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Comparative Analysis of Infiltration Measurements of Two Irrigated Soils in Akure, Nigeria

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ABSTRACT

Infiltration test on two irrigated soils was carried out to determine the infiltration rates of the soils for proper irrigation scheduling and planning at the Federal University of Technology Akure (FUTA). The soil samples were taken from Agricultural Engineering Demonstration and the University Research farms. Soil classification was carried out using USDA textural triangle and a double ring infiltrometer was constructed and installed in the soil for the tests. Two models: Kostiakov and Philips were used to predict infiltration and compared with actual field measurements From the analysis, the soils were classified as sandy loam with 49.0% sand, 24.5% silt and 26.5% clay. The higher constituent of sand enables higher infiltration rate. The measurements of the soil chemical properties showed that the soil had a pH of 6.59 that was almost neutral and therefore did not have adverse negative effect on crops grown on it. Organic matter was 2.61(mg/l), Nitrogen 2.20(kg), Phosphorus 2.36(kg), Sodium 1.30(Na/ml), Calcium 3.00(Ca/ml) and Magnesium 0.70(mg/l) respectively. All these mineral constituents are within tolerable limits in soil for optimum crop growth. The constants of linear regression of the infiltration rates were obtained using Kostiakov and Philips equations which were a=58.87, n=0.12 and b=–66.4 respectively for Agricultural Engineering Experimental farm. Kostiakov equation derived was $F_t=58.87t^{0.167}$ *while Philips equation was* $F_t= 58.87^{-0.5}–66.4$ *for the soil from the same farm. The average infiltration rate for the Agricultural Engineering Experimental Farms was 32.50 cm/min, and the cumulative infiltrations were found to be 16.58 cm/min. As for the University research farm, the average infiltration rates and cumulative infiltration were 28.30 cm/min and 11.46 cm/min respectively. Kostiakov equation derived was* $F_t = 66.52t^{0.09}$ *while that of Philips was* $F_t = 66.52t^{0.09} – 61.84$*. From the statistical analyses carried out, there were obvious differences among the treatments at 5% significance level. This result could be used to plan for good irrigation scheduling and also to advice farmers on the type of irrigation techniques to be adopted based on the prevailing soil and weather conditions of such locations.*

Keywords: Infiltration rates, Irrigation, Infiltrometer, Kostiakov, Philips, Models.

INTRODUCTION

Efficiency in the application of irrigation water is of great economic importance especially to countries with limited water supplies [1].Water is essential natural resources that affect crop production and it plays a very important role in plants growth. Proper management of water is one of the key factors to increase Agricultural Production. Industrial and domestic requirements for water increased dramatically further limiting agricultural use of water. The criterion that determines the uniformity of water distribution is entirely economic and the emphasis on efficient water use in irrigated agriculture has created the need for steady improvement in irrigation design and operations [2]. Infiltration capacity is a very important parameter to be determined during design of irrigation system especially surface irrigation system. The process of water infiltration through surface soil is a complex interaction between rainfall and irrigation intensities, soil type and surface condition. These factors govern the ability at which water passes through the soil [3]. Infiltration rate may vary from very low to very high due to changes in the soil characteristics within a field [4]. This could be controlled by some means and then irrigation efficiency could be increased to a high level[5]. In determining when to irrigate and how much water to apply in rapidly changing systems of soils, soil moisture tension and infiltration rate of soil are important parameters that must be studied. The objective of this study was to carry out infiltration measurements on two irrigated soils in the Federal University of Technology, Akure (FUTA) experimental and research farm for proper classification and irrigation scheduling.

MATERIALS AND METHODS

Location

The study was conducted on the Agricultural Engineering experiment farm and University Research Irrigation farm, located at Obanla, Federal University of Technology, Akure Ondo State, Nigeria. Akure lies on latitude 7.14^0 north and longitude 5.08^0 east. The mean annual rainfall is 1500 mm. Old metamorphic rocks underlie the whole of this region, which outcrops to form high hills in many districts. The land surface is undulating and the characteristics landscape consists of extensive plains broken by steep sided inselbergs (dome-shaped hills). The materials used for the project work include graduated cylinder, water container, stopwatch, steel rule, cutlass, digger, shovel, plank, hammer, water tank, cylindrical infiltrometer, and mercury and soil auger. The cylindrical infiltrometer is 45 cm high and formed from 2 mm rolled steel into concentric cylinders. The inner and outer diameters of the cylinder are 30 cm and 60 cm respectively.

