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The Evaluation and Determining of Soil Infiltration Models Coefficients

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Abstract: Applying infiltration equations in modeling of both surface and subsurface flows results in easier surface irrigation systems designing and evaluating. Due to the correlation between the coefficients of the equations and type of soil and surface conditions exacting field tests seems to be really necessary. The infiltration rate into the soil in one of the important parameters in designing and performing irrigation and drainage projects, hydrological studies, soil conservation and water supply management, designing and performing green areas, soil pools of fish farming etc. This research deals with the rate of soil water infiltration using double ring method in 4 different positions having clay loam soil texture (0-30cm) and kamyaran. Soil physical characteristics including bulk density, soil texture and chemical ones such as EC, PH, anions, and cations. With infiltration rest were executed by using 13 rings in 4 different points in the summer in 2011. In addition to evaluation and determining the coefficients of 4 soil infiltration models (Kostiakov, Kostiakov- *Lwies,* Philip*s and* SCS) integrated infiltration equations, infiltration rate and average infiltration rate were simultaneously determined for the fields. After analyzing the models the Phillip's model tended to be the most appropriate one to estimate integrated infiltration rate. There were some effective factor in applying Phillip's model including high correlation coefficient, low variation of data and estimating the integrated infiltration and its infiltration rate in comparison to real values of data. The Kostiakov - Lwies and Kostiakov models were respectively alternative models according to homogeneity of the soil texture and the same moisture condition. The SCS model is mot recommended for this region since it underestimates the integrated infiltration and infiltration rate. One of the results of this paper is the proximity of K coefficient in Kostiakov equation to S absorption coefficient of in Philips equation which implies the dependency of K coefficient on physical characteristics of the soil.

Key words: *infiltration, double ring,* Kostiakov*,* Kostiakov- *Lowies,* Philip*s and* SCS *infiltration equations.*

INTRODUCTION

In order to design and manage different irrigation methods the awareness of soil infiltration characteristics seem to be necessary. Infiltration depends on soil characteristics and field surface conditions. The value of infiltration equation for a field necessitates executing field's tests under common conditions. The infiltration equations are presented as basic, empirical and physical models. The infiltration differential equations are of nonlinear kind and they could be solving as by computer. Being dependent on the soil moisture, the hydraulic conductivity coefficients of this equation step by step and by applying hydraulic conductivity function are complicated and burdensome to solve. So basic and physical equations of infiltration are rarely used in designing irrigation systems and the focus is on empirical ones.

Some researchers such as Clemmens (1983), Strelkoff and Soza (1984), Walker and Willardson (1983), Bautista and Wallender (1993) recommend empirical equations to design and evaluate surface irrigation. In order to choose and recommend appropriate infiltration equations for surface irrigation , Clemmens evaluated and compared the applicability of eight infiltration equations including Philips, Green – Ampt, Kostiakov, Kostiakov - Lowies SCS equation , Horton and field data. He concluded that the results of empirical equations correspond to field data much better than those of physical equations. Clemmens recommends Kostiakov, Kostiakov - Lowies equations. The results of a measurement by-Childs et al (1993) in 27 points of 21- hectare field show that spatial variation in addition to seasonal variation influence the infiltrated. Childs et al(1993) observed that the infiltration depth in the first irrigation is more than the second, but from the second one on, the changes tend to reduce.

In this paper empirical equation of Kostiakov, Kostiakov - Lowies, SCS, and Philips are evaluated the following empirical equation to determine the integrated infiltration depth of water:

$$Z = KT^{n} \qquad (1)$$

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In which Z is integrated infiltration, T is the time of infiltration and n, K are the coefficients of the equation.

Kostiakov equation is very applicable because if being easy, but it has got some restrictions. One of those restriction is that the amount of calculated infiltration rate tends to approach zero in long times and the results do not correspond to the reality. In order to eliminate these restrictions the Kostiakov-lowies equation is presented as follow:

$$Z = KT^n + f_o T \tag{2}$$

In which f_o is the final infiltration rate.

SCS experts hove executed too many tests in field based on Kostiakov model. They finally calculated SCS model as follow.

$$Z = aT^b + c \tag{3}$$

In which the a, b coefficients are functions of infiltration curve and c is invariable. Philips (1957) used Richards's equation for unsaturated flow and he was presented the following model:

$$Z = ST^{\frac{1}{2}} + AT \tag{4}$$

In which Z stands for integrated infiltration T stands for the time of infiltration and $A . S$ Are respectively absorption and transitive coefficient.

MATERIALS AND METHODS

There are numerous methods to evaluate soil water infiltration such as double rings method. The tests were executed in an eight- hectare field located 15 km for from Sanandaj to Kamiaran in 2011 summer. The surface soil texture was (0-30)cm clay loam and from 30-90 it was sand soil physical characteristics tests including bulk density, soil texture etc and chemical ones such as EC, PH, Cations, Anions, etc with infiltration tests were executed by using 13 rings in 4 different points. The needed materials and how the tests were executed are shown by Figure1 and 2. The results of physical as well as chemical characteristics tests are presented in tables 1 and 2.

