# STATISTICAL APPLICATION ON INFILTRATION MODEL STUDIES

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**Abstract**
**Infiltration is treated as one of the important parameter of the hydrological cycle as far as ground water recharge is concerned. It depends on soil characteristics such as soil texture, hydraulic conductivity, soil structure, vegetation cover, porosity, permeability, degree of saturation etc. Infiltration models are the empirical formulae developed using infiltration concepts which is used to determine the infiltration rate of soil. In the present study an attempt is made to validate the Horton's and Kostiakov's infiltration model with observed field data for MITS campus site**.

**Index terms: Infiltration, Double Ring Infiltrometer, Horton's model, Kostiakov's model**

## I.INTRODUCTION

Soil infiltration refers to the soil's ability to allow water movement into and through the soil profile. Infiltration rates are a measure of how fast water enters the soil and are typically expressed in inches per hour. Infiltration capacity may be defined as the maximum rate at which a given soil at a given time can absorb water. It depends upon a large number of factors such as characteristics of the soil, vegetative cover, condition of the soil surface, soil temperature, water content of the soil, rainfall intensity, etc. Infiltration of water into the soil can be determined by a simple instrument called Double ring infiltrometer. The cylindrical ring made up of stainless steel are partially inserted into the soil and filled with water, after which the speed of infiltration is measured. Two cylinders of different diameter are taken for this experiment. The outer ring limits the lateral spread of water after infiltration. The field work for finding the infiltration rate is time consuming and is troublesome. There are certain infiltration models using which we can find the infiltration rate without any field work. The infiltration models selected for the present study are Horton's and Kostiakov's model.

## II. METHODOLOGY

### *A. DOUBLE RING INFILTROMETER*

The double ring infiltrometer which consists of two concentric hollow rings or cylinders is driven into the soil uniformly without any tilt and disturbing the soil, to the least depth of 15 cm. The diameter of the inner ring is 30 cm and that of outer ring is 60 cm. Water is applied in both the inner and outer rings. The water depth in the outer ring should be kept the same during the observation period. The measurement includes the recording of volume of water added into the inner compartment, to maintain the constant water level and the corresponding elapsed time. As the purpose of the outer ring is to suppress the lateral percolation of water from the inner ring, the water added to it need not be measured though water is added to it to maintain the same depth as the inner ring. Observations are continued till constant infiltration rate is observed.

**Fig. 2.1 : Double Ring Infiltrometer**

*B. INFILTRATION MODELS*

1. Horton's Model

Horton expressed decrease of infiltration capacity with time as an exponential function.

$$F = f_c + (f_o - f_c)\, e^{-kt}$$

f → Infiltration capacity at any time
$f_c$ → Final steady state infiltration capacity
$f_o$ → Initial infiltration capacity
t → Time in hours
k → Horton's constant representing rate of decrease in infiltration capacity

2. Kostiakov's Model

$$f = K_k\, t^{-\alpha}$$

f → Infiltration capacity
t → Time after infiltration starts
$K_k$, α → Graphical parameters

*C. STATISTICAL PARAMETERS*

Three statistical parameters such as one way ANOVA test, correlation coefficient and standard error was used for comparing the observed values of infiltration rate with the infiltration models.

1. One way ANOVA

The one-way analysis of variance (ANOVA) is used to determine whether there are any statistically significant differences between the means of an independent group and related dependent groups**.** The level of significance of various infiltration models with the observed infiltration rate from the field was found out using one way ANOVA test.

Total sum of squares = Sum of squares between groups + Sum of squares within groups

2. Correlation Coefficient

A correlation coefficient is a number that quantifies a type of correlation and dependence meaning statistical relationships between two or more values in fundamental statistics. Pearson's *r*, a measure of the strength and direction of the linear relationship between two variables that is defined as the covariance of the variables divided by the product of their standard deviations. The range of values for the correlation coefficient is from -1.0 to 1.0. A correlation of -1.0 indicates a perfect negative correlation, while a correlation of 1.0 indicates a perfect positive correlation. If the correlation is 0, this simply means there is no relationship between the two variables. The strength of the relationship varies in degree based on the value of the correlation coefficient.

