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REVIEW ARTICLE

VALIDATION AND UTILIZATION OF THE SOIL CONSERVATION SERVICES (SCS) FOR FURROW IRRIGATION DESIGN METHOD

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Soil type.

ABSTRACT

The main objective of this work is to validate and utilize USDA-SCS furrow irrigation design method. Soil data were collected from 22 locations in Nile Delta to get the soil texture and infiltration functions. According to the collected data, the Egyptian soils were classified into three groups: clay, clay loam, and sandy loam. Linear regression analysis was used to determine the average infiltration constants for each group. It was found that the infiltration constant C= 7 for all families must be adjusted in order to use the USDA-SCS intake families for Egyptian soils, the constant 'C' in the infiltration equation is taken C =4 for clay soil, C =11 for clay loam soil, and C = 17 for sandy loam soil. The SCS method and volume balance equations were programmed in MATLAB computer language (EGY) to design and evaluate furrow irrigation. The program output was validated using field experiments data conducted at the Etay El-baroud ARC, Behera Governorate. According to results, SCS model and Volume Balance can be used for determining infiltration depths and advance times along furrow length for the three groups of the Egyptian soils. The field experiments and volume balance results are very close to each other. However, Experimental results are different from SCS model, but using a coefficient made close agreement. A sensitivity analysis was performed using the EGY model to study the effects of varying Manning coefficient, land slope, inflow rate cutoff time length of run, and soil type on the performance parameters.

INTRODUCTION

Surface irrigation referred to as "flood irrigation", the essential feature of this irrigation system is that water is applied at a specific location and allowed to flow freely over the field surface and thereby apply and distribute the necessary water to refill the crop root zone. Surface irrigation has evolved into an extensive array of configurations which can broadly be classified as: (1) basin irrigation, (2) border irrigation, (3) furrow irrigation, and (4) wild flooding. The distinction between the various classifications is often subjective. For example, a basin or border system may be furrowed. Wild flooding is a catch-all category for the situations where water is simply allowed to flow onto an area without any attempt to regulate the application or its uniformity. Primary goal of efficient surface irrigation is to complete the advance phase as quickly as possible without erosion. Because of the advance time, difference in opportunity times may exist between the upper and lower ends of the fields that may cause non-uniformity in the depth of water infiltrated along the furrow length. Increasing furrow inflow rate, reducing the length of run and improving the slope of the field can reduce the differences in advance time and help improve the performance of an irrigation system. Many commercial systems have been found to be operating with significantly lower and highly variable efficiencies. Previous research in the sugar industry (Raine and Bakker, 1996) found application efficiencies for individual irrigation ranging from 14 to 90%. While well design and managed surface irrigation systems may have application efficiencies of up to 90% (Anthony, 1995). Furrow irrigation method principal of applying water at a specific rate of flow into spaced small channels, these channels convey the water down or across the slope of the field to infiltrates in the soil both vertically and horizontally (Hornbuckle, 1999). How long water must be applied in the furrows depends on the volume of water required to fill the soil to the desired application depth, according to the intake rate of the soil, and the spacing of the furrows (Walker, 1998). So water applied until the desired application depth and lateral penetration are obtained.

Main objectives: Model the (SCS) soil conservation service furrow irrigation system, simulate performance indicators of the (SCS) system, categorize Egyptian soils characteristics and finally utilize

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Field Data Collection

In surface irrigation, water application efficiency is influenced principally by the amount of water applied, which calculated through the identification of the soil type, intake characteristics and the rate of advance of water over the soil surface. Optimal furrow length and irrigation cutoff (flow rate) can be determined according to soil infiltration characteristics and by the time ratio, to achieve maximum application efficiency. The evaluation of surface irrigation at the field level is an important aspect of both management and design. Filed measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function and to develop alternative means for improving systems (Tekin Kara *et al*, 2008 and Walker, 1989).

Egyptian Soil Infiltration Constants and Texture

Walker and Busman, (1990) reported that estimation of soil infiltration constants are a major problem in irrigation studies due to proper selection of the technique used to determine the parameters of infiltration characteristics, which uniform flow in furrow depends on soil infiltration properties of soil texture. Generally, field experiments need a high level of labor, considerable installation time and management needs high attention levels to get good results (Oyonart *et al*., 2002).

The soil groups under study are namely Menouf, Qaliub, Damanhour, Menia El-Qamh, Tell El-Kebir, Belbeis, Itay El-Barud and Kafer El-Shiekh. These groups are located at Qalubiya, Menoufiya, Sharkia, Gharbia, Ismailia, Daqhlieh and Behira governorates, which presented in Figure (1)

Soil Texture

A trail was undertaken to classify the studied soils according to the USDA soil textural triangle. After the disturbed soil samples were crushed by hand, and passed through 8 mm sieve. Then, 100 gm. soil sample was placed on the top sieve of a set having the openings 6, 4, 2.5, and 1.25 mm. The sieves were gently shaken for 10 minutes, and then the fractions remaining on each sieve were weighed. Dry sieving stability (DSS) was calculated using the following equation:

$$DSS = \sum \grave{n} / (\grave{N} \times 100) \quad (1)$$

Where $\grave{n}$ is the weight of dry sieving fraction in gm and $\grave{N}$ is weight of soil sample used in the sieving in gm. knowing the percentage of clay, sand and loam in the soil sample the textural triangle was used to determine the soil type of the sample. The texture of all soil series under study ranged between heavy textured (Menouf, Qaliub, and Damanhur soil series).

