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Evaluation of Philip's and Kostiakov's Infiltration Models on Soils Derived from three Parent Materials in Akwa Ibom State, Nigeria

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Abstract Knowledge of water infiltration into soils is required in determining how much water is stored in the root zone for crops and for the design of irrigation systems. Therefore, infiltration models are useful tools in predicting water infiltration into the soil. A study was conducted to evaluate two infiltration models on soils derived from coastal plain sands (CPs), sandstone (SSt) and river alluvium (ALv) in Akwa Ibom State, Nigeria. The models were Kostiakov's (KOS), and Philip's (PHI) models. Ten observation points were selected from each of the three parent materials totaling thirty (30), where infiltration studies were carried out. Topsoil (0-20 cm) samples were also collected for laboratory analysis of some soil physical properties. Data generated were summarized using mean, standard deviation and coefficient of variation. Coefficient of determination (R^2), Nash-Sutcliffe model efficiency (NE) and root mean square error (RMSE) were used to determine the goodness of fit of the infiltration models with the field-measured data. Infiltration model with the highest R^2 and NE as well as lowest RMSE was adjudged best in predicting water infiltration. Results showed that the highest means of infiltration model parameters were observed in SSt soil as follows: Kostiakov's K (1.376 cm min^{-1}) and α (0.893) and Philip's S (0.667 cm min$^{-1/2}$) and A (0.813 cm min^{-1}). Alluvial (ALv) soil had the lowest mean values of the models' parameters as follows: 0.067 cm min^{-1} and 0.800 for Kostiakov's K and α, respectively as well as 0.068 cm min$^{-1/2}$ and 0.018 cm min^{-1} for Philip's S and A, respectively. In the CPs soil, Philip's model with the highest R^2, highest NE and lowest RMSE of 0.999, 0.999 and 0.013 predicted water infiltration better than Kostiakov's model with R^2, NE and RMSE of 0.998, 0.998 and 0.015, respectively. In the SSt soil, Kostiakov's model, with R^2, NE and RMSE of 0.999, 0.999 and 0.012, respectively gave better predictions of water infiltration than Philip's model with R^2 of 0.998, NE of 0.998 and RMSE of 0.018. In the ALv soil, KOS had R^2, NE and RMSE of 0.998, 0.997 and 0.016 while the values for PHI were 0.997, 0.994 and 0.019, respectively, indicating that KOS predicted water infiltration better than PHI in this soil. Philip's model gave the best prediction of water infiltration in CPs soil while the Kostiakov's model was best for soils of sandstone and alluvial parent materials. The Philip's model was therefore recommended for the prediction of water infiltration in soils derived from coastal plain sands while the Kostiakov's model was recommended for sandstone and alluvial soils of Akwa Ibom State, Nigeria.

Keywords Infiltration, Philip's model, Kostiakov's model, parent materials, Akwa Ibom

1. Introduction

The study of soil water infiltration is important in environmental management and agriculture because of its connection with soil erosion, ground water recharge and crops sustenance. The amount of water infiltrating the soil surface has a direct influence on the magnitude of surface runoff, erosion, and the recharge of both soil and ground water [1]. Knowledge of soil infiltration characteristics is required in determining how much water is stored in the root zone for crops, design of irrigation systems, water and soil losses through runoff and erosion, all of which are crucial factors in agriculture. However, given the drudge involved in point to point infiltration measurement using infiltrometers, the use of predictive equations becomes a useful tool to predict water infiltration into soils. Soil complexity and variability affect the values of infiltration model parameters, thereby making them soil-specific.

A number of infiltration models have been developed to evaluate the infiltration process into soils. Since the parameters used in these equations are highly dependent on the soil types and surface conditions, field test is necessary for the determination of these parameters [2]. Studies have been conducted to evaluate infiltration models either for the purpose of validation or establishing the model parameters for different soils or to compare model efficiencies and applicability for different conditions [3-7]. There is a great need for continuous and in-depth study of the applicability of infiltration models for different soils since model parameters and performance vary for different soils. Some of the commonly used infiltration models include Philip's, modified Philip's, Kostiakov's, modified Kostiakov's and Horton's infiltration models.

