Journal of Agricultural Research Advances
ISSN: 2582-7227

Research Article
Open Access

Improving furrow irrigation performance using Skogerboe models of continuous flow for different soil

Garelnabi MA and Mohammed HI
[1]Department of Agricultural Engineering, Faculty of Agricultural Technology and Fish Sciences, Al Neelain University, Khartoum, Sudan
[2]Department of Agricultural Engineering, College of Agricultural Studies, Sudan University of Science and Technology, Sudan
Corresponding author: garow2010@gmail.com

Received on: 17/01/2024 Accepted on: 01/05/2024 Published on: 10/05/2024

ABSTRACT

Aim: The aim of this study was to assess the furrow lengths suggested by Boher using Skogerboe model (which was based on the volume balance equation) for continuous flow.

Materials and Methods: Four slopes (0.02,0.03,0.05 and 1%) were selected with three flow rates for each slope, four furrow lengths, and four net irrigation requirements for two types of soil (clay and sandy).

Results: The results indicated that the highest application efficiency obtained was 80.2% for a furrow length of 100 m at a flow rate of 0.59 l/s and slope of 1% in clay soils, while the highest distribution efficiency was 95.9% for a furrow length of 100 m at a flow rate of 1.19 l/s and a slope of 0.5%.

Conclusion: It was concluded that a mathematical model gives a better representation of the design parameters (inflow rate, slope and furrow length) with variables constant (a, k, f_0, Zreq, n, S0, σy, p1 and p2) and is more flexible because it permits easy changes in these three variables and that lead the designer to a maximum efficiency.

Keywords: Furrow irrigation, skogerboe model, soil.

How to cite this article: Garelnabi MA and Mohammed HI (2024). Improving furrow irrigation performance using Skogerboe models of continuous flow for different soil. J. Agri. Res. Adv., 06(02): 33-41.

Introduction

Eldeiry et al (2005) mention is almost 25% of the total cultivated lands in world areirrigated. The majority of this land is irrigated using surface methods. Surface irrigation systems have some advantages such as lower capital and operating costs, simplicity of maintenance, andability to use unskilled labor. Improvements in surface irrigation methods including automation, cut back, and surge irrigation have further increased their appeal. Furrow irrigation is the most common type of surface irrigation, but in most cases the design of furrow systems is not optimal for water use in arid locations with unique infiltration characteristics, such as those present with clay soils. Furrow design parameters are often chosen with limited or no analysis of unique local conditions. There is a need for basic parameters that can be easily applied to furrow irrigation system designso that systems can be optimized for local conditions.

It was reported that a volume balance model can be satisfactorily applied to clay soils and found furrow length and its inlet inflow is the main factors affecting application efficiency.

The selection of an intake flow rate (Qmax) that maximizes application efficiency (Ea) is the most important challenge in thedesign of surface irrigation systems. According to the reports of inflowrate and cut-off time are the most effective parameters of furrow irrigation design.Found that the yield and water productivity were significantly affected by the interaction of furrow length and inflow rate. Furrow length of 50 m combined with (1.2 l/s) inflow rate for 35.6 minutes produced the highest water application efficiency (65.0 %). The lowest water application efficiency (38.3 %), with inflow rate (1.6 l/s) for 9.75 minutes were achieved from 10 m furrow length.Fikaduet al. (2022).In many Sudan farms, traditional furrow irrigation is used for row plants.

Konukcu et al (2006) reported in a study dealing with Optimum Time Ratio for Maximum Application Efficiency in Furrow Irrigation, model was tested on potatoes grown furrows, 0.75 m wide and 120 m long,with three different slopes and each slope had three different inflow rates, The achieved application efficiency was 64% for an average soil inflow rate on slopes.

Materials and Methods

The furrow irrigation was designed using the volume balance equation (law of conservation of mass) that can be used to describe the flow of water longitudinally down the furrow, including the infiltration of water into the soil to represent the storage phase. With a selection of lengths, slopes and flow rates can be made that will maximize application efficiency. Considerations such as erosion and water supply limitations will act as constraints on the design procedures. Maximum application efficiencies, the implicit goal of design, will occur when the least-watered areas of the field receive a depth equivalent to Zreq. Minimizing differences in intake opportunity time will minimize deep percolation. The volume balance model assumes that at any time (t) water entering the field will progress a distance (x) toward the lower end of the field. The furrow inflow at the inlet of the field (Q_o) is assumed steady, so that at time (t) the product of (Q_o) in (t) equals the volume of water on the soil surface, Vy(t), plus the volume infiltrated, Vz(t), which are both time dependent.

$$\int_o^t Q_o(t)dt = \int_o^x A(x,t)d\,x + \int_o^x Z(x,t)dx \quad (1)$$

$$Q_o t = V_y(t) + V_z(t) \quad (2)$$

$$\int_o^x A(x,t)dx = V_y t = A^{-}x = \sigma_y A_o x \quad (3)$$

$$\int_0^x Z(x,t)dx = V_z t = \sigma_z Z_o X = \sigma_z\, k t^a x + \frac{r}{r+1} f_o t \quad (4)$$

