Available online at http://www.ijabbr.com

International journal of Advanced Biological and Biomedical Research

Volume 1, Issue 8, 2013: 822-829

Evaluation and determination of the coefficients of infiltration models in Marvdasht region, Fars province

Haneyeh Mazloom[*1] and Hamidreza Foladmand [2]

[1] M.Sc. student of Irrigation and drainage, Islamic Azad University, Marvdasht branch, Iran.

[2] Assistance professor of Irrigation and drainage, Islamic Azad University, Marvdasht branch, Iran.

ABSTRACT

Infiltration process plays an important role in water cycle of the nature. Conducting field experiments is necessary to determine the coefficients of infiltration equations due to the dependence of these coefficients to the soil type, soil surface conditions and the amount of initial soil moisture content. This study has been carried out in a field located in Islamic Azad University, Marvdasht branch, Fars province. With regard to various initial amounts of soil moisture content and clay loam soil texture of the study area, permeability tests including double rings and single ring methods were conducted in 8 points as well as the coefficients of Philippe and Kostiakov models were determined to estimate the coefficients of infiltration models and to determine a proper model to forecast cumulative infiltration values. Results of the evaluation shows that, Kostiakov model has more proper operation in estimating the amount of infiltration compared with Philippe model, and coefficients of the studied models (Kostiakov and Philippe models) vary with soil moisture variation. These variations in some cases are high and for some others are low. Variations trend also is not fully compatible with soil moisture content.

Key words: Philippe model, Kostiakov model, Permeability, Model coefficients, Initial moisture

INTRODUCTION

Quantification of infiltration phenomenon is of great importance in watersheds management. Prediction of the areas prone to flooding, soil erosion and pollutants transport are all dependent on the amount of created runoff which is dependent on infiltration phenomenon (Tesansis, 2006). Study of soil water infiltration is of great importance considering both aspects of intensity and the amount of infiltration in design and implementation of all irrigation methods. Therefore, infiltration can be considered as an important soil trait in agriculture (Neshat & Parehkar, 2007). Water infiltration into the soil which is an important issue of soil physics, depends on some factors such as soil physical characteristics (texture and structure), amount of initial moisture content, slope, roughness, intensity, type of vegetative cover, water

Corresponding Author Email: hanimazloom@yahoo.com

depth, soil and water temperature, applied water quality, amount of dissolved salts particularly, exchangeable sodium in water and soil and most importantly, dispersion of the soil surface particles. Among the mentioned factors, initial soil moisture content has a wide range of variations (Alizadeh, 2001; Darbandi *et al*, 2010; Gildia & Tiripay, 1987). Amount of soil moisture and physical traits including soil texture are the most important determinant factors of infiltration (Campbell, 1985; Radcliffe & Rasmussen, 2000). Infiltration equations have been presented as basic, empirical and physical models. In most equations, the basic and physical equations of infiltration are rarely used and for irrigation system design, empirical equations are mostly used (Rahimi *et al*, 2008). Neshat and Parehkar (2007) by evaluating the infiltration on three types of soil texture including clay, loam and clay loam, showed that, Kostiakov is the best model to estimate cumulative infiltration and infiltration rate for all conditions however, by increasing the time of infiltration, Kostiakov model had more errors and variations than other models. Empirical estimation models have less limits considering the assumptions which are related to soil surface and soil profile conditions. Egbadon and Idris (2007) in an evaluation of infiltration models capabilities to in estimating the amount of cumulative infiltration in hydromorphic soils in the flood of Zango village plains, showed that, Kostiakov model and Adjusted Kostiakov model have more compatibility with observed values. Fahad *et al*, (1982) by applying the infiltration models in plots with soybean concluded that, Kostiakov and Philippe models are more consistent with empirical data but, in early stages of infiltration, Kostiakov model is more consistent. The importance and role of infiltration phenomenon in other soil factors, environmental and biological factors has caused that, the researchers always look for providing a suitable model and determination of its coefficients to explain it, quantitatively. The objectives of this study are to evaluate and to estimate the coefficients of infiltration models in 8 points with a soil texture of clay loam under different soil moisture conditions in Marvdasht region of Fars province.

