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REGIONAL APPROACH TO THE MODIFICATION OF THE KOSTIAKOV INFILTRATION CONSTANTS FOR IRRIGATION PURPOSES FOR THE CALABAR METROPOLIS, SOUTH-SOUTH, NIGERIA

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ABSTRACT

Infiltration equations are necessary in designing and evaluating surface irrigation systems. This research work applied the empirical Kostiakov‟s infiltration model on the soils of Calabar Metropolis catchment. In order to determine the infiltration model parameters of the soils, field measurements of infiltration were made using a double ring infiltrometer during the wet Season; readings were taken at 5, 10, 15, and 30 minutes intervals. Infiltration rate ranged from 0.0lcm/min to 2.54cm/min. Kostiakov infiltration model was then applied on the field data in order to determine the soils infiltration parameters and also in order to estimate the model equations for the soils. The twelve sampling locations for this study were: (Unical Mary Slessor, Atimbo, Ediba, Army Junction, Ekorinim 2, Wapi Junction, Big Qua, CRUTECH, Akia-Efa, Goldie, and Marina). The Kostiakov infiltration decay constants obtained were: for "a" : -0.63, -0.67, -0.89, -0.89, -0.89, -1.0, -0.77, -0.89, -1.11, -1.0, -1.0, -0.7 respectively. The values for "b" were: 0.121, 0.442, 0.683, 0,475, 0.426, 0.341, 0.678, 0.678, 0.085, 0.250, 0.549, and 0.248 respectively. These were used to simulate data which were evaluated by comparing them with the field data. The two data sets showed close relationships. This showed that the model could be used to simulate water infiltration during irrigation projects in Calabar Metropolis Catchment.

1.0: INTRODUCTION

The most important soil parameter in the design evaluation and management of surface irrigation systems is, by far, infiltration (Antigha & Essien, 2007., Smith, 1972: Singh, 1990). This is because it determines to a large extent, the amount of water intake by a soil profile beyond which the processes of overland flow, runoff and erosion are initiated. In order to plan and achieve different irrigation methods, the consciousness of soil infiltration characteristics is of utmost necessity. The rate of infiltration is determined by soil characteristic including ease of entry, storage capacity and transmission rate through the soil. The soil texture and structure, vegetation type and cover, water content of the soil, soil temperature and rainfall intensity all play key pivotal roles in guiding infiltration rate as well as its capacity.

Infiltration is a multifaceted physical procedure in time and space, which is tough to characterize with exactness under the intrinsic diverse and dynamic soil situations. Computing soil infiltration as one of the major mechanisms in the hydrological cycle can be useful in the management of catchments. Closely bound soil particles infiltrate smaller amount of water into the soil and bring about more runoff and flood (Rao, et al 2006). Conversely, with the increasing infiltration of water into the soil, there is decrease runoff and flood which will in effect reduce the human and financial losses (Navar & Synnott, 2006). Soil infiltration is an essential factor for increasing agricultural production since an efficient application of water fundamentally depends on the infiltration capacity of soil and it is also essential for the design of irrigation systems (Antigha et al, 2014).

Various models have been developed in order to estimate soil infiltration such as Green-Ampt, Kostiakov, 1932; Horton, 1940; and Philip, 1957. In this research, an attempt was made to modify the Kostiakov (1932) model to fit into the Calabar Metropolis Catchment.

Kostiakov (1932) developed a physically based infiltration model used extensively because of its simplicity and accuracy in fitting experimental data and for determining the point at which equilibrium is reached as a function of soil structural stability or resistance to wetting front.

The equation is given as: $I = at^b$ eqn 1

Where I is the cumulative infiltration rate; a is a measure of initial rate of infiltration and structural condition of the soil; t = elapsed time, and, b is the index of soil structural stability

Taking Log of both sides.

$Log\, I = Log\, a + b\ Log\ \ t$ eqn 2

A plot of Log I against Log t gives a straight line whose slope gives the value of Log a. The constants a, and b, are then substituted into (eqn. 1) to get the Kostiakov infiltration model for

Calabar metropolis catchment, which will be used in designing and optimizing irrigation project for the region.

1.1: AIMS AND OBJECTIVES OF THE STUDY

The aim of this study was to obtain the water infiltration parameters of the soils of Calabar Metropolis catchment.

The specific research objectives of the study were:

To obtain rainfall infiltration data for design purposes from the area.
Plot a graph of Log I against Lot t.
Obtain the Kostiakov infiltration constants a, and b from the intercept and slope respectively.
Use the constants obtained to generate the water infiltration model for the catchment.
Compare the modified model with the existing one.

