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ESTIMATE INFILTRATION RATE USING PHYSICAL, CHEMICAL, AND HYDRO-PHYSICAL SOIL PROPERTIES IN THE NEW LAND – EL WADI EL GADIAD GOVERNORATE, EGYPT

Ismail, M.[(1)]; Yacoub, R. K.[(1)] and Eid S. F. M.[(2)]

[(1)] RS and GIS Unit, Soils, water, and Environment Research. Institute., Agric. Res. Center, Giza.

[(2)] Agricultural Engineering Research. Institute., Agric. Res. Center, Giza.

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ABSTRACT: Measuring the infiltration rate (IR) in different types of soil is very important to determine the optimum irrigation application rate (i.e., discharge) to prevent the surface run-off, that causes a decrease in the productivity of the land as a result of the loss of seeds, fertilizers and irrigation water. Therefore, researchers tend to use high-accuracy field measurements of IR (i.e., double ring method) to reach the precise actual values of IRs in different soils that help in setting up suitable irrigation system and intensity rate of irrigation water to allow only suitable flux based on the soil infiltrability and eliminate losses through run-off. To reach this goal field and laboratory measurements were conducted to evaluate IR and chosen related soil properties. The obtained results of the study concluded the following:

The differences in the values of the IR are attributed to the changes in the physical properties of the soil due to the variation of soil textures, which leads to the heterogeneity of the soil grains, which greatly affects the IR; the differences in the bulk density of the studied soils affect the geometry of the soil particle and pore sizes distribution which resulted in large extent on IR; as a result of the heterogeneity of the soil particles size, the smaller ones fill the spaces between the large particles, which limits the porosity and thus reduces the IR; the presence of calcium carbonate improves the permeability up to a certain limit, but when it increases such limit, this leads to reduction in soil permeability; employing mathematical equations, developed based on statistical analysis of the relationship between IR and the soil properties (physical, chemical and hydro-physical properties), are useful in reducing the time and effort required to conduct the double ring experiment; the results of the significant relationships at 99% and 95% confidence limits between the results of using mathematical equations to infer infiltration rates showed satisfied significance (R^2 value) for most of the results of the studied physical, chemical and hydro-physical soil properties; statistically, this method can be used under the soil's conditions of the study area, with the need to implement it in different types of soils for the purpose of validating the obtained regression equations to reach similar accuracy as the field measurement of IR using the method of double-ring infiltrometer.

Key words: Double-ring method, infiltration rate, physical properties, chemical properties, hydro-physical properties, El-Wadi El-Gidid area

INTRODUCTION

In the physical, chemical and biological properties of soil, the movement of water, air, solubility, and sedimentation, as well as being a place of residence for roots and living soil organisms. Zur Erlangung (2009) illustrated that the infiltration rate was strongly influenced by the land use systems and concluded that, the high IR were a consequence of improved clay soil properties. Osuji *et al.,* (2010) were concluded that the different land use practices affect the infiltration rate of the soils. IR was also observed as affected by pH and exchangeable acidity values of the soils. Dagadu J. S., *et al.,* (2012) illustrated that the values of infiltration parameters models vary from soil to soil and the graphs of IR the initial IR values were high and decreased with time until reach a constant rate. Ayu I. W., *et. al.,* (2013) were concluded that, the factors influencing infiltration are texture, structure, organic matter, porosity, bulk density, particle density and initial moisture content of the experimental soil. Girei *et al.,* (2016), were illustrated that the relationship between IR and time showed high correlation (R^2 value was

*Corresponding author: Ismail62@gmail.com

0.9956). In addition, they concluded that further study of infiltration characteristics of the trial exploring other Models is recommended to improve its hydraulic properties. Anderson, Rebecca Lynn (2019) was demonstrated that land use affects surface infiltration, water-stable aggregation, and select near-surface soil physical and chemical properties in fine-textured, loessal and alluvial soils. Chenxia *et al.*, (2019) were illustrated that, the regression models explained 13% to 63% of the variability of the measured soil properties, and the model for clay which had the highest R^2 value, followed by total nitrogen, silt, bulk density, soil organic matter and total phosphorus. Farid H. U., *et al.*, (2019) were illustrated that based on the evaluation of three infiltration models, all the models showed good agreement with the measured cumulative infiltration depths in the field using the estimated model's parameters. Patle G. T., *et al.*, (2019) were concluded that, the soil physical properties, land use, vegetation coverage, and seasons play a very important role in IR. Predicted models, with all soil properties, were best fitted, according to the highest value of R^2 value and the lowest value of RMSE and standard error. Bayabila H. K., *et al.*, (2019) were concluded that, the overall of most values of studied soil parameters from the FAO and AfSIS datasets were comparable with field observations fail to capture spatial variability of critical soil parameters (e.g., available water). Yang X. *et al.*, (2019) and Patle G. T. (2021) were illustrated that, the relationship between cumulative infiltration and time of Kostiakov model showed the best fitting comparing to the other studied models.

Harisuseno D. *et al.*, (2020) were illustrated that soil porosity contributes mostly to the regression equation that indicates great influence in controlling soil infiltration behaviour. Singh B., *et al.*, (2021) were concluded that infiltration characteristics measuring in field is a time-consuming and complicated task for water resource and agriculture researchers. Failache M. F. *et al.*, (2021) illustrated that, the land uses and management practices affected the accuracy of the selected infiltration models. Nugroho S. *et al.*, (2021) showed that soil compaction, vegetation cover, and soil texture had a significant effect on the basic infiltration rate (BIR). Dahak A. *et al.*, (2022) found that the Horton model, was the most suitable to assess IR.

MATERIALS AND METHODS

Location of the studied area

The studied area is located at the northern part of the end of Branch 1 in Toushka area. It is suited between latitude 23° 12´ 0.0″ N and 23° 21´ 0.0″ N and between longitude 31° 30´ 0.0″ E and 31° 45´ 0.0″ E. The studied area target to be new agriculture area in Toushka at the south part of El Wadi El Gddied Governorate. Figure (1) shows the geographical location of the random distribution of soil site.

Images and Maps

Recent satellite images of Sentinel-2 with 10-meter resolution date at 19 July 2021.

12 Topographic maps scale 1:25000 (Loha 576, 577, 578, 588, 589, 590, 591, 601, 602, 603, 604, and west Jabal um Shagher) were cover the study area (GDMS 2009).

Software

Geographic Information System, ArcGIS (ESRI, 2016).

The Statistical Production and Service Solutions Software (SPSS-17, 2008).

Map projection

The UTM WGS1984 Zone 36 north projection system was used as Projected Coordinate systems for all satellite images used in this paper.

Field and laboratory Work

Sixty-six soil sites were randomly selected in the study area, 26 sites out the 66 soil sites were subjected to measure the IR (infiltration rate) in the field plus measurements of physical, chemical, and hydro physical analyses. The other 40 sites were subjected to measure selected physical, chemical, and hydro physical analyses only to estimate the IR (see Fig. 1).

