International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 11 | Nov -2016 www.irjet.net p-ISSN: 2395-0072

A Review on Modelling on Infiltration in Different Areas with Different Types of Soils

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Abstract: *Infiltration is the process by which water enters the soil from the ground surface. The maximum rate at which a soil can absorb water at a given time is known as infiltration rate. It is measured in cm/h or inches/hr or mm/hr. Infiltration rate is measured by using an infiltrometer. Infiltration rate of soil is a topic of continued interest. Several works have been done by many researchers in this field. In this paper, an attempt has been made to study the various research works done till now to study the variation of infiltration rate using double ring infiltrometer.*

Keywords: Infiltration, Horton's model, Kostiakov's model, Green-Ampt model, Philip's model, infiltrometer.

1. INTRODUCTION: The process through which water enters the soil from the ground surface is known as infiltration. This process is caused by force of gravity and capillary action. Infiltration capacity may be defined as the maximum rate at which a given soil at a given time can absorb water and is expressed in cm/h or mm/h or inches/h. The infiltration capacity is dependent on a large number of factors; some of them are characteristics of the soil, vegetative cover, condition of the soil surface, soil temperature, water content of the soil, rainfall intensity, etc. If the intensity of rainfall exceeds the infiltration rate of a given soil it results in a runoff. Horton[1] showed that during a period of constant precipitation, the rate of infiltration decreases with time. When there is plenty of water available, infiltration rates follow the limiting function, until a constant rate is reached. There are different methods to measure infiltration, for example. Flooding-Type Infiltrometers (Single ring infiltrometer and double ring infiltrometer), Rainfall Simulator and Hydrograph analysis.

Many equations have been developed for finding best fitting model to observed field infiltration rate data.

Horton's equation (1933):

$$f_p = f_c + (f_0 - f_c)e^{-k_h t}$$

Where, f_p=infiltration capacity at any time t from the start of the rainfall

f_0=initial infiltration capacity at t=0

f_c=final steady state infiltration capacity occuring at t=t_c

k_h= Horton's decay coefficient which depends upon soil characteristics and vegetation cover

Philip's Equation (1957):

$$F_p = st^{1/2} + Kt$$

Where, s= a function of soil suction potential called sorptivity

K=Darcy's hydraulic conductivity

Kostiakov's Equation (1932):

$$F_p = at^b$$

Where, a and b are local parameters with a>0 and 0<b<1

Green-Ampt Equation (1911):

$$f_p = K(1 + \frac{\eta S_c}{F_p})$$

Where, η=porosity of soil

S_c=capillary suction at the wetting front

K=Darcy's hydraulic conductivity

2. BACKGROUND:

The research on measuring infiltration rate started many years back and has been a topic of interest to as recent as 2016. Different papers and journals have been brought forward by many researchers on measuring the infiltration rate on different soils under different soil conditions using both single and double ring infiltrometers of different diameters and comparing the results with the different infiltration models such as Horton's model, Kostiakov model, modified Kostiakov model, Green-Ampt model and Philip's model.

3. LITERATURE REVIEW:

A number of Literatures and research papers have been studied, which deals with infiltration through different types of soils and related investigations. The findings of these papers have been presented here.

Jagdale Satyawan Dagadu, Nimbalkar P.T (2012) has calculated the constant infiltration rates of different soils under differentsoil conditions at Sangola, district Solapur of Maharashtra region and comparing it with the infiltration rates obtained by Kostiakov, Modified Kostiakov, Horton's and Green-Ampt infiltration models. They carried out their experiment on black cotton soil, sandy and clay soil. The soil conditions for black cotton soil were compacted, ploughed and harrowed, for clay soil ploughed and unploughed and for sandy soil unploughed. Double ring infiltrometer of diameter 30cm and 60cm having depth of 25cm were used to measure the infiltration rates. From the results of the research work, it was found that the values of parameters of infiltration models vary from soil to soil. From the standard error calculations and correlation coefficient it was found that the Horton's model is best fitting with high degree of correlation coefficient and minimum standard error for all types of soil except for ploughed clay soil to which Green-Ampt model is best fitting. It was also found that the soil condition highly affects the infiltration rate [2].