Where Q_o= inflow rate m^3/min,t = advance time min, Z (x,t)= infiltrated volume per unit length over the advance length m3/min/min,V_y= volume of surface storage (water in furrow), m^3,V_z= volume of subsurface storage (infiltrated volume), m^3x= distance m,A^{-}= average area of the furrow shape m^2, A_o = cross-sectional flow area at the field inlet m^2,σ_y = surface shape parameter,σ_z = subsurface shape parameter and Z_o = percolated surface at the entry point (product of percolated water depth width of the furrow).The volume balance equation can be formulated as follows:

$$Q_o t = \sigma_y A_o x + \sigma_z k t^a x + \frac{r}{r+1} f_o t x = x(\sigma_y A_o + \sigma_z k t^a + \frac{r}{r+1} f_o t) \quad (5)$$

Model Inputs: Design data include field data collection and soil data measurement of hydraulic parameters (flow rate; furrow geometry characteristics). The input design parameters can be summarized (Table 1).

Table 1. Shows input data for the furrow irrigation process

Parameters and notes	Values	
Manning roughness (n)	0.04	
Furrow length (L)	Four length each slope	
Flow rate (Q)	Three flow each slope	
Furrow width (w)	1.2 for clay soil and 0.75 for sand soil	
Infiltration parameters	for clay soil	for sand soil
a	0.303	0.638
k (m^3/mim^a/m)	0.0063	0.0031
f_o(m^3/min/m)	0.00032	0.00027
requirement depth (Z_{req})	60,120,180 and 240 mm	40,55,70 and 90 mm
P_1	0.275	0.472
P_2	2.695	2.826

Model design processes: The design process starts by choosing length and flow rate to each furrow and entering the rest of the required data to determine the rates of advance and recession. Once advance and recession are computed; the field performance levels for various combinations of inflow and cutoff times are determined.

Compute of Furrow Cross-Section: The furrow cross-sectional area was compute using equation (Walker and Skogerboe; 1987) as below:

$$A_o = \left(\frac{Q_o^2 n^2}{3600 S_o \rho_1}\right)^{1/\rho_2} \quad (6)$$

Where: Ao : cross-sectional flow area (m2) Qo : inlet discharge per furrow (m3/min), n :manning coefficient, So : field slope m/m and p1 and p2 : empirical shape coefficients.

Compute velocity water: The velocity water was compute from equation following

$$V_f = \frac{Q_o}{A_o} \quad (7)$$

Compute the time required: The time required was compute to infiltration the required depth for irrigation by solving a modified Kostiakov equation using the Newton-Raphson method according to equation following:

$$(\tau_{req})_{i+1} = (\tau_{req})_i + \frac{Z_{req} - k(\tau_{req}^a)_i - f_o(\tau_{req})_i}{\frac{ak}{(\tau_{req}^{1-a})_i} + f_o} \quad (8)$$

Compare the values of the initial and revised estimates. If they are equal to each other, or within an acceptable tolerance, the value of τ_{req} is determined. If they are not sufficiently equal in value, replace the initial value of τ_{req} with the revised value, (τreq,)i = (τreq)i+1 in equation.

Determination the subsurface shape factor: The subsurface shape factor (σz) is calculated by the Hamid approximation (Hamidet al., 2021) as follows:

$$\sigma_z = \frac{a+r(1-a)+1}{(1+a)(1+r)} \quad (9)$$

Compute the advance time: Advance time is computed by following these steps:

i- Choose the value of the power advance exponent (r) typically has a value from 0.3 to 0.9. The first step is to make an initial estimate of its value and label this value (ri).

ii- compute the advance time of the volume balance equation by solving it using the Newton-Raphson method as follows:

$$(t_L)_{i+1} = (t_L)_i - \frac{Q_o(t_L)_i - \sigma_y A_o L - \sigma_z k(t_L^a)_i L - \frac{f_o(t_L)_i L}{(1+r_i)}}{Q_o - \frac{\sigma_z akL}{(t_L^{1-a})_i} - \frac{f_o L}{(1+r_i)}} \quad (10)$$

Assume an initial estimate of$(t_L)_{i+1}$as $(t_L)_i$

$$(t_L)_i = 5A_oL/Q_o (11)$$

Compare the initial (tL)i and revised (tL)i+1 estimates of tL. If they are equal to each other, or within about 0.5 minutes or less the value of tL is determined. If they are not equal, replace the initial value of $(t_L)i = (t_L)_{i+1}$ and repeat the step.

Compute the advance time to the field midpoint: The advance time to the field midpoint is computed (t0.5L) in the same manner as finding (tL), by replacing (L) by (0.5L) and (tL) with (t0.5L) in equations 10 and 11.

Determination of the power advance exponent as follows:

$$r_{i+1} = \frac{log(2)}{log(t_l/t_{l/2})} \quad (12)$$

Compare the initial estimate; ri; with the revised estimate; ri+1. The differences between the two should be less than $5x10^{-7}$. If they are equal; the procedure for finding TL is concluded. If not; let ri= ri+1 and repeat steps 7-9.