Soil Classification

Soil samples were collected from the Agricultural Engineering demonstration and research farm at FUTA, Akure, Nigeria. The sieve analysis and hydrometer methods were used to estimate the Soil class.

Methodology

A double ring infiltrometer was used to provide comparative measurement of the irrigated soils. A 16-gauge iron sheet Cylinders of 30 cm and 60 cm diameters and 55 cm was used in making outer and inner cylinder parts of the infiltrometer, respectively. The infiltrometer was driven into the soil to a depth of 10 cm with a graduated steel rule placed in the inner ring. The levels of

water infiltrating into the soil were noted at a given pre-determined time interval. Infiltration measurements were carried out on the soils using three trials on the first portion which typified daily measurement. In all, six infiltration runs were carried out in order to compare the infiltration capacities of both soil conditions to see if measurable differences in infiltration could be detected and how comparable the differences are. The outer diameter of the infiltrometer served as a buffer. It is necessary to pond the outer cylinder first so as to prevent lateral movement of water level in the inner cylinder. A steel rule was adjusted to the desired level to which water is to be added. Water was added to the inner cylinder from a container of a known volume. A stopwatch was used to note the time the water begins to infiltrate and the time water reaches the cleared level and the readings were recorded every 2 minutes. In the two locations, three different points were used to determine the infiltration rates as follows:
Infiltration rate (I) = Volume of infiltrated water / cross-sectional area

The average values were taken for each of the plots and subjected to regression analyses using the following equations.

$F_t = at^n$ (Kostiakov) (1)

where
F_t = Cumulative infiltration (mm)
t = time (hrs)
a and b = constants specific to the soil
By taking logs of each side, this can be expressed as

Log F_t = loga + n log t (2)

The values of *a* and *n* are obtained from the graph as the intercept and the slope respectively.

$F_t = at^{-0.5} + b$ (Philips) (3)

RESULTS AND DISCUSSION

The result of the particle size analysis from the experimental field showed that the Soil is Sandy Loam with 49% sand, 24.52% silt, and 26.48% clay. The percentage of sand, clay and silt promotes the agricultural productivity. The tabulated results for the infiltration tests are shown in Tables 1 and 2 for the Agricultural Engineering and University research irrigation demonstration plots of FUTA respectively. From the models, the constants of linear regression of the infiltration rates were obtained using Kostiakov and Philips equations which were a= 58.87, n=0.12 and b= –66.4 respectively for Agricultural Engineering Experimental farm. Kostiakov equation derived was F_t= $58.87t^{0.167}$ while Philips equation was F_t= $58.87^{-0.5}$– 66.4 for the soil from the same farm. The average infiltration rate for the Agricultural Engineering Experimental Farms was 32.50 cm/min, and the cumulative infiltration was found to be 16.58 cm/min.

Figure 1a showed the average infiltration rate against time in the Agricultural Engineering farm. The very high correlation R^2 = 0.99 indicated linear relationship between the two parameters. Also, average infiltration rates decreases as time increases which is an indication of higher degree of saturation of soil as time increases. Figure 1b showed a comparison between measured infiltration and model prediction in the Agricultural Engineering farm. High correlation value (R^2 = 0.99) was also indicative of excellent experimental values when compared with the modeled values.

Table 1: Average Value of Infiltration Test on Agricultural Engineering Irrigation Plot (Average Antecedent Moisture Content=9.85%)

