Predicating Irrigation Water Quantity, Soil Moisture Content and Pore Size Distribution of Some Egyptian Alluvial Soils Using Soil Routine Analysis

El Gendy, R.W.[1] and R. I. Fayed[2]

[1]Soil &Water Res. Dept., Nuclear Res. Center, Atomic Energy Authority, Cairo , Egypt
[2]Soil Salinity Lab., Alex., Soil, water and Enviro. Res. Institute, Agric. Res. Center-Egypt

ABSTRACT

The aims of the present study are to predict the soil moisture content, pore size distribution and irrigation scheduling from routinely measured data using simple and multiple regression equations. Twenty five soil profiles were selected to represent alluvial soils in Nile delta at El-Behera Governorate. Seventy five soil samples (3 layers per profile, 0-20, 20-40, and 40-70 cm) were collected to determine the main soil physical, hydrophysical, and chemical properties. Some soil properties (sand, silt, clay, soil bulk density and sodium adsorption ratio) were used individually and altogether as independent variables to predict soil moisture contents (at the moisture tensions of 0.1, 0.33, 1.0, 3.0 and 15.0 bars), pore size distribution and net irrigation water quantities as dependent variables.

The correlation coefficients are highly significant (R^2>0.88**) for the relation between soil moisture content at different soil moisture tensions and altogether soil properties. Soil moisture contents at low tensions (0.1 and 0.33 bar) were negatively high correlated with sand% and bulk density, but they were positively correlated with clay content. While soil moisture contents at high tensions (3 and 15 bar) were highly significant and positively correlated with clay content and SAR, but they were negatively correlated with silt content.

The pore size distribution in the studied soils followed the order of WHP (water holding pores) >FCP (Fine capillary pores) >SDP (slowly drainable pores) > QDP (quickly drainable pores). Generally, the values of volume drainable pores (SDP+QDP) were lower than WHP. Regression analysis revealed that the QDP was significantly and positively correlated with sand% (R^2=081**), but negatively correlated with WHP (R^2 =-0.80**). Fine capillary pores was significantly affected by clay% and SAR with R^2 = 0.84** and 0.63*, respectively.

The predicted net irrigation water quantity and soil moisture content values (at 70, 60, and 50% from available water) from soil properties were highly significant with a correlation coefficient of R^2> 0.91**.

Models for predicting soil moisture tensions as a function of the soil moisture contents were developed for the studied soils. High correlation coefficient (R^2 =0.996**) were found between the predicted soil moisture content and the soil moisture tension ($\theta = a\ h^{-b}$) with the measured data.

Key words: alluvial soils, Pore size distribution, irrigation water quantities, soil moisture content and soil moisture tensions.

Introduction

Soil moisture characteristic is an important hydrophysical soil property. It reflects the physical, chemical and mineralogical properties of the soil. Its measurement is tedious, expensive and time consuming either in field or laboratory. Simplified methods may be worthy to predict the soil moisture contents at different tensions, pore size distribution and irrigation scheduling from easily and routinely measured data. These data may be including soil particle size distribution, bulk density and SAR.

Several efforts were made to estimate the soil water contents at different tensions from measured soil properties (Kandil *et al.*, 1976; Gupta and Larson, 1979; Vachaud *et al.*, 1985 and Baker *et al.*, 1996). According to Kandil *et al.* (1976), sand is the most significant fraction controlling of available water capacity, whereas all mechanical fractions are related to the moisture content at field capacity. They also found that the clay and sand fractions are feat related to wilting point. In the same connection, Baker *et al.* (1996) used sand, silt, clay, organic matter and bulk density to predict soil water content and some relevant concepts by using regression equations. They applied different models for calculating net irrigation water (m^3 /fed/irrig.) in different soils. These models were derived from the differences of soil moisture contents between field capacity and wilting point.

De-Leenheer and De-Boodt (1965) classified the pore size into drainable pores (DP), water holding pores (WHP) and fine capillary pores (FCP). The drainable pores are further classified into quickly and slowly pores (QDP and SDP). The values of moisture content on volume basis were used for calculating the percentage of quickly drainable pores (QDP), slowly drainable pores (SDP), volume drainable pores (VDP), water holding pores (WHP), fine capillary pores (FCP) and coarse capillary pores (CCP), which have the diameters, >28.8, 28.8-8.62, >8.62, 8.62-0.19, <0.19 and 28.8-0.19 µm, respectively.