The trajectory of the advance of the waterfront in a furrow can be described as a simple power function:

$$x = Pt_x^r = L\, t_x^r/t_L^r$$
(13)

$$t_x = (x/P)^{1/r} = (xt_L^r/L)^{1/r} \quad (14)$$

Computation time cut off (tco): The time cut off is computed from the following equation:

$$t_{co} = t_L + \tau_{req} \quad (15)$$

Computation of recession time t_{rec}; from the following equation:

$$t_{rec} = t_{co} \quad (16)$$

Computation of water volume added (applied) to soil V_{in} according to t_{co}; from the following equation:

$$V_{in} = Q_o.t_{co}$$
(17)

Computation of water infiltrated depth; Z_{inf} from the following equation:

$$Z_{inf} = k\tau_{opp}^a + f_o\tau_{opp} = k(t_a - t_{rec})^a + f_o(t_a - t_{rec}) \quad (18)$$

Computation of water infiltrated volume for each I[st] distance (station); V_{inf} from the following equation:

$$V_{inf} = x\left[\left(\left(Z_{inf}\right)_i + \left(Z_{inf}\right)_{i+1}\right)/2\right]$$
(19)

$$\left(Z_{inf}\right)_i = k[t_{rec} - (t_a)_i]^a + f_o[t_{rec} - (t_a)_i] \quad (20)$$

Model Output: The output of the program was the application efficiency, deep percolation ratio, tailwater ratio, distribution efficiency and storage efficiency.

Determination total infiltration volume: The total infiltrated volume (TV_{inf}) was computed as the following equation:

$$TV_{inf} = \sum_{i=1}^{i=N} V_{inf} \quad (21)$$

Where: N: number of stations

Determination of Tailwater Ratio: The tailwater ratio, TWR, was computed by following equation:

$$TWR = TWR_v/V_{in} = \frac{V_{in} - TV_{inf}}{V_{in}} \quad (22)$$

Determination of Furrow Application Efficiency: The application efficiency was calculated as the ratio of the required water infiltrated volume (VZ_{req}) to the total water applied according to the following equation

$$E_a = \left(100Z_{req}L\right)/V_{in} \quad (23)$$

Determination of Deep Percolation Ratio: The deep percolation ratio was computed as below.

$$DP = 100 - (E_a + TWR) \quad (24)$$

Determination of distribution uniformity: The distribution uniformity was computed from the following equation

$$DU = 100(1 - Y/D) \quad (25)$$

Where; DU water distribution efficiency % , Y average numerical absolute deviation of soil moisture D average soil moisture content stored as computed at certain time of irrigation

Determination of water storage efficiency: The water storage efficiency was computed from the following equation $E_s = Vz_{req}/Vz_{ave}$ (26)

Performance calculation (adjust recession): The new values for cut-off time (tco1) and recession time (trec1) were estimated and the same steps were repeated, using these values to compute the total volume added to the soil (Vin1) according to cutoff time (tco1) instead of old values of cutoff time; (tco) recession time (trec) and the total volume added to the soil (Vin) by Guirguis et al (2015) using the following equations:

$$t_{co} = t_A(L) + t_{req} - (V_y/Q_o) \quad (27)$$

$$V_{in1} = Q_o . t_{co1} \quad (28)$$

$$t_{rec1} = t_{rec1} + (t_{rec} - t_{rec1})(\Delta x/L) \quad (29)$$

Where: ΔX: station distance

Results and Discussion

Water infiltrated depth: It was showed the results of the mean infiltration depth along the furrow for clay soils (Fig 1-4). It was observed (Fig. 1) that mean infiltration depth ranged between (96-8), (200-16.4), (295.8-24.7) and (375.3 -32.7) (mm) for 370,470,530 and 545 m respectively. While ranged between (79.-7.8), (152.7-15.5), (241.3-23.6) and (341.3 -32) (mm)) for 200,250,300 and 350 m (Fig. 2) respectively. It was ranged between (70.7-7.6), (146.8-15.4), (258.9-24.0) and (332.4-31.8) (mm)) for 100,150,200 and 210 m respectively (Fig. 3). It was ranged between (84.6-7.9), (155.3-15.6), (235.7-23.5) and (313.5 -31.4) (mm)) for 70, 80, 90 and 100 m respectively (Fig. 4).

It was showed that the results of the mean infiltration depth along the furrow for sand soils (Fig 4-8). It was observed that mean infiltration depth ranged between (56.2-5.2), (101.6-7.7), (169.6-10.7) and (247.4 -14.5) (mm)) for 120,190,250 and 300 m respectively (Fig. 5). While ranged between (53.8 -5.2), (77.2-7.2), (137.1-10.0) and (240.2 -14.5) (mm)) for 80,100,150 and 200 m (Fig. 6) respectively. It ranged between (83.5-5.8), (113.9-8.0), (152.1-10.5) and (245.5-14.8) (mm)) for 80, 90,100 and 120 m respectively (Fig. 7). It ranged between (46-5.1), (72.3-7.2), (111.1-9.6) and (161.3 -12.8) (mm)) for 20, 30, 40 and 50 m respectively (Fig. 8).