MATERIALS AND METHODS

The used samples in this research were collected in Islamic Azad University, Marvdasht branch, since February to May, 2012. To eliminate the influence of other factors such as lack of soil uniformity, the selected land must be considered uniform. Therefore, a piece of land which was apparently uniform was selected. In order to measure soil moisture in this study, undisturbed sampling method was used. Then, to determine the proper infiltration equation for the study area and considering clay loam soil of the region, permeability tests were carried out using double rings and single ring methods in 8 points for 180 min. in each point.

Coefficients of both infiltration models (Kostiakov and Philippe models) were determined using SPSS software. Kostiakov model: Kostiakov suggested the empirical model as below, to determine the amount of water infiltration in the soil:

$$i = ct^{a}$$

Where, t is infiltration time (since the beginning) by minute, i is infiltrated water since the beginning of infiltration by cm, a and c are empirical coefficients for different soils and their values are greater than 0 and are between 0, 1 respectively. Kostiakov equation is valid when infiltration rate is higher than saturated hydraulic conductivity of the soil.

Philippe model: An equation which is almost complicated as following: $i = st^{0.5} + K$

Where, s is constant coefficient related to water absorbency which is a function of soil water suction, and K is constant coefficient related to soil hydraulic conductivity by $cm.Min^{-1}$.

Table1. Infiltration models and their coefficients

Coefficients	Infiltration equation	Model name
c و a	$i = ct^a$	Kostiakov
s و k	$i = st^{0.5} + K$	Philippe

To assess the accuracy of the models, some parameters such as Root Mean Square Error (RMSE), Geometric Mean Error Ratio (GMER) and Geometric Standard Deviation of Error Ratio (GSDER) were used which are calculable using following equations (Teytije and Hnyngz, 2006).

$$RMSE = [\frac{\sum_{i=1}^{n}(x_i - y_i)^2}{n}]^{0/5}$$

$$GMER = exp\,[\frac{1}{n}\sum_{i=1}^{n}\ln(e_i)]$$

$$GSDER = exp\,[(\frac{1}{n-1}\sum_{i=1}^{n}[\ln(e_i) - \ln(GMER)]^2)^{0.5}]$$

$$e_i = \frac{y_i}{x_i}$$

Where, e is error ratio and x_i , y_i respectively are estimated and measured values in each soil moisture. The minimum value of RMSE is equal with zero and whatever the amount is less, it is more appropriate. RMSE value indicates that the estimated parameters have been estimated how high or low. If GMER value is equal with 1 then, the measured and estimated values are completely overlapped. If GMER is less than 1 then, the estimated values are less than measured values and if GMER is higher than 1 then, the estimated values are greater than measured values. Also, if GSDER value is equal with 1 then, the measured and estimated values are completely overlapped and increasing GSDER of 1 indicates increasing distance between estimated and measured values. Therefore, it is most appropriate that, GMER to be close to 1 and GSDER value also to be small that means not much bigger than 1 (Vanger *et al*, 2001). At the stage of creation of new functions, 70% of all measured soil moisture contents were used to produce equations, and the remaining data were used for validation of determined equations.

RESULTS

Coefficients of the infiltration models and the coefficient of R^2 for two infiltration models have been presented in Tables 2 and 3 respectively for single ring and double rings measurements.

