

Assessment of Infiltration Rate Parameters for Water Management in Reclaimed Area.

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Abstract: The rapid progress and development of agriculture in Egypt aim towards the expansion of agricultural land, the utilization of all water sources and the increase in crop production to meet the needs of rapidly increasing population. Water is the most triggering factor in this concern. This study was carried out in east of the Nile Delta, the area under study located between Latitudes 30° 59' and 31° 10' N and Longitudes 32° 10' to 32° 27' E. The area divided into two transects, the first transect was extended from El-Tina plain, south Bur Said (North direction) to behind El-Salam canal, north Ismailia (South direction) along 36 Km, and the second transect was started from the same point and extended from west to east direction (vertically on the Suez Canal, along 20 Km). The distance between each infiltration test was 2 Km (18 tests in the first transect and 10 tests in the second transect). The area under study is characterized by loam and clay loam textured. The obtained results reveal that the correlation coefficient between infiltration parameter (B) and the percent of clay and silt plus clay were negative and highly significant, while the correlation was positive and highly significant with total sand. In contrast, the reverse was true with parameter (-n) in the same sequences. Also, the values of Infiltration rate varied from 0.25 to 8.33 cm/hr, in the first transect and from 0.17 to 4.36 cm/hr in the second transect. The area has divided into three main categories by using Kriging techniques, moderately slow (0.17 to 2.0 cm/hr), moderate (2.0 to 6.0 cm/hr) and moderately rapid (6.0 to 8.33 cm/hr).

Key words: infiltration parameters, infiltration rate, water management Kriging techniques.

INTRODUCTION

Most of Egypt's land is in semi-arid and arid climate regions where water is one of the key factors limiting agricultural proper management of water is one of the key factors to increase agricultural production, so water is one of the main factors limiting agricultural development. Note worthy is that Nile water is not enough to confront the expansion of land, especially in the remote desert areas in Egypt, Abdel Samie^[1].

Therefore the horizontal and vertical agricultural in Egypt depend mainly on the rational use of the available water resources. The quantity of consumed water in irrigated agricultural or the depletion of water resources within a hydrologic basin is affected by the type of irrigation and the crop.

In dry land agricultural and or arid and semi-arid conditions, the main objective of water management is usually to capture and save the natural precipitation within the soil for crop production, and to reduce the evaporation rate. In irrigated agriculture water is applied in various methods through many different irrigation systems. In this respect infiltration data is a fundamental prerequisite for designing, evaluating and managing irrigation systems. Thus, infiltration is a very important key process in the management of water resources for crop production in both irrigated and dry land agriculture.

Infiltration rates on a field may vary from very low to very high in the soil characteristics which control infiltration characteristics; nevertheless, the accurate evaluation and consequently, modeling and application of infiltration data may be influenced significantly by the extent and nature of soil variability, thus the variability of the approximated steady-state infiltration rate was evaluated using the classical statistical and geostatistical techniques. Therefore, the studies on soil variability have been reflected the work done in this area, Jensen *et.al.*^[2], Warrick and Nielsen^[3], Tabor *et.al.*^[4], Zhang *et.al.*^[5], Dhillon *et.al.*^[6], Cressie and Horton^[7], Gupta *et.al.*^[8], Logsdon and Jaynes^[9], Humphrey and Fisher^[10], Atkinson and Tate^[11], Chiles and Delfiner^[12], Goovaerts^[13,14], Hoosbeek and Bouma^[15], Liu^[16] and Sobieraj *et.al.*^[17].

Infiltration is a very important process in the management of water resources for crop production in both irrigated and dry land agriculture. In irrigated agriculture, it is a fundamental prerequisite for designing, evaluating and managing irrigation systems. Likewise, under dry-farming conditions, knowledge of infiltration is needed to model, evaluate and design management technologies to conserve soil and water resources. Nevertheless, the accurate evaluation and consequently, modeling and application of infiltration data may be influenced significantly by the extent and nature of soil variability. Thereafter the variability of

the approximated steady-state infiltration rate was evaluated using the classical statistical and geostatistical techniques.

The objective of this study was measurement the infiltration rate and infiltration parameters to divide the area under study into zones with homogenous infiltration properties so that a management program could be operated for the purpose of increasing irrigation water application efficiency and nutrient losses through deep percolation.

MATERIAL AND METHODS

The current investigation was carried out in east of the Nile Delta, the area Under study located between Latitudes 30° 59' and 31° 10' N and Longitudes 32° 10' to 32° 27' E. The area divided into two transects, the direction of the first transect was extended from El-Tina plain, south Burt Said (North direction) to behind El-Salam canal, north Ismailia (South direction) along 36 Km, and the direction of the Second transect was started from the same point (the end point of the first transect at North Ismailia, it's consider the first point of the second transect,) and extended from West to East direction (vertically on the Suez Canal, along 20 Km). The distance between each Infiltration test was 2 Km (18 tests in the first transect and 10 tests in the second transect).

At each test site, soil samples collected from three soil layers 0-25, 25-50, and 50-90 cm. All 84 samples were analyzed for percent clay, silt and sand by survey laboratory method manual, USDA, [18], water content at 0.1 and 15 bar, according, Klute [19]. Undisturbed soil samples were taken to determine soil bulk density, Blake and Hartge [20].