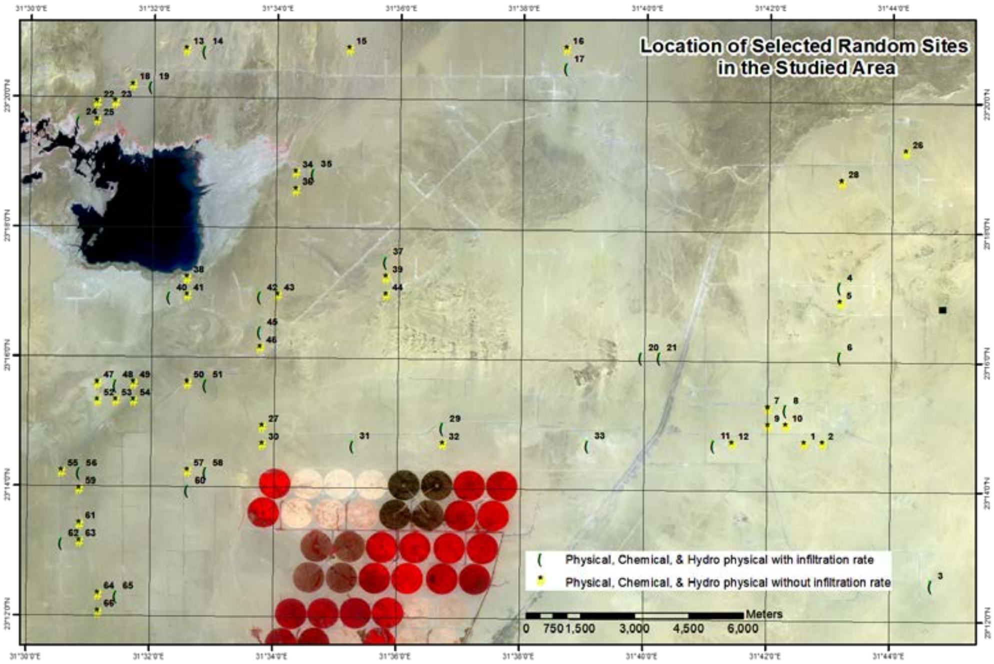


Figure (1): location of the geographical random distribution of soil sited.

Hydro-physicalproperties measurement

The IR were measured in the field using a double-ring method. HC (Hydraulic conductivity), BD (bulk density), MRC (moisture retention curves) were measured in the laboratory to estimate IR. The double-ring consists of two cylinders with outer cylinder diameter of 60 cm, the inner cylinder diameter is 30 cm by 30 cm in height of both cylinders. The two cylinders were fixed and planted in the soil to depth of (10-15 cm), as shown in Figure (2). The measurement time generally ranges between 2: 120 minutes Hence, the IR is defined as the depth of the water infiltrating from the surface of the soil during a unit of time, and it crosses the speed of water passage in the soil. The measurement was recoded continues until the reading becomes stable with time (Tricker, A. S. 1978).

Hydraulic conductivity measurement

The saturated HC was measured by taking undisturbed soil samples from the depths of 0-25 cm and 25-50 cm using a cylinder with a height of 15 cm and diameter of 5 cm (Klute, 1986).

Bulk density measurement

The BD was determined in undisturbed soil samples, collected, using metal cylinders with 5 cm in their height and diameter. The sample was taken with the cylinder from the soil without disturbing at depth of 0-25 and 25-50 cm. The wet and dry weight and volume were determined and BD was calculated (Burt 2004).

Moisture retention curve measurement

The MRC was estimated for the study area soil using porous plate extractor apparatus. Undisturbed soil samples were collected from two depths of 0-25 and 25-50 cm. The soil samples were taken by soil cores with 2.5 cm in their height and diameter. The soil cores were saturated from bottom to top and exposed to different pressures (0.1, 0.33, 0.66, 1 and 15 bar) and the equilibrated soil moisture content were recorded (Stolte, J *et al.,* 1997).

Chemical analysis

Disturbed soil samples were air dried, gently crushed, and then sieved through a 2-mm sieve. Fractions below 2 mm were subjected to chemical analysis. Chosen chemical properties (i.e., soluble cations and anions, EC, and pH) were determined in soil paste extraction (Burt 2004).

Figure (2): Show the double infiltrating cylinder in the field.

Particle size distribution

Particle size distribution (through pipette method), $CaCO_3$% (calcium carbonate content), and OM (organic matter) were determined in undisturbed soil samples (Burt, 2004).

Measure Soil pore size distribution:

The QDP (Quick drainage pores), SLDP (Slowly Drainable Pours), WHP (Water Holding Pours), and FCP (Fine Capillary Pours) were calculated using the data of water moisture tension Klute (1986).

Statistical analysis (ANOVA)

The statistical analysis (ANOVA) was carried out for the soil texture and the selected physical, chemical, and hydro-physical soil properties of the studied area (Sand%, Silt%, Clay%, $CaCO_3$%, gypsum%, SP (saturation present), soil pH, EC, SAR, BD, HC, P (total porosity%), FC (field capacity), WP (wilting point), AW (available water), pore size distribution, IR, and BIR).

Statistical analysis (correlations)

The correlation between previously mentioned studied parameters was done using SPSS software V.17, to evaluate the relation between physical, chemical, and hydro physical soil properties and IR and BIR.

Estimated IR and BIR at significant level 99% and 95%

The multiple regression operation in SPSS software V.17 was used to estimate IR and BIR based on the two significant levels (99% and 95%). The linear regression model applied on this study to express the relationship between x and y variables.

RESULTS AND DISCUSSION

Physical and chemical properties

Chosen physical, and chemical soil properties of the studied area (Sand%, Silt%, Clay%, $CaCO_3$%, Gypsum%, SP%, pH, EC, SAR were determined (Table, 1). The results illustrated that the main soil texture is sandy loam class (65.15% of soil samples), then sandy clay loam class (25.76% of soil samples), and in end loamy sand class (9.09% of soil samples). Bolded soil sites number were subjected to measure the IR in the field included soil samples for physical, chemical, and hydro-physical.

Table (1): Studied physical, and chemical soil properties.

