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Philip's and green-Ampt model capability to estimate infiltration for solis of Mahilambadi, Tamil Nadu state, India

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Abstract

The present study was taken up in the watershed of community pond located in Mahilambadi Village, Trichy District, Tamil Nadu. The catchment area of 132 ha occupied by four different land cover conditions such as agricultural land, barren land, orchard, and lake. The constant infiltration rates of agricultural land and barren land were experimentally found as 5.55 and 5.70 cm h^{-1} respectively. Four locations were chosen within the pond area for finding infiltration rate of community pond for designing rainwater harvesting structure. The constant infiltration rates of four locations were 3.84, 3.75, 2.85 and 1.35 cm h^{-1}. Philip's and Green-Ampt model well fitted with the field data. The Philip's model was best suited to agricultural, barren land and four locations of pond with higher correlation coefficients values well compared with Green- Ampt model.

Keywords: Green Ampt model, Philip's model

1. Introduction

Infiltration is the one of the most valuable variables for runoff estimation. It depends on the land use cover, vegetation and soil texture. Initially, the infiltration rate is initially more infiltration and then it will decrease gradually and reach constant rate. If rainfall intensity is more than infiltration rate then it will begin runoff at that place. In this study area infiltration studies were undertaken to find the infiltration rate characteristics of pond and catchment. Double ring infiltrometer was used at five different locations such as cultivated land and barren pond itself for infiltration measurement. Infiltration rates observed were fitted to infiltration models Philip's equation and Green-Ampt model. Stored water from runoff will percolate and recharges the wells in command area.

Infiltration is an intricate procedure with numerous components adding to the rate. Distinctive rough conditions for infiltration vary in the parameters they require and predict different infiltration rate curves.

Two conditions including those of Philip's and Green-Ampt were contrasted with figure out which one most precisely anticipated estimated infiltration rates from infiltrometer test information at four unique areas for pond and two land use patterns in catchment attributes. Parameters were developed from estimated infiltration information and fitting of curves.

2. Methodology

2.1 Double ring infiltrometer test

The double infiltrometer test was conducted on two different land use patterns of the catchment area and in the community pond and four locations were selected for studying infiltration characteristics for designing the pond. The double ring infiltrometer is shown in figure. 1. This is most commonly and simply used infiltrometer. Two concentric rings having the diameter of 30 cm and 60 cm and the length of 30 cm are used. The two rings are embedded into the ground by a driving plate and hammer to infiltrate into the soil consistently without the unsettling influence of soil surface to a depth of 15 cm. The scale was fix in the center of the rings for taking readings. The water was poured into the inner ring at depth of 11 cm and at the same level was maintained in the outer ring also. Water was added to maintain the original constant depth at regular interval of 5 min duration and after some time increased the duration of time. The total time taken for the experiment was different for different locations.

The total time taken for agricultural land because in the barren land there is low infiltration rate compared to agricultural land.

Fig 1: Measurement of field infiltration rate

2.2 Philip's equation

Philip's built up a boundless arrangement answer for settle the non-straight halfway differential Richards' condition. Which describes transient liquid stream in a permeable medium for both vertical and horizontal infiltration. Philip's quickly meeting arrangement solves the flow equation for a homogeneous deep soil with uniform initial water content under ponded conditions. For cumulative infiltration the general type of the Philip's infiltration model is communicated in powers of the square-root of time, t, as

$$f_p = \frac{1}{2} s t^{\frac{-1}{2}} + K$$

Where

fp = the infiltration capacity or potential infiltration rate; [Lt-1],
fc = the final constant infiltration rate; [Lt -1],
fo = the infiltration capacity at t = 0; [Lt-1],
Kh = a soil parameter [t-1] that controls the rate of decrease of infiltration and must depend on initial water content,θi [L3 L-3] and application rate, R; [Lt -1].
t = time after start of infiltration.

The values of f_p are plotted against $t^{-0.5}$ on a simple arithmetic graph paper and the best fit straight line is drawn through the plotted points.

2.3 Green-Ampt model

The Green-Ampt model is considered in the form

$$fp = m + \frac{n}{F_p}$$

The values of f_p are plotted against $1/F_p$ on a simple arithmetic graph paper and the best fit straight line is drawn through the plotted points.

3. Results and Discussion

3.1 Comparison of measured infiltration data with predicted data

Field estimation of soil infiltration rate is often time consuming and laborious. Hence models offer a viable alternative for predicting infiltration. Several infiltration models are available for the prediction of the infiltration rate of soil and each model requires varied parameters. The observed data from the field were compared with the infiltration models to find out the best model that suits for the sandy loam soil of study area.

Green-Ampt and Philip's infiltration models were selected for the comparison. The statistical index of correlation coefficient (R^2) was determined for identifying the best model. The values of the different constants in the models mentioned above were calculated and furnished in Table 1.

The infiltration rates for different conditions were calculated using the constant values for different models. The graphical representation of observed and predicted model infiltration rates is given in figure 2 and 3.

The observed infiltration rate was fitted using Philip's and Green-Ampt infiltration model and found that Philip's model seems to be good fitting model for agricultural and barren land condition.