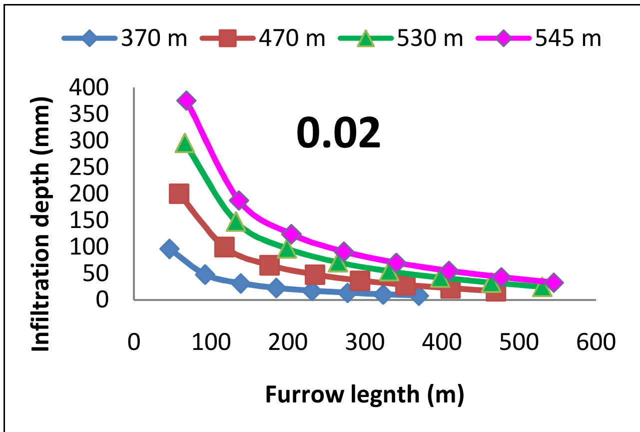

Fig.1. Water infiltrated depth for slope 0.02% in clay soil

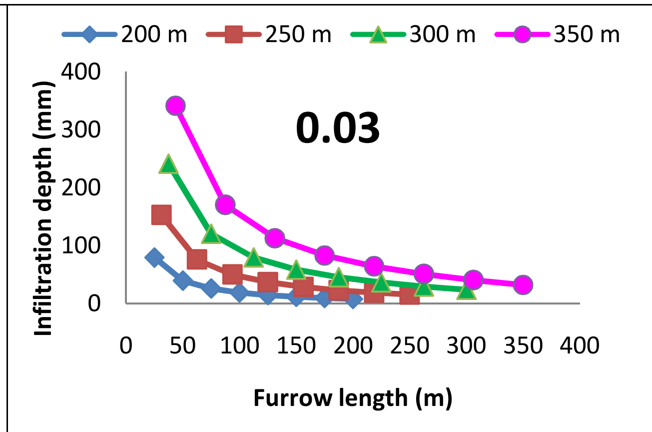

Fig.2. Water infiltrated depth for slope 0.03% in clay soil

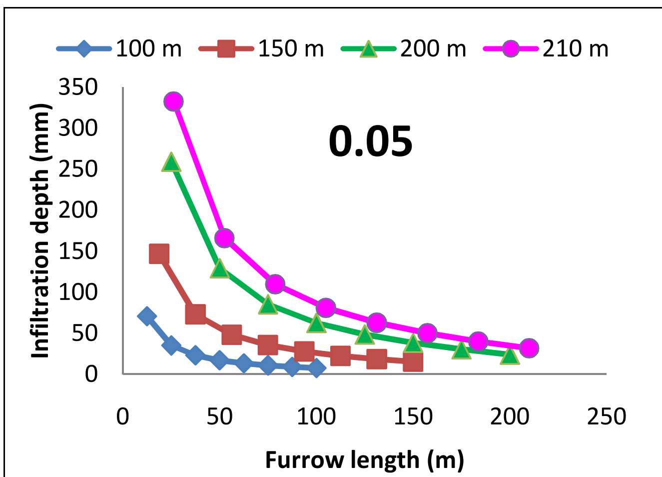

Fig.3.water infiltrated depth for slope 0.05% in clay soil

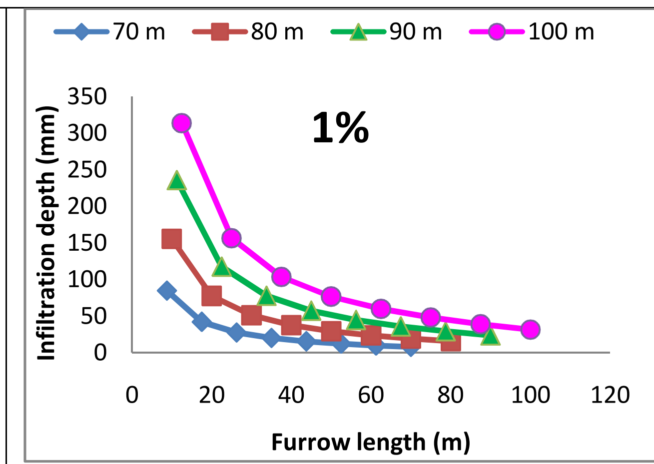

Fig.4.water infiltrated depth for slope 1% in clay soil

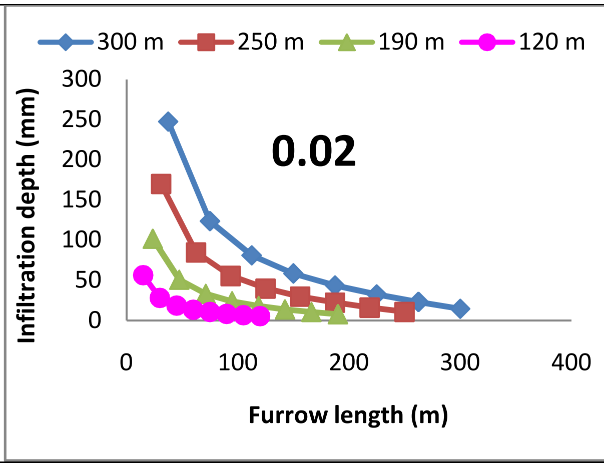

Fig.5.water infiltrated depth for slope 0.02% in sand soil

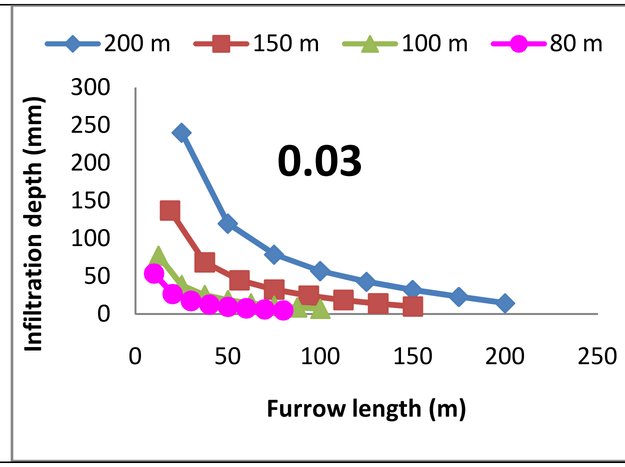

Fig.6.water infiltrated depth for slope 0.03% in sand soil

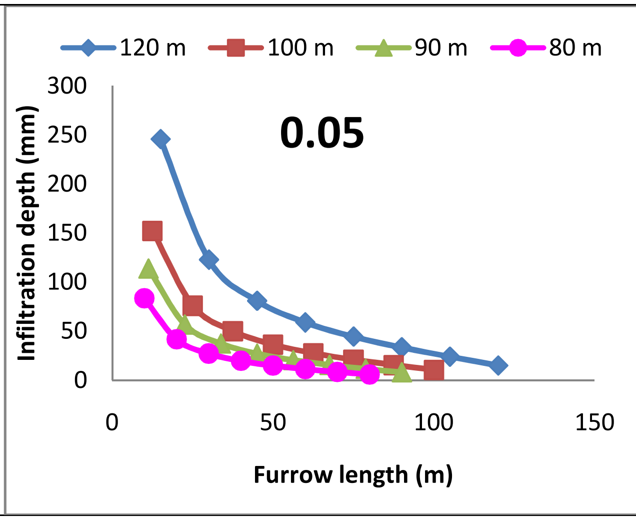

Fig.7. Water infiltrated depth for slope 0.05% in sand soil

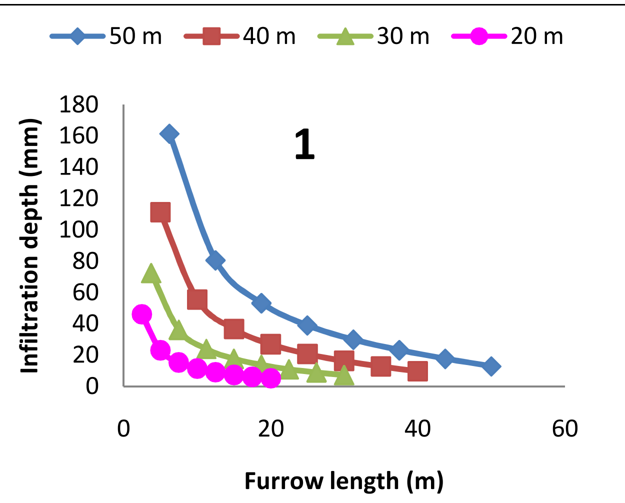

Fig.8. Water infiltrated depth for slope 1% in sand soil

Irrigation performance for clay soil: The irrigation performance results computed for the slope of 0.2% were shown (Table 2). It was achieved higher Ea 70.6% for furrow length 545 m at a flow rate of 3 l/s compared to furrow length 370,470 and 530 m. While the maximum value of RO 15.6% was obtained for furrow length 370 m at a flow rate of 2.94 l/s and the lowest value of 0% was for furrow length 545 m at a flow rate of 3l/s. For DP, the maximum and minimum values were 33.5 and 23.3% for furrow length of 470 and 370 m at 2.8 and 2.94 l/s respectively. There was a higher value of Ed 90.3% for furrow length 545 m at 3 l/s, while there Es 100% were obtained for all chosen lengths at flow rates except for furrow length 470 at flow rate 2.94 l/s.