Table 2. Parameters of Kostiakov equation for various soil moisture contents in double rings and single ring tests

Single ring			Double rings			Initial soil moisture
R^2	b	a	R^2	b	a	
0.997	0.759	4.896	0.993	0.849	2.244	32.66 *
0.997	0.741	5.436	0.999	0.812	2.722	31.76
0/998	0.766	6.54	0.996	0.834	3.053	28.8 *
0.997	0.755	6.937	0.997	0.812	3.426	28.55
0.997	0.766	6.917	0.997	0.83	3.415	27.43 *
0.997	0.76	7.253	0.997	0.817	3.728	27.0 *
0.997	0.756	7.914	0.996	0.805	4.357	25.66 *
0.996	0.757	7.979	0.995	0.807	4.421	25.55 *
0.995	0.759	8.05	0.995	0.809	4.448	25.44 *
0.995	0.761	8.323	0.995	0.808	4.77	24.1 *
0.996	0.753	8.85	0.995	0.795	5.274	23.35 *
0.995	0.758	8.821	0.995	0.801	5.252	23.28 *
0.992	0.76	8.877	0.994	0.801	5.308	23.15 *
0.995	0.76	8.95	0.995	0.803	5.388	22.9 *
0.995	0.761	9.001	0.995	0.804	5.441	22.7
0.995	0.766	9.097	0.995	0.81	5.5545	20.03
0.996	0.76	9.589	0.996	0.798	6.039	19.1 *
0.997	0.755	10.28	0.997	0.897	6.617	16.8
0.996	0.756	10.24	0.996	0.79	6.667	16.6 *
0.996	0.758	10.29	0.996	0.792	6.728	16.35 *
0.996	0.764	10.28	0.996	0.799	6.728	15.8 *
0.995	0.769	10.30	0.995	0.806	6.761	15.6
0.996	0.768	10.23	0.996	0.805	6.769	15.38 *
0.994	0.771	10.3	0/992	0.804	6.773	11.01 *
0.992	0.741	4.896	0.993	0.789	2.244	Minimum
0.998	0.741	11.3	0.999	0.849	6.763	Maximum
0.995	0.76	8.606	0.996	0.776	5.119	Mean

* Applied tests for validation of the results

Table 3. Parameters of Philippe equation for various soil moisture contents in double rings and single ring tests

Single ring			Double rings			Initial soil moisture	
R^2	k	s	R^2	k	S		
0.973	1.202	4.616	0.904	0.912	1/983	32.66	*
0.977	1.152	5.336	0.934	0.864	2/702	31.76	
0.96	1.758	5.722	0.949	1.192	2/537	28.8	*
0.925	1.778	5.983	0.93	1.212	2/795	28.55	
0.917	1.941	5.699	0.902	1.375	2/522	27.43	*
0.947	1.919	6.227	0.937	1.353	3/039	27.03	*
0.936	2.055	6.744	0.917	1.489	3/556	25.62	*
0.923	2.117	6.691	0.892	1.551	3/504	25.55	*
0.908	2.177	6.642	0.963	1.611	3/454	25.44	*
0.892	2.31	6.668	0.854	1.744	3/5	24.1	*
0.89	2.327	7.298	0.889	1.761	4/11	23.35	*
0.904	2.389	7.201	0.873	1.823	4/013	23.28	*
0.91	2.45	7.148	0.845	1.884	3/96	23.15	*
0.89	2.483	7.186	0.857	1.917	3/998	22.9	*
0.883	2.521	7.174	0.845	1.995	3/986	22.7	
0.869	2.698	7.14	0.825	2.037	3/952	20.03	
0.893	2.647	7.753	0.869	2.081	4/565	19.1	*
0.91	2.699	8.389	0.901	2.133	5/21	16.8	
0.91	2.754	8.357	0.883	2.188	5/169	16.6	*
0.888	2.812	8.309	0.863	2.246	5/121	16.35	*
0.87	2.916	8.191	0.883	2.315	5/004	15.8	*
0.855	3.02	8.092	0.799	2.461	4/904	15.6	
0.873	2.97	8.12	0.826	2.404	4/932	15.38	*
0.845	3.31	9.031	0.873	2.765	5.843	11.01	*
0.845	1.202	4.616	0.873	0.864	1.983	Minimum	
0.997	3.31	9.031	0.963	2.765	5.843	Maximum	
0.903	2.257	7.703	0.9	1.805	3.992	Mean	

* Applied tests for validation of the results

It was needed to make a relationship between cumulative infiltration equations used in this study and initial soil moisture content. Hence, about 70% of the measurements (including 17 tests) for calibration and the other 30% of the measurements (including 7 tests) for evaluation of the results, were considered. The selected initial soil moisture for the stage of results calibration have been marked with * in tables 2, 3.

