SOIL GROUPING OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,MAIN CAMPUS FARM USING INFILTRATION RATE.

BY

MUSA, JOHN JIYA
M. ENG./SEET/99/368

A THESIS PRESENTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING IN PARTIAL FULFILMENT OF MASTER OF ENGINEERING (AGRICULTURAL ENGINEERING)

SEPTEMBER 2003.

CERTIFICATION

John Jiya Musa , a masters student in the Department of Agricultural Engineering with registration number: M.Eng./1999/368, has satisfactorily completed the requirements for the project works for the award of Masters degree in Agricultural Engineering. The work embarked upon in the project area is original. I certify that it was carried out under my supervision.

.... 13TH APRIL 2004..

MUSA, JOHN JIYA **DATE**

M.ENG/SEET/99/2000/368

APPROVAL PAGE

This thesis is an original work of Mr. John Jiya Musa (M.Eng. /SEET/1999/368) under the supervision of Engr. Dr. N A Egharevba of the Department of Agricultural Engineering, Federal University of Technology, Minna, Nigeria.

This thesis has been prepared, in accordance with the standards, for the preparation of the Masters of Engineering (M.Eng.) thesis in the Federal University of Technology, Minna. It is submitted to the post-graduate school, in partial fulfillment for the award of Masters of Engineering (M.Eng.) degree in Agricultural Engineering (Soil and Water Engineering Option).

It is hereby approved.

.... 31st March 2004

Engr. DR. NOSA A EGHAREVBA **DATE**

(SUPERVISOR)

.... 31-03-2004

Engr. Dr. O J MUDIARE

EXTERNAL EXAMINER **DATE**

.... 15-04-04

Engr. DR. DONALD ADGIDZI **DATE**

HEAD, AGRIC ENGINEERING

DEPARTMENT.

ACKNOWLEDGEMENT

I want to thank first of all God for giving me strength and intention to feed the nation. Thank you God for your goodness to me.

I wish to express my profound gratitude to Dr. Nosa Egharevba, who was my major project supervisor for the hard work and dedication demonstrated during the period of this study. Particular mention most be made of Dr. Donald Adgidz, the head of department, for his advice and support; God bless you. I wish to also thank Dr. J.K Adewumi (my project co-supervisor), Dr. Akin E.S. Ajisegiri, Dr. M.G. Yisa and to the entire staff of the department, you all are wonderful people. Thank you for your support.

To my classmate, you were all so good to me, I had a wonderful time with all of you and may God grant us the grace of knowing more of each other.

To Esther, Lizzy, Dorcas, Sunday, Joe, Samuel, Benjy, Elijah, Jumai, Danladi, James, Samson, Lara, Tobi, Dayo, Daddy and Mummy (though you are gone but your spirit goes on), thank you all for having faith in me, may the goodness of the Lord abide with us all (Amen).

Nma Makun, Aunty Suzan, Ya Mathew Kolo, Dr. Mathew A. Kolo, Mr. & Mrs. J. Crown and Mr. Akin Jeff (AK), Uncle Olarinde Henry, Kola Amos (Sir K) and Adi A. Goshi; the road to the top was rough but for the way you all encouraged me to keep moving on, I say thank you. I especially pray that your of love will not be vein; you all are my mentors. I cannot forget your financial support and advice; God almighty rewards all of you. To all those whose names were not mention, they have a special part of my heart, God bless and reward you all for your understanding. Thank you.

DEDICATION

This work is dedicated to the Almighty God and to my late mother, Mrs. F.K. Musa for her undying love. God bless you mama.

ABSTRACT

Infiltration rates of different types of soil under different land use system were measured using double ring infiltrometer. After prolonged wetting (2 hours), the nature of the soils, were determined with these final infiltration rates. The descriptions of the soils, were then grouped into four infiltration groups of sandy, loamy, silt and clay soils. Under the fallowed land use practice, it was discovered to have a higher volume of infiltration rate (5.80-46.20cm/hr) than the soil under cultivated land practice (2.40-62.70cm/hr). However, the influence of land use on volumetric water content was not statistically significant which could be attributed to the clayey nature of the soils in the site, which masked the effect of land use. Generally, soils under the fallow land use practice showed a higher infiltration rates than those under cultivation. Regression analysis was performed on final infiltration as a function of bulk density, field capacity and initial moisture content. It was discovered that the surface bulk density had the highest correlation coefficient and the average soil property down the profile do not affect infiltration rates. Curve fitting carried out on Philip's, Horton's and Kostiakov's models, showed that Horton's equation had a great consistent deviation during the early part of the test (i.e. the first 40 minutes) but Philip's equation started deviating during the later part of the tests, particularly for swelling soils. Kostiakov's equation gave a more accurate result and is recommended for the soils tested and other similar soils.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

1.0 INTRODUCTION

Water resources management is an important issue of our days, especially in the arid and semi-arid region, where Niger State Falls; where a better water balance in the soil is very crucial/important. One important issue is to evaluate qualitatively and quantitatively the spatial distribution of water in this area; that is the irrigation farm of the Federal University of Technology permanent site Minna.

Water in any part of the world is one of the key Factors limiting agricultural practices. Proper management of water is one of the key factors to increase agricultural production in these regions. Infiltration is one of the key processes controlling the water budget and transport processes in the soil profile. Thus, evolution of infiltration will determine the proportions of the water moving through the root zone, beyond it stored in the soil and available for surface runoff (Serrano, 1990). Infiltration rates on a field may vary from very low to very high rate of water intake but it depends on the soil characteristic which control infiltration characteristics. If the infiltration characteristics on a field can be kept constant, then irrigation efficiency could be increased to a high level (Jensen et al, 1987).

Infiltration refers to the entry of water into a soil profile from the soil surface. Generally, it refers to the vertical infiltration, here water moves downwards from the soil surface to replenish the soil water/moisture deficiency. Since infiltration cause the soil to become wetter with time, water at the leading edge of the wetting front advances into the drier soil region ahead of the front under the influence of matric potential gradient as well as gravity; for infiltration which are vertical (Blake, et al, 1986). Infiltration of water into soils is one the most studied of all the important hydrologic process occurring at the soil atmosphere interphase. It is a dynamis property, which changes drastically both temporally and spatially in response to changes in soil and crop management practices. Gumbs and Warketin (1972) reported large variations in soil infiltration capacity following small changes in bulk density, and Mbagwu (1987, 1990) and Lal et al (1980) observed much high cumulative infiltration, infiltration rate and time to attain equilibrium on mulched than unmulched plots irrespective of the tillage treatments.

Infiltration rate data of soils can be used to supplement other soil information which should help soil scientists, engineers, hydrologists and other deal more precisely with a wide spectrum of water resources management and conservation problem (Ahmed, 1982) different types of soil are known to have different water intake rates. Movement of the water through the soil profile tells a lot about the pore sizes and permeability; the larger the pore sizes of the soil the higher the rate at which water is taken in while the reverse is the case for smaller pore sizes. In some cases, the pore sizes can be large but the rate which water moves through the profile can be slow, this may depends on the presence of air within the profile and where such exist, there will be a sudden upstroke of water releasing the air into the atmosphere and then the process of infiltration will continue. It was therefore based on this that our soil classification was made possible which further helps to determine the type of irrigation practice that will be necessary for that area. Much work has been carried out on using infiltration rate in grouping soils. Musgrave (1955) suggested that most soils could be placed into one of the four infiltration groups depending on their measured and inferred infiltration capacity. Work or infiltration (ASCE, 1949) showed infiltration rates listed in relation to the texture of the surface soils. However, this approach either assumes uniform deep surface soils or insignificant changes in permeability with depth (Ahmed, 1982).

When a different soil layer in terms of texture and permeability from the surface layer is present in the soil profile, it will reduce the infiltration rates, regardless of weather it is coarser or finer than the surface layer. If the texture is finer, the reduction in infiltration is due directly to its lower permeability, if on the opposite, a substance coarse textured lay above it. The unsaturated conductivity of the resulting partially saturated coarse-textured region is actually lower than the wetter finer textured region above the infiltration rate decreases as the front reaches the interface (Miller and Gardner, 1962).

Layered soils are known to induce unstable flow when a fine-textured region lies over a coarse-textured one. (Raats, 1973). During infiltration into dry soil layered in this manner, water cannot enter the coarse-textured zone until the pressure has built up sufficiently to wet the layer pore. If this occurs at discrete locations along the wetting point. The new wetted channels in the coarse-textured zone may become conduits for all the water entering from above. These narrow-flow channels, called fingers can persist through the entire coarse-textured zone. As the flow paths become smaller which explains partly the decline of the infiltration rate in time. By the time infiltration rate has constant, a pronounced transition zone is established with nearly uniform moisture content close to saturation. Pressure difference here is smaller and the water movement is dominated by the gravity force. The final infiltration rate. Thus becomes approximately equal to the saturated hydraulic conductivity of the soil.

Infiltration measurement is labourious and tiresome. It can be expensive where water is limiting. A method of using infiltration rates to describe the hydrological grouping of soils is therefore desirable and is possible through some simple time dependent infiltration equations. However, not all these equations are applicable in all conditions and therefore test on their applicability accuracy are important.

1.1 Justification For The Study

Considering the problem of soil classification, it is important to know the rate at which water moves into the soil under a wide range of condition. This tells a lot about the type of the soil in that area, since the rate of movement of water through the soil profile help to tell about the texture, and structure of the soil. It is the infiltration capacity of the soil that determines the rate that water can be applied to the surface without runoff. The measurement of soil infiltration rate is essential in irrigation layout and design and also in estimating catchment runoff models (Clark, 1974;). This therefore entails realistic planning of water management activities (erosion control and irrgation) which requires simple information on the rate at which different soils take up water under varying conditions. Infiltration rate data collected can help in determining the hydrological soil grouping and other soil information which could help the soil scientists, engineers and hydrologists to deal more effectively with a wide spectrum of water resource management and conservation problems.

1.2 Statement of The Problem

Classification of soil has been of difficult task in the past years for soil scientists because they have to go through stages of digging the soil profile to varying depth and collecting samples at designated points. These samples are taken to the laboratory for further detailed work to be carried out (this part is called pedology). The work reported herein is aimed at simplifying the process of soil classification.

1.3 OBJECTIVE

The following are the objective of the study:

1. To predict relative infiltration rates using some time dependent infiltration equation and to determine which equation best fits the permanent site of the university farm.
2. To classify soil according to infiltration rate.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

A great deal of work has been carried out on infiltration rate since 1933 when Horton explained its importance in the hydrological circle; infiltration refers to water moving into soil from rainfall or irrigation and is the first stapes of water movement in the soil. It is of great importance in any irrigation plan, for any runoff problem, to know the infiltration rate and the soil water content after infiltration (Ahmed, 1982; Eze, 2000). In the hydrological cycle, a falling drop of water may be intercepted by vegetation or may fall directly on to the ground. Water on reacting the earth's surface is either evapourated back to the atmosphere or enters into the soil (infiltration) or run-off the soil surface. Infiltration start as soon as the first drop of rainfall touches the ground surface and continues even after precipitation ceases until all depression on the land surface are empty (Ahmed, 1982).

Infiltration rate may be limited in two ways. Firstly, it cannot exceed the rate at which water is added to the soil surface that is, rainfall intensity and secondly, it is limited by the rate at which water can enter and move through the soil. The following are the processes, which increase infiltration;

(i) passage of water through the soil surface,

(ii) movement of water through soil mass (percolation) and

(iii) depletion of soil moisture storage.

2.2 Infiltration Theory

The theory and process of infiltration has been reviewed by Philip (1969), Hillel (1971) and Baver et al (1972). Infiltration rate usually shows a sharp decline with time from the start of the application of water. The constant rate approached after a sufficiently large time is referred to as the steady infiltration rate. This process is described by several equations showing a decreasing infiltration rate as a function of time.

The theory of infiltration can be divided into two major groups which are

(i) downward or vertical infiltration; and

(ii) downward infiltration into a layered soil.

The mathematical theory of vertical infiltration based upon the solution of the Richard's equation (Pillbury and Richard's 1954) as cited by Philip (1969) is given in equation 2.1

$$\frac{d\O}{dt} = \frac{d}{dz}\left[K(h)\left(\frac{dh}{dz} + 1\right)\right] \text{------------------------} 2.1$$

where:

Ø = volumetric moisture content (m^3/m^3)

t = time (sec)

z = gravitational potential

K = hydraulic conductivity (m/sec)

h = hydraulic potential (m)

K (h) = hydraulic conductivity, a function of h.

The infiltration model was derived from Darcy's law which is given as

$$q = -k\Delta h \quad \text{---} 2.2$$

Where:

q flow rate ($m^3/s/m$)

Δ = gradient vector

h = hydraulic potential (m)

Equations 2.1 and 2.2 are Darcy's and continuity equations respectively.

The infiltration equations and models chosen for this work are

(i) Koskiakov's equation,

(ii) Horton's equation, and

(iii) Phillip's equation

2.2.1 Kostiakov's equation

The functional relationship between infiltration, I, and time, t, is best represented by the equation

$$I = Mt^n + b \text{---} 2.3$$

Where I =Infiltration rate (cm/hr)

- t =time (minns

The values of the suggested b, M and n may be determined by the method of averages using the procedure suggested by Davis (1943). The first step is to plot the graph of infiltration rate, I, against time, t and using normal graph, choose two points (t_1, I_1) and (t_2, I_2) on and near the extremes of the smooth curve representing the data. After which, a point $t_3 = \sqrt{t_1 t_2}$ is chosen, I_3 is read against t_3. The value of b is determined by using the following equation

$$b = \frac{I_1 I_3 - I_3^2}{I_1 + I_2 - 2I_3} \text{---} 2.4$$

The value of b is subtracted from each value of I, the logarithms of (I-b) and t were taken. The variables are related by the expression

$$I - b = Mt^n \text{------------------------} 2.5$$

Taking the logarithm of the above equation, we have

$$Log(I - b) = Log\ M + n\ log\ t \text{------------------------} 2.6$$

The logarithm of the above equation helps to express it to the line equation of Y Mx + C where M is the slope, X is the variable and C is the intercept along the Y axis.

Assuming the relationship between t and I can be expressed by equation 2.3 It is not important to determine the value of the rectifying factor, b, the logarithm form of the expression will therefore be taking the form

$$Log\ I = Log\ M + n\ Log\ t \text{------------------------} 2.7$$

To determine the values that fit the equation, the values of I are calculated by substituting the values of b, M and n in the equation 2.3 for each value observed at t.

However, the values may be substituted in the equation in the logarithm from

$$Log\ (I - b) = Log\ M + nLogt \text{------------------------} 2.8$$

$$I - b = Log^{-1}\ (Log\ M + nLogt) \text{------------------------} 2.9$$

$$I = Log^{-1}\ (Log\ M + nLogt) + b \text{------------------------} 2.10$$

The instantaneous infiltration rate at any time, t, after the beginning of the test may be obtained from

$$\frac{di}{dt} = Mnt^{n2-1} \text{------------------------} 2.11$$

2.2.2 Horton's Equation

This equation is given by

$$I = Ic + (Io \quad Ic)\ e^{-kt} \text{------------------------} 2.12$$

$$(I - Ic) = (Io - Ic)\ e^{-kt} \text{------------------------} 2.13$$

Changing the equation 2.13 to the form of Y = Mx + C, we have to take the logarithm of both sides of the equation

$$\text{Log}\,(I - Ic) = \text{Log}\,(Io - Ic) - k\log e\, t \text{--} 2.14$$

Where,

C = Log (I - Ic) which is the intercept on the Y axis,

M = kLoge which is the slope and

X = t which is the variable

If M = kloge

Then $k = \dfrac{-M}{\text{Log } e}$

The foremost important thing is to plot the graph of the infiltration, I, against time t, to obtain the value for Io and Ic. Another graph of Log (I - Ic) against time, t, along the Y – axis and M, slope (Horton's, 1933). The coefficient of (Io - Ic) in Horton's model according to Ahmed and Duru (1985) is constant for any given soil condition.

Horton's equation was used to evaluate the accumulated depth of water which infiltrated during a given time period.

$$I = \int_{c}^{t} I_s \, dt \text{--} 2.15$$

$$= \int_{0}^{t} Ic + (Io + Ic)e^{-kt}\, dt \text{--} 2.16$$

$$Ic + \frac{Ic - Io\,(1}{k} - e^{-kt}) \text{---} 2.17$$

where,

I =	accumulated infiltration (cm),
Ic =	the constant/final infiltration capacity as t approaches infinity (cm/mins)
K =	positive constant for a given soil and initial condition,
Io	infiltration capacity at the beginning of infiltration capacity (cm/min) and
t =	time (minutes)

2.2.3 Philip's Equation

The mathematical and physical analysis of the infiltration process developed by Philip (1957) separated the process into two components which are that caused by a sorportivity factors and that influenced by gravity. Sorportivity is the rate at which water will be drawn into a soil in the absence of gravity; it comprises the combined effects of absorption at surfaces of soil particles and capillarity in soil pores. The gravity factor is due to the impact of pore on the flow of water through soil under the influence of gravity. The Philip's model takes the form of a power series but in practice an adequate description is given by the two parameter equation.

$$i = st^{1/2} + At \quad \text{--} 2.18$$

The value of the constants A and S can be determined by employing the method of multiple regression analysis. From the above equation, there is one dependent variable, i (cumulative infiltration, cm) and two independent variable $t^{-1/2}$ and t where A is the intercept and S is the slope. To know the goodness of fit, the values of I are calculated by substituting the values of A and S in the equation in the equation 2.18 for each observed value of t.

The rate of infiltration is determined by differentiating equation 2.18 thus.

$$\frac{dI}{dt} = \frac{1}{2} st^{-1/2} + A$$

The constants of A and S may be determined by plotting the graph of dI/dt against $t^{-1/2}$

2.3 Soil sampling

2.3.1 Initial soil moisture content

The initial soil moisture content at any given time was considered to influence the initial rate and total amount of infiltration, both decreasing as the soil moisture content rises (Michael, 1992). The drier the soil, the greater the rate of entry of water because the gradient of the matric potential is then of greater magnitude. The initial moisture content of the soil per site was obtained by pushing a core sampler (50mm diameter and 50mm high) into the ground and was gradually brought out. The ends were scraped with a knife and the content emptied into moisture cans of known weights and covered immediately. In the laboratory, the cans were weighed and dried in an oven at $115^{0}C$ for 24 hours, after which they were weighed again. The moisture content of the soil was obtained from

$$M.C = \frac{(\text{Weight of wet soil + can}) - (\text{Weight of dry soil + can})}{(\text{Weight of dry soil + can})} \quad \text{------------------} 2.19$$

Where M.C. = moisture content.

2.3.2 Soil bulk density (BD)

According to Marshall and Holmes (1988), bulk density increases with the degree of compaction which may be due to the effect of cultivation practices and/or rainfall events on the top soil. A high bulk density would affect infiltration rates (Brady, 1984). Boardman et al (1990) noted that bulk density decrease is closely associated with an increase in infiltration capacity. Ahmed and Duru (1985) found a strong correlation between bulk density and infiltration rate of soil tested in Samaru, Kaduna State of Nigeria.

After all infiltration replicates had been completed in a given site, two of the spots where measurement had taken place were covered with a plastic sheet to prevent evaporation for about twenty-four hours. Eight soil samples were taken from this site, as described above for determining the field capacity and bulk density. On each of the two spots, two samples were taken on the surface and two at 50cm down the soil profile. The field capacity was determined in the same way as the initial moisture content. The bulk density (BD) was calculated from the equation given below.

$$BD = \frac{(\text{Weight of dry soil + can}) - (\text{Weight of the can})}{(\text{Volume of core sampler})} \quad \text{------------------------2.20}$$

2.4 Factors affecting infiltration

Factors affecting infiltration rates can be divided into two groups according to Lewis and Powers (1938). They are;

i. factors influencing the average infiltration rate over a considerable period of time; for example slope, vegetation and surface roughness;

ii. factors influencing the infiltration rate at a given time and part; for example, texture, structure and organic matter.

Horton (1940) made clear that infiltration rate is governed mainly by conditions at/or near the soil surface. He suggested that soil type, soil profile, biological and micro-structure within the soil and vegetal cover are the basic factors affecting infiltration rates of soils.

Musgrave (1955), gave a summary of factors that affect intake rate of water by soil; as follows:

i. surface conditions and the amount of protection against the rainfall impact,

ii. the internal characteristics of the soil mass, including pore size, depth or thickness of the permeable portion, degree of swelling of clay and colloids, organic matter content and degree of aggregation;

iii. soil moisture content and degree of saturation;

iv. duration and intensity of water application and

v. season of the year and temperature of the soil and water.

The initial infiltration rate of a particular soil is influenced by the soil moisture of the area. Smith (1949) discovered that the larger the time of application, the less effect antecedent soil moisture would have. In other words, the final infiltration rate is unaffected by the antecedent soil moisture.

The presence of vegetation and moulding/residue increases the infiltration rates of soils. Vegetation absorbs the raindrop impact, preventing crust formation and promotes microbial activity and soil structure. On decay, plant roots have large conducting pores, which supports the rate of infiltration. A small increase in the hydrostatic head over these pores results in an increase in the flow through the soil surface. Detailed reports on effect of vegetation could be found elsewhere (Duley and Russel, 1939; Daley and Kelly, 1939; Kidder et al, 1943; Williams and Doneen, 1960; Mannering and Meyer, 1963; Lawes, 1966; etc).

Exposed soils can be rendered almost impermeable by the compacting impact of large drops coupled with the tendency of wash off of very small particles into voids. The surface tends to become puddle and the infiltration rate value drops sharply. Also, compaction due to man/animal treading the surface, or to vehicle traffic can severely reduce infiltration capacity.

Burrowing animals and insects opening up ways into the soil, the cover preventing compaction and the vegetation's transpiration removing soil moisture, all tend to help the infiltration process. Hopp and Siater (1948) found that earthworms increase infiltration rates by a factor of 4, another report by Dixon and Peterson (1971) stated that undisturbed earthworm activity could increase infiltration within a few months. Similar effects were reported by Wilkinson (1975), Euler (1975), Wilkinson and Aina (1976), Lauritzen and Stoltenberg (1940)

Dense vegetal cover such as grass or forest tends to promote high values of infiltration. The dense root systems, all providing increase rate of infiltration to the subsoil, the layer of organic debris forming a sponge like surface burrowing animals and insects opening up ways into the soil, the cover preventing compaction and vegetation's transpiration removing soil moisture, all tend to help the infiltration processes.

Cultivation affects infiltration because of its effects on the conducting pores in soils. It may either increase infiltration depending on the soils surface after cultivation. Cultivation practices that leave the surface rough with many pockets are likely to have more infiltration than smooth heavily worked surface. Heavy machineries used on farm lands compacts the soil, reducing the pore sizes which in turn reduce the infiltration rate. Parker and Jenny (1945) found that compaction of soils by heavy machines is more pronounced on wet soils than dry soil and infiltration rates were reduced in both cases.

The rate of infiltration into the soil depends, sometimes on the rate of movement of water down the profile. Within the profile, finer materials like sill and clay particles can be washed or leached down, which may result in the blockage of the smaller pore spaces in subsequent layers. In most profiles there may be considerable variation in hydraulic conductivity with depth. When a coarse layer overlies a finer layer, infiltration is initially controlled by the finer layer. In many cases, a perched water table may be formed in the coarser layer just above its boundary with an impending finer layer. This was supported by a study undertaken by Hillel (1971). The effects of texture and swelling on the pore size distribution and permeability was found to increase exponentially with an increase in particles size.

Some chemicals have effect on infiltration rates of soil. Chemicals which support the dispersion of soil aggregates (such as some sodium salts) can reduce the soil infiltration rate. Other chemicals that tend to cement or stabilize the soil aggregates increase infiltration rates. Pillsbury and Richards (1954) found that moderate application of ammonium sulphate resulted in significantly higher infiltration rates than urea when combined with large amounts of organic matter.

Dulley and Domingo (1943) discovered that temperature have effect on infiltration rates, but any variation in infiltration causes by changes in temperature likely to occur under conditions of natural rainfall which would be too slight to have any practical significance in determining the amount of rainfall that would be absorbed by agricultural land.

The factors, however, affecting the rate of infiltration are not all present in a given soil at a given time. Further more, some of the effects present in the soils overshadow those of others.