Table 1: Values of constants of infiltration models

Soil Conditions	Philip's Model $fp = \frac{1}{2} st^{-\frac{1}{2}} + K$		Green-Ampt Model $fp = m + \frac{n}{Fp}$	
	S	K	m	n
Agricultural land	10.01	2.61	-0.70	20.04
Barren land	6.25	5.45	4.45	11.74
Pond loaction1	3.89	3.05	2.69	3.472
Pond location2	7.80	1.55	1.78	6.08
Pond location3	14.82	-2.19	12.06	-7.40
Pond location4	6.08	0.59	3.47	0.89

Table 2: Calculated infiltration rates from different infiltration models at agricultural land condition

Time (min)	Observed infiltration rate (cm h^{-1})	Infiltration rates by Philip's model (cm h^{-1})	Infiltration rates by Green-Ampt model (cm h^{-1})
5	19.20	19.95	11.81
10	16.80	14.87	13.60
20	12.00	11.28	9.31
30	9.00	9.69	12.65
45	7.20	8.39	10.42
60	6.40	7.62	11.81
85	6.20	6.82	7.00
110	6.00	6.31	7.30
140	5.80	5.89	6.20
170	5.80	5.59	6.20
200	5.60	5.36	6.20
240	5.55	5.12	4.70
280	5.55	4.93	4.70
320	5.55	4.78	4.70
Correlation coefficient		0.96	0.50

It seems that the initial infiltration capacity of agricultural land is 19.2 cm h^{-1}. Which is high in pond catchment area. The agricultural land cover will be contributing very less volume as the runoff. All rainfall is lost through infiltration as initial abstraction, as the soil condition in agricultural land is under continuous disturbance. At cumulative time of 240 minutes the infiltration rate reached to steady state.

In barren land cover, it is observed that the initial infiltration capacity of barren land is 14.4 cm h^{-1}, which is low in pond catchment area. The barren land cover will be contributed more runoff than agricultural land because of its low infiltration rate. At cumulative time of 160 minutes the infiltration rate reached to steady state.

In pond location 1 condition the observed maximum infiltration rate was 9.6 cm h^{-1}. The calculated maximum infiltration rates from Green-Ampt model showed more deviation from observed infiltration rates. The calculated infiltration rates from Philip's model showed better results from initial condition to final steady condition. At the constant infiltration rates Philip's model showed best fitting infiltration rates.

In pond location 2 condition calculated infiltration rates from Green-Ampt model showed more deviation from observed infiltration rates. The predicted infiltration rates from Philip's model showed better results and best fitting for observed infiltration rates from initial condition to final steady condition.

In pond location 3 condition calculated infiltration rates Green-Ampt model showed more deviation from observed infiltration rates. The calculated infiltration rates from Philip's model showed better results and best fitting to observed infiltration rates.

In pond location 4, the calculated infiltration rates Green-Ampt model showed greater deviations from observed infiltration rates. The calculated infiltration rates from Philip's model showed better results and best fitting to observed infiltration rates from initial condition to final steady condition.

From the results it was found that the values of the parameters of infiltration models vary with soil conditions. Also, the correlation coefficients were different for different soil conditions. From analysis it is found that for all soil conditions Philip's model is best fitting with high degree of correlation coefficient. The correlation coefficient under different soil conditions were calculated Philip's model with observed infiltration rates. The Philip's model showed minimum correlation coefficient for agricultural land and barren land.

Additionally, the measured infiltration rates and predicted infiltration rates by various infiltration models against time were drawn for various soils under varying soil conditions and it was noted that in the beginning infiltration rates were high and decreased with time up to steady infiltration rate. The figure 2 and 3 shows graphical comparison of observed infiltration rates with infiltration rates from Philip's and Green-Ampt model.