2.0: Historical Perspective

Cerda, (1997), studied the Mediterranean scrub land in Spain to explore the spatial and seasonal changes of infiltration rates. The measurements were taken with cylinder infiltrometer and simulated rainfall on limestone data, which were also collected for autumn, winter, spring and summer seasons. The study concluded that, measurements with the help of ponding and simulated rainfall were found to be very high in summer while the surface runoff was observed to be very low.

Salim, (2011) presented the effect of land use on soil infiltration rate in a heavy clay soil in Egypt using double ring infiltrometer. The investigation was carried out on three sites which were located in the carnal command of El- Salim, Egypt. The first location was a cultivated land; the second un- cultivated land, and the third was under fish farming. The bulk density and water content of the soils were determined using samples from 20cm of the soil layer. The infiltration and cumulative infiltration curves for the different sites were obtained by Salim (2011). The gravimetric water content method was used for determination of volumetric water content. For determination of particle size and sieve analysis, the hydrometer method was applied. It was concluded that, the rate of infiltration mainly depended on the initial moisture content in case of deep clayey soil.

Jagdale et al., (2012), observed the infiltration rate of sandy and clay soil under different soil conditions in Sangola in Solapur district, comparing the results obtained from Kostiakov, modified Kostiakov, Horton and Green-Ampt infiltration models. Horton model gave best fitting with high degree of correlation coefficient and minimum standard error for all soil types except for ploughed clay soil which was best fitted for Green-Ampt model.

Adindu et al., (2014), studied the Sandy Loam Soils of Ikwuano-Umuhia, Nigeria using double ring infiltrometer during wet season. The Kostiakov infiltration model was applied on the experimental data to determine the soils infiltration parameters and also estimate the model equation for the soils. The result showed that the soils were saturated at that time of the year (wet season) due to much rain as a result of which the soils were no longer absorbing water but were gushing out.

2.1: Antecedent Moisture Content / Antecedent Precipitation Index (API)

The antecedent precipitation index (API) is often used for the estimation of runoff yields from rainfall events on those watersheds whose auxiliary data are limited or not available. The antecedent precipitation index is precipitation falling before, but influencing the runoff yields of a given rainfall event and API gives a measure of moisture index (httgrferun Wikipedia.org).

Heggen (2001) proposed the use of a normalized antecedent precipitation index (NAPI) in place of API because the NAPI modified the API in three aspects. Inclusion of antecedent precipitation earlier in the day of event, normalization in terms of the station mean and normalization in terms of antecedent series length. Heggen et al. (2001) provided a lumped to estimate runoff linking the NAPI and rainfall event as follows;

$$\frac{Q}{P} = 1 - e^{a+bp+CNAP} \qquad \text{eqn 4}$$

Where Q is the runoff from event rainfall depth, P, a, b and c are coefficient specific to a watershed.

2.2: Development of Kostiakov Infiltration Model

Kostiakov (1932) developed an infiltration model used extensively because of its simplicity and accuracy in fitting experimental data and for determining the point at which equilibrium is reached as a function of soil structural stability or resistance to wetting front, the equation is given as:

$$I = at^{b} \qquad \text{eqn 5}$$

Where, ‘a' and ‘b' are constants and evaluated using the observed infiltration data.

I= cumulative infiltration rate

t= Elapsed time.

$\text{Log } I = \log a + b \text{ Log } t$ eqn 6

A plot of Log I against Log T gives a straight line whose slope gives the value of log a. Both the parameters rely on soil type, initial moisture content, rainfall intensity and the vegetative cover. The values of parameters are determined experimentally.

3.0: MATERIALS AND METHODS

Infiltration measurements were carried out during the wet season using cylinder infiltrometer on soils of the different properties. A metal tube was driven into the ground to a depth of 10cm hammer. Care was taken to prevent damage to soil structure in the process. A constant ponding level of 5cm was maintained in the metal tube (ring) throughout the experiment. With the aid of a stop watch, readings were taken at intervals. The readings continued until a steady state of equilibrium was reached.

Soil samples were also collected using cylindrical iron cores of about 5cm long and 30cm in diameter for bulk density (moisture content can), particle size distribution, total porosity and particle density determination. The soil samples were labeled and taken to laboratory for analysis. Saturated hydraulic conductivity (KS) values of each soil was estimated by the clay content based on soil component method of the EPIC (Erosion Induced Productivity Loss Index Calculation) model developed by William et al., (1984).