2.5 Infiltration Rate Measurement

2.5.1 CYLINDER INFILTROMETERS

Haise et al, (1956) gave a detailed analysis on the use of the cylinder infiltrometer. A metal cylinder with an inner diameter of 300mm and an outer diameter of 600mm respectively, which both have the height 250mm was driven into the soil using a driving plate set on top of the infiltrometer and a heavy hammer to some heads so as to prevent the blow out effect around the bottom of the cylinders. Water is pounded in the cylinders to some depths and at subsequent times, that is when the water level has dropped about one-half of the depth of the cylinder, water should be added to return the water surface to it initial point. The infiltration rate is measured by noting the amount of water added or by the drop in head in the inner cylinder in a given time.

The purpose of outer cylinder is to eliminate to some extent the edge effect of the surrounding drier soil and to prevent the water in the inner cylinder from spreading over a large area after penetrating the bottom of the ring.

In some cases, most later studies, only single infiltrometers were employed (Evan et. al, 1950). This was discovered not to have any control on the lateral movement of water from the ring. In most studies, however, the double-ring (Shiff, 1953; Burgy and Luthin, 1956, 1957; Swartzendruber and Olson, 1961) or multiple ring (Kohnke, 1938) devices were used so that divergent flow could be minimized by means of area surrounding the central compartment.

Some automatic/self-recording ring infiltrometers have been developed by Pittman and Kohnke (1942) and Daniel (1952). This consisted of metal rings or squares having the same area as the conventional rain gauge (8 inches diameter). The water applied was recorded with the rain gauge recording device. Carburetor floats were used to maintain uniform water level in both the inner and outer compartments.

2.4.1.1 Limitations of Cylinder Infiltrometer

The process of placing the ring device in to the soil causes some serious limitations to cylinder infitrometers. In driving the ring into the soil, some degree of disturbance of the natural soil condition is caused, the resulting disturbance is manifested as shattering or compaction which may be caused by large variation in infiltration rates between replicated runs. Another limitation is the soil-metal interface which may cause unnatural seepage planes which results in abnormally high infiltration rates. A further limitation to the use of the rings is the problem of entrapping air in the soil column: caused when a constant head of water is applied upon the surface. Under the saturated condition, the entrapped air may not be able to escape from the soil which results in the creation of internal air cushion and in turn impedes downward movement of the water.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of experimental Site.

The Federal University of Technology permanent site is known to have a total land mass of eighteen thousand nine hundred hectares (18,900 ha) which is located along kilometer 10 Minna Bida road, South - East of Minna under the Bosso local Government area of Niger State (Fig. 3.1). It has a horse shoe shaped stretch of land, lying approximately on longitude of 06^0 28' E and latitude of 09^0- 35' N (Sani, 1999). The site is bounded at Northwards by the Western rail line from Lagos to the northern part of the country and the Eastern side by the Minna Bida road and to the North West by the Dagga hill and river Dagga (Sani, 1999).

The entire site is drained by rivers Gwakodna, Weminate, Grambuku, Legbedna. Tofa and their tributaries. They are all seasonal rivers and the most prominent among them is the river Dagga. The most prominent of the features are river Dagga, Garatu Hill and Dan Zaria dam.

3.1.1 Soils of the area.

The major soil found in this area is the sandy loam type with a sparse distinction of the sandy clay soil and sandy soils. This has so far encouraged the residents of Minna metropolis and neighbouring villager to use the land for agricultural activities such as farming and grazing by the nomadic cattle rearers (Eze, 2000).

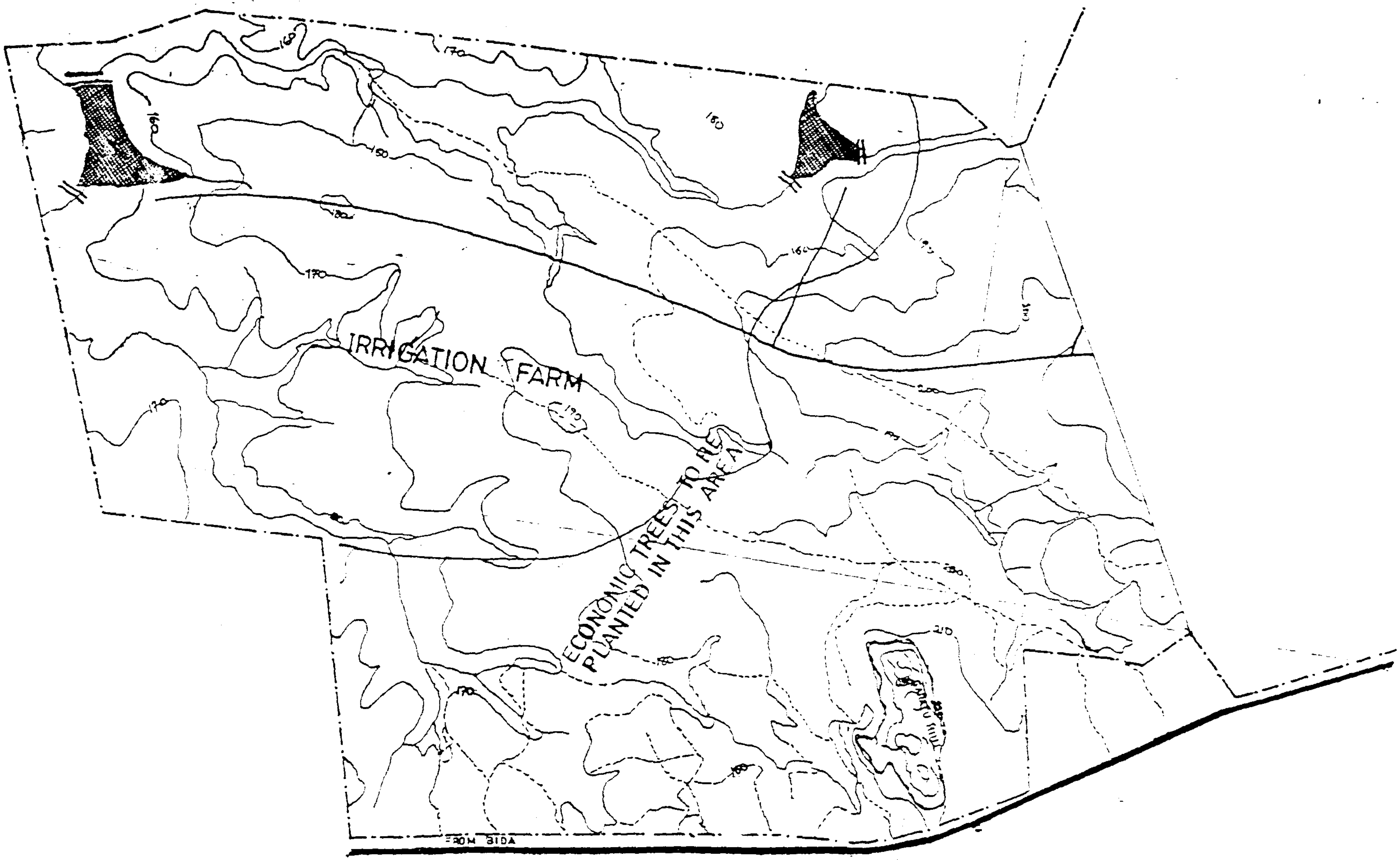

Fig 3.1: Irrigation farm of the Federal University of Technology Minna. Permanent Site Farm.

Source: (Works Department, Federal University Of Technology)

3.1.2. Vegetation And Land Use.

Minna falls within the semi wood land or tree forest vegetation belt with derived dry grass or shrub land known as the southern guinea savannah (Fubara, 1986). This is also known as the transition belt, which lies between the savannah grass/shrub land of the north and the rain forest of the south. Due to intensive fallow type of agricultural practice and grazing of the land, the area is dominated by stunted shrubs; interspersed with moderate height tree and perennial foliage (Sani, 1990). Similarly, due to human activities and land use abuse which is a characteristic of most expanding urban centre in Nigeria, the site is fast loosing its remaining tree species to development. Along some river course and lowland areas, the vegetation is more wooded and resembles some forest affinities (Sani, 1999). The area is still being used as farm and grazing land by the residents of Minna and her environs.

3.1.3 Climate

3.1.3.1 Rainfall

Minna, generally is known to experience rainfall from the month of May to the month of October and on rear occasions, to November. It is known to reach its peak between the months of July and August. Towards the end of the rainfall season, around October, it is known to be accompanied by great thunder storms (Sani, 1999).

3.1.3.2 Temperature

The maximum temperature period in this area is usually between the months of February, March and April which gives an average minimum temperature record of 33^0C and a maximum temperature of 35^0C (Minna Airport Metrological Center, 2000). During the rainfall periods, the temperature within the area drops to about 29^0C.

3.3 Area of study

The area of study is using infiltration rates to determine soil hydrological group on the permanent site farm of the Federal University of Technology, Minna, located along the Minna-Bida highway, Niger State Nigeria.

3.4 Description of the equipment

The infiltrometer rings were rolled iron sheet of 12-gauage steel and the diameters of the inner and outer ring were 300 mm and 600mm, respectively as suggested by Bambe (1995) and also by Swartzendruber and Osio (1961). They both have a height of 250mm and the bottom ends of the ring were sharpened for easy penetration into the soil.

Each infiltrometer was equipped with a float consisting of a plastic rule placed perpendicularly to one face of the wooden block. This wooden block was painted so as to prevent it from soaking water as it floats on the water. The plastic meter rule was clamped to the inner side of the inner rings; with another sharp edge wood placed near the rule to facilitate taking reading from the rule. Figure 3.2 shows a typical infiltrometer ring.

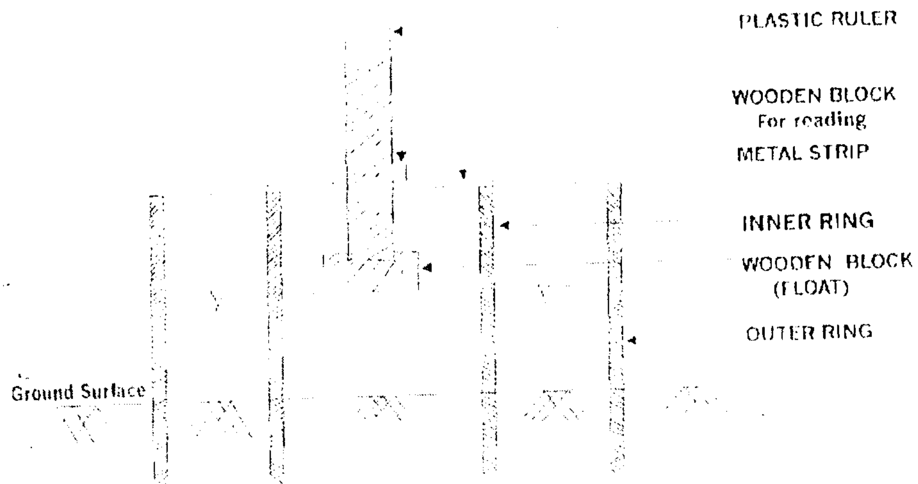

Fig: 3.2 A Dissected infiltroment.

3.5 Site selection

It should be kept in mind that the areas surveyed were not large enough to be referred to as soil series but soil unit because the survey was more or less a point description. The following guidelines were used to select the sites.

i. High slope: These are areas which have been eroded and also have their horizons exposed.

ii. Middle slope: These are areas where deposition of coarse and heavier materials start.

iii. Lower slopes: This is usually the fadama area where deposition of clay silts materials stops.

The various land management practices (cultivated, fallow, bush or bare) were taken into consideration on each of the soil unit. Where it was observed that more than one management practice existed, all available types of land use system were taken into consideration.

3.6 Parameters considered

In this study, only a few of the physical characteristics of the soil will be considered; these are:

1. Texture
2. Organic matter
3. Field capacity
4. Bulk density
5. Land use
6. Soil profile

3.7 Infiltration measurement

The infiltrometer rings were placed randomly from each other and the measurement were taken to the nearest centimeter. The rings were then driven into the ground by hammering a wooden bar placed diametrically on the rings to prevent any blowout, effects around the bottoms of the rings. In areas where ridges and furrows existed, the inner rings were always placed in the furrow. Having done that, a mat/jute sack was spread at the bottom of the inner and outer compartments of each infiltrometer so as to minimize soil surface disturbance when water was poured into the compartments. In grass - covered areas, they were cut as low as possible with a cutlass so that the float could have free movement and care was taken not to uproot grasses. Four (4) infiltration measurements were conducted at each location of which an average was to be taken later. Points of measurements were chosen based on the layout in fig. 3.1

Water from jeri-cans was poured into the infiltrometer compartments simultaneously and as quickly as possible. As soon as the jeri cans were emptied, the water level from the inner cylinder was read from the float (rule) and the local time was also noted. Repeated readings were taken at intervals of 0 minute, 1 minute, 2 minute, 5 minutes, 10 minutes, 15 minutes 20 minutes 30 minutes, 45 minutes, 60 minutes, 75 minutes, 90 minutes, 100 minutes and finally at 120 minutes. The cylinder compartment was refilled from time to time when the water level dropped half way. The water levels at both compartments (inner and outer) were constantly kept equal by adding water, as needed, into the outer compartment, which is faster. Some time is allowed before starting another replicate. So that no two infiltrometer should require reading at the same time, each replicate was allowed a time duration.

At each site, ten soil samples were taken using the 50mm x 50mm core sampler from the surface layer (0-50cm) in the area outside the outer rings. These were bulked for the determination of the initial moisture content and bulk densities.

In grass covered areas, they were cut as low as possible with a cutlass so that the float could have free movement and care was taken not to uproot grasses. Four (4) infiltration measurements were conducted at each location of which an average was to be taken later. Points of measurements were chosen based on the layout in fig. 3.1

Water from jeri-cans was poured into the infiltrometer compartments simultaneously and as quickly as possible. As soon as the jeri cans were emptied, the water level from the inner cylinder was read from the float (rule) and the local time was also noted. Repeated readings were taken at intervals of 0 minute, 1 minute, 2 minute, 5 minutes, 10 minutes, 15 minutes 20 minutes 30 minutes, 45 minutes, 60 minutes, 75 minutes, 90 minutes, 100 minutes and finally at 120 minutes. The cylinder compartment was refilled from time to time when the water level dropped half way. The water levels at both compartments (inner and outer) were constantly kept equal by adding water, as needed, into the outer compartment, which is faster. Some time is allowed before starting another replicate. So that no two infiltrometer should require reading at the same time, each replicate was allowed a time duration.

At each site, ten soil samples were taken using the 50mm x 50mm core sampler from the surface layer (0-50cm) in the area outside the outer rings. These were bulked for the determination of the initial moisture content and bulk densities.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Analysis of results

Table 4.1 shows the initial soil moisture content of tested soils while Table 4.2 shows the various bulk densities of the tested soils. Table 4.1, site 11 on Fig 4.19 shows a high moisture content of 0.0620g, which may be due to the clayey nature of the soil and its closeness to a stream. Site 3,5,6,7 and 8 closely follows site 11 in term of moisture content present in the area and this may be due to the clay nature of the soil around the area, except for site 5, which has a different soil characteristic (loamy in nature). There is a higher correlation between the cumulative infiltration {I (cm)} and time {$t^{-1/2}$ (mins)} at Table 4.2 of site 6 which shows that the wet bulk density is slightly higher than that of the wet bulk density of site 12 on the same table which could be as a result of the type of soil available in the area. The bulk densities as presented, were taken for both dry and wet soils. Table 4.2 shows (the bulk density of the tested soils) that site 6 had the highest wet bulk density of 1.83 g/cm^3 which is described under appendix A.2 as slightly plastic dark sandy clay. This was closely followed by site 12,8,4,15 and 14 respectively. It can be observed that the value of wet bulk density was relatively higher than the dry bulk density. Similarly, Table 4.3 shows the particle size distribution, which is based on the soil unit within the irrigation farm of the permanent site and this also classified using the soil textural triangle. The horizon depth in Table 4.3 was divided into two ranges which are 0-25cm and 25-50cm. The particle size was classified into the various soil using the soil textured triangle. The presence of organic matter at each of the range was clearly represented also. Under Table 4.4, below, shows the percent count of R square values from the curve fittings from which it could be observed that the Kostiakov's equation has the best fit with 99.35% for fallowed land and 98.79% for cultivated land. Although Philip's equation had a R square value of 53.10% for cultivated land and 55.22% for fallowed land, when compared with the R square value of Kostiakov's, it was far lower, since Philips model is limited to swelling homogenous soils and for vertical flow while Kostiakov's equation has no limitation, it is also known to apply to the three-dimensional flow (Serrano, 1990). A closer look at Table 4.5 shows the average infiltration rate (cm/hr) for various land use practices while Table 4.6 (A and B) shows the average infiltration rate (cm/hr) for various land use practices during the dry and wet season. Table 4.6 shows the average infiltration rate for 12 weeks in fallowed and cultivated soils.

TABLE 4.1 Initial Soil Moisture Content Of The Experimental Site. (Depth Of Between 10cm - 50cm)

SITE	Weight of sample (g)	Weight of oven-dry sample (g)	Moisture content
1	161.48	158.73	0.0173
2	168.88	165.28	0.0218
3.	167.18	159.56	0.0478
4	178.67	171.19	0.0402
5	166.83	159.02	0.0491
6	189.81	182.76	0.0386
7	166.94	159.21	0.0486
8	179.62	172.28	0.0426
9.	187.11	161.22	0.0363
10	167.97	161.04	0.0430
11	160.52	153.97	0.0620
12	180.05	176.98	0.0173
13	146.35	141.23	0.0362
14	176.95	171.03	0.0346
15	178.00	172.45	0.0322
16	161.20	157.10	0.0261
17	150.69	148.00	0.0182
18	149.66	144.18	0.0380
19	155.51	152.08	0.0226
20	155.47	150.54	0.0327
21	158.26	153.81	0.0285
22	151.93	146.77	0.0352
23	155.36	152.61	0.0180
24	155.85	152.41	0.0226
25	167.12	162.68	0.0273
26	160.78	157.67	0.0197
27	155.56	153.36	0.0143
28	159.84	156.25	0.0229
29	162.59	157.44	0.0327
30	168.99	164.54	0.0331

TABLE 4.2 Bulk Densities Of The Experimental Site (Depth Of 10cm - 50cm)

SITE	WET (g/cm³) (BD)	DRY (g/cm³) (BD)
1	1.634	1.545
2	1.709	1.581
3.	1.692	1.574
4	1.793	1.641
5	1.597	1.517
6	1.831	1.688
7	1.639	1.560
8	1.819	1.652
9	1.691	1.611
10	1.720	1.640
11	1.624	1.537
12	1.823	1.700
13	1.480	1.397
14	1.791	1.690
15	1.792	1.715
16	1.631	1.538
17	1.524	1.509
18	1.514	1.468
19	1.573	1.548
20	1.573	1.533
21	1.611	1.600
22	1.547	1.515
23	1.581	1.564
24	1.586	1.552
25	1.701	1.687
26	1.637	1.605
27	1.583	1.561
28	1.627	1.591
29	1.655	1.633
30	1.710	1.675

TABLE 4.3 Particle Size Distributions.

Soil Unit	Horizon Depth (cm)	Percent Clay	Percent Silt	Percent Sand	Organic Matter (g/kg)	Soil Classification using Soil Textural Triangle
1	0-25cm 25-50 cm	28 35	42 30	30 35	2.52 2.81	Loam Soil Clay Loam Soil
2	0-25cm 25-50 cm	33 24	33 36	34 40	2.40 3.26	Clay Loam Soil Loam Soil
3	0-25cm 25-50 cm	42 38	40 38	18 24	2.59 2.52	Silty Clay Soil Clay Loam Soil
4	0-25cm 25-50 cm	45 39	35 36	20 25	1.40 2.09	Clay Soil Clay Loam Soil
5	0-25cm 25-50 cm	32 20	24 30	44 50	3.06 2.43	Clay Loam Soil Loam Soil
6	0-25cm 25-50 cm	21 21	34 36	45 43	2.27 2.06	Loam Soil Loam Soil
7	0-25cm 25-50 cm	35 33	30 38	35 29	2.09 2.06	Clay Loam Soil Clay Loam Soil
8	0-25cm 25-50 cm	30 21	41 40	29 39	3.05 2.81	Clay Loam Soil Clay Loam Soil
9	0-25cm 25-50 cm	17 19	39 36	44 45	3.36 2.07	Loam Soil Loam Soil
10	0-25cm 25-50 cm	31 41	39 29	30 30	2.81 2.09	Clay Loam Soil Clay Soil
11	0-25cm 25-50 cm	32 23	40 39	28 38	2.52 2.59	Clay Loam Soil Loam Soil
12	0-25cm 25-50 cm	19 28	41 33	40 39	3.05 2.98	Loam Soil Loam Soil
13	0-25cm 25-50 cm	19 19	41 46	40 35	2.30 2.29	Loam Soil Loam Soil
14	0-25cm 25.50 cm	19 29	40 46	41 25	1.98 2.41	Loam Soil Loam Soil
15	0-25cm 25-50 cm	30 39	35 30	35 31	2.20 1.95	Clay Loam Soil Clay Loam Soil
16	0-25cm 25-50 cm	22 31	40 35	36 34	2.27 2.06	Loam Soil Clay Loam Soil
17	0-25cm 25-50 cm	39 36	30 28	31 36	2.27 1.54	Clay Loam Soil Clay Loam Soil
18	0-25cm 25-50 cm	39 34	30 25	31 41	2.09 1.41	Clay loam Soil Clay Loam Soil
19	0-25cm 25-50 cm	40 39	30 31	30 30	2.01 2.11	Clay Loam Soil Clay Loam Soil
20	0-25cm 25-50 cm	30 30	39 30	31 40	2.09 1.98	Clay Loam Soil Clay Loam Soil

21	0-25cm 25-50 cm	22 17	40 41	36 42	2.03 1.41	Clay Loam Soil Loam Soil
22	0-25cm 25-50 cm	29 17	39 38	32 45	2.52 2.79	Clay Loam Soil Loam Soil
23.	0-25cm 25-50 cm	19 31	41 39	40 30	2.88 1.55	Loam Soil Clay Loam Soil
24	0-25cm 25-50 cm	42 17	40 39	18 44	2.65 2.37	Silty Clay Soil Nil
25	0-25cm 25-50 cm	30 26	38 34	32 30	1.74 2.47	Clay Loam Soil Nil
26	0-25cm 25-50 cm	30 36	39 28	31 36	2.61 2.31	Clay Loam Soil Clay Loam Soil
27	0-25cm 25-50 cm	14 21	46 45	40 34	2.08 1.54	Loam Soil Loam Soil
28	0-25cm 25-50 cm	20 36	45 28	35 36	2.09 1.41	Loam Soil Clay Loam Soil
29	0-25cm 25-50 cm	43 40	27 30	30 30	2.42 2.01	Nil Clay Loam Soil
30	0-25cm 25-50 cm	34 27	30 30	36 43	2.41 2.03	Clay Loam Soil Loam Soil

It was discovered, however, that the infiltration rate of cultivated land when compared with the fallowed land was higher which may be due to the presence of underlying rocks covered by some layers of soils. Where this is present, it will not allow easy penetration of water. Another reason may also be that the area under fallow may have a high water table. For example, it was observed from Table 4.5A (in the month of April at week 0) the average final infiltration rate for cultivated land is 35.54 cm/hr, with a cumulative water intake of 70.32cm at the end of the infiltration while

Table 4.4: The R square values for the three models used.

% of R Square greater than	Horton's	Philip's	Kostiakov's
0.50	Nil	53.10 (cultivated land)	Nil
	Nil	55.22 (fallowed land)	Nil
0.60	Nil	Nil	Nil
0.70	75.88 (cultivated land)	Nil	Nil
	75.69 (fallowed land)	Nil	Nil
0.80	Nil	Nil	Nil
0.90	Nil	Nil	98.79 (Cultivated land)
	Nil	Nil	99.35 (Fallowed land

for the fallowed land had a final infiltration rate of 15.23cm/hr and a cumulative water intake rate of 30.47cm. This difference may be due to the presence of hard rock underlay or the water table been near the earth surface. In the month of May, the cultivated land had an infiltration rate of 32.28cm/hr, and cumulative water intake rate of 64.57cm while the infiltration rate for the fallowed land was 11.30cm/hr and the cumulative water intake rate was 22.60cm; a reduction in the water intake rate could be observed between the month of April and May which may be due to the two day rain during that month. In the month of June, a further reduction was observed in the cultivated land, an infiltration rate of 24.37cm/hr and a cumulative water intake rate of 48.74cm was observed respectively. There was further reduction in soil-water intake rate in month of July, for the cultivated land the infiltration rate was 17.12cm/hr and cumulative water intake rate was 34.24cm while for the fallowed land the infiltration rate

Table 4.5: Average Infiltration Rate (Cm/Hr) For Various Land Use Practice.

