DETERMINATION OF INFILTRATION RATE OF SOILS USING SINGLE AND DOUBLE RING INFILTROMETER

AND

STUDY OF DROUGHT ANALYSIS IN KARIMNAGAR DISTRICT OF ANDHRA PRADESH

A thesis submitted in the partial fulfillment of the requirements for the

Degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

BY

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UNDER THE GUIDANCE OF

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National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the Project Report entitled, "**DETERMINATION OF INFILTRATION RATE OF SOILS USING SINGLE AND DOUBLE RING INFILTROMETERS" AND "STUDY OF DROUGHT IN KARIMNAGAR DISTRICT OF ANDHRA PRADESH"** submitted by **BALMURI VINAY KUMAR (110CE0357)** in partial *fulfillment for the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matters embodied in the thesis have not been submitted to any other university/Institute for the award of any Degree or Diploma.*

Date: 12th may 2014

Prof. Kanhu Charan Patra

Department of Civil Engineering

NIT ROURKELA

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Abstract

Infiltration is a process that continuously affects the magnitude and distribution of surface runoff. Field measurement of infiltration is often a tedious task and the infiltration rates can be estimated from the proposed models. Single-ring and Double-rings are used to estimate the infiltration rate of different soils. The main aim of the present study is to find constant infiltration rate of soil. Various infiltration rates obtained during the experiment time are plotted. Results of various infiltration models are compared with the observed data and graphs are drawn for better presentation. The parameters considered for best fitting model were correlation coefficient and standard error.

Drought can be considered as strictly meteorological phenomenon. It can be assessed as a meteorological unusual characterized by abnormal moisture deficiency. Drought severity is dependent on the duration and magnitude of the abnormal moisture deficiency. Within the reasonable limits and time the comparison of drought severity is possible. It is assumed that a certain time series model adequately describe the annual rainfall in the region. Based on this assumptions the drought frequency is calculated in the particular region.

Calculation of drought is done according to the drought frequency method. There is a software that allows to perform and it is a part of comprehensive computer package. And it was developed early to perform water resources analysis and hydro-meteorological data processing. The procedure of setting up data and running gives a drought estimation and the application was described it in detail.

CHAPTER 1

INTRODUCTION

1.1General

Infiltration is the process by which water on the ground surface enters the soil surface. Precipitation falling on the soil wets down and it starts penetrating into the soil. Water restores to the formal level the soil moisture deficiency excess moving down by the gravity force through percolation or seepage to build up the water table. The water is driven into the porous soil by force of gravity. First the water wets soil grains and then the extra water moves down due to gravitational force. The rate at which a soil absorbing the water in a given time is called infiltration rate and it depends on soil characteristics such as hydraulic conductivity, soil structure, vegetation cover. The infiltration plays an important role in generation of runoff volume, if infiltration rate of given soil is less than intensity of rainfall then it results in either accumulation of water on soil surface or in runoff. The different soil conditions affect the soil infiltration rate. Compacted soils due to movement of agricultural machines have a low infiltration rate which is prone to runoff generation. Infiltration will be maximum at the beginning and it decays exponentially and gets a constant value. There will be a decrease in infiltration rate day by day due to the saturation of the soil where as on the first day the infiltration rate will be more because soil will be dry in condition.

Infiltration of water into the soil has important impact in the overall functioning of the variable land-based activities. Two factors can greatly undermine availability of water for crops which is impervious layer and ground water table. The former might be due to excess infiltration which mostly a function of soil characteristic get through the later may be largely due to the deposit of clay that can create crust below the surface. The study of infiltration comes in many hydrological problems like runoff estimation, soil moisture budgeting and for planning of irrigation. Infiltration has an important place in the hydrological cycle.

Drought means a various things to a various people depending on their day-to-day life activities and interests. To farmer drought means a shortage of water for crops. To the hydrologist it suggests that the below average water level in streams, rivers and lakes and canals. Drought mainly depends on the effect of fairly prolonged weather anomaly. Where as to economist it is shortage of water, which mainly affects the economy. A water supply deficit is defined relative to specified water demand level. As all we know rainfall is the main resources for human beings and animal for life consumption as well for vegetation. Agriculture is most economic activities in the present life. Water scarcity raises a great threat on environment, quality of life and for social activities. Water is a necessary supply for day-to-day life in maintaining the stability of environment. This is purely a meteorological problem. It is also more an engineering problem which involves not only meteorology &hydrology it is also a problem for geology.

However, most farmers do not call a “Dry spell” a drought until matters begin to become rather serious. The sustainable fact is that concerning disastrous drought provides a general frame work for speculations concerning the period of time intervals in a definition of “Prolonged”; it is apparently in the order of months. That the mild drought could develop in a single month. So drought planning is necessary as a process that concentrates on enhancing the abilities in monitoring drought, Understanding the changes in drought vulnerability and mitigation drought effects. Forecasting future drought in area play a very important role in searching the solution for water magnitude and Drought cause. Where we collected precipitation data of one rainfall station in Andhra Pradesh from year of 2001 to 2011 data was available we are analyzed to determine the drought events.

Meteorological droughts are temporary, recurring natural disasters, which originate from the lack of precipitation and can bring significant economic losses. It is not possible to avoid meteorological droughts, but they can be predicted and monitored, and their adverse impacts can be alleviated. The success of the above depends, among the others, on how well the droughts are defined and drought characteristics quantified. Quantitative drought definitions identify the beginning, end, spatial extent and severity of a drought. They are often region-specific and are based on scientific reasoning, which follows the analysis of certain amounts of hydro-meteorological information. Quantitative definitions of a drought are formulated in terms of *drought indices*.

1.2 Factors affecting Infiltration

Factors affecting infiltration depends on both meteorological and many soil properties. These are

i. **Texture**

The liquid moves very quickly in large pores of sandy soil than it does through small pore in clayey soil. Texture plays main role in susceptible of soil only when the organic matter is low.

ii. **Clay mineralogy**

Some types of clay may develop cracks as they are dry. These kinds of cracks may rapidly conduct water to the sub-surface once and the seal shuts down once the soil becomes wet.

iii. **Vegetation**

Soil covered with vegetation has grater infiltration than the barren land .Because of the bacterial activities, dense forest may have good infiltration rate than sparsely planted crops.

iv. **Physical Crusts**

Physical crusts from when purely aggregated soil are subject to the impact of raindrops and/or to ponding. Particles broken from weak aggregates can clog pores and seal the surface,thus limiting water infiltration.

v. **Soil Density**

A compacted zone close to surface restricts the entry of water into the soil and often results in Surface ponding. Increased bulk density reduces pore space and thus the amount of water available for plant growth.

vi. **Biological crusts**

Biological crusts can either increase or reduce the infiltration rate. This affects the infiltration rate on many other factors, including soil texture

vii. **Antecedent Moisture content**

Infiltration mainly depends on the presence moisture content in the soil. When compare to first day the second day will have lesser infiltration rate because soil becomes saturated on the first day.

viii. **Human activities**

When vegetation was done or a grass covering barren land has the high infiltration rate. Whereas the other side the construction work, over gazing of pastures and playgrounds reduce infiltration capacity of the area considerably.

1.3 Objectives of Research work

The objectives of the study are

1. To determine the infiltration rate of soil in inner space and annular space.
2. To calculate the Incremental infiltration velocity by maintaining the constant head in Inner and Annular space.
3. To calculate the infiltration characteristics by using Horton's Infiltration Model.
4. To determine the infiltration rates using Horton's, Kostikov and Green-ampt model.
5. To compare the observed infiltration rates with the calculated infiltration rates.
6. To identify Agricultural Drought
7. To Identify Meteorological Drought

1.4 Thesis outline

Chapter 1: Introduces the work related to the infiltration and the importance of infiltration and the objectives of the study work.

Chapter 2: Here we just focus on the previous research papers related to the infiltration and its models around the world by many hydrologists.

Chapter 3: Describes about the geographical location of the study area and its characteristics and observed infiltration data

Chapter 4: It covers the kind of methods used in the research study and how we collected the data

Chapter 5: Discussion about results obtained from the research work and analysis about the same.

Chapter 6: Provides the summary, important conclusions derived from the infiltration data.

Chapter 7: References which i referred to know more about of our research study.

CHAPTER 2

REVIEW OF LITERATURE

Hsin –Yu Shan;(1991)

Explained that 4 types of setup can be used in ring infiltrometer i.e. open single or double ring infiltrometer and sealed single or double ring infiltrometer.

Srinivasan & S.Poongothai; (2007)

Experimented to determine the infiltration rate of soil samples for the particle size distribution in laboratory

Sebastien Fortin, Elrick& Reynolds ;(1992)

Measured the field saturated hydraulic conductivities i.e. often done by bore hole permeameters.

I.A.Johnson;(1963)

Studied that the infiltration rate have applications, such as liquid waste disposal, evaluation of potential septic tank disposal fields, leaching &drainage efficiencies, irrigation requirement**.**

Ward & Robinson;(1990)

He evaluated that the double ring infiltrometer is suitable for almost any type of soil with the exception of clogging soil, stony soil or the soil of steep slope. Explained the factors that are affecting the infiltration capacity at the soil surface are soil compaction

which is caused by ruts & treading, washing of fine particles into surface pores, cracks & fissures.

Scott Andres, Edward Walther , Muserref Turkmen;(2010)

Done a experiment of mechanical valve system in a small building in the middle of the array of 8 infiltration basin.

Tarek Selim;(2011)

Investigated the effect of land use in heavy clayey soil on soil infiltration rate by using double ring infiltrometer. Based on the results, it appears that the initial infiltration rate depended mainly on the water content in heavy clayey soil & in addition, it was affected by the amount of cracks caused by the plant root, earth movement.

Donald A Wilhite, Mark D Svoboda;(1981)

Explained that magnitude of drought is very closely related to the timing of the onset at the precipitation shortage, intensity & duration.

Rathore, L.S; (2002)

Kinds of medium range weather forecasting for drought Prediction and Drought Management in arid zone of India.

Samara J.S Singh; Gurubachan; (2002).