Mbagwu [8] recommended either the modified Kostiakov's or modified Philip's models for routine modeling of the infiltration process on soils with rapid water intake rates. Musa and Adeoye [9] found Kostiakov's model to be better than Philip's model in soils of the Permanent Site Farm of the Federal University of Technology, Minna, Nigeria. Akpan [10] reported that the Kostiakov's model best predicted infiltration in soils of three landforms in Akwa Ibom State, Nigeria. Oku and Aiyelari [11] deduced that Philip's model was more suitable than Kostiakov's model for predicting water infiltration in Inceptisols of the humid forest zone of Nigeria. Elsewhere in Brazil, de Carvalho *et al.* [12] reported that Horton's model best described soil infiltration while Naeth *et al.* [13] found Kostiakov's model to be the best for vertisols in Alberta.

Although there is a wide usage of these models in infiltration studies the world over [14], there is no sufficient usage of models in infiltration studies in the southeast agro ecological zone of Nigeria.

The evaluation of the predictability of different infiltration models for their abilities to predict water infiltration into soil will inform the recommendation of the model(s) that best fit(s) the soil. Therefore, this study seeks to evaluate two infiltration models (Kostiakov's and Philip's) on soils formed over three parent materials (coastal plain sands, sandstone and river alluvium) in Akwa Ibom State.

Materials and Method

Physical Environment

This study was conducted in three locations, based on parent material, in Akwa Ibom State. The locations were the Teaching and Research Farm of Akwa Ibom State University, Obio Akpa (coastal plain sands), the upland area of Cross River Basin Development Authority Research Farm, Itu (Sandstone) and the floodplain area of the Cross River Basin Development Authority Research Farm, Itu (River Alluvium). Akwa Ibom State is located within the tropical rainforest belt in Nigeria and lies between latitudes $4^{o}30^{'}$ and $5^{o}30^{'}$ N and Longitudes $7^{o}27^{'}$ and $8^{o}27^{'}$ E [15]. The climate of Akwa Ibom State is basically uniform with slight variations from the coastal areas in the South to the North. The climate is typically warm humid tropical. The mean annual temperature is uniform, ranging from 26^{o} to 28^{o} C. The climate is divided into the wet season (April to October) and dry season (November to March). The rainy season is bimodal with peaks in July and September and a short dry spell in August, referred to as August Break. The rainfall ranges from about 3000 mm along the coast to about 2000 mm in the hinterlands [16]. Relative humidity varies between 75 and 90 % [17].

Field Methods

Ten observation points were randomly selected across each location where ten (10) infiltration runs were conducted. At each observation point, top soil samples (0-20cm) were collected with auger for the determination of particle size distribution and aggregate stability. Undisturbed core samples were also collected in each of the sampling points for the measurement of saturated hydraulic conductivity and bulk density. Total porosity was estimated from bulk density value assuming a particle density of 2.65 Kg m^{-3}.

Infiltration test was made using the double ring infiltrometer method [18]. The rings were vertically driven into the soil and the depth of penetration was noted. The soil surface was protected from scouring by laying grasses and leaves on the soil surface within the rings prior to the commencement of infiltration. The rate of fall of water level was measured in the inner ring while a pool of water was maintained at approximately the same level in the outer ring to reduce lateral flow from the inner ring.

Other equipments used were water container, hammer and wooden plank (to drive the infiltrometer into the soil), stop watch and ruler. The rate of fall of the water level in the inner cylinder was measured at 1, 2, 5 and 10 minute intervals. Each infiltration run continued until the steady state infiltration rate was attained. Infiltration data obtained from the field were used to estimate the infiltration models' parameters.

Infiltration Models Evaluated and Models Parameterization

Infiltration models tested and methods of estimating the models parameters are presented on Table 1.