(A)

Time (min)	APRIL			
	FALLOWED LAND		CULTIVATED LAND	
	Cum. Water Intake (cm)	Infiltration rate (cm/hr)	Cum Water Intake (cm)	Infiltration rate (cm/hr)
0	-	-	-	-
1	0.73	44.00	1.17	70.00
2	1.32	39.50	2.18	65.50
5	2.65	31.36	4.73	56.08
10	4.43	26.60	8.35	50.10
15	5.98	23.93	11.25	45.00
20	7.28	21.85	14.72	44.65
30	10.02	20.03	21.27	42.49
45	13.78	18.38	30.03	40.05
60	17.55	17.55	38.93	38.94
75	21.00	16.08	47.08	37.67
90	24.57	16.38	55.82	37.21
100	26.48	15.89	60.18	36.10
120	30.47	15.23	70.32	35.54

(B)

Time (min)	MAY			
	FALLOWED LAND		CULTIVATED LAND	
	Cum. Water Intake (cm)	Infiltration rate (cm/hr)	Cum Water Intake (cm)	Infiltration rate (cm/hr)
0	-	-	-	-
1	0.90	54.00	1.48	89.00
2	1.52	45.50	2.58	77.50
5	2.65	31.80	5.15	61.08
10	4.17	25.00	8.77	52.60
15	5.45	21.80	12.20	48.80
20	6.58	19.75	15.72	47.15
30	8.27	16.53	21.62	43.23
45	11.33	15.11	27.93	39.91
60	13.67	13.67	37.90	37.90
75	51.75	12.60	44.92	35.93
90	18.08	12.06	52.13	34.76
100	19.70	11.82	56.52	33.88
120	22.60	11.30	64.57	32.28

(C)

Time (min)	JUNE			
	FALLOWED LAND		CULTIVATED LAND	
	Cum. Water Intake (cm)	Infiltration rate (cm/hr)	Cum Water Intake (cm)	Infiltration rate (cm/hr)
0	-	-	-	-
1	0.61	36.75	0.86	51.75
2	1.11	33.38	1.55	46.50
5	2.25	27.00	3.33	39.30
10	3.93	23.55	5.94	35.63
15	5.58	22.30	8.13	32.51
20	7.16	21.49	10.04	30.11
30	10.14	20.28	14.44	28.88
45	13.73	17.85	20.69	27.58
60	17.53	17.23	26.75	26.75
75	21.09	16.84	32.78	26.22
90	24.88	16.59	38.54	25.69
100	27.14	16.38	42.28	25.33
120	31.76	15.88	48.74	24.37

(D)

Time (min)	JULY			
	FALLOWED LAND		CULTIVATED LAND	
	Cum. Water Intake (cm)	Infiltration rate (cm/hr)	Cum Water Intake (cm)	Infiltration rate (cm/hr)
0	-	-	-	-
1	0.82	49.20	0.96	57.60
2	1.32	40.80	1.64	49.20
5	2.68	32.16	3.30	39.54
10	4.59	27.54	5.54	33.24
15	6.20	24.80	7.74	29.72
20	8.24	22.82	9.07	27.54
30	10.05	20.05	11.91	23.82
45	13.38	17.86	16.52	22.03
60	16.39	16.39	20.62	20.71
75	19.85	15.88	24.07	19.26
90	23.01	15.38	27.75	18.50
100	24.79	14.87	30.23	18.14
120	28.31	14.16	34.24	17.12

Table 4.6a: Average Infiltration Rate (Cm/Hr) For The Dry Season For Various Land Use Practice.

Time (min)	DRY SEASON			
	FALLOWED LAND		CULTIVATED LAND	
	Cum. Water Intake (cm)	Infiltration rate (cm/hr)	Cum Water Intake (cm)	Infiltration rate (cm/hr)
0	-	-	-	-
1	0.82	49.00	1.33	79.50
2	1.42	42.50	2.38	71.50
5	2.65	31.58	4.94	58.58
10	4.30	25.80	8.56	51.35
15	5.72	22.87	11.73	46.90
20	6.93	20.80	15.22	45.90
30	9.15	18.28	21.45	42.86
45	12.56	16.75	28.98	39.98
60	15.61	15.61	38.42	38.42
75.	36.38	14.34	46.00	36.80
90	21.33	14.22	53.98	35.99
100	23.09	13.86	58.35	34.99
120	26.54	13.27	67.45	33.91

Table 4.6b: Average Infiltration Rate (Cm/Hr) For The Wet Seaons For Various Land Use Practice.

Time (min)	WET SEASON			
	FALLOWED LAND		CULTIVATED LAND	
	Cum. Water Intake (cm)	Infiltration rate (cm/hr)	Cum Water Intake (cm)	Infiltration rate (cm/hr)
0	-	-	-	-
1	0.72	42.98	0.91	54.68
2	1.22	37.09	1.60	47.85
5	4.93	29.58	3.32	39.42
10	4.26	25.55	5.74	34.44
15	5.89	23.55	7.94	31.12
20	7.85	22.16	9.56	28.83
30	10.10	20.17	13.18	26.35
45	13.56	17.86	18.61	24.81
60	16.96	16.81	23.69	23.73
75	20.47	16.36	28.43	22.74
90	23.95	15.99	33.15	22.10
100	25.97	15.63	36.26	21.74
120	30.04	15.02	41.49	20.75

was 14.12cm/hr and the cumulative water intake was 28.31cm. These reductions signifies the intense rate of rain fall during those months (April and May) which the test was carried out.

Table 4.6A shows the average infiltration rate (cm/hr) for the dry seasons for the various land use practices which show that the cultivated land, the infiltration rate was 33.91cm/hr while the cumulative intake water was 67.45cm. The fallowed land the infiltration rate was 13.27cm/hr and the cumulative water intake rate had a staggering figure because at the 75th minutes, the intake rate increased to 36.38cm and at the 90th minutes, it dropped to 21.33cm from were it increased gradually to 26.54cm at the 120th minutes. Table 4.6B shows the average infiltration rate (cm/hr) for the wet season for various land use practice which shows that infiltration rate for the cultivated land was 20.75cm/hr while the cumulative water intake was 41.49cm and the fallowed land, the infiltration rate was 15.02cm/hr and the cumulative water intake was 30.04cm. When the data obtained from the dry and wet seasons were compared, the values of wet seasons were known to have a higher water intake rate. On the average, as seen on Table 4.7, the infiltration rate for cultivated land was 27.33cm/hr and the cumulative water intake was 54.47cm while for the fallowed the infiltration rate was 14.14cm/hr and the cumulative water intake was 28.29cm. It was observed, therefore, that on the average there was a higher water intake rate in the cultivated land when compared with the fallowed land which could possible be due to rocky underlay or hard capping existing in the fallowed area.

Table 4.7: Average Infiltration Rate (Cm/Hr) For 12 Weeks For The Various Land Use Practice.

Time (min)	JULY			
	FALLOWED LAND		CULTIVATED LAND	
	Cum. Water Intake (cm)	Infiltration rate (cm/hr)	Cum Water Intake (cm)	Infiltration rate (cm/hr)
0	-	-	-	-
1	0.77	45.99	1.12	67.09
2	1.32	39.80	1.99	59.68
5	2.56	30.58	4.13	49.51
10	4.28	25.67	1.15	42.89
15	5.80	23.21	9.83	39.01
20	7.39	21.48	12.39	37.36
30	9.16	19.22	17.31	34.61
45	13.06	17.30	23.79	32.39
60	16.29	16.21	31.05	31.08
75	19.42	15.53	37.21	29.77
90	22.64	15.10	43.56	29.04
100	24.53	14.74	47.30	28.36
120	28.29	14.14	54.47	27.33

Figures 4.1 and 4.2 shows the graphs of average rate {I(cm/hr)} against elapsed time {t (mins)} for cultivated and fallowed land respectively, while figure 4.3 and 4.4 shows the graph of cumulative infiltration {I (cm)} against elapsed time {t (mins)} for cultivated and fallowed land practices respectively. Figures 4.5 and 4.6 shows the graph of Log (Ic – Io) against time {t (mins)} using Horton's equation for cultivated and fallowed land practices, when these graphs were compared with the graphs obtained from the calculated figures using the estimated soil parameter on Table 4.7, a little deviation was observed indicating lower values of observed data when compared with the values obtained from the calculated data. Figures 4.7 and 4.8 shows the graph of cumulative infiltration {I (cm)} against elapsed time {$t^{1/2}$ (mins)} using Philips equation for cultivated and fallowed land practices. When this graph was compared with the graphs of the calculated data, a greater deviation was observed. Also on comparing the values used to plot Horton's equation a greater difference was observed between them. The graph of infiltration {I (cm)} against elapsed time {t (mins)} using Kostiakov's equation for

cultivated and fallowed land practices as shown in figures 4.9 and 4.10 respectively. The graphs of the observed data when compared with that of the calculated data had a negligible difference. Comparing the graphs of Philip, Horton and Kostiakavo's a greater degree of accuracy was shown in terms of parameter that best describe the soil properties of the irrigation farm of the Federal University of Technology Minna Permanent Site. Figs. 4.11 and 4.12 shows the graphs of infiltration rate {I (cm/hr)} against elapsed time {t (mins)} for fallowed and cultivated land during the dry season while Figs. 4.13 and 4.14 shows the graphs of infiltration rate { I(cm/hr)} against elapsed time {t (mins)} for fallowed and cultivated land during the wet season.

The graph of Fig . 4.15 above shows the best fit line for the graph of infiltration rate {I(cm/hr)} against elapsed time {t(mins.)} for 12weeks during which the infiltration rate test was carried out in the irrigation farm of the Federal University of Technology Minna, Niger State, Nigeria. The R square value for 12weeks is 89.9% for the whole farm site while the equation that best describe this area is given in form of Y = MX + C as Y = 0.48881x + 1.2192; where

M = slope = 0.4881

C = intercept = 1.2192

X = variable factor =time

Fig. 4.16 shows the best fit line for the cumulative infiltration {i(cm)} against elapsed time {t(mins.)} for 12 weeks during which the rate of infiltration of water into the soil was carried out for the same site; the irrigation farm site of the Federal University of Technology, Minna, Niger State, Nigeria. The R square (R^2) value was 84.99% which is slightly lower when compared with that obtained in Fig. 4.15 below.

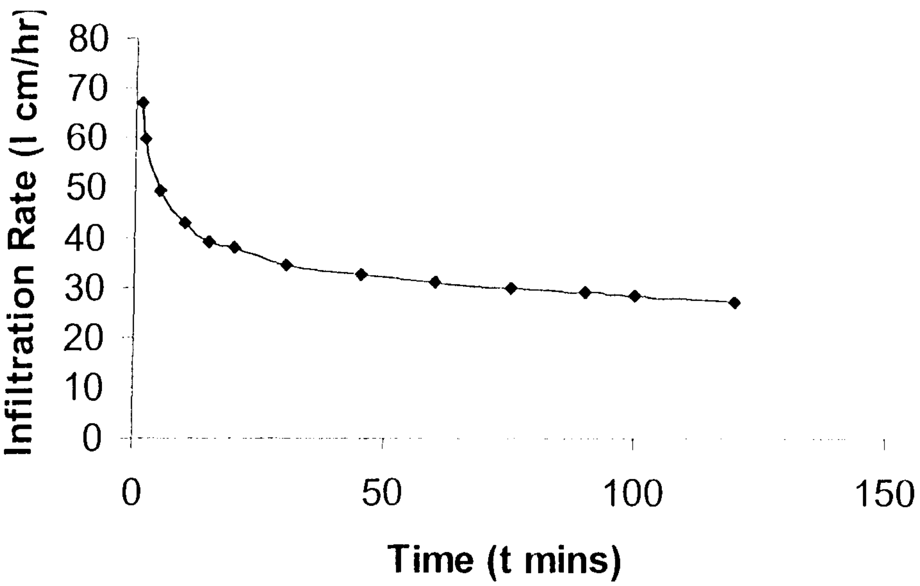

Fig. 4.1 Average infiltration rate {I(cm/hr)} against elapsed time {t(mins)} for cultivated Land (for 12 weeks)

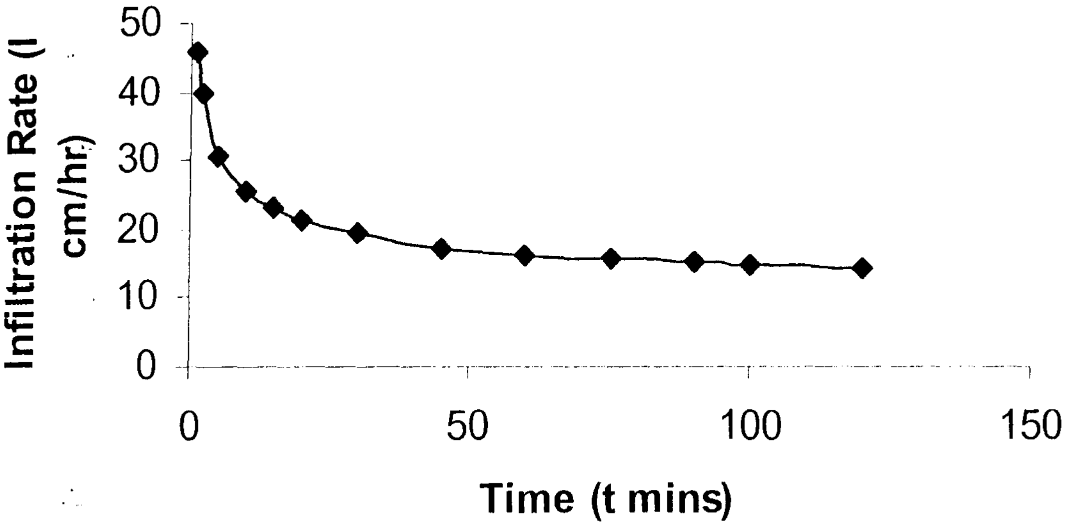

Fig .4.2 Average infiltration rates [I (cm/hr)] against elapsed time{t(mins.)} for fallowed land (for 12 weeks).

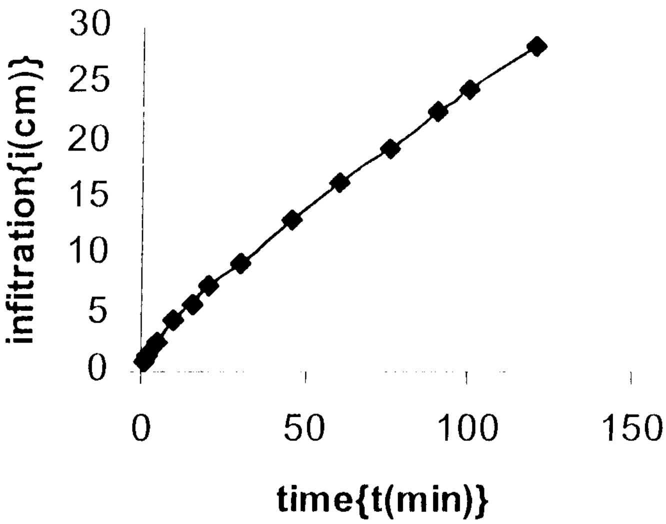

Fig. 4.3 Cumulative infiltration {i(cm)} against elapsed time {t(mins.)} for fallowed land (for 12 weeks).

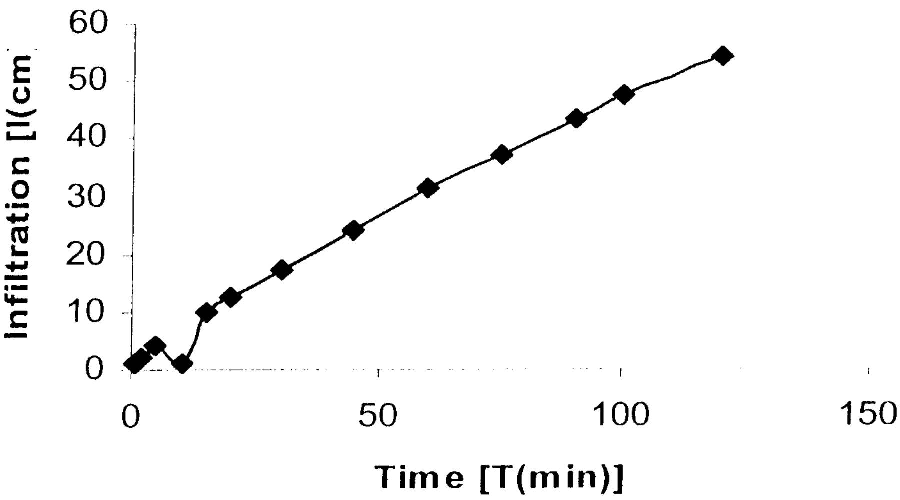

Fig . 4.4 Cumulative infiltration {i(cm)} against elapsed time {t(mins)} for cultivated land (for 12weeks).

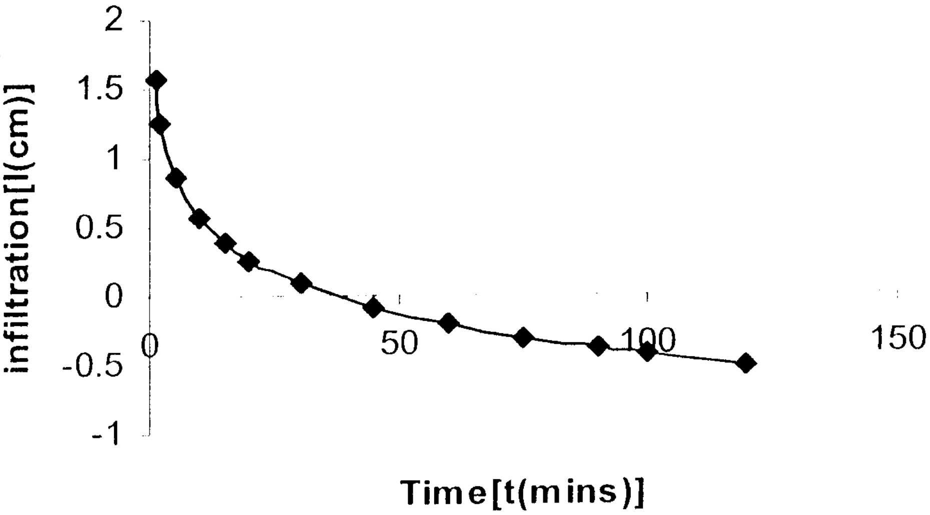

Fig.4.5 $Log(I_c-I_o)$against elapsed time {t(mins.)} using Horton's equation for cultivated land.

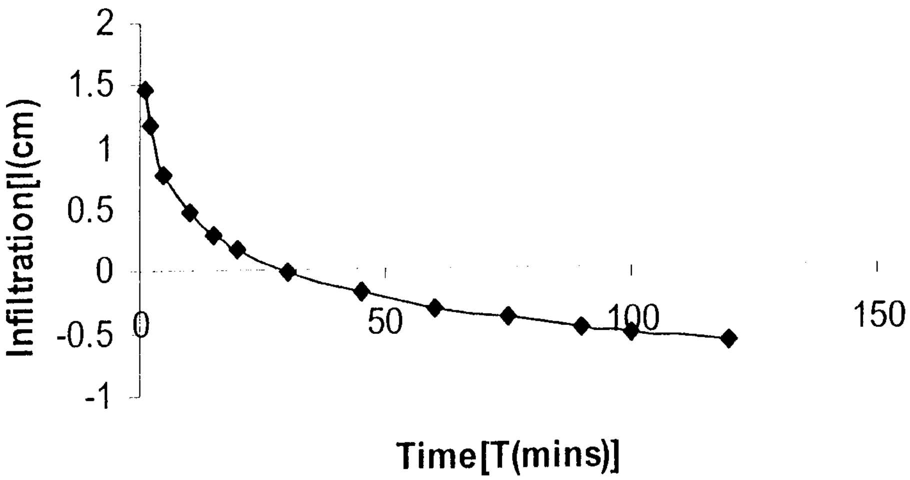

Fig.4.6 $Log(I_c-I_o)$ against elapsed time {t(mins.)} using Horton's equation for fallowed land.

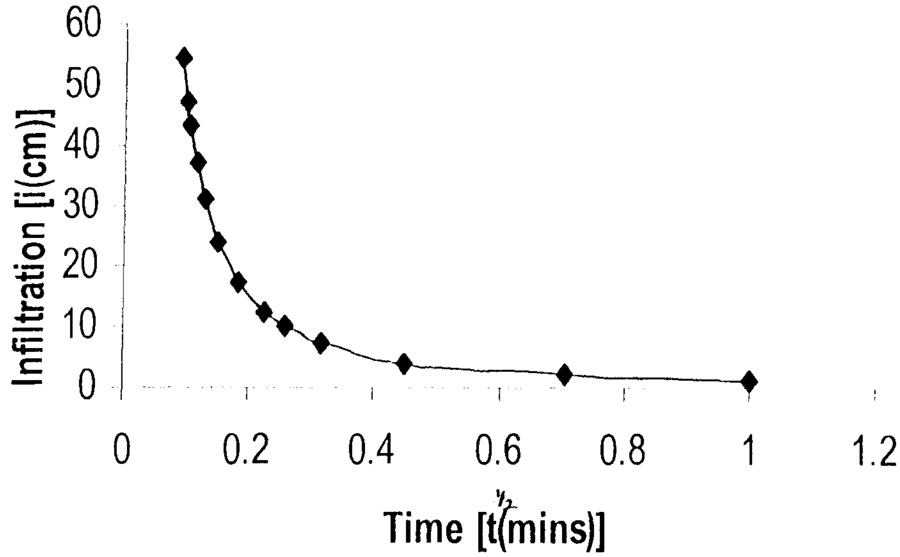

Fig. 4.7 Cumulative infiltration {i(cm)} against elapsed time{$t^{-1/2}$(mins.)} using Philip's equation for cultivated land .

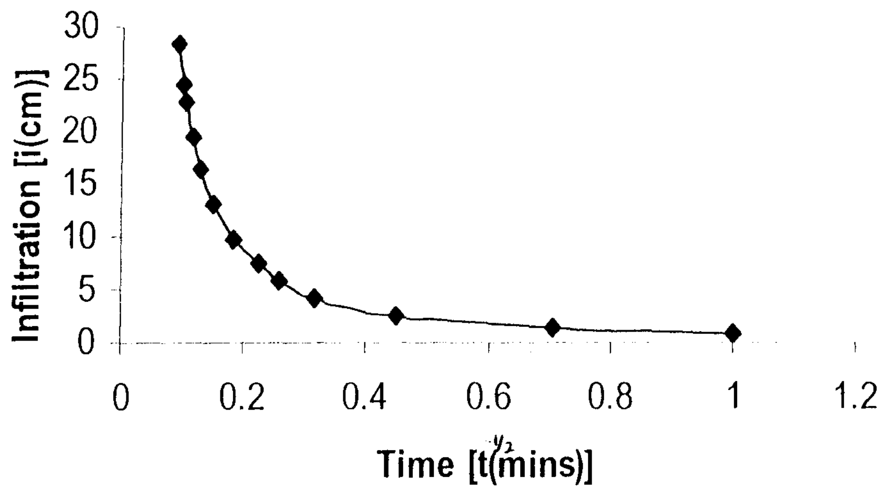

Fig. 4.8 Cumulative infiltration {i(cm)} against elapsed time {$t^{-1/2}$(mins.)} using Philip's equation for fallowed land.