Infiltration rate was determined under constant head of water, using double ring infiltrometer as described by Klute [19]. The cumulative depth of infiltrated water D in cm as a function of time t was approximated by the Kostiakov's equation [21]:

$$D = Bt^n \quad i = Bnt^{n-1}$$

Where, i is the infiltration rate, t is time, and parameters B and n are empirical constant. These two constants find by plotting log D against log t, then log B and n are calculated as the intercept and slope, respectively.

Statistical Methods: Classical statistics was used to calculate the mean, standard deviation, coefficient of variation, coefficient of skewness and coefficient of Kurtosis, according to Snedecor and Cochran [22].

Kriging: Kriging method was used for interpolating or estimating the values of a soil property at unsampled location and find out isoline maps for either the

determined values or the estimated variance of each of the studied properties. In the current study iso-character lines maps of the actual data for infiltration rate and infiltration parameters: (B and-n) along the South-North, and West-East direction were drawn using computer program (Geo-eas; Geostatistical Environmental Assessment Software, Las Vegas, Nevada, USA.), Davis [23], Warrick *et.al.* [24] and Vieira *et.al.* [25].

RESULTS AND DISCUSSION

Site Description: The current area is located to the East of Nile Delta between Latitudes 30° 59' and 31° 10' N and Longitudes 32° 10' to 32° 27' E. the area is characterized by long hot rainless summer and short mild rainy winter. Climatic normal reveal that summer temp, ranges from 30 to 37 C° while winter temperature ranges from 7.5 to 15 C°. Rainfall is very scarce (40 – 60 mm/year). Relative humidity ranges from 50 to 70%. Wind direction is mostly NW and wind velocity is slow to moderate (7 – 21 Km/h). Duration sunshine is 6 to 12.5 h/day and evapotranspiration rate is moderate (1500 – 2000 mm/year).

Classical Statistical: The data in table (1) and Figures (1 a, b and c) clearly show that the values of infiltration rate widely varied between 0.17 to 8.33 cm/hr, and classified between slow to moderately rapid. Undoubtedly, this behavior is due to the heterogeneous conditions in soil layers. Moreover, the presence of clay layers slightly impeded the downward water movement owing to their lower macropores and the correlation between clay content and intake rate is considered highly significant negative correlation, Talaat [26].

Data in tables (2, 3 and 4) reveal that the area under study had an average texture classification of sandy loam, loam and clay loam in the major portions of the field. The values of coarse sand and fine Sand percentages in the first soil layer (0 – 25 cm). Were appreciably higher than in the 2nd soil layer (25 - 50 cm) and 3rd soil layer (50 – 90 cm).

The coefficients of skewness for coarse sand in the all soil layers were very small and negative, indicating that the distribution is slightly skewed to the left, but the values were positive for the fine sand percentage, and the distribution is slightly skewed to the right.

The coefficient of variance elucidate that the variability of coarse sand along the three soil layers were higher than those of fine sand content, also the variability in the first soil layer is low.

Moreover, the small values of the coefficient of kurtosis along three soil layers for coarse sand and fine sand content confirm the distribution of sand content slightly asymmetric.

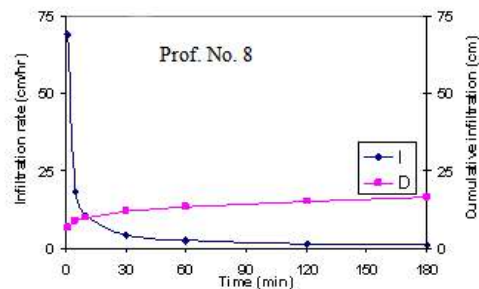
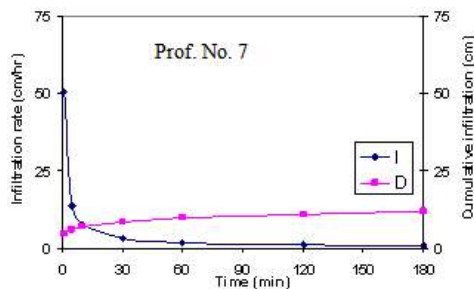
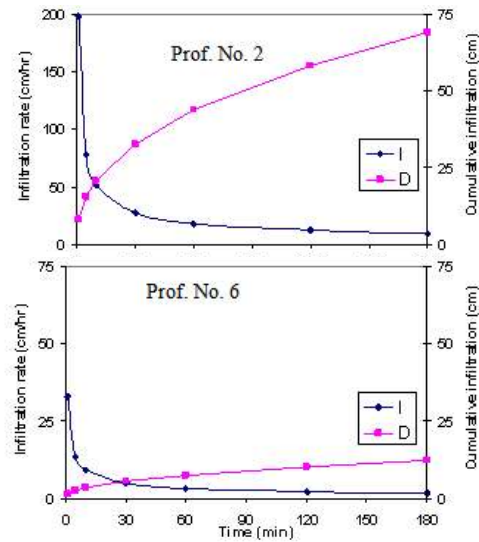
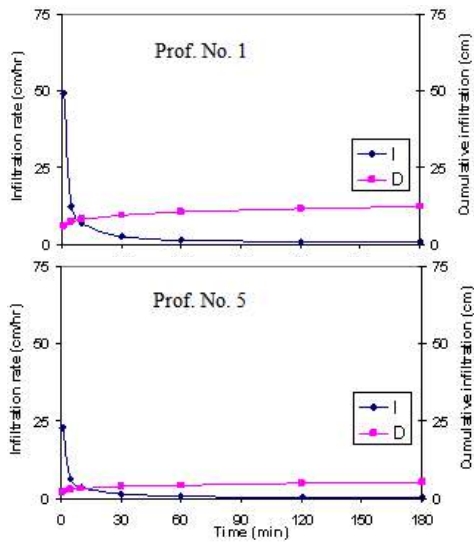
Table 1: Infiltration rate parameters of different soil profiles.