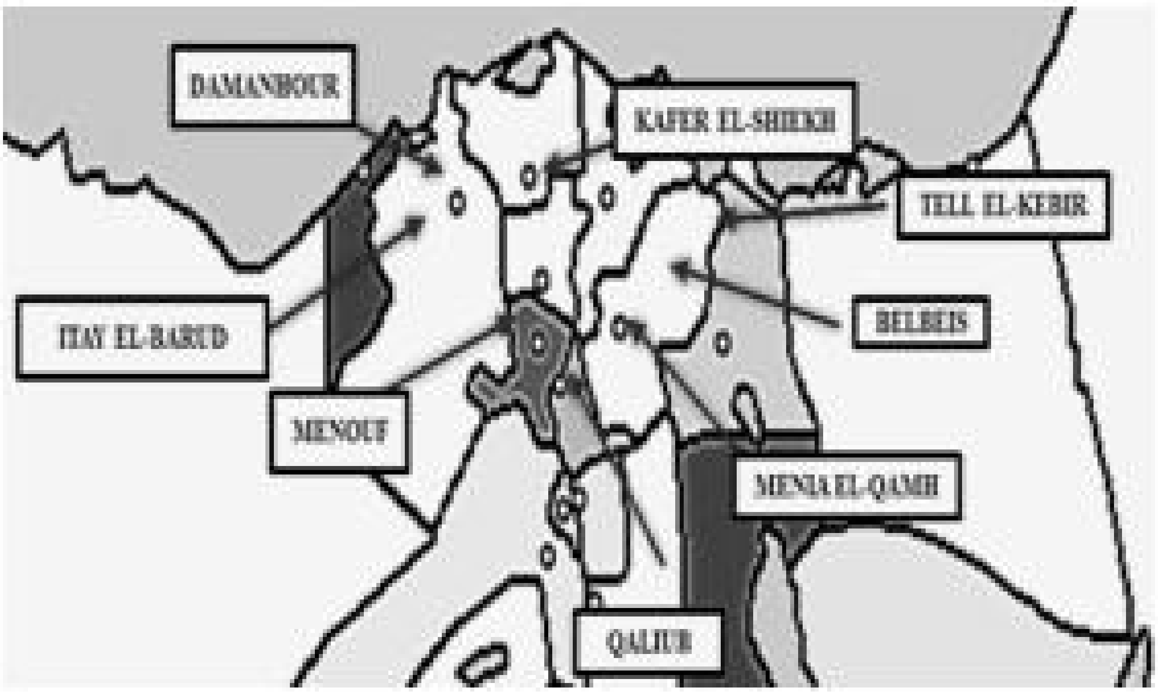

Fig. 1. Egyptian Delta soil data map.

Data collection includes:

- Soil texture and
- Infiltration constants

Ampling Locations

Twenty two profiles were chosen to represent the eight major soil groups of the alluvial soils at the Delta of the river Nile, Egypt.

Light textured (Menia El-Qamh, Tell El-Kebir, Belbeis, Itay El-Barud and Kafer El-Shiekh soil series).

Infiltration Constants

Field measurements of infiltration are used to determine the correct infiltration characteristics of the soil, which is often a major problem in surface irrigation. Double-ring infiltrometer method is the most common method enables field data to be collected that give the values of the soil infiltration parameters.

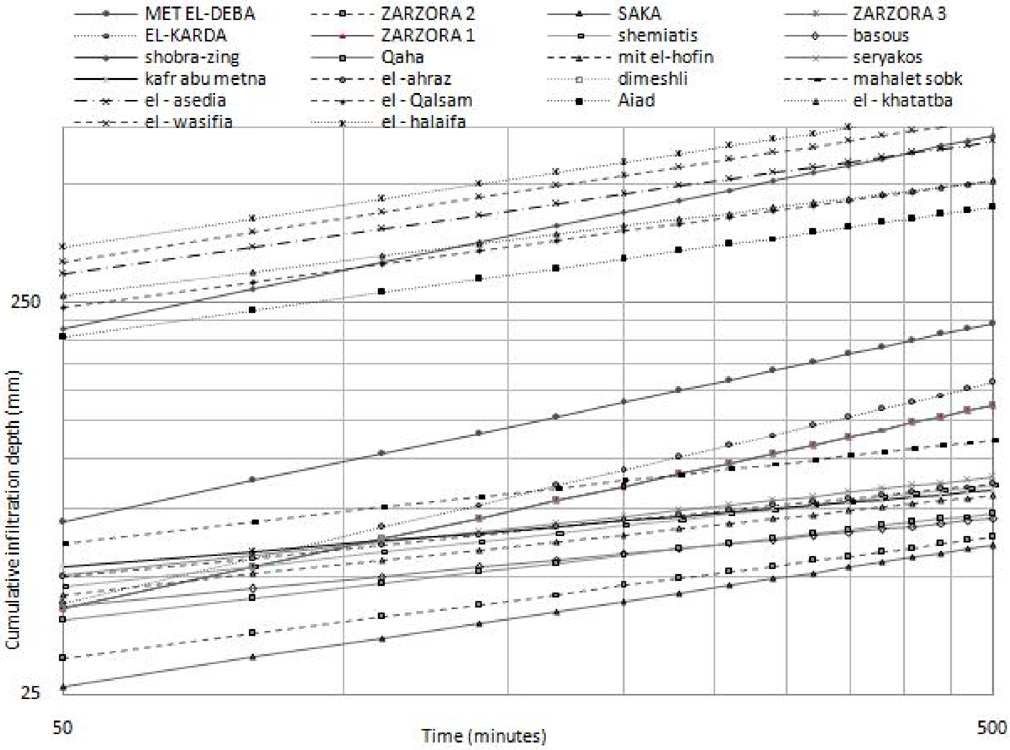

Fig. 2. Cumulative infiltration rate curves of Egyptian soil.

The infiltration rate was determined in triplicates at each site using the double rings cylinder. The height of each cylinder was 50 cm, while the diameters of both inside and outside cylinders were 30 and 50 cm, respectively. The infiltration rate I was calculated by using the following equation:

$$I = Q_0 / (A_c . T) \qquad (2)$$

Where: I is infiltration rate cm / hr, Q_0 is volume of water infiltrated in cm^3, A_c is cross section area of the internal cylinder cm^2 and T is time hr. Infiltrated depths and time data were used to get the Kostiakov cumulative infiltration rate equation for all soil groups. They were plotted on logarithmic scales, making it possible to determine the values of (a and b) either by regression or by taking them directly from the graphs (b being the positive slope of the straight line and a indicating the intercept with the vertical axis), as in Figure (2) or Table (1).

The Egyptian soil texture of the study area can be classified into three types: clay, clay loam and sandy loam as presented in Table (1). Cumulative infiltration rate equations constants are not similar in any group of soil. Statistical data analysis was used to know how the samples belonging to the families of sidecars (Significance) and extract the general Egyptian equations which describe Delta soil series (linear regression).