They explained the strategies need for Drought Management in India

A.Cancellier, B. Bonaccorso and G. Rossi; (2008)

Described the probabilistic methods and characterization of drought events in University of Catania

I.Bordi & A. Sutera

Methods and tools that can be used for analysis of drought using Rainfall Data.

Yevjevich, V.M;(1964)

Briefly described and showed the fluctuations occurred during wet and dry years

CHAPTER 3

STUDY AREA AND DATA ANALYSIS

3.1 The Study Area:

Nit Rourkela region in Sundergarh district of Orissa state was selected for the study. Geographically it is on the southern east part of Sundergarh district. It spreads from longitude $85^0 07'$to $85^0 14'$E and the latitude $21^0 52' to 22^0 05'$N.

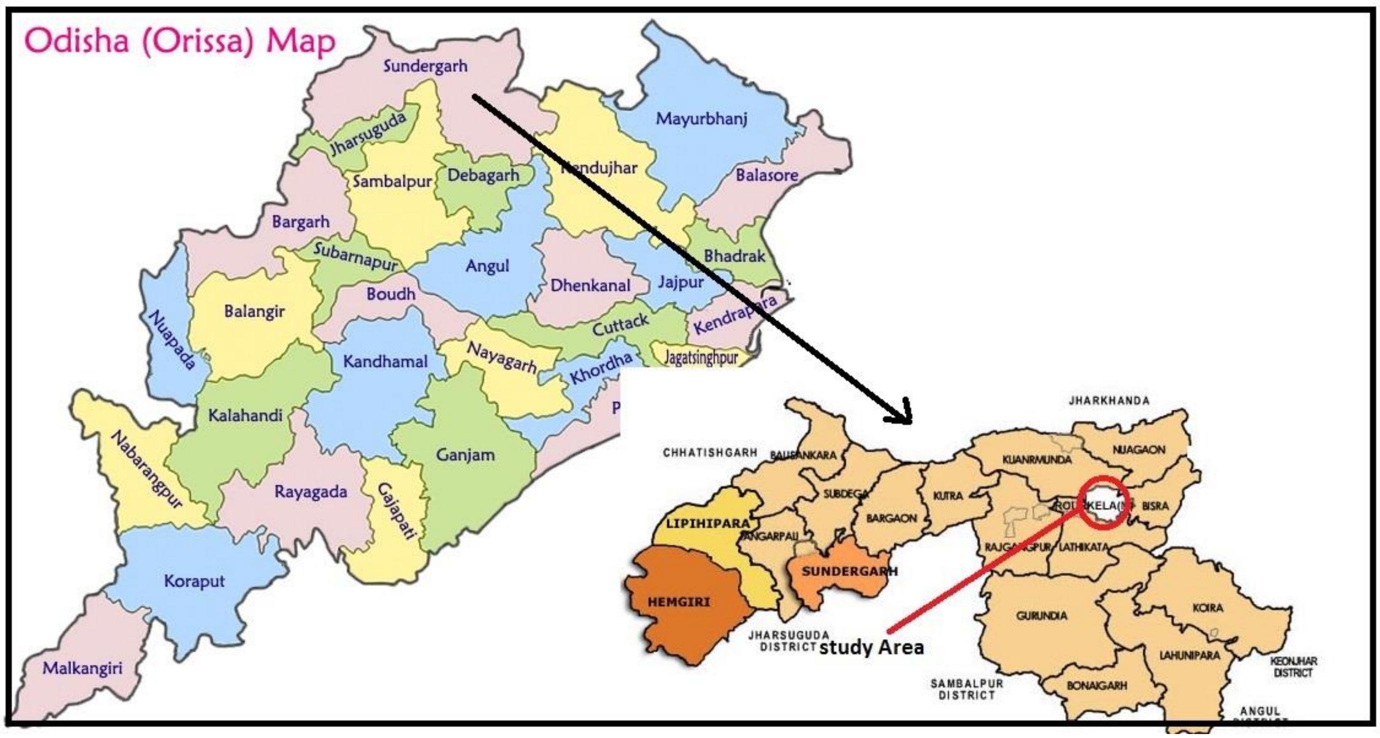


Figure 3.1: Location of a study area of Infiltration

DROUGHT STUDY

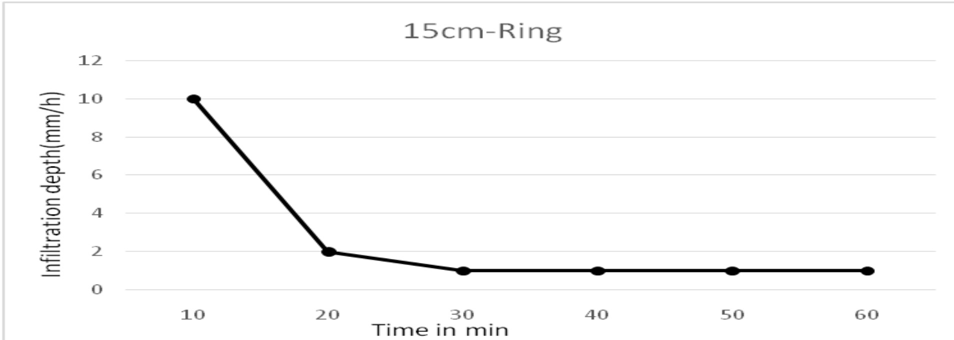
The data was collected from Krish vignana Kendra of Karimnagar District of Andhra Pradesh. Karimnagar is situated between 18°26' Northern and 79°9' Eastern. And about 38, 11,738 population. It lies in the North Western region of Andhra Pradesh. Karimnagar district has its own identity in the Production of agriculture point of view having geographical area of 11,823 Sq.km. Due to Erratic Monsoon a lot of dry spell occurred before. I was just studying this area to analyze the drought.

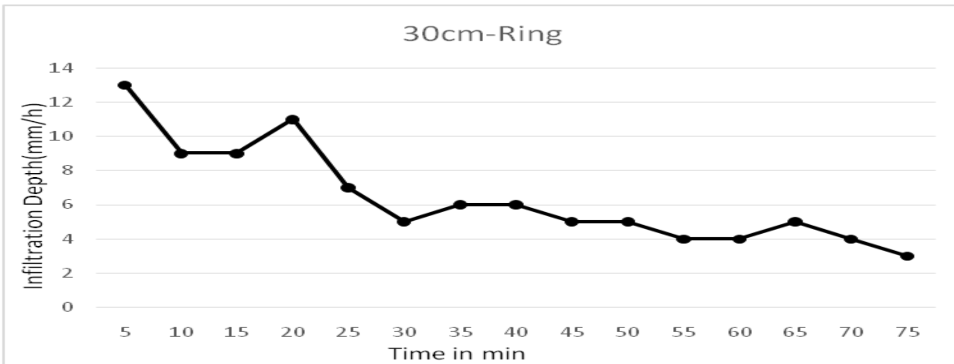
Figure 3.2: Study area of my research

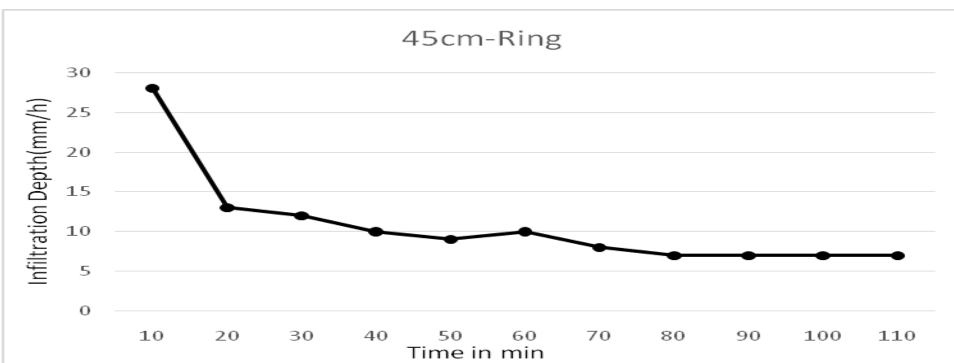
3.2 Data collection & Analysis

Monsoon season starts from June and ends in September. We will be calculating the average rainfall in the area. Around the 85% of rainfall occurs during monsoon period. During this period the most of the time the rainfall is high. For the research present data was collected from one of the nearby rain gauge station of the study area rainfall data is available from the year of 2001 to 2012. From the observed data it was clear that the rainfall during the January to May was more less when compared to June to September. Most of the time intensity is high in the monsoon season. As the data was collected from Krishi Vignan Kendra of Karimnagar district. They have provided me the day wise rainfall data for the period of twelve years i just analyzed the data and I arranged it in months and week wise. Below figures determine the rainfall for the 12years in week wise.

At first our Experimental setup was placed in the Garden area we measured the infiltration depth for every 5 and 10 mins and the below figures 3.2 show the plot of infiltration depth of four rings 15, 30, 45 and 60cm diameter. In the forest area also we measured the infiltration depth of the entire four ring. Figure 3.3 shows the plot of infiltration depth of forest area versus time.