For the slope of 0.3%, highest Ea was 75.5% for furrow length 300 m at a flow rate of 1.95 l/s compared to furrow length 200,250 and 350 m (Table 3). The maximum value of RO 24.6% was obtained for furrow length 200 m at a flow rate of 1.95 l/s, while the lowest value of 1.1% for furrow length 350 m at a flow rate of 2l/s. For DP, maximum and minimum values were 23.5 and 12.1% for furrow length of 350 and 250 m at 2 and 1.95 l/s respectively. The highest Ed was obtained at 94.4% for furrow length 250 m at 1.95 l/s, while the Ed of100% was obtained for all chosen lengths at flow rates except for furrow length 200m (at 1.85 and 1.9 l/s)and 250m (at 1.85 and 1.95 l/s).

For the slope of 0.5%, highest Ea was 77.5% for furrow length 210 m at a flow rate of 1.2 l/s compared to furrow length 100,150 and 200 m (Table 4). The maximum value of RO 34.4% was obtained for furrow length 100 m at a flow rate of

1.18 and 1.19 l/s, while the lowest value of 0.4% for furrow length 350 m at a flow rate of1.2 l/s. For DP, maximum and minimum values were 24.5 and 6.6% for furrow length of 200 m (at 1.9 l/s) and 100 m all flow rate. The highest Ed was obtained at 95.9% for furrow length 100 m at 1.19 l/s, while the Ed of100% was obtained for all chosen lengths at flow rates except for furrow length 100m (at 1.17 and 1.18 l/s),150 m (at 1.17l/s)and 200 m (at 1.18 l/s).

