Saving Irrigation Water in Sandy Soils

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Abstract

Quantifying the hydraulic properties of irrigated soils is an urgent task to achieve optimum water management and saving irrigation water. RETC is a computer program which can be used to estimate soil hydraulic functions from easily determined soil properties. Using van Genuchten model in RETC program gave high accuracy for estimating the hydraulic functions e.g. θ (h), k (θ) and D (h), under various textures of the studied soils (Sandy, Loamy sand, sandy loam, Sandy clay loam, Sandy clay).

The obtained results both empirically or the estimated ones were used to calculate quantity of irrigation water and its intervals in each soil under study.

There are high significant differences between experimental and modeled data. The obtained results show that, RETC program is considered a good tool for potential optimization of water management especially though calculating irrigation water after consuming 60% of the available water in root zone restoring technique.

Keywords: Sandy soil, Irrigation scheduling, Water management, RETC, Saving irrigation water

Introduction

Huygen *et al.* (1995) stated that the objectives of irrigation management are 'Maximize net return, minimize irrigation costs, maximize yield, optimally distribute a limited water supply, minimize groundwater pollution...etc.'

To reach these goals, it is necessary to schedule irrigation accordingly, in other words, to decide, when and how much do you have to irrigate, this management benefits included also water saving.

Hess, (1996), reported that overirrigation have negative effects on quantitative and qualitative yield.

Timing and depth criteria for irrigation scheduling can be established by using several approaches based on soil water measurements, soil water balance estimates and plant stress indicators, in combination with simple rules or sophisticated models, (Huygen *et al.,* 1995).

For irrigation purposes, it is generally expressed as a fraction of the available water. This fraction is given by the ratio of available water content over available water capacity which is defined by water contents at field capacity and at wilting point, normally 60% of available water. Whatever the technique used to determine this measurement, one has always to deal with the problem of spatial variability, even when using tensiometers to control the wetted volume under furrow irrigation and drip irrigation, Peymorte and Chol (1992).

Specty and Isbérie (1996) reported the case of a local climatological association which takes 15 000 samples per year for gravimetric measurements of soil moisture. Besides the sampling, which makes this technique time consuming and cumbersome, the main problem is the accuracy and spatial variability. Neutron probes are also used to monitor changes in soil moisture content as a guide to irrigation scheduling. Its main advantages are that non-destructive and direct measurements can be performed without disturbing the soil. While, the main limitation relates to safety rules which have to be followed to operate, transport and store the probe. This is the main reason why there is a tendency to replace this equipment by the recently developed Time Domain Reflectrometry apparatus (TDR). TDR measures soil water content through the dielectric properties of the soil. But, the main limitations seem to be due to gaps and cracks which may arise during installation of the rods or as a result of shrinking of the soil during drying, Topp et. al. (1987).

Water potential measuring devices give direct information about soil water status. The more precise techniques are psychrometry, but unfortunately their use is not only far beyond any farmer's reach but also beyond current agronomic field experiments. Gypsum blocks exhibit a wide range relationship between their electric conductivity and soil water potential. However, their use is limited because temperature and salinity effects make them not very reliable.

Tensiometer measures *in situ* and in real time soil matric potential down to -0.8 bars. This allows an empirical use of this device to schedule irrigation, especially for drip irrigation and even for furrow one, Specty and Isbérie (1996).

Tensiometers require considerable time for preparation, installation, recording of observations periodic servicing and removal from the field. Also Interpretation of the sensed matric potential may be confounded by poor soil contact- especially in sandy soil -, leaks and a limited tensiometer range, Hoffman et. al. (1990)

Most of the researchers recommend irrigation after consuming 60 % of the available water which stored in the root zone

Soil water balance is also a technique used to predict the water content in the rooted soil by means of a water conservation equation:

D (AWC × Root depth) = Balance of entering + outgoing water fluxes

where AWC is the available water content.

The soil water balance approach has been used by different authers (e.g., Mailhol *et al.,* 1995; Przybyla, 1996; Hess, 1996, etc.).

Estimates of actual evapotranspiration are mentioned in several contributions, e.g. (Hoffman et al. 1990)

El-Gindy and Abdel-Aziz (2003) and Singh et al. (2004) .