Table 4. Evaluation of the results of estimating infiltration in double rings test

Kostiakov equation			Kostiakov equation			
GSD ER	GMER	RMSE	GSD ER	GMER	RMSE	Initial soil moisture content
1.31	1.084	85.4	1.27	1.07	9.27	31.76
1.29	1.08	19	1.78	1.05	8.54	28.55
1.36	0.93	25.55	1.48	0.88	20.87	23.15
1.19	0.98	30.31	1.29	0.92	15.78	22.7
1.96	1.04	45.22	1.06	1	15.5	16.8
1.13	1.97	36.15	1.96	1.04	11.88	15.16
1.14	1.01	33.21	1.16	0.96	12.24	20.3
1.34	1.013	39.25	1.429	0.989	13.37	average

Table 5. Evaluation of the results of estimating infiltration in Single ring test

Kostiakov equation			Kostiakov equation			
GSD ER	GMER	RMSE	GS DE R	GMER	RMSE	Initial soil moisture content
1.093	1.147	38.9	1.066	1.178	29.2	31.76
1.11	1.017	26.902	1.056	1.008	9.312	28.55
1.15	0.962	39.512	1.083	0.938	20.35	23.15
1.149	0.959	39.35	1.082	0.933	21.044	22.7
1.142	1.041	59.763	1.063	1.016	22.515	16.8
1.142	1.014	51.947	1.079	0.993	17.166	15.16
1.142	1.008	46.3	1.087	1.016	16.746	20.3
1.33	1.035	43.24	1.074	1.013	19.476	average

By examining RMSE values presented in tables 4, 5 it can be concluded that in both groups of the measured data, Kostiakov model has a more appropriate performance than Philippe model, in estimation of the amount of infiltration. Also by examining GMER values it can be stated that in double rings test, Kostiakov model underestimates the values while Philippe model overestimates the values but, in single ring test, both models overestimate the values.

DISCUSSION AND CONCLUSION

The results of table 2, 3 calculations show that, in both Kostiakov and Philippe models, mean R^2 values in double rings test is greater than single ring, it states that, infiltration measurement through double rings is more accurate than single ring. Also, the group of Kostiakov model with higher value of coefficient of explanation, has more accuracy in estimation of infiltration compared with Philippe model. The results also show that, in beginning times, the estimated values measured by both models have negligible difference but, Kostiakov model presents more appropriate estimations over the time. Ultimately, Kostiakov model is introduced as the more suitable model for soil of the study area in this research and this result is in accordance with the results of conducted studies by Soufi Ahmadi (2002), Mohammadi and Refahi (2005), and Neshat and Parehkar (2007). It is necessary to adjust the results of measurement in certain soil moisture content for other soil moisture contents. This adjustment or modification of the coefficients of infiltration models can plays an important role in management and use of soil and water resources considering estimation of infiltration and runoff amounts in watersheds, irrigation management, etc. (Darbandi *et al*, 2010). Kostiakov infiltration model is more appropriate for the soil texture of the study area. With this consideration that, initial soil moisture variations on the ground surface is high and infiltration features depend on this parameter, water infiltration measurement in certain soil moisture is valid for the same soil moisture condition. The results showed that, coefficients of the examined infiltration models in this study (Kostiakov and Philippe models) vary with soil moisture content variation. These variations in some cases are high and for some others are low. Variations trend also is not fully compatible with soil moisture content. Examination of statistical parameters including Root Mean Square Error (RMSE), Geometric Mean Error Ratio (GMER) and Geometric Standard Deviation of Error Ratio (GSDER) in both models and various levels of soil moisture contents showed that, Kostiakov model estimates more appropriate results compared with Philippe model for the amount water infiltration with initial soil moisture variations. So, when soil moisture is variable, it is suggested to use Kostiakov model that is consistent with conducted studies in this field. Considering that, accurate estimation of the amount of water infiltration is of great importance for estimation of runoff in watershed management, efficient use of water resources and irrigation systems design and on the other hand, initial soil moisture content has high influence on the amount of infiltration so, the coefficients of infiltration models must be modified relative to initial soil moisture content.