Balraj Singh, Parveen Sihag, Diwan Singh (2014) has studied the variation of cumulative infiltration using double ring infiltrometer of size 30cm and 60cm and depth 60cmin Karnal, Kurukshetra and Ambala district of Haryana state. The time in minutes and infiltration in mm has been calculated using the Phillip's equation. The graph was plotted with time in x-direction and cumulative infiltration in y-direction and infiltration rate is also at y-direction. For determining the hydraulic conductivity of the soil, different parameters such as coefficients A(absorption) and S(sorptivity) were determined from the equation for the cumulative infiltration curve. It was observed that there was a lot of variation in the infiltration rate from time to time and is mainly due to the meteorological properties. Initial infiltration rate was found very high but after 60 minutes the infiltration rate was low. The hydraulic conductivity has been determined from the value of coefficient A. Hence for understanding the variation of hydraulic conductivity, a table has been listed to show the variation of A and S in the study area. It was observed

that there is a large variation in cumulative infiltration in Haryana and in the same districts and a large variation in infiltration parameter particularly saturated hydraulic conductivity. All the 9 sites have been divided into permeable and highly permeable soils with similar hydraulic conductivity characteristics. Using dimensional analysis technique and measured cumulative infiltration, an attempt was also made to develop a relationship among the different parameters. Non-linear regression was used to develop relationship between cumulative infiltration and time [3].

Adindu Ruth Uloma, Akoma Chigozie Samuel, Igbokwe Kelechi Kingsley (2014) has carried out their experiment in sandy loam soils of Ikwuano – Umuahia, Nigeria using double ring infiltrometer during wet season. At an interval of 5, 10, 15 and 30 minutes readings were taken. The infiltration rate ranged from 0.02cm/min to 0.88cm/min. The Kostiakov's infiltration model was then applied on the experimental data in order to determine the soil's infiltration parameters and also to estimate the model equations for the soils. 'α' values ranged from-0.62,-0.84 while the 'C' values ranged from 0.35 - 2.47. In order to obtain the specific infiltration equations for the soils, these estimated values were put into the model equation. The model equations obtained from this study were: : I = 0.87t−0.54 , I = 0.35t−0.48 , I = 0.45t−0.62 , for points 1, 2 and 3 locations. Others were I = 1.63t−0.50 , I = 2.47t0.84, I = 1.91t−0.59, and I = 1.79t−0.59 for the rest of the (points) locations. . The infiltration decay constants obtained were negative (-0.48, -0.50, - 0.54, - 0.59, - 0.62 and - 0.84), which indicates that the soils were saturated at that time of the year (wet season) due to much rains as a result of which the soils were no longer absorbing water but were giving off [4].

Adindu Ruth U., Igbokwe Kelechi K. and Dike Ijeoma I. (2015) have evaluated the simulation of water infiltration on the soils of Aba, Abia state Nigeria from the capability of Philip's infiltration model. Field experiments were done in five different locations using double ring infiltrometer and each test lasted for 150 minutes. Philip's infiltration model was applied on the field data to determine the soil's infiltration parameters and also to simulate the model equations for the soils. Sorptivity values 'Sp' ranged from 0.457 cms- 1/2 - 2.734cms-1/2 while transmissivity values (Ap) ranged from 0.076 cm/s to 0.142 cm/s, Sp and Ap values were substituted into the model equation to simulate specific infiltration equations for each location. Simulated infiltration rate equations obtained were: 0.457t½ + 0.102t, 1.322t½ + 0.076t, 2.708t½ + 0.142t , 0.691t½ + 0.135t, 1.708t½ + 0.142t. The field data was found to be similar to the simulated data and this results that Philip's model was able to estimate water infiltration depths for Aba soils [5].