Location NO.	Equations	Parameters			Initial infil	I.R cm\hr	Class of infiltr. rate-
		r	B	- n			
1	$D = 5.9362 * t^{0.1374}$	0.92484					M.S
	$I = 48.924 * t^{-0.86264}$		48.92	-0.86	48.92	0.55	
2	$D = 7.9163 * t^{0.4171}$	0.97168					M.
	$I = 98.924 * t^{-0.5829}$		98.92	-0.58	98.92	4.79	
3	$D = 1.1734 * t^{0.57299}$	0.99568					M.
	$I = 40.3414 * t^{-0.4270}$		40.34	-0.43	40.34	4.39	
4	$D = 2.1663 * t^{0.5735}$	0.97341					M.R
	$I = 74.541 * t^{-0.4265}$		74.54	-0.43	74.54	8.14	
5	$D = 2.01133 * t^{0.1880099}$	0.9247					S.
	$I = 22.6887 * t^{-0.81199}$		22.69	-0.81	22.69	0.33	
6	$D = 1.2557 * t^{0.43743}$	0.93847					M.S
	$I = 32.95690 * t^{-0.56257}$		32.96	-0.56	32.96	1.77	
7	$D = 4.404 * t^{0.19129}$	0.98228					M.S
	$I = 50.546 * t^{-0.80871}$		50.55	-0.81	50.55	0.76	
8	$D = 6.5677 * t^{0.17552}$	0.97177					M.S
	$I = 69.166 * t^{-0.8245}$		69.17	-0.82	69.17	0.96	
9	$D = 2.16318 * t^{0.19224}$	0.94987					S.
	$I = 24.951 * t^{-0.80776}$		24.95	-0.81	24.95	0.38	
10	$D = 3.5802 * t^{0.32918}$	0.96342					M.
	$I = 70.7114 * t^{-0.67082}$		70.71	-0.67	70.71	2.17	
11	$D = 1.49433 * t^{0.24774}$	0.99455					S.
	$I = 22.2123 * t^{-0.75226}$		22.21	-0.75	22.21	0.45	
12	$D = 5.17995 * t^{0.128622}$	0.88405					S.
	$I = 39.975 * t^{-0.87138}$		39.98	-0.87	39.98	0.43	
13	$D = 2.1747 * t^{0.39016}$	0.91118					M.
	$I = 50.90886 * t^{-0.86264}$		50.91	-0.61	50.91	2.15	
14	$D = 3.7021 * t^{0.39985}$	0.89912					M.
	$I = 88.8159 * t^{-0.60015}$		88.82	-0.60	88.82	3.93	
15	$D = 2.051187 * t^{0.5591}$	0.90425					MR
	$I = 68.81 * t^{-0.4409}$		68.81	-0.44	68.81	6.97	
16	$D = 2.62104 * t^{0.54958}$	0.95425					MR
	$I = 86.4283 * t^{-0.45042}$		86.43	-0.45	86.43	8.33	
17	$D = 4.47376 * t^{0.10017}$	0.93335					S.
	$I = 26.8882 * t^{-0.89983}$		26.89	-0.90	26.89	0.25	
18	$D = 10.9672 * t^{0.054226}$	0.95821					S.
	$I = 35.6822 * t^{-0.945774}$		35.68	-0.95	35.68	0.26	
19	$D = 2.7913 * t^{0.31477}$	0.91152					MS
	$I = 52.7176 * t^{-0.68523}$		52.72	-0.69	52.72	1.50	

Table 1: continue

20	$D = 0.948 * t^{0.279712}$	0.96625				S.
	$I = 15.9102 * t^{-0.72029}$		15.91	-0.72	15.91	0.38
21	$D = 2.61733 * t^{0.10864}$	0.96253				S.
	$I = 17.0608 * t^{-0.89136}$		17.06	-0.89	17.06	0.17
22	$D = 5.34482 * t^{0.110667}$	0.85571				S.
	$I = 35.4896 * t^{-0.88933}$		35.49	-0.89	35.49	0.35
23	$D = 4.21669 * t^{0.1824}$	0.89814				MS
	$I = 46.1475 * t^{-0.81765}$		46.15	-0.82	46.15	0.66
24	$D = 3.0665 * t^{0.16343}$	0.79895				S.
	$I = 30.0685 * t^{-0.83657}$		30.07	-0.84	30.07	0.39
25	$D = 4.13761 * t^{0.181552}$	0.92589				MS
	$I = 45.0715 * t^{-0.81845}$		45.07	-0.82	45.07	0.64
26	$D = 4.3779 * t^{0.111172}$	0.99264				S.
	$I = 29.202 * t^{-0.8888}$		29.20	-0.89	29.20	0.29
27	$D = 1.51858 * t^{0.4328}$	0.94485				MS
	$I = 39.434 * t^{-0.5672}$		39.43	-0.57	39.43	2.07
28	$D = 1.3342 * t^{0.56213}$	0.96676				M.
	$I = 44.999 * t^{-0.43787}$		44.99	-0.44	44.99	4.63