Table 1. Egyptian soil constants and textures,

	Location	Infiltration Constants			
A	Menouf	a	b	Texture	
1	Shemiatis	2.819	0.260	clay	1
2	Basous	2.903	0.224	clay	2
3	Shobra-Zing	3.834	0.293	clay	3
4	Qaha	2.226	0.272	clay	4
B	Qaliub	a	b	Texture	
1	Mit El-Hofin	2.787	0.253	clay	5
2	Seryakos	3.201	0.247	clay	6
3	Kafr Abu Metna	2.807	0.264	clay	7
C	Damanhour	a	b	Texture	
1	El -Ahraz	3.267	0.238	clay	8
2	Dimeshli	6.526	0.261	clay loam	9
3	MahaletSobk	3.641	0.262	clay	10
D	Menia El-Qamh	a	b	Texture	
1	El - Asedia	12.990	0.340	sandy loam	11
2	El - Qalsam	11.470	0.323	sandy loam	12
E	Belbeis	a	b	Texture	
1	Aiad	9.237	0.332	clay loam	13
2	El - Khatatba	13.930	0.291	sandy loam	14
F	Tell El-Kebir	a	b	Texture	
1	El - Wasifia	13.470	0.347	sandy loam	15
2	El - halaifa	14.130	0.360	sandy loam	16
G	Itay El-Barud	a	b	Texture	
1	Zarzora 1	5.411	0.520	clay	17
2	Zarzora 2	9.140	0.311	clay loam	18
3	Zarzora 3	4.600	0.500	clay	19
K	Kafer El-Shiekh	a	b	Texture	
1	Met el-deba	9.597	0.505	sandy loam	20
2	Saka	6.442	0.359	clay	21
3	EL-Karada	4.711	0.564	clay	22

Statistical Data Analysis

Least significant difference is used to determine whether the sample drawn from a population or if by the chance factor. Significance is then used to determine whether the relationship exists or not. For example, the regression coefficient is significant at 5% level.

This means that we have a rejected null hypothesis and we are accepting an alternative hypothesis that the relationship exists between the dependent and independent variable. Significance at 5% shows that at minimum, out of hundred, at least 5% characteristics show that our decision is correct from that variable. Least significant difference statistical analysis used with Kostiakov equation constants (a and b) to test the significance of the same type of soil.

It was found that the group of clay soil which includes mahaletsobk and shobra-zing. Group of clay loam which includes zarzora and aiad and group of sandy loam which includes el-wasfia and el-halfia did not have significant differences.

Linear regression analysis used to draw a conclusion about the parameter of regression as to whether or not there were any true relationships between a dependent and independent variable. Linear regression analysis was used to determine the average constants (a and b) in Kostiakov equation for Egyptian soil groups. The cumulative infiltration rate equations were described in the same group by one equation with two. Kostiakov equation $Z = a\ T^b$ shows the relationship between the cumulative infiltrated depth Z (dependent variable) and the elapsed time of infiltration T (independent variable). A Kostiakov equation gives a straight line when they are plotted on double-logarithmic scales. Written in logarithms form, Kostiakov equationconverts to linear equation ($\log Z = \log a + b\log T$). Linear regression analysis merged the logarithm cumulative infiltration rate linear equations constants which located in the same soil group to one main linear equation with two constants (a and b). The Egyptian logarithmic linear equations was converted back to the power equations to get the general Kostiakov cumulative infiltraion rate equations describing soil type. The general constants of the three Egyptian soil groups are shown in Figures (3 to 5).

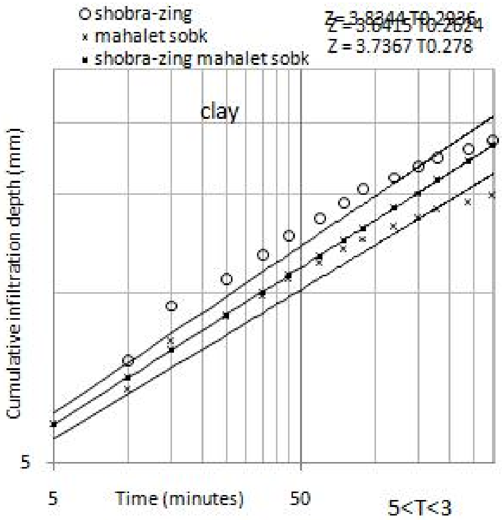

Fig. 3. Egyptian average cumulative infiltration rate curve for clay soil

The cumulative infiltration rate curve for the three Egyptian soil groups can be described by power equation as follows:

$Z = 3.7367\ T^{0.278}$ for clay soil, $Z = 9.2534\ T^{0.311193}$ for clay loam soil and $Z = 13.8\ T^{0.3536}$ for sandy loam soil as shown in Figure (6).

Using SCS method with Egyptian Data

In order to classify Egyptian soil in the Nile Delta to intake families it should be compared with SCS methodology, to impose a limited number of standard classes on the widely varying infiltration coefficients and exponents, US soil Conservation Service developed several “intake families” of soil types according to soil texture and infiltration rate.

U.S. department of agriculture (1974) adopted SCS, as the best approach in terms of classifies American soil into families.

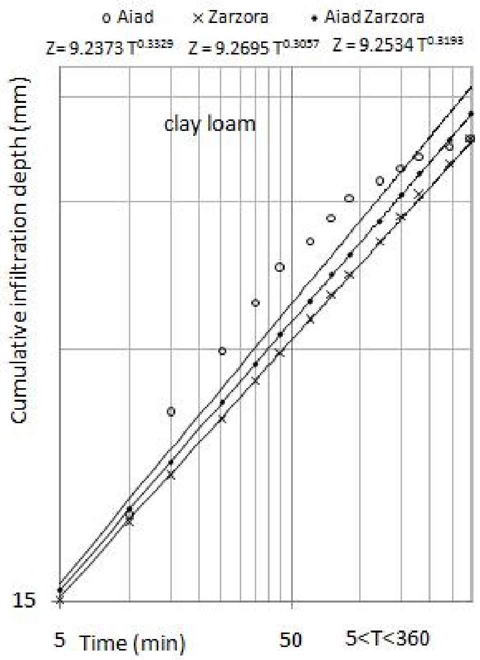

Fig. 4. The average cumulative infiltration rate curve for the Egyptian clay loamsoil

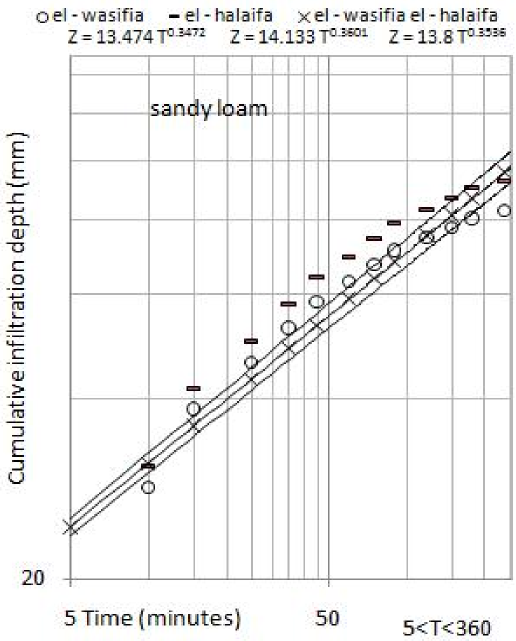

Fig. 5. The average cumulative infiltration rate curve for the Egyptian sandy loamsoil

SCS became commonly used after the addition in calculations system to calculate by English units and SI units. SCS intake families expressed numerically using the power equation with two constants to each intake family added to it correction factor special for American soil ($Z = a\ T^b + C$).