Site No	Selected Physical Soil Properties						Selected Chemical Soil Properties			
	Sand%	Silt%	Clay%	Texture	$CaCO_3$	Gypsum	SP %	pH	EC dS/m	SAR
1	83.0	12.0	5.0	Loamy Sand	17.0	1.4	30.0	8.0	5.9	13.5
2	50.0	20.0	30.0	Sandy Clay Loam	14.9	1.3	31.5	8.6	0.7	2.3
3	69.0	20.0	11.0	Sandy Loam	11.5	1.2	27.0	7.8	3.0	5.8
4	68.0	21.1	11.0	Sandy Loam	11.2	0.9	24.0	8.5	5.3	11.7
5	68.0	20.0	12.0	Sandy Loam	20.1	0.6	25.0	8.0	4.2	11.5
6	68.0	21.0	11.0	Sandy Loam	14.3	1.3	26.0	8.1	3.1	9.5
7	68.0	22.0	10.0	Sandy Loam	22.1	0.3	25.0	8.3	7.3	8.2
8	82.0	10.5	7.5	Loamy sand	10.2	1.6	25.0	8.1	4.3	11.4
9	68.0	21.1	11.0	Sandy Loam	24.2	0.4	25.0	8.0	3.4	9.3
10	67.0	20.5	12.5	Sandy loam	18.7	1.4	25.0	8.0	4.0	11.4
11	68.0	23.0	9.0	Sandy loam	14.9	0.5	27.0	8.0	1.7	7.9
12	67.0	20.5	12.5	Sandy loam	15.9	0.8	26.0	8.1	2.6	9.9
13	68.0	20.0	12.0	Sandy Loam	4.0	4.0	29.0	7.6	12.6	4.9
14	68.0	21.1	11.0	Sandy Loam	4.2	4.2	48.0	7.8	16.1	13.2
15	65.0	21.0	14.0	Sandy Loam	4.1	3.5	35.0	7.8	15.6	14.4
16	53.0	16.0	31.0	Sandy Clay Loam	21.6	21.6	38.0	7.9	57.7	39.0
17	55.0	17.0	28.0	Sandy Clay Loam	17.8	20.6	34.0	7.7	57.7	4.2
18	67.0	20.5	12.5	Sandy Loam	3.6	3.6	26.0	8.1	1.9	3.0
19	68.0	22.0	10.0	Sandy Loam	4.5	4.5	28.0	7.8	3.4	4.0
20	69.0	20.0	11.0	Sandy Loam	4.3	1.0	39.0	7.2	24.1	20.8
21	67.0	23.0	10.0	Sandy Loam	16.5	3.2	19.5	8.3	7.1	7.2
22	67.0	23.0	10.0	Sandy Loam	2.3	20.3	32.0	7.7	8.2	6.9
23	68.0	22.0	10.0	Sandy Loam	2.2	20.7	29.0	7.6	21.3	4.9
24	69.0	20.0	11.0	Sandy Loam	3.1	22.0	46.0	7.9	21.4	34.0
25	68.0	22.0	10.0	Sandy Loam	2.2	20.7	29.0	7.6	21.3	4.9
26	68.0	21.1	11.0	Sandy Loam	3.6	25.8	35.0	7.8	5.0	8.2
27	68.0	23.0	9.0	Sandy Loam	3.9	9.1	32.5	8.7	1.1	2.9
28	68.0	23.0	9.0	Sandy Loam	3.7	24.5	42.8	7.7	28.0	13.5
29	80.0	17.5	2.5	Loamy sand	21.0	0.9	38.5	8.5	2.2	4.5
30	69.0	20.0	11.0	Sandy Loam	10.2	4.4	32.5	8.4	4.5	5.1
31	82.0	10.0	8.0	Loamy sand	19.8	0.5	31.5	8.6	1.5	4.2
32	81.0	9.5	9.5	Loamy sand	15.9	0.8	32.0	8.4	1.8	4.2
33	83.0	12.0	5.0	Loamy sand	19.2	0.6	38.5	8.4	15.0	12.8
34	51.0	20.0	29.0	Sandy Clay Loam	3.5	10.1	53.0	7.6	44.2	26.1
35	52.0	21.0	27.0	Sandy Clay Loam	6.6	8.8	45.0	7.5	56.0	57.8
36	52.0	21.0	27.0	Sandy Clay Loam	11.3	11.2	28.0	7.6	8.8	4.8
37	66.0	19.5	14.5	Sandy Loam	9.0	8.0	18.0	7.8	6.4	6.0
38	50.0	20.0	30.0	Sandy Clay Loam	3.7	10.1	28.0	7.6	14.1	9.4
39	50.0	20.0	30.0	Sandy Clay Loam	11.5	8.4	35.0	7.7	5.7	10.7
40	52.0	23.0	25.0	Sandy Clay Loam	11.2	11.3	52.0	8.1	18.3	10.7
41	53.0	23.0	24.0	Sandy Clay Loam	10.6	9.8	35.0	7.8	6.7	9.5
42	70.0	22.0	13.0	Sandy Loam	6.5	12.7	53.0	7.6	26.0	12.7
43	68.0	21.0	11.0	Sandy Loam	8.7	12.7	52.0	8.0	16.0	10.0

Table (1): (continued).

Site No	Selected Physical Soil Properties						Selected Chemical Soil Properties			
	Sand%	Silt%	Clay%	Texture	$CaCO_3$	Gypsum	SP %	pH	EC dS/m	SAR
44	50.0	20.0	30.0	Sandy Clay Loam	11.5	8.4	35.0	7.7	5.7	10.7
45	68.0	21.1	11.0	Sandy Loam	11.7	12.6	40.0	7.8	6.1	9.0
46	68.0	23.0	9.0	Sandy Loam	19.4	4.5	36.0	7.7	19.5	11.0
47	52.0	21.0	27.0	Sandy Clay Loam	11.3	13.3	35.0	7.7	9.2	11.1
48	53.0	16.0	31.0	Sandy Clay Loam	22.1	4.2	32.0	7.6	33.4	11.0
49	54.0	17.0	29.0	Sandy Clay Loam	22.4	3.3	48.0	7.9	35.3	17.9
50	68.0	23.0	9.0	Sandy Loam	18.4	13.1	35.0	7.9	52.0	14.5
51	67.0	20.5	12.5	Sandy Loam	19.1	12.1	35.0	7.8	4.9	8.1
52	52.0	21.0	27.0	Sandy Clay Loam	17.1	8.7	50.0	8.0	48.5	60.0
53	50.0	20.0	30.0	Sandy Clay Loam	22.0	4.5	33.0	7.8	8.4	10.7
54	51.0	20.0	29.0	Sandy Clay Loam	17.0	2.9	32.0	7.4	60.5	12.4
55	68.0	23.0	9.0	Sandy Loam	4.3	4.6	34.0	7.4	54.7	10.3
56	67.0	20.5	12.5	Sandy Loam	3.6	5.4	35.0	7.8	7.4	10.0
57	69.0	20.0	11.0	Sandy Loam	3.7	3.1	40.0	7.8	4.9	8.1
58	68.0	23.0	9.0	Sandy Loam	3.3	2.8	27.0	7.5	42.6	19.5
59	65.0	20.0	15.0	Sandy Loam	3.6	4.4	36.0	7.8	14.7	9.6
60	68.0	20.0	12.0	Sandy Loam	5.0	4.1	33.0	7.6	4.9	5.1
61	69.0	20.0	11.0	Sandy Loam	3.1	4.4	31.0	8.7	8.7	9.7
62	68.0	20.0	12.0	Sandy Loam	3.7	4.4	27.5	7.8	14.6	13.9
63	68.0	22.0	10.0	Sandy Loam	3.6	5.4	30.0	8.1	31.6	10.9
64	68.0	22.0	10.0	Sandy Loam	19.1	4.2	40.0	7.8	11.2	12.3
65	68.0	20.0	12.0	Sandy Loam	5.3	4.7	30.8	7.6	48.9	17.8
66	68.0	20.0	12.0	Sandy Loam	18.7	2.7	28.0	7.8	29.8	32.5

Hydro-physical properties

The selected hydro-physical soil properties of the studied area are BD, HC, P, FC, AW, permanent WP, pore size distribution (QDP, SLDP, WHP, FCP), IR, and BIR were shown in Table (2). Bolded soil sites number were subjected to measure the IR in the field included soil samples for physical, chemical, and hydro-physical. Figures (3 to 6) show the three IR classes (Low, Moderate, and High Infiltration rate).