M.R: Moderately rapid M: Moderate MS: Moderately slow IR: Infiltration rate S: Slow



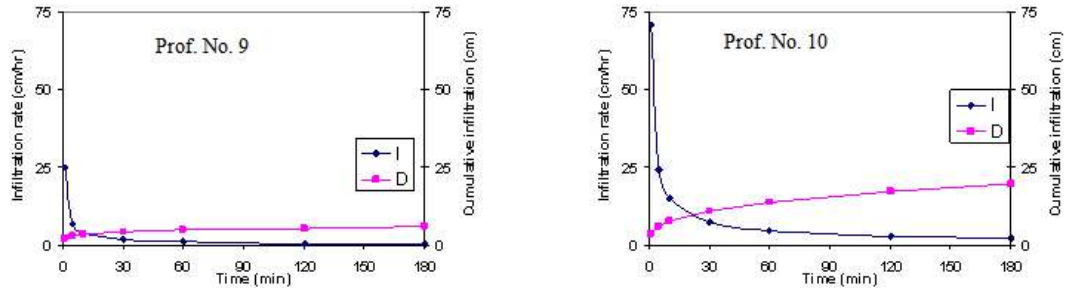
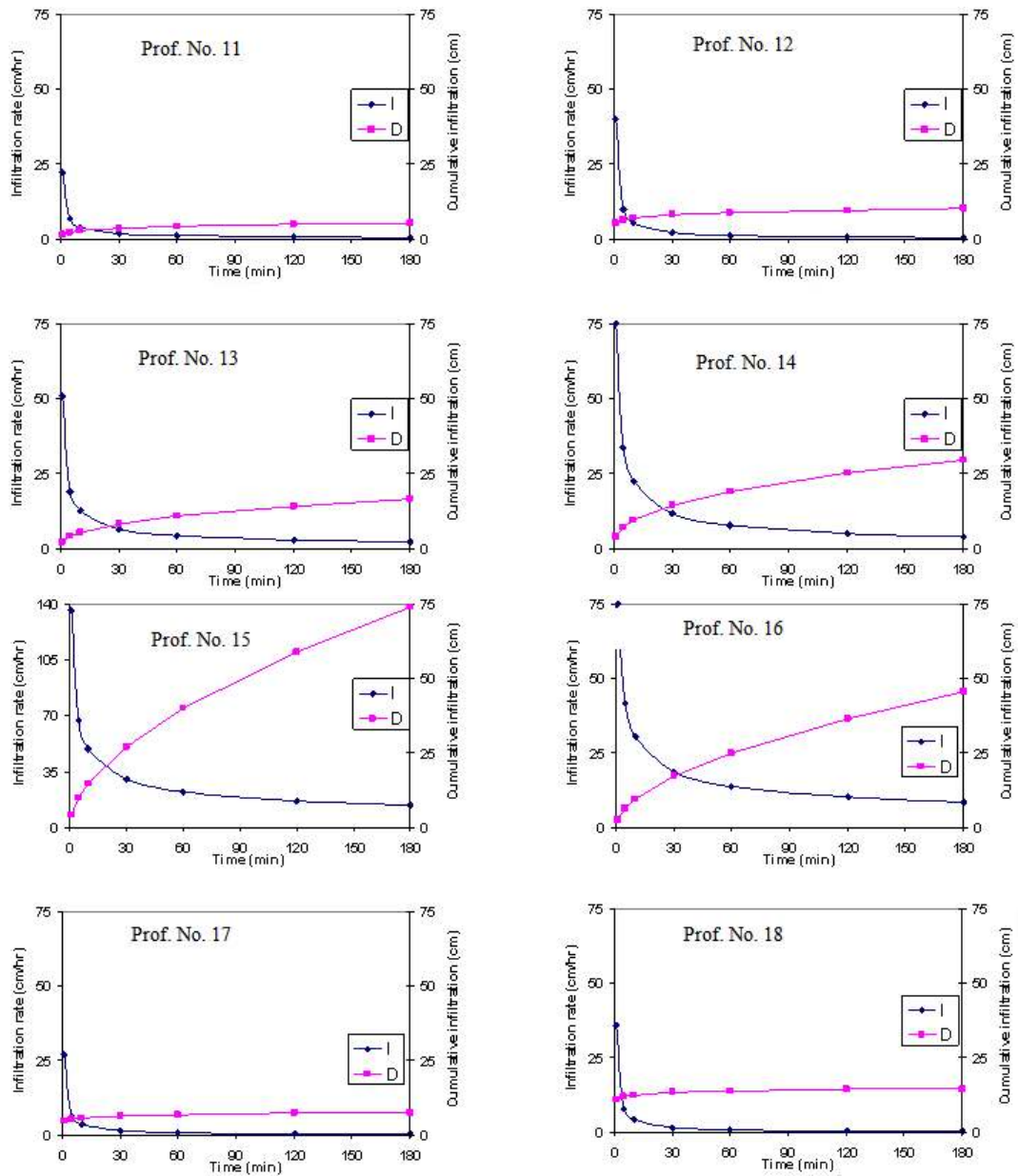


Fig. (1a): Instantaneous and Cumulative infiltration in the studied area.