Amreeta Champatiray, Vinay Balmuri, K. C. Patra, Mrunmayee M Sahoo (2014) has carried out their experiment in two different places; in garden area and in forest area on the University of NIT campus, Rourkela by using double ring infiltrometer. Several double ring infiltrometer rings are used- 30cm-60cm, 15cm-45cm, 15cm-30cm & 45cm-60cm ring cylinder for constant head and for falling head method. As water was spread for plants in regular interval so the infiltration to the soil got constant after a short time interval due to saturation of the soil. The infiltration rate and incremental infiltration rate values are approximately equal, which shows the rate of infiltration is equal in both of the methods applied. The Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) are calculated for collected data and predicted data by both regression analysis and ANN. The permeability and soil water content were found to be 1.369×10^{-4} and 16.128%. It was found that the 30-60cm double ring infiltrometer is best fitting than the 15-30cm rings and also the garden

soil infiltrated more rapidly than the forest soil due to high hydraulic conductivity as calculated by Horton's equation [6].

Amit H. Mulani, Dr. R. B. Khasiya, Dr. J. N. Patel (2014) has found out the infiltration rate of Bhimrad Area of Surat district. Both single ring infiltrometer and double ring infiltrometer have been used which uses two tipping bucket rain gauges. One gauge measures rainfall onto and the other measures runoff from a 0.5m diameter small circular plot. The data were collected during the summer of 2014. The different infiltrometers shows the capability to capture different infiltration rates and temporal variability associated with convective (high intensity, short duration) and cyclonic (low intensity, long duration) rainstorms. The saturated hydraulic conductivity of soil was estimated using the data from different infiltrometer. It was found that the results matched after comparing the infiltration rate calculated by single ring infiltrometer, double ring infiltrometer and Horton's equation. And also, Double ring infiltrometer is more accurate than Single ring infiltrometer on the field [7].

Anjaneya Prasad M, Sundar Kumar P, Kaushik KHS, Bharath Kumar V, Sai Krishna PN and Vamshi Krishna G (2015) They had found out the infiltration rate at —KL University campus located at Vaddeswaram near Vijayawada. The infiltration rate was measured in mm/hr. A double ring infiltrometer which consists of outer and inner rings of diameter 30cm and 60cm have been used to measure the infiltration rate entering the soil. The study area have been divided into four locations which is nearby the laboratory of Civil and lawn area, in front of Civil engineering block and in front of girl's hostel and the experiment was conducted in both wet and dry state soil. By plotting graph between time taken and infiltration rate in mm/hr in excel, they got the equation in similarity with the general equation f= (fc-fo)e^{-kt} and finally they had obtained the different (infiltration parameter —K) values at the four stations. Horton's equation have been used for calculation. The analysis indicated that the soil for the four selected areas is Black cotton soil with less sand content. The infiltration rate at KL University is comparatively uniform. The correlation coefficient and standard error calculations obtained showed that for all types of soils and their conditions, Horton's model is fitting well with correlation coefficient and minimum standard error obtained. The infiltration parameter K lies between 1.4 to 2.5, which is closer to the standard K value for black cotton and laterite soils [8].

C. L. Jejurkar, Dr. M. P. Rajurkar (2012) In this paper, an attempt has been made to determine infiltration rates of soil under different land cover conditions and to compare validity of different infiltration equations viz. Kostiakov, modified Kostiakov, Horton and Philip. The various land covers such as Grapes, Gram, Bajra, Weeds and Cucumber were selected at a location Brahmangaon in Tq. Kopargaon, dist. Nagar (M.S.). Experiment was carried out using double ring infiltrometer for two seasons, winter and summer. It was observed from the field observations, analysis of data and graphical representations that the infiltration rate in summer was around twice the infiltration rate in winter. The suitability of the different infiltration model under different land covers has been found out. The Kostiakov equation was found to be the best for almost all cultivated land covers [9].