The results showed that the values of BD vary in three axes. The BD was low and ranges between 1.35 g/cm^3 to 1.41 g/cm^3, then it begins to rise and range between 1.41 g/cm^3 to 1.47 g/cm^3, and finally, the BD values increase and reach between 1.46 g/cm^3 to 1.53 g/cm^3 in some parts of the study area. The results of the HC of the study area indicate that it is different within each area, where the HC values are low values ranged from 0.87 cm/hour to 0.97 cm / hour. And it is higher in some areas and ranged from 1.1 cm/hour to 2.0 cm/hour. Small parts of the study area, the HC values rise to values ranged from 2 cm/hour to 2.8 cm/hour. The results of the FC values illustrated that the FC was increased in some areas if compared with the soils had low FC values. While it decreases more in some parts of the study area. The results of the WP values illustrated that it is related to the FC values in the study area, as the change in texture, as well as some soil characteristics, leads to a change in the FC values. Generally, the data in the Table (2), clearly show that there is a decrease in the values of the QDP in the most of study area. The values range from 2.1 to 3.3, while in the rest of the study area the values of the FDP rise and ranged from 3.5 to 4.4. On the other hand, SDP increased in some locations of the study area. WHP was high in some locations and low in the other parts of the study area. As for the area with the greatest decrease in the values of WHP, unlike some areas that are divided as the areas with the lowest decrease in the values of WHP. The infiltration rate and cumulative infiltration variation with time were calculated for measuring points using the following formula:

$$f_P=f_c+(f_0-f_c)e^{kt}$$

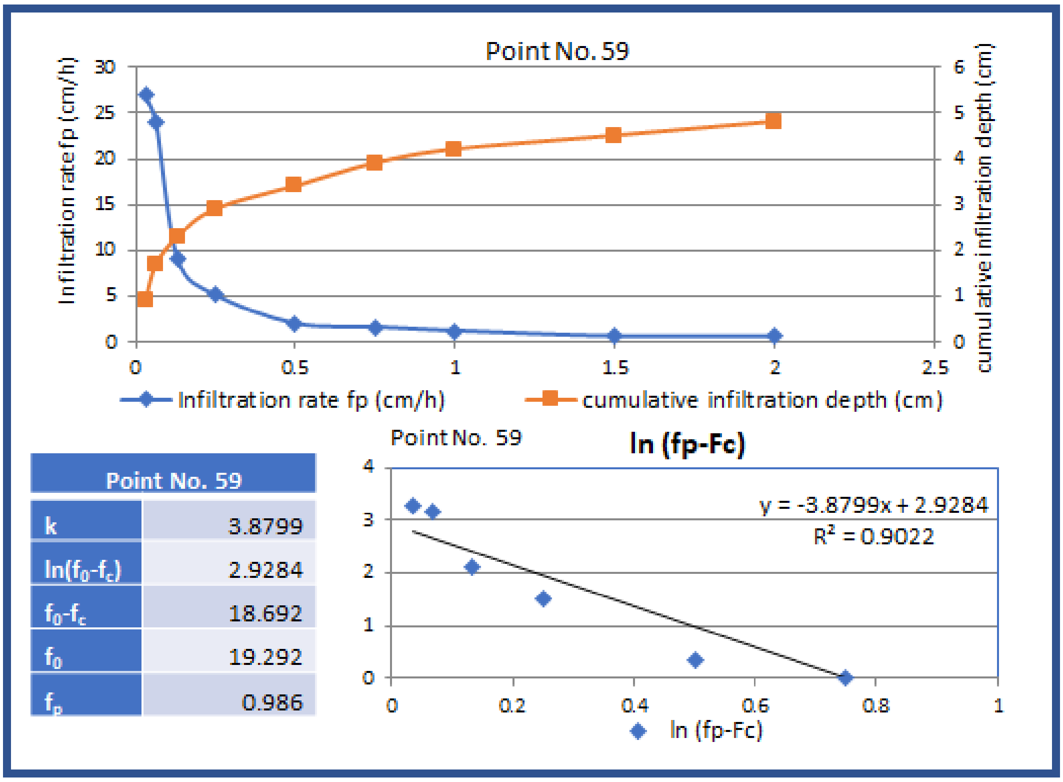
where f_p: Infiltration capacity at time t, f_0: initial infiltration capacity, f_c: final steady state infiltration capacity, k: Horton's decay coefficient, which depends on soil characteristics and vegetation. The results of four point were selected to present very low, low, moderate, and high infiltration rate (points No. 59, 65, 22, 19 respectively show in Figures 3, 4, 5, 6).

Table (2): Studied hydro-physical soil properties.

Site No.	BD	HC	P	FC	AW	WP	QDP	S.LDP	WHP	FCP	IR	BIR
1	1.47	1.70	44.70	24.40	15.50	8.90	3.30	3.60	18.20	11.40		
2	1.44	1.60	45.80	30.40	18.40	12.00	3.20	3.60	18.40	12.00		
3	1.39	0.93	47.70	35.20	22.60	12.60	3.40	6.10	18.50	12.60	1.80	0.97
4	1.48	1.70	44.30	27.00	15.00	12.00	3.60	3.70	18.90	14.20	2.30	2.63
5	1.48	1.70	44.30	26.80	14.60	12.20	3.20	3.40	19.10	14.80		
6	1.44	2.20	45.80	32.60	19.20	13.40	3.20	4.20	19.10	13.40	1.90	0.99
7	1.51	2.50	43.20	31.10	18.50	12.60	3.20	4.30	16.40	9.80		
8	1.48	2.20	44.30	25.30	15.70	9.60	2.60	3.70	17.60	10.30	3.10	2.47
9	1.52	2.70	42.80	26.30	16.10	10.20	2.40	3.30	19.60	10.90		
10	1.51	2.50	43.20	27.00	15.00	12.00	3.00	3.40	20.20	11.60		
11	1.44	1.80	45.80	29.20	18.10	11.10	3.30	3.90	18.10	11.10	2.04	1.72
12	1.41	1.60	46.90	30.10	18.30	11.80	3.30	4.20	18.30	11.80		
13	1.44	1.41	45.83	27.20	17.30	9.90	4.30	3.00	17.30	9.90		
14	1.42	1.23	46.62	28.20	18.00	10.20	4.30	2.70	18.00	10.20	2.40	2.25
15	1.45	1.43	45.95	27.60	15.80	11.80	4.40	3.10	16.00	8.30		
16	1.45	1.32	45.41	31.00	17.90	13.10	3.40	3.50	17.90	13.10		
17	1.43	1.30	46.24	32.10	18.50	13.60	3.20	3.10	18.50	13.60	1.09	1.65
18	1.48	1.70	44.30	26.80	14.60	12.20	3.60	3.70	18.90	14.20		
19	1.46	1.50	45.10	33.90	21.10	12.80	3.20	3.40	19.10	14.80	3.79	3.30
20	1.48	2.50	44.30	35.80	23.00	12.80	3.40	2.40	16.00	11.90	2.95	2.40
21	1.50	2.60	44.30	29.60	15.20	14.40	4.20	2.60	16.60	9.20	2.95	2.40
22	1.52	2.70	42.80	26.40	15.30	11.10	3.20	4.00	13.30	11.10		
23	1.51	2.59	42.69	26.80	14.60	12.20	3.30	3.90	18.10	11.10		
24	1.48	2.30	44.30	27.60	15.80	11.80	3.50	4.00	13.80	11.80	3.80	3.47
25	1.51	2.59	42.69	26.80	14.60	12.20	3.30	3.90	18.10	11.10		
26	1.51	2.30	43.20	27.20	17.30	9.90	4.30	3.00	17.30	9.90		
27	1.51	2.30	43.20	33.00	19.10	13.90	3.90	3.90	16.30	12.40		
28	1.48	2.10	44.30	28.20	18.00	10.20	4.30	2.70	18.00	10.20		
29	1.53	2.80	42.40	24.60	15.90	8.70	3.30	3.30	15.90	8.70	3.10	2.47
30	1.48	2.10	44.30	26.80	14.60	12.20	3.70	3.00	15.90	13.20		
31	1.52	2.60	42.80	27.10	15.80	11.30	3.20	4.30	16.40	9.80	3.90	3.32