15cm-Ring
Infiltration depth(mm/h)
12
10
8
6
4
2
0
10
20
30
40
50
60
Time in min


30cm-Ring
Infiltration Depth(mm/h)
14
12
10
8
6
4
2
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Time in min


45cm-Ring
Infiltration Depth(mm/h)
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100
110
Time in min

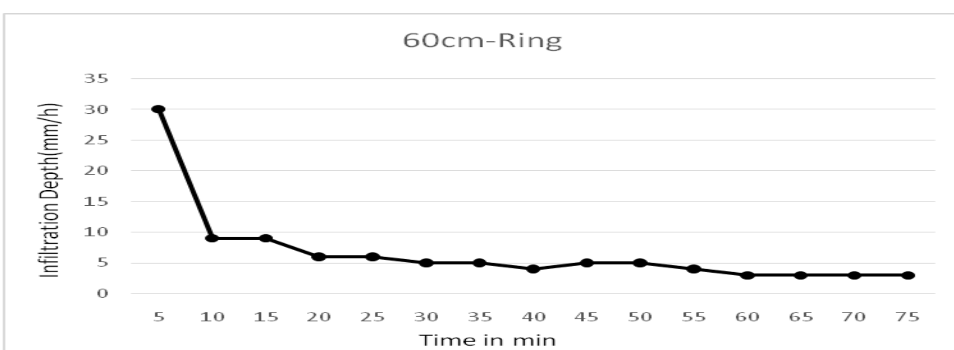
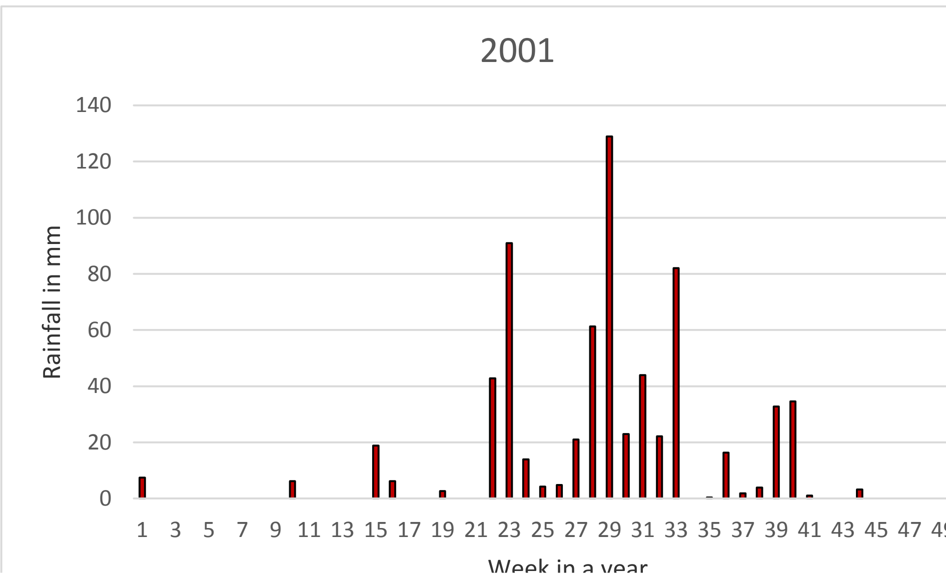
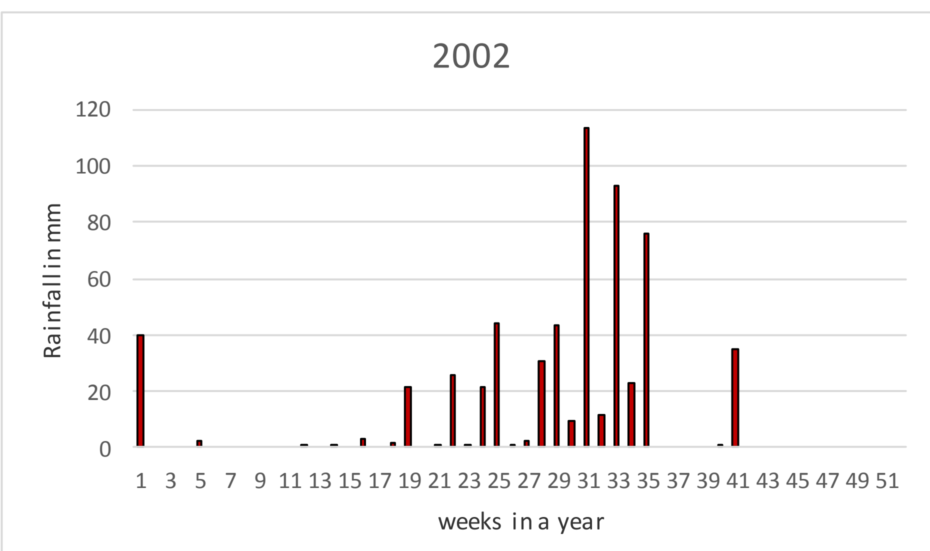
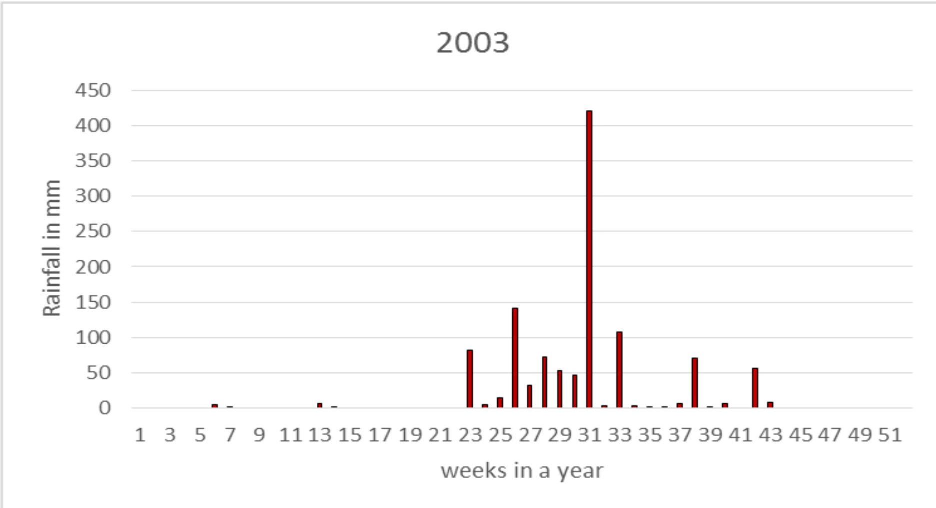
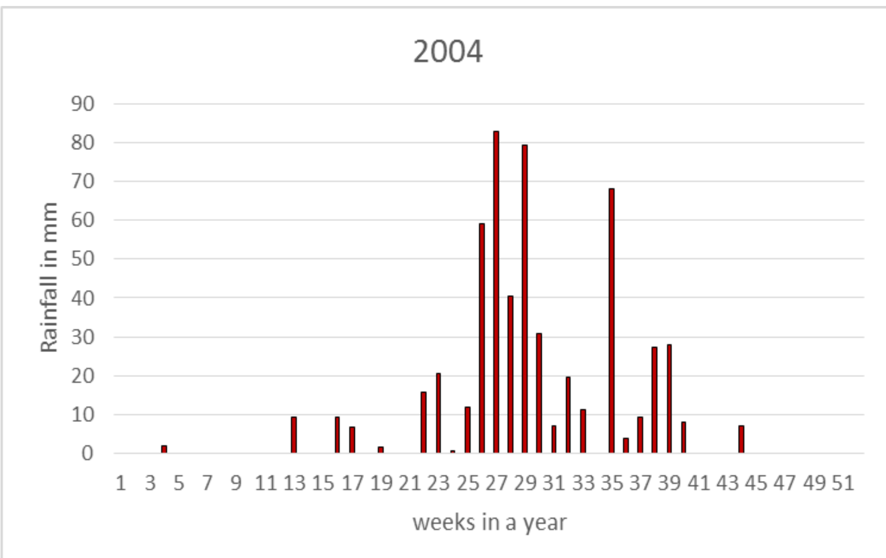

60cm-Ring
Infiltration Depth(mm/h)
35
30
25
20
15
10
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Time in min

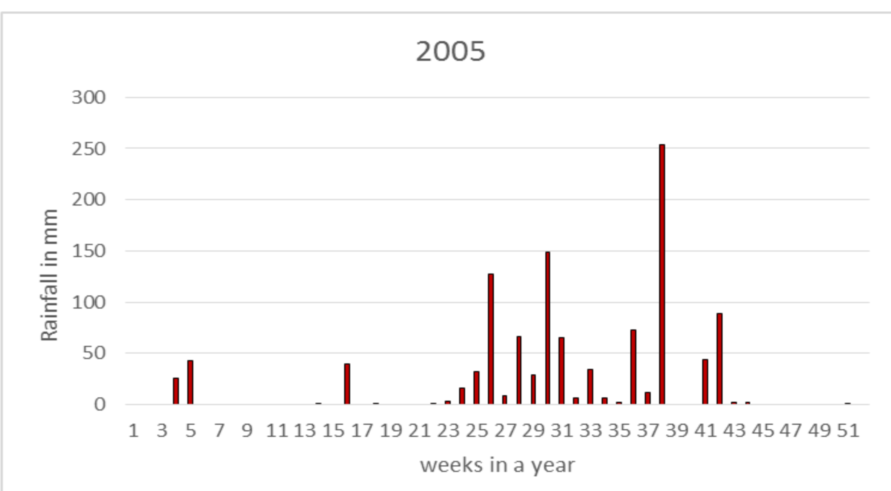
Figure 3.2 (a), (b), (c) and (d): Plot between infiltrated depths versus time