3. Standard error of correlation coefficient

The standard error of the correlation coefficient is a parameter which measures how precisely the model estimates the coefficient's unknown value. The smaller the standard error, the more precise the estimate. The standard error of the coefficient is always positive. The standard error of correlation coefficient is given by

$$\sqrt{\frac{1 - R^2}{n - 2}}$$

$R^2$ → coefficient of determination
n → Number of observations

4. Decision factor

Decision factor is the difference between correlation coefficient and standard error. The one with highest value of decision factor is said to be the best fitting one. Here, the model with highest value of decision factor will be the model best matching with the observed field data.

Decision factor(η) = Coefficient of determination ($R^2$) – Standard error (SE)

5. SPSS

SPSS Statistics is a software package used for logical batched and non-batched statistical analysis. The software name originally stands for Statistical Package for the Social Sciences. Bivariate statistics is also included in the base software. One way ANOVA test and Correlation Coefficient can be analyzed using this software.

## III. DATA COLLECTION

The set of data was collected from MITS campus. The infiltration test was conducted at the site using double ring infiltrometer. The initial moisture content of the selected area was determined by adopting oven dry method and was found to be 14%.

From the observed value the infiltration rate was determined as shown in the table 3.2

**Table 3.1 Determination of infiltration rate**

| Time (min) | Volume of water added ($cm^3$) | Infiltration rate (cm/hr) |
|---|---|---|
| 5 | 600 | 10.216 |

| | | |
|---|---|---|
| 10 | 360 | 6.144 |
| 20 | 420 | 3.556 |
| 30 | 300 | 2.538 |
| 50 | 340 | 1.44 |
| 60 | 170 | 1.44 |

The constant infiltration capacity of the MITS campus was found to be 1.44 cm/hr.The infiltration capacity curve for the site was drawn by plotting infiltration rate (cm/hr) against time in minutes.

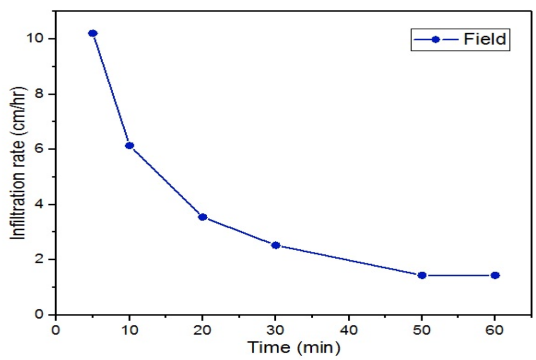


**Fig. 3.1 Infiltration Capacity Curve**

Comparison of field infiltration data with horton's model and Kostiakov model is done. By making use of the parameters defined earlier, horton's model values and Kostiakov values are determined.

**Table 3.2 Comparison of Infiltration Rates**

| Time (min) | Observed infiltration rate (cm/hr) | Horton's infiltration model (cm/hr) | Kostiakov's infiltration model (cm/hr) |
|---|---|---|---|
| 5 | 10.216 | 10.59 | 16.86 |
| 10 | 6.144 | 8.204 | 8.67 |
| 20 | 3.556 | 5.154 | 4.51 |
| 30 | 2.538 | 3.473 | 3.06 |
| 50 | 1.44 | 2.05 | 1.88 |
| 60 | 1.44 | 1.77 | 1.31 |

## IV. ANALYSIS OF RESULTS

One way ANOVA test was performed to find the significance of the infiltration models. The permissible level of significance was 0.5 and all the data obtained were within the permissible limits. Therefore the data obtained was reliable and comparable. The value of significance level of the two models are shown below.