Elapsed Time, t_n (min)	$T = t_n/60$	Height of Infiltration (mm)	Depth (mm)	Cumulative Infiltration (mm)	Infiltration Rate, T (mm/hr)
-	(hrs)	-	-	-	-
0	0	40	-	-	-
2	0.033	35.2	4.8	4.8	145
4	0.067	31.2	4	8.8	131
6	0.1	28.2	3	11.8	118
8	0.133	25.7	2.5	14.3	108
10	0.167	23.5	2.2	16.5	99
12	0.2	21.5	2	18.5	93
14	0.233	19.8	1.7	20.2	87
16	0.267	18.2	1.6	21.8	82
18	0.3	16.7	1.5	23.3	78
20	0.333	15.3	1.4	24.7	74
22	0.367	14	1.3	26	71
24	0.4	12.8	1.2	27.2	68
26	0.433	11.7	1.1	28.3	65
28	0.467	10.7	1	29.3	63
30	0.5	9.8	0.9	30.2	61
32	0.533	9	0.8	31	58
34	0.567	8.3	0.7	31.7	56
36	0.6	7.7	0.6	32.3	59
38	0.633	7.2	0.5	32.8	52
40	0.667	6.8	0.3	33.5	48
42	0.7	6.5	0.3	33.5	48
44	0.733	6.2	0.3	33.8	46
46	0.767	6	0.2	34	44
48	0.8	5.8	0.2	34.2	43
50	0.833	5.6	0.2	34.4	41
52	0.867	5.5	0.1	34.5	40
54	0.9	5.4	0.1	34.6	38
56	0.933	5.3	0.1	34.7	37
58	0.967	5.2	0.1	34.8	36
60	1	5.1	0.1	34.9	35

As for the University research farm, the average infiltration rates and cumulative infiltration were 28.30 cm/min and 11.46 cm/min respectively. Kostiakov equation derived was F_t =

$66.52t^{0.09}$ while that of Philips was $F_t = 66.52t^{0.09} - 61.84$. Figures 2a and b showed average infiltration rates against time and comparison between modeled and measured infiltration values in the University research farm. Similar behaviours and comments to Figures 1a and b were observed. $R^2 = 0.98$ were recorded on both graphs and showed a strong relationship between the parameters considered. Summarily, it could be inferred that the higher the constituent of sand, the higher the infiltration and percolation rates from the two research fields. From the statistical analyses carried out, there were obvious differences among the treatments at 5% significance level.

Table 2: Average value of Infiltration Test for University Irrigation Research Plot (Average Antecedent Moisture Content=15.68%)

Elapsed Time, t_n (min)	$T = t_n/60$	Height of Infiltration (mm)	Depth (mm)	Cumulative infiltration (mm)	Infiltration Rate, T (mm/hr)
	(hrs)	-	-	-	-
0	0	30	-	-	-
2	0.033	26	4	4	120
4	0.067	22	4	8	120
6	0.1	20.2	1.8	9.8	98
8	0.133	18.1	2.1	11.9	89
10	0.167	16.3	1.8	13.7	82
12	0.2	14.5	1.8	15.5	78
14	0.233	12.7	1.6	17.1	73
16	0.267	11.6	1.3	18.4	69
18	0.3	10.4	1.2	19.6	65
20	0.333	9.5	0.9	20.5	61
22	0.367	8.8	0.7	21.2	58
24	0.4	8.4	0.4	21.6	54
26	0.433	8.1	0.3	21.9	51
28	0.467	7.9	0.2	22.1	47
30	0.5	7.8	0.1	22.2	44
32	0.533	7.7	0.1	22.3	42
34	0.567	7.6	0.1	22.4	40
36	0.6	7.5	0.1	22.5	38
38	0.633	7.4	0.1	22.6	36
40	0.667	7.3	0.1	22.7	34