This equation intermediate between the Kostiakov equation and the Kostiakov-Lewis equation, a comparison shows that the Kostiakov equation has no basic infiltration rate at all for that the infiltration rate approaches zero when values of T are high.

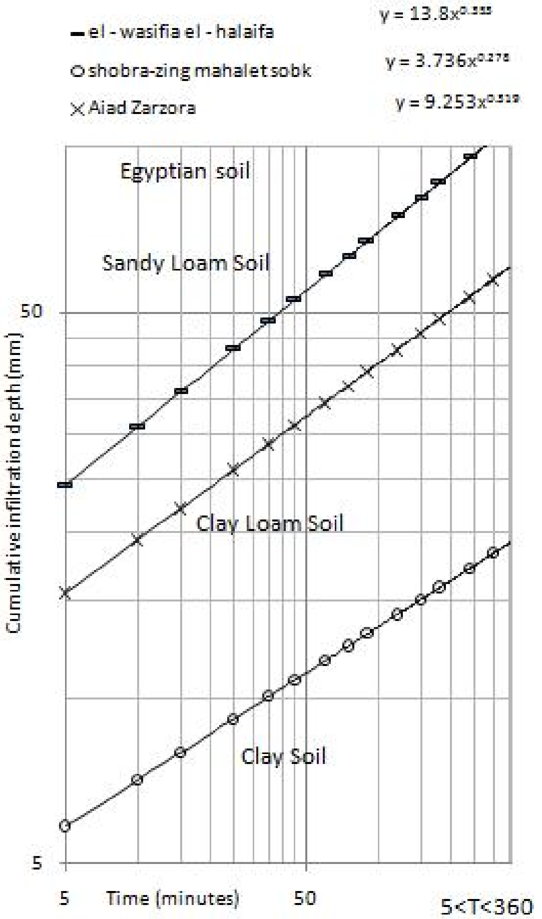

Fig. 6. The average cumulative infiltration rate curves for the three Egyptian soil groups.

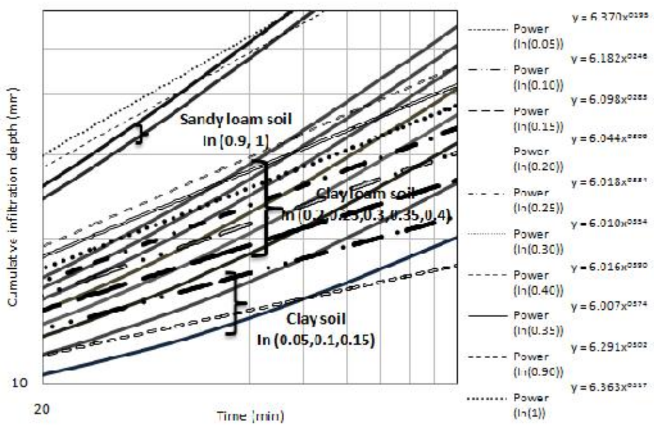

Fig. 7. Soil conservation service cumulative infiltration depth curves with the power equation

As this is often incorrect a constant term can be added to the infiltration equation. In which the constant term f_o in Kostiakov-Lewis equation is called the basic infiltration rate or the long-term constant infiltration rate. After this creation the equation then called the Kostiakov-Lewis infiltration equation. A comparison with SCS shows that Kostiakov-Lewis equation has f_oT instead of C. The constant C in SCS equation equals 0.275 inch or 6.985 mm. Tables (2 and 3) gives the SCS family numbers (0.05, 0.1, 0.15, etc.) and their corresponding values for (a and b) according to SCS equation.

Table 2. SCS intake family and Egyptian Delta soil infiltration constants

I_n	SCS Soil Type	a	b	C
0.05	Very Heavy Clay	0.533	0.618	4
0.40	Very Light Clay-Loam	1.064	0.736	11
0.90	Fine Sandy Loam	1.674	0.779	17
I_n	Egyptian Soil Type	a	b	
0.05	Clay	3.7	0.28	
0.40	Clay Loam	9.25	0.32	
0.90	Sandy Loam	13.8	0.35	

The SCS family numbers approximate the long-term infiltration rate in inches per hour according to equation ($I = a\ b\ T^{(b-1)}$). It is possible to modify the SCS intake families for use with the Kostiakov equation, by linearizing the original curves between two particular depths.

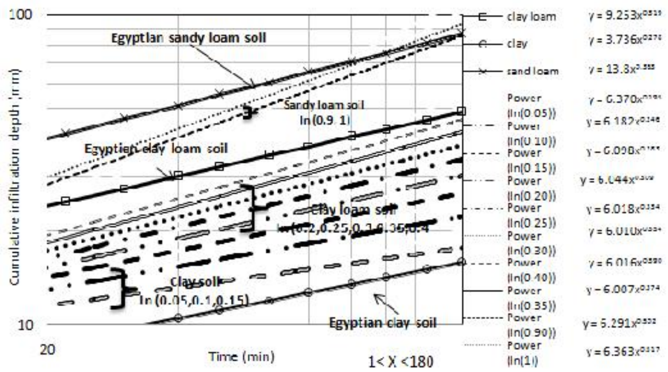

Fig. 8. SCS intake family curves for different Egyptian Delta soilintake curves

Table 3. Observed, USDA-SCS and adjusted USDA-SCS advance time (minutes)

Observed	USDA-SCS	Multiplied SCS
2.1	1.34	3.02
5.5	2.8	6.29
14.5	6.11	13.63
18.3	7.98	17.74
22.1	10	22.16
26.4	12.18	26.91
38	17.09	37.5
41.5	18.9	41.58

Fangmeier and Strelkoff (1978) made such a linearization based on infiltration depths of 50 and 100 mm. Corrections of SCS intake equations changed the power exponential and intercept constants. This affects directly on families intake curves trend. The Egyptian Delta soil curves were plotted with SCS intake family curves to test the ability of using SCS in Egyptian Delta soil. According to Walker (1989), it is also possible to modify the SCS intake families to fit the Kostiakov-Lewis equation. This has been done by determining a different value of f_0, for each intake family and then calculating the values of (a and b) to equal the values of the original SCS intake families (Walker and Skogerboe, 1987). Egyptian Delta soil equations described the relation between cumulative intake and time that water is in contact with soil by power equation with two constants ($Z = a\ T^b$). While SCS described by adding the correction factor (C) to the power equation.