The higher value of Ea 80.2% for furrow length 100 m at a flow rate of 0.59 l/s compared to furrow length 70, 80 and 90 m. While maximum value of RO14.9% was obtained for furrow length was 70 at a flow rate of 0.59 l/s and lowest value of 1.7% was for furrow length 100 m at a flow rate of 0.59 l/s. For DP, maximum and minimum values were 22.4 and 12.7% for furrow length of 70 and 80 m at 0.54 and 0.59 l/s. There was a higher value of Ed 94.6 % for furrow length 90 m at 0.59l/s, while there of Es 100% were obtained for all chosen lengths at flow rates except for furrow length 70 and 80 m at flow rate 0.57 and 0.54 l/s respectively (Table 5).

Table 2. Impacts of furrow length and inflow rate on irrigation performance for clay soil (slope 0.2%).

L m	Q l/s	tL min	Tco min	VT m3	V infl m3	Ea%	RO%	DP%	Ed%	Es%
370	2.8	156.58	294.07	44	38.2	60.5	13.2	26.3	88.5	100
370	2.87	148.51	286	43.8	37.5	60.8	14.4	24.8	89	100
370	2.94	141.31	278.8	43.6	36.8	61.1	15.6	23.3	89.4	100
470	2.8	347.86	683.2	107.9	103.8	62.7	3.8	33.5	87.9	100
470	2.87	314.39	649.73	104.9	99.6	64.5	5.1	30.4	88.7	100
470	2.94	287.55	622.89	102.8	96.4	65.8	6.2	28	89.4	99.9
530	3	453.17	995.53	171.1	168.4	66.9	1.6	31.5	89.2	100
545	3	528.41	1281.88	222.4	222.5	70.6	0	29.4	90.3	1001

Table 3. Influence of furrow length and inflow rate on irrigation performance for clay soil (slope 0.3%).

L m	Ql/s	tL min	Tco min	VT m3	V infl m3	Ea%	RO%	DP%	Ed%	Es%
200	1.85	82.36	219.85	22.6	17.6	63.7	22.1	14.2	92.8	99.9
200	1.9	78.45	215.94	22.7	17.4	63.4	23.3	13.3	93.1	99.9
200	1.95	74.15	211.64	22.8	17.2	63.2	24.6	12.2	93.5	100
250	1.85	141.09	476.43	50.6	43.2	71.1	14.6	14.3	93.7	99.9
250	1.9	132.35	467.69	51	42.6	70.6	16.5	12.9	94.1	100
250	1.95	124.63	459.97	51.4	42.2	70	17.9	12.1	94.4	99.9
300	1.85	263.8	806.16	86.7	82.3	74.7	5.1	20.2	92.5	100
300	1.9	240.52	782.88	86.4	80.6	75	6.7	18.3	93.1	100
300	1.95	215.94	758.3	85.8	78.6	75.5	8.4	16.1	93.7	100
350	2	389	1142.47	133.7	132.2	75.4	1.1	23.5	92.1	100

Table 4. Effect of furrow length and inflow rate on irrigation performance for clay soil (slope 0.5%).

L m	Ql/s	tL min	Tco min	VT m3	V infl m3	Ea%	RO%	DP%	Ed%	Es%
100	1.17	42.72	180.21	12.1	8	59.5	33.9	6.6	95.8	100
100	1.18	42.02	179.51	12.2	8	59	34.4	6.6	95.8	99.9
100	1.19	41.49	178.98	12.2	8	59	34.4	6.6	95.9	99.9
150	1.17	106.17	441.51	30.2	25	71.5	17.2	11.3	94.9	99.9
150	1.18	103.45	438.79	30.2	24.9	71.5	17.5	11	95	99.9
150	1.19	101.59	436.93	30.4	24.8	71.1	18.4	10.5	95.1	100
200	1.17	306.39	848.75	58.5	57.7	73.8	1.4	24.8	91.6	100
200	1.18	291.27	833.63	57.9	56.9	74.6	1.7	23.7	91.9	99.9
200	1.19	282.44	824.8	57.8	56.5	74.7	2.2	23.1	92.1	99.9
210	1.2	345.39	1098.86	78	77.7	77.5	0.4	22.1	92.7	100

Table 5. Effect of furrow length and inflow rate on irrigation performance for clay soil (slope 1%).

L m	Ql/s	tL min	Tco min	VT m3	V infl m3	Ea%	RO%	DP%	Ed%	Es%
70	0.54	96.2	233.69	7.4	6.7	68.1	9.5	22.4	91	100
70	0.57	82.04	219.53	7.3	6.4	69	12.3	18.7	92	99.9
70	0.59	75.32	212.81	7.4	6.3	68.1	14.9	17	92.5	100
80	0.54	149.3	484.64	15.5	14.3	74.3	7.7	18	93	99.9
80	0.57	122.04	457.38	15.4	13.8	74.8	10.4	14.8	94	100
80	0.59	110.27	445.61	15.6	13.5	73.8	13.5	12.7	94.5	100
90	0.54	245.01	787.37	25.3	24.8	76.8	2	21.2	92.8	100
90	0.57	195.19	737.55	25	23.6	77.8	5.6	16.6	93.9	100
90	0.59	167.15	709.51	24.9	22.9	78.1	8	13.9	94.6	100
100	0.59	268.89	1022.36	35.9	35.3	80.2	1.7	18.1	93.9	100

Table 6. Impacts of furrow length and inflow rate on irrigation performance for sand soil (slope 0.2%).