Table 1: Infiltration models evaluated and methods of parameters estimation

Model Name	Equation	Model Parameters	Method of Parameter Estimation
Kostiakov	$I = Kt^{\alpha}$	K, α	Log I was plotted as ordinate against log t as abscissa to give K and α as intercept and slope, respectively.
Philip	$I = St^{1/2} + At$	S, A	S was obtained by determining the slope of I/t versus $t^{-1/2}$ while the intercept of this graph gave A.

K = Kostiakov's time coefficient; α = Kostiakov's time exponent; S = Philip's sorptivity; A = Philip's transmissivity; I = cumulative infiltration depth, t = elapsed time of infiltration (min).

Laboratory Methods

Particle size distribution was done using the Bouyoucos hydrometer method as described by Klute [19]. The textural class of soil was determined using the textural triangle.

Bulk density was calculated from the mass-volume relationship of oven-dry soil as follows:

$$\ell b = \frac{Ms}{Vt} \qquad \text{------------------------------} (1)$$

where, ℓb is bulk density (Kg m^{-3}), M_s is dry soil mass (Kg), V_t is total volume of soil (m^3) (volume of core sampler)

Total porosity, *f* was calculated using the formula:

$$f = 1 - \left(\frac{\ell b}{\ell p}\right) \qquad \text{------------------------------} (2)$$

where, *f* is total porosity (m^3m^{-3}), ℓb is bulk density (Kg m^{-3}), ℓp is particle density, assumed to be 2.65 Kg m^{-3} for mineral soils.

Saturated Hydraulic Conductivity (K_{sat}) was measured using the constant head method [20]. The quantity of water (Q) draining through the soil column over a fixed period of time (t) was collected and hydraulic conductivity was calculated as follows:

$$Ksat = \frac{QL}{\Delta hAt} \qquad \text{------------------------------} (3)$$

where, K_{sat} is saturated hydraulic conductivity (cm hr^{-1}), Q is water discharge (cm^3), L is length of soil column (length of core sampler) (cm), Δh is pressure head difference causing the flow, A is cross sectional area (cm^2) of core sampler and t is time (h).

Validation of models

To validate the two infiltration models, the field measured cumulative infiltration (I_m) and predicted cumulative infiltration (I_p) were used to compute the coefficient of determination (R^2), root mean square error (RMSE) and Nash-Sutcliffe Model Efficiency (NE). The model with the higher values of R^2 and NE, and a corresponding lower value of RMSE was considered to give the better fit of the field measured data. The regression procedure was used to obtain the R^2.

RMSE was calculated using the formula:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(I_m - I_p)^2}{N}} \quad \text{------------------------------} \quad (4)$$

where, I_m, I_p and N are measured cumulative infiltration, predicted cumulative infiltration and number of measurements made, respectively.

Nash-Sutcliffe Model Efficiency (NE) was calculated using the formula:

$$\mathrm{NE} = 1 - \frac{\sum(I_p - I_m)^2}{\sum(I_m - \overline{I_m})^2} \quad \text{------------------------------} \quad (5)$$

where $\overline{I_m}$ is the mean of measured cumulative infiltration; I_m and I_p are as shown in equation 4

Statistical Analysis

Data of infiltration model parameters generated were summarized using mean, standard deviation and coefficient of variation.

Results and Discussion

Some Physical Properties of Soils Studied

The result of soil analysis presented in Table 2 showed that the soils derived from coastal plain sands (CPs) and sandstone (SSt) were dominated by sand while clay was the dominant particle fraction in alluvial (ALv) soil. The CPs soil had the highest mean bulk density (1.55 Kg m^{-3}), followed by the SSt soil (1.39 Kg m^{-3}) and then the ALv soil (1.20 Kg m^{-3}) in that order. Higher bulk densities of the SSt and CPs soils than the ALv soil could be attributed to the preponderance of coarse sand fractions in the SSt and CPs soils compared to that of ALv. Chaudhari *et al.* [21] and Tanveera *et al.* [22] observed the profound effect of soil texture on bulk density and also reported an increase in bulk density with increase in sand fraction. The ALv soil had the least bulk density probably because of its high clay content and low sand fraction.