Baver *et al.* (1972) stated that pore size distribution could be classified to non-capillary pores (>28.8 µm), coarse capillary pores (28.8-0.19 µm) and fine capillary pores (<0.19 µm). Ghazy (1982) found that the volume drainable pores and the capillary pores are the major factors affecting water movement. Ibrahim (2002) used regression equations to predict pore size distribution from particle size distribution and soil bulk density.

Hwang *et al.* (2011) found by examining the symmetry between the distributions of particle-size (PSD) and pore-size (POD) in a soil, as hypothesized by early pore-solid fractal (PSF) models, they found significant discrepancies in fractal dimensions between the PSD and the water retention curve (WRC) of a soil.

Draper (1996) developed a scheduling computer program to predict the number of days until the next irrigation. This program used the relationship between soil texture, soil holding capacity and soil matric potential to estimate the remaining soil moisture within soil profile.

Steven *et al.* (2012) studied the spatial and temporal influences on hydraulic properties in macroporous tile-drained soil. They reported that the hydraulically effective macroporosity was not influenced by drain position but tended to be greater in wetter soil, although hydraulically effective macroporosity attributable to pores with equivalent diameter >0.3 cm tended to be greater in dry soil. The hydraulically effective macroporosity was approximately 100 times less than visible macroporosity.

Russell (2010) modeled the particle size distribution of the double porosity soil using a fractal distribution, which may have a fractal dimension very different to those defining the pore sizes. The curve, and the underlying assumptions regarding the distributions of pore and particle sizes, showed good agreement with experimental data for a range of soils having double porosity.

Dikinya *et al.* (2007) determined size of the pores as a function of deposited clay particles and reported that the modal pore size of the agricultural soil as indicated by the constant water retention curve was 45 µm and was not affected by the leaching process. In the case of the mining residue, the mode changed from 75 to 45 µm. This reduction of pore size corresponds to an increase of capillary forces that is related to the measured shift of the water retention curve.

The present study was carried out to obtain regression equations which can be used in prediction of soil moisture contents at different tensions, pore size distribution and irrigation schedule in alluvial soils using sand%, silt%, clay%, soil bulk density and SAR data obtained from soil routine analysis.

Materials and Methods

Seventy five soil samples were collected from 25 soil profiles (3 layers per profile 0-20, 20-40 and 40-70cm) of alluvial soils in the north-western part of the Nile Delta, Behera Governorate. The soils were air dried, crushed and passed through a 2mm sieve. Some main chemical, physical and hydrophysical analysis were carried out according to Page *et al.* (1982) and Klute (1986).The soil moisture contents at soil matric tensions of 0.1, 0.33, 1.0, 3.0 and 15 bars were determined using pressure cooker and pressure membrane according to Richards (1949). Data in Tables 1and 2 represent some main chemical, physical and hydrophysical properties for selected profiles in the studied alluvial soils (profile per site). The pore size distribution was calculated and classified according to De-Leenher and De-Boodt (1965) as shown in Table (3). Table (4) presents the total porosity and pore-size distribution for selected profiles in the studied alluvial soils.

Statistical analysis:

Simple and multiple linear regression analyses were done to calculate prediction equations for soil moisture contents, pore size distribution and irrigation scheduling. Regression analysis was performed according to the COSTAT manual (CoHort Software, 2004).

Linear regression equations:

Least squares difference was calculated to get the simple regression equation:

$$Y = a + bX$$

Where:

Y: is dependent variable, i.e., the soil moister content (θ) at a certain soil moisture tension (h).

X: is independent variable (sand% or silt% or clay% or soil bulk density or SAR)

a: is the intercept of Y axis b: is regression coefficient

Multiple regression equations of soil moisture content (θ) at a different tensions (h), pore size distribution and net Irrigation water quantity are considered to be functions of the independent variable (x) as follows:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$$

Where:

Y: is dependent variable (soil moisture content or pore size distribution or net Irrigation water quantity

a: is the intercept of Y axis

b_1, b_2, b_3, b4 and b_5 are partial regression coefficients for sand %(x_1), silt% (x_2), clay% (x_3), soil bulk density (x_4) and SAR (x_5)