The aim of this study is to calculate the optimum amount of applied irrigation water to avoid overirrigation from a side and saving irrigation water from another. So, RETC code is used to refine water retention curve through minimizing the residual error according to van Genuchten – Mualem approach (1980)

Materials and Methods

Five soil samples (0-50 cm depth) were selected to represent five texture classes from homogeneous profiles at different locations in Egypt. Some physical properties of the studied soil samples were determined according to the standard methods described by Klute (1986) and presented in Table (1).

Table (1): Some physical properties of the studied soil samples.

Soil Property	Sample No.				
	1	2	3	4	5
Sand %	97.5	84	56.5	51.6	47.8
Silt %	1.5	9.6	33.5	26.0	14.4
Clay %	1.0	6.4	10.0	22.4	37.8
Texture class	Sandy	LS	SL	SCL	SC
Bulk density (g/cc)	1.76	1.63	1.56	1.47	1.41
θ_{10} kPa (cm^3/cm^3)	0.1003	0.1565	0.2615	0.3363	0.3664
θ_{1500} kPa (cm^3/cm^3)	0.0471	0.0520	0.0732	0.0917	0.1311

LS = Loamy sand, SL = Sandy loam, SCL = Sandy clay loam, and SC = Sandy clay

Soil samples, which collected from different locations of Egypt, Inshas, El-Tal El-Kebeer, Belbies, Ismailia, Mataria were saturated with water before subjecting them to suction on sand box instrument (under low values of pressure heads, e.g., 10, 50 and 100 mbar). While, the saturated soil samples were subjected to high pressure on pressure apparatus 330, 1000, 3000, 5000, 10000 and 15000 mbar). After equilibrium, soil water contents were determined, immediately and presented on volume bases, Fig (1).

Absolute value of the slope of "θ" with respect to "log h" can be calculated from θ(h) function or equivalently, assuming that the inflexion point "P" be the point on the soil water retention curve at which $\theta = (\theta r + \theta s) / 2$. Then m, n, λ and α. can be calculated using non linear least-squares method according to van Genuchten model (1980).

Output data, e.g., θs, θr, α and n were used in RETC program as input data besides the deterministic data of soil water retention curve.

Parameters of van Genuchten's model were refined using RETC code to get high accuracy of estimated parameters.

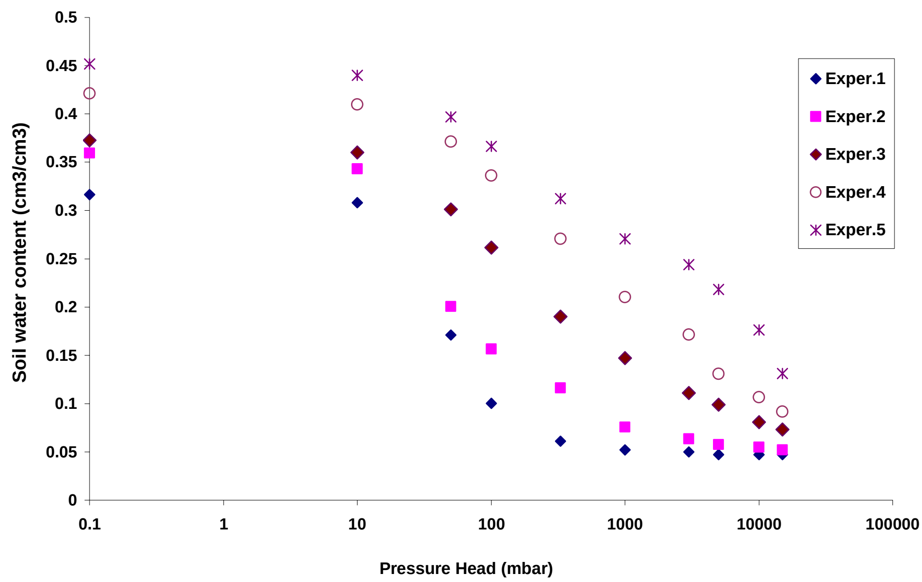

Fig.(1) Experimentally water retention curves of the studied soil samples

Table (2): Fitted values of van Genuchten parameters by RETC program of the studied soil samples.