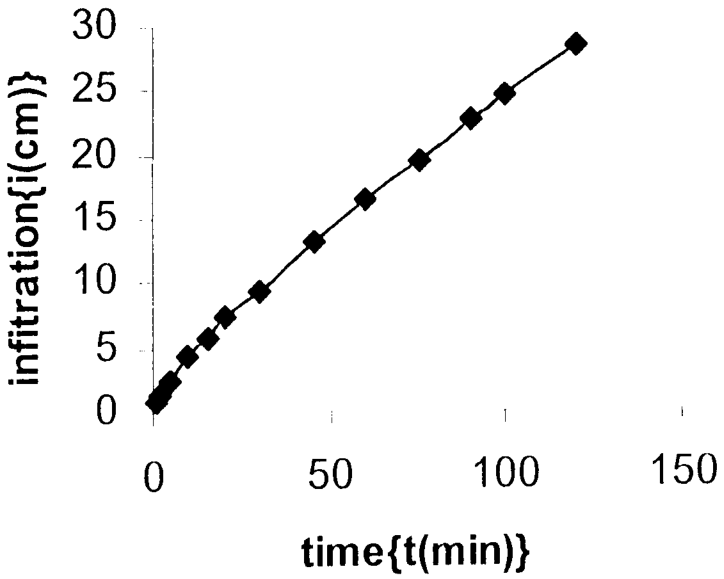

Fig.4.9 Infiltration {i(cm)} against elapsed time {t(mins.)} using Kostiakov's equation for fallowed land.

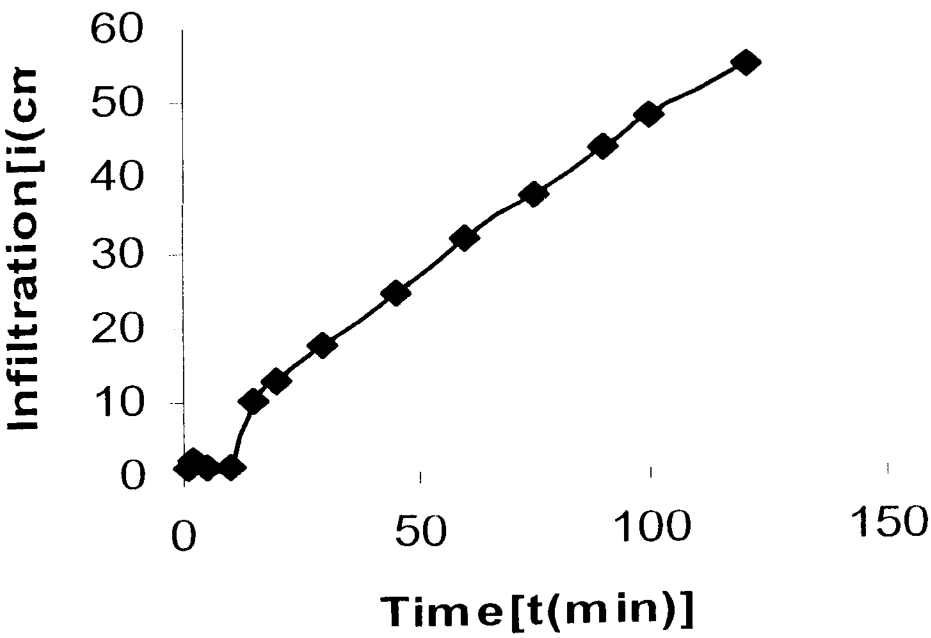

Fig.4.10 Infiltration {i(cm)} against elapsed time {t(mins.)} using Kostiakov's equation for cultivated land.

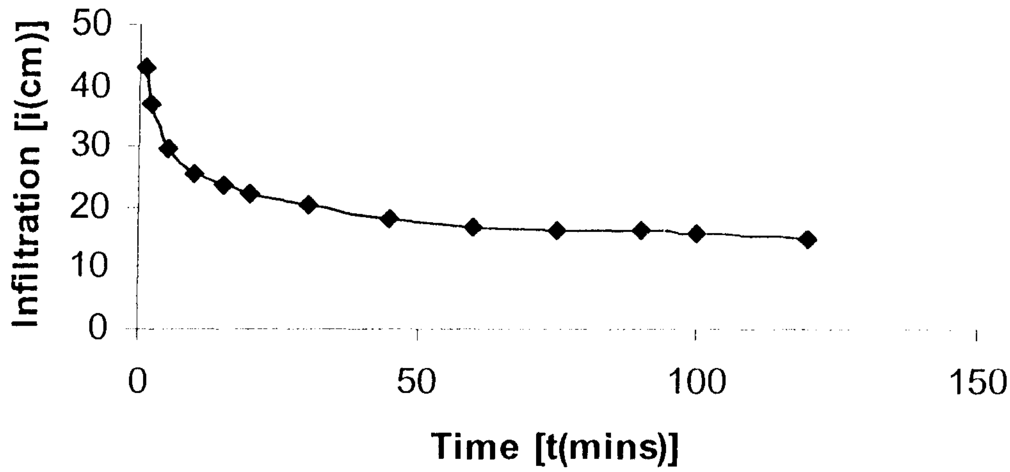

Fig.4.11 Infiltration rate {I(cm/hr)}against elapsed time {t(mins.)} for fallowed land during the wet season.

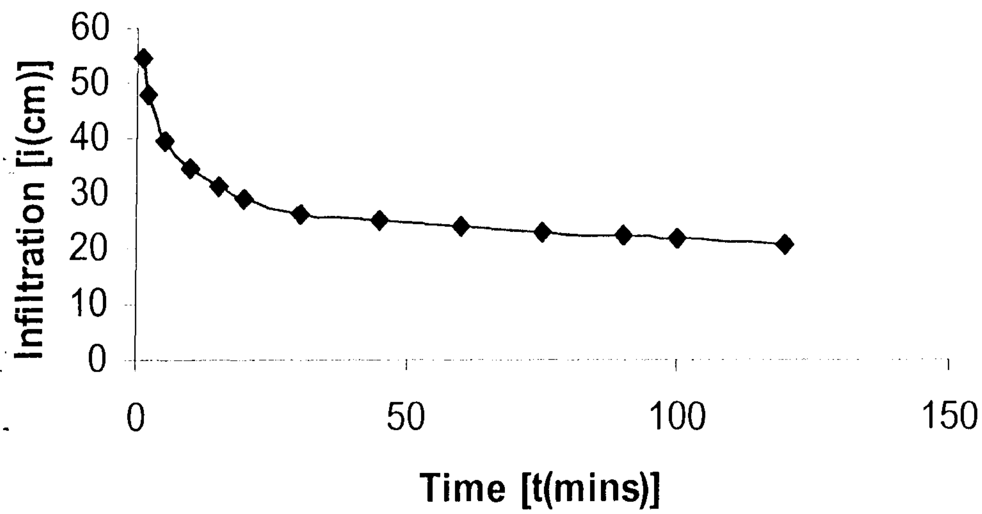

Fig. 4.12 Infiltration rate {I(cm/hr)} against elapsed time {t(mins)} for cultivated land during the wet season.

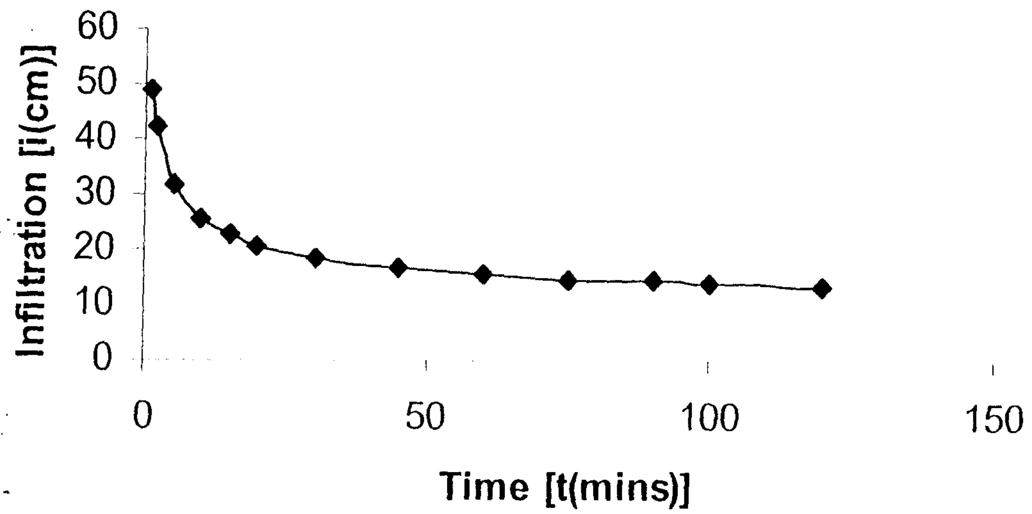

Fig.4.13 Infiltration rate {I(cm/hr)} against elapsed time {t(mins.)} for fallowed land during the dry season.

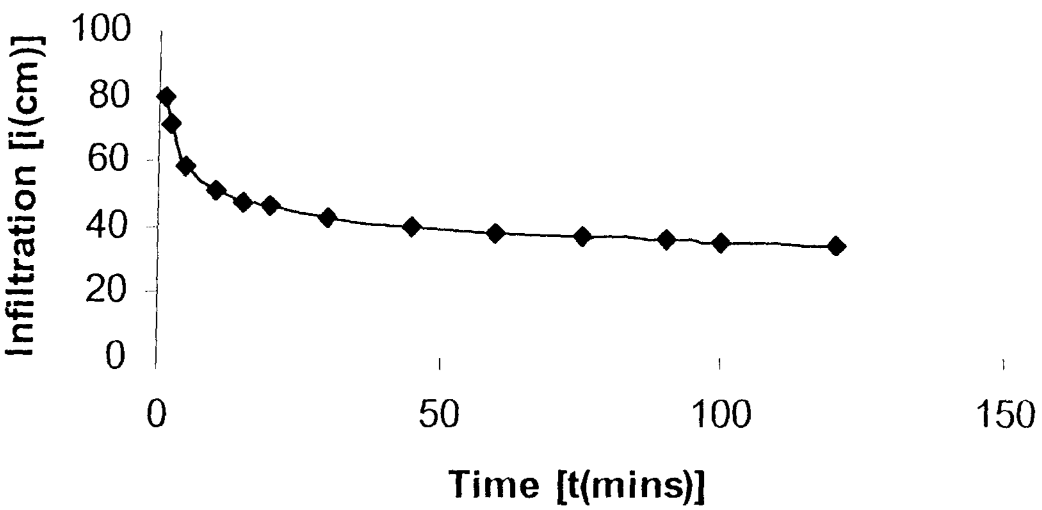

Fig.4.14 Infiltration rate {I(cm/hr)} against elapsed time {t(mins.)} for cultivated land during the dry season.

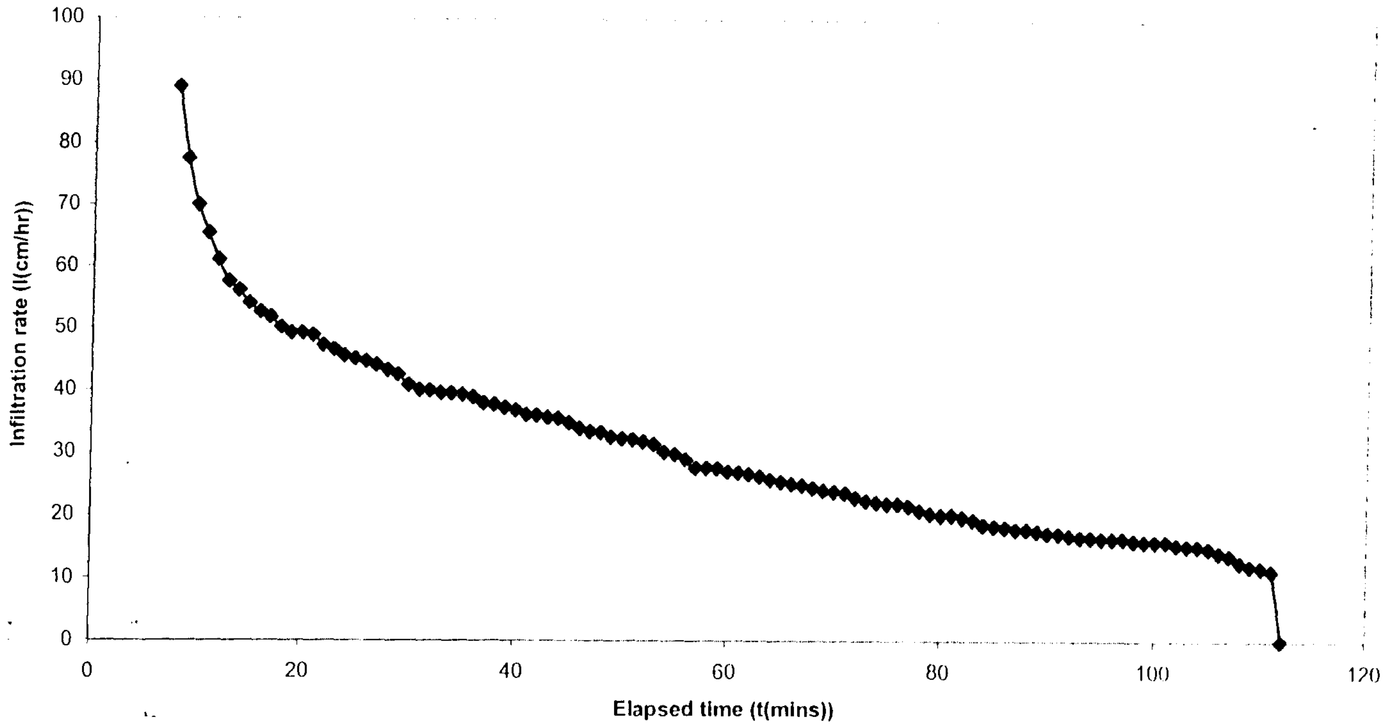

Fig. 4.15: Best fit of Infiltration rate {I(cm/hr)} against Elapsed time {t(mins)} for 12weeks

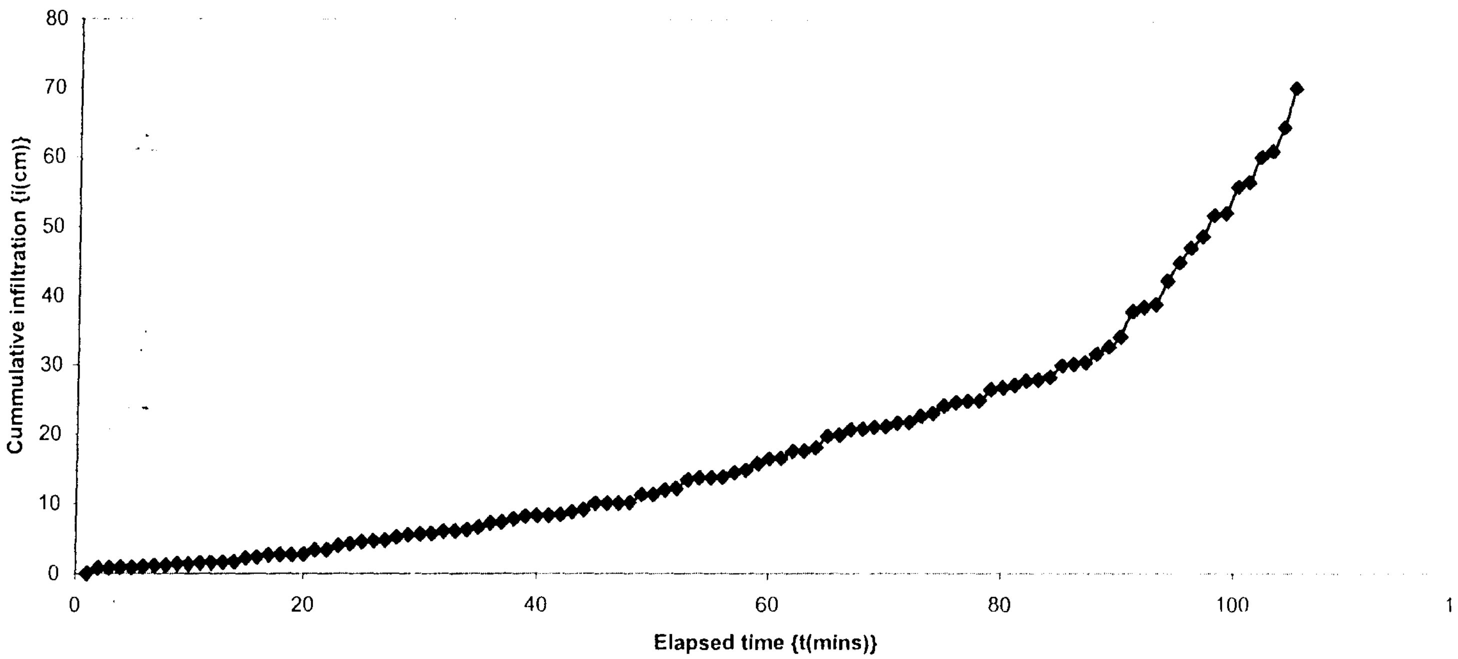

Fig. 4.16; Best fit of cumulative infiltration {i(cm)} against elapsed time {t(mins)} for 12weeks

An equation in the form of Y = MX + C was also obtained, which is given as

Y = 0.5094X - 9.04 31; where

M = slope = 0.5094

C = intercept = -9.0431

X = variable factor = time

From the above two equations it can observed that value for the intercept obtained for figure 4.15 was positive while that for figure 4.16 was negative which may due to the fact that water was being emitted/given off from the soil during the rainy season.

The graphs for the various infiltration rates carried out are shown in Appendix C. These graphs were obtained using the data in Appendix B for the various land management practice. It was discovered that the curve fitting graphs drawn under cultivated land showed similar shapes while those of the fallowed land were different which may be due to the nature of the soil, the underlay and organic matter present in the area. Though, the conditions of operation were different, the results obtained compared with Ahmed and Duru (1982) and that of Eze (2000) under similar conditions the result were found to be almost the same.

4.2 Predicting Infiltration Rate

Curve fitting was carried out as explained in section 3.5 and the chi-square/regression and least square methods were used to calculate the excepted infiltration rate data for the three equation as shown in Table 4.8 to 4.13 for the various land management practice and various seasons (that is the wet and dry season). The curve fitting methods gave an almost same figure for a given parameter in the equations considered when the calculated data was compared with the observed data. For example, when the observed data for the cumulative infiltration is compared to the calculated date for the cumulative infiltration under Kostiakov's model (Table 4.8), it shows a negligible difference between the calculated and the observed data, which makes the model more closer in predicting infiltration rate when compared to those of Philip and Horton's. It is discovered from Tables 4.8, 4.9, 4.10 and 4.11 that Philip model had a higher deviation in all cases tested which means that Kostiakov's model/equation adequately describes the field experimental data predict the infiltration rates of soils within the irrigation farm of the permanent site of the Federal University of Technology Minna, using the available information's on Tables 4.8 to 4.13. It was observed that the figures obtained for the calculated cumulative infiltration was negative under the Kostiakov's equation as shown in Tables 4.12 and 4.13. This could be due to the fact that water was been given off during the rainy season and also a clear indication that water is not required during the rainy season on the farm, instead water is given off which in turn accounts for the fadama nature of some parts of the farm.

Table 4.8: Determination Of Goodness Of Fit Of Kostiakov's Philip's And Horton's Infiltration Models Using Chi-Square Test For Cultivated Soils On The Permanent Site.

TIME	KOSTIAKOV'S MODEL			PHILIP'S MODEL			HORTON'S MODEL		
Min	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$ /E	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$ /E
0	-	-	-	-	-	-	-	-	-
1	1.12	1.12	0.0000	67.09	48.38	7.236	67.09	63.70	0.180
2	1.99	1.94	0.00129	59.68	41.78	7.669	59.68	45.52	4.405
5	4.13	4.06	0.00121	49.51	35.90	5.160	49.51	34.60	6.425
10	7015	7.13	0.00006	42.89	32.95	2.999	42.89	30.79	4.588
15	9.83	9.93	0.00101	39.01	31.64	1.717	39.01	29.75	2.882
20	12.39	12.56	0.00230	37.36	30.86	1.369	37.36	29.14	2.319
30	17.31	17.50	0.00206	34.61	29.93	0.732	34.61	28.54	1.291
45	23.79	24.39	0.01460	32.39	29.17	0.355	32.39	28.14	0.642
60	31.05	30.88	0.00094	31.08	28.72	0.194	31.08	27.94	0.353
75	37.21	37.07	0.00005	29.77	28.42	0.064	29.77	27.81	0.138
90	43.56	43.05	0.00604	29.04	28.19	0.026	29.04	27.73	0.062
100	47.30	46.93	0.00292	28.36	28.07	0.003	28.36	27.67	0.016
120	54.47	54.50	0.00002	27.33	27.87	0.010	28.36	27.63	0.0033
Total			$X^2 = 0.0325$			$X^2 = 27.534$			$X^2 = 23.3043$

Table 4.9: Determination Of Goodness Of Fit Of Kostiakov's, Philip's And Horton's Infiltration Models Using Chi-Square Test For Fallowed Soils On The On The Permanent Site.

TIME	KOSTIAKOV'S MODEL			PHILIP'S MODEL			HORTON'S MODEL		
Min	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$ /E	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$ /E	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$ /E
0	-	-	-	-	-	-	-	-	-
1	0.77	0.78	0.00013	45.99	30.51	7.854	45.99	43.84	0.105
2	1.32	1.29	0.00069	39.80	25.17	8.504	39.80	28.99	4.301
5	2.56	2.55	0.0004	30.58	20.42	5.055	30.58	20.08	5.491
10	4.28	4.30	0.00009	25.67	18.03	3.237	25.67	17.11	4.28
15	5.80	5.84	0.00027	23.21	16.97	2.287	23.21	16.22	3.118
20	7.39	7.26	0.00233	21.48	16.34	1.617	21.48	15.62	2.198
30	9.61	9.86	0.00634	19.22	15.59	8.452	19.22	15.13	1.106
45	13.06	13.41	0.00913	17.30	14.98	0.359	17.30	14.80	0.422
60	16.29	16.68	0.00912	16.21	14.62	0.173	16.21	14.63	0.171
75	19.42	19.75	0.00551	15.53	14.37	0.094	15.53	14.54	0.0674
90	22.64	22.68	0.00007	15.10	14.18	0.060	15.10	14.47	0.0274
100	24.53	24.57	0.00007	14.74	14.08	0.031	14.74	14.44	0.0062
120	- 28.29	28.22	0.00017	14.14	13.93	0.0032	14.14	14.39	0.0043
Total			X^2 = 0.03395			X^2 37.726			X^2 21.030

Table 4.10: Determination Of Goodness Of Fit Of Kostiakov's, Philip's And Horton's Infiltration Models Using Chi-Square Test For Cultivated Soils In The Dry Seasons On The Permanent Site.

TIME	KOSTIAKOV'S MODEL			PHILIP'S MODEL			HORTON'S MODEL		
Min	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$ /E	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$/E	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2$ /E
0	-	-	-	-	-	-	-	-	-
1	1.33	1.35	0.0003	79.50	14.419	293.7469	79.50	79.40	0.00010
2	2.38	2.32	0.0016	71.50	13.440	250.8157	71.50	79.31	0.7691
5	4.94	4.87	0.0010	58.55	12.571	168.3898	58.58	79.00	5.2782
10	8.56	8.60	0.0002	51.35	12.133	126.7595	51.35	78.55	9.4187
15	11.73	12.02	0.0070	46.90	11.939	102.3764	46.90	78.09	0.0046
20	15.22	15.25	0.00006	45.90	11.824	98.2048	45.90	77.60	12.9496
30	21.45	21.35	0.00047	42.86	11.686	83.1609	42.86	76.72	14.9439
45	28.98	29.89	0.0277	39.98	11.574	69.7167	39.98	75.39	16.6318
60	38.42	37.97	0.00533	38.42	11.508	62.9349	38.42	74.10	17.1803
75	46.00	45.72	0.00171	36.80	11.462	56.0124	36.80	72.84	17.83.19
90	53.98	53.21	0.0111	35.99	11.428	52.7907	35.99	71.65	17.7479
100	58.35	58.09	0.00116	34.99	11.410	48.7306	34.99	70.86	18.1577
120	67.45	67.61	0.00038	33.91	11.381	44.5968	33.91	69.34	18.1033
Total			X^2 = 0.0563			X^2 = 1458.2361			X^2 = 149.0171

Table 4.11: Determination Of Goodness Of Fit Of Kostiakov's, Philip's And Horton's Infiltration Models Using Chi-Square Test For Fallowed Soils In The Dry Seasons On The Permanent Farm.