Table (1). Some chemical properties for the selected profiles in the studied alluvial soils

profile	Depth	pH	EC(1:5)	SAR	Cations meq/L (1: 5)				Anions meq/L(1: 5)		
No.	cm	(1:2.5)	dS/m		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{--}
1	0-20	8.42	0.71	2.04	2.00	1.60	3.03	0.36	1.60	1.80	3.70
	20-40	8.02	0.71	3.59	1.40	1.30	3.84	0.10	1.80	1.50	3.80
	40-70	8.06	0.56	5.00	1.20	0.60	3.15	0.06	2.20	1.50	1.90
2	0-20	7.74	0.63	4.77	1.00	0.80	4.23	0.06	2.00	1.60	2.70
	20-40	7.79	1.08	8.40	0.80	1.00	7.98	0.04	1.80	2.50	6.50
	40-70	7.87	1.14	8.80	1.00	1.00	8.80	0.06	2.80	3.00	5.60
3	0-20	7.52	0.40	2.64	1.00	0.80	2.15	0.06	2.20	1.40	0.40
	20-40	7.59	0.42	3.20	0.80	1.00	2.25	0.06	2.10	1.80	0.30
	40-70	7.95	0.45	3.56	1.00	0.80	2.58	0.04	2.00	1.50	1.00
4	0-20	7.50	0.47	2.80	1.20	0.60	2.80	0.08	2.80	1.50	0.40
	20-40	7.63	0.59	4.29	1.40	0.80	3.68	0.06	2.90	2.00	1.00
	40-70	7.93	0.95	5.96	1.60	1.00	6.79	0.08	5.20	2.60	1.70
5	0-20	8.05	0.73	3.68	1.20	1.80	4.19	0.08	5.00	1.30	1.00
	20-40	8.08	0.51	4.05	0.90	0.60	3.40	0.06	2.20	1.50	1.40
	40-70	8.22	0.49	4.11	0.80	1.00	3.02	0.02	2.80	1.50	0.60

Table (2). Measured soil moisture contents, particle size distribution, soil bulk density and SAR values for the selected profiles in the studied alluvial soils

Profile No.	Depth (cm)	Particle size distribution (%)			BD (g/cm³)	SAR	Water content (θ_v) at tension (bar)					
		Sand x_1	Silt x_2	Clay x_3	X_4	x_5	0.0	0.1 y_1	0.33 y_2	1.0 y_3	3.0 y_4	15 y_5
	0-20	20.50	33.50	46.00	1.20	2.04	58.48	54.38	45.78	37.56	31.86	16.89
1	20-40	19.50	28.00	52.50	1.22	3.59	58.96	55.67	46.11	35.28	30.25	18.26
	40-70	27.00	32.50	40.50	1.30	5.09	50.22	40.15	34.36	27.31	23.81	13.51
	0-20	19.50	29.50	51.50	1.22	4.77	61.13	55.11	47.22	38.10	32.38	17.47
2	20-40	18.00	26.75	55.25	1.20	8.40	61.20	55.98	49.83	40.05	35.66	20.46
	40-70	20.00	23.00	56.50	1.25	8.80	59.96	54.63	48.12	40.60	34.89	21.00
	0-20	17.50	33.25	42.25	1.20	2.64	57.86	51.98	42.83	33.44	26.18	16.95
3	20-40	18.00	29.25	46.25	1.22	3.20	56.27	52.15	46.10	37.16	28.15	16.47
	40-70	19.00	29.25	47.25	1.24	3.56	55.73	49.33	42.11	30.95	24.18	14.21
	0-20	23.75	29.50	46.75	1.28	2.80	54.44	44.28	36.17	32.36	28.63	17.33
4	20-40	22.25	24.00	53.75	1.25	4.29	56.21	48.05	38.56	37.07	31.48	18.23
	40-70	22.00	21.75	56.25	1.23	5.96	56.13	49.09	39.91	37.95	34.18	19.65
	0-20	24.25	30.75	45.00	1.29	3.68	51.13	41.58	36.55	30.00	26.18	15.09
5	20-40	22.25	29.25	48.50	1.25	4.05	52.00	46.44	40.66	33.69	29.22	16.29
	40-70	23.00	28.50	48.50	1.25	4.11	52.80	45.18	39.10	32.18	28.76	15.11
Mean	0-70	21.10	28.58	49.12	1.24	4.46	56.16	49.6	42.23	34.91	29.72	17.13

Table (3). The pore size distribution according to De-Leenher and De-Boodt (1965)

Pore size class	Pore size range (µm)	Potential range (bar)
QDP	>28.8	0.001-0.1
SDP	28.8-8.62	0.1-0.33
WHP	8.62-0.19	0.33-15
FCP	<0.19	>15

Where: QDP: Quickly drained pores SDP: Slowly drained pores
WHP: Water Holding pores FCP: Fine Capillary Pores

Table (4). Total porosity and pore size distribution as percent of total volume for some profiles in the studied alluvial soils