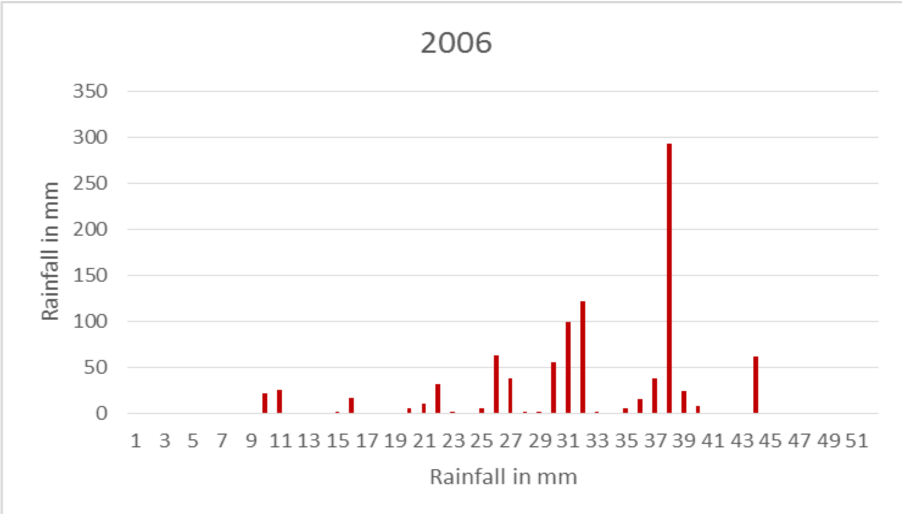


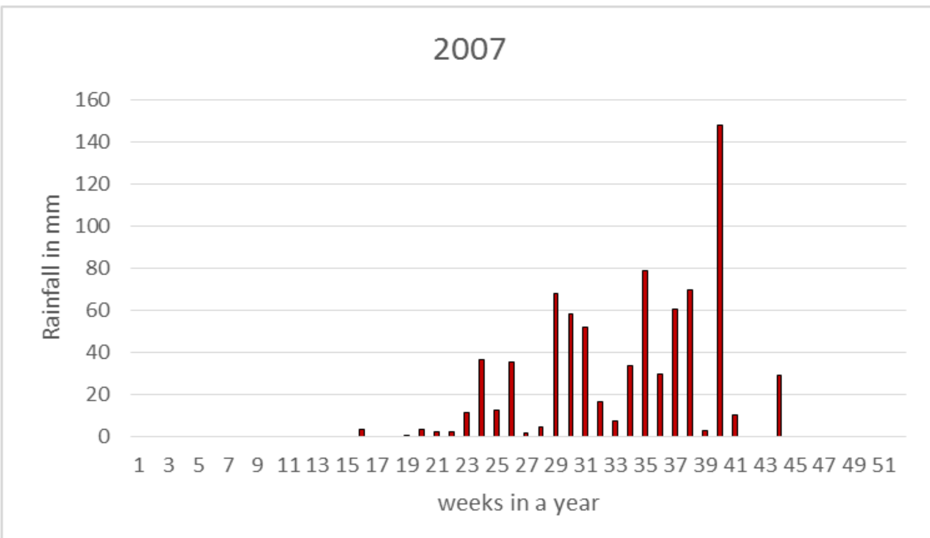


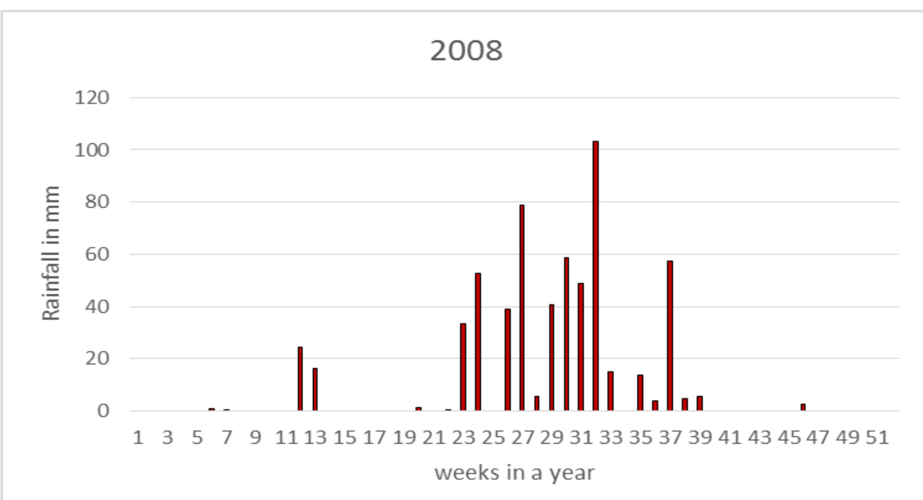

2003
Rainfall in mm
450
400
350
300
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year

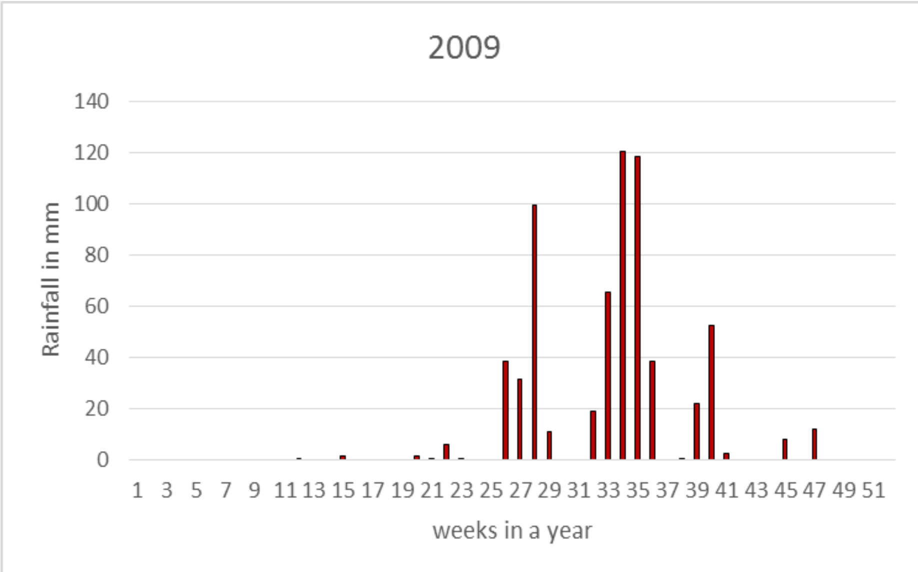

2004
Rainfall in mm
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year

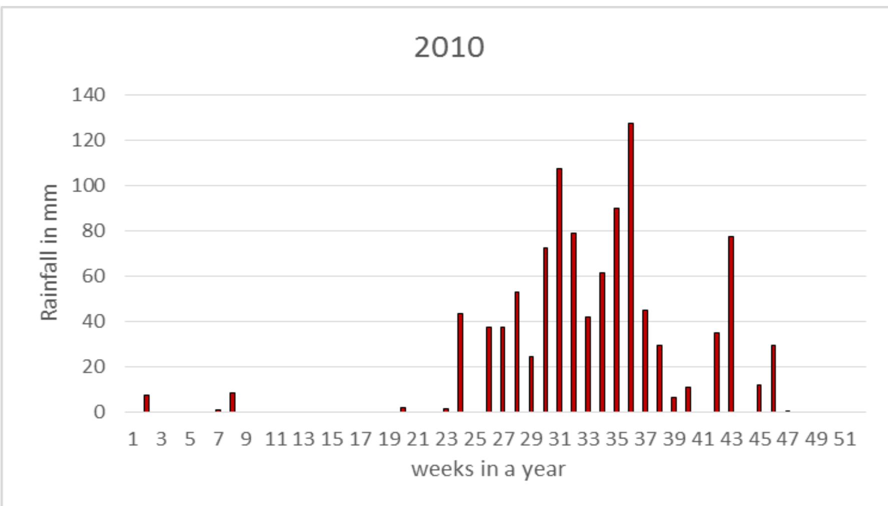

2005
Rainfall in mm
300
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year

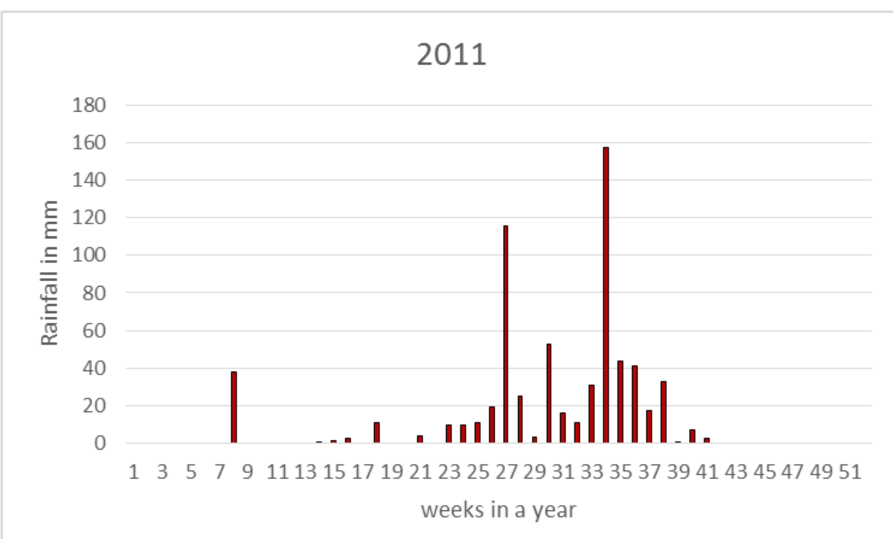

2006
350
300
250
200
150
100
50
0
Rainfall in mm
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
Rainfall in mm

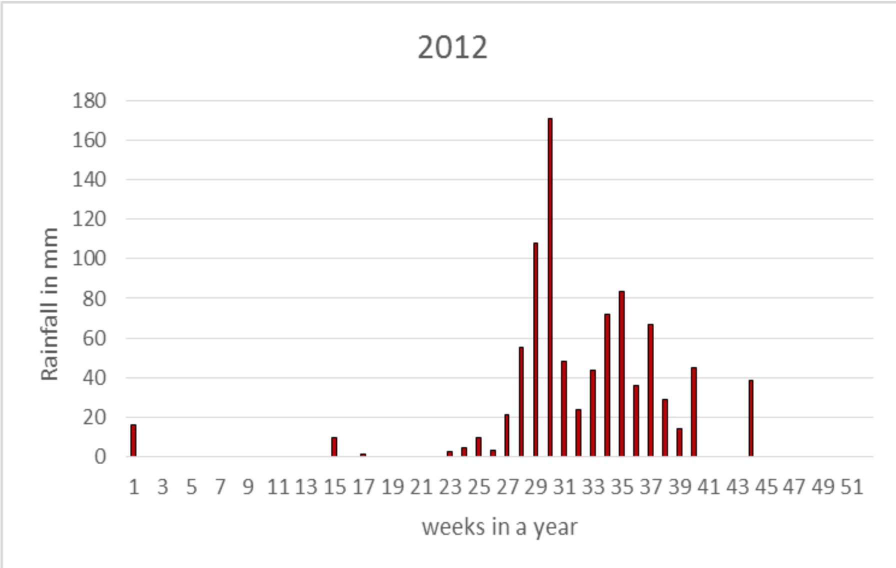

2007
160
140
120
100
80
60
40
20
0
Rainfall in mm
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year


2008
120
100
80
60
40
20
0
Rainfall in mm
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year


2009
140
120
100
80
60
40
20
0
Rainfall in mm
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year


2010
140
120
100
80
60
40
20
0
Rainfall in mm
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year


2011
180
160
140
120
100
80
60
40
20
0
Rainfall in mm
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
weeks in a year



CHAPTER 4

METHODOLOGY

It consists of thin metal cylinder with diameter of 15cm and 30cm and the 60cm long and this cylinders were driven into ground and 10-12cm of the cylinder must be above the ground level. And water is poured from the top and we should note the volume of water added to the ring to find the Incremental Infiltration velocity. We should also note the infiltrated water depth for 5,10,20mins until we get the constant infiltration depth A graduated jar was used to add water and scale was used to measure the depth of water infiltrated. To overcome the results of single ring here we use a set of concentric rings with same length are used.