The clayey alluvial soil contained more pores (0.55 m^3 m^{-3}) than the sandy SSt (0.48 m^3 m^{-3}) and CPs (0.42 m^3 m^{-3}) soils. This result corroborated that of Chaudhari *et al.* [21] and Krull *et al.* [23] who reported higher total porosity of clayey soils than sandy soils. The higher total porosity of the ALv soil could be linked to its finer texture.

Regarding moisture conduction, the ALv soil conducted less water than the CPs and SSt soils as shown by their mean values of K_{sat} (Table 2). The CPs and SSt soils were statistically ($P \leq 0.05$) similar in moisture conduction. However, the SSt conducted more water. The larger pore spaces (macro pores), as a result of higher coarse sand fraction observed in the CPs and SSt soils may have influenced rapid drainage compared to the micro pores of the clayey ALv soil. Hillel [24] had stated that micro pores occur typically in clayey soils.

Table 2: Some properties of soils studied

	CPs	SSt	ALv
CS (%)	59.50	63.26	37.10
FS (%)	23.10	17.20	6.40
TS (%)	82.60	80.46	43.50
Silt (%)	5.57	7.09	15.20
Clay (%)	11.83	12.45	41.30
Texture	LS	LS	Cl
ℓb (Mg m^{-3})	1.55	1.39	1.20
f (m^3 m^{-3})	0.42	0.48	0.55
K_{sat} (cm hr^{-1})	3.32	5.85	0.40

Values are means of ten sampling points

CPs = coastal plain sands, SSt = sandstone, ALv = alluvium, CS = coarse sand, FS = fine sand, TS = total sand, ℓb = bulk density, *f* = total porosity, K_{sat} = saturated hydraulic conductivity, LS = loamy sand, Cl = clay.

Parameterization of Infiltration Models

Infiltration models' parameters of coastal plain sands (CPs), sandstone (SSt) and alluvial (ALv) soils are presented in Table 3. Mean value of Kostiakov's time coefficient (K) was highest in the SSt soil (1.376 cm min^{-1}), followed by the CPs soil (0.924 cm min^{-1}) while the lowest was observed in the ALv soil (0.067 cm min^{-1}). The K parameter in Kostiakov's model is an index of infiltrability at the beginning of infiltration [25]. The greater the value of K, the greater the initial infiltration value [13]. Therefore the higher value of K observed in SSt soil, than the CPs and ALv soils was indicative of the higher infiltration in SSt than in CPs and ALv soils in that order. Mbagwu [8] and Ogbe *et al.* [26] associated higher infiltration with higher Kostiakov's K while lower infiltration was associated with lower value.

Kostiakov's time exponent (α) was highest in the SSt soil, followed by the CPs soil and lowest in the ALv soil. The constant, α does not have clear physical meaning. It reflects the influence of the soil physical properties and initial soil moisture condition on infiltration [25, 27-28]. When α value is small, the infiltration rate rapidly decreases with time [25]. Consequently, the result obtained indicated highest infiltration rate in the SSt soil, followed by the CPs soil while that of the ALv soil was the lowest. The Kostiakov's time exponent (α) in this study revealed that the SSt and CPs soils were more permeable than the ALv soil possibly due to the higher coarse sand fractions and K_{sat} values (Table 2) in the SSt and CPs soils than the ALv soil. This observation confirmed the findings of Ball [29] and Brouwer *et al.* [30] who stated that coarse textured soils have a higher infiltration rate than fine textured soils. The values of α ranged from 0.704 to 0.959 in the CPs soil, 0.824 to 0.940 in SSt and 0.743 to 0.906 in ALv soil (Table 3). These values of Kostiakov's time exponents conformed to the theory of infiltration whereby the values are positive and always less than unity [26]. The values were also in tandem with most observed values which ranged between 0.2 and 0.9 [31-32]. The variability of K was high (CV, > 35%) while that of α was low (CV < 15%) in all the soils. A size comparison of Kostiakov's model parameters showed that K was greater than α. Wang *et al.* [33] and Ogbe *et al.* [26] made similar observations.