Sample No.	θ_r	θ_s	α	n	SSQ before RETC refining	SSQ after RETC refining	R^2
1	0.0488	0.3086	0.0321	2.5829	0.00148	0.00038	0.9962
2	0.0452	0.3519	0.0384	1.9279	0.00274	0.00042	0.9955
3	0.0582	0.3527	0.0252	1.4022	0.00343	0.00012	0.9989
4	0.0634	0.4041	0.0168	1.3211	0.01772	0.00051	0.9968
5	0.0855	0.4489	0.0206	1.3104	0.01768	0.00027	0.9966

θ_r = Residual water content. (cm^3/cm^3) n = Water release parameter
θ_s = Soil water at saturation.(cm^3/cm^3) SSQ = Sum of squares (Residual error).
α = Water release parameter (cm^{-1}) R^2 = Coefficient of determination

The obtained data after refining are used to calculate the amount of needed irrigation water for each soil and compared with the experimentally ones, Table (3). The obtained data used also to get refining water retention curves of the studied soil samples, Fig(2).

Table (3) Amount of irrigation water (mm) per irrigation after depletion 60% of available water based on experimentally and modeled data of the studied soil samples.

Soil sample No	Experimental data	Modeled data	Difference*
1	16.00	11.95	4.05
2	31.35	24.20	7.15
3	56.50	52.05	4.45
4	73.40	69.45	3.95
5	70.60	62.20	8.40

$T_{calc.}$= 6.130 $T_{Tab.}$ (4, 0.01) = 4.604 $T_{Tab.}$ (4, 0.05) = 2.776

* Highly significant

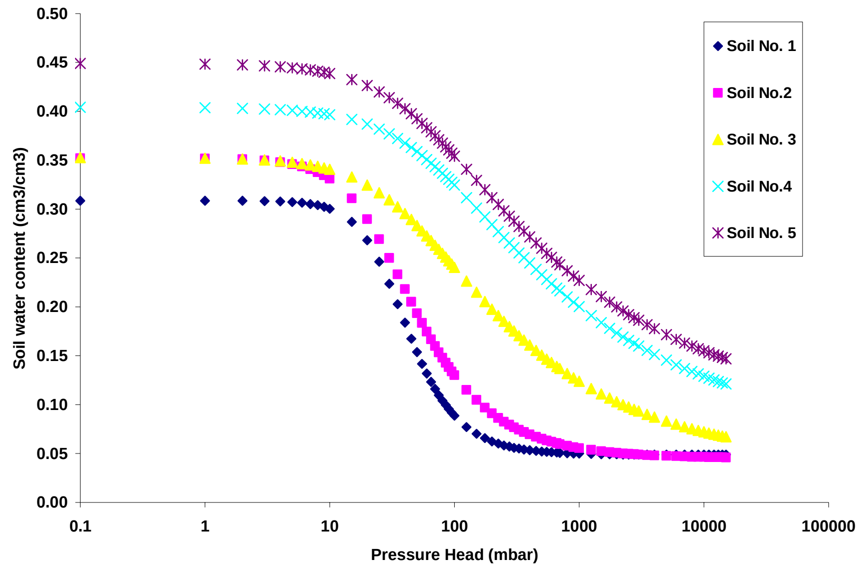

Fig.(2)Soil water retention curves of the studied Soil samples after refining using RETC code

Soil hydraulic conductivity was determined under saturation condition by a constant head permeameter, using stainless steel cylinder of 5.0 cm in diameter and 5.0 cm height. Soil samples were inserted in the internal cistern of the permeameter to saturate with water by capillary. Water was allowed to flow through the soil for 2 h under the effect of hydraulic gradient for all soil samples to avoid time effect on the values of soil hydraulic conductivity and reach to saturation. This period was quite enough to achieve almost steady-state flow. Each value of hydraulic conductivity was an average of four replicates. Then, unsaturated hydraulic conductivity is estimated using the refined van Genuchten parameters, Fig. (3).

Statistical and mathematical analyses were performed using "Microsoft Excel' program.