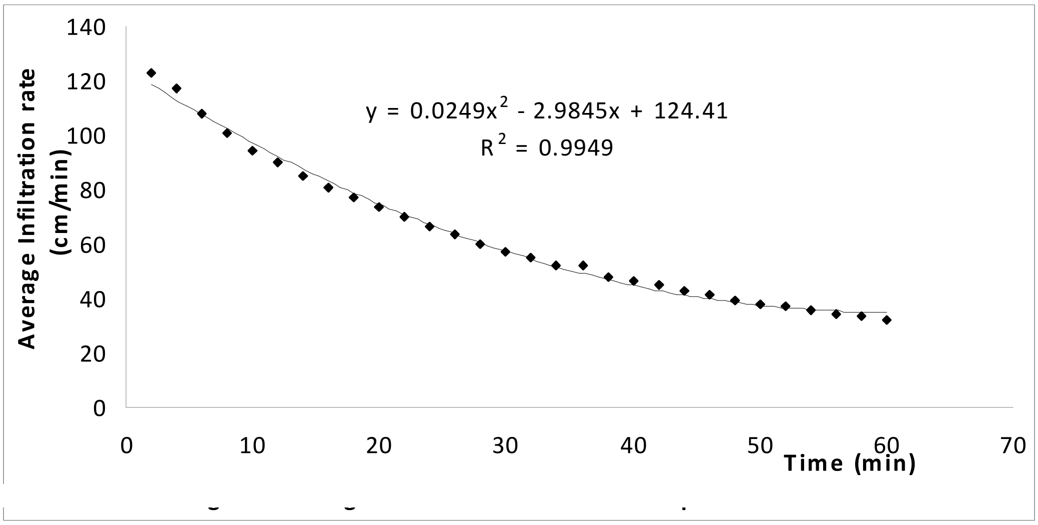

Fig: 1a Average infiltration rate curve in Agricultural Engineering Farm

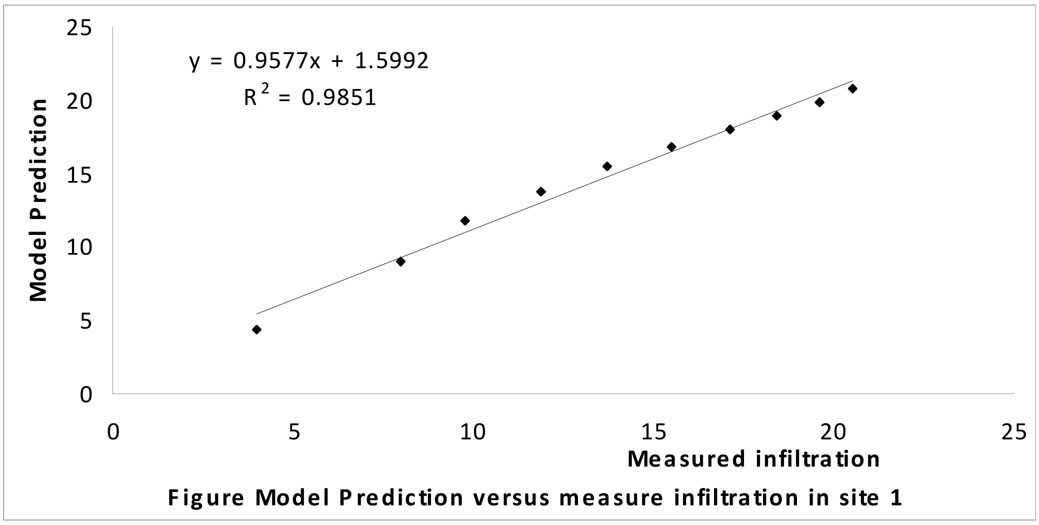

Fig 1b: Model prediction versus measured infiltration in Agricultural Engineering Farm