Fig. 1: The needed materials to execute infiltration test in double rings method.

Fig. 2: Ring installing and soil infiltration measuring in the field.

RESULTS AND DISCUSSION

The Kostiakov, Kostiakov - Lwies, SCS and Philip's infiltration equations coefficients and integrated infiltration equations infiltration rate and average infiltration rate are calculated by practicing the best empirical data graph, the results of these coefficients and also those of integrated infiltration equations are presented by Figures 3 and 4.

One interesting thing about K coefficient in Kostiakov equation is its proximity to S or absorption coefficient in Philip's equation which shows the dependency of K coefficient on physical characteristics of soil. Phillip's (1957) Haverkamp et al (1977) pointed it out that in initial times of infiltration K is close to S . n Coefficient in all tests is greater than 0.5 in Kostiakov equation.

Hartly (1992) put it that in homogenous soils the n is mostly greater than 0.5, the values less than have been reported by other researchers, though. A coefficient in Philip's equation has a direct relation with soil infiltration. The absorption coefficient of s in this equation is greater than zero.

According to the Figures 3 and 4, it is obvious that Philips model estimates integrated infiltration and infiltration rate with high precise and Philips model it was the next suitable after Kostiakov, Kostiakov - Lwies models. The SCS model underestimated integrated infiltration and infiltration rate in all condition so it is not recommended for the area.

Haverkamp et al. (1997) put it that according to the time of the test the coefficients of the above mentioned models are variable which it can be related to the duration of the test time. The infiltration coefficients are usually obtained based on practicing the best graph according to the data of infiltration measurement in short term period. Applying these coefficients for a long time could mean going on the infiltration curve out of the time of measurement and it could lead to a considerable error.

The variation values average and homogeneity coefficient shown in table 2 accounts for that and models have high correlation coefficient but the best model is that with the lowest variation. So, the best model for estimating the integrated infiltration and infiltration rate for agricultural fields of Azad University in sanandaj and similar fields is the Philips model. The obtained results of this model are used for estimating the integrated infiltration and infiltration rate in designing surface irrigation systems (except furrow irrigation method) and other given objectives. Haverkamp et al (1977) recommended Philips model as the first choice and Kostiakov - Lwies model as the second one.

It is highly recommended that too much attention must be paid to determining infiltration equations in order to precisely design and evaluate surface irrigation systems. Hydrological studies, green area designing and executing breeding fish soil ponds and to apply the best one among all other different equations. In addition, the infiltration values and equations must be estimated for any irrigation system (except furrow irrigation method). The existence of variability for the coefficients of models was clarified by analyzing field data.

Table 1: Models coefficients and average values for different rests.

Num.	SCS			Philips		Kostiakov - Lowies			Kostiakov	
	C (cm)	b	a(cm)	s $(cm/min)^{0.5}$	A (cm/min)	$f_{\circ}$ (cm/min)	n	k $(cm/min)^n$	n	k $(cm/min)^n$
1	0.6985	0.8230	0.4445	1.119	0.1269	0.1613	0.3660	1.318	0.6670	1.094
2	0.6985	0.8230	0.4445	0.7590	0.1874	0.1909	0.4180	0.8960	0.7430	0.8300
3	0.6985	0.8230	0.4445	1.690	0.0662	0.1200	0.3860	1.892	0.5820	1.618
4	0.6985	0.8230	0.4445	1.400	0.0906	0.1394	0.3810	1.562	0.6240	1.317
5	0.6985	0.8230	0.4445	1.242	0.1178	0.1530	0.3850	1.417	0.6500	1.201

Table 2: Integrated infiltration equations, variations, and correlation coefficient for different tests.