- Double-ring infiltrometer consists of open cylinders, which was driven into the ground, then pour the water into the rigs, and then maintain the water at a fixed level.
- The volume of liquid added to the inner ring, to maintain the liquid level constant is the measure of the volume of liquid that infiltrates the soil.
- The volume of water infiltrated during time intervals is convinced to an incremental infiltration velocity, here it was expressed in millimeter per hour
- The maximum-steady state or mean incremental infiltration velocity, depends on the purpose of the test is equivalent to the infiltration rate.
- First we have taken two single cylinders of 15cm & 30cm diameter having a depth of 60cm.

- Secondly, the cylinder was installed by manually impact force vertically inside the soil up to a depth of 50cm.
- Then we have taken initial & final depth of infiltration with a time interval of 10mins.
- First we have taken two single cylinders of 45cm diameter& 60cm diameter& having length of 60cm.
- Double ring infiltrometers consists of two cylinders ring tubes with varying inner and outer diameters.
- The measurements will be continued until the infiltration rate became constant.

4.1 Single-Ring Infiltrometer:

Single-ring Infiltrometer test was conducted using 15cm and 30 rings as shown in the figure. The ring is driven into the soil approximately 12-14 inches into the soil. Then water is poured into the ring that above the soil surface. In some cases the above surface of the ring is covered to avoid evaporation. For measuring the depth of water in ring we need hook gage, steel tape or scale. We should take care of a ring while it is driving into the ground there may be chance of having hapless connections between the thin wall of a ring and soil. That hapless connection may cause leak of water and that leads to over estimation of a Infiltration rate.

Fig.4.1: Single Ring Infiltrometer of 15cm diameter

Fig.4.1.1: Single Ring Infiltrometer of 30cm diameter

4.2 Double-Ring Infiltrometer:

Double-ring infiltrometer was well known technique for measuring or estimating the infiltration rate of soils. Double ring infiltrometer are developed in reaction to fact that single-ring infiltrometer tends to estimate the over infiltration rates. This has been ascribed the fact that liquid in the cylinder is not purely vertical but it also diverges laterally. Double ring infiltrometer understate the standard errors affiliated with the single-ring infiltrometer because the water in the outer ring forces vertical infiltration of water inside the inner ring. We should take care of a ring while it is driving into the ground there may be chance of having hapless connections between the thin wall of a ring and soil.

A typical Double-ring infiltrometer consists of 45cm diameter inner ring and 60cm diameter outer ring. Whereas there are two techniques used in double-ring one is constant head method and the other is falling head method. In constant head method water is systematically added to both the inner and outer rings. The volume of water wanted to maintain the constant level of inner-ring is measured. For measuring the depth of water in ring we need hook gage, steel tape or scale.

Fig.4.2: Double-Ring Infiltrometer of 45-60cm diameter rings

Weather Cock

This software is developed Indian meteorological, Department to find the agricultural Drought and Meteorological drought. Weather cock uses Simple excel programmed methodology for calculation of various parameters such as agricultural drought, meteorological drought, No of rainy days etc..,based on metrological data of study.

- Meterological drought based on rainfall deflect from
  Normal: Moderate (26 to 50%)
  Severe: Greater than 50%

4.3 Horton's Infiltration Model:

The Horton's Equation was one the popular empirical models stimulating infiltration of water into soil.The relation for determining the Infiltration Capacity is

$$fp = fc + (fo - fc)e^{-kt} \quad \text{………………………. (Eq. 4.3.1)}$$

fp= the infiltration capacity at some time t(depth/time)

k = a constant representing the rate of decrease in f capacity.

fc = a final or equilibrium capacity

*f*0 = the initial infiltration capacity

Compute accumulated precipitation volume as a function of time. The incremental volume over each time period of 10 minutes is

ΔP = iΔ…………………………………………………………..(Eq.4.3.2)

Compute the accumulated infiltration rate at the surface using the following equation

$$F(t) = fct + \frac{fo - fc}{k}(1 - e^{-kt}) \quad \text{……. (Eq.4.3.3)}$$

Compare infiltration capacity with precipitation intensity Observe that if infiltration capacity outgoes the precipitation intensity. Thus, during this period all of the precipitation infiltrates. The actual infiltration rate is

$$f(t) = \min[i(t), fp(t)] \quad \text{…...……………….. (Eq.4.3.4)}$$

Because the actual infiltration rate is less than the infiltration capacity during, the actual infiltration capacity does not decay as predicted by Horton's equation. This is because, as indicated above, Horton's equation assumes that the supply rate exceeds the infiltration capacity from the start of infiltration. Therefore, we must determine the true infiltration capacity. To do so, first determine the time *tp* by solving the following equation

$$F(t) = fctp + \frac{fo - fc}{k}(1 - e^{-kt})$$

…..……… (Eq.4.3.5)

$$fp = fc + (fop - fc)e^{-k(t-t*)}$$

. ……….. (Eq.4.3.6)

Because the precipitation rate exceeds the infiltration capacity, there is excess precipitation available for runoff and depression storage, $\sigma + v$

$$\sigma + v = i(t) - f(t)$$

……. …………(Eq.4.3.7)

4.4 Green-Ampt Infiltration Model:

Green and Ampt (1911) presented an approach that is based on fundamental physics and also gives results that match empirical observations. We can also predict the wetted front depth using Green-ampt infiltration model.

Assumptions:

$\Delta\theta$ = Increase in moisture content as wetting front passes

Ψ = Suction head

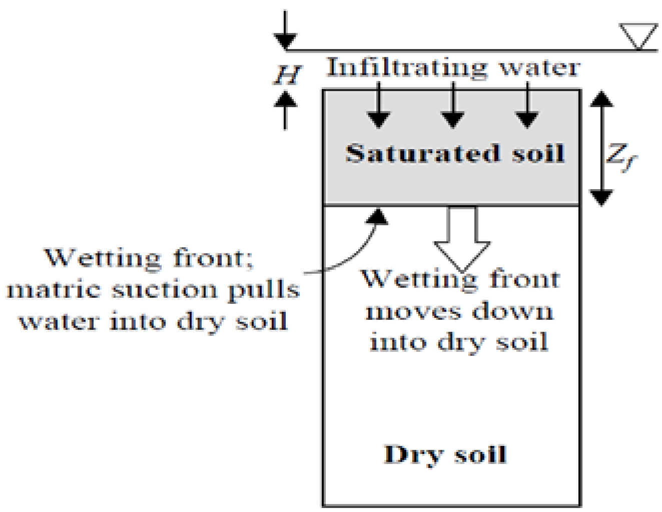
L = Wetted depth

K = Conductivity in wetted zone

θr = Residual water content of a dry soil

θe = Effective Porosity

n = Porosity



To find the infiltration rate:

$$f = K\left(\frac{\psi\Delta\theta}{F} + 1\right)$$ ………………………………………………..……. (Eq.4.4.1)

Accumulated Cumulative infiltration rate:

$$F = Kt + \psi\Delta\theta \ln\left(1 + \frac{F}{\psi\Delta\theta}\right)$$ ………………………………..…………… (Eq.4.4.2)

Wetted Front Depth (L):

$$F(t) = L\Delta\theta$$

$$L = \frac{F}{\Delta\theta}$$ ………………………………………………………….. (Eq.4.4.3)

Table 4.1: Green-Ampt Parameters

Texture	**Porosity**	**Residual Porosity, θr**	**Effective Porosity, θe**	**Suction head(cm)**	**Conductivity,K(cm/h)**
Sand	0.437	0.02	0.417	4.95	11.78
Loamy Sand	0.437	0.036	0.401	6.13	2.99
Sandy Loam	0.453	0.041	0.412	11.01	1.09
Loam	0.463	0.029	0.434	8.89	0.34
Silt Loam	0.501	0.015	0.486	16.68	0.65
Sandy Clay Loam	0.398	0.068	0.33	21.85	0.15
Clay Loam	0.464	0.155	0.309	20.88	0.1
Silty Clay Loam	0.471	0.039	0.432	27.3	0.1
Sandy Clay	0.43	0.109	0.321	23.9	0,06
Silty Clay	0.47	0.047	0.423	29.22	0.05
Clay	0.475	0.09	0.385	31.63	0.03

CHAPTER 5

RESULTS AND DISCUSSIONS

The measured infiltration rate of soils are shown below and also we converted the volume of water used during the experiment or measure time in to the incremental infiltration velocity for both the garden area and forest area. And calculated infiltration rate of soil using various infiltration models are given in Table 5.6 - 5.6.3. From the results it was also found that the parameters of models vary. Correlation coefficient and Standard Errors of infiltration models also varies.