Table 3: Infiltration models parameters for coastal plain sand, sandstone and alluvial soils

Observation Point	**KOS**		**PHI**		**KOS**		**PHI**		**KOS**		**PHI**	
	K	**α**	**S**	**A**	**K**	**α**	**S**	**A**	**K**	**α**	**S**	**A**
	cm min^{-1}		**cm min$^{-1/2}$**	**cm min^{-1}**	**cm min^{-1}**		**cm min$^{-1/2}$**	**cm min^{-1}**	**cm min^{-1}**		**cm min$^{-1/2}$**	**cm min^{-1}**
	Coastal Plain Sand				**Sandstone**				**Alluvium**			
1	1.247	0.910	0.606	0.787	1.575	0.900	0.719	0.969	0.040	0.895	0.029	0.022
2	1.548	0.925	0.741	1.037	1.371	0.824	0.894	0.585	0.095	0.777	0.093	0.026
3	0.566	0.875	0.315	0.308	1.277	0.931	0.443	0.921	0.040	0.878	0.032	0.020
4	1.258	0.959	0.285	1.032	1.006	0.918	0.459	0.665	0.084	0.743	0.096	0.016
5	0.560	0.891	0.263	0.335	0.901	0.940	0.266	0.683	0.038	0.906	0.027	0.022
6	0.715	0.704	0.662	0.136	1.840	0.890	0.847	1.092	0.052	0.803	0.053	0.016
7	0.433	0.889	0.263	0.242	1.800	0.906	0.756	1.150	0.069	0.778	0.079	0.017
8	1.115	0.940	0.252	0.866	1.105	0.874	0.442	0.652	0.121	0.638	0.137	0.010
9	0.803	0.747	0.745	0.192	2.226	0.846	1.478	1.014	0.044	0.840	0.039	0.018
10	0.993	0.813	0.811	0.362	0.663	0.903	0.366	0.398	0.084	0.743	0.096	0.016
Mean	0.924	0.865	0.494	0.530	1.376	0.893	0.667	0.813	0.067	0.800	0.068	0.018
SD (±)	0.366	0.084	0.237	0.358	0.484	0.036	0.357	0.249	0.028	0.083	0.038	0.005
CV (%)	39.635	9.744	47.982	67.658	35.189	4.077	53.540	30.596	42.798	10.349	55.028	24.172

KOS = Kostiakov's model, PHI = Philip's model, K = Kostiakov's model coefficient (cm min^{-1}), α = Kostiakov's model exponent (dimensionless), S = sorptivity (cm min$^{-1/2}$), A = transmissivity (cm min^{-1})

Table 3 revealed that Philip's sorptivity term (S) was highest in SSt soil (0.667 cm min$^{-1/2}$), followed by CPs soil (0.494 cm min$^{-1/2}$) while that in the ALv soil (0.068 cm min$^{-1/2}$) was the lowest. The transmissivity term (A) in the Philip's equation was highest in the SSt soil (0.813 ± 0.249 cm min^{-1}), followed by the CPs soil (0.530 ± 0.358 cm min^{-1}) and lowest in the ALv soil (0.018 ± 0.005 cm min^{-1}). Sorptivity (S) measures infiltrability at the beginning of infiltration process [25] and represents the rate at which water is drawn into a soil in the absence of gravity. It comprises the combined effects of adsorption at surfaces of soil particles and capillarity in soil pores [9]. On the other hand, the transmissivity term (A) is due to the impact of pore spaces on the flow of water through soil under the influence of gravity [9]. The reason for the higher values of S and A obtained in the SSt and CPs soils compared to ALv soil in this study could therefore be attributed to the loamy sand texture and higher permeability of the soils of SSt and CPs compared to the clayey texture and lower permeability of ALv soil (Table 2). The results of Adindu *et al.* [34] and Mbagwu [8] also showed direct relationship between the Philip's S and A with soil permeability and infiltration capacity. Asiedu *et al.* [35] also related high sorptivity to landforms with high infiltration and drainage capacities.