TIME	KOSTIAKOV'S MODEL			PHILIP'S MODEL			HORTON'S MODEL		
Min	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$
0	-	-	-	-	-	-	-	-	-
1	0.82	0.7499	0.0066	49.00	5.702	328.782	49.00	48.88	0.0003
2	10.42	1.2676	0.0183	42.50	5.271	262.948	42.50	48.76	0.804
5	2.65	2.5569	0.0034	31.58	4.888	145.758	31.58	48.42	5.857
10	4.30	4.3619	0.0009	25.80	4.695	94.871	25.80	47.84	10.154
15	5.72	5.9659	0.0101	22.87	4.609	72.351	22.87	47.27	12.595
20	6.93	7.4522	0.0366	20.80	4.559	57.857	20.80	46.72	14.380
30	9.15	10.1989	0.1079	18.28	4.498	42.228	18.28	45.63	16.393
45	12.56	13.9611	0.1406	16.75	4.449	34.011	16.75	44.07	16.936
60	15.61	17.4468	0.1934	15.61	4.419	28.341	15.61	42.58	17.083
75	36.38	20.7404	11.7933	14.34	4.399	22.465	14.34	41.17	17.485
90	21.33	23.885	0.2740	14.22	4.384	22.068	14.22	39.82	16.458
100	23.09	25.9215	0.3093	13.86	4.376	20.554	13.86	38.96	16.171
120	26.54	29.8569	0.3685	13.27	4.364	18.175	13.27	37.32	15.498
Total			**X^2 =13.2629**			**X^2 = 1150.409**			**X^2 = 159.814**

Table 4.12: Determination Of Goodness Of Fit Of Kostiakov's, Philip's And Horton's Infiltration Models Using Chi-Square Test For Cultivated Soils In The Wet Seasons On The Permanent Site Farm.

IME	KOSTIAKOV'S MODEL			PHILIP'S MODEL			HORTON'S MODEL		
Min	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$
0	-	-	-	-	-	-	-	-	-
1	0.91	0.5104	0.3129	54.68	8.517	250.208	54.68	54.59	0.0001
2	1.60	-0.5859	-8.1488	47.85	7.917	201.420	47.85	54.52	0.8160
5	3.32	-3.4598	-13.2856	39.42	7.385	138.963	39.42	54.28	4.0682
10	5.74	-7.6755	-23.4481	34.44	7.117	104.896	34.44	53.88	7.0139
15	7.94	-11.5438	-32.8851	31.12	6.998	83.148	31.12	53.48	9.3487
20	9.56	-15.2025	-40.3342	28.83	6.927	69.257	28.83	53.09	11.0858
30	13.18	-22.1093	-56.3263	26.35	6.843	55.608	26.35	53.32	13.4180
45	18.61	-31.8041	-79.9136	24.81	6.774	48.021	24.81	51.21	13.6098
60	23.69	-40.9735	-102.0506	23.73	6.734	42.896	23.73	50.13	13.9031
75	28.43	-49.7711	-122.8707	22.74	6.706	38.337	22.74	49.09	14.1439
90	33.15	-58.2833	-143.4381	22.10	6.685	35.546	22.10	48.09	14.0462
100	36.26	-63.8276	-156.9466	21.74	6.674	34.010	21.74	47.44	13.9226
120	41.49	-74.6550	-180.6933	20.75	6.656	29.844	20.75	46.19	14.0116
Total			**X^2 = -960.0281**			**X^2 = 1132.154**			**X^2 = 129.3879**

Table 4.13: Determination Of Goodness Of Fit Of Kostiakov's, Philip's And Horton's Infiltration Models Using Chi-Square Test For Fallowed Soils In The Wet Seasons On The Permanent Site Farm.

TIME	KOSTIAKOV'S MODEL			PHILIP'S MODEL			HORTON'S MODEL		
Min	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$	Observed (0) i (cm)	Calculated (E) i (cm)	$(0-E)^2/E$
0	-	-	-	-	-	-	-	-	-
1	0.72	-3.8754	-5.4542	42.98	5.302	267.754	42.98	42.91	0.00011
2	1.22	-8.4969	-11.1121	37.09	4.882	212.486	37.09	42.83	0.7693
5	4.93	-23.9077	-34.7843	29.58	4.509	139.400	29.58	42.62	3.9897
10	4.26	-52.2332	-61.1006	25.55	4.320	104.332	25.55	42.26	6.6073
15	5.89	-82.4909	-94.6915	23.55	4.238	88.002	23.55	41.91	8.0432
20	7.85	-114.0759	-130.3161	22.16	4.189	77.096	22.16	41.56	9.0558
30	10.10	-180.1370	-200.9093	20.17	4.190	62.296	20.17	40.88	10.4918
45	13.56	-284.4438	-312.2102	17.86	4.082	46.505	17.86	39.89	12.1665
60	16.96	-393.3261	-427.9774	16.81	4.053	40.153	16.81	38.94	12.5767
75	20.47	-505.7424	-465.6309	16.36	4.034	37.662	16.36	38.03	12.3479
90	23.95	-621.0576	-669.8812	15.99	4.019	35.657	15.09	37.15	12.0524
100	25.97	-699.3266	-752.2310	15.63	4.012	33.644	15.63	36.58	11.9984
120	30.04	-858.7786	-919.9094	15.02	3.999	30.373	15.02	35.49	11.8067
Total			**X^2 = -4076.2344**			**X^2 = 1175.350**			**X^2 = 111.9058**

Table 4.14 Estimated Soil Parameters For Infiltration Equations For Curve Fitting For 12 Weeks.

Land Use Practice	Estimated Soil Parameter (Kostiakov's)	Estimated Soil Parameter (Philip's)	Estimated Soil Parameter (Horton's)
Cultivated Soil	M =1.069 n = 0.821 b = 0.054	A = 25.811 S = 45.131	I_o = 67.09 I_c = 27.33 M = 0.006 Ø = 2.98
Fallowed Soil	M = 0.741 n = 0.760 b = 0.034	A = 12.259 S = 26.506	I_o = 45.99 I_c = 14.14 M = 0.0081 Ø = 2.98^{-3}

Table 4.15 Estimated Soil Parameters For Infiltration Equations For Curve Fitting Equations For Dry And Wet Season

Land Use Practice	Estimated Soil Parameter (Kostiakov's)		Estimated Soil Parameter (Philip's)		Estimated Soil Parameter (Horton's)	
	Dry	Wet	Dry	Wet	Dry	Wet
Cultivated Soil	M = 1.2454 n = 0.834 b = 0.102	M = -1.3970 n = 0.8363 b = 1.9074	A = 6.6865 S = 11.074	A = 4.0961 S = 6.4691	I_o = 79.50 M = 0.0057 K 0.0021	I_o = 54.68 I_c 20.75 M -0.0065
Fallowed Soil	M = 0.7269 n = 0.7759 b = 0.023	M = -3.9057 n = 1.1265 b = 0.0303	A = 2.9456 S = 4.2292	A = 2.8682 S = 3.8257	I_o = 49.00 I_c = 13.27 M = -0.009 K = -0.003	I_o 42.98 I_c 15.02 M -0.0072 K -0.0026

The result is similar to those of Eze (2000), Wuddirira (1998) and Ahmed and Duru (1985) who used similar models for the soil of Minna Niger State and Samaru in Zaria (Kaduna State) respectively. The Kostiakov's model is presented by the expression:

$$I = Mt^n + b$$

Where I = accumulated infiltration (cm)

t = elapsed time since infiltration started (minutes).

M, n and b = constants.

The parameters M, n and b have been evaluated for the tested soils by the method of average as suggested by Davis (1943). Differences were observed in the values for a particular area (within the same area or location), which may be because of the soil heterogeneity and variations in the surface conditions. It was discovered that sandy loam soil upon wetting started with very high values from 114 cm/hr in the first few minutes to 43.35 cm/hr at the end of the time of 2 hours for sites 21,22,23 and 24 all under the same month of May and a gradual reduction in the rate of infiltration was observed in site 26, though relatively high also.

The end values of each data for the infiltration rate in centimeter per hour was grouped according to the classification of the American society of civil engineers found under the manual of engineering practice, no 28 (ASCE, 1949). These results were compared with that obtained from the classification based on the soil textural triangle in Table 4.3. A clear difference between the two was observed, except for a few cases where the classification corresponds, for example site 6 which implies that the hydrological grouping method based on infiltration rate be studied over a long period of time.

Table 4.16 shows typical infiltration rate values according to ASCE (1949) used for soil grouping. The corresponding cover factor for savannah region was selected to be 6.985 (ASCE, 1949). On multiplying this cover factor with values in Table 4.16 resulted in values showed in Table 4.17. These set of values where then used to classify the soil in the study area based on the measured soil intake characteristics (infiltration rate).

Table 4.16 Typical infiltration rate {I (cm/hr)} values with corresponding soils

Soil group	I (cm/hr)
High (sandy soils)	1.27 – 2.54
Intermediate (loam, clay, silt)	0.254 – 1.27
Low (clay, clay loam)	0.0254 – 0.254

Source: ASCE (1949)

Table 4.17 Typical infiltration rate {I (cm/hr)} values after it were multiplied with a cover factor of 6.985 with the corresponding soils.

Soil group	I (cm/hr)
High (sandy soils)	8.87 – 17.742
Intermediate (loam, clay, silt)	1.774 – 8.87
Low (clay, clay loam)	0.1774 – 1.774

It was observed that site 23 had a very high infiltration rate, which implies that the area is predominantly sandy soil. Sites 1,2,9 and 21 closely followed by site 23, they also have a relatively high infiltration rate though not as high as in site 23.

The rest of the site were predominantly known to have low rate of infiltration, which implies that they were mainly sandy, loam, clay and silt soils as shown in Table 4.11, which does not completely correspond with the classification of Adesoye and partners who carried out the soil survey of University permanent site (Fig. 4.15). From the map they produced, clear differences were observed with the classification, which was carried out using the infiltration rate method. For example, the area classified as clay soils (B) on the Adesoye soil classification map when compared with the map obtained based on the infiltration rates showed that the area was more of sandy soil than clay soil. Fig. 4.19 shows some of the distances of the sites from the starting point of bearing A, B and C, the distances calculated and the respective benchmarks are presented in Appendix D.

TABLE 4.18 Soil Classification Based On The End Data Of Infiltration Rates.

SITE	INFILTRATION RATE (CM/HR).	CLASSIFICATION	TYPE OF LAND
1	44.70	High	Cultivated
2	46.20	High	Fallowed
3.	36.75	High	Cultivated
4.	29.00	High	Fallowed
5.	10.85	High	Cultivated
6.	6.25	Intermediate	Fallowed
7.	2.40	Intermediate	Cultivated
8.	6.15	Intermediate	Fallowed
9.	49.55	High	Cultivated
10	9.95	High	Fallowed
11	39.95	High	Cultivated
12	20.60	High	Fallowed
13.	7.90	Intermediate	Cultivated
14	9.60	High	Fallowed
15	10.00	High	Cultivated
16	20.35	High	Fallowed
17	11.35	High	Cultivated
18	8.60	Intermediate	Fallowed
19	21.30	High	Cultivated
20	4.30	Intermediate	Fallowed
21	43.35	High	Cultivated
22	32.05	High	Fallowed
23	62.70	(Very) High	Cultivated
24.	30.00	High	Fallowed
25	19.10	High	Cultivated
26	39.35	High	Fallowed
27	6.65	Intermediate	Cultivated
28	6.70	Intermediate	Fallowed
29	27.45	High	Cultivated

30	17.15	High	Fallowed
31	34.20	High	Cultivated
32	33.05	High	Fallowed
33	4.50	Intermediate	Cultivated
34	6.15	Intermediate	Fallowed
35	4.90	Intermediate	Cultivated
36	6.30	Intermediate	Fallowed
37	37.75	High	Cultivated
38	27.40	High	Fallowed
39	24.90	High	Cultivated
40	26.45	High	Fallowed
41	22.55	High	Cultivated
42	25.00	High	Fallowed
43	24.15	High	Cultivated
44	18.30	High	Fallowed
45	23.90	High	Cultivated
46	7.70	Intermediate	Fallowed
47	16.10	High	Cultivated
48	12.25	High	Fallowed
49	18.45	High	Cultivated
50	10.75	High	Fallowed
51	12.50	High	Cultivated
52	5.80	Intermediate	Fallowed
53	7.35	Intermediate	Cultivated
54	23.10	High	Fallowed
55	15.30	High	Cultivated
56	18.55	High	Fallowed
57	7.80	Intermediate	Cultivated
58	24.60	High	Fallowed
59	10.70	High	Cultivated
60	7.90	Intermediate	Fallowed

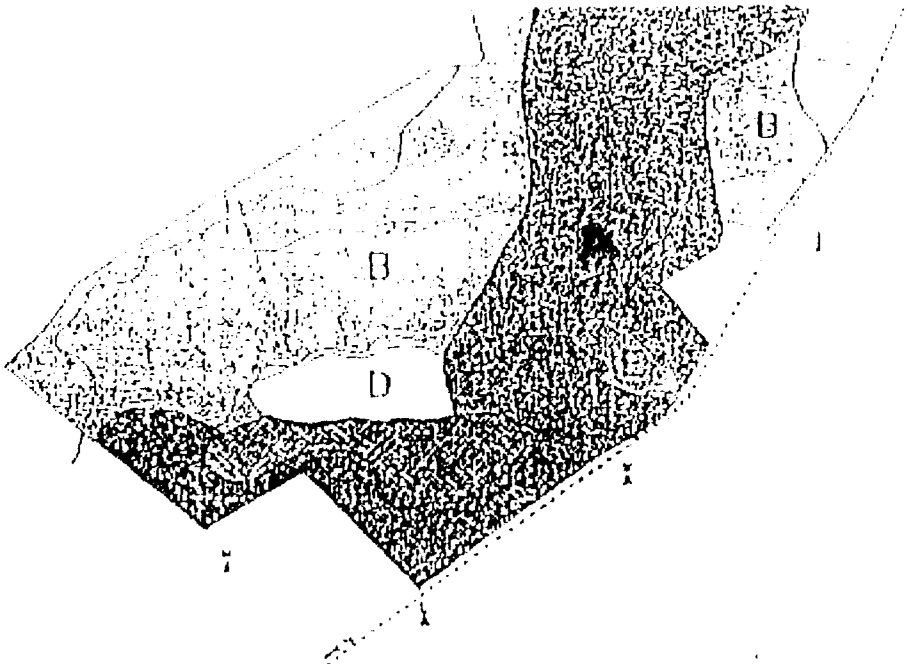

Fig. 4.15: Subsoil classification map according to Adesoye and Partners (1994)

A	Clayey Silty Soils
B	Clay Soils
C	Soft Clayey Soils
D	Silty or Clayey Gravel or Sand
E	Hills

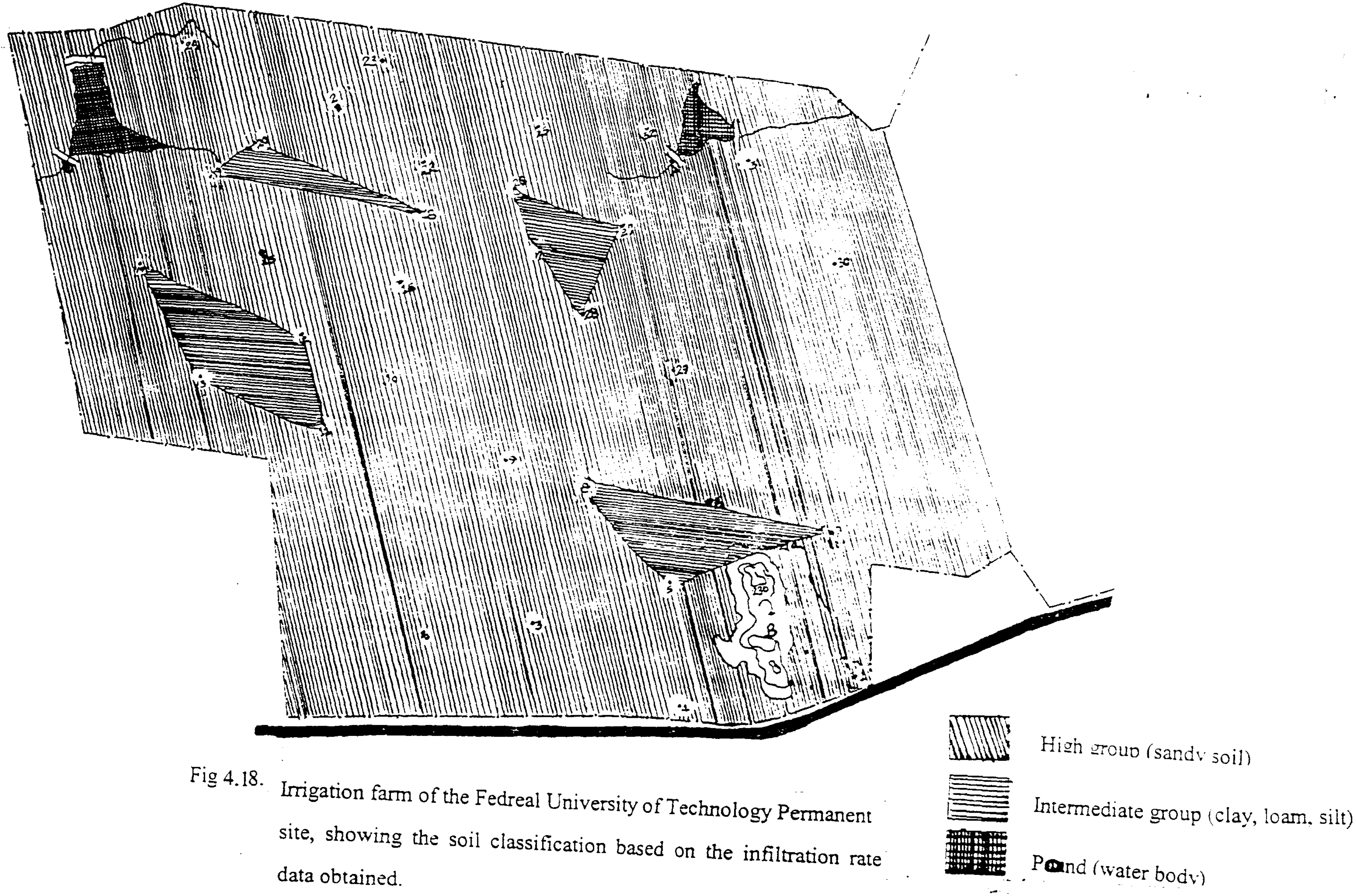

Fig 4.18. Irrigation farm of the Fedreal University of Technology Permanent site, showing the soil classification based on the infiltration rate data obtained.

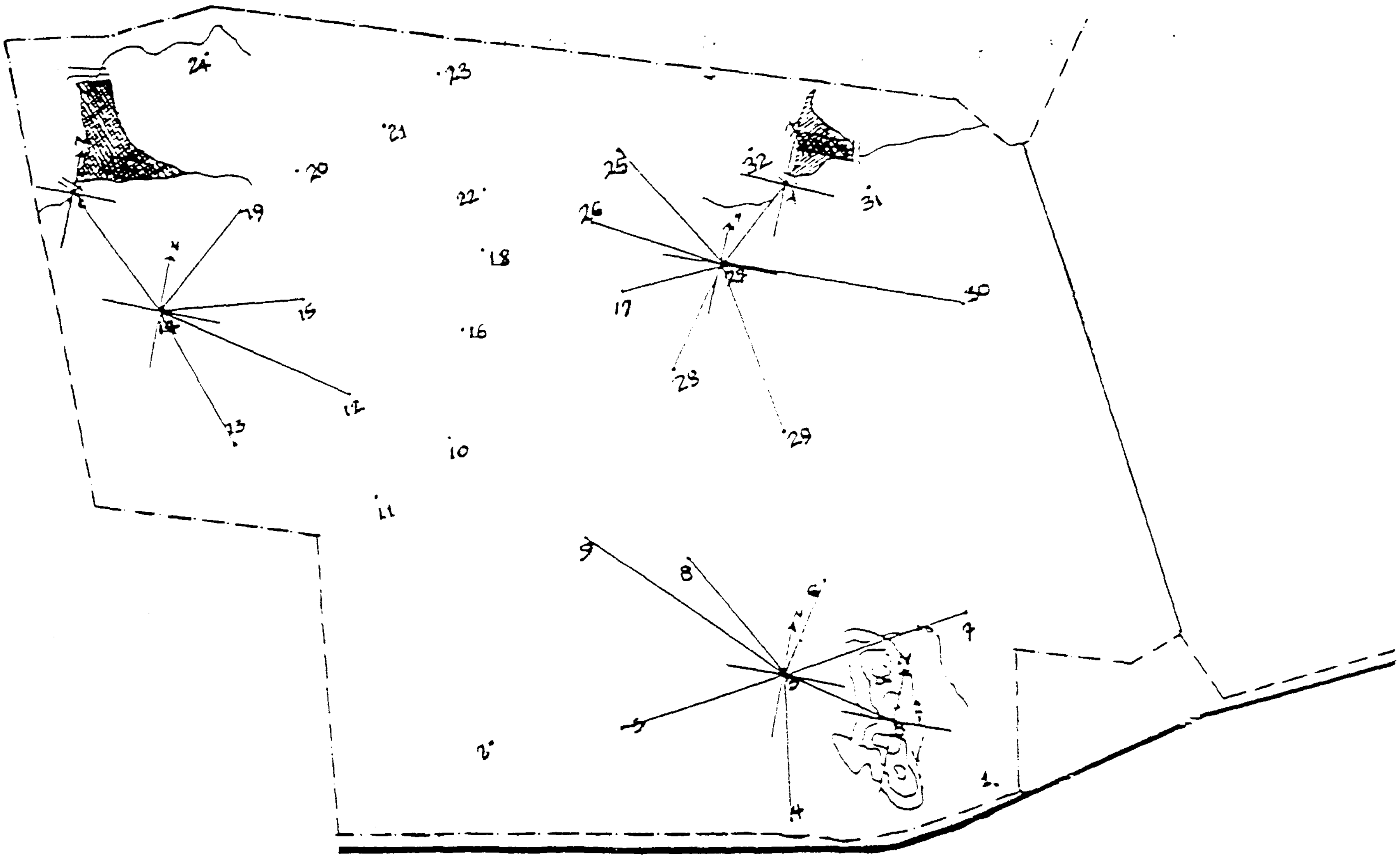

Fig 4.19. Distance of some of the sites on the irrigation farm of the Federal University of Technology, Permanent site, Minna.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

The aim of this study was to determine the infiltration rates of some selected soil under various management practices and to classify the soils according to hydrological groups based on infiltration rate. Also the aim is to predict relative infiltration rates of some time dependent infiltration equations and determine which equation that best fits the permanent site of the University farm. This study involved the use of double-ring infiltrometer to measure infiltration rates of soils left to fallow and those under cultivation. Some factors affecting infiltration includes the texture, management practice and bulk density the most important. Light textured soil were observed to have a higher infiltration rates than the heavier textured soils which is due to the large conducting pores in sandy soil. Cultivated lands normally have lower values of infiltration rates than those of fallowed soils. But the presence of hard capping over shadow the effect of fallowed land: a soil with hard capping can have lower infiltration rate in a cultivated soil. Surface bulk density is directly proportional to infiltration rate since it is related to soil texture.

5.2 Conclusion

It was discovered that

(i) The infiltration rates of the tested soil range between 5.80-46.20 cm/hr. This infiltration capacity can become stable over a long period of time say eight years (Serrano, 1990).

(ii) Based on the end data obtained from the infiltration rates, classification of the various soils on the irrigation farm of the Federal University of Technology Minna was made possible. The soil grouping of the tested soils of the irrigation farm was carried out with the soils been divided into the high infiltration rate (sandy soils), the intermediate infiltration rate (Loam, clay and silt) and the low infiltration rate (clay and clay Loam).

(iii) Kostiakov's equation showed a better performance over those of Philip and Horton's equation which is known to have the following parameters for cultivated soils of the irrigation farm site, M=1.069, n=0.821 and b=0.054 while for the fallowed soils of the same location as M=0.741, n=0.760 and b=0.034, based on there values, a higher degree of calculated infiltration data is observed in the case of Kostiakov than those of Horton and Philip's equation.

(iv) The equation that best describe the irrigation farm of the Federal University Technology Minna, Niger State, Nigeria; is given as Y=0.4881x + 1.2192; while that which describe the graph of cumulative infiltration against elapsed time {t(min)} as Y=0.5094x-9.0431 for the same area; where x is the time.