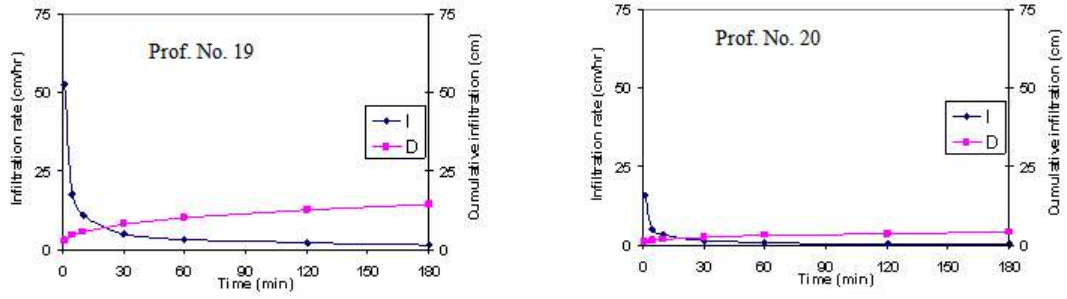


Fig. (1b): Instantaneous and Cumulative infiltration in the studied area.

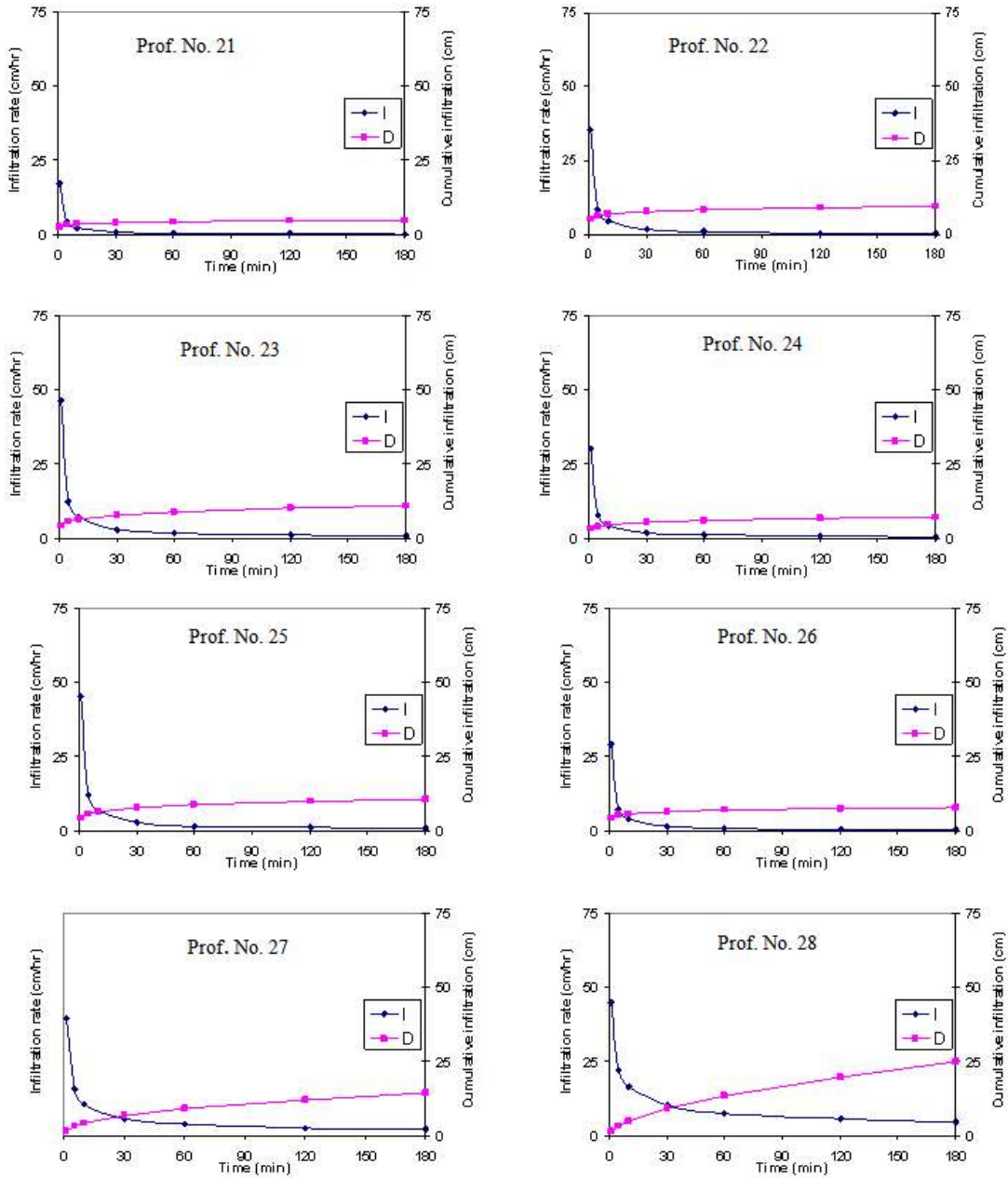


Fig. (1c): Instantaneous and Cumulative infiltration in the studied area.