Prof. No.	Depth cm	Total poros. %	QDP* >28.8 µm	SDP 28.8-8.62 µm	VDP >8.62 µm	WHP 8.62-0.19 µm	CCP 28.8-0.19 µm	FCP <0.19 µm
	0-20	58.48	4.10	8.6	12.7	28.89	37.49	16.89
1	20-40	58.96	3.29	9.56	12.85	27.85	37.41	18.26
	40-75	50.22	10.07	5.79	15.86	20.85	26.64	13.51
	0-20	61.13	5.02	7.89	13.91	29.75	37.64	17.47
2	20-40	61.20	5.22	6.15	11.37	29.37	35.52	20.46
	40-75	59.96	5.33	6.51	11.84	27.12	33.63	21.00
	0-20	57.86	5.88	9.15	15.03	25.88	38.03	16.95
3	20-40	56.27	4.12	6.05	10.17	29.63	35.68	16.47
	40-75	55.73	6.40	7.22	13.62	27.90	35.12	14.21
	0-20	54.44	10.16	8.11	18.27	18.84	26.95	17.33
4	20-40	56.21	8.16	9.40	17.56	20.42	29.82	18.23
	40-75	56.13	8.04	9.18	17.22	20.26	29.44	19.65
	0-20	51.13	9.55	5.03	14.58	21.46	26.49	15.09
5	20-40	52.00	5.56	5.78	11.34	24.37	30.15	1629
	40-75	52.80	7.62	6.08	13.70	23.99	30.07	15.11

*QDP: Quickly drained pores= $\theta_{at0.0} - \theta_{at0.1bar}$
SDP: Slowly drained pores = $\theta_{at\,0.1} - \theta_{at0.33bar}$
VDP: Volume drained pores = $\theta_{at\,0.0} - \theta_{at0.33bar}$
WHP: Water Holding pores (available water) = $\theta_{at\,0.33} - \theta_{at15bar}$
CCP: Coarse Capillary pores= $\theta_{at0.1} - \theta_{at15bar}$
FCP: Fine Capillary Pores= $\theta_{at15bar}$

Irrigation schedules:

Baker *et al.* (1996) applied model for calculating net irrigation water quantity (m^3/fed/irrig.) as follows.

$$NIW = AW \times D \times A \times R$$

Where:

NIW: is Net irrigation water quantity (m^3 / fed / irrig.)

AW: is Available water (the differences of soil moisture contents between field capacity at 0.33 bar and wilting point at 15 bar), volumic basis (m^3/m^3)

D: is soil moisture depletion (30%, 40% or 50% from the available water)

A: is area (m^2) R: is root depth (m)

An example for calculating net irrigation water (m^3/fed/irrig.):

$\Theta_{0.33ba}$ $= a_1 + b_1$ sand% $+ b_2$ silt% $+ b_3$ clay% $+ b_4$ BD $+ b_5$ SAR

$\Theta_{15\ bar}$ $= a_{11} + b_{11}$ sand% $+ b_{22}$ silt% $+ b_{33}$ clay% $+ b_{44}$ BD $+ b_{55}$ SAR

available water $= \theta_{at\ 0.33bar} - \theta_{at\ 15bar} = (a_1 - a_{11}) + (b_1 - b_{11})$ sand $+ (b_2 - b_{22})$ silt $+ (b3 - b_{33})$ clay $+ (b_4 - b_{44})$ BD $+ (b_5 - b_{55})$ SAR

NIW $= [(a_1 - a_{11}) + (b_1 - b_{11})$ sand $+ (b_2 - 3\ b_{22})$ silt $+ (b3 - b_{33})$ clay $+ (b_4 - b_{44})$ BD $+ (b_5 - b_{55})$ SAR$] \times 4200 \times D \times R$

An example for calculating soil moisture content at available water depletion

$\theta_{at\ 70\%\ available\ water} = 0.7(\theta_{0.33bar} - \theta_{15bar}) + \theta_{15bar} = 0.70\ \theta_{0.33bar} + 0.3\ \theta_{15bar}$

$= 0.7(a_1 + b_1 sand + b_2 silt + b_3 clay + b_4 BD + b_5 SAR) + 0.3\ (a_{11} + b_{11}\ sand + b_{22}\ silt + b_{33}\%\ clay + b_{44}\ BD + b_{55} SAR)$