Classification of Egyptian Delta soil to families by SCS method, need a calibration for SCS equations constants in the range of Egyptian Delta soil. To get the same comparison level between Egyptian equations and SCS equations converted SCS intake equations to the power equation origin as shown in Figure (7). This illustrated that Egyptian intake curves take different trend, because of the intercept and slope different from SCS curves as shown in Figure (8). Using SCS equations of infiltration and advance need adjustment. Calibration of the cumulative infiltration equation depended on the correction coefficient (C), which can be varied with free relationship between (a and b) constants (valintzas *et al*., 2001 and Khatri and smith, 2006). Moreover SCS advance equation depends on (f and g) constants. Therefore calibration of SCS method is performed using observed infiltration and advance record data. Determined the suitable constants of SCS method, make it useful to use with Egyptian Delta soil data. Comparison of SCS with Volume Balance advance equation outcomes helped selecting more acceptable method to use with Egyptian Delta soil.

Practical application of SCS infiltration equation $Z = a\,T^b \underline{+\,C}$

Figure (8) showed that SCS and Egyptian curves have different trend from each other. Therefore, SCS had to change to fit the trend of Egyptian soil. This would lead to get the value of constant C and described the soil group. However, this had to proceed through the trial and error method to get value of constant C then describe the soil texture of Egyptian Delta soil. Figure (8) indicated that the range of clay soil laid between intake family (0.05 to 0.15), clay loam soil located between intake family (0.2 to 0.4), while sandy loam soil ranged between intake family (0.9 and 1).

Egyptian clay soil

Egyptian clay soil curve plotted in the range of SCS clay soil family as shown in Figure (9).

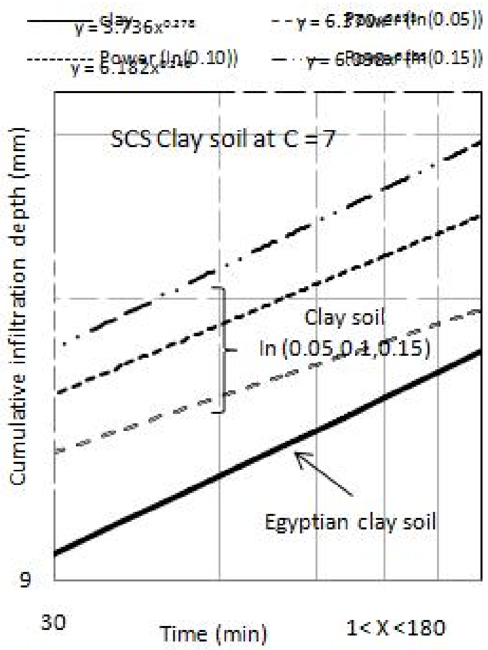

Fig. 9. Egyptian clay soil with the range of clay soil in SCS at constant C 7

The SCS clay soil at C = 7 make Egyptian clay soil far from intake family 0.05 and infiltration equation differ from SCS equations in the clay soil range. Changing C constant for SCS equations from 7 to 4 was done by using trial and error method. Egyptian clay soil curve and SCS curves were plotted as simulated obviously to identify which SCS curve would describe the Egyptian clay soil as shown in Figure (10). Figure (10) showed that the Egyptian clay soil curve at C equal 4 was next to intake family ($I_{n0.05}$) which known as very heavy clay soil.

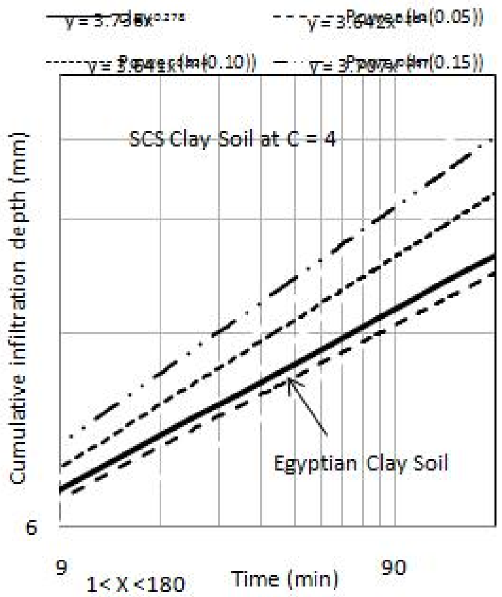

Fig. 10. Egyptian clay soil with clay soil rang of SCS at constant C 4

Corrected SCS clay power equations became similar to Egyptian clay soil equation. Therefore the slope of $I_{n0.05}$ became adjusted to Egyptian clay soil curve as shown in Figure (11).

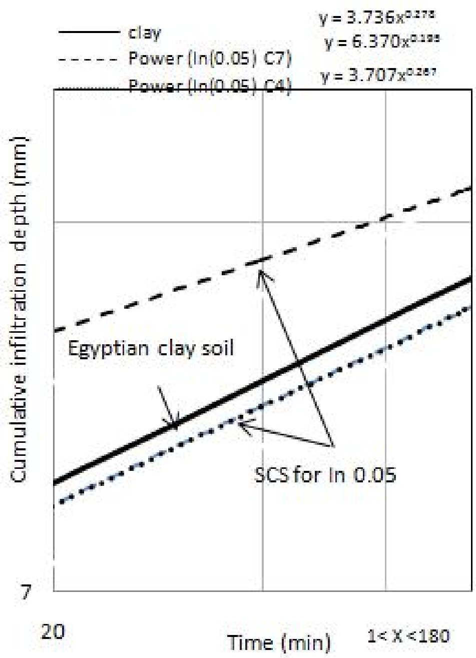

Fig. 11. Egyptian clay soil with SCS intake family 0.05 at C 7 and 4

Egyptian clay loam Soil

Egyptian clay loam soil data were laid in the range of SCS clay loam soil ($I_{n0.2} – I_{n0.4}$), with the standard value of C (7 mm) as shown in Figure (12). However, Egyptian clay loam soil curve located over all curves of SCS clay loam soil. The constants of SCS equations are not identical to the Egyptian clay loam soil as shown in Figure (12). Changing the value of C from 7 to 11 made Egyptian clay loam soil curve parallel to SCS ($I_{n0.4}$).