L m	Q l/s	tL min	Tco min	VT m3	V infl m3	Ea %	RO %	DP %	Ed %	Es %
120	2.8	25.31	49.28	6.5	4.6	55.4	29.2	15.4	91.4	100
120	2.87	24.53	48.5	6.6	4.6	54.5	30.3	15.2	91.7	99.9
120	2.94	23.84	47.81	6.6	4.5	54.5	31.8	13.7	92	99.9
190	2.8	67.4	104.68	14.8	12.8	53	13.5	33.5	86.1	100
190	2.87	64.23	101.51	14.7	12.5	53.3	15	31.7	86.5	100
190	2.94	61.52	98.8	14.6	12.3	53.7	15.8	30.5	86.9	100
250	2.8	147.58	199.44	29.9	27.9	43.9	6.7	49.4	82.3	100
250	2.87	138.03	189.89	29	26.8	45.3	7.6	47.1	82.8	100
250	2.94	126.98	178.84	27.8	25.6	47.2	7.9	44.9	83.4	99.9
300	3	225.98	298.85	49.2	46.7	41.2	5.1	53.7	81.8	100

Irrigation performance for sand soil: The irrigation performance results computed for the slope of 0.2% were observed (Table 6). It was clear that achieved higher Ea of 55.4% for furrow length was 120 m at a flow rate of 2.8 l/s compared to furrow length 190,250 and 300 m. While the maximum value of RO 31.8% was obtained for furrow length 120 m at a flow rate of 2.94 l/s and the lowest value of 5.1% was for furrow length 300 m at a flow rate of 3 l/s. For DP, the maximum and minimum values were 53.7 and 13.7% for furrow length of 300 m and 120 m at flow rate 3 and 2.94 l/s respectively. There was a higher value of Ed 92% for furrow length 120 m at 2.94 l/s, the Ed has been achieved of 100%.

For the slope of 0.3% was recorded value (Table 7). In the table we find that the highest Ea was 61.6% for furrow length 100 m at 1.85 and 1.9 l/s compared to furrow length 80,150 and 200 m. The maximum value of RO 29.3% was obtained for furrow length 80 m at a flow rate of 1.95 l/s, while the lowest value of 3.5% for furrow length 200 m at a flow rate of 2 l/s. For Dp, maximum and minimum values were 53.8 and 12.2% for furrow length of 200 and 80 m at 2 and 1.95 l/s respectively. The highest Ed was obtained at 93% for furrow length 80 m at 1.95 l/s, the Ed has been achieved of 100%.

For the slope of 0.5% was recorded value (Table 8). The highest Ea was ***52.***3% for furrow length 9***0***m at a flow rate of ***1.17*** and 1.18 l/s compared to furrow length 80,100 and 120 m. The maximum value of RO8.7% was obtained for furrow length 80 m at a flow rate of 1.19 l/s,while the lowest value of 1.6% for furrow length 120 m at a flow rate of1.18 and 1.19 l/s. For DP, maximum and minimum values were 56.8 and 39.1% for furrow length of 120 and 80 at flow rate 1.17 and 1.19 l/srespectively. The highest Ed was obtained at85.6% for furrow length 90 m at 1.19 l/s, the Ed has been achieved of 100%.

For the slope of 1% was recorded value (Table 9). In the table we find that the highest Ea was 68.8% for furrow length 3***0*** m at flow rate 0.57 l/s compared to furrow length 20, 40 and 50 m. The maximum value of RO30% was obtained for furrow length 20 m at all flow rates,while the lowest value of 5.3% for furrow length 50 m at a flow rate of0.6 l/s. For DP, maximum and minimum values were 35.5 and 10% for furrow length of 50 (at 0.6 l/s) and 20 m at all flow rates. The highest Ed was obtained of 96.8% for furrow length 20 m at 0.59 l/s, the Ed has been achieved of 100% all length each flow rates.

Table 7. Impacts of furrow length and inflow rate on irrigation performance for sand soil (slope 0.3%).

L m	Q l/s	tL min	Tco min	VT m3	V infl m3	Ea %	RO %	DP %	Ed %	Es %
80	1.85	19.51	43.48	4.1	3	58.5	26.8	14.7	92.4	99.9
80	1.9	18.79	42.76	4.1	3	58.5	26.8	14.7	92.7	99.9
80	1.95	18.11	42.08	4.1	2.9	58.5	29.3	12.2	93	100
100	1.85	31.58	68.86	6.7	5.4	61.6	19.4	19	91.5	100
100	1.9	30.15	67.43	6.7	5.3	61.6	20.9	17.5	91.9	100
100	1.95	28.83	66.11	6.8	5.2	60.7	23.5	15.8	92.2	100
150	1.85	94.68	146.54	14.9	13.8	52.9	7.4	39.7	85.4	100
150	1.9	88.57	140.43	14.6	13.4	53.9	8.2	37.9	86	99.9
150	1.95	80.63	132.49	14	12.8	56.3	8.6	35.1	86.7	100
200	2	207.18	280.05	31.6	30.5	42.7	3.5	53.8	82.6	100

Table 8. Impacts of furrow length and inflow rate on irrigation performance for sand soil (slope 0.5%).