REFERENCES

Darbandi, S., Darbandi, S. and Taghavi, S, 2012. Deremination of the best infiltration equation for Nematabad station (Azad Islamic University, Tabriz branch) soils and sensitivity analysis of infiltration equations coefficients to the initial soil moisture content. Journal of Irrigation and Drainage of Iran. 3 (4): 330-337.

Rahimi, 1., Boroumandnasab, S. and Kashkooli, H. 2009. Evaluation and determination of the coefficients of water infiltration models. 7th seminar on irrigation and reducing evaporation. Kerman Bahonar University.

Soufi Ahmadi, A. 2002. Evaluation of the best infiltration equation for Antisol soils. M.Sc Thesis, Faculty of Agriculture, Tarbiat Modarres University.

Alizadeh, A. 2001. Principals of applied hydrology. Astan-e-Ghods-e-Razavi Press. 800 p.

Mohammadi, M. H. and Refahi, H. Gh. 2005. Estimation of infiltration equations parameters using soil physical characteristics. Journal of Agricultural sciences of Iran. 36(6): 1391-1398.

Neshat, A. and Parehkar, M. 2007. Comparison of the methods of determination of vertical soil water infiltration rate in the soil. Journal of Natural Resources and Agriculture. 14(3): 1-10.

Campbell, G.S. 1985. Soil physics with BASIC Elsevier, New York, N.Y.

Fahad, A. A., L. N. Mielke, A. D. Flowerday, and D. Swatzendruber. 1982. Soil physical properties as affected by soybeans and other cropping sequences. Soil Sic. Soc. Am. J., 46: 377-381.

Kostiakov, A. V. 1932. On the dynamics of the coefficient of water percolation soils and the necessity for studying it from a dynamics point of view for purposes of amelioration. Transaction of the Sixth Commission of International Society of Soil Science. Part A., pp. 17-21.

Ghildya, B. P. and M. Tripathi. 1987. Soil physics. Wiley Eastern Limited-New Delhi-pp: 345-380.

Igbadun, H. E_, and Idris, U. D. 2007. Performance Evaluation of infiltration models in a Hydromorphic Soil. Journal of Soil and Environment Research, 7 (3): 53-5.

Philp, J. R. 1957. The theory of infiltration. 2. The profile at infinity. Soil Sci. 83: 435-448.

Radcliffe, D. E. and T. C. Rasmussen. 2000. Soil water movement. In, Hand Book of Soil Science. M. E., Sumner. C.R.C. Press.

Tsanis, I. K. 2006. Modeling leachate contamination and remediation of groundwater at a landfill site. Water Resour. Manage. 20: 109-132.

Tietje, O., and V. Hennings. 1996. Accuracy of the saturated hydraulic conductivity prediction by pedotrasfer function compared to the variability within FAO textual classes. Geoderma. 69: 71-89.

Wanger, B., V. R. Tarnawski, V. Hennings, U. Muller, G. Wessoleu, and R. Plagge. 2001. Evaluation of pedotransfer for unsaturated soil hydraulic conductivity using an independent data swt. Geoderma. 102: 275-297.