Erwin R. Berglund, Abdelaziz Ahyoud, M'Hammed Tayaa (1980) Studied the comparison of soil and infiltration properties of range and afforested sites in Northern Morocco. Soil characteristics and infiltration rates were determined for heavily grazed, moderately grazed and afforested sites. Soil properties were similar except for afforested sites and mean infiltration rates were well fitted by Horton model. The relationships between

infiltration, clay and organic matter contents that were attributable to vegetative influences were proved positive by Regression analysis. A negative relation existed between infiltration and soil bulk density during their studies. They finally found out that the forest vegetation and absence of grazing create favourable surface conditions which increases infiltration [10].

Gret Aron (1992) It is seen that in most of the methods of measuring Infiltration Capacity are based on the assumption that rainfall intensity exceeds infiltration capacity, but in actual field it does not happen. So the previous Horton equation which was presented by Horton and Soil Conservation Services(SCS) was modified & in this modified Horton Equation the recovery of Infiltration Capacity for the rainless period was allowed [11].

Maheshwari (1996) described the advantage of using Double Ring Infiltrometer in estimating infiltration as it is a straight forward procedure and also the instrument is simple. DRI consists of two concentric rings with a simple handle, water level sensors, water container, depth sensor; DRI are relatively inexpensive and can be easily fabricated. However, minimum specifications including inner and outer ring diameter, height, and material of construction must be followed [12].

Robert Pitt, et.al., (2000) The research of infiltration through disturbed urban soils was done and more than 150 infiltration tests were conducted and the data was compared with the site conditions and they also examined the interactions and effects of soil texture, soil moisture and compaction. The important finding was that compaction had major effects on infiltration rates through sandy soils, moisture level had little effect on infiltration rate at sandy sites while compaction was equally important as soil moisture at sites with predominantly clay rich soils [13].

Abdelkadir, F. Yimer (2011) In their studies to find the parameters that affect the infiltration properties of soil, total 81 soil & core samples(3 replications x 3 treatments x3 profiles x 3 soil depths) were used. In open grazed and cultivated lands the infiltration rates were slow and so there will be high potential for runoff. They concluded that there was 57% smaller infiltration in soils under cultivation and open grazing than in controlled grazing [14].

Wu, L., Pan, et.al., (1997) Double-Ring Infiltrometer can be operated under constant head or falling head conditions. A comparison of these two approaches using numerical modelling had shown that estimated infiltration rates in fine textured soils were similar, but for coarse textured soils infiltration rates can drop as much as 30% as the water head decreases. They concluded that measurements taken immediately after refilling the DRI under falling head conditions were similar to the estimated infiltration rate by the constant head condition [15].

Tarek Selim (2011) Investigated the effect of land use on soil infiltration rate in heavy clayey soil by using double ring infiltrometer [16]. Dr. Avinash S. Kadam (2016) determine the infiltration rate for site selection of artificial water recharge and discuss the various general physical parameters affecting on it [17]. J.H. Gregory, M.D. Dukes, P.H. Jones, and G.L. Miller (2006) studied the effect of compaction on infiltration rates on sandy soils measured with a double ring infiltrometer on urban construction sites and across various levels of compaction [18]. Gray, D. M., and Norum, D. I. (1968) They gave special attention to the quantitative influence of the initial soil moisture content as it affects both the infiltration rate and the amount of infiltration of frozen and unfrozen soils [19]. Franzluebbers, A. J. (2002) studied that soil organic matter is an important characteristic of soil quality that impacts soil aggregation and water infiltration [20].

4. CONCLUSION:

After going properly through the extensive literatures on infiltration it has been observed that that many investigators have proposed different mathematical models for estimating infiltration for different types of soil and soil conditions. It has been found that the values of parameters of infiltration models vary from soil to soil. Still many aspects of infiltration needs extensive study. Again, extensive study has been carried out also to practically determine rate of infiltration using single ring and double ring infiltrometer. It has been found that the double ring infiltromter is more suitable than the single ring infiltrometer for almost any type of soil.

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