Studying the Philip model capability to estimate water infiltration parameters

Amir Mansour Shahsavar[A] Ebrahim Pazira[B] and Maryam Dadgar[C]

[A] Islamic Azad University, Roodehen Branch, mansoorshahsavar_amir@yahoo.com
[B] Islamic Azad University, Science and Research Branch, ebrahimpazira@ yahoo.com
[C] Islamic Azad University, Roodehen Branch, Maryam.Dadgar2008@ Gmail.com

Abstract
Infiltration refers to the entry of water into a soil profile from the boundary. Generally, it refers to vertical infiltration, where water moves downward from the soil surface. The Philip model is one of the infiltration models with an algebraic equation based on sound physical reasoning for vertical infiltration under ponded conditions. We designed a program in Quick Basic software and wrote algorithms for three models that include Kostiakove, Modified Kostiakove and Philip. Afterwards we gathered factual infiltration data by the double ring method in 12 soil series of Saveh plain in Markazi province in Iran. After assessing model coefficients, these equations were regenerated by EXCEL software and calculations related to observations and related graphs were done. Infiltration parameters, such as cumulative infiltration and infiltration rate were obtained from the models. Then observed and determined parameters of infiltration were compared. Results showed that for seven series the Philip model could determine the infiltration parameters with a good agreement. Also the Philip model for five series of soils, after passing of time, had a curve shape as shown in the Philip model for Saveh (2), Labar (1), Harisan (2), Gharehtappeh and Anjilavand series, including 5 series with heavy to very heavy texture. The sorptivity coefficient of the Philip model became less than zero, for long times, consequently accumulative infiltration decreased during this period. Other models particularly Modified Kostiakove could quantify amounts of cumulative infiltration and infiltration rate. In the short and middle time for most series, Kostiakove and Modified Kostiakove models were better than the Philip model in estimating infiltration parameters. However for long times the Philip model could determine infiltration parameter better than the other models.

Key Words
Infiltration, model, Kostiakove, modified Kostiakove, Philip.

Introduction
Infiltration phenomenon explain water entering into the soil in a vertical direction, therefore this process needs to suitable model for simulation. Equations, have been designed according to the type of model (experimental or analytical models) and have various and different capabilities. A combination of Darcy's law and flow continuity equation provides a general water flow equation for unsaturated soils. The simplest application for this equation is for describing horizontal water into soil infiltration. If relationships between water and soil matric potential and hydraulic conductivity are defined, then a description of the infiltration phenomenon by solving Richard's equation is possible. Using a serial hypotheses in solving Richard's equation, is inevitable. In solving the Richard's equation, soil physical parameters are often consider fixed, but these parameters may change and determining these changes and entering them in the Richard's equation is difficult. Philip (1, 2) was the first to solve Richard's equation for unsaturated flows as a serial of potential functions. His hypothesis considered a unit soil with infinite depth and some primary fixed water as a thin layer of water. The structure of this research is based on analysis of the Philip model's capability in determining accumulative infiltration quantities compared to real quantities.

Methods
The study area was located on the Saveh Plain (491109ha) covering 12 soil series.

By the method of double ring in filtration and three repetitions in any series, cumulative infiltration quantities were obtained. In the studied series, accumulative infiltration quantities after determined times and terminal infiltration velocity, calculated traits were determined. In this research three models of water infiltration into the soil, consisting of the Kostiakove, Modified Kostiakove and Philip models were assessed. After designing models algorithms in QUIC BASIC software, the coefficients of models were obtained from experimental data. In the Kostiakove model we took logarithms from both sides of the the equation to make a linear equation:

Table1. Characteristics of soil series according the Soil Taxonomy.