(v) The infiltration tests performed during the dry season are preferable, as tests performed in the wet season are unlikely to reflect the stable soil characteristics which shows the influence of antecedent soil water content on the measured infiltration capacities.

5.3 Recommendation

It is recommended that Kostiakov's equation is appropriate for the tested soils and other similar soils of the Federal University of Technology, Minna. The usefulness of this infiltration model equation can be used to design and carefully plan irrigation projects on this part of the campus. A theoretically derived equation may have physical significance but the assumptions made could cause serious deviation from field conditions. Secondly, the application of Kostiakov's equation is best applied to irrigation works where there is ponding and is therefore best for border and basin irrigation methods.

Thirdly, the infiltration grouping carried out is tentative because the data is insufficient for comprehensive soil grouping in the guinea Savannah zone. The best would have been to collect data from other parts of this zone for the adequate grouping. The soils tested have been put into three different infiltration groups. Any other soil not tested can be put into any of the groups to which its description best fits.

Finally, it is recommended that similar work should be carried out in other part the guinea savannah zone where such work has not been done.

REFERENCE

ASCE, (1949). Manuel of Engineering Practices No. 28 In Hydrology Handbook. John Wileys, Washington D.C

Ahmed, A. (1982). Infiltration rates and related soil parameters for some selected Samaru Soils. Unpublished M.Sc Thesis, A.B.U Zaria. 99PP.

Ahmed, A. and Duru, J.O., (1985). Predicting infiltration rates and determining Hydrologic grouping of Soils near Samaru, Kaduna State, Nigeria. Samaru Journal Agric. Res. 3(1 and 2): 51 – 60 PP

Bambe, C.T., (1995). Water characteristic of Soil in selected Mechanized farms in Niger State. Unpublished B. Eng (Project),Report.Federal University of Technology, Minna. 98 PP

Baver, L.D., Gardner, W.H. and Gardner W.R. (1972). Soil Physics. New York John Wiley and Sons, 365 – 37-376 pp

Blake, G.R and Hartge, K.H., (1986). Bulk density 363 – 375pp. In a Klute (edition) methods of Soil Analysis Par Agronomy 9. ASA and SSSA Madison, WI.

Brady, N.C., (1984). The nature and properties of soils (9th edition). Macmillan, New York . 707pp.

Clark, R.D., (1974) Mathematical models in hydrology. symposium of Warsaw, July, 1971. IAHS Publication NO. 100, IAHA UNESCO – INNO.

Davis, D.S., (1943) Emperical Equations and nomography. Soil Sci. Soc. 108: 137 – 142pp

Duley, F.L. and Russel, J.G., (1939). The use of crop residue for soil and moiture conservation. J. Amer Soc. Agron. 31:703-709pp.

Duley, F.L. and Kelly, S., (1939). The effect of soil type, slope and surface conditions on intake of water. Nebraska University Bull. 112-156pp

Dixon, R.M. and Perterson, A.E., (1971). Water infiltration control: a channel system concept. Soil Sci Soc. Am. 35: 968-973.

Eulers, W., (1975). Observation of earthworm channels and infiltration on tilled and untilled loss soil Soc. Sci. 119:242-249pp

Eze, P.C. (2000). Infiltration rates of soils as influenced by Land use management in the Nigeria Guinea Savanna. Soil Science Department, Federal University of Technology, Minna, Nigeria.(Unpublished thesis). 62pp.

Greeen, W. H.and Ampt,G.,(1911). Studies of Soil Physics, Part I- The flow of air and water through soils. J. Agr. Sci. 4:1-24.

Gumbs, F.A., and Warkentin, B.P., (1972). The effect of bulk density and initial water content on infiltration in dry soil samples. Soil Sci. Soc. Am. Proc. 36: 720 – 724pp

Hillel, D., (1971). Soil and Water-Physical Properties and processes. Academic Press. New York 74pp

Hillel, D. and Gardner, W.R., (1969).Steady infiltration in crust topped profiles.Soil Sci. Soc. 108: 137-142pp

Horton. R.E., (1933). The role of infiltration in hydrological cycle. Trans. Am. Geo. Union 14:446 – 460pp

Horton R.E., (1940). An approach towards physical interpretation of infiltration capacity. Soil Sci. Soc. Am. Proc. 5: 399-417pp.

Hopp, H. and Slater, C.S., (1948). Influence of earthworm on soil productivity. Soil Sci. 66:421-428pp.

Hottan, H.N., (1961). Concept of infiltration estimates in watershed engineering. USDA – ARS 41-51, 55pp.

Hurberty, M.R. and Pillsbury, A.F., (1941). Factors affecting infiltration rates into California Soils. Trans Am. Geophy. Union 22: 686-697pp.

Jensen, M.E., Swarner, L.R. and Phelan, J.T., (1987). Improving Irrigation efficiencies. 1120-1142pp. In R.M. Hag and T.W.

Kostiakov. A.N., (1932). The dynamics of the coefficients water percolation in soils and the necessity for studying in from a dynamic point of view for purpose of amelioration. Trans. 6th Comm. Inter. Soil Sci. Soc. Russia, Part A. 17-21pp

Lal, R., De Vleeschanwer, D and Ngauje, R.M., (1980). Changes in properties of a newly cleared Tropical ALFBOL as affected by mulching. Soil Sci. Am. J. 44: 827-833pp

Lawes, D.A., (1966). Rainfall conservation and the yields of sorghum and groundnuts in Nigeria. Samaru. Res. Bull. NO. 70.

Lauritzen, C.W., and Stoltenberg, N.I., (1940). Some factors which influence infiltration and its measurements in Housten Black Clay. J. Amer. Soc. Agron. 32:853-866pp

Lewis, M.R. and Powers, W.L., (1963). Study of factors affecting infiltration. Soil Sci. Am. Proc. 3: 334-338pp.

Mannering, J.V. and Mayer, L.D., (1963). The effect of infiltration of various surface mulch on infiltration and erosion. Soil Sci. Soc. Am Proc. 30:101-105pp

Marshal, T.J. and Holmes, J.W., (1988). Soil physics (2nd edition). John Wiley's and Sons, New York. 333pp.

Mbagwu, J.S.C., (1987). Effects of land use on the hydrological properties of a south-eastern Nigeria Soil, Beitrage trop. Landwirtsch veterinarmed, 25:37-382pp.

Mbagwu, J.S.C, (1990). Mulch and tillapc effects on water transmission characteristics of an ultisol and pedologic 40: 155-168pp.

Michael, A.M., (1992). Irrigation: Theory and Practice (2nd edition), Vikas Publishing house, New Delhi, India. 740 pp.

Miller, D.E. and Gardner, W.H., (1962). Water infiltration into stratified soil, Soil Sci. Soc. Am. Proc. 37: 681-68pp.

Musgrave, [illegible]W., (1955). How much of the rain water enters the ground? USDA. [illegible]k of Agriculture 151-159pp.

Parker, [illegible] and Jenny, H., (1945). Water infiltration and related Soil properties affected by cultivation and organic fertilizers. Soil Sci. 60: 353-376pp.

Philip, J.R., (1957). The theory of infiltration: 5. the influence of the initial moisture content. Soil Sci. 84: 329-339 pp.

Philip, J.R., (1954). An infiltration equation with physical significance Soil Sci. 77: 153-157pp

Philip, J.R., (1957). The theory of infiltration: 4 sorptivity and algebraic infiltration equations. Soil Sci. 84:257-264

Philip, J.R., (1969). The theory of infiltration for sorptivity and algebric Infiltration entry into Rumania Sandy Loam Soil Sci. 78:211 – 217pp

Pillsbury, A.F. and Richards, S.J., (1954). Some factors affecting rates of irrigation water entry into Rumania Sandy Loam Soil Sci. 78: 171-182.

Roats, P.A.C., (1973). Unstable wetting frots in uniform and non uniform soils. Soil Sci. Soc. Am. Proc. 37:681-685pp

Sani, O. M.S, (1999).Design of Erosion Control Measures for Federal University of Technology Main Campus site, Minna. Agricultural Engineering Department, Federal University of Technology Minna, Nigeria. Unpublished PGD Project. 120 pp.

Serrano, E.S., (1990). Stochastic differential equation models of erratic infiltration. Water Resources Res., Vol. 26

Smith, W.O. (1949). Pedological relations of infiltration phenomenia. Trans. Amer. Geophy. Union 30: 555-562pp

Swartzendeuber, D. and Oiso, C.T., (1961). Sand model study of buffer effects in the double ring-infiltrometer. Soil Sci.Soc. Am. Proc. 25: 5-8pp

Williams, W.A. and Doneen, L.D., (1960). Field infiltration studies in green manures and crop residues on irrigated soils. Soil Sci. Soc. Am. Proc. 24:58-61. Wilkinson,

G.E., (1975). Effect of grass fallow rotations on the infiltration of water into the savanna zone of Northern Nigeria. Trop. Agric. 97-103pp

Wilkinaon, G.E. and Aina, P.O., (1976). Infiltration of water into two Nigeria soil under secondary forest and subsequent arable cropping. Geoderina 15:51-59pp.

APPENDIX A

SOIL

DESCRIPTION.

A-1: Soil surface description at the time the measurement were taken are as follows

SITE 1

The site was discovered to have dry grasses with few shrubs scattered around the area. Traces of ridges were seen around this area. The soil was very hard with traces of medium size quartz stones.

SITE 2

The site was seen to have dry grasses and sparsely populated trees/shrubs. Traces of sprouting grasses the area was of a gradual slope with a dry steam path not far.

SITE 3

The area was cultivated by a tractor (harrowed) with fresh grasses seen growing around the area, which was of a gentle slope

SITE 4

Cultivated area, ridges were made of hand with yams that have not been harvested. Few ant holes were very feasible few shrubs can be seen.

SITE 5

Feasible ant holes with little anthills around. The area had few scattered shrubs. The area was cultivated, because of the presence of the corn stacks that were seen.

SITE 6

The site had few scattered trees, with the presence of the nomadic farmers on the land. The area was a flate land with little grasses sprouting here and there.

SITE 7

The area hard scattered shrubs. This was a fadama area though the stretch was not large enough. Heavy black soil, dry and creaked. The surface was covered with short green grasses, which survived the dry season.

SITE 8

The area was made of fine sandy soil with particles of clay sand. The area had more of dry grasses around to show that no from of farming during the previous season. Presence of scattered shrubs.

SITE 9

The area was seen to have ridges though very small in size with a fairly brownish soil with the presence of medium size quartz stones. Gradual gentle slope.

SITE 10

Almost flat land, with scattered shrubs and sprouting, grasses present. Nomadic settlement was seen the nature of soil was light gray with scattered medium size quartz. Not too far was big rock.

SITE 11

The area has a thin bush with scattered shrubs. The soil was fairly gray in colour with patches of medium size quartz present this area was farmed the previous season.

SITE 12

The same thing was observed as of site 10

SITE 13

A fadama area, which shows the presence of rice stocks around, heavy black clayey soil was seen. Grasses seen here showed that they survived the dry season.

SITE 14

The area has been under fallow for some years. This was confirmed by the nature of grasses, which was seen around here, which were tall. Plenty termites and ants were seen in the areas a day after the rainfall.

SITE 15

A flat land with scattered shrubs. Shows the area was under intensive farming. The nature of soil was light brown in colour.

SITE 16

What was observe here was not in anyway different from what was seen in site 15

SITE 17

A fadama area dark gray soil was observed with medium size quartz particle present. Scattered shrubs were seen. With the presence of anthills of moderate height, not Mary though about three was seen.

SITE 18

Flat smooth land, with scattered shrubs predominately white land soil with patches of gray and brown soil was observed. The area was cultivated during. The last farming season as ground milt shells and items were observed.

SITE 19

Gradual gentle slop, the Dan Zaria dam was a prominent feature along with the dagga river: the area was a fadama zone with heavy dark soils seen. Some of which were looking dry.

SITE 20

The area has a gradual undulating slope with scattered shrubs around the land. Close to the riverbank was a thick devise forest like collation of trees and dark colored soil was observed. The area was cultivated with rice.

SITE 21

This is a fallowed fadama land, heavy black clay soil grains of particle. The surface was covered with dry grasses most of which survived the day season No out activity was seen but plenty of ants were seen.

SITE 22

The area was under fallow and the nature of soil seen here was light gray in colour with traces of white sandy soil present. The land in this area was flat.

SITE 23

From here the rail serving as the boarder at the Northern part of the main campus could be seen. The land was under cultivation. Light brown soil with medium size quartz was also seen.

SITE 24

The area here was a Fadama area with mixture of heavy dark clay soil and light brown soils with patches of medium size granular quartz. Dan Zaria dam was very obvious.

SITE 25

First grasses were seen to be growing. The soil was light brown in colour. Activities of cultivation were observed.

SITE 26

This area was close to a stream, which had just started flowing because of the heavy rainfall the previous two days. The area had a lightish brown with patches of granular quartz. The area was almost flat with fresh graces seen coming up growing.

SITE 27

The same thing was observed in terms of the colour of the soil as in site 26, though no stream was seen around here.

SITE 28

This area was a flat land, grasses were seen growing around the area and the area was previously cultivation because of the traces of trimly ridges that were seen. Not far, fresh ridges were seen as farmers prepare for the new planting season.

SITE 29

An almost flat land which is under cultivation. Dark clay soil was seen around with some sparsely populated giant stones -- were obvious.

A – 2 PROFILE DESCRIPTIONS OF THE SOIL UNITS.

SOIL UNIT	**SITE 1.**
Parent Material	Fine colluvial-loessial
Vegetation	Scattered grasses
Micro topography	Upper slope
HORIZON DEPTH.	**DESCRIPTION**
0 – 25cm.	Light Dark sandy clay was seen, with Massive structure, land dry firm most soil, slightly plastic in nature with patches of gravel, with grass roots present within this area.
25 – 50 CM.	Very few roots were seen in this zone. Pale sandy clay soil, weak medium subangular blocky structure, dry, hard and firm soil slightly plastic, sticky and wet the boundary was clear and smooth.

SOIL UNIT 2	**SITE 2.**
Parent material	Collivial – loessial
Vegetation	Scattered grasses
Micro topography	Gentle slope
HORIZON DEPTH	**DESCRIPTION**
0 – 25CM.	Brownish sandy loam soil was seem with scattered medium size quartz particles present. Traces of grass and shrub roots were seen also. The soil was hard and dry.
25 – 50CM	Very few roots of grasses were seen, the soil having same colour but with less presence of roots in this region.

SOIL UNIT 3.	**SITE 3 AND 4**
Parent material	Basement complex.
Vegetation.	Short grasses
Micro topography.	Flate land.
HORIZON DEPTH	**DESCRIPTION.**
0 – 25CM.	Dark sandy clay soil was observed. Few roots were seen probably dew to active farming been carried out here by the use of the tractor. The soil here was hard and dry.
25 CM -50 CM.	Darker sandy clay was observed and fewer roots present. The soil was hard.

SOIL UNIT 4	**SITE 5**
Parent material	Basement complex
Vegetation	Short grasses
Micro topography	lower slope. (Gentle in nature).
HORIZON DEPTH	**DESCRIPTION**
0 – 25CM.	Slightly plastic sandy loam soil (Brownish) was seen with very few small sized quartz particles present. Very few ant holes were observed. Roots of grasses and planted crops were seen in this zone.
25 – 50CM	Plastic sandy loam soil, very few roots, no ant holes was seen. Hard and dry in nature.

SOIL UNIT 5	**SITE 6.**
Parent material	Losessial-colluvium
Vegetation	Short grasses
Micro topography	Flate land

HORIZON DEPTH	DESCRIPTION.
0 – 25CM.	slightly plastic dark sandy clay was observed. Plant roots were seen along sides some pods of grandaunt. Thinny particles of sand were felt when touched.
25 – 50 CM.	Plastic darker sandy clay was observed and cut off. The nature of the soil remained the same.

SOIL UNIT 6	SITE 7.
Parent material	Fine colluvial - loessial
Vegetation	Short grasses
Micro topography	Upper slope

HORIZON DEPTH	DESCRIPTION
0 – 25CM	Dark sandy clay massive structure, plastic and sticky, few medium roots were seen.
25 – 50CM	Dark grayish –brown clay, very weak sub-angular blocky dark yellowish brown mottle, hand dry, firm moist; plastic and sticky wet; few, very fine vertical horizontal, tubular and interstitial pores, few fire roots.

SOIL UNIT 7	SITE 8 AND 9.
Parent material	Basement Complex
Vegetation	Short grasses
Micro topography	Flate land

HORIZON DEPTH	DESCRIPTION.
0 – 25CM.	Very dark grayish - brown coarse clay; massive structure; hard dry, firm;

and fairly sticky, common very fine and few medium roots, abrupt smooth boundary.

25 50CM. Dark yellowish brown clay, moderately weak sub angular blocky structure, hard dry, firm; plastic and very sticky, common very fire and vertical oblique tubular pores; very few fine roots, abrupt smooth boundary

SOIL UNIT 8. SITE 10.

Parent material: Basement Complex

Vegetation: Short grasses

Micro topography: Flate land

HORIZON DEPTH / DESCRIPTION.

0 –25cm Pale brown gravelly concretionary sandy loam massive structure, hard dry, firm moist, slightly plastic and sticky when wet, few coarse roots, gradual smooth boundary.

25 – 50CM. Brownish yellow gravelly concretionary sandy clay loam; massive structure; slightly hard clay, slightly plastic and sticky wet, common fine vertical oblique random vesicular and interstitial pores; abrupt smooth boundary.

SOIL UNIT 9 SITE 11, 12 AND 13.

Parent material: Alluvial deposit

Vegetation: Short grasses

Micro topography: Flate land

HORIZON DEPTH | **DESCRIPTION.**

0 – 25CM

Very dark brown coarse clay was seen; massive structure; hard dry, firm mist; plastic and sticky wet; very fine and few medium sized roots, abrupt smooth boundary.

25 – 50CM.

Dark yellowish brown clay, hard dry, moderate weak subangular block structure, plastic and very sticky when wet; very fire and vertical oblique tubular pores was seen with very fire few roots and abrupt smooth boundary was seen

SOIL UNIT 10. | **SITE 14.**

Parent material — Losessial-colluvium

Vegetation — Short grasses

Micro topography — Flate land

HORIZON DEPTH | **DESCRIPTION.**

0 – 25CM.

Light yellow brown sandy loam, weak fine and medium subangular structure; soft and slightly hard dry, slightly plastic and slightly sticky when wet; fire and medium horizontal random interstitial and tubular pores, very common, very fire and fine roots; abrupt smooth boundary.

25 – 50 CM.

Reddish brown clay loam; strong medium subanqular structure; continuous and brown shirring dark brown cutans on peel surfaces, common fine coarse, horizontal, vertical tubular and interstitial pores, very few, very fine roots; gradual boundary.

SOIL UNIT 11	**SITE 15 AND 16**
Parent material	Fine losessial-colluvium
Vegetation	Short grasses cover
Micro topography	Upper low slope
HORIZON DEPTH	**DESCRIPTION.**
0 – 25 CM.	Sandy loam, very weak fine and medium subangular blocky structure; loose dry, very friable moist, non-plastic and sticky wet; very few swan hard black and reddish brown red and irregular concentrations; common fine vertical and tubular pores; very few coarse roots; abrupt smooth boundary.
25-50	Reddish brown sandy clay loam; moderate fine and medium subangular blocky structure; hard dry, friable moist, plastic and sticky wet; broken and patchy, common, fine vertical and oblique, interstitial and tubular pores; frequent, small hard reddish brown irregular iron concretions very few coarse roots, gradual smooth boundary.

SOIL UNIT 12	**SITE 17 AND 18**
Parent Material	Fine loessial-alluvial deposit
Vegetation	Moderately high grass land
Microphotography	Valley bottom (Fadama fringe)
HORIZON DEPTH	**DESCRIPTION.**

0-25CM.	Dark gray sandy loam, few fine, distinct, clear, dark reddish brown mottles very weak crumb tending hard dry slightly firm moist and non-sticky when wet; many very fine and few vertical, horizontal, tubular and interstitial pores; common, very fine and few medium roots; abrupt smooth boundary.
25-50cm.	Reddish yellow distinct clay Loam; many fine to faint district reddish brown to red mottles, massive structure; hard dry, firm moist; plastic and sticky when wet; common very fine vertical, horizontal, tubular and interstitial pores; few fine roots; abrupt smooth boundary.

SOIL UNIT 13	**SITE 19 AND 20.**
Parent Material	losessial-alluvial deposit
Vegetation	Short grasses with thick weed cover.
Micro topography.	Flate Land

HORIZON DEPTH	**DESCRIPTION.**
0-25cm	Very dark grayish- brown coarse clay, massive structure, hard when dry, firm moist, plastic and sticky wet; common very fine and few medium roots; abrupt smooth boundary.
25-50cm	Dark yellowish-brown clay subangular blocky structure; hard dry and firm moist; plastic and very sticky when wet; few fine; faint dark yellowish-

brown mottles; common very fine and vertical oblique tubular pores; very few fine roots; abrupt smooth boundary.

SITE UNIT 14 — **SITE 21 AND 22.**

Parent Material: Mixture of alluvial deposit and basement complex

Vegetation: Short grasses.

Micro topography.: Flate Land

HORIZON DEPTH	DESCRIPTION.
0 – 25	Brown sandy loam; weak presences of clay, medium blocky structure, plastic and sticky when wet, common very fine and few medium roots, abrupt smooth boundary.
25 – 50CM.	Strong brown sandy loam; moderate, medium subanqular blocky structure; slightly hard, plastic and sticky when wet few root channels, patchy and broken dark brown fine earth,

SOIL UNIT 15 — **SITE 23. AND 25.**

Parent Material: Alluvial deposit

Vegetation: Short grasses with thick weed cover.

Micro topography.: Valley bottom. (Fadama)

HORIZON DEPTH	DESCRIPTION.
0 – 25CM	Very dark grayish – brown clay, massive structure, hard when dry, firm moist, plastic and sticky when wet, common very fine and few medium roots abrupt boundary.

25 – 50CM. Dark yellowish brown clay, moderate weak subangular blocky structure, hard dry and firm moist; plastic and very sticky when wet; common very fine and vertical oblique tabular pores, very few fine roots; abrupt smooth boundary.

SOIL UNIT 16	**SITE 24**
Parent Material	losessial-colluvium.
Vegetation	Short grasses with thick weed cover.
Micro topography.	Lower Flate Land
HORIZON DEPTH	**DESCRIPTION.**
0 – 25CM.	Light yellow brown sandy loam, weak fine and medium subangular structure, soft and slightly hard dry, slightly plastic and slightly stick when wet; fire and medium horizontal random interstitial and tabular pores, very common, very fine, and fire roots. Abrupt smooth boundary.
25 – 50 CM.	Brown sandy clay loams. Moderate medium subangular blocky structure, slightly hard, very friable, moist, plastic and sticky when wet; continuous and brown shining dark brown cutans on pad surfaces, common coarse, horizontal vertical tubular and interstitial pores, very few fire roots present.

SOIL UNIT 17	**SITE 26.**
Parent Material	Basement complex

Vegetation	Short grasses and weed cover.
Micro topography.	Flate Land
HORIZON DEPTH	**DESCRIPTION.**
0 25CM.	Strong brown sandy loam, weak medium subangular blocky structure, slightly plastic and non sticky when wet; very few small and soft hard irregular brown concretion, common fine and medium vertical horizontal oblique, interstitial, tubular pores, frequently very fine and few coarse roots.
25 – 50CM	Strong brown loamy sand, moderate medium subangular blocky structures, slightly hard friable moist, plastic and sticky when wet, patchy and broken dark brown fine earth in inset cast, root channels, common fine and medium vertical oblique vascular and interstitial pores, few inset voids.

SOIL UNIT 18	**SITE 27.**
Parent Material	Basement complex - colluviums
Vegetation	Fallow (tall grasses)
Micro topography.	Lower slope
HORIZON DEPTH	**DESCRIPTION.**
0 – 25CM	Dark brown, loamy sandy weak granular structure, slightly sticky, firm, hard; few fine coarse roots; abrupt smooth boundary.