3.1: Sample Collection

Soil samples were collected from twelve (12) different areas in Calabar metropolis. The soils were collected at an average fixed depth of 0.5m using the soil auger and taken to the laboratory. The areas which the samples were taken were: Ekorinim 2, Ediba, Wapi Junction, Army Junction, Marina, Big-Qua Town, Goldie, Mary Slessor, Atimbo, Akai Efa, UNICAL and CRUTECH.

3.2: Sample Preparation

Collected samples were named after the location or unit where it was obtained for proper identification, and was taken to the Department of Civil Engineering hydraulic laboratory, CRUTECH, Nigeria, for natural moisture content test and sieve analysis. For the moisture content test, the wet air mass were obtained by weighing the sample with the weighing balance machine to determine the weight of the soil. The weighed soils were kept inside the oven for 48 hours after which the dried soil sample was re-weighed to obtain the antecedent moisture content of the soil.

For the sieve test, the samples were placed on the stacked sieves and vibrated and the various percentages passing, determined by weighing, were recorded accordingly.

3.4 Sample Analysis

Modified Form of Kostiakov Equation

The simplest of the empirical infiltration equation is the kostiakov equation mathematically; this power equation can be written as

$I = at^{-b}$ eqn 7

Where a and b are constant obtained in infiltration trials. Since in this equation I go to 0 and t to infinity, the modified kostiakov equation is usually used. This is

$I = at^{-b} + c$ eqn 8

Where c is the infiltration rate at large t. this modified form of Kostiakov equation usually fits the experimental infiltration data quite well, particularly for time periods of less than a few hours. Equation (i) and (ii) can be integrated to obtain the cumulative infiltration at any time t:

$I = At^{b}$ eqn 9

or

$I = At^{b} + Ct$ eqn 10

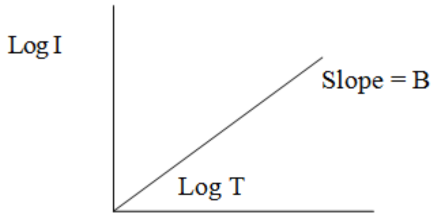
For a time period of about three hours, equation 10 was recommended for ease of convenience

$I = at^{b}$ eqn 11

Using logarithmic transformation

Log I = log A + B log t eqn 12

A graph of log I versus log t gives a straight line:



Parameters A and B have no obvious physical meaning and are determined from the experimental data.

4.0: RESULTS AND DISCUSSION

4.1: Data Presentation

Presentation of Tables for the Twelve Sampling Points.

Table 4.1: UNICAL Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
11:00	0	0	0	0	0	0
11:5	5	5	8.30	1.66	0.22	0.70
11:10	5	10	6.80	0.68	-1.20	1.00
11:15	5	15	5.40	0.36	-0.44	1.18
1:20	5	20	4.30	0.22	-0.70	1.30
1:25	5	25	3.00	0.12	-0.92	1.40
1:30	5	30	2.10	0.07	-1.20	1.50
1:40	10	40	0.30	0.08	-1.10	1.60
1:50	10	50	7.10	0.14	-0.90	1.70
2:00	10	60	5.50	0.09	-1.05	1.80
2:15	15	75	3.00	0.04	-1.40	1.90
2:30	15	90	1.40	0.02	-1.70	2.00
3:00	30	120	5.40	0.05	-1.30	2.10
3:30	30	150	1.40	0.09	-1.05	2.20
4:00	30	180	5.80	0.03	-1.52	2.30
Total		**870**		**3.65**		

Table 4.2: Goldie Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	Log T
10:15	0	0	0	0	0	0
10:20	5	5	7,8	1.56	0.20	0.70
10:25	5	10	3.8	0.38	-0.42	1.00
10:30	5	15	9.40	0.63	-0.20	1.18
10:35	5	20	5.3	0.27	-0.60	1.30
10:40	5	25	2.0	0.08	-1.10	1.40
10:45	5	30	9.8	0.33	-1.50	1.50
10:55	10	40	2.6	0.07	-1.20	1.60
11:05	10	50	6.4	0.13	-0.90	1.70
11:15	10	60	1.5	0.03	-1.52	1.80
11:30	15	75	3.2	0.04	-1.40	1.90
11:45	15	90	3.6	0.04	-1.40	2.00
12:15	30	120	6.6	0.06	-1.22	2.10
12:45	30	150	1.3	0.09	-1.05	2.20
1:15	30	180	6.9	0.04	-1.40	2.30
Total		**870**		**3.37**		