$= (0.7a_1 + 0.3a_{11}) + (0.7b_1 + 0.3b_{11})$ sand $+ (0.7\ b_2 + 0.3\ b_{22})$ silt $+ 0.7b_3 + 0.3b_{33})$clay $+ (0.7b_4 + 0.3b_{44})$BD $+ (0.7\ b_5 + 0.3b_{55})$ SAR

Soil moisture tension

The linear relationship was used to explain the relation between soil moisture tension and soil moisture content according the formula of Ascroft and Taylor (1962).

$$\theta = a\ h^{-b}$$

where,

θ: soil moisture content on volume basis ,

h: soil moisture tension in cm,

a, b: the intercept and regression coefficient of $\theta = a\ h^{-b}$ model

The constant a and b were calculated from the logarithmic form of the above- mentioned formula, i. e.

$$\log \theta = \log a - b \log h.$$

Then the regression between log θ and log h was calculated to obtain the constants a and b.

Results and discussion

Soil moisture content

Table (2) illustrate the measured values of soil moisture content at tensions 0.1, 0.33, 1.00, 3.00 and 15 bar in addition to particle size distribution (sand, silt and clay percentage), soil bulk density and SAR values for the studied soil samples.

Simple and multiple linear regression equations were carried out using COSTAT statistical software (CoHort software, 2004) and illustrated in Table (5). Some soil properties (sand%, silt%, clay%, bulk density and SAR) were used individually and all together to predict the soil moisture content at different tensions (0.1, 0.33, 1.0, 3.0, and 15 bar). The multiple regression equations in Table (5) showed that the correlation coefficients were highly significant ($R^2 > 0.88^{**}$) for the relationship between soil moisture content at different soil moisture tensions and soil properties, all together. These results are found in agreement with those of Baker *et al.* (1996). They revealed that the predicted soil moisture content values by using simple and multiple equations were highly significant ($R^2 > 0.76^{**}$).

Simple regression equations indicated that the only effective soil variable for predicting soil moisture content at whole tensions is clay content with $R^2 = 0.53^*$, 0.49^*, 0.78^{**}, 0.87^{**} and 0.84^{**} at tensions of 0.1, 0.33, 1.0, 3.0 and 15 bar, respectively. Sand content and bulk density were highly significant and negative correlation at tensions of 0.1, 0.33, and 1.0 bar {R^2= (0.87^{**}, 0.88^{**}) – (0.85^{**}, 0.81^{**}) and (0.62^*, 0.67^{**})} respectively), while silt% gave a significant and negative correlation at tensions 3 and 15 bar (R^2= 0.66^* and 0.53^*). Sodium adsorption ratio (SAR) gave a positive correlation at high suction range 1, 3 and 15 bars ($R^2 = 0.50^*$, 0.62^* and 0.63^*, respectively), as shown in Table (5). These results are partly in agreement with those of Talha *et al.* (1978). They showed that the moisture contents at only 0.1 and 15 bar were highly significant and positively correlated with clay content but negatively correlated with fine sand.

It can be concluded from the above discussion that the soil moisture content depends on sand%, clay% and soil bulk density at low tensions (0.1, 0.33 and 1.0 bar), while at high soil moisture tensions (3 and15 bars) they depend on %silt, %clay, and SAR. It is worthy to mention that the correlation coefficient for clay content with moisture content is positive and highly significant at all soil moisture tensions.

Table (5). The regression equation and correlation coefficient between soil moisture content at different tensions and some soil properties in alluvial soils

Tension (bar)		Empirical equations	R^2
	θ_v(0.1 bar)	= 85.1461-1.6847 sand%	-0.87**
		=58.3553-0.3063 silt%	-0.21
		=22.3702+0.5544 clay%	+0.53*
0.1		=227.8194-143.7259 BD	-0.88**
		=46.4997+0.6952 SAR	+0.26
		=52.1707-0.8863 sand%+0.8569 silt% +0.8156 clay%-39.7599 bD+0.1968 SAR	0.96**
	θ_v(0.33 bar)	= 74.1845-1.5143 sand%	-0.85**
		=48.7242-0.2271 silt%	-0.17
		=19.0167+0.4727 clay%	+0.49*
0.33		=192.7886-121.4115 BD	-0.81**
		=38.1668+0.9119 SAR	+0.37
		=73.6369-0.8736 sand%+0.7665 silt% +0.5548 clay%-53.5336 BD +0.8549 SAR	0.93**
	θ_v(1.0 bar)	= 53.7773-0.8940 sand%	-0.62*
		=49.9099-0.5315 silt%	-0.47
		=5.1055+0.6069 clay%	+0.78**
1.00		=136.5497-81.9648 BD	-0.67**
		=30.5206+0.9851 SAR	+0.50*
		=124.8342+0.1006 sand%+0.1244 silt% +0.3408 clay%-86.1540 BD +0.3019 SAR	0.91**
	θ_v(3.0 bar)	= 39.3332-0.4556 sand%	-0.33
		=49.5408-0.6934 silt%	-0.66**
		=-1.9421+0.6446 clay%	+0.87**
3.00		=97.7548-54.8662 BD	-0.47
		=24.4419+1.1838 SAR	+0.62*
		=50.5353+0.6559 sand%+0.3797 silt% +0.7517 clay%-67.9009 BD +0.3962 SAR	0.94**
	θ_v(15.0 bar)	= 24.6684-0.3574 sand%	-0.44
		=39.3601-0.4270 silt%	-0.53*
		=-0.7979+0.3650 clay%	+0.84**
15.00		=56.2404-31.5423 BD	-0.46
		=13.9852+0.7048 SAR	+0.63*
		=27.1852-0.0048 sand%-0.0113 silt% +0.2552 clay%-18.7556 BD +0.2447 SAR	**0.88****