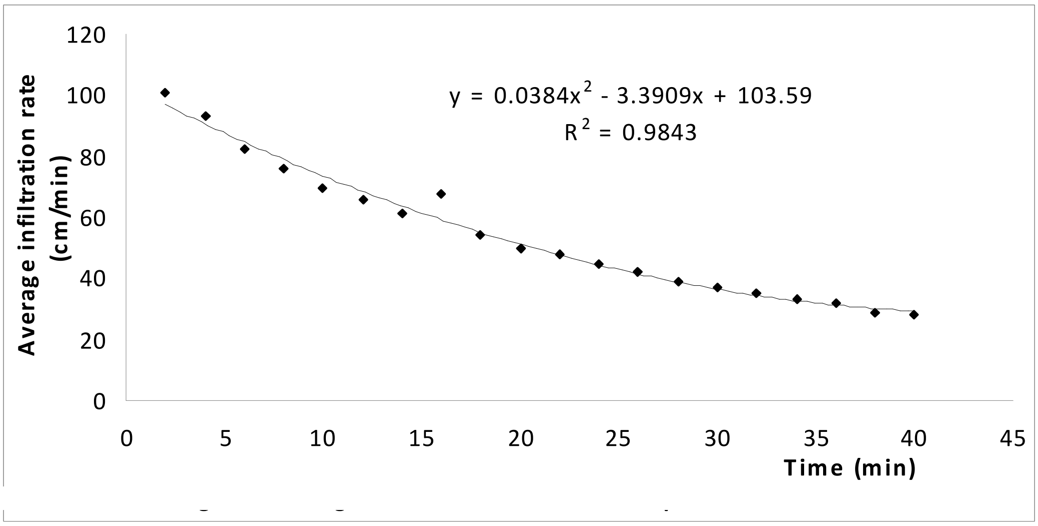

Fig: 2a Average infiltration rate curve in University Research Farm

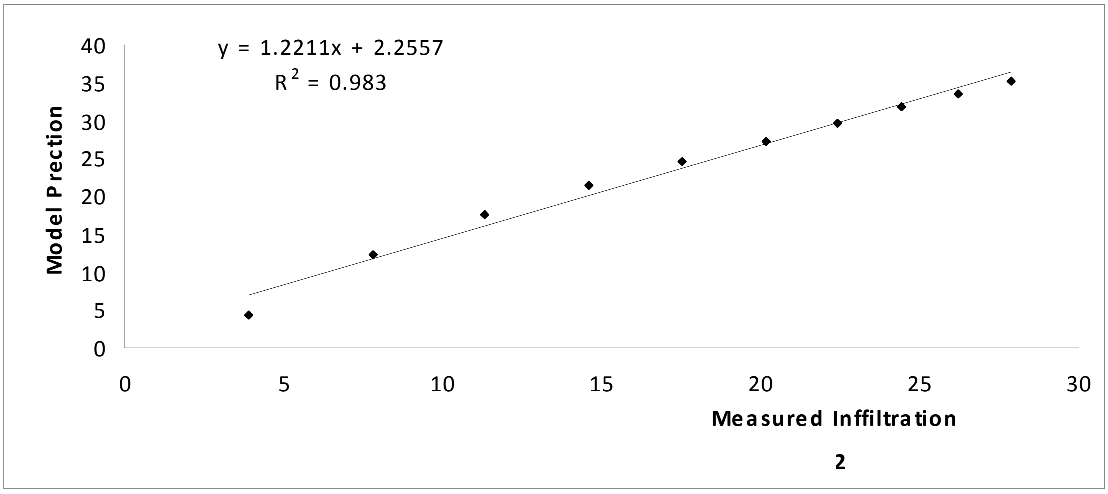

Fig 2b: Model prediction versus measured infiltration in University Research Farm

Chemical Properties of the agricultural soil

The results of the chemical measurements of the soil properties are as shown in Table 3. pH value was 6.59 which showed that the soil is almost neutral and therefore does not have adverse negative effect on crops grown on it. Therefore the soil is very good and will promote healthy agricultural practices. Organic matter was 2.61 mg/ml, but the minimum quantity permitted for healthy crop growth was 6.34. This may be due to continuous cultivation of soil for research purposes hence the depletion. The organic matter when improved will increase the absorption rate of the soil and nutrient accumulation. Fallowing for a minimum of two years will boost organic matter of the soil. The nitrogen content in the experimental soil was 2.2 kg/ha and the required quantity for optimum plant growth is 3.5 kg/ha. To improve the nitrogen content, growing of leguminous and cover crops should be encouraged, or addition of fertilizer with significant nitrogen content (such as N – P – K: 15 – 15 – 15). From Table 3, the quantities of calcium present in the experimental soil were 3.00, this is an essential cation in soils and has beneficial effect in development of soil structure and plant growth but it varies from region to region. The sodium present was 1.30 but sodium was not seriously considered essential for plant growth. The potassium present in the soil was 2.46 g/k. This is tolerable for plant growth since the standard value for potassium was 2.2 g/k. Magnesium has a value of 0.7 which is well above the minimum permissible limit. This is an indication of increased Chlorophyll formation which is vital during photosynthesis. Phosphorus was 2.03 and is within the minimum limit for crop growth.

Table 3: Chemical Properties of Agricultural Engineering Experimental Soil at FUTA

Parameters	Value(s)	Minimum permissible level (FAO,1996)
pH (H_20)	6.59	6.68
Organic matter (mg/L)	2.61	6.34
Nitrogen (kg)	2.2	3.50
Phosphorus (kg)	2.03	>2.00
Potassium (g/k)	2.46	2.20
Sodium (Na/ml)	1.30	>0.63
Calcium (Ca/ml)	3.00	-
Magnesium (mg/ml)	0.70	0.50

CONCLUSION

This result could be used to plan for good irrigation scheduling for optimum crop growth. It could also be used to advice the users (most of whom are students) on the type of irrigation method to be adopted during farming season and the frequency of machine operations based on soil conditions in the research farms.

Finally, this experiment should be repeated in other areas of the state to be able to adequately identify inherent characteristics of such soils and also carry out the hydraulic conductivities of the soils for national planning with regards to Agricultural Mechanization in Ondo State.

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