5.1 Infiltration Results by 15cm ring:

Table 5.1: Day-1 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	1.5	15	2.50
2	10	1.5	2	5	0.83
3	10	2	2.5	5	0.83
4	10	2.5	2.8	3	0.50
5	10	2.8	3	2	0.33
6	10	3	3.2	2	0.33
7	10	3.2	3.4	2	0.33

Table 5.1.1: Day-2 Infiltration Measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	1.3	13	2.17
2	10	1.3	1.5	2	0.33
3	10	1.5	1.7	2	0.33
4	10	1.7	1.9	2	0.33
5	10	1.9	2.1	2	0.33
6	10	2.1	2.3	2	0.33
7	10	2.3	2.4	1	0.17

Table 5.1.2: Day-3 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	1.2	12	2
2	10	1.2	1.7	5	0.83
3	10	1.7	2.2	5	0.83
4	10	2.2	2.5	3	0.50
5	10	2.5	2.7	2	0.33
6	10	2.7	2.9	2	0.33

5.2 Infiltration Results by 30cm ring:

Table 5.2: Day-1 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	1	10	1.67
2	20	1	1.5	5	0.83
3	30	1.5	2	5	0.83
4	40	2	2.5	5	0.83
5	50	2.5	3	5	0.3
6	69	3	3.2	2	0.33

Table 5.2.1: Day-2 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	1.8	18	3
2	20	1.8	2.5	8	1.17
3	30	2.5	3.2	7	1.17
4	40	3.2	3.9	7	1.17
5	50	3.9	4.6	7	1.17
6	60	4.6	5.2	6	1

Table 5.2.2: Day-3 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	1.7	17	2.83
2	20	1.7	2.4	7	1.17
3	30	2.4	3.1	7	1.17
4	40	3.1	3.6	5	0.83
5	50	3.6	4.1	5	0.83
6	60	4.1	4.4	3	0.50
7	70	4.4	4.7	3	0.50

5.3 Infiltration Results by Double ring Infiltrometer:

Table 5.3: Day-1 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	4	40	6.67
2	10	4	7.5	35	5.83
3	10	7.5	10	25	4.16
4	10	10	12	20	3.33
5	10	12	13.5	15	2.50
6	10	13.5	15	15	2.50

Table 5.3.1: Day-2 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	2	20	3.33
2	10	2	3.1	11	1.83
3	10	3.1	4	9	1.50
4	10	4	4.9	9	1.50
5	10	4.9	5.7	8	1.33
6	10	5.7	6.2	5	0.83

Table 5.3.2: Day-3 Infiltration measurement results

Sl.no	Time(min)	Initial reading(mm)	Final reading(mm)	Infiltration Depth(mm)	Infiltration rate(mm/h)
1	10	0	1.6	16	2.67
2	10	1.6	2.5	9	1.50
3	10	2.5	3.1	6	1

4	10	3.1	3.5	4	0.67
5	10	3.5	3.8	3	0.50
6	10	3.8	4.1	3	0.50

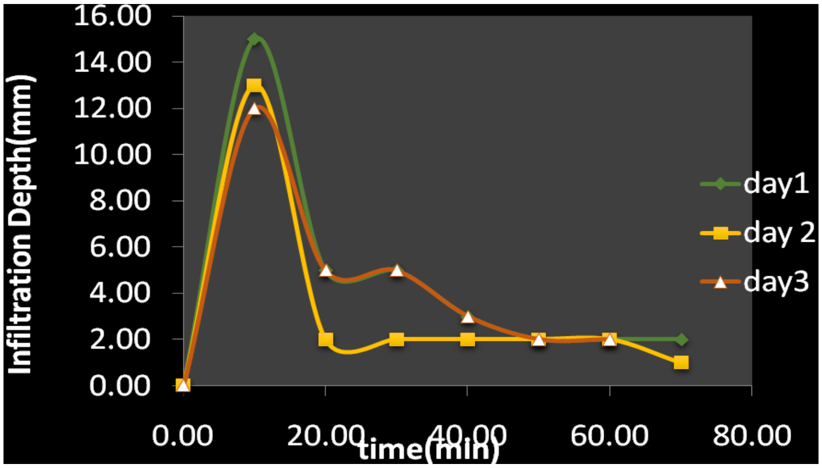


Figure 5.1: Graph of Infiltration depth of 15cm

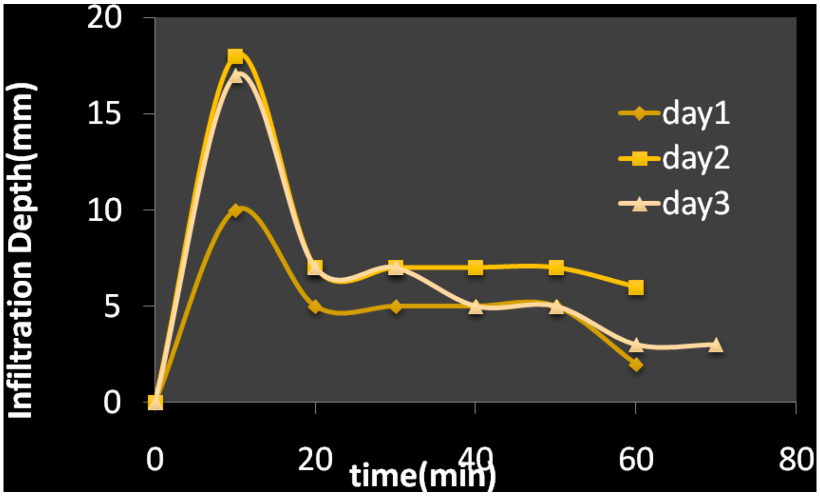


Figure 5.2: Graph of Infiltration depth of 30cm ring

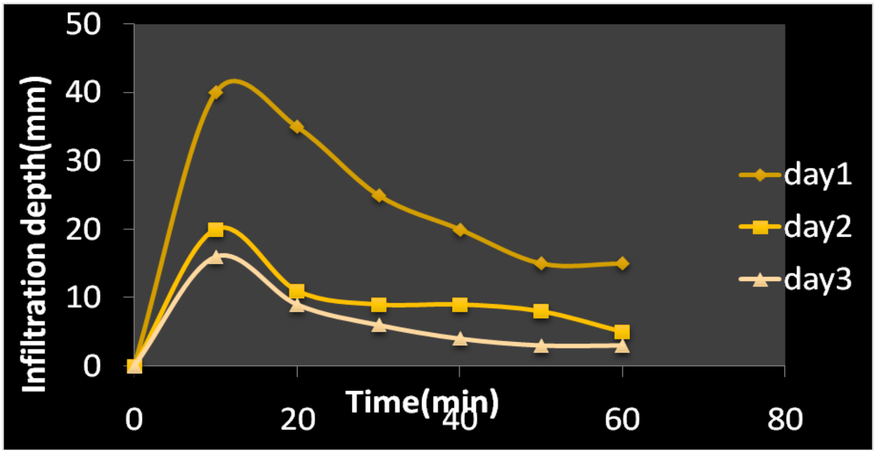


Figure 5.3: Graph of Infiltration Depth of Double ring Infiltrometer

5.4 Incremental Infiltration Velocity

The volume of water used during each measured time interval was converted in to the incremental infiltration velocity using the equation:

$$I_t = \frac{V}{A*t} \quad \text{(Eq.5.4.1)}$$

Whereas here time was considered in minutes and infiltration rate and incremental velocity are in mm/h.

Garden Area:

Table 5.4.1: Calculation of Incremental Infiltration Velocity of Garden area

Sl.no	Time in min		Infiltration Rate in mm/h		Incremental Infiltration Velocity(mm/h)	
			Inner	Annular	Inner	Annular
1	5		70	168	33.97	3.77
2	10		65	78	30.88	2.26
3	15	Day-1	60	72	20.92	1.89
4	20	15-45cm	54	60	13.43	1.77
5	25		47	54	9.84	1.70
6	30		30	60	6.33	1.77
7	35		20	48	4.53	1.43

8	40		12	44	3.23	1.28
9	45		6	42	3.06	1.28
10	50		6	42	3.06	1.13
11	55		6	42	1.83	0.75
1	5		60	144	67.94	7.55
2	10	Day-2	58	72	51.64	4.53
3	15	15-45cm	52	60	32.99	3.02
4	20		48	52	22.42	2.87
5	25		44	48	19.76	2.64
6	30		32	40	13.59	2.87
7	35		28	36	9.51	2.64
1	5		156	310	16.99	4.25
2	10		108	108	11.89	4.03
3	15	Day-1	108	90	11.38	3.82
4	20	30-60cm	90	72	10.2	3.61
5	25		84	70	8.49	3.40
6	30		72	62	9.43	3.18
7	35		72	60	9.68	2.97
8	40		60	52	9.68	2.76
9	45		60	44	8.15	2.55
10	50		60	41	7.98	2.34
11	55		48	40	6.79	2.12
12	60		48	36	5.94	1.70
13	65		40	36	6.79	1.61
14	70		36	36	5.10	1.27
15	75		36	36	3.40	0.85
1	5		180	240	16.99	4.25
2	10		108	140	11.89	4.03

3	15		88	90	15.29	2.55
4	20	Day-2	84	60	13.59	2.55
5	35	30-60cm	80	51	13.59	2.12
6	30		70	48	14.44	2.12
7	35		65	48	5.10	2.12
8	40		54	48	5.20	2.12

Forest Area:

Table 5.4.2: Calculation of Incremental Infiltration velocity of Forest Area

Sl.no	Time in min		Infiltration Rate in mm/h		Incremental Infiltration Velocity(mm/h)	
			Inner	Annular	Inner	Annular
1	5		80	105	67.94	7.55
2	10		48	80	20.38	3.77
3	15	Day-1	36	70	16.99	3.02
4	20	15-45cm	36	60	13.59	2.64
5	25		24	48	10.19	2.26
6	30		24	46	6.79	1.89
7	35		12	36	3.40	1.51
8	40		12	36	3.40	1.13
1	5		98	120	67.94	7.55
2	10		80	110	47.56	6.72
3	15		72	100	27.18	5.28
4	20		60	95	25.82	5.06
5	25		52	88	24.46	4.90
6	30	Day-2	48	75	23.10	4.15
7	35	15-45cm	36	60	21.74	3.40
8	40		24	55	20.38	2.64
9	45		19	52	19.02	1.89
10	50		12	48	13.59	1.13
1	5		72	168	16.99	4.25
2	10		60	155	8.49	1.70

3	15		52	145	3.40	1.70
4	20	Day-1	36	130	3.40	1.70
5	25	30-60cm	24	115	3.40	1.70
6	30		24	100	1.70	1.27
7	35		24	88	1.70	0.85
8	40		12	74	1.70	0.85
9	45		12	60	1.70	0.85
10	50		12	53	1.70	0.85
1	5		75	132	17.10	4.25
2	10		52	125	10.19	3.40
3	15	Day-2	48	84	5.10	2.97
4	20	30-60cm	36	72	3.40	2.12
5	25		32	60	3.40	2.97
6	30		24	60	5.10	2.55
7	35		18	48	3.40	1.70
8	40		12	48	3.40	1.70
9	45		12	36	1.70	1.70