L m	Q l/s	tL min	Tco min	VT m3	V infl m3	Ea %	RO %	DP %	Ed %	Es %
80	1.17	49.16	73.13	4.7	4.3	51.1	8.5	40.4	84.9	100.1
80	1.18	48.16	72.13	4.7	4.3	51.1	8.5	40.4	85.1	100.1
80	1.19	46.98	70.95	4.6	4.2	52.2	8.7	39.1	85.2	100.1
90	1.17	71.31	108.59	7.1	6.7	52.3	5.6	42.1	85.3	100
90	1.18	69.68	106.96	7.1	6.7	52.3	5.6	42.1	85.5	100
90	1.19	67.75	105.03	7	6.6	53	5.7	41.3	85.6	99.9
100	1.17	105.81	157.67	10.5	10	50	4.8	45.2	84.8	100.1
100	1.18	103.13	154.99	10.4	9.9	50.5	4.8	44.7	85	100
100	1.19	97.31	149.17	10.1	9.6	52	5	43	85.3	100.1
120	1.17	220.03	292.9	19.9	19.4	40.7	2.5	56.8	82.7	100
120	1.18	205.37	278.24	19	18.7	42.6	1.6	55.8	82.9	100
120	1.19	199.22	272.09	18.7	18.4	43.3	1.6	55.1	83.1	100

Table 9. Impacts of furrow length and inflow rate on irrigation performance for sand soil (slope 1%).

L m	Q l/s	tL min	Tco min	VT m3	V infl m3	Ea %	RO %	DP %	Ed %	Es %
20	0.55	7.14	31.11	1	0.7	60	30	10	96.2	100
20	0.57	6.69	30.66	1	0.7	60	30	10	96.5	100
20	0.59	6.18	30.15	1	0.7	60	30	10	96.8	100
30	0.55	21.25	58.53	1.9	1.6	65.1	15.8	19.1	93	100
30	0.57	18.95	56.23	1.8	1.5	68.8	16.7	14.5	93.7	100
30	0.59	17.42	54.7	1.9	1.5	65.1	21.1	13.8	94.1	100
40	0.55	53.56	105.42	3.4	3.1	61.8	8.8	29.4	89.4	100
40	0.57	47.84	99.7	3.3	3	63.6	9.1	27.3	90.1	100
40	0.59	41.87	93.73	3.2	2.9	65.6	9.4	25	90.9	100
50	0.6	88.73	161.6	5.7	5.4	59.2	5.3	35.5	88.3	100

Conclusions

It was concluded that the model can be used to compare different types of furrow irrigation management strategies in different types soilsIn this study, the performance of furrow irrigation was tested using the approach of the volume balance method for two different soil types and four different slopes, with each slope three inflow rates were chosen and four furrow lengths**.**The slope, inflow rate selected showed that the furrow application efficiency, deep percolation ratio and tailwater ratio varies for the different soil types.The results showed that the furrow length of 100 m achieved the highest application efficiency with a flow rate of 0.59 l/s and a slope of 1%, while the same length achieved the highest distribution efficiency with a flow rate of 1.19 l/s and a slope of 0.05% for clay soils. While the highest application efficiency was for furrow length 30 m at a flow rate of 0.57 l/s and a slope of 1%, the highest distribution efficiency was achieved for furrow length 20 m at a flow rate of 0.59 l/s and a slope of 1% for sandy soils.

References

Eldeiry AA, Garcia LA, El-Zaher M and El-Sherbini K (2005).Furrow irrigation system design for clay soil in arid regions. American Society of Agricultural Engineers. 21(3): 411−420.

Fikadu R, Mohammed J, Nanesa K and Abebe N (2022). Determination of Appropriate Furrow Length and Inflow Rate for Furrow Irrigation Practice under Werer Climatic Conditionfor Cotton Production at Middle Awash, Ethiopia. "Irrigation and Drainage Sys Eng. 11(2022): 332.

Guirguis AE and Zayton AM (2015). Modeling Furrow Surface Irrigation Design and Predicting of Infiltration Parameters underDifferent Inflow Rates. Egypt. J. Agric. Res., 93(1): 163-184

Hamid RM, Mohammad MC, Peyman A and Masoomeh D (2021). Investigation of various volume– balance methods in surface irrigation. Arabian Journal of Geosciences. 14(4): 241. https://doi.org/10.1007/s12517-021-06505-9

Konukcu F and Delibas L (2006). Optimum time ratio for maximum application efficiency in furrow irrigation. Journal of Tekirdag Agricultural Faculty- 3(3): 129-137.

Walker WR and Skogerboe GV (1987). Surface Irrigation Theory and Practice. Prentice-Hall Inc., Englewood Cliffs, xiii, 386 p.

****