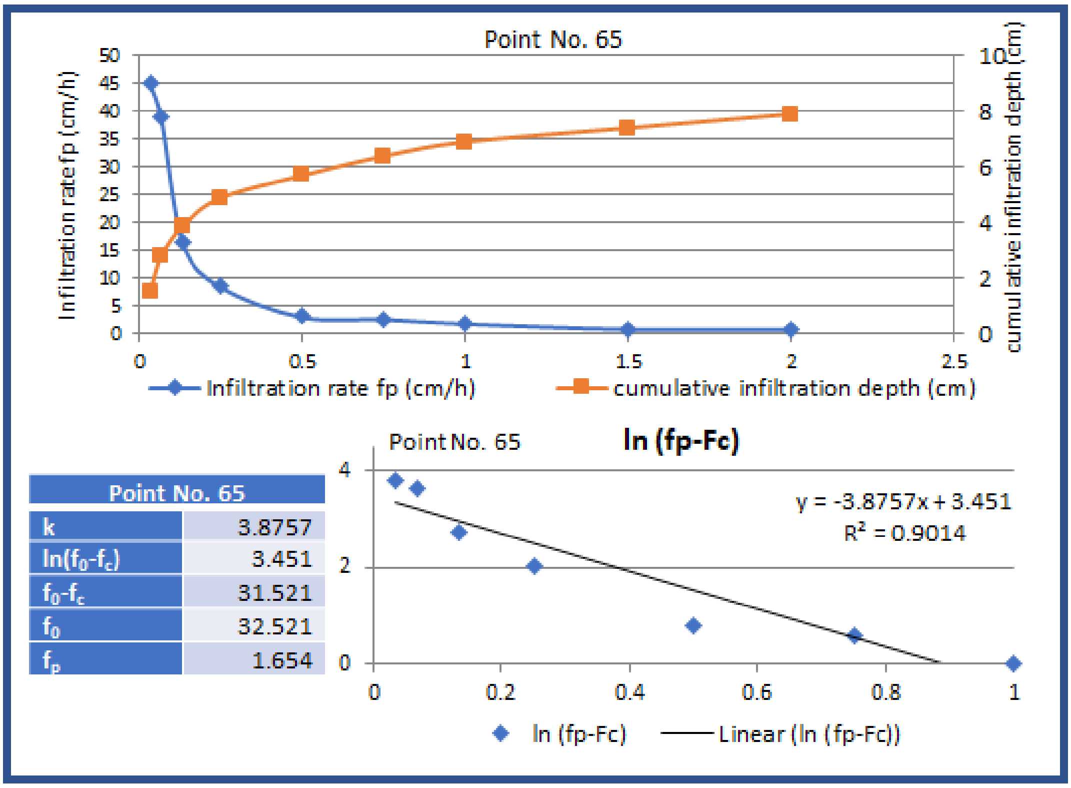
Table (2): (continued).

Site No.	BD	H	P%	FC	AW	WP	QDP	S.LDP	WHP	FCP	IR	BIR
32	1.51	2.50	43.20	25.20	16.00	9.20	3.60	3.40	16.00	9.20		
33	1.52	2.70	42.80	24.30	16.00	8.30	4.20	2.60	16.60	9.20	3.95	3.39
34	1.42	1.40	46.60	29.40	17.30	12.10	3.30	3.80	17.30	12.10		
35	1.40	1.30	47.70	29.90	17.60	12.30	3.30	3.90	17.60	12.30	1.86	1.55
36	1.41	1.40	47.80	32.10	18.50	13.60	3.30	3.30	16.30	13.90		
37	1.48	1.95	44.30	25.30	15.70	9.60	3.60	3.70	18.90	14.20	1.50	1.30
38	1.37	1.35	48.80	36.20	20.90	15.30	2.10	5.20	17.70	15.30		
39	1.50	1.65	47.62	33.00	19.10	13.90	3.20	3.40	19.10	14.80		
40	1.35	1.29	49.20	36.20	20.90	15.30	2.10	5.20	17.70	15.30	1.10	0.95
41	1.37	1.26	47.80	37.20	21.00	16.20	1.90	4.90	19.00	16.20		
42	1.43	1.60	46.20	29.40	16.20	13.20	3.30	3.10	16.20	13.20	2.30	2.07
43	1.41	1.40	47.80	30.20	17.20	13.00	3.30	3.30	16.30	13.90		
44	1.50	1.65	47.62	33.00	19.10	13.90	3.20	3.40	19.10	14.80		
45	1.39	1.12	47.70	35.00	21.90	13.10	3.60	5.60	18.30	13.10	1.50	0.96
46	1.36	1.14	48.80	35.10	21.30	13.80	4.20	5.00	20.30	13.80		
47	1.39	1.90	47.80	35.30	20.80	14.50	3.50	5.60	18.00	11.20		
48	1.37	1.87	48.81	36.10	21.10	15.00	3.80	5.40	17.80	11.90	1.04	0.89
49	1.40	1.99	47.30	37.20	21.00	16.20	3.90	3.90	16.30	12.40		
50	1.38	1.97	44.36	33.20	21.10	12.10	2.90	5.90	19.30	12.90		
51	1.40	1.41	45.30	33.80	21.50	12.30	2.90	4.10	19.90	13.20	2.01	0.98
52	1.37	1.95	48.80	38.20	24.00	14.20	3.80	5.40	17.80	11.90		
53	1.39	1.90	47.80	36.00	21.20	14.80	3.30	5.50	20.00	13.50		
54	1.37	1.87	48.81	36.20	20.90	15.30	2.90	5.20	19.80	14.10		
55	1.40	0.99	47.30	34.90	22.90	12.00	3.30	5.10	18.80	11.00		
56	1.38	0.97	48.10	35.80	23.00	12.80	4.10	4.90	19.10	11.80	2.10	0.99
57	1.46	1.40	45.10	30.50	19.60	10.90	2.40	3.30	19.60	10.90		
58	1.43	1.20	46.20	31.80	20.20	11.60	3.00	3.40	20.20	11.60	2.40	1.27
59	1.42	1.40	46.60	34.90	22.90	12.00	4.10	4.90	19.10	11.80		
60	1.47	1.50	45.30	31.80	20.20	11.60	3.00	3.40	20.20	11.60	2.60	2.74
61	1.38	0.93	48.10	36.50	23.00	13.50	3.30	5.50	20.00	13.50		
62	1.37	0.92	48.40	37.10	23.00	14.10	2.90	5.20	19.80	14.10	1.90	0.98
63	1.41	0.99	46.60	30.10	18.30	11.80	3.60	5.60	18.30	13.10		
64	1.43	1.09	46.60	33.20	21.10	12.10	3.10	5.80	20.20	11.40		
65	1.40	0.96	46.90	33.80	21.50	12.30	3.20	6.40	20.00	12.50	2.30	1.65
66	1.43	1.60	46.20	35.80	23.00	12.80	3.30	5.10	18.80	11.00		



Point No. 59	
k	3.8799
$\ln(f_0-f_c)$	2.9284
f_0-f_c	18.692
f_0	19.292
f_p	0.986

Figure (3): Very low infiltration rate and cumulative infiltration variation with time of point No. 59.