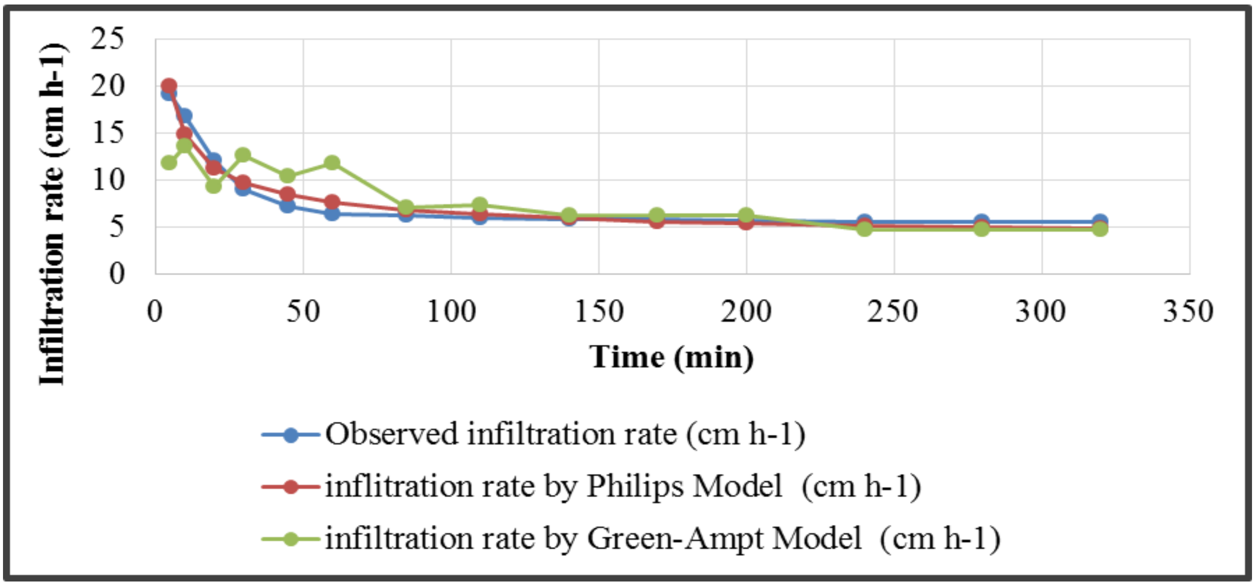

Fig 2: Observed infiltration rates and calculated infiltration rates vs time for agricultural land

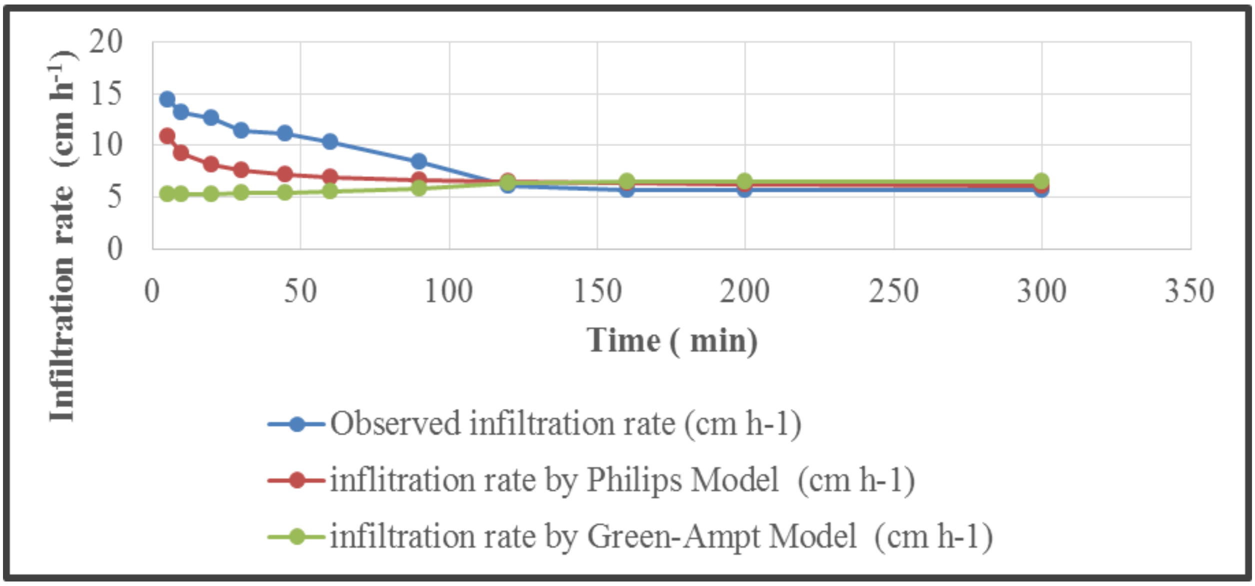

Fig 3: Observed infiltration rates and calculated infiltration rates vs time for barren land

4. Conclusion

The double ring in filtro meter test was conducted in the study area to determine the infiltration parameters of agricultural land and barren land conditions of catchment area and pond characteristics. The initial infiltration rate of agricultural land and barren land were found as 19.20 and 14.40 cm h^{-1}, respectively. The initial infiltration rates for four different locations of inside pond were found as 9.00, 16.8, 24 and 12 cm h^{-1}, respectively. The constant infiltration rates of agricultural land, and barren land were 5.55 and 5.70 cm h^{-1} respectively. The constant infiltration rates in the four locations of pond 3.84, 3.75, 2.85 and 1.35 cm h^{-1}, respectively.

The field observed infiltration data was fitted into Philip's and Green-Ampt model in order to estimate respective model parameters. The Philip's equation constants of s and K varied from 6.25 to 10.01 and 2.61 to 5.45, respectively for agricultural land and barren land and for the pond surface characteristics varied from 3.894 to 14.82 and -2.19 to 3.05, respectively. The Green-Ampt model constants of m and n for agricultural land, barren land were -0.706 to 4.45 and 11.74 to 20.04 and for pond locations are 1.789 to 12.067, -7.404 to 3.472. The results indicated that Philip's model is best fitted for the agricultural, barren land and four locations of pond surface with higher correlation coefficient values of 0.96, 0.95, 0.95, 0.95 and 0.87.

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