25 – 50	Very pale brown sandy clay loams weak spheroid structure, very sticky, friable, slightly hard, few fine roots.
SOIL UNIT 19	**SITE 28 AND 29.**
Parent Material	Colluviums-from Basement complex
Vegetation	Short growing grasses
Micro topography.	Flate Land
HORIZON DEPTH	**DESCRIPTION.**
0 – 25CM.	Brown loamy sand, strong, blocky structure, slightly sticky, firm hard few fine coarse roots abrupt smooth boundary.
25 – 50CM	Brownish yellow, sandy clay loam, strong blocky structure, very sticky when wet, very firm, very hard, few coarse roots clear irregular boundary.
SOIL UNIT 20	**SITE 30.**
Parent Material	Colluviums from Basement complex
Vegetation	Short growing grasses
Micro topography.	Flate Land
HORIZON DEPTH	**DESCRIPTION.**
0 – 25CCM.	Dark brown loamy sand, weak granular structure; non – sticky, very friable soft many fine roots, smooth boundary.
25 – 50 CM.	Strong brown sandy loam, weak crumbly structure, slightly sticky, very friable, slightly hard, few fine roots, abrupt, irregular boundary.

APPENDIX B

INFILTRATION RATE DATA

INFILTRATION RATES AT NORMAL FOR APRIL

A Elapsed Time (min)	B Final Reading (cm)	C Initial Reading (cm)	D Water Intake (B-C) (cm)	E Cum. Water Intake (ΣD) (cm)	F Infiltration Rate (E/A) (cm/min)	G Infil. Rate (Fx60) (cm/hr)
0	6.00	6.00	-	-	-	-
1	6.60	6.00	0.60	0.60	0.600	36.00
2	7.10	6.60	0.50	1.10	0.550	33.00
5	9.10	8.10	1.00	2.10	0.420	25.20
10	10.60	9.10	1.50	3.60	0.360	21.60
15	11.80	10.60	1.20	4.80	0.320	19.20
20	13.10	11.80	1.30	6.10	0.305	18.30
30	14.90	13.10	1.80	7.90	0.263	15.80
45	17.40	14.90	2.50	10.40	0.231	13.87
60	19.60	17.40	2.20	12.60	0.210	12.60
75	10.70	8.000	2.70	15.30	0.204	12.24
90	13.00	10.70	2.30	17.60	0.196	11.73
100	14.50	13.00	1.50	19.10	0.191	11.46
120	16.10	13.50	2.60	21.70	0.181	10.85

TABLE B5 CULTIVATED LAND

A Elapsed Time (min)	B Final Reading (cm)	C Initial Reading (cm)	D Water Intake (B-C) (cm)	E Cum. Water Intake (ΣD) (cm)	F Infiltration Rate (E/A) (cm/min)	G Infil. Rate (Fx60) (cm/hr)
0	7.30	7.30	-	-	-	-
1	7.70	7.30	0.40	0.40	0.400	24.00
2	7.00	6.70	0.30	0.70	0.350	21.00
5	7.60	7.00	0.60	1.30	0.260	15.60
10	8.40	8.60	0.80	2.10	0.210	12.60
15	9.20	8.40	0.80	2.90	0193	11.60
20	9.80	9.20	0.60	3.50	0.175	10.50
30	11.00	9.80	1.20	4.70	0.157	9.40
45	12.60	11.00	1.60	6.30	0.140	8.40
60	14.00	12.60	1.40	7.70	0.128	7.70
75	15.30	14.00	1.30	9.00	0.120	7.20
90	16.70	15.30	1.40	10.40	0.116	6.93
100	17.40	16.70	0.70	11.10	0.111	6.66
120	18.80	17.40	1.40	12.50	0.104	6.25

TABLE B6 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR APRIL

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.40	7.40	-	-	-	-
1	7.80	7.40	0.40	0.40	0.400	24.00
2	9.00	8.80	0.20	0.60	0.300	18.00
5	9.20	9.00	0.20	0.50	0.160	9.60
10	9.50	9.20	0.30	1.10	0.110	6.60
15	9.80	9.50	0.30	1.40	0.090	5.60
20	10.00	9.80	0.20	1.60	0.080	4.80
30	10.50	10.00	0.50	2.10	0.070	4.20
45	11.00	10.50	0.50	2.60	0.058	3.47
60	11.50	11.00	0.50	3.10	0.052	3.10
75	12.00	11.50	0.50	3.60	0.048	2.88
90	12.40	12.00	0.40	4.00	0.044	2.67
100	12.70	12.40	0.30	4.30	0.043	2.58
120	12.20	11.70	0.50	4.80	0.040	2.40

TABLE B7 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.20	8.20	-	-	-	-
1	8.80	8.20	0.60	0.60	0.60	36.00
2	9.20	8.80	0.40	1.00	0.500	30.00
5	11.10	10.20	0.90	1.90	0.380	22.50
10	12.20	11.10	1.10	3.00	0.300	18.00
15	13.00	12.20	0.50	3.80	0.253	15.20
20	13.70	13.00	0.70	4.50	0.225	13.50
30	14.90	13.70	1.20	5.70	0.190	11.40
45	16.40	14.90	1.50	7.20	0.160	9.60
60	17.50	16.40	1.10	8.30	0.138	8.30
75	18.70	17.50	1.20	9.50	0.127	7.60
90	19.60	18.70	0.90	10.40	0.116	6.93
100	19.30	18.60	0.70	11.10	0.111	6.66
120	20.50	19.30	1.20	12.30	0.103	6.15

TABLE B8 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR APRIL

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.10	8.10	-	-	-	-
1	9.40	8.10	1.30	1.30	1.300	78.00
2	9.90	8.40	1.50	2.80	1.400	84.00
5	13.50	9.90	3.60	6.40	1.280	76.80
10	18.10	13.50	4.60	11.00	1.100	66.00
15	21.70	18.10	3.60	14.60	0.973	58.40
20	14.10	8.30	5.80	20.40	1.020	61.20
30	22.50	14.10	8.40	28.80	0.960	57.60
45	18.80	5.00	13.80	42.60	0.947	56.80
60	19.60	6.70	12.90	55.50	0.925	55.50
75	18.00	6.00	12.00	67.50	0.900	54.00
90	19.60	7.50	12.10	79.60	0.884	53.07
100	24.10	19.60	4.50	84.10	0.841	50.46
120	22.00	7.00	15.00	99.10	0.826	49.55

TABLE B9 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.10	7.10	-	-	-	-
1	7.60	7.10	0.50	0.50	0.500	30.00
2	6.80	6.60	0.20	0.70	0.350	21.00
5	7.40	6.80	0.60	1.30	0.260	15.60
10	8.20	7.40	0.80	2.10	0.210	12.60
15	11.10	10.20	0.90	3.00	0.200	12.00
20	11.80	11.10	0.70	3.70	0.185	11.10
30	13.50	11.80	1.70	5.40	0.180	10.50
45	15.90	13.50	2.40	7.80	0.173	10.40
60	17.10	14.90	2.20	10.00	0.164	10.00
75	10.30	7.70	2.60	12.60	0.168	10.08
90	12.90	10.30	2.60	15.20	0.169	10.13
100	14.50	12.90	1.60	16.80	0.168	10.08
120	17.60	14.50	3.10	19.90	0.166	9.95

TABLE B10 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR APRIL

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.30	6.30	-	-	-	-
1	7.60	6.30	1.30	1.30	1.300	78.00
2	8.70	7.60	1.10	2.40	1.200	72.00
5	10.90	7.70	3.20	5.60	1.12	67.20
10	15.20	10.90	4.30	9.90	0.990	59.40
15	18.80	15.20	3.60	13.50	0.900	54.00
20	21.50	18.80	2.70	15.20	0.810	48.60
30	15.70	7.20	8.50	24.70	0.823	49.40
45	24.90	15.70	9.20	33.90	0.753	45.20
60	15.60	5.60	10.00	43.90	0.732	43.90
75	18.00	8.20	9.80	53.70	0.716	42.96
90	16.50	6.30	10.20	63.90	0.710	42.60
100	21.30	16.50	4.80	68.70	0.687	41.22
120	1980	8.60	11.20	79.9	0.666	39.95

TABLE B11 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(cm)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.70	6.70	-	-	-	-
1	7.50	6.70	0.80	0.80	0.800	48.00
2	7.00	6.50	0.50	1.30	0.650	39.00
5	8.50	7.00	0.50	1.80	0.360	21.60
10	10.70	8.50	2.20	4.00	0.400	24.00
15	12.60	10.70	1.90	5.90	0.393	23.60
20	14.30	12.60	1.70	7.60	0.380	22.80
30	17.50	14.30	3.20	10.80	0.360	21.60
45	14.30	8.00	6.30	17.10	0.380	22.80
60	19.30	14.30	5.00	22.10	0.368	22.10
75	23.00	19.30	3.70	25.80	0.344	20.64
90	13.70	8.00	5.70	31.50	0.350	21.00
100	16.90	13.70	3.20	34.70	0.347	20.82
120	18.60	12.10	6.50	41.20	0.343	20.60

TABLE B12 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR APRIL

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	9.90	8.50	1.40	1.40	1.400	84.00
2	12.30	10.90	1.40	2.80	1.400	84.00
5	15.80	12.30	3.50	6.30	1.26	75.60
10	20.50	15.80	4.70	11.00	1.100	66.00
15	24.00	20.50	3.50	14.50	0.967	58.00
20	11.80	6.30	5.50	20.00	1.000	60.00
30	20.30	11.50	8.50	28.50	0.950	57.00
45	19.20	7.50	11.70	40.20	0.893	53.60
60	18.60	7.30	11.30	51.50	0.858	51.50
75	16.80	5.50	11.30	62.80	0.837	50.24
90	16.20	5.50	10.70	73.50	0.817	49.00
100	22.10	17.20	4.90	78.40	0.784	47.00
120	21.50	10.50	11.00	89.40	0.745	44.70

TABLE B1 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.40	4.40	-	-	-	-
1	9.10	7.40	1.70	1.70	1.700	102.00
2	10.50	9.10	1.40	3.10	1.550	93.00
5	14.40	10.50	3.90	7.00	1.400	84.00
10	18.50	13.40	5.10	12.10	1.210	72.60
15	22.40	18.50	3.90	16.00	1.067	64.00
20	14.90	9.50	5.40	21.40	1.07	64.20
30	22.90	14.90	8.00	29.40	0.98	58.80
45	18.90	9.70	9.20	38.60	0.858	51.47
60	21.00	9.00	12.00	50.60	0.843	50.60
75	18.40	8.90	9.50	60.10	0.801	48.08
90	18.60	7.50	11.10	71.20	0.791	47.47
100	18.00	10.80	7.20	78.40	0.784	47.00
120	21.70	7.70	14.00	92.40	0.770	46.20

TABLE B2 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR APRIL

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	9.70	8.50	1.20	1.20	1.200	72.00
2	12.90	11.70	1.20	2.40	1.200	72.00
5	15.80	12.90	2.90	5.30	1.060	63.60
10	19.80	15.80	4.00	9.30	0.930	55.80
15	23.20	19.80	3.40	12.70	0.847	50.80
20	23.80	21.20	2.60	15.30	0.765	45.90
30	16.90	9.30	7.60	22.90	0.763	45.80
45	23.90	15.90	8.00	30.90	0.687	41.20
60	18.00	8.20	9.80	40.70	0.678	40.70
75	15.70	6.70	9.00	49.70	0.663	39.76
90	1680	7.50	9.30	59.00	0.656	39.33
100	93.33	16.80	4.30	63.30	0.633	37.98
120	19.90	9.70	10.20	73.50	0.613	36.75

TABLE B3 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(cm)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.50	6.50	-	-	-	-
1	7.70	6.50	1.20	1.20	1.200	72.00
2	8.60	7.70	0.90	2.10	1.050	63.00
5	9.60	7.60	2.20	4.30	0.860	51.60
10	13.00	9.80	3.20	7.50	0.750	45.00
15	15.80	13.00	2.80	10.30	0.687	41.20
20	18.20	15.80	2.40	12.70	0.635	38.10
30	23.30	18.20	4.10	16.80	0.560	33.60
45	16.30	7.80	8.50	25.30	0.562	33.73
60	15.40	7.80	7.60	32.90	0.548	32.90
75	22.40	16.4	6.00	38.90	0.519	31.12
90	15.90	8.80	7.10	46.00	0.511	30.67
100	19.90	15.90	4.00	50.00	0.500	30.00
120	19.40	11.40	8.00	58.00	0.483	29.00

TABLE B4 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR MAY

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.80	6.80	-	-	-	-
1	8.70	7.80	0.90	0.90	0.900	54.00
2	9.10	8.70	0.40	1.30	0.650	39.00
5	10.00	9.10	0.90	2.20	0.440	26.40
10	11.20	10.00	1.20	3.40	0.340	20.40
15	13.20	11.20	1.00	4.40	0.293	17.60
20	12.10	11.20	0.90	5.30	0.265	15.90
30	14.20	13.10	1.10	6.40	0.213	12.80
45	16.60	14.20	2.40	8.80	0.196	11.73
60	18.20	16.60	1.60	10.40	0.173	10.40
75	18.50	17.20	1.30	11.70	0.156	9.36
90	19.70	18.50	1.20	12.90	0.143	8.60
100	14.00	12.90	1.10	14.00	0.140	8.40
120	15.80	14.00	1.80	15.80	0.132	7.90

TABLE B13 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.80	8.80	-	-	-	-
1	9.70	8.80	09.0	0.90	0.900	54.00
2	11.20	10.70	0.50	1.40	0.700	42.00
5	12.30	11.20	1.10	2.50	0.500	30.00
10	13.60	12.30	1.30	3.80	0.380	22.80
15	14.80	13.60	1.20	5.00	0.333	20.00
20	15.90	14.80	1.10	6.10	0.305	18.30
30	17.60	15.90	1.70	7.80	0.260	15.60
45	18.70	16.60	2.10	9.90	0.220	13.20
60	19.30	17.70	1.60	11.50	0.192	11.50
75	10.60	8.30	2.30	13.80	0.184	11.04
90	12.50	10.60	1.90	15.70	0.174	10.47
100	13.60	12.50	1.10	16.80	0.168	10.08
120	16.00	13.60	2.40	19.20	0.160	9.60

TABLE B14 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR MAY

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	9.30	8.50	0.80	0.80	0.800	48.00
2	9.80	9.30	0.50	1.30	0.650	39.00
5	11.80	10.80	1.00	2.30	0.460	27.60
10	13.00	11.80	1.20	3.50	0.350	21.00
15	14.10	13.00	1.10	4.60	0.307	18.40
20	15.10	14.10	1.00	5.60	0.280	16.80
30	16.80	15.10	1.70	7.30	0.243	14.60
45	18.80	16.80	2.00	9.30	0.207	12.40
60	19.60	17.80	1.80	11.10	0.185	11.10
75	8.70	6.00	2.70	13.80	0.184	11.04
90	12.00	9.70	2.30	16.10	0.179	10.73
100	12.30	11.00	1.30	17.40	0.174	10.44
120	14.90	12.30	2.60	20.00	0.167	10.00

TABLE B15 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.00	6.00	-	-	-	-
1	7.20	6.00	1.20	1.20	1.200	72.00
2	9.20	8.20	1.00	2.20	1.100	66.00
5	9.50	7.20	2.30	4.50	0.900	54.00
10	12.30	9.50	2.80	7.30	0.730	43.81
15	14.60	12.30	2.30	9.60	0.640	38.40
20	16.50	14.60	1.90	11.50	0.575	34.50
30	20.60	17.50	3.10	14.60	0.487	29.20
45	14.30	7.60	6.70	21.30	0.473	28.40
60	18.80	14.30	4.50	25.80	0.430	25.80
75	22.20	18.80	3.40	29.20	0.389	23.36
90	14.20	9.20	5.00	34.20	0.380	22.81
100	16.90	14.20	2.70	36.90	0.369	22.14
120	20.70	16.90	3.80	40.70	0.339	20.35

TABLE B16 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR MAY

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.00	7.00	-	-	-	-
1	9.00	8.00	1.00	1.00	1.000	60.00
2	9.40	9.00	0.40	1.40	0.700	42.00
5	10.30	9.40	0.90	2.30	0.460	27.60
10	11.60	10.30	1.30	3.60	0.360	21.60
15	12.70	11.60	1.10	4.70	0.313	18.80
20	13.60	12.70	0.90	5.60	0.280	16.80
30	14.20	12.60	1.60	7.20	0.240	14.40
45	17.30	14.20	3.10	10.30	0.229	13.73
60	20.00	17.30	2.70	13.00	0.217	13.00
75	20.40	19.00	1.40	14.40	0.192	11.52
90	9.90	7.70	2.20	16.60	0.184	11.07
100	11.90	9.90	2.00	18.60	0.186	11.16
120	16.00	11.90	4.10	22.70	0.189	11.35

TABLE B17 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.20	6.20	-	-	-	-
1	6.80	6.20	0.60	0.60	0.600	36.00
2	9.70	8.80	0.90	1.50	0.750	45.00
5	10.30	9.70	0.60	2.10	0.420	25.20
10	11.60	10.30	1.30	3.40	0.340	20.40
15	12.90	11.60	1.00	4.40	0.293	17.60
20	13.90	12.90	1.00	5.40	0.270	16.20
30	15.80	13.90	1.90	6.30	0.210	12.60
45	15.90	13.80	2.10	8.40	0.187	11.20
60	16.70	14.90	1.80	10.20	0.170	10.20
75	19.10	17.70	1.40	11.60	0.155	9.28
90	20.50	19.10	1.40	13.00	0.144	8.67
100	12.50	11.00	1.50	14.50	0.145	8.70
120	15.20	12.50	2.70	17.20	0.143	8.60

TABLE B18 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR MAY.

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	10.40	8.50	1.90	1.90	1.900	114.00
2	13.20	11.40	1.80	3.70	1.850	111.00
5	17.40	13.20	4.20	7.90	1.580	94.80
10	15.50	8.40	7.10	15.00	1.500	90.00
15	15.20	8.30	6.90	21.90	1.460	87.60
20	15.00	8.20	6.80	28.70	1.435	86.10
30	19.80	8.00	11.80	40.50	1.350	81.00
45	21.50	4.80	16.70	57.20	1.271	76.27
60	23.30	6.80	16.50	73.70	1.228	73.70
75	25.70	12.10	13.60	87.30	1.164	69.84
90	20.10	6.60	13.50	100.80	1.120	67.20
100	13.40	4.40	9.00	109.80	1.098	65.88
120	22.90	7.30	15.60	125.40	1.045	62.70

TABLE B19 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.00	7.00	-	-	-	-
1	8.70	7.00	1.70	1.70	1.700	102.00
2	9.90	8.70	1.20	2.90	1.450	87.00
5	13.70	10.90	2.80	5.70	1.140	68.40
10	16.10	12.70	3.40	9.10	0.910	54.60
15	12.10	7.80	4.30	13.40	0.893	53.60
20	14.10	11.10	3.00	16.40	0.820	49.20
30	14.20	8.00	6.20	22.60	0.753	45.20
45	20.70	14.20	6.50	29.10	0.647	38.80
60	17.10	10.90	6.20	35.30	0.588	35.30
75	13.40	6.30	7.10	42.40	0.565	33.92
90	16.50	10.00	6.50	48.90	0.543	32.60
100	20.00	16.50	3.50	52.40	0.524	31.44
120	17.20	9.60	7.60	60.00	0.500	30.00

TABLE B20 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR MAY.

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.90	6.90	-	-	-	-
1	8.80	6.90	1.90	1.90	1.900	114.00
2	11.00	9.80	1.20	3.10	1.550	9300
5	13.90	11.00	2.90	6.00	1.200	72.00
10	18.00	13.90	4.10	10.10	1.010	60.60
15	21.50	18.00	3.50	13.60	0.907	54.40
20	10.30	5.30	5.00	18.60	0.930	55.80
30	18.10	10.30	7.80	26.40	0.880	52.80
45	16.50	4.50	12.00	38.40	0.853	51.20
60	17.50	6.80	10.70	49.10	0.818	49.10
75	17.60	7.50	10.10	59.20	0.789	47.36
90	17.20	7.60	9.60	68.80	0.764	45.87
100	14.00	7.60	6.40	75.20	0.752	45.12
120	18.50	7.00	11.50	86.70	0.723	43.35

TABLE B21 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	5.80	5.80	-	-	-	-
1	7.60	5.80	1.80	1.80	1.800	108.00
2	8.80	7.60	1.20	3.00	1.500	90.00
5	12.70	9.80	2.90	5.90	1.180	70.80
10	16.40	12.70	3.70	9.60	0.960	57.60
15	19.60	16.40	3.20	12.80	0.853	51.20
20	11.50	7.50	4.00	16.80	0.840	50.40
30	17.50	11.50	6.00	22.80	0.760	45.60
45	24.50	17.50	7.00	29.80	0.662	39.73
60	18.20	9.50	8.70	38.50	0.642	38.50
75	16.00	9.00	7.00	45.50	0.607	36.40
90	16.20	9.40	6.80	52.30	0581	34.87
100	18.00	14.20	3.80	56.10	0.561	33.66
120	15.80	7.80	8.00	64.10	0.534	32.05

TABLE B22 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR MAY

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.30	7.30	-	-	-	-
1	8.40	7.30	1.10	1.10	1.100	66.00
2	9.30	8.40	0.90	2.00	1.000	60.00
5	10.40	8.30	2.10	4.10	0.820	49.20
10	15.10	12.40	2.70	6.80	0.680	40.80
15	18.30	16.10	2.20	9.00	0.600	36.00
20	17.10	15.30	1.80	10.80	0.540	32.40
30	20.90	18.10	2.80	13.60	0.453	27.20
45	14.60	8.00	6.60	20.20	0.449	26.93
60	19.40	14.60	4.80	25.00	0.417	25.00
75	20.80	17.40	3.40	28.40	0.79	22.72
90	15.70	9.50	6.20	34.60	0.384	23.07
100	16.90	13.70	3.20	37.80	0.378	22.68
120	20.70	15.90	4.80	42.60	0.355	21.30

TABLE B23 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	10.00	9.50	0.50	0.50	0.500	30.00
2	10.30	10.00	0.30	0.80	0.400	24.00
5	10.80	10.30	0.50	1.30	0.260	15.60
10	11.50	10.80	0.70	2.00	0.200	12.00
15	12.00	11.50	0.50	2.50	0.167	10.00
20	12.50	12.00	0.50	3.00	0.150	9.00
30	13.30	12.50	0.80	3.80	0.127	7.60
45	13.40	12.30	1.10	4.90	0.109	6.53
60	14.40	13.40	0.90	5.80	0.097	5.80
75	15.20	14.30	0.90	6.70	0.089	5.36
90	16.90	16.20	0.70	7.40	0.082	4.93
100	17.30	16.90	0.40	7.80	0.078	4.68
120	18.10	17.30	0.80	8.60	0.072	4.30

TABLE B24 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JUNE.