Table 4.3: Mary Slessor Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
2:15	0	0	0	0	0	0
2:20	5	5	7.50	1.50	0.20	0.70
2:25	5	10	2.00	0.20	-0.70	1.00
2:30	5	15	8.10	0.54	-0.30	1.18
2:35	5	20	3.80	0.19	-0.72	1.30
2:40	5	25	9.70	0.39	-1.41	1.40
2:45	5	30	5.00	0.17	-1.80	1.50
2:55	10	40	4.20	0.11	-1.96	1.60
3:05	10	50	4.20	0.08	-0.10	1.70
3:15	10	60	4.20	0.07	-1.20	1.80
3:30	15	75	1.50	0.02	-1.70	1.90
3:45	15	90	1.30	0.01	-2.00	2.00
4:15	30	120	3.00	0.03	-1.52	2.10
4:45	30	150	0.70	0.05	-1.30	2.20
5:15	30	180	0.80	0.01	-2.00	2.30
Total		870		3.37		

Table 4.4: Atimbo Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
9:45	0	0	0	0		0
9:50	5	5	12.70	2.54	0.40	0.70
9:55	5	10	11,80	1.18	-0.10	1.00
10:00	5	15	10.90	0.73	-0.14	1.18
10:05	5	20	10.30	0.52	-0.30	1.30
10:15	5	25	9.50	0.38	-0.42	1.40
10:20	5	30	8.80	0.29	-0.54	1.50
10:30	10	40	7.60	0.19	-0.72	1.60
10:40	10	50	6.80	0.14	-0.90	1.70
10:50	10	60	5.80	0.10	-1.00	1.80
11:05	15	75	4.60	0.06	-1.22	1.90
11:20	15	90	3.70	0.04	-1.40	2.00
11:50	30	120	9.90	0.08	-1.10	2.10
12:20	30	150	6.60	0.04	-1.40	2.20
12:50	30	180	4.10	0.02	-1.70	2.30
Total		**870**		**6.85**		

Table 4.5: Ediba Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
1:05	0	0	0	0		
1:10	5	5	7.80	1.56	0.20	0.70
1:15	5	10	6.80	0.68	-0.17	1.00
1:20	5	15	6.90	0.46	-0.34	1.18
1:25	5	20	7.70	0.39	-0.40	1.30
1:30	5	25	8.80	0.35	-0.50	1.40
1:35	5	30	3.80	0.13	-0.90	1.50
1:45	10	40	4.80	0.12	-0.92	1.60
1:55	10	50	2.20	0.04	-1.40	1.70
2:05	10	60	4.40	0.07	-1.20	1.80
2:20	15	75	2.90	0.04	-1.40	1.90
2:35	15	90	1.70	0.02	-1.70	2.00
3:05	30	120	5.40	0.05	-1.30	2.10
3:35	30	150	9.10	0.06	-1.22	2.20
4:05	30	180	4.80	0.03	-1.52	2.30
Total		**870**		**3.97**		

Table 4.6: Army Junction Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
11:05	0	0	0	0		
11:10	5	5	8.20	1,64	0.21	0.70
11:15	5	10	5.50	0.60	-0.22	1.00
11:20	5	15	3.30	0.22	-0.70	1.18
11:35	5	20	1.40	0.07	-1.20	1.30
11:30	5	25	9.30	0.37	-0.43	1.40
11:35	5	30	6.50	0.22	-0.70	1.50
11:45	10	40	4.40	0.11	-0.96	1.60
11:55	10	50	1.50	0.03	-1.52	1.70
12:05	10	60	5.50	0.09	-1.05	1.80
12:20	15	75	1.10	0.01	-2,00	1.90
12:35	15	90	4.20	0.05	-1.30	2.00
1:05	30	120	2.70	0.02	-1.70	2.10
1:35	30	150	1.80	0.01	-2.00	2.20
2.05	30	180	8.10	0.05	-1.30	2.30
Total		**870**		**4.12**		

Table 4.7: Ekorinim II Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
2:40	0	0	0	0	0	0
2:45	5	5	7.30	1.50	0.20	0.70
2:50	5	10	5.50	0.60	-0.22	1.00
2:55	5	15	4.10	0.27	-0.60	1.18
3:00	5	20	2.90	0.15	-0.82	1.30
3:05	5	25	1.80	0.07	-1.20	1.40
3:10	5	30	0.80	0.03	-1.52	1.50
3:20	10	40	7.40	0.19	-0.72	1.60
3:30	10	50	5.00	0.10	-1.00	1.70
3:40	10	60	3.00	0.05	-1.30	1.80
3:55	15	75	8.50	0.11	-1.00	1.90
4:10	15	90	5.10	0.06	-1.22	2.00
4:40	30	120	7.60	0.06	-1.22	2.10
5:10	30	150	2.10	0.01	-2.00	2.20
5:40	30	180	3.30	0.02	-1.70	2.30
Total		**870**		**3.22**		