Pore size distribution

The volume of pore, space size, shape, type and continuity of pores through different soils are not constant but vary according to changes in physical and chemical conditions. The amount of water remaining in the soil at equilibrium is a function of the size and volume of water filled pores. Table (4) shows the measured values of total porosity and pore size distribution for the studied alluvial soils. As a general trend, the values of coarse capillary pores (28.8-0.19 µm) as percent of total volume are higher than those of fine capillary pores (<0.19 µm). Also, the water holding pores (8.62-0.19 µm) is higher than volume drained pores (>8.62 µm). However, quickly drained pores are very low compared with those of coarse capillary pores, as shown in Table (4). So, it could be concluded that the distribution of different pores in alluvial soils follows the descending order WHP >FCP>SDP> QDP. These results are in agreement with those obtained by El-Sharkawy (1994) in Shebin El-Kom and Kafr El-Sheikh clayey soils.

Table (6) show the simple and multiple regression equations and correlation coefficient for predicting pore size distribution using some soil properties (sand, silt, clay, soil bulk density and SAR). Multiple regression equations showed highly correlation coefficient with R^2 =0.85**, 0.74**, 82**, 0.91**, 95** and 0.88** for QDP, SDP, VDP, WHP, CCP and FCP, respectively. Quickly and slowly are called volume drainable pores, while water holding and fine capillary pores are called water storage pores. Slowly drainable plus water holding pores are called coarse capillary pores (CCP) (Talha *et al.*, 1978).

Concerning the relation between pore size distribution and some soil properties data showed that the %sand and soil bulk density were high significant and positively correlated with QDP (R^2=0.81**), while it was negatively correlated with WHP (R^2>0.74**). On the other hand, volume drainable pores (VDP) is positively correlated with %sand only (R^2 =0.54*). These results are in agreement with those obtained by Ghazy (1982). Except fine capillary pores, no significant relationships were found between %silt, %clay and SAR and other pore types (QDP, SDP, VDP, WHP and CCP). Regarding the fine capillary pores, the data positively correlated with %clay (R^2=0.84**) and SAR (R^2=0.63**) and negatively correlated with %silt. These results are in agreement with those of Talha *et al.* (1978) and Ibrahim (2002).

Hence, it could be concluded that pore size distribution is of great importance as it is usually taken as an indication of the status and behavior of soil water. It depends mainly on the particle size distribution as well as the soil bulk density. This means that in alluvial soils both of soil texture and soil bulk density have great influence on pore size distribution.

Table (6). The regression equation and correlation coefficient between pore size distribution and some soil properties in alluvial soils