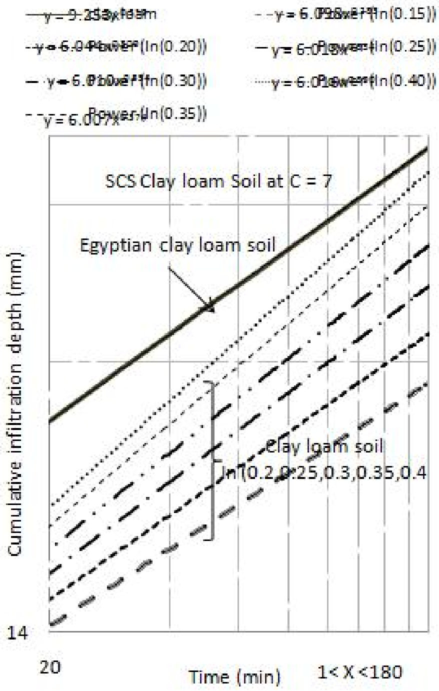

Fig. 12. Egyptian clay loam soil with the range of SCS clay loam soil at C 7.

The constants of cumulative infiltration equations became similar with their counterparts in SCS. Egyptian clay loam soil described by SCS as very light clay loam within take family ($I_{n0.4)}$ and constant C equal 11 is shown in Figure (13).

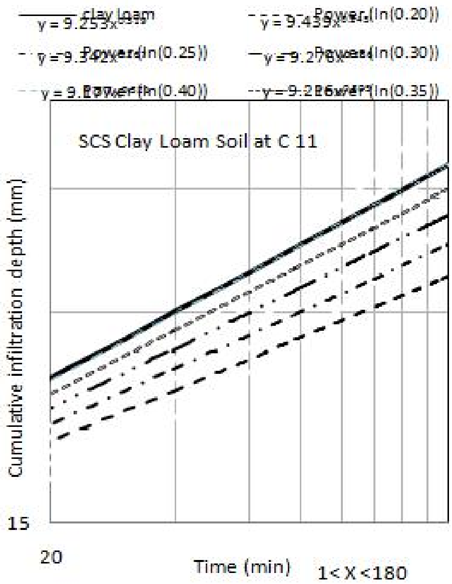

Fig. 13. Egyptian clay loam soil with the range of SCS clay loam soil at C 11

Variation of constants C, respectively change the constants of cumulative infiltration rate equation where the slope was affected by exponential constant b and intercept of y axis was affected by *a* constant as shown in Figure (14).

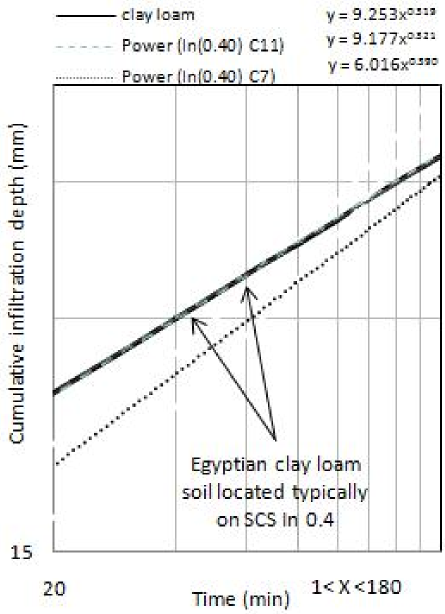

Fig .14. Egyptian clay loam soil with SCS intake family 0.4 at C 7 and 11

Egyptian sandy loam soil

The pervious procedure was carried out for sandy loam soil to know which intake family of SCS can be used with the new constant C to describe the intake constants and family number. Egyptian sandy loam soil curve at C 7 cross over SCS curves and SCS infiltration equations are differ from Egyptian sandy loam soil equation as shown in Figure (15).

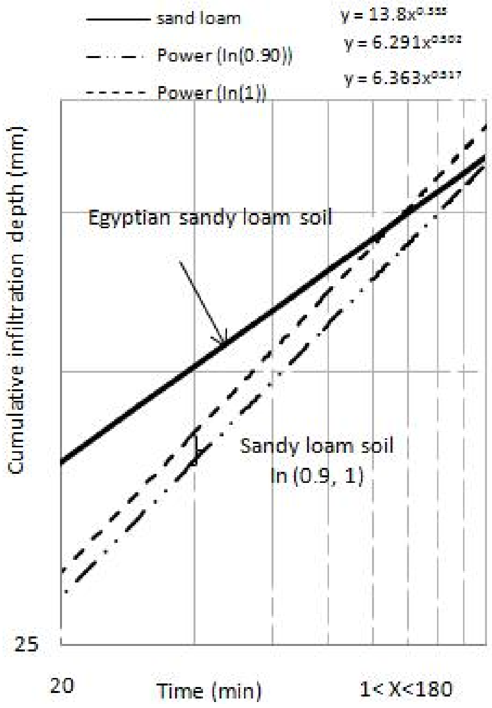

Fig. 15. Egyptian sandy loam soil with the range of SCS sandy loam soil at C 7

Constant C was changed from 7 to 17 by using trial and error. Due to the change of Egyptian sandy loam soil curve, it became next to intake family ($I_{n0.9}$), as shown in Figure (16). Egyptian sandy loam soil curve described in SCS families as fine sandy loam soil with intake family number equal 0.9 with constant C equal 17.