Table 4.8: Wapi Junction Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
10:20	0	0	0	0		
10:25	5	5	11.30	2.26	0.40	0.70
10:30	5	10	10.80	1.08	0.03	1.00
10:35	5	15	10.50	0.70	-0.20	1.18
10:40	5	20	9.90	0.50	-0.30	1.30
10:45	5	25	9.60	0.40	-0.40	1.40
10:50	5	30	9.40	0.31	-0.50	1.50
11:00	10	40	8.80	0.22	-0.70	1.60
11:10	10	50	8.20	0.16	-0.80	1.70
11:20	10	60	7.90	0.13	-0.90	1.80
11:35	15	75	7.10	0.9	-1.05	1.90
11:50	15	90	6.60	0.07	-1.20	2.00
12:20	30	120	5.80	0.05	-1.30	2.10
12:50	30	150	4.60	0.03	-1.52	2.20
1:20	30	180	3.90	0.02	-1.70	2.30
Total		**870**		**6.02**		

Table 4.9: Biq Qua Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
2:35	0	0	0	0	0	0
2:40	5	5	3.20	0.64	-0.19	0.70
2:45	5	10	7.20	0.72	-0.14	1.00
2:50	5	15	2.20	0.15	-0.82	1.18
2:55	5	20	6.70	0.34	-0.47	1.30
3:00	5	25	2.10	0.08	-1.10	1.40
3:05	5	30	7.10	0.24	-0.62	1.50
3:15	10	40	7.30	0.18	-0.74	1.60
3:25	10	50	8.20	0.16	-0.80	1.70
3:35	10	60	8.70	0.15	-0.82	1.80
3:50	15	75	4.10	0.05	-1.30	1.90
4:05	15	90	1.30	0.01	-2.00	2.00
4:35	30	120	1.70	0.01	-2.00	2.10
5:05j	30	150	3.50	0.02	-1.70	2.20
5.35	30	180	3.70	0.02	-1.70	2.30
Total		**870**		**2.77**		

Table 4.10: Akai – Efa Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
10:05	0	0	0	0	0	0
10:10	5	5	5.40	1.08	0.33	0.70
10:15	5	10	1.40	0.14	-0.85	1.00
10:20	5	15	5.80	0.40	-0.4	1.18
10:25	5	20	2.20	0.11	-0.95	1.30
10:30	5	25	5.70	0.23	-0.64	1,40
10:35	5	30	1.80	0.06	-1.22	1.50
10:45	10	40	9.40	0.24	-0.62	1.60
10:55	10	50	2.10	0.04	-1.40	1.70
11:05	10	60	8.50	0.14	-0.90	1.80
11:20	15	75	5.50	0.07	-1.20	1.90
11:35	15	90	2.70	0.03	-1.52	2.00
12:05	30	120	5.40	0.05	-1.30	2.10
12:35	30	150	8.20	0.05	-1.30	2.20
1:05	30	180	4.70	0.03	-1.52	2.30
Total		870		2.61		

Table 4.11: Marina Sampling Point.

Local time	Time Interval (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log!	LogT
3:10	0	0	0	0	0	0
3:15	5	5	8.10	1.62	0.21	0.70
3:20	5	10	6.80	0.68	-0.17	1.00
3:25	5	15	5.80	0.39	-0.41	1.18
3:30	5	20	5.10	0.26	-0.59	1.30
3:35	5	25	4.30	0.17	-0.80	1.40
3:40	5	30	3.80	0.13	-0.90	1.50
3:50	10	40	8.90	0.23	-0.64	1.60
4:00	10	50	7.90	0.16	-0.80	1.70
4:10	10	60	6.80	0.11	-1.00	1.80
4:25	15	75	5.50	0.07	-1.16	1.90
4:40	15	90	4.80	0.05	-1.30	2.00
5:00	30	120	3.30	0.03	-1.52	2.10
5:30	30	150	2.80	0.02	-1.70	2.20
6:00	30	180	2.10	0.01	-2.00	2.30
Total		870		3.93		

Table 4.12: CRUTECH Sampling Point.

