used to irrigate the examined field.

Table 3
Parameters of drainage network

Depth from soilsurface to drain, B, cm	200
Spaceing between drains, L, cm	8000
Actual distance from surface to impermeable layer, H, cm	350
Equivalent depth from drain to impermeable layer, De, cm	130
Drainage coefficient, cm day^{-1}	10
Kirkham,s coefficient, G	11.83
Initial depth to water table, W, cm	100

Table 4
Amounts and time of irrigation and precipitation in the examined field

Date	Amount of irrigationand precipitation, mm
08.21.2012	60
08.27.2012	60
09.03.2012	1.6
09.04.2012	9.5
09.06.2012	60
09.16.2012	60

Plant parameters

In this section, the depth of root development (the depth on which its moisture is depleted by root or evaporation from the soil surface) for alfalfa consider with respect to the crop pattern of the region. Since the simulation process is continuous, an effective depth is defined for the whole simulation period (Liyaqat and Kavyani, 2001). The depth of root development for alfalfa is considered to be 3 to 6 feet according to the model guide.

Inputs required for the implementation of DRAINMOD-S model

In addition to the input parameters mentioned for DRAINMOD model, the following parameters are also required for DRAINMOD-S model: Dispersion coefficients in soil, time interval (Δs), average depth of salt and salt density in different depths of soil (Liyaqat and Kavyani, 2001).

These parameters are considered for soil profile shown in Table 6. It should be noted that these values are obtained from the model calibration.

Model implementation way

After collecting the required parameters, to make meteorological and soil files, Utilities section, drainage network, Drainage Design section, plant Crop section, irrigation management Irrigation section, and salinity, Salinity section of the software was employed and the model was implemented.

Evaluation the model accuracy in predicting the changes in soil salinity and waters drain

To evaluate the model in simulating the soil and water drain salinity, a test field was selected where the executive operations had been completed and the drains worked on it, and the samples of water drain were supplied from the lateral of the field. These samples were taken by clean plastic

Table 6
Dispersion coefficients of soil

Dispersivity	0.05
Tortousity Factor	0.783
Diffusion Coeff Molecular	1

Table 5
Average amounts of the parameters of water quality

pH	Na^+, meq lit^{-1}	Mg^{++}, meq lit^{-1}	Ca^{++}, meq lit^{-1}	$SO4^{--}$, meq lit^{-1}	Cl^-, meq lit^{-1}	$HCO3^-$, meq lit^{-1}	Ec, dS m^{-1}	TDS, mg lit^{-1}
6.8	2.5	2.6	4.4	3.8	2	3.6	0.95	624

containers, daily and for one month (31 days), and in 4°C in a refrigerator and transferred to the laboratory at the end of sampling. The sampling of the field water drain starts one day after digging the soil profile in the test field. Also, in order to evaluate the model for simulating the soil salinity, the soil samples were taken from the test field and their salinity was measured.

In the laboratory, the rate of soil and waters drain electronic conductivity was determined by electronic conductivity meter device. After collecting the required information, the model was evaluated through comparing the measured salinity amount on the field and the amount of salinity predicted during 31 day.

To evaluate the model accuracy, the statistical index, mean absolute error (MAE), root mean square error (RMSE) and the coefficient of residual mass (CRM), were used. These indices are as follows:

$$MAE = \frac{\sum_{i=1}^{n} |Oi - Pi|}{n} \quad (1)$$

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n} (Pi - Oi)^2\right]^{0.5} \quad (2)$$

$$CRM = \frac{\sum_{i=1}^{n} Oi - \sum_{i=1}^{n} Pi}{\sum_{i=1}^{n} Oi} \quad (3)$$

Where O_i is the measured amount of salinity, P_i is the amount of salinity predicted by the model, P is the average amount of predicted salinity and n is the number of measurements.

RMSE determines the total simulation value, *CRM* defines that the model is over-estimator or under-estimator and *MAE* states the accuracy of the model which decreases with the increase in the model accuracy (Nash and Sutchliffe, 1970).

Results and Discussion

As it is seen in Figure 1, there is a high consistency between the measured and simulated data so that the maximum rate of difference between the observational and measured data is in the third day, being 0.8 ds/m and in the rest of the days, this difference is very low. On the days 7, 12, 22, 23, 24, 27, 30 and 31, simulated values are very close to the observational ones. The values of statistical indices RMSE, MAE and CRM are 0.51 dS/m, -0.24 dS/m and 5.82 dS/m, respectively, which indicate the high accuracy of the model in simulating the salinity of waters drain.