Point No. 65	
k	3.8757
$\ln(f_0-f_c)$	3.451
f_0-f_c	31.521
f_0	32.521
f_p	1.654

Figure (4): Low infiltration rate and cumulative infiltration variation with time of point No. 65.

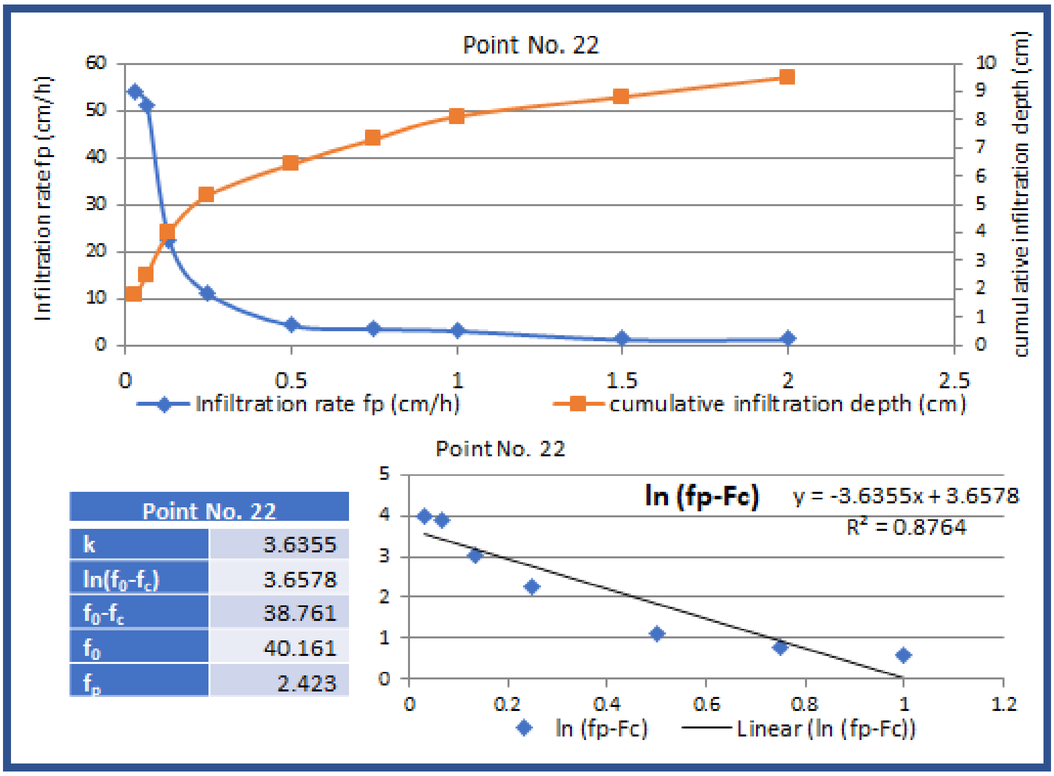


Figure (5): Moderate infiltration rate and cumulative infiltration variation with time of point No. 22.

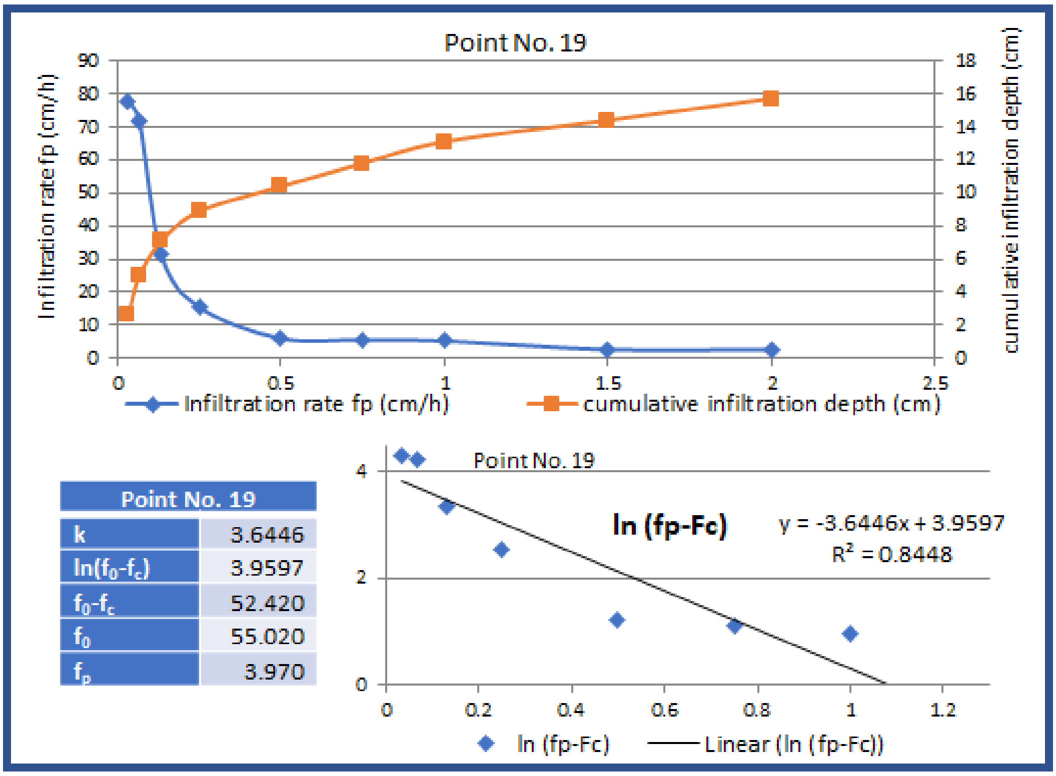


Figure (6): High infiltration rate and cumulative infiltration variation with time of point No. 19.

ANOVA of selected physical, chemical, and hydro-physical soil properties

ANOVA is a statistical test for detecting differences in group means when there is one parametric dependent variable and one or more independent variables. Table (3) shows the significant probability value of the F-test shows that the probability of the random distribution of the soil properties of sand%, silt%, slay%, $CaCO_3$%, pH, EC, BD, HC, P, FC, AW, WP, FCP, IR, and BIR, are highly significant (Significant probability less than 0.02 of population). The significant probability value of the F-test shows that the probability of the random distribution of the soil properties of gypsum %, SP, SAR, and WHP were low significant (Significant probability less than 0.05 of population). Finally, there is not significant of the probability of the random distribution of the soil properties of QDP, and SLDP (Significant probability more than 0.05 of population).