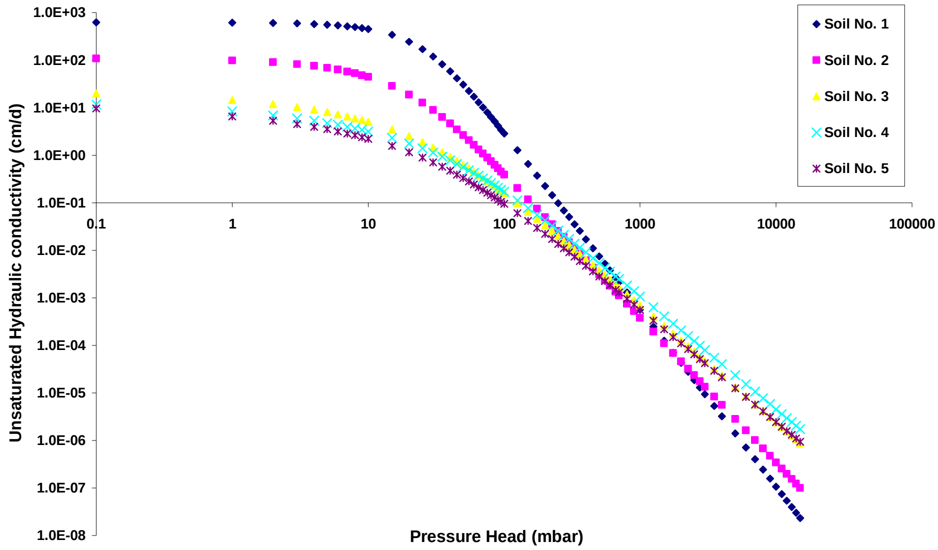

Fig.(3) Unsaturated hydraulic conductivity of the studied soil samples after refining using RETC code

Results and Discussion

An improved irrigation schedule based on restoring field capacity in the 0 - 50 cm soil layer was tested for saving irrigation water.

RETC code was used to analyze soil water retention curve and hydraulic conductivity functions which are the key parameters in any quantitative description of water flow into the unsaturated zone of soils, van Genuchten et. al. (1991)

This program uses the parametric models of Brooks – Corey (1966) and van Genuchten (1980) to represent soil water retention curve, and the theoretical pore-size distribution models of Mualem (1976) and Burdine (1953)

Data in Table (1) reveal that all of the selected soil samples lay in the sand group with different texture classes and also varied in their physical properties.

Fig. (1) reveals also that these soil samples are differing in their soil water behavior.

Amount of needed irrigation water to restore the root zone (assume equal 50 cm) after consuming 60% of the available water was calculated using the experimental data, Table (3).

After the running of RETC code, Summation squares of the determined water characteristic curves became less especially in relative finest textured soils, Table (2).

AS the same way, amount of needed irrigation water to restore the root zone (assume equal 50 cm) after consuming 60% of the available water was calculated using the modeled data and the difference between experimental and modeled data are presented in Table (3).

Statistical analysis reveal that the difference between calculated amount of irrigation water based on both experimental and modeled data are highly significant, Table (3)

So, refining the water retention data using RETC code reduced the needed water to restore the root zone of the soil for each irrigate and consequently save the irrigation water.

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توفير مياه الرى بالأراضى الرملية

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تحديد الخواص الهيدروليكية للأراضى المروية من المهام الضرورية للوصول الى أنسب أدارة للمياه فى هذه الأراضى و توفير المياه المستخدمة للرى بها . برنامج RETC للحاسب الألى يمكن أستخدامه للحصول على الدوال الهيدروليكية للتربة و كذلك ضبط البيانات المتحصل عليها عملياً على نموذج van Genuchten لتقليل الخطأ التجريبى . أستخدام نموذج van Genuchten فى برنامج RETC أعطى دقة عالية فى تقدير الخواص الهيدروليكية لعدة رتب قوامية مختلفة (رملية – لومية رملية – رملية لومية – رملية طينية لومية – رملية طينية)

أستخدمت القيم المتحصل عليها للخواص الهيدروليكية بطريقة عملية و المستنتجة من البرنامج فى تقدير كميات مياه الرى و أظهرت النتائج المتحصل عليها وجود فروق معنوية جداً بين القيم المقدرة عملياً و المستنتجة من البرنامج و ذلك لصالح توفير مياه الرى . و بالتالى يعتبر برنامج RETC أداة جيدة للوصول الى أنسب أدارة للمياه فى هذه الأراضى خصوصاً حساب كميات مياة الرى اللازمة بطريقة Root zone restoring بعد أستتراف 60% من الماء الميسر بالتربة .

الكلمات المفتاحية: التربة الرملية - جدولة الرى – أدارة المياه – برنامج RETC - توفير مياه الرى