Figure 2 shows the simulated and measured amounts of the mean salinity of the test field soil during August - September in three different depths. As it is seen in Figure 2, the measured and simulated values of soil salinity are close to each other so that the difference between them in the depth 0-30 is 1.45 dS/m, and in the depth 30-60, 1.03 dS/m and in the depth 60-90, 0.5 dS/m.

The values for the statistical indices RMSE, MAE and CRM are found to be 1.06 dS/m, 0.66 dS/m and 0.14, respectively, which are also indicative of the high accuracy of the

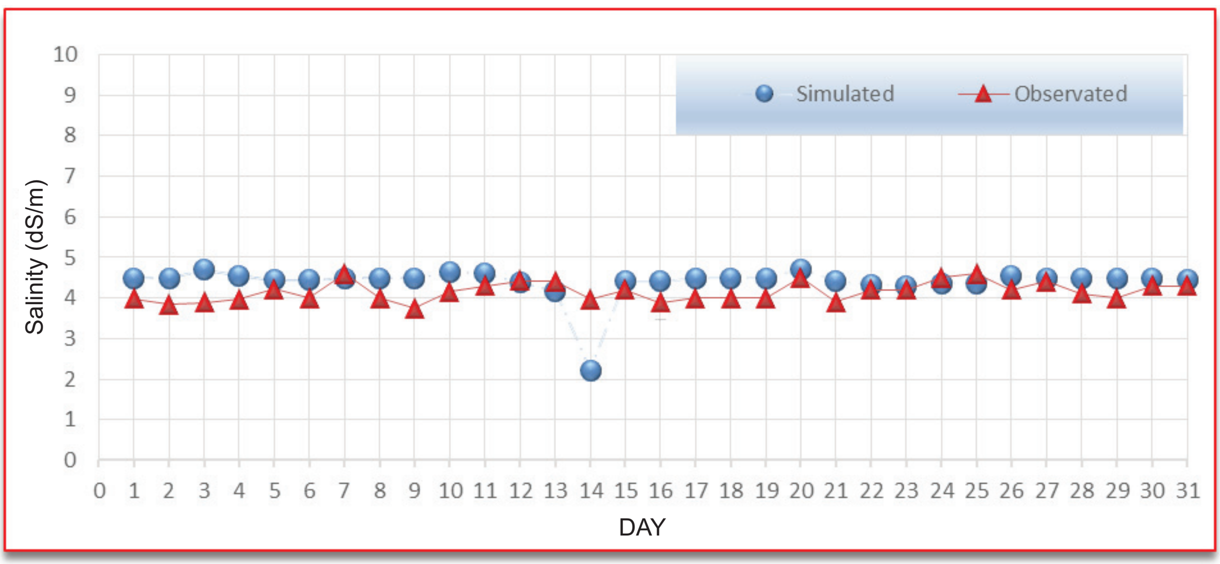

Fig. 1. Comparison between the measured and simulated amounts of the waters drain salinity in the test field

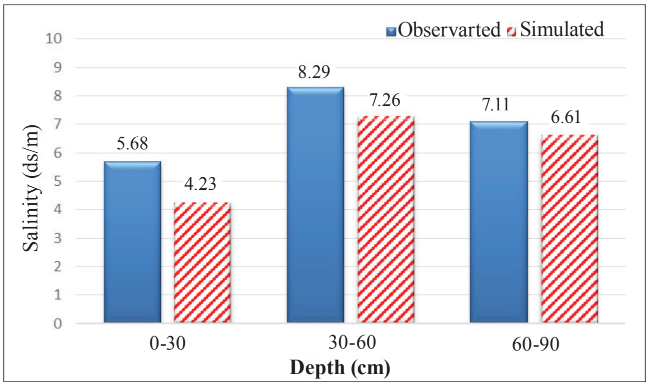

Fig. 2. Comparison between the measured and simulated amounts of the soil salinity in the test field

model in simulating the soil salinity. As mentioned before, these differences are negligible, so it can be said that DRAINMOD model can be used in simulating the soil salinity.

Suggestions

It is suggested that before implementing the drain plans, the test field is prepared and then the Drainmod model is evaluated in the field. Then, the results are generalized to the whole plan and it is used in simulating the waters drain and soil salinity and environmental outcomes in the future.

After evaluating Drainmod model and ensuring its accuracy and efficiency, it can be used in predicting the amount of soil and water drain salinity and also design and management of underground drainage networks.

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