Correlations of physical, chemical, and hydro-physical soil properties

Table (4) shows the correlation between soil properties with infiltration rate and basic infiltration rate. The results illustrated that sand%, clay%, bulk density, hydraulic conductivity, field capacity, wilting point, and fine capillary pours are very high significant correlation with infiltration rate at the 0.01 level (2-tailed). Only available water, slowly drainable pours, and water holding pours are high significant correlation with infiltration rate at the 0.05 level (2-tailed). Also, the sand%, bulk density, hydraulic conductivity, total porosity%, field capacity, available water, slowly drainable pours and water holding pours are very high significant correlation with basic IR at the 0.01 level (2-tailed). Only clay%, wilting point, and WHP are high significant correlation with BIR at the 0.05 level (2-tailed).

Table (3): ANOVA of physical, chemical, and hydro-physical soil properties.

Soil properties		Significant probability	Significant
Physical properties	Sand%	0.000	**
	Silt%	0.000	**
	Clay%	0.000	**
	$CaCO_3$%	0.004	**
	Gypsum %	0.031	*
Chemical properties	SP	0.053	*
	pH	0.001	**
	EC	0.005	**
	SAR	0.035	*
Hydro-physical properties	BD	0.000	**
	HC	0.003	**
	P	0.000	**
	FC	0.000	**
	AW	0.007	**
	WP	0.000	**
	QDP	0.122	n.s.
	SLDP	0.175	n.s.
	WHP	0.092	*
	FCP	0.000	**
	IR	0.000	**
	BIR	0.016	**

**: variables very high significant with Significant probability less than 0.02.
*: variables high significant with Significant probability less than 0.05.
n.s.: variables not significant with Significant probability more than 0.05.

Table (4): Correlations of Physical, Chemical, and Hydro Physical Soil Properties.

Soil properties Correlations		Infiltration Rate	Basic Infiltration Rate
Physical	Sand%	0.749^{**}	0.558^{**}
	Silt%	-0.380	-0.382
	Clay%	-0.690^{**}	-0.455*
	$CaCO_3$%	-0.074	-0.022
	Gypsum %	-0.268	-0.104
Chemical	SP	-0.009	0.076
	pH	0.381	0.387
	EC	-0.306	-0.184
	SAR	0.035	0.024
Hydro Physical	BD	0.755^{**}	0.806^{**}
	HC	0.598^{**}	0.608^{**}
	P	-0.754	-0.763^{**}
	FC	-0.508^{**}	-0.616^{**}
	AW	-0.400^{*}	-0.576^{**}
	WP	-0.516^{**}	-0.480*
	QDP	0.185	0.200
	SLDP	-0.455*	-0.576^{**}
	WHP	-0.466*	-0.531^{**}
	FCP	-0.545^{**}	-0.444*

******. Correlation is significant at the 0.01 level (2-tailed)., ***.** Correlation is significant at the 0.05 level (2-tailed).

Estimated the IR and BIR using multi regression operation

The multi regression operation of SPSS was used to determine the formula for each IR and BIR based on the significant of the relation analysis. The linear regression model applied on this study assumes that the M mean of the response variable Y depends on the explanatory variable X according to a linear equation. In the multiple setting, the response variable Y depends on not one but B explanatory variables. The mean response is a linear function of the explanatory variables

M Y = B0 + B1X1 + B2X2 + … + BpXp

Estimated IR

Based on the results of the ANOVA, and correlations in Table (3 &4) the linear regression model was applied to calculate the IR and BIR using both physical, chemical, and hydro physical soil properties which are highly significant at 99% and 95% level.

Estimated IR at very high and high significant

To estimate the IR using significant (Significant probability less than 0.02.and Significant probability less than 0.05) the following multiple regression formula:

Est.IR. < 0.02 and <0.05 significant =-7.522 +(0.041*Sand%)+(-.006*Clay%)+(10.276* BD)+ (-0.608* HC)+(-0.103*P)+ (0.068* AW)+(0.089* WP)+(-0.05* SDP)+(-0.193* WDP)+(-0.045* FCP).

Estimated IR at very high significant only

To estimate the IR using previously mentioned soil properties, which are very highly significant at (Significant probability less than 0.02. only) the following multiple regression formula:

Est.IR. < 0.02 significant =-3.404+(0.04*Sand%) +(-0.007*Clay%)+(10.3*BD)+(-0.205* HC)+(-0.052*P)+(0.035*FC)+(0.07* WP)+ (-0.07* FCP).

Estimated BIR at very high and high significant

To estimate the BIR using soil properties which are highly significant at (Significant probability less than 0.02.and Significant probability less than 0.05) the following multiple regression formula:

Est.BIR. < 0.02 and <0.05 significant =-30.408+(0.04*Sand%)+(-0.038*Clay%)+(22.495*BD) +(-1.034*HC)+ (0.03*P)+(0.035* AW)+(0.075* WP)+(-0.076* SDP)+ (-0.237* WHP)+(-0.011*FCP).

Estimated BIR at very high significant only

To estimate the BIR using soil properties which are very highly significant at (Significant probability less than 0.02. only) the following multi regression formula:

Est.BIR. < 0.02 significant =-26.161 +(0.009* Sand%)+(21.43* Bulk Density)+(-0.945* Hydraulic Conductivity)+(0.032* Total Porosity%)+(0.068* Field Capacity)+(-0.046* Available Water)+(-0.053* SDP)+(-0.238* WHP).

Final correlation between collected data with estimated IR and BIR

Table (5) shows the correlation between soil properties with IR and BIR in the field, and estimated IR and BIR at < 0.02 and <0.05 significant. The results of correlation illustrated that, the correlation significant between different soil properties with measured IR, estimated IR at <0.02 and 0.05 of significant, and, estimated IR at level (<0.02 significant only) were increased the significant (R^2) with the soil properties and become higher with estimated IR at level (<0.02 significant only). Also, silt%, SP, EC, SAR, and QDP were started to be have high significant with estimated IR at both significant levels and, estimated IR at level (<0.02 significant only), which were non-significant with measured data. On the other hand, the correlation test illustrated that, the correlation significant between selected soil properties with calculated BIR, estimated BIR at both significant levels, and estimated BIR at level (<0.02 significant only), were increased the significant value of R^2 with the soil properties and become higher with estimated BIR at level (<0.02 significant only), but significant of sand% and clay% were reduced. Also, silt%, and EC, were started to be have high significant with estimated BIR at level (Significant probability less than 0.02.and Significant probability less than 0.05), and, estimated BIR at level (<0.02 significant only), which were non-significant with measured data.

CONCLUSION

Measuring the IR in different types of soil is very important for optimizing the irrigation water flow intensity and establish adjusted irrigation practice to prevent the surface run-off that causes reduction in the productivity of the land as a result of the loss of seeds, fertilizers and irrigation water. Therefore, researchers tend to follow high-accuracy techniques of measuring IR using double ring field experiments to reach precise values of IR in different soils that help in setting up suitable irrigation system and quantities that eliminate losses though run-off. However, IR measurements, which take from two to three hours and more, conditional to soil type, are stressful and costly, and time consuming to reach the final results, despite the accuracy of the field test. Therefore, this research studied the possibility of deriving mathematical equations to calculate IR after studying the relationships between measured IR in the field and measured physical, chemical and hydro-physical properties. A total of 66 sites were identified randomly in the study area, and a double ring experiment was conducted for 26 sites. Soil samples were collected to conduct the analyzes in addition to measuring the soil moisture retention curves, bulk density, total porosity and hydraulic conductivity. The results of the study concluded that the differences in the values of the IR are attributed to the changes in the physical properties of the soil due to the variations in the soil texture, which leads to the heterogeneity of the soil grains, which greatly affects IR.