Table 2: Summary of some classical statistical of soil physical properties in the first soil layer (0-25cm)

Normal. distribution	C.sand%	F.sand%	Silt%	Clay%	pb(g/cm ³)	moisture content% at		Avail.w %
						0.1bar	15bar	
Max.	16.56	47.11	50.09	42.29	1.31	35.66	17.02	18.79
Min.	0.83	9.88	17.01	16.21	1.14	20.88	12.00	7.89
Mean	8.70	26.14	34.21	30.95	1.22	27.30	14.25	13.06
S.D	3.44	9.30	10.09	7.33	0.05	4.09	1.27	3.07
C.V%	39.54	35.58	29.49	23.68	4.09	14.98	8.91	23.51
Kurt.	0.52	-0.20	-1.13	-0.40	-0.83	-0.45	-0.10	-0.56
Skew.	-0.49	0.37	-0.17	-0.51	0.28	0.33	0.52	0.31

Table 3: Summary of some classical statistical of soil physical properties in the first soil layer (25-50cm)

Normal. distribution	C.sand%	F.sand%	Silt%	Clay%	pb(g/cm ³)	moisture content% at		Avail.w %
						0.1bar	15bar	
Max.	13.30	40.34	50.22	49.11	1.33	37.06	18.32	19.5
Min.	0.12	6.33	19.51	17.22	1.10	19.88	12.50	7.16
Mean	6.98	22.16	34.35	36.37	1.19	30.27	15.58	14.71
S.D	4.03	9.25	8.31	9.16	0.07	4.70	1.48	3.56
C.V%	57.74	41.74	24.2	25.19	5.88	15.53	9.50	24.20
Kurt.	-1.48	-0.53	-0.74	0.03	-0.91	0.032	0.04	-0.14
Skew.	-0.10	0.44	0.41	-0.97	0.37	-0.87	-0.42	-0.78

• C.sand: Coarse sand F.sand: Fine sand b: Bulk density g/cm³ Avail.w: Available water

Table 4: Summary of some classical statistical of soil physical properties in the first soil layer (50-90cm)

Normal. distribution	C.sand%	F.sand%	Silt%	Clay%	pb(g/cm ³)	moisture content% at		Avail.w %
						0.1bar	15bar	
Max.	12.69	40.11	44.72	51.92	1.33	38.07	18.55	20.14
Min.	0.59	8	18.99	16.99	1.01	19.54	11.05	7.77
Mean	6.73	22.22	32.57	38.1	1.17	31.10	15.71	15.39
S.D	3.81	9.05	7.95	9.07	0.09	5.09	1.83	3.57
C.V%	56.61	40.73	24.41	23.81	7.69	16.37	35.95	23.2
Kurt.	-1.45	0.01	-0.92	0.79	-0.73	0.61	0.68	-0.01
Skew.	-0.04	0.92	-0.36	-1.11	0.16	-1.01	-0.82	-0.85

• C.sand: Coarse sand F.sand: Fine sand b: Bulk density g/cm³ Avail.w: Available water

These findings are concomitant with those reported by Warrick and Nielsen [3]. Also, in the same table data show that the maximum value of clay content is higher in the 3rd soil layer (50 – 90 cm) 51.92% than those obtained in the 2nd and 1st soil layers, while the opposite was true for silt content. Also, the variability of clay content along the three soil layers was lower (23.68 – 25.19%) than silt content (24.2 – 29.49%). On the other hand, data clearly that the coefficient of

kurtosis and skewness for silt and clay content, more or less similar in all soil layers and the distribution of silt and clay content indicates that such distribution is slightly skewed to the left.

The results in the same tables (2, 3 and 4) elucidates that the mean values of soil water content (field capacity) along the three soil layers vary between 27.3 to 31.10%, the highest value is found in the 3rd soil layer followed by the 2nd soil layer one, while the

1st soil layer have the lowest mean value of FC content. But the values of mean for (welting point WP) varied between 14.25 to 15.71%, the magnitudes of SD and CV were relatively low compared to the other parameters coarse sand, fine sand, silt and clay content. The coefficient of skewness and kurtosis for FC and WP content along the three soil layers are very small and almost negative which indicating that their distribution is slightly skewed to the left, therefore the distribution of FC and WP along the three soil layers fits the normal distribution. Noted that the coefficient of kurtosis for all parameters along the three soil layers were displayed a negative which indicating that the types of distribution were flat topped.

The classical statistical parameters of the steady state or basic infiltration rate (cm/hr) of area under study, the data in table (5) demonstrate the values of mean, maximum and minimum were 2.21, 8.33 and 0.17 cm/hr respectively. The coefficient of variation for the basic infiltration rate was 112.22% indicating high variation, this behavior could be explained on the basis that soil infiltration rate is controlled by the resultant of various factors including pore size distribution, particle size distribution, percent gravel soil moisture retention capacity and soil hydraulic conductivity, Nielsen *et al.* [27] and Warrick and Nielsen [3]. The

coefficients of skewness indicated that the distribution of the steady-state infiltration data is significantly skewed to the right. Meanwhile, the coefficient of kurtosis of such data is relatively high and positive which indicating high-peak (Leptokurtic) distribution.

The classical statistical describe the distribution of parameters (B) and (-n), the investigated were given in table (5). From this table it is evident that the values of maximum, minimum and mean for the parameter B was 98.92, 15.91 and 47.48, while for -n parameter were 0.95, 0.43 and 0.71 respectively.