Goodness of Fit of Infiltration Models

The goodness of fit of the infiltration models were statistically evaluated using the coefficient of determination (R^2), Nash-Sutcliffe model efficiency (NE) and root mean square error (RMSE). The evaluation was by using the field measured cumulative infiltration (I_m) and model predicted cumulative infiltration (I_p). The model with the larger value of R^2, larger value of NE and smaller value of RMSE was considered the best in predicting cumulative infiltration.

The R^2, NE and RMSE of the infiltration models in the CPs soils are presented in Table 4. Mean of R^2 was 0.998 for KOS and 0.999 for PHI. For NE, it was 0.998 for KOS and 0.999 for PHI while that of RMSE was 0.015 for KOS and 0.013 for PHI. Therefore, Philip's model (PHI), which had the higher R^2, higher NE and lower RMSE gave the better fit than the KOS with the field-observed cumulative infiltration and was therefore considered the better in predicting water infiltration into the CPs soil. This observation corroborated the report of Mbagwu [8] who suggested that the Philip's model was among those suited for highly permeable soils of Nsukka.

Table 4: Coefficient of determination (R^2), Nash-Sutcliffe model efficiency (NE) and root mean square error (RMSE) of infiltration models for coastal plain sand soil

	R^2		**NE**		**RMSE**	
	KOS	**PHI**	**KOS**	**PHI**	**KOS**	**PHI**
1	0.999	1.000	0.999	1.000	0.012	0.007
2	0.999	1.000	0.999	1.000	0.015	0.007
3	1.000	0.999	1.000	0.999	0.006	0.015
4	1.000	1.000	1.000	1.000	0.006	0.009
5	1.000	0.999	1.000	0.998	0.008	0.017
6	0.995	0.998	0.995	0.997	0.022	0.016
7	0.998	0.999	0.997	0.999	0.020	0.010
8	0.999	0.998	0.999	0.997	0.018	0.027
9	0.996	1.000	0.996	1.000	0.022	0.008
10	0.998	1.000	0.998	1.000	0.019	0.007
Mean	**0.998**	**0.999**	**0.998**	**0.999**	**0.015**	**0.013**
Rank	**2**	**1**	**2**	**1**	**2**	**1**

KOS – Kostiakov's model, PHI – Philip's model

For the SSt soil, R^2, NE and RMSE of the models are presented in Table 5. In this soil, mean of R^2 was 0.999 for KOS and 0.998 for PHI. Value of Nash-Sutcliffe model efficiency (NE) was 0.999 for KOS and 0.998 for PHI while that of RMSE was 0.012 for KOS and 0.018 for PHI. Kostiakov's model (KOS) gave a better fit than the PHI with the field-observed infiltration data and therefore was considered better than PHI in the prediction of water infiltration into the SSt soil. Mbagwu [8] also observed that the Kostiakov's model gave good prediction of water infiltration in highly permeable soils of Nsukka.

With regard to the ALv soil, (Table 6) the R^2, NE and RMSE of the infiltration models are presented in Table 6. Mean of R^2 was 0.998 for KOS and 0.997 for PHI and that of NE was 0.997 for KOS and 0.994 for PHI while that of RMSE was 0.016 for KOS and 0.019 for PHI. Kostiakov's model (KOS), which had the higher R^2, higher NE and lower RMSE gave the best fit with the observed infiltration data and was ranked better than PHI in predicting water infiltration into the ALv soil.