Pore type	Equation	R^2
	=-7.2383+0.6575 sand%	+0.81**
	=6.7913-0.0055 silt%	-0.08
	=12.7310-0.1241 clay%	- 0.28
QDP	=-63.0324+56.1831 BD	+0.81**
	=6.7803-0.0337 SAR	-0.03
	=-2.0287-0.2344 sand%+16.7116 silt%-0.2344 clay% +0.385 BD -0.3103SAR	+0.85**
	=10.9615-0.1704 sand%	-0.38
	=9.6311-0.0792 silt%	-0.17
	=3.3533+0.0817 clay%	+0.27
SDP	=35.0308-22.3099 BD	-0.46
	=8.3329-0.2167 SAR	-0.27
	=53.1375+0.2230 sand%0.2188 silt%+0.5844 clay% -35.9698 BD -0.5584 SAR	+0.74**
	=3.723+0.4871 sand%	+0.54*
	=16.4225-0.0847 silt%	-0.14
	=16.0844-0.04241 clay%	-0.10
VDP	=-28.0015+33.8732 BD	+0.45
	=15.1321-0.2536 SAR	-0.20
	=51.1088+0.6081 sand%-0.5292 silt%-0.1759 clay% -19.2582 BD -0.5143 SAR	+0.82**
	=49.5161-1.1569 sand%	-0.80**
	=19.4363+0.2015 silt%	+0.17
	=19.8148+0.1077 clay%	+0.14
WHP	**=136.5482-89.8732 BD**	-0.74**
	=24.1816-20.71 SAR	-0.10
	=-28.4953-1.1055 sand%+1.0885 silt%+0.5029clay% +15.1944 BD +0.51 SAR	+0.91**
	=92.91-1.7331 sand%	-0.89**
	=26.8452+0.2039 silt%	+0.17
	=26.2778+0.1308 clay%	+0.14
CCP	=182.258-120.6338 BD	-0.89**
	=33.17366-0.1125 SAR	-0.17
	=59.4761-0.9457 sand%+0.6991 silt%+0.3366 clay% -35.0697 BD +0.0274 SAR	+0.95**
	=24.6684-0.3574 sand%	-0.44
	=29.3601-0.4270 silt%	-0.53*
	=-0.7979+0.3650 clay%	+0.84**
FCP	=56.2404-31.5423 BD	-0.46
	=13.9852+0.7048 SAR	+0.63*
	=27.1852-0.0048 sand%-00113 silt%+0.5252 clay% -18.7556 BD +0.2447 SAR	+0.88**

Net irrigation water

Soil moisture retention is one of the limiting factors in agricultural development, particularly in arid and semi-arid zone, where the amount of water is very limited. Irrigation scheduling is an application of soil moisture retention. It is known that the meaning of Irrigation scheduling is how much irrigation water quantities are plants need to their water consumptive use, and when to irrigation.

Net irrigation water calculates the needed irrigation water quantities per feddan per irrigation (m^3/fed/irrig). The following model was developed to calculate the net irrigation water for the studied soils using some measured soil properties (Table 2):

Net irrigation water (m^3/fed/irrig.)= water holding pores (total available water) x area x root depth

Water holding pores= -28.4953-1.1055 sand%+1.08849 silt%+0.5029 clay%+15.1944 BD +0.51 SAR (as shown in Table 6)

Net irrigation water (m^3/fed/irrig)= [-28.4953-1.1055 sand%+1.08849 silt%+0.5029 clay%+15.1944 BD +0.51 SAR] x Area (4200m^2) x root depth

The model was derived at 100% available water or zero depletion from AW. Models in Table (7) were developed to calculate the net irrigation water (m^3/fed/irrig.) and soil moisture content using the measured soil characteristics at different soil moisture depletion percentage (30, 40, and 50%) of available water. Multiple regression equations in Table (7) indicated that the relations between net irrigation water, soil moisture content and measured soil properties were highly significant ($R^2 > 0.91^{**}$).

Table (8) illustrates the values of soil moister content and soil moisture tensions which were obtained from the relation ($\theta = a\ h^{-b}$, where: a=100.6972, b=0.1523 and R^2=0.998) as well as net irrigation water (m^3/fed/irrig.) at different percentage (70, 60, and 50%) from available water.

Data in Tables 7 and 8 help workers in agriculture field to calculate irrigation water quantity using some soil routine analysis by simple calculation methods such as soil moisture content or soil moisture tension at different depletable fraction of the available water.

Table (7). The regression equation and correlation coefficient between net irrigation water (m^3/fed/irrig) and soil moisture content at different soil moisture depletion percentage (SMD%) of AW and some soil properties in alluvial soils

SMD(%)	Empirical equation	R^2
SMD (30%)	NIW= (-8.5486-0.3317 sand% +0.3265 silt% +0.1508 clay%+4.5583 BD+0.1530 SAR) x area x root depth	0.91**
	θ =-92.9653-1.2475 sand%+1.3393 silt%+0.9185 clay% +54.8745 BD +0.5645 SAR	0.94**
SMD (40%)	NIW= (-11.3981-0.4482 sand% +0.4353 silt% +0.2012 clay%+6.0778 BD +0.2040 SAR) x area x root depth	0.91**
	θ =10.0881-0.6682 sand%+0.6418 silt%+0.557 clay% -9.639 BD +0.5508 SAR	0.96**
SMD (50%)	NIW= (-14.2476-0.5528 sand% +0.5442 silt% +0.2514 clay%+7.5972 BD +0.255 SAR) x area x root depth	0.91**
	θ =12.9376-0.5577sand%+0.5329 silt%+0.5067 clay% -11.1584 BD +0.4998 SAR	0.96**