On the other hand, SD and CV values were higher for parameter (B) 22.39 and 47.16 than the parameter (-n) 0.17 and 23.94, in the same sequences; these results might be attributed to the parameter B is affected by hydraulic conductivity in soil. The coefficient of kurtosis reveals that the distribution of B and -n are flat-topped but skewed to the left for parameter -n.

The statistical relation ship between each of the above mentioned soil physical properties i.e. Total sand %, clay content, silt plus clay % and Bulk densities and infiltration parameter (B). Data in table (6) declared that, the simple correlation coefficient between

Table 5: Summary of some classical statistical of infiltration rate parameters.

Normal.distribution	B	n-	I.R(cm/hr)
Max.	98.92	0.95	8.33
Min.	15.91	0.43	0.17
Mean	47.48	0.71	2.21
S.D	22.39	0.17	2.48
C.V%	47.16	23.94	112.22
Kurt.	-0.15	-1.15	1.19
Skew.	0.77	-0.5	1.49
S.D	Standard deviation		
C.V%	Coefficient of variation		
Kurt.	Coefficient of Kurtosis		
Skew.	Coefficient of Skewness		

Table 6: Correlation Coefficient, Coefficient of determination (C.D) , regression equation for the relation between infiltration parameter (B) and the studied soil variables (Xi).

Soil Factors.	Type of relation	Correlation Coefficient	The regression equation	C.D
T.sand % X1	Yx1	0.6758*	Y =2.6083 x + 34.364	45.67
Clay % X2	Yx2	0.74833**	Y =-1.961 x + 89.89	55.99
Silt plus Clay % X3	Yx3	0.6535*	Y =-1.01 x + 99.41	42.71
Bulk density % X4	Yx4	0.5643*	Y = 145.11 x -126.22	31.84

infiltration parameter (B) and each of clay % and silt plus clay were negative and highly significant ($r = 0.74833$ and $r = 0.6545$ in the same sequences, respectively). Whereas, it was positively correlated at significant level with T.sand % ($r= 0.6758$) and bulk density g/cm^3 ($r= 0.5643$), the obtained regression equation is a linear function.

In contrast, the reverse was true with infiltration parameter (-n) and the same soil fractions. The obtained results in table (7) showed that less significant correlation between (-n) and the percent of T.sand % ($r= 0.5779$) and bulk density g/cm^3 ($r=0.5535$) the correlation is negative, but its highly significant positive correlation between infiltration parameter (-n) and clay content ($r=0.8787$) and silt plus clay ($r=0.6775$).Also the obtained regression equation is a linear function.

This behavior generally indicates, the percent of clay, silt and silt plus clay are the most important factors affecting infiltration rate. Also, the results declared that the design and management of farms should be depending on infiltration parameter (-n). So irrigation design should be monitored more carefully to decrease volumes of nutrients moving beyond the root zone and increase water application efficiency.

Kriging: Kriging used to estimate the values of the variable at any unsampled locations, and can be used to make iso-character lines map, the method provides measures of the errors and the change in the variable according to the geographic arrangement of the samples, Davis ^[24].

In the current study, iso-character lines maps or the actual data of steady-state infiltration rate and parameters B and n along the North-South and West-East directions were drawn using computer program (Geo-eas; Geostatistical Environmental Assessment Software, Las Vegas, Nevada, U.S.A).

Fig. (2) Show that the value of parameter B was divided the area into three zones, the first zone had low values (15-45.0) and occupy in the south west corner and some isolated portions in the North East side, the second zone had moderately values (45 – 75) and exists in the major area, especially in the North East and east corner. Nevertheless, the third zone had a high values (> 75.0) and exists in the very small portions towards the North and east corner.

Concerning, Fig. (3) shows the iso -n parameter, also the are divided into three zones according values of (-n) values, the low values (- 0.95 to - 0.75) were displayed in the south direction and some small portion in the north corner (first zone), the highest values $> - 0.55$ (third zone) were very small area about 1.5% from total area and exists in north and east corners, while the remain area (second zone) was displayed a moderately values, from above mentioned that values of parameter -n corresponding with infiltration rate values and tends to moderate variance.

In case of Fig. (4) shows the iso-infiltration rate lines map of the steady-state infiltration rate values divided the area into four zones, the first zone had a low values (0.17 to 2.0 cm/hr) displayed a moderately slow and existing through the center from west to east direction and small portion in the north-east direction, this area is about 30% from the total area, while the areas had a highest values of infiltration rates 6.0 to 8.0 cm/hr and > 8.0 cm/hr were occupy in two zones and occur in isolated very small spots in the northern and easting parts of the studied area, the percentage of this area is 1.29% from the total area. The map also points out that the infiltration rate had moderately values, second zone 2.0 to 6.0 cm/hr exist in the remain area, the percentage of this area is about 68.67% from the total area.

Table 7: Correlation Coefficient, Coefficient of determination (C.D) , regression equation for the relation between infiltration parameter (-n) and the studied soil variables (Xi).