Soil Taxonomy		Percentage of Area	Area(ha)	Soil series	Land Physiography	Row
Family	Order					
Fine,Mixed,Thermic	Aridisols	2.10	5017	Dolatabad	Piedmont Alluvial Plain	1
Fine,Mixed,Thermic	Aridisols	8.17	8730	Harisan		2
Fine,Mixed,Thermic	Aridisols	2.5	2560	Masoomabad	River Plain	3
Fine,Loamy,Mixed,Calcarous,Thermic	Entisols	1.8	3960	Saveh		4
Fine,Mixed,Thermic	Aridisols	4.15	7555	Anjilavand		5
Fine,Mixed,Thermic	Aridisols	5.6	3200	Gharehtappeh		6
Very Fine, Carbonatic,Thermic	Aridisols	5.4	2210	Akbarabad	Low Land	7
Very Fine, Carbonatic,Thermic	Aridisols	1.1	540	Abbasabad		8
Very Fine, Carbonatic,Thermic	Aridisols	7.25	12630	Labar		9
Fine,Loamy,Mixed,Calcarous,Thermic	Entisols	5.2	1218	Gharehchay	River Trace	10

Log (I) =log (a) + (b) log (t)

In this equation (b) is slope, and log (a) is intercept. Values of (b) and log (a) can be derived from graphs of log time versus log cumulative infiltration.

In the Modified Kostiakove model, by dividing of both sides of the equation by t, the following equation is obtained:

$$\frac{I}{t}=a\ t^{(b-1)}+c$$

Values of (a) and (c) coefficients are calculated by regression.

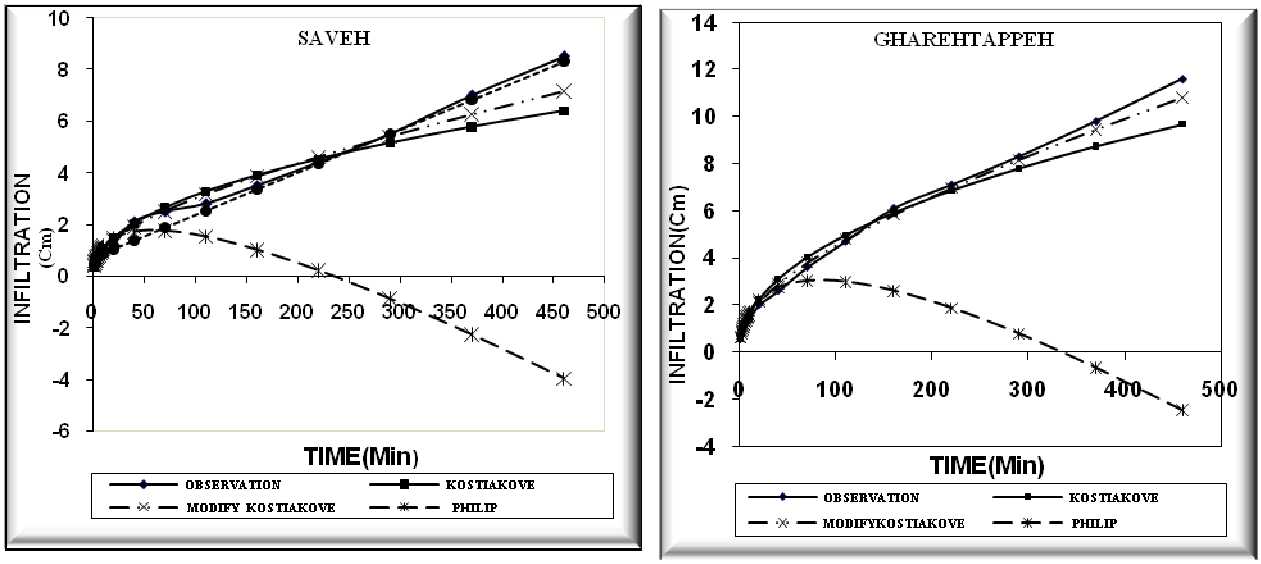
In the Philip model, by dividing of both side of equation on (t) we will have:

$$I / t = S \frac{1}{t^{1/2}} + A$$

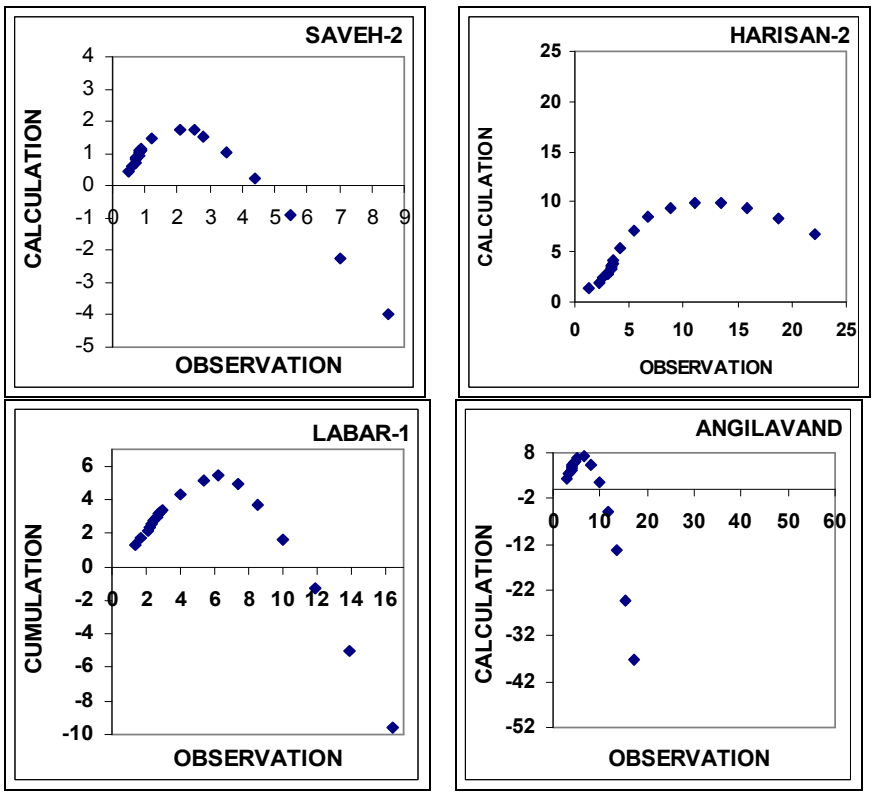
Coefficients A (Soil hydraulic conductivity function) and S (Sorptivity coefficient) were determined by regression. After assessing to models coefficients, these equations were regenerated by EXCEL software and calculations using the models were related to observations.

Results

After calculation of coefficients, we used of these models for calculation of cumulative infiltration and infiltration rate, that we compared with observations.



Graphs1 and 2. Comparative plots of cumulative infiltration with time from observational data and models for the Saveh (2) and Gharehtappeh series.



Graphs 3, 4, 5 and 6. Comparison between observation and calculated (Philip model) amounts of cumulative infiltration.

Conclusion

Using the Philip model for the Saveh (2), Labar (1), Harisan (2), Gharehtappeh and Anjilavand series, including heavy to very heavy texture soils; (a) coefficient became less than zero and after time cumulative infiltration decreased. For short times (90min, 110min, and 120min) for all series except Akbarabad series, the Kostiakove and Modified Kostiakove models for determining cumulative infiltration rate, were better than the Philip model. For the Akbarabad series; Philip model shows better correlation with observations. For longer times (360min, 460min), the Philip model compares to other models in determining cumulative infiltration. For moderate times (184min, 220min, 240min) except for the following cases, conditions are similar to long times. For the Dolatabad and Labar (2) series, the Philip model is second after the Kostiakove model and for the Labar (3) series the Philip model is most suitable.

References

Digman SL (2002) Physical hydrology, 2th. edition (Prenticehal, Inc.USA.).

Philip JR (1958) The theory of infiltration.7. *Soil Sci*. **85**, 333-337

Philip JR (1957a) The theory of infiltration: 1.The infiltration equation and its solution. *Soil.Sci*. **83**, 345-388.

Philip JR (1957b) The theory of infiltration: 4.Sorptivity and algebraic infiltration equation. *Soil. Sci*. **83**, 257-264.

William AJ, Wilford RG, Walter HG (1991) Soil physics, 5th edition: pp.122-157 (John Wiley & Sons, Inc)