Table (8). Calculation of soil moisture content (θ), soil moisture tensions (h) and net irrigation water (NIW) at 70, 60 and 50% from available water in alluvial soils

Available water	θ (%)	h (bar)	NIW (m^3/fed/irrig.)
70%	34.70	1.081	221
60%	32.19	1.787	295
50%	30.68	3.045	369

$\theta = a\,h^{-b}$, where: a=100.6972, b=0.1523

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الملخص العربى

التنبؤ بكمية مياه الرى، المحتوى الرطوبى والتوزيع الحجمى للمسام فى بعض الأراضى الرسوبية المصرية مستخدما التحليل الروتينى للأراضى

رشدي واصف الجندي[1] ، رجب إسماعيل فايد[2]

[1] قسم بحوث الأراضي والمياه- شعبة تطبيقات النظائر المشعة- مركز البحوث النووية- هيئة الطاقة الذرية- القاهرة

[2] معمل بحوث الأراضى الملحية والقلوية بالإسكندرية - معهد بحوث الأراضي و المياه والبيئة- مركز البحوث الزراعية- مصر

تهدف هذه الدراسة الى استخدام معادلات الارتداد البسيط والمتعدد للتنبؤ بالمحتوى الرطوبى ، التوزيع الحجمى للمسام وجدولة مياه الرى (كمتغيرات تابعة) بواسطة استخدام التحليلات الارضية الروتنية الممثلة فى نسب الرمل والسلت والطين وكذلك الكثافة الظاهرية ونسبة الصوديوم المدمص(SAR) (كمتغيرات مستقلة). لذلك تم اختيار خمسة وعشرين قطاعا أرضيا لتمثل الأراضى الرسوبية فى دلتا النيل عند محافظة البحيرة. تم جمع خمسا وسبعين عينة أرض (ثلاث أفاق لكل قطاع)

على أعماق (0-20، 20-40، 40-70 سم) لتقدير بعض الخواص الفيزيائية، الهيدروفيزيائية والكيميائية للأرض.

أظهرت معادلات الارتداد المتعدد وجود ارتباط معنوى عالى (R^2>88**) بين المحتوى الرطوبى عند الشدود المختلفة وبين خصائص التربة (متجمعة). كذلك أظهرت معادلات الارتداد البسيط أنه يوجد ارتباط معنوى سالب بين كل من المحتوى الرطوبى عند الضغوط المنخفضة (0.1 و 0.33 بار) ومحتواها من الرمل والكثافة الظاهرية، بينما كان موجب مع الطين . عند الضغوط المرتفعة (3 و 15بار) كان معامل الارتباط للمحتوى الرطوبى معنوى موجب مع %الطين و SAR وسالب مع %للسلت. لذلك يعتبر محتوى الأرض من الطين عامل مؤثر فى محتواها الرطوبى عند جميع الضغوط.

من حيث التوزيع الحجمى للمسام وجد أن مقدار المسام المسؤلة عن مسك الماء (WHP) أعلى من المسام الكلية المسؤلة عن الصرف (VDP). كما أظهرت معادلات الارتداد البسيط أنه توجد علاقة معنوية موجبة (R^2=0.88**) بين محتوى التربة من الرمل ومسام الصرف السريع (QDP) بينما كانت هذه العلاقة معنوية سالبة مع مسام حفظ الماء (WHP). المسام الشعرية الدقيقة (FCP) ترتبط بقيم معنوية موجبة مع محتوى التربة من الطين وكذلك نسبة الصوديوم المدمص (SAR).

تم عمل نماذج للتنبؤ بصافى كميات المياه اللازمة للرى (م^3/فدان/الرية) وكذلك المحتوى الرطوبى فى التربة عند نسب70، 60 و 50% من الماء الميسر للنبات وذلك باستخدام قيم بعض خصائص التربة ووجد أن معاملات الارتباط عالية (R^2> 0.91**) . وكذلك تم التنبؤ بالشد الرطوبى كدالة للمحتوى الرطوبى وذلك من العلاقة ($\theta = a\ h^{-b}$) وكان معامل الارتباط عالى جدا (R^2=0.996**).