This study ranked the Philip's model to be better than the KOS for the prediction of water infiltration in the CPs soil while the Kostiakov's model was better for the SSt and ALv soils. Many researchers also comparatively recommended these two infiltration models for the prediction of water infiltration in different soils. Mbagwu [8] found Kostiakov's model to give the best fit among the six infiltration models that he evaluated in southeastern Nigeria. Wuddivira [36] recommended the Kostiakov's and Philip's models for the prediction of infiltration rates of Samaru soils in the Northern Guinea Savanna of Nigeria. Fahad *et al.* [37] studied the effects of soybean and other cropping sequences on infiltration and found that Philip's and Kostiakov's equations simulated field data reasonably well and that Kostiakov's equation provided a better fit for the early and late stages of infiltration. Dixon *et al.* [38] indicated that Kostiakov's equation best predicted infiltration characteristics of soils of southeastern Nigeria. Ezekiel *et al.* [39] found Kostiakov's model to give a perfect agreement between the observed and predicted cumulative infiltration.

Table 5: Coefficient of determination (R^2), Nash-Sutcliffe model efficiency (NE) and root mean square error (RMSE) of infiltration models for sandstone soil

	R^2		NE		RMSE	
	KOS	**PHI**	**KOS**	**PHI**	**KOS**	**PHI**
1	1.000	0.999	1.000	0.998	0.010	0.022
2	0.999	0.997	0.999	0.996	0.012	0.027
3	1.000	0.999	1.000	0.999	0.010	0.014
4	0.999	1.000	0.999	1.000	0.015	0.008
5	1.000	1.000	1.000	1.000	0.003	0.010
6	0.999	0.997	0.999	0.996	0.016	0.031
7	0.998	0.999	0.998	0.999	0.021	0.013
8	0.999	0.998	0.999	0.998	0.012	0.023
9	1.000	0.999	1.000	0.998	0.008	0.019
10	0.999	0.999	0.999	0.999	0.017	0.011
Mean	**0.999**	**0.998**	**0.999**	**0.998**	**0.012**	**0.018**
Rank	1	2	1	2	1	2

KOS – Kostiakov's model, PHI – Philip's model

Table 6: Coefficient of determination (R^2), Nash-Sutcliffe model efficiency (NE) and root mean square error (RMSE) of infiltration models for alluvial soil

	R^2		NE		RMSE	
	KOS	**PHI**	**KOS**	**PHI**	**KOS**	**PHI**
1	0.999	0.999	0.999	0.999	0.012	0.009
2	0.999	0.997	0.998	1.000	0.014	0.007
3	0.996	0.997	0.996	0.992	0.018	0.026
4	0.998	0.993	0.997	0.984	0.018	0.040
5	0.997	0.999	0.996	0.999	0.019	0.010
6	0.999	0.999	0.999	0.997	0.010	0.015
7	0.995	0.998	0.995	0.998	0.021	0.013
8	0.996	0.993	0.996	0.981	0.016	0.035
9	0.999	0.996	0.999	0.999	0.011	0.007
10	1.000	0.997	0.995	0.992	0.019	0.026
Mean	**0.998**	**0.997**	**0.997**	**0.994**	**0.016**	**0.019**
Rank	**1**	**2**	**1**	**2**	**1**	**2**

KOS – Kostiakov's model, PHI – Philip's model

Conclusion and Recommendation

Values of KOS model parameters (K and α) and PHI model parameters (S and A) increased with increase in water intake. Thus, the lower and higher of these parameters were recorded in the ALv and SSt soils, respectively. The Philip's model was better than the Kostiakov's model for predicting water infiltration in the CPs soil while Kostiakov's model (KOS) was better for the SSt and ALv soils.

Based on the findings of this study, the Philip's model is recommended for the prediction of water infiltration in the soils formed over coastal plain sands while the Kostiakov's model is recommended for sandstone and alluvial soils of Akwa Ibom State.

Therefore, for successful irrigation farming, the Philip's model is recommended to the Teaching and Research Farm of Akwa Ibom State University, Obio Akpa campus while the Kostiakov's model is recommended to the Cross River Basin Development Authority (CRBDA), Itu.

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