Local time	Time Interv al (min)	Cumulative Time (min)	Cumulative Intake (cm)	Infiltration Rate (cm/min)	Log I	LogT
11:00	0	0	0	0	0	0
11:05	5	5	1.30	0.26	-0.60	0.70
11:10	5	10	2.50	0.25	-0,60	1.00
11:15	5	15	4.20	0.28	-0.60	1.18
11:20	5	20	5.20	0.26	-0.60	1.30
11:25	5	25	1.90	0.08	-1.10	1.40
11:30	5	30	6.70	0.22	-0.70	1.50
11:40	10	40	1.50	0.04	-1.40	1.60
11:50	10	50	5.50	0.11	-1.00	1.70
12:00	10	60	1.10	0.02	-1.70	1.80
12:15	15	75	3.80	0.05	-1.30	1.90
12:30	15	90	9.85	0.11	-1.00	2.00
1:00	30	120	9.70	0.08	-1.10	2.10
1:30	30	150	9.40	0.06	-1.20	2.20
2:00	30	180	9.20	0.05	-1.30	2.30
Total		**870**		**1.87**		

AVERAGE INTERCEPT FOR THE CONSTANT (B) OF THE CATCHMENT

Average (b) $=\frac{sum\ of\ intersepts}{No\ of\ sampling\ points}$

$=\frac{0.121+0.442+0.683+0.475+0.426+0.341+0.678+0.427+0.085+0.250+0.549+0.248}{12}$

Average (b) = 0.394

Average slope for the constant (a) of the catchment

$$\text{Average (a)} = \frac{sum\ of\ slope}{No\ of\ sampling\ point}$$

$$= \frac{-0.63+(-0.67)+(-0.89)+(-0.89)+(-0.89)+(-1.0)+(-0.77)+(0.89)+(-1.11)+(-1.10)+(-1.0)+(-0.7)}{12}$$

= -0.90

Average (a) =-0.90

4.2 Soils Parameter and Equation

Table 4.2.1: Simulated kostiakov soil infiltration parameter for the 12 locations.

S/N	Locations	(a)	(b)	Kostiatov Equation I=at^b	R^2
1	UNICAL	-0.63	0.121	I=-0.63t$^{0.121}$	0.6733
2	Goldie	-0.67	0.442	I=-0.67t$^{0.442}$	0.6872
3	Mary Slessor	-0.89	0.683	I=-0.89t$^{0.683}$	0.6872
4	Atimbo	-0.89	0.475	I=-0.89t$^{0.475}$	0.8051
5	Ediba	-0.89	0.426	I=-0.89t$^{0.42}$	0.8051
6	Army Junction	-1.0	0.341	I=-1.0t$^{0.341}$	0.7142
7	Ekorinim	-0.77	0.678	I=-0.77t$^{0.678}$	0.7415
8	Wapi Junction	-0.89	0.678	I=-0.89t$^{0.427}$	0.819
9	Big Qua	-1.11	0.085	I=-1.11t$^{0.085}$	0.7412
10	Akai Efa	-1.0	0.250	I=-1.0t$^{0.250}$	0.7243
11	Marina	-1.0	0.549	I=-1.0t$^{0.549}$	0.8423
12	CRUTECH	-0.7	0.248	I=-0.7t$^{0.248}$	0.617

4.3.0 Moisture Content Computation

Soil sample were collected from each sampling point and here are result obtained.

4.3.1: UNICAL

$$MC = \frac{7}{97}x\frac{100}{1} = 7.2\%\ \frac{14}{93}x\frac{100}{1} = 15.05\%$$

$$\text{Average} = \frac{7.2+15.05}{97} = 11.12\%$$

4.3.2: Goldie

$$MC = \frac{11}{103}x\frac{100}{1} = 10.68\%\ \ \frac{17}{105}x\frac{100}{1} = 16.19\%$$

4.3.3: Mary Slessor

$$MC = \frac{18}{106}x\frac{100}{1} = 16.98\%\ \ \frac{19}{98}x\ \frac{100}{1} = 19.98\%$$

$$\text{Average} = \frac{16.98+19.38}{2} = 18.18\%$$

4.3.4: Army Junction

MC = $\frac{16}{120} x \frac{100}{1} = 13.37\%$ $\frac{18}{131} x \frac{100}{1} = 13.74\%$

Average = $\frac{13.37+13.74}{2} = 13.55\%$

4.3.5: Ekorinim

MC = $\frac{12}{103} x \frac{100}{1} = 11.65\%$ $\frac{12}{101} x \frac{100}{1} = 10.89\%$

Average = $\frac{11.65 + 10.89}{2} = 11.27\%$

4.3.6: Atimbo

MC = $\frac{17}{103} x \frac{100}{1} = 14.30\%$ $\frac{19}{128} x \frac{100}{1} = 14.84\%$