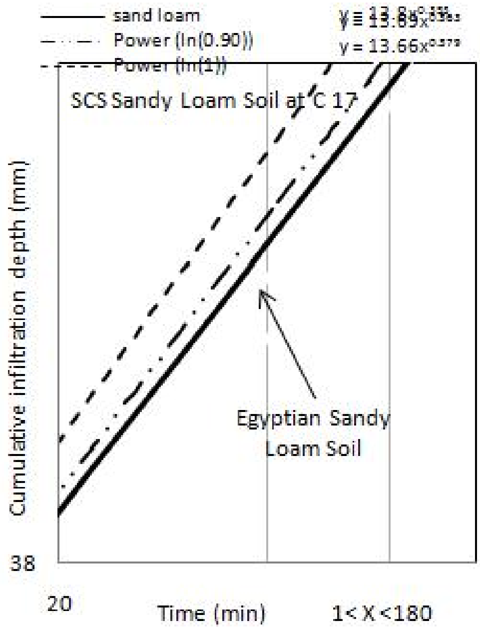

Fig. 16. Egyptian sandy loam soil with SCS sandy loam range at C 17

The constant C varied from 7 to 17 in SCS, which made the change in constants of cumulative infiltration rate equations, and affected the intercept and slope of the power equations curves as shown in Figure (17). The previous analysis shown that the Egyptian clay soil can be described in SCS soil is equivalent to very heavy clay with intake family number 0.05 and constant C 4. Egyptian clay loam soil is equivalent to very light clay-loam with intake family number 0.4 with constant C 11. While Egyptian sandy loam soil can be described in SCS soil as fine sandy loam with intake family number 0.9 with constant C 17, as shown in Table (2)

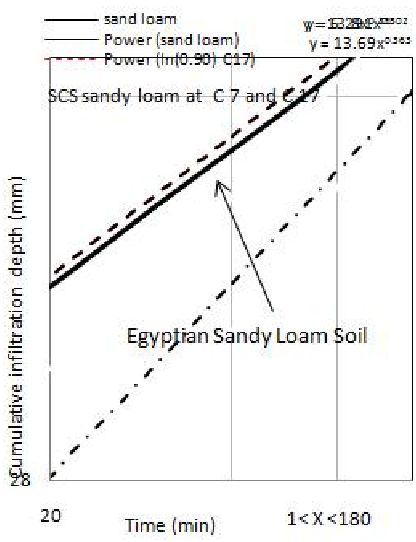

Fig. 17. Egyptian sandy loam soil with SCS intake family 0.9 at C 7 and 17

Practical application of advance equations

Empirical methods such as USDA-SCS and Volume Balance equations were used for determining furrow advance curve. The main purpose was to prove the application of the SCS.

Practical application of SCS advance equations

$$\left(T_a = \frac{L}{f}\exp\frac{gL}{Q\,S^{0.5}}\right)$$

Since the time for water advance to successive points along the furrow calculated by regression analysis of trial measurements, is a semi- logarithmic relation of length, inflow rate, slope and constants of advance f and g which are related to intake family numbers (Hart *et al*., 1980). Observed advance data for clay loam soil at slope 0.0012 m/m and flow rate 1.48 L/s versus the predicted advance data of USDA-SCS intake family number 0.4 illustrated in Figure (18).

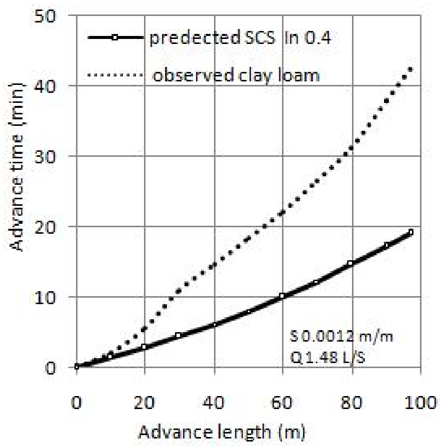

Fig. 18. Comparison between observed and predicted SCS advance data

USDA-SCS predicted data were under estimated compared to experiment data compared to. However there was relationship between both of them. Tekin Kara *et al*. (2008) proved that USDA-SCS method can be used to determine furrow advance length with time, but there is a coefficient factor between USDA-SCS method and observed values. Plotted observed data against USDA-SCS to know the coefficient factor as shown in Figure (19).

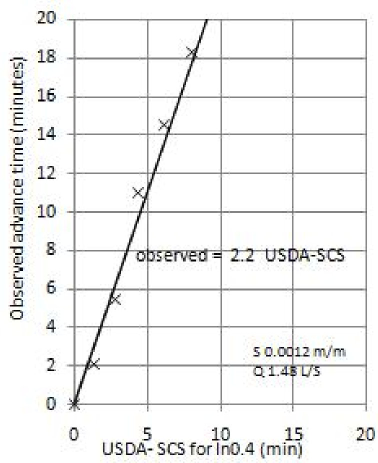

Fig. 19. Coefficient factor between USDA-SCS method and observed values

Coefficient factor between both observed and USDA-SCS furrow advance time, multiplied by the coefficient of 2.2, which can be getting close values. Table (3) showed that the outcomes of multiplied USDA-SCS became 41.58 min, which is very close to the field experimental data of 41.5 min at the end of furrow length as shown Figure (20).

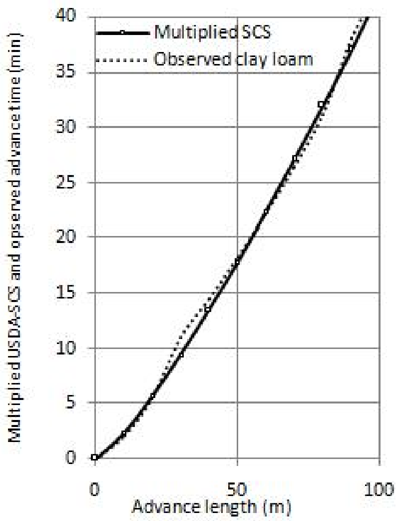

Fig. 20. Observed and multiplied SCS advance length using SCS after correction

Practical application of Volume Balance advance equations

The basic objective of a surface irrigation field evaluation is to establish a water balance for the field and thereby identify each of the components necessary to determine the efficiencies and uniformities noted. Observed advance data for clay loam soil at flow rate 1.48 l/s and slope 0.0012 m/m were plotted with Volume Balance method advance output at the same flow rate and slope as shown in Figure (21).