5.5: Calculation of Infiltration characteristics using Horton's Model

Garden Area:

Figure 5.5.1: Infiltration characteristics using Horton's

	T	i	P	fp	F	F(t)	f(t)	σ+v
	0	0	0	1	0			
	10	1	0.17	0.6	0.134	0.96	0.96	0.04
15-cm	20	0.3	0.21	0.36	0.22	0.62	0.3	0
	30	0.1	0.23	0.22	0.28	0.41	0.1	0
	40	0.1	0.25	0.135	0.32	0.29	0.1	0
	50	0.1	0.27	0.08	0.35	0.21	0.1	0
	60	0.1	0.29	0.05	0.38	0.17	0.1	0
30-cm	0	0		2.8	0	2.8	0	0
	10	2.8	0.47	1.97	0.39	>2.56	>2.56	0.53
	20	1.3	0.69	1.47	0.67	2.56	1.3	0
	30	1.2	0.9	1.17	0.89	1.85	1.2	0
	40	1	1.1	0.98	1.07	1.42	1	0.08

	50	0.9	1.25	0.87	1.22	1.15	0.9	0.3
	60	1	1.42	0.81	1.36	0.99	0.99	0.2
	70	0.8	1.56	0.76	1.49	0.89	0.8	0.15
	80	0.7	1.68	0.74	1.62	0.84	0.7	0.01
	90	0.7	1.8	0.72	1.74	0.76	0.7	0
45-cm	0	0	0	2.6	0	0	0	0
	10	2.2	0.36	1.74	0.36	2.045	2.2	0
	20	2	0.69	1.21	0.59	1.4	1.4	0.8
	30	2.6	1.12	0.89	0.76	1.005	1.005	1.595
	40	1.2	1.32	0.69	0.9	0.76	0.76	0.44
	50	1	1.48	0.58	1	0.62	0.62	0.38
	60	0.8	1.62	0.5	1.09	0.53	0.53	0.27
	70	0.9	1.77	0.46	1.17	0.48	0.48	0.42
	80	0.4	1.83	0.44	1.25	0.44	0.44	0.04
60cm	0	0	0	3.9	0	0	0	0
	10	3.9	0.65	2.36	0.522	3.37	3.37	0.53
	20	1.5	0.9	1.43	0.85	2.16	1.5	0
	30	1.1	1.08	0.87	1.08	1.42	1.1	0
	40	0.9	1.23	0.52	1.23	0.82	0.82	0.08
	50	1	1.39	0.32	1.35	0.7	0.7	0.3
	60	0.7	1.5	0.19	1.44	0.5	0.5	0.2
	70	0.6	1.6	0.11	1.51	0.45	0.45	0.15
	80	0.4	1.66	0.07	1.57	0.39	0.39	0.01
	90	0.3	1.71	0.04	1.63	0.35	0.3	0

Forest Area:

Table 5.5.2: Infiltration characteristics using Horton's Model

	T	i	P	fp	F	F(t)	f(t)	σ+v
	0	0	0	0.7	0	0	0	0
15-cm	10	0.5	0.083	0.59	0.092	0.69	0.5	0
	20	0.7	0.199	0.5	0.175	0.57	0.57	0.13
	30	0.6	0.299	0.42	0.25	0.5	0.5	0.1
	40	0.4	0.365	0.35	0.32	0.46	0.4	0
30-cm	0	0	0	1.7	0	0	0	0
	10	1.5	0.25	1.03	0.39	1.62	1.5	0.12
	20	1.7	0.53	0.62	0.67	1.21	1.21	0.49
	30	0.8	0.66	0.37	0.89	0.97	0.8	0
	40	0.6	0.76	0.23	1.07	0.82	0.6	0
	0	0	0	1.4	0	0	0	0
45-cm	10	1.2	0.2	0.849	0.2	1.35	1.2	0
	20	1.4	0.43	0.51	0.35	1.01	1.01	0.39
	30	0.9	0.58	0.31	0.48	0.81	0.81	0.09
	40	0.6	0.68	0.189	0.59	0.68	0.6	0.18
	50	0.5	0.76	0.11	0.69	0.61	0.5	0
60-cm	0	0	0	1.6	0	0	0	0
	10	1.6	0.26	0.97	0.22	1.26	1.26	0.34
	20	0.8	0.39	0.58	0.38	0.72	0.72	0.08
	30	0.7	0.5	0.35	0.51	0.61	0.61	0.09
	40	0.5	0.59	0.21	0.61	0.49	0.49	0.01
	50	0.4	0.65	0.13	0.7	0.51	0.4	0

Garden Area:

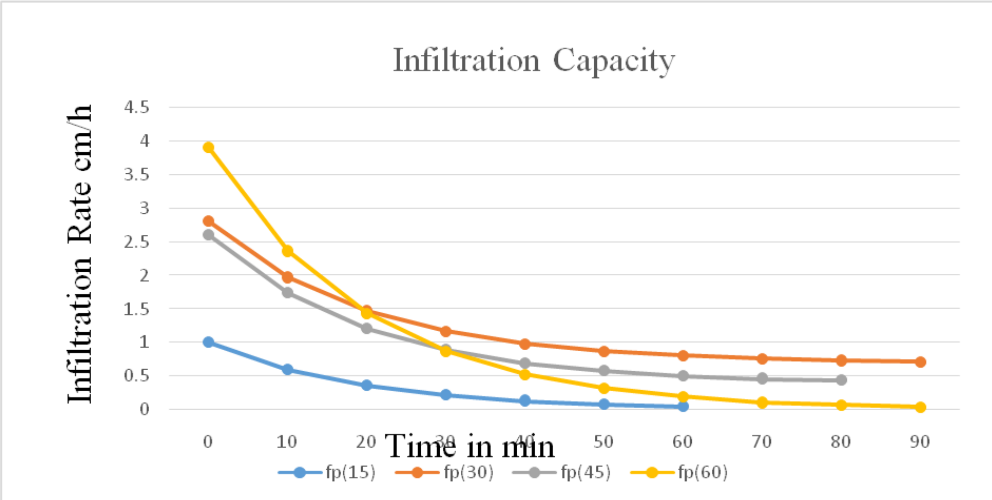


Figure 5.5.1: Graph Representation of Infiltration rate versus time of all four rings

Forest Area:

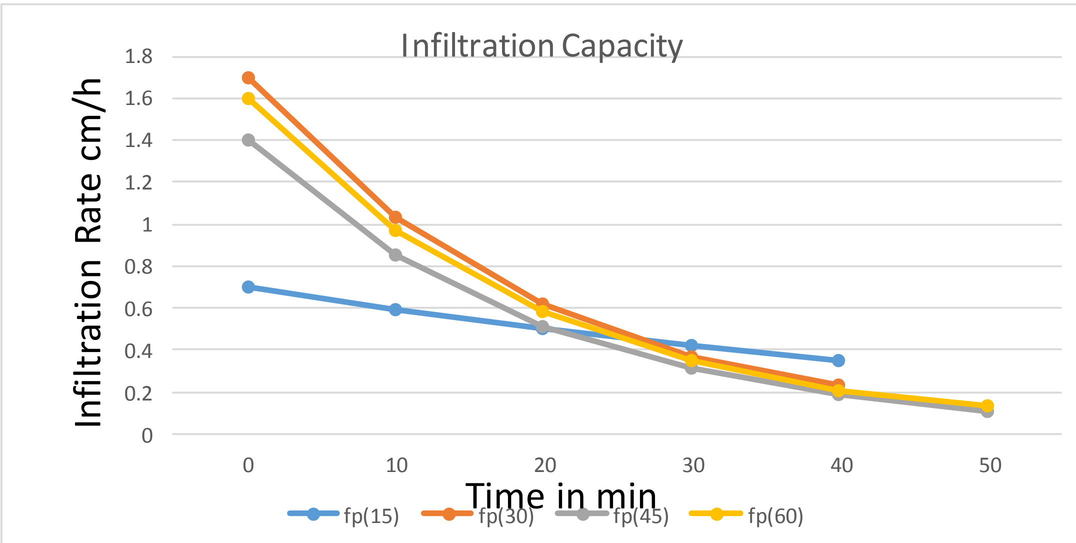


Figure 5.5.2: Graph Representation of Infiltration rate versus time of all four rings

5.6 Calculation of Infiltration rates using different Models:

Table 5.6: Calculation of Infiltration rates of 15cm-ring

Time(min)	Observed Infiltration Rate(mm/h)	Horton's Model	Green Ampt model	Kostiakov model
10	4.8	4.133	5.13	5.28
20	3.7	3.58	3.52	3.36
30	3	2.79	2.62	2.82
40	3.6	2.25	2.21	2.4
50	2	1.76	2.02	2.16
60	1.6	1.5	1.93	1.92
70	1.2	1.33	1.85	1.8
80	1.2	1.26	1.81	1.68
Correlation Coefficient		0.96	0.91	0.93
Standard Error		0.06	0.12	0.11