Average = $\frac{14.30+14.84}{2} = 14.57\%$

4.3.7: Ediba

MC = $\frac{9}{123} x \frac{100}{1} = 7.30\%$ $\frac{10}{127} x \frac{100}{1} = 7.87\%$

Average = $\frac{7.30 + 7.87}{2} = 7.58\%$

4.3.8: Wapi Junction

MC = $\frac{11}{107} x \frac{100}{1} = 10.30\%$ $\frac{12}{111} x \frac{100}{1} = 10.81\%$

Average = $\frac{10.30 + 10.81}{2} = 10.56\%$

4.3.9: Big Qua

MC = $\frac{15}{99} x \frac{100}{1} = 15.15\%$ $\frac{16}{106} x \frac{100}{1} = 15.09\%$

Average = $\frac{15.15 + 15.09}{2} = 15.12\%$

4.3.10: CRUTECH

MC = $\frac{10}{85} x \frac{100}{1} = 11.76\%$ $\frac{16}{75} x \frac{100}{1} = 21.33\%$

Average = $\frac{11.76 + 21.33}{2} = 16.55\%$

4.3.11: Marina

MC = $\frac{10}{85} x \frac{100}{1} = 11.76\%$ $\frac{16}{75} x \frac{100}{1} = 21.33\%$

Average = $\frac{11.76 + 21.33}{2} = 16.55\%$

4.3.12: Akai Efa

MC = $\frac{5}{85} x \frac{100}{1} = 5.6\%$ $\frac{16}{91} x \frac{100}{1} = 6.6\%$

Average = $\frac{5.6 + 6.6}{2}$ = 6.10%

Gross average percentage moisture content for the catchment is given by

$$\frac{11.12+13.45+18.18+13.55+11.27+14.57+7.58+14.98+10.56+14.98+14.22+16.55+6.10}{12} = 152.27$$

Average moisture content for the catchment = $\frac{152.27}{12}$ = **12.69%**

4.4: DISCUSSION

Table (4.1 to 4.12), show the infiltration depths and infiltration rates for each of the 12 locations. The infiltration rates for the soil of UNICAL was 0.03cm/min while its cumulative infiltration depth was 2.67cm after 180mins, for Goldie 0.03cm/min and cumulative depth 3.75cm, Mary Slessor 0.01cm/min and 3.75cm cumulative depth, Army Junction 0.01cm/min and 4.12cm cumulative depth, Ekorinim II 0.01cm/min and 3.22cm cumulative depth, Atimbo 0.02cm/min and 6.88cm cumulative depth, Ediba 0.03/min and 3.97cm cumulative depth, Wapi Junction 0.02cm/min and 6.02cm cumulative depth, Big Qua 0.01cm/min and 2.77cm cumulative depth, Akai Efa 0.03cm/min and 2.67cm cumulative depth, Marina 0.01cm/min and 3.93cm cumulative depth, CRUTECH 0.02cm/min and 1.87cm cumulative depth respectively. These were influenced by the texture moisture content and vegetation cover of the soils.

Table 4.2.1 shows the values of the estimated parameters. It showed that “a” values ranged from-0.63 to-1.11. “b” varied from location to location and ranged from 0.085 to 0.683. The infiltration equation obtained from the soils were: $-0.63t^{0.121}$, $-0.68t^{0.442}$, $-0.89t^{0.683}$, $-0.89t^{0.475}$, $-0.89t^{0.42,}$ $-1.0t^{0.341}$, $-0.77t^{0.678}$, $-0.89t^{0.427}$, $-1.11t^{0.085}$, $-1.0t^{0.250}$, $-1.0t^{0.549}$, and $-0.7t^{0.248}$. This confirmed the fact that the values of the estimated parameters are soil dependent and site specific.

The kostiakov constants (a) and (b) were obtained from the graph of Log I against Log T, the slope of the graph gave the structural condition of the soil while the intercept gave the index of soil structural stability for the different sampling points.

The constants **a,** and **b** are summarized in the table 4.2.1. The constants in kostiakov infiltration model for the catchment are the structural conditions of the soil which gives lower bound value and the index of soil structural stability value at UNICAL was a lower bound value.

Because a lumped model necessarily averages together properties of the system, and also makes some approximations to simplify the solution, there is no real way to actually measure all the model inputs.

It was observed that sandy soil gave high infiltration rate and is highly permeable and porous, estimating quick infiltration of precipitation for the catchment.