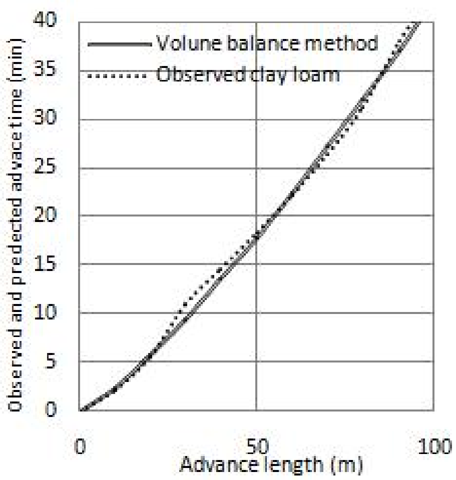

Fig. 21. Comparison between observed and predicted advance values using volume balance method

Experimental values and the empirical method Volume Balance outcomes were compared using correlation factor statistical analysis to know the relationship extent between both outcomes as shown in Figure (22) and Table (4). Statistical analysis illustrated that the relationships between the experiment data and Volume Balance method (y = 1.0089 X) at (R^2 = 0.9971).

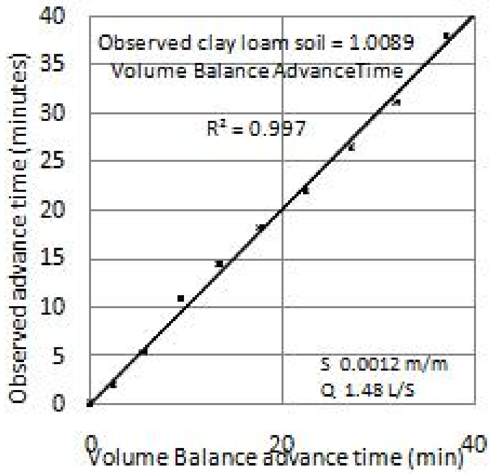

Fig. 22. Correlation factor of calculated data and observed data of advance time

Table 4. Observed and Volume Balance method advance time values (minutes)

Observed	Volume Balance
2.1	2.41
5.5	5.71
10.95	9.45
14.53	13.52
18.33	17.84
22.1	22.38
26.42	27.11
31.2	32.01
38	37.06
41.5	40.67

The outcomes data are very close to each other so suggested that, Volume Balance method to be used to determine furrow advance length directly. In general, USDA-SCS and Volume Balance equations can be used for determining furrow water advance, because advance time for furrow length does not differ significantly for each method as shown in Figure (23).

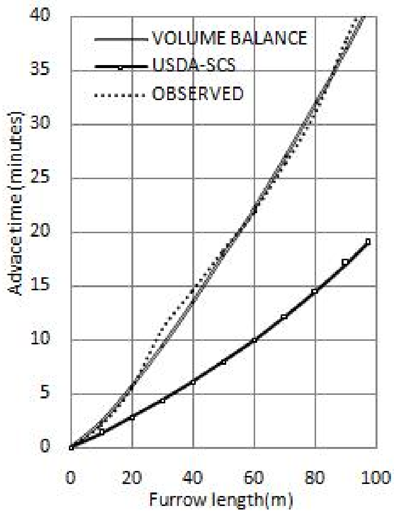

Fig. 23. Observed and predicted advance curves

However calculated USDA-SCS furrow advance time values are slightly different than field measurements. The study has shown that the Volume Balance method predicts well the advance time. However USDA-SCS method can be used to predict but need calibration with a coefficient factor of 2.2.

In this chapter, the various parameters and variables involved in the surface irrigation furrow designs, focusing somewhat more on simulation aspects of SCS method. The main outcomes were discussed in the following points:

- Egyptian clay soil expressed by cumulative intake equation ($Z = 0.533\ T^{0.618} + 4$),
- Egyptian clay loam soil expressed by cumulative intake equation ($Z = 1.064\ T^{0.736} + 11$),
- Egyptian sandy loam soil expressed by cumulative intake equation ($Z = 1.674\ T^{0.779} + 17$).
- Advance time is predicted closely using Volume Balance method.

The data shows three types of Egyptian soil with their infiltration constants. A model was designed to deal with Egyptian soils in order to get accurate advance time. Modeling is relatively inexpensive and has the additional advantage that once verified a multitude of analyses can be performed to investigate changes in both design and operational conditions. Calibration of program performance is the ultimate aim to prove the possibility of use.

Conclusions

The Soil Conservation Services (SCS) method has been developed and widely used in the United States to bring significant improvements in irrigations performance and simple management. Substantial reductions in the total volume of water applied per irrigation are achievable, that could be used beneficially to grow a greater area of crop. The use of this method in Egypt needs readjustment to the variables of SCS method. The SCS method classified soils into four soil groups (clay, silt, loam, and sand) according to soil texture and infiltration rate. The intake curve number is determined based on the infiltration rate. The SCS produced five constants of infiltration and advance for each group of soil. According to the collected data, the Egyptian soils were classified into three groups: clay, clay loam, and sandy loam. Linear regression analysis was used to determine the average infiltration constants for each group. The SCS intake families expressed numerically using the power equation with two constants to each intake family plus a correction factor C equals 7 for all 2American soils ($Z = a\ T^b + C$). It was found that the infiltration constant C= 7 for all SCS soil families must be adjusted in order to use the USDA-SCS intake families for Egyptian soils as follows;

- Cumulative intake equation ($Z = 0.533\ T^{0.618} + 4$) and intake family number $I_n = 0.05$ are used for Egyptian clay soil in which Z is the cumulative infiltration depth in mm, and T is the intake time in minutes.
- Cumulative intake equation ($Z = 1.064\ T^{0.736} + 11$) and intake family number $I_n = 0.40$ are used for Egyptian clay loam soil.
- Cumulative intake equation ($Z = 1.674\ T^{0.779} + 17$) and intake family number $I_n = 0.90$ are used for Egyptian sandy loam soil.

According to results, SCS model and Volume Balance can be used for determining infiltration depths and advance times along furrow length for the three groups of the Egyptian soils. The field experiments and volume balance results are very close to each other. However, Experimental results are different from SCS model, but using a coefficient made close agreement. A sensitivity analysis was performed using the EGY model to study the effects of varying Manning coefficient, land slope, inflow rate, cutoff time, length of run, and soil type on the performance parameters. It can be concluded that the advance and infiltration trajectories were not significantly sensitive to the Manning roughness in the range of (0.02 and 0.038) which was of great advantage since it was difficult to determine it. In contrast dense growth (Manning roughness 0.15) had pronounced effects on the advance and infiltration trajectories.

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