**Table 4.1 Significance of Infiltration Models with Field data**

| Infiltration Models | Significance with field data |
|---|---|
| Horton's | 0.037 |
| Kostiakov's | 0.046 |

Similarly correlation coefficient and standard error of the correlation coefficient was found out and are shown in table 4.2 and 4.3 respectively.

**Table 4.2 Correlation Coefficients of Infiltration Models with field data**

| Infiltration Models | Correlation Coefficient(R) |
|---|---|
| Horton's | 0.980 |
| Kostiakov's | 0.996 |

**Table 4.3 Standard Error of Models**

| Infiltration Models | Coefficient of determination ($R^2$) | Standard Error |
|---|---|---|
| Horton's | 0.961 | 0.0988 |
| Green Ampt's | 0.989 | 0.0525 |
| Kostiakov's | 0.993 | 0.0418 |

Decision factor is the parameter which determines the best fitting model for the study area. Here, the model with highest value of decision factor will be the model best matching with the observed field data. Table 4.4 shows the decision factor of the two models.

**Table 4.4 Decision Factor for Infiltration Models**

| Infiltration Models | Decision Factor(η) |
|---|---|
| Horton's | 0.862 |
| Kostiakov's | 0.951 |

## V. RESULTS AND DISCUSSION

Best fit line is drawn for both the models and are shown in fig. 5.1 and 5.2.

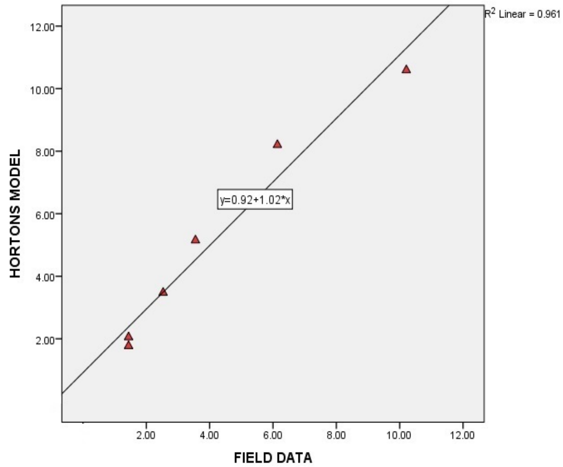


**Fig 5.1 Horton's Model vs Field Data**

From the best fit line Field infiltration rate

$$x = \frac{y - 0.92}{1.02}$$

where (y) is corresponding horton's model value.

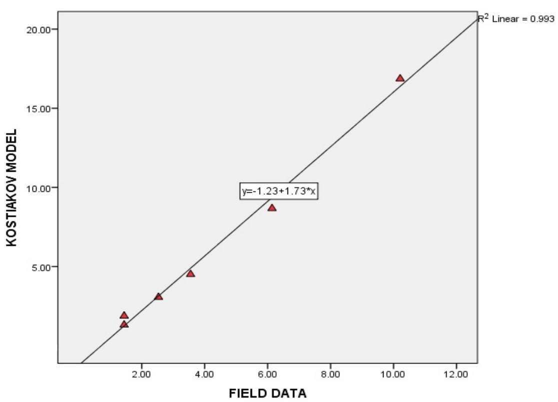


**Fig 5.2 Kostiakov's Model vs Field Data**

From the best fit line Field infiltration rate

$$x = \frac{y - 1.23}{1.73}$$

Where (y) is corresponding Kostiakov's model value.

## VI. CONCLUSION

From the analysis of field infiltration rate with other infiltration model at MITS campus site, the following conclusions are arrived.

- Infiltration capacity curve for the site has been plotted.
- Constant infiltration rate for MITS campus site is obtained as 1.44 cm/hr.
- Significance of field infiltration rate with other models has been analyzed using one way ANOVA test and found with in reliable significance level.
- Correlation of field data with various infiltration models has been studied.
- Based on decision factor parameter, it was found that Kostiakov's model is the best fit model with observed infiltration rate for the MITS campus site.

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