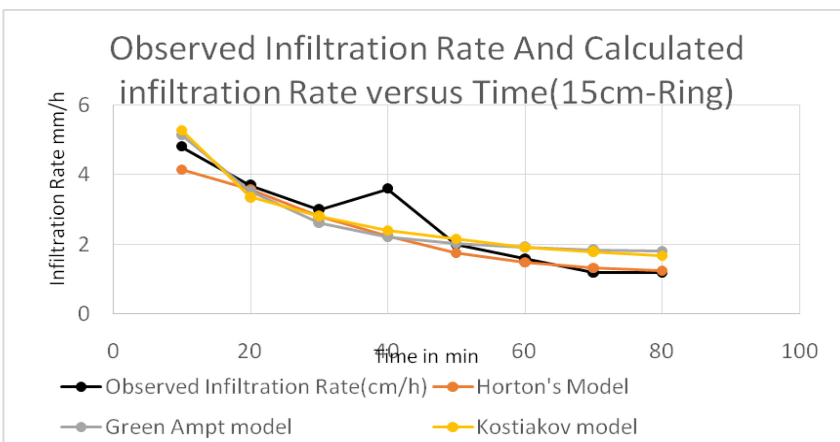


Figure 5.6: Graph of 15cm ring

Table 5.6.1: Calculation of Infiltration rates of 30cm-ring

Time(min)	Observed Infiltration Rate (mm/h)	Hortons Model	Green-ampt Model	Kostiakov Model
10	3.6	3.23	43	54.9
20	3.2	2.83	26	25.6
30	2.7	2.35	16.6	18.8
40	2.6	1.88	13.2	12.4
50	1.8	1.36	11.4	10.6
60	1.5	1.08	10.40	9.4
70	8	6.91	9.8	8.4
80	6	4.93	9.6	7.6
90	3.2	3.26	9.3	6.8
100	2.8	2.42	9.1	6.0
110	1.6	1.89	8.9	5.5
Correlation Coefficient		0.99	0.83	0.83
Standard Error		0.22	2.39	2.22

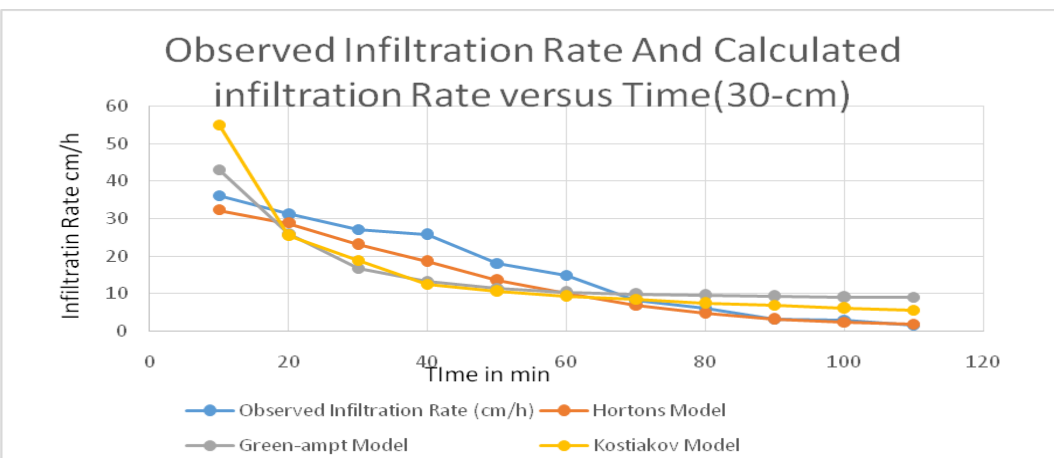


Figure 5.6.1: Graph of 30cm ring

Table5.6.2: Calculation of Infiltration rates of 45cm-ring

Time(min)	Observed Infiltration Rate	Horton's Model	Green-Ampt Model	Kostiakov Model
10	3.4	28.9	39	51.86
20	2.9	25.8	22	21.24
30	2.67	20.6	12.9	14.92
40	16.1	16.6	10.8	11.5
50	1.2	12	9.1	9.35
60	11.2	8.8	8.2	7.98
70	4.2	6	7.7	6.89
80	3.6	2.7	7.4	5.9
90	3.2	2.8	7.1	5.30
100	2.8	2.2	6.86	4.69
110	1.46	1.9	6.64	4.27
Correlation Coefficient		0.99	0.85	0.81
Standard Error		0.15	1.87	2.01

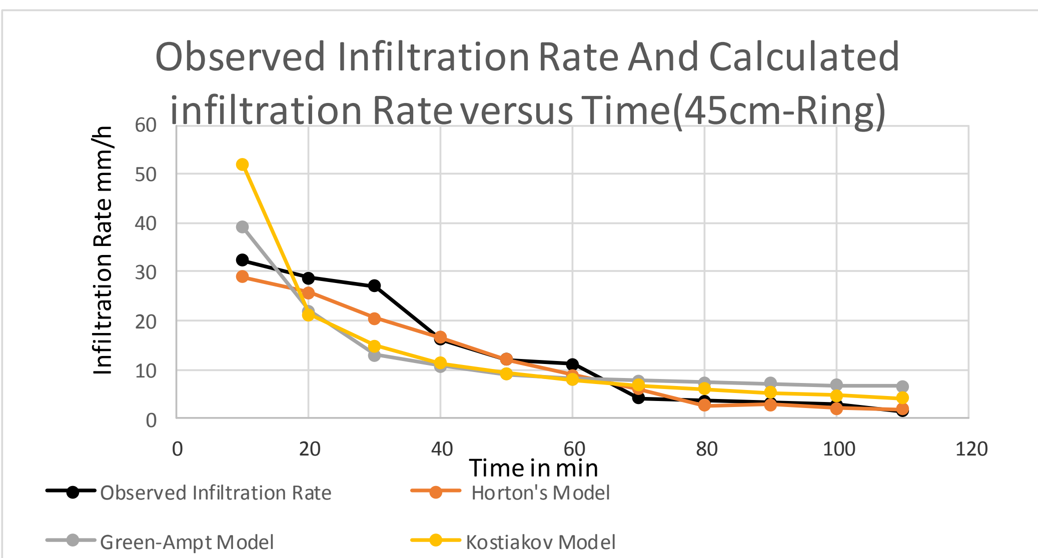


Figure 5.6.2: Graph of 45cm ring

Table 5.6.3: Calculation of Infiltration rates of 60cm-ring

Time(min)	Observed Infiltration Rate(mm/h)	Infiltration Rate by Horton's Model	Infiltration Rate by Green-ampt	Infiltration Rate by Kostiakov Model
10	61	55	78	77.6
20	49	49.5	46	39.6
30	38.6	40.3	29.1	29.2
40	29.5	33.3	23.5	24.2
50	22.1	25.6	19.6	20.5
60	18.5	20.2	17.7	17.9
70	15.7	15.6	15.6	15.9
80	13	12.9	14.8	14.4
90	11	10.5	13.7	12.9
100	9.3	9.47	12.9	11.9
110	8.4	8.62	11.5	9.8
Correlation Coefficient		0.99	0.95	0.94
Standard Error		0.13	0.9	0.99

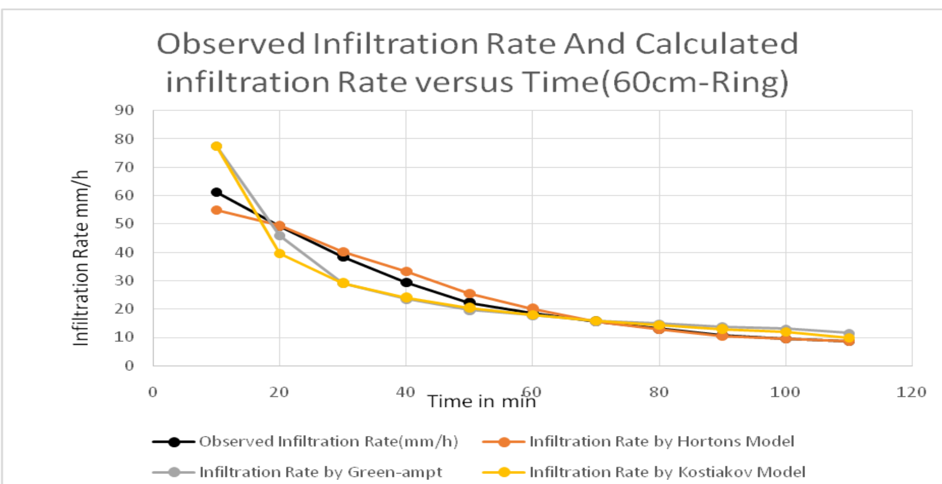


Figure 5.6.3: Graph of 60cm ring

5.7 Meteorological Drought

YEAR	RAINFALL(MM)	DEVIATION	DROUGHT
2000	455.9	-42.251	MODERATE
2001	688.2	-11.3373	NO DROUGHT
2002	601.6	-22.4942	NO DROUGHT
2003	1145.8	47.6166	NO DROUGHT
2004	556	-28.369	MODERATE
2005	1142.9	47.243	NO DROUGHT
2006	971.8	25.1997	NO DROUGHT
2007	777	0.1031	NO DROUGHT
2008	607.6	-27.1212	NO DROUGHT
2009	6512	-16.1041	NO DROUGHT
2010	1043.2	34.3983	NO DROUGHT
2011	673.2	-13.2698	NO DROUGHT

5.8 AGRICULTURAL DROUGHT

KHARIF YEAR DROUGHT PERIOD

YEAR	WEEKS
2001	34-38 weeks
2002	36-40 weeks
2003	34-37 weeks
2006	33-36 weeks
2008	33-36 weeks
2011	30-42 weeks

RABI YEAR DROUGHT PERIOD	
2001	41-46 weeks
2008	40-46 weeks
2011	40-46 weeks

CHAPTER 6
CONCLUSIONS

- As the measurements were taken in NIT field and 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.
- From the results it was concluded that the double ring infiltrometer gives better infiltration rate than single infiltrometer of 15cm & 30cm.
- From the research work it was found that constant infiltration rate was occurring in a short time.
- From the result after analysis it was found that an infiltration models varies. From correlation coefficient and Standard Error it was found that Horton's model is the best fitting model with high degree correlation coefficient and minimum standard error.
- From research work it was also found that soil conditions effects infiltration rate. From the graphs of infiltration rates against time it is found that initial infiltration rates were high and decreased with time up to constant infiltration rate.
- From analysis of meteorological drought, it is clear that there is no problem of volume of available water. But the timely distribution of rainfall is erratic that's why there occurs many prolonged drought spell between cropping period.
- Results of agricultural drought for Khari indicates that between 34 to 39 weeks of the year, are generally affected by severe drought. So for this time period, there must be requirement of supplemental irrigation for crops. In Rabi season also there occurs long dry spell occurred between 41- 46weeks and if we are going to cultivate wheat or other water crops then there must be facility for irrigation.

CHAPTER 7

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