Location	Model	Infiltration equation	R^2	S^2
One	Kostiakov	$Z = 1.094T^{0.667}$	0.9974	1.515
	Kostiakov - Lowies	$Z = 1.318T^{0.366} + 0.1613T$	0.9621	0.511
	Philips	$Z = 1.119T^{0.50} + 0.1269T$	0.9992	0.281
	SCS	$Z = 0.4445T^{0.823} + 0.6985$	-	6.971
Two	Kostiakov	$Z = 0.83T^{0.743}$	0.9979	1.913
	Kostiakov - Lowies	$Z = 0.896T^{0.418} + 0.1909T$	0.9788	0.247
	Philips	$Z = 0.759T^{0.50} + 0.1874T$	0.9876	1.597
	SCS	$Z = 0.4445T^{0.823} + 0.6985$	–	24.070
Three	Kostiakov	$Z = 1.618T^{0.582}$	0.9983	0.591
	Kostiakov - Lowies	$Z = 1.892T^{0.386} + 0.12T$	0.9808	0.800
	Philips	$Z = 1.69T^{0.5} + 0.0662T$	0.9995	0.023
	SCS	$Z = 0.4445T^{0.823} + 0.6985$	–	6.391
Fourth	Kostiakov	$Z = 1.317T^{0.624}$	0.9970	1.033
	Kostiakov - Lowies	$Z = 1.562T^{0.381} + 0.1394T$	0. 9758	0.689
	Philips	$Z = 1.4T^{0.5} + 0.0906T$	0.9994	0.041
	SCS	$Z = 0.4445T^{0.823} + 0.6985$	–	5.162
Average	Kostiakov	$Z = 1.201T^{0.65}$	0.9973	1.423
	Kostiakov - Lowies	$Z = 1.417T^{0.385} + 0.153T$	0.9767\	0.518
	Philips	$Z = 1.242T^{0.50} + 0.1178T$	0.9994	0.199
	SCS	$Z = 0.4445T^{0.823} + 0.6985$	–	8.293

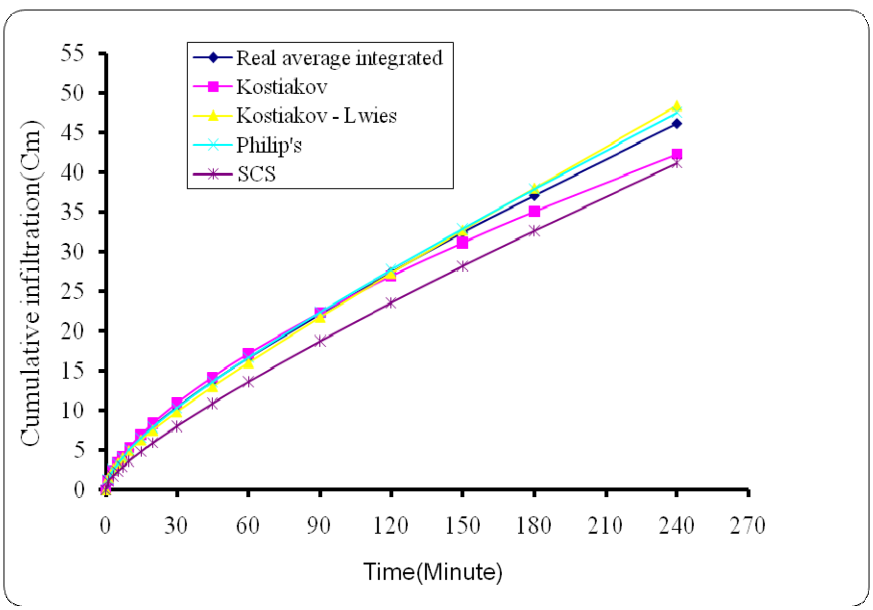

Fig. 3: The comparison of real average integrated infiltration values and predicted one by different models (the average of four positions)

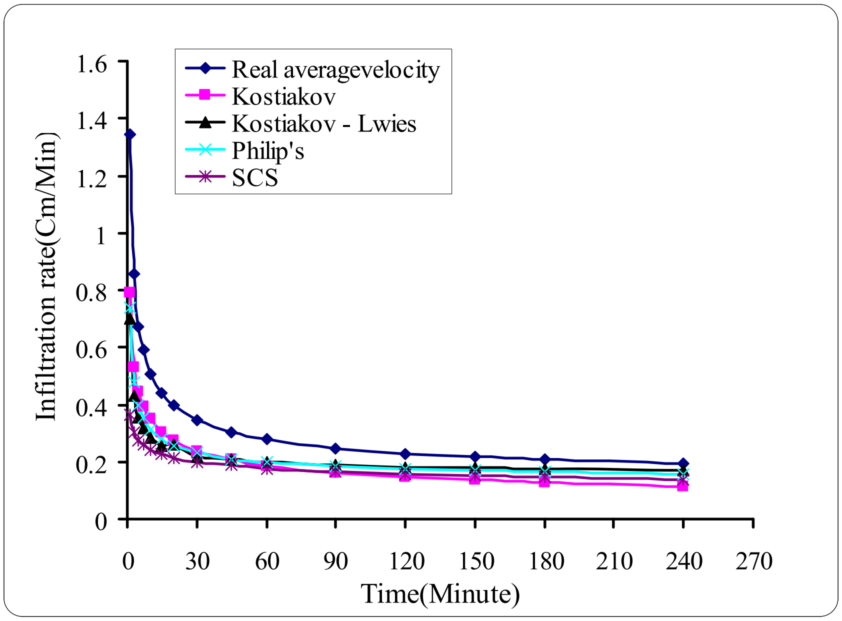

Fig. 4: The comparison of real average infiltration rate and predicted one by different models (the average of four positions).

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