Tabel (5): Final correlation of estimated IR and BIR using significant at 99% and 95% with collected data.

Soil properties	Field measurement		Estimated IR		Estimated BIR	
	IR	BIR	99% & 95%	99%	99% & 95%	99%
Sand%	0.749**	0.558**	0.816**	0.825**	0.392**	0.434**
Silt%	-0.380	-0.382	-0.274*	-0.287*	-0.308*	-0.221
Clay%	-0.690**	-0.455*	-0.772**	-0.781**	-0.301*	-0.380**
$CaCO_3$%	-0.074	-0.022	-0.159	-0.039	-0.164	-0.199
Gypsum %	-0.268	-0.104	-0.077	-0.139	0.067	0.083
SP	-0.009	0.076	-0.186	-0.306*	-0.093	-0.113
pH	0.381	0.387	0.357**	0.385**	0.278*	0.283*
EC	-0.306	-0.184	-0.386**	-0.423**	-0.352**	-0.370**
SAR	0.035	0.024	-0.271*	-0.310*	-0.191	-0.209
BD	0.755**	0.806**	0.795**	0.856**	0.864**	0.884**
HC	0.598**	0.608**	0.473**	0.597**	0.445**	0.474**
P	-0.754**	-0.763**	-0.803**	-0.866**	-0.669**	-0.712**
FC	-0.508**	-0.616**	-0.632**	-0.659**	-0.654**	-0.681**
AW	-0.400*	-0.576**	-0.481**	-0.519**	-0.632**	-0.653**
WP	-0.516**	-0.480*	-0.669**	-0.669**	-0.480**	-0.508**
QDP	0.185	0.200	0.271*	0.224	0.220	0.242
SLDP	-0.455*	-0.576**	-0.516**	-0.483**	-0.702**	-0.695**
WHP	-0.466*	-0.531**	-0.432**	-0.291*	-0.547**	-0.559**
FCP	-0.545**	-0.444*	-0.587**	-0.612**	-0.355**	-0.392**

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

There is also a difference in the bulk density of the soil, which affects the homogeneity of the soil grains to a large extent on the IR; as a result of the heterogeneity of the particles size distribution, the smaller ones fill the spaces between the large particles, which limits the porosity and thus reduces the IR; also, dry soil contains fine grains, and at the beginning of the filtration process, water carries them during permeability, as it blocking the soil pores, which leads to a decrease in the infiltration capacity after a period of starting the measurement; the presence of calcium carbonate, with a small amount, improves the permeability, but with an increase in it's amount beyond a certain limit, leads to poor permeability of the soil and perhaps a difference in the ratio of sodium, which caused a difference, in general, in the values of the measured IR under all the conditions and locations specified in the study; the use of mathematical equations after conducting a good statistical study to determine the relationship between IR and the physical, chemical and hydro-physical properties of studied soils found to be useful in reducing the time and costs required to conduct the double-ring experiment; the results of the significant relationships at 99% and 95% confidence limits between the results of using mathematical equations to infer IR showed a high degree of significant (R^2) for most of the results of the studied physical, chemical and hydro-physical soil properties; statistically, this method can be used under the soil's conditions of study area, with the need to implement in different types of soils to determine its impact on a degree of accuracy to reach satisfied accuracy of using the double-ring method in the field.

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تقدير معدل الترشيح باستخدام خصائص التربة الفيزيائية والكيميائية والفيزيائية–المائية – بالأراضى الجديدة – محافظة الوادي الجديد– مصر

محمد إسماعيل[١]، رأفت كمال يعقوب[١]، سمير فتوح محمد عيد [٢]

[١] وحدة الإستشعار عن بعد ونظم المعلومات الجغرافية – معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية

[٢] معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية

الملخص العربى

إن قياس معدل الرشح فى أنواع التربة المختلفة مهم جدا لتحديد كميات مياه الرى وتحديد التصرف الأمثل لكميات ماء الرى لمنع الجريان السطحى للمياه الذى يسبب انخفاض انتاجية الأرض نتيجة فقد البذور والأسمدة ومياه الرى. لذلك يتجه الباحثين الى إستخدام طرق قياس معدل الرشح ذات الدقة العالية بإجراء تجارب الحلقات المذدوجة بالحقل للوصول الى قيم فعلية لمعدلات الرشح بالأراضى المختلفة تساعدهم فى وضع نظام وكميات رى تمنع عمليات الجريان السطحى. وقد خلصت نتائج الدراسة الى الأتى:

تُعزى الإختلافات فى قيم معدل الرشح للتغيرات الفيزيائيّة في الخواص الطبيعيّة للتربة لوجود تباين في قوام التربة مما يؤدى الى عدم تجانس حبيبات التربة التى تؤثر بدرجة كبيرة على معدل الرشح.

كذلك هناك اختلاف في كثافة التربة الظاهريه، الذى يؤثر على مدى تجانس حبيبات التربة بدرجة كبيرة على معدل الرشح.

نتيجة عدم تجانس حجم حبيبات التربة فإن الأصغرحجماً منها تسد الفراغات بين الحبيبات الكبيرة الحجم مما يحد من المسامية وبالتالي يقل معدل الرشح. كما أن التربة الجافة تحتوي على حبيبات دقيقة ومع بداية عمليات الترشيح تحملها المياه اثناء نفاذيتها للتربة حيث تتجمع في مسام التربة مما يؤدي الى انخفاض سعة الترشيح بعد فترة من بداية القياس.

وجود كميات من كربونات الكالسيوم تحسن النفاذية إلا انه مع زيادة كمية كربونات الكالسيوم عن حد معين فإن ذلك يؤدي الى سوء النفاذية للتربة وربما اختلاف في نسبة الصوديم المتبادل الأمر الذي سبب اختلاف بشكل عام فى قيم معدل الرشح المقاس تحت جميع الظروف والمواقع المحدده بالدراسه.

أن إستخدام المعادلات الرياضية بعد إجراء دراسة إحصائية جيدة لتحديد العلاقة بين معدلات الرشح وخواص التربة الطبيعية والكيميائية والهيدروفيزيائية مفيد فى تقليل الوقت المطلوب والتكاليف لاجراء تجربة الحلقات المذدوجة.

أظهرت نتائج العلاقات المعنوية عند حدود ثقة ٩٩٪ و ٩٥٪ بين نتائج إستخدام المعادلات الرياضية لإستنتاج معدلات الرشح إرتفاع درجات المعنوية (R^2) لمعظم نتائج خواص التربة الطبيعية والكيميائية والهيدروفيزيائية المدروسة.

إحصائياً يمكن إستخدام هذه الطريقة تحت ظروف أراضى منطقة الدراسة مع الأحتياج الى تنفيذها فى انواع أراضى مختلفة لتحديد تأثرها على درجة دقة لتماثل دقة استخدام طريقة الحلقات المذدوجة بالحقل.

الكلمات المفتاحية:

معدل الرشح – الكثافة الظاهرية – المسامية الكلية – منحني الشد الرطوبي – التوصيل الهيدروليكي – منطقة الوادي الجديد