The particle sizes of the soil matters a lot in infiltration because the bigger the particle size the higher the infiltration rate, while the smaller the particles sizes the lower the infiltration rate. For this work, soil obtained from Uncial, Ediba, Goldie, Big-Qua, Mary Slessor and CRUTECH were found to be predominantly sandy soils and possessed high infiltration rate. Samplings points at Wapi, Army Junction, Ekorinim 2, Marina, Atimbo and Akai Efa had low rate of infiltration. The plot with the best regression index was at $R^2 = 0.8423$, while the least was 0.617.

4.5 Test of Goodness of Fit

To test the goodness of fit, using the Kolmogorov – Smirov approach, Kostiakov infiltration model was applied on the field data to determine the soils infiltration model coefficients. The coefficients obtained for ‘a’ were: -0.63 for UNICAL, -0,67 for Goldie, -0.89 for Mary Slessor, -0.89 for Atimbo, 0.89 for Ediba, -1.0 for Army Junction, -0.77 for Ekorinem, -0.89 for Wapi Junction, -1.11 for Big Qua, -1.0 for Akai Efa, -1.0 for Marina, -0.7 for CRUTECH. The corresponding ‘b’ values ranged 0.085 to 0.683. Infiltration equations obtained for the soils were: $-0.63t^{0.121}$, $-0.68t^{0.442}$, $-0.89t^{0.683}$, $-0.89t^{0.475}$, $-0.89t^{0.42}$, $-1.0t^{0.341}$, $-0.77t^{0.678}$, $-0.89t^{0.427}$, $-1.11t^{0.085}$, $-1.0t^{0.250}$, $-1.0t^{0.549}$, and $-0.7t^{0.248}$. Simulated data were evaluated by comparing them with field data and they showed a close agreement with each other, indicating that Kostiakov infiltration model was capable of simulating infiltration for the soils of Calabar Metropolis Catchment.

5.0 SUMMARY

Infiltration is a major hydrologic process controlling the amount of runoff at scales from hill slopes to river basins. Measurements of infiltration and the soil characteristics are usually done at point locations. Estimating infiltration from different sampling points may be the only feasible alternative to making extensive measurements. Applying the kostiakov equations requires soil properties, as well as regression equations that relate the kostiakov parameters to the soil properties. Because the mapped soil properties are not well known and some variations are expected within the mapping unit, uncertainty in the parameter value results. The amount of spatial detail in a soil map relative to a river basin has important consequences for the simulated hydrologic response.

5.1 CONCLUSION

The objective of this study was to use Kostiakov model to obtain the water infiltration parameters and equations of the soils of calabar metropolis catchment, which could be used in simulating infiltration for these soils when designing irrigation projects, thereby saving time and cost of field measurement.

Field measurements of infiltration were first made using a double ring infiltrometer in 12 different locations at Calabar metropolis catchment. Infiltration rate ranged from 0,0lcm/min to 2.54cm/min. Kostiakov infiltration model was then applied on the field data to determine the soils infiltration model coefficients. The coefficients obtained for 'a' were : -0.63 for UNICAL, -0.67 for Goldie, -0.89 for Mary Slessor, -0.89 for Atimbo, 0.89 for Ediba, -1.0 for Army Junction, -0.77 for Ekorinem, -0.89 for Wapi Junction, -1.11 for Big Qua, -1.0 for Akai Efa, -1.0 for Marina, -0.7 for CRUTECH. The corresponding 'b' values ranged 0.085 to 0.683. Infiltration equations obtained for the soils were :-0.63t° ^{121}, -0.68t^{0442}, -0.89t^{0683}, -0.89t°$^{'475}$, -0.89t°$^{'42}$, -l.Ot^{0341}, -0.77t°$^{'678}$,-0.89t°-^{427}, -1.1 It$^{0'085}$, -l.Ot^{0}-^{250}. -l.Ot^{0}-^{549} and-0.7t°$^{'248}$. Simulated data were evaluated by comparing them with field data and they showed a close agreement with each other, indicating that Kostiakov infiltration was capable simulating infiltration for the soils of Calabar Metropolis Catchment Area.

5.2 Recommendations

Using the available kostiakov model for storage basins within Calabar metropolis SWMM could yield misleading results in many cases. It is therefore recommended that at the minimum, engineered soil zone be added to the SWMM model for use in the catchment to give it a regional applicability. Additionally, to make the model more practicable, it would be beneficial to have more information about the behavior of the initial soil moisture. It would be enough to develop an understanding of what acceptable engineering values are to be used, but even more interesting would be to develop a physical based soil moisture accounting method that is viable for practical use in the catchment.

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