Soil Factors.	Type of relation	Correlation Coefficient	The regression equation	C.D
T.sand % X1	Yx1	0.5779*	$Y = -0.266 x + 1.324$	33.39
Clay % X2	Yx2	0.8787**	$Y = 0.990.84 x + 5.52$	77.21
Silt plus Clay % X3	Yx3	0.6775*	$Y = 1.24 x + 3.21$	45.90
Bulk density % X4	Yx4	0.5535	$Y = -0.9796 x + 1.88$	30.64

* Significant at 5%
 ** Significant at 1%

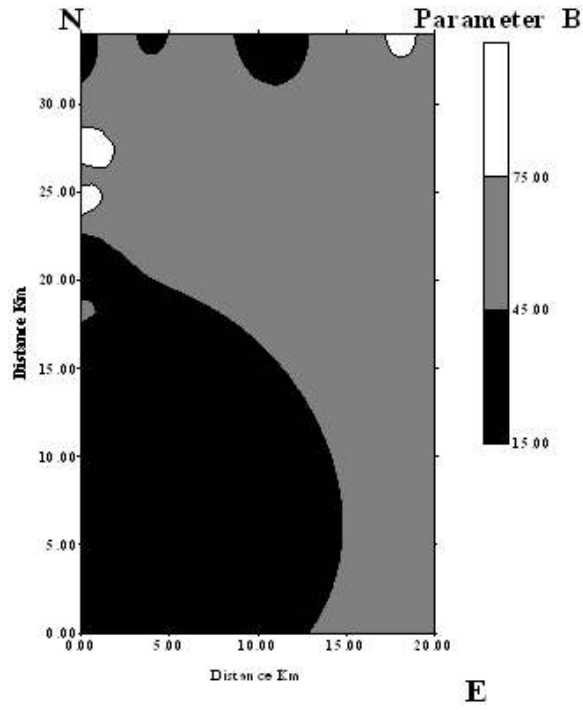


Fig. 2: Spatial pattern in parameter B

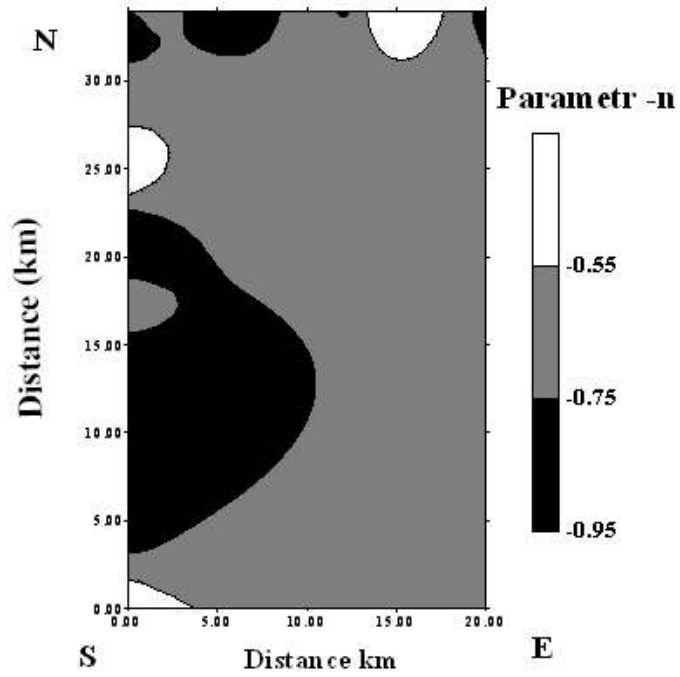


Fig. 3: Spatial pattern in parameter n

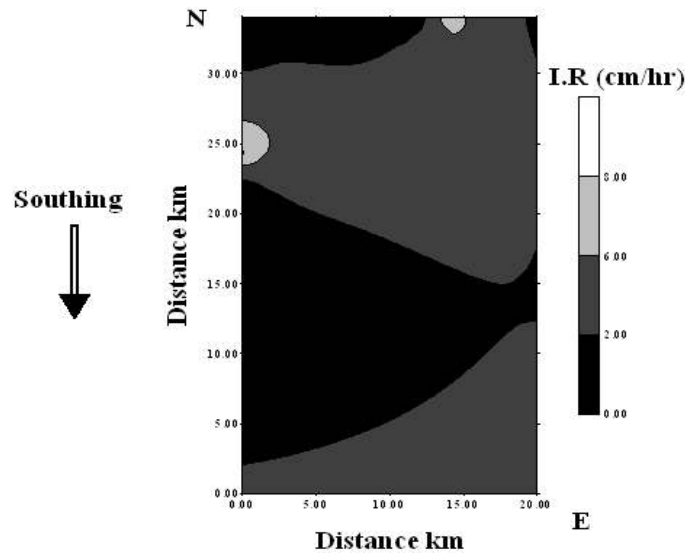


Fig. 4: Location of infiltration zones

Generally, the South West side was occupied by moderately slow infiltration rate zones Fig. (4). Therefore, irrigation should be monitored more carefully and suitable for surface irrigation system to decrease volumes of water and mobile nutrients (i.e. nitrate). While, the two zones in the North and East side characterized by high infiltration rate 6.0 to 8.0 cm/hr and > 8.0 cm/hr and coincide in the same area, in this regions, since use of surface irrigation techniques (drip irrigation) could be the suitable system for this area to avoid deep percolation and seepage of irrigation water.

Regarding the moderately basic infiltration rate in the second zone (2.0 to 6.0 cm/hr), about 68% from total area, it is suitable for modifying surface and subsurface irrigation system. Therefore, the contour maps obtained in this study can provide useful information for designing area and irrigation management and achieved high application efficiency and uniform water fulfilling waters distribution by reducing deep percolation and runoff while fulfilling water requirements. Proper management not only saves water and energy but reduces environmental problems caused by an rational use of irrigation water.

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