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	13.70	13.70	-	-	-	-
1	14.00	13.70	0.30	0.30	0.300	18.00
2	14.70	14.00	0.70	1.00	0.500	30.00
5	15.80	14.70	1.10	2.10	0.420	25.20
10	18.50	16.80	1.70	3.80	0.380	22.80
15	20.10	18.50	1.60	5.40	0.360	21.60
20	20.70	19.10	1.60	7.00	0.350	21.00
30	14.50	10.50	4.00	11.00	0.367	22.00
45	19.90	14.50	5.40	16.40	0.364	21.87
60	14.30	9.50	4.80	21.20	0.353	21.20
75	16.80	12.30	4.50	25.70	0.343	20.56
90	13.00	8.00	5.00	30.70	0.341	20.47
100	15.90	13.00	2.90	33.60	0.336	20.16
120	20.50	15.90	4.60	38.20	0.318	19.10

TABLE B25 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	12.80	12.80	-	-	-	-
1	15.30	13.80	1.50	1.50	1.50	90.00
2	16.50	15.30	1.20	2.70	1.35	81.00
5	19.50	16.50	3.00	5.70	1.14	68.40
10	22.70	18.50	4.20	9.90	0.990	59.40
15	15.70	11.00	4.70	14.60	0.973	58.40
20	20.20	15.70	4.50	19.10	0.955	57.30
30	27.50	20.20	7.30	26.40	0.880	52.80
45	23.80	16.50	7.30	33.70	0.749	44.93
60	15.50	5.50	10.00	43.70	0.7.28	43.70
75	16.00	7.00	9.00	52.70	0.703	42.16
90	16.50	7.50	9.00	61.70	0.686	41.13
100	20.60	15.50	5.10	66.80	0.668	40.08
120	24.50	12.60	11.90	78.70	0.656	39.35

TABLE B26 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JUNE

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	12.80	12.80	-	-	-	-
1	13.10	12.80	0.30	0.30	0.300	18.00
2	13.30	13.10	0.20	0.50	0.250	15.00
5	13.70	13.30	0.40	0.90	0.180	10.80
10	15.30	14.70	0.60	1.50	0.150	9.00
15	16.00	15.30	0.70	2.20	0.147	8.80
20	17.70	16.00	0.70	2.90	0.145	8.70
30	17.10	15.70	1.40	4.30	0.143	8.60
45	19.00	17.10	1.90	6.20	0.138	8.26
60	12.80	10.70	1.10	7.30	0.122	7.30
75	16.80	14.80	2.00	9.30	0.124	7.44
90	16.50	14.80	1.70	11.00	0.122	7.33
100	17.30	16.50	0.80	11.80	0.118	7.88
120	18.80	17.30	1.50	13.30	0.111	6.65

TABLE B27 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	9.50	9.50	-	-	-	-
1	9.70	9.50	0.20	0.20	0.200	12.00
2	11.00	10.70	0.30	0.50	0.250	15.00
5	11.50	11.00	0.50	1.00	0.200	12.00
10	12.30	11.50	0.80	1.80	0.180	10.80
15	12.90	12.30	0.60	2.40	0.160	9..60
20	12.50	11.90	0.60	3.00	0.150	9.00
30	13.60	12.50	1.10	4.10	0.137	8.20
45	15.10	13.60	1.50	5.60	0.124	7.47
60	15.50	14.10	1.40	7.00	0.117	7.00
75	17.80	16.50	1.30	8.30	0.111	6.64
90	9.30	7.80	1.50	9.80	0.109	6.53
100	9.60	8.30	1.30	11.10	0.111	6.66
120	11.90	9.60	2.30	13.40	0.112	6.70

TABLE B28 FALLOWED LAND

· INFILTRATION RATE AT NORMAL SURFACE FOR JUNE

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	11.30	11.30	-	-	-	-
1	12.30	11.30	1.30	1.30	1.300	78.00
2	13.00	12.30	0.70	2.00	1.000	60.00
5	16.00	14.00	2.00	4.00	0.800	48.00
10	18.80	16.00	2.80	6.80	0.680	40.80
15	21.20	18.88	2.40	9.20	0.613	36.80
20	12.10	9.30	2.80	12.00	0.600	36.00
30	17.20	12.10	5.10	17.10	0.570	34.20
45	22.60	17.20	5.40	22.50	0.500	30.00
60	16.10	8.80	7.30	29.80	0.497	29.80
75	20.80	15.10	5.70	35.50	0.473	28.40
90	13.50	6.50	7.00	42.50	0.472	28.33
100	17.50	13.50	4.00	46.50	0.465	27.90
120	19.10	10.70	8.40	54.90	0.458	27.45

TABLE B29 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.80	7.80	-	-	-	-
1	8.60	7.80	0.80	0.80	0.800	48.00
2	9.20	8.60	0.60	1.40	0.700	42.00
5	11.60	10.20	1.40	2.80	0.560	33.60
10	13.70	11.60	2.10	4.90	0.490	29.40
15	15.70	13.70	2.00	6.90	0.460	27.60
20	16.10	14.70	1.40	8.30	0.415	24.90
30	20.00	17.10	2.90	11.20	0.373	22.40
45	11.90	7.30	4.60	15.50	0.351	21.07
60	15.00	10.90	4.10	19.90	0.332	19.90
75	18.60	15.00	3.60	23.50	0.313	18.80
90	14.70	11.20	3.50	27.00	0.300	18.00
100	17.00	14.70	2.30	29.30	0.293	17.58
120	16.50	11.50	5.00	34.30	0.286	17.15

TABLE B30 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JUNE

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.30	8.30	-	-	-	-
1	9.50	8.30	1.20	1.20	1.200	72.00
2	11.50	10.50	1.00	2.20	1.100	66.00
5	13.10	10.50	2.60	4.80	0.960	57.60
10	16.80	13.10	3.70	8.50	0.850	51.00
15	19.00	15.80	3.20	11.70	0.780	46.80
20	12.60	10.00	2.60	14.30	0.715	42.90
30	15.30	8.50	6.80	21.10	0.703	42.20
45	21.50	14.30	7.20	28.30	0.629	37.73
60	15.60	6.80	8.80	37.10	0.618	37.10
75	19.60	11.50	7.80	44.90	0.599	35.92
90	14.50	5.60	8.90	53.80	0.598	35.87
100	19.10	14.50	4.60	58.40	0.584	35.04
120	18.10	8.10	10.00	68.40	0.570	34.20

TABLE B31 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.20	8.20	-	-	-	-
1	9.30	8.20	1.10	1.10	1.100	66.00
2	10.30	9.30	1.00	2.10	1.050	63.00
5	13.80	11.30	2.50	4.60	0.920	55.20
10	17.40	13.80	3.60	8.20	0.820	49.20
15	20.40	17.40	3.00	11.20	0.747	44.80
20	17.10	14.40	2.70	13.90	0.695	41.70
30	13.80	7.00	6.80	20.70	0.690	41.40
45	21.50	13.80	7.70	28.40	0.631	37.87
60	14.60	5.30	9.30	37.70	0.628	37.70
75	20.60	13.60	7.00	44.70	0.596	35.76
90	16.00	7.90	8.10	52.80	0.587	35.20
100	19.40	15.00	4.40	57.20	0.572	34.32
120	20.70	11.80	8.90	66.10	0.551	33.05

TABLE B32 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JUNE

A Elapsed Time (min)	B Final Reading (cm)	C Initial Reading (cm)	D Water Intake (B-C) (cm)	E Cum. Water Intake (ΣD) (cm)	F Infiltration Rate (E/A) (cm/min)	G Infil. Rate (Fx60) (cm/hr)
0	12.20	12.20	-	-	-	-
1	12.50	12.20	0.30	0.30	0.300	18.00
2	12.60	12.50	0.10	0.40	0.200	12.00
5	21.80	12.60	0.20	0.60	0.120	7.20
10	13.20	12.80	0.40	1.00	0.100	6.00
15	13.30	12.80	0.50	1.50	0.100	6.00
20	13.10	12.70	0.40	1.90	0.095	5.70
30	13.90	13.10	0.80	2.70	0.090	5.40
45	15.20	13.90	1.30	4.00	0.089	5.34
60	16.20	15.20	1.00	5.00	0.083	5.00
75	17.00	16.20	0.80	5.80	0.073	4.38
90	12.00	11.00	1.00	6.80	0.076	4.56
100	12.70	12.00	0.70	7.50	0.075	4.50
120	13.20	11.70	1.50	9.00	0.075	4.50

TABLE B33 CULTIVATED LAND

A Elapsed Time (min)	B Final Reading (cm)	C Initial Reading (cm)	D Water Intake (B-C) (cm)	E Cum. Water Intake (ΣD) (cm)	F Infiltration Rate (E/A) (cm/min)	G Infil. Rate (Fx60) (cm/hr)
0	13.20	13.20	-	-	-	-
1	13.40	13.20	0.20	0.20	0.200	12.00
2	13.60	13.40	0.20	0.40	0.200	12.00
5	14.10	13.60	0.50	0.90	0.180	10.80
10	14.90	14.10	0.80	1.70	0.170	10.20
15	16.60	15.90	0.70	2.40	0.160	9.60
20	17.30	16.60	0.70	3.10	0.155	9.30
30	18.50	17.30	1.20	4.30	0.143	8.60
45	18.10	16.50	1.60	5.90	0.131	7.87
60	16.50	15.10	1.40	6.30	0.105	6.30
75	15.10	13.50	1.60	7.90	0.105	6.32
90	16.70	15.10	1.60	9.50	0.106	6.33
100	18.70	17.70	1.00	10.50	0.105	6.30
120	19.50	17.70	1.80	12.30	0.103	6.15

TABLE B34 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JUNE

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	13.50	13.50	-	-	-	-
1	14.70	13.50	0.20	0.20	0.200	12.00
2	14.70	14.70	0.00	0.20	0.100	6.00
5	14.80	14.70	0.10	0.30	0.060	3.60
10	15.00	14.80	0.20	0.50	0.050	3.00
15	15.20	15.00	0.20	0.70	0.047	2.80
20	15.30	15.20	0.10	0.80	0.040	2.40
30	15.80	15.30	0.50	1.30	0.043	2.60
45	17.30	15.80	1.150	2.80	0.062	3.73
60	15.80	14.30	1.150	4.30	0.072	4.30
75	17.30	15.80	1.50	5.80	0.077	4.64
90	12.30	11.00	1.30	7.10	0.079	4.73
100	13.20	12.30	0.90	8.00	0.0800	4.80
120	16.00	14.20	1.80	9.80	0.082	4.90

TABLE B35 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	13.00	13.00	-	-	-	-
1	13.40	13.00	0.40	0.40	0.400	24.00
2	13.60	13.40	0.20	0.60	0.300	18.00
5	14.10	13.60	0.50	1.10	0.220	13.20
10	14.80	14.10	0.70	1.80	0.180	10.80
15	15.30	14.80	0.50	2.30	0.153	9.20
20	15.80	15.30	0.50	2.80	0.140	8.40
30	16.60	15.80	1.10	3.90	0.130	7.80
45	18.00	16.60	1.40	5.30	0.118	7.07
60	18.30	17.00	1.30	6.60	0.110	6.60
75	12.00	10.50	1.50	8.10	0.108	6.48
90	13.60	12.00	1.60	9.70	0.108	6.47
100	14.70	13.60	1.10	10.80	0.108	6.48
120	16.50	14.70	1.80	12.60	0.105	6.30

TABLE B36 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE. FOR JUNE.

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.30	7.30	-	-	-	-
1	9.30	8.30	1.00	1.00	1.000	60.00
2	10.40	9.30	1.10	2.10	1.050	63.00
5	12.00	9.40	2.60	4.70	0.940	56.40
10	16.00	12.00	4.00	8.70	0.870	52.20
15	19.20	16.00	3.20	11.90	0.793	47.60
20	22.00	19.20	2.80	14.70	0.735	44.10
30	15.20	7.90	7.30	22.00	0.733	44.00
45	20.40	12.20	8.20	30.20	0.671	40.27
60	15.50	5.60	9.90	40.10	0.668	40.10
75	16.30	6.60	9.70	49.80	0.664	39.84
90	16.50	5.80	9.70	59.50	0.661	39.67
100	22.60	16.50	6.10	65.60	0.656	39.36
120	21.70	11.80	9.90	75.50	0.629	37.75

TABLE B37 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	5.80	5.80	-	-	-	-
1	6.90	5.80	1.10	1.10	1.100	66.00
2	8.80	7.90	0.90	2.00	1.000	60.00
5	10.10	7.80	2.30	4.30	0.860	51.60
10	12.30	9.10	3.20	7.50	0.750	45.00
15	15.10	12.30	2.80	10.30	0.687	41.20
20	17.40	15.10	2.30	12.60	0.630	37.80
30	19.40	16.40	4.00	16.60	0.553	33.20
45	11.60	2.50	9.10	25.70	0.571	34.27
60	18.50	12.60	5.90	31.60	0.527	31.60
75	13.30	6.50	6.80	38.40	0.512	30.72
90	16.80	11.30	5.50	43.90	0.488	29.27
100	12.50	8.50	4.00	47.90	0.479	28.74
120	19.40	12.50	6.90	54.80	0.457	27.40

TABLE B38 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JUNE

A Elapsed Time (min)	B Final Reading (cm)	C Initial Reading (cm)	D Water Intake (B-C) (cm)	E Cum. Water Intake (ΣD) (cm)	F Infiltration Rate (E/A) (cm/min)	G Infil. Rate (Fx60) (cm/hr)
0	10.30	10.30	-	-	-	-
1	11.30	10.30	1.00	1.00	1.000	60.00
2	11.90	11.30	0.60	1.60	0.800	48.00
5	12.50	10.90	1.60	3.20	0.640	38.40
10	15.10	12.50	2.60	5.80	0.580	34.80
15	17.30	15.10	2.20	8.00	0.533	32.0
20	20.40	18.30	2.10	10.10	0.505	30.30
30	11.70	6.60	5.10	15.20	0.507	30.40
45	17.70	10.70	7.00	22.20	0.493	29.60
60	20.90	14.70	6.20	28.40	0.473	28.40
75	11.80	5.00	6.80	35.20	0.469	28.16
90	16.70	11.80	4.90	40.10	0.446	26.73
100	14.00	10.30	3.70	43.80	0.438	26.28
120	20.00	14.00	6.00	49.80	0.415	24.90

TABLE B39 CULTIVATED LAND

A Elapsed Time (min)	B Final Reading (cm)	C Initial Reading (cm)	D Water Intake (B-C) (cm)	E Cum. Water Intake (ΣD) (cm)	F Infiltration Rate (E/A) (cm/min)	G Infil. Rate (Fx60) (cm/hr)
0	7.20	7.20	-	-	-	-
1	8.10	7.20	0.90	0.90	0.900	54.0
2	9.80	9.10	0.70	1.60	0.800	48.0
5	11.80	9.80	2.00	3.60	0.720	43.20
10	12.70	11.80	2.90	6.50	0.650	39.00
15	17.10	12.70	2.40	8.90	0.593	35.66
20	18.30	16.10	2.20	11.10	0.555	33.30
30	21.90	18.30	3.60	14.70	0.490	29.40
45	12.50	4.60	7.90	22.60	0.502	30.13
60	20.10	14.50	5.60	28.20	0.470	28.20
75	13.30	6.20	7.10	35.30	0.471	28.26
90	18.40	12.30	6.10	41.40	0.460	27.60
100	23.50	18.40	5.10	46.50	0.465	27.9
120	19.20	12.80	6.40	52.90	0.441	26.45

TABLE B40 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JULY

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.20	6.20	-	-	-	-
1	7.20	6.20	1.00	1.00	1.000	60.00
2	6.90	6.20	0.70	1.70	0.850	51.00
5	8.60	6.90	1.70	3.40	0.680	40.80
10	11.20	8.60	2.60	6.00	0.600	36.00
15	13.60	11.20	2.40	8.40	0.560	33.60
20	15.70	13.60	3.10	11.50	0.575	34.50
30	19.20	15.70	3.50	15.00	0.500	30.00
45	14.50	7.60	6.90	21.90	0.487	29.20
60	19.50	14.50	5.00	26.90	0.448	26.90
75	23.40	19.50	3.90	30.80	0.411	24.64
90	13.00	7.00	6.00	36.80	0.409	24.53
100	16.20	13.00	3.20	40.00	0.400	24.00
120	21.30	16.20	5.10	45.10	0.376	22.55

TABLE B41 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	11.00	9.50	1.50	1.50	1.50	90.00
2	12.00	11.00	1.00	2.50	1.250	75.00
5	14.80	12.00	32.80	5.30	1.060	63.60
10	18.20	14.80	3.40	8.70	0.870	52.20
15	21.00	18.20	2.80	11.50	0.767	46.00
20	23.20	21.00	2.20	13.70	0.685	41.10
30	26.80	23.20	3.60	17.30	0.577	34.60
45	16.30	8.00	8.30	25.60	0.569	34.13
60	21.40	16.30	5.10	3.070	0.512	30.70
75	25.40	21.40	4.00	34.70	0.463	27.76
90	12.90	6.50	6.40	41.10	0.457	27.40
100	16.30	12.90	3.40	44.50	0.445	26.70
120	21.80	16.30	5.50	50.00	0.417	25.00

TABLE B42 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JULY

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.70	7.70	-	-	-	-
1	8.80	7.70	1.10	1.10	1.100	66.00
2	8.80	7.80	1.00	2.10	1.050	63.00
5	11.30	8.80	2.50	4.60	0.920	55.20
10	14.80	11.30	3.50	8.10	0.810	48.60
15	17.70	14.80	2.90	11.00	0.733	44.00
20	20.10	17.70	2.40	13.40	0.670	40.20
30	24.20	20.10	4.10	17.50	0.583	35.00
45	16.00	8.20	7.80	25.30	0.562	33.73
60	21.20	16.00	5.20	30.50	0.508	30.50
75	25.30	21.20	4.10	34.60	0.461	27.68
90	14.20	8.30	5.90	40.50	0.450	27.00
100	17.10	14.20	2.90	43.40	0.434	26.04
120	22.00	17.10	4.90	48.30	0.4.3	24.15

TABLE B43 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.60	7.60	-	-	-	-
1	8.50	7.60	0.90	0.90	0.900	54.00
2	8.00	7.50	0.50	1.40	0.700	42.00
5	9.70	8.00	1.70	3.10	0.620	37.20
10	12.00	9.70	2.30	5.40	0.540	32.40
15	14.00	12.00	2.00	7.40	0.493	29.60
20	15.70	14.00	1.70	9.10	0.455	27.30
30	18.50	15.70	2.80	11.90	0.397	23.80
45	22.40	18.50	3.90	15.80	0.351	21.07
60	13.40	7.80	5.60	21.40	0.357	21.40
75	17.90	13.40	4.50	25.90	0.345	20.72
90	21.40	17.90	3.50	29.40	0.327	19.60
100	23.40	21.40	2.00	31.40	0.314	18.84
120	20.00	14.80	5.20	36.60	0.305	18.30

TABLE B44 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JULY

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.30	7.30	-	-	-	-
1	8.70	7.30	1.40	1.40	1.400	84.00
2	8.80	7.70	1.20	2.60	1.300	78.00
5	11.50	8.80	2.70	5.30	1.060	63.60
10	15.20	11.50	3.70	9.00	0.900	54.00
15	18.10	15.20	2.90	11.90	0.793	47.60
20	20.60	18.10	2.50	14.40	0.720	43.20
30	24.70	20.60	4.10	18.50	0.617	37.00
45	14.40	6.30	8.10	26.60	0.591	35.47
60	19.60	14.40	5.20	31.80	0.530	31.80
75	23.30	19.60	3.70	35.50	0.473	28.40
90	13.80	8.60	5.20	40.70	0.452	27.13
100	16.40	13.80	2.60	43.30	0.433	25.90
120	20.90	16.40	4.50	47.80	0.398	23.90

TABLE B45 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.80	7.80	-	-	-	-
1	8.60	7.80	0.80	0.80	0.800	48.00
2	8.00	7.60	0.40	1.20	0.600	36.00
5	8.70	8.00	0.70	1.90	0.380	22.80
10	9.80	8.70	1.10	3.00	0.300	18.00
15	10.70	9.80	0.90	3.90	0.260	15.60
20	11.60	10.70	0.90	4.80	0.240	14.40
30	13.00	11.60	1.40	6.20	0.207	12.40
45	14.50	13.00	1.80	8.00	0.178	10.67
60	16.40	14.80	1.60	9.60	0.160	9.60
75	17.80	16.40	1.40	11.00	0.147	8.80
90	19.10	17.80	1.30	12.30	0.137	8.20
100	12.50	11.30	1.20	13.50	0.135	8.10
120	14.40	12.50	1.90	15.40	0.128	7.70

TABLE B46 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JULY

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.20	6.20	-	-	-	-
1	7.20	6.20	1.00	1.00	1.000	60.00
2	6.90	6.20	0.70	1.70	0.850	51.00
5	8.40	6.90	1.50	3.20	0.640	38.40
10	10.60	8.40	2.20	5.40	0.540	32.40
15	12.50	10.60	1.90	7.30	0.487	29.20
20	14.20	12.50	1.70	9.00	0.450	27.00
30	17.10	14.20	2.90	11.90	0.397	23.80
45	20.70	17.10	3.60	15.50	0.344	20.67
60	11.90	7.30	4.60	20.10	0.335	20.10
75	15.40	11.90	3.50	23.60	0.315	18.88
90	17.30	14.40	2.90	26.50	0.294	17.67
100	19.20	17.30	1.90	28.40	0.284	17.04
120	17.60	13.80	3.80	32.20	0.268	16.10

TABLE B47 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.50	7.50	-	-	-	-
1	8.40	7.50	0.90	0.90	0.900	54.00
2	7.90	7.40	0.50	1.40	0.700	42.00
5	9.20	7.90	1.30	2.70	0.540	32.40
10	10.90	9.20	1.70	4.40	0.440	26.40
15	12.40	10.90	1.50	5.90	0.393	23.60
20	13.70	12.40	1.30	7.20	0.360	21.60
30	15.90	13.70	2.20	9.40	0.313	18.80
45	18.60	15.90	2.70	12.10	0.269	16.13
60	20.90	18.60	2.30	14.40	0.240	14.40
75	11.60	8.50	3.10	17.50	0.233	14.00
90	14.20	11.60	2.60	20.10	0.223	13.40
100	15.80	14.20	1.60	21.70	0.217	13.02
120	18.60	15.80	2.80	24.50	0.204	12.25

TABLE B48 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JULY

c	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.00	7.00	-	-	-	-
1	7.90	7.00	0.90	0.90	0.900	54.00
2	8.40	7.90	0.50	1.40	0.700	42.00
5	8.50	7.40	1.10	2.50	0.500	30.00
10	10.40	8.50	1.90	4.40	0.440	26.40
15	11.90	10.40	1.50	5.90	0.393	23.60
20	13.40	11.90	1.50	7.40	0.370	22.20
30	16.00	13.40	2.60	10.00	0.333	20.00
45	19.50	16.00	3.50	13.50	0.300	18.00
60	22.20	19.50	2.70	16.20	0.270	16.20
75	12.90	8.20	4.70	20.90	0.279	16.72
90	16.80	12.90	3.90	24.80	0.276	16.53
100	19.00	16.80	2.20	27.00	0.270	16.20
120	22.60	19.00	3.60	30.60	0.255	15.30

TABLE B49 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.00	7.00	-	-	-	-
1	8.00	7.00	1.00	1.00	1.000	60.00
2	7.60	7.00	0.60	1.60	0.800	48.00
5	9.20	7.60	1.60	3.20	0.640	38.40
10	11.50	9.20	2.30	5.50	0.550	33.00
15	13.50	11.50	2.00	7.50	0.500	30.00
20	15.30	13.50	1.80	9.30	0.465	27.90
30	18.40	15.30	3.10	12.40	0.413	24.80
45	21.70	18.40	3.30	15.70	0.349	20.93
60	24.10	21.70	2.40	18.10	0.302	18.10
75	15.10	8.50	6.60	24.70	0.329	19.76
90	19.90	15.10	4.80	29.50	0.328	19.67
100	22.30	19.90	2.40	31.90	0.319	19.14
120	23.00	17.80	5.20	37.10	0.309	18.55

TABLE LAND B50 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JULY

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.10	8.10	-	-	-	-
1	8.70	8.10	0.60	0.60	0.600	36.00
2	8.10	7.70	0.40	1.00	0.500	30.00
5	9.10	8.10	1.00	2.00	0.400	24.00
10	10.30	9.10	1.20	3.20	0.320	19.20
15	11.40	10.30	1.10	4.30	0.287	17.20
20	12.40	11.40	1.00	5.30	0.265	15.90
30	14.00	12.40	1.60	6.90	0.230	13.80
45	16.10	14.00	2.10	9.00	0.200	12.00
60	17.80	16.10	1.70	10.70	0.178	10.70
75	19.30	17.80	1.50	12.20	0.163	9.76
90	20.50	19.30	1.20	13.40	0.149	8.93
100	21.30	20.50	0.80	14.20	0.142	8.52
120	22.70	21.30	1.40	15.60	0.130	7.80

TABLE B51 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	9.50	8.50	1.00	1.00	1.000	60.00
2	10.40	9.50	0.90	1.90	0.950	57.00
5	11.40	9.40	2.00	3.90	0.780	46.80
10	14.30	11.40	2.90	6.80	0.680	40.80
15	16.80	14.30	2.50	9.30	0.620	37.20
20	18.90	16.80	2.10	11.40	0.570	34.20
30	23.50	18.90	3.60	15.00	0.500	30.00
45	14.30	6.80	7.50	22.50	0.500	30.00
60	20.50	14.30	6.20	28.70	0.478	28.70
75	25.20	20.50	4.70	33.40	0.445	26.72
90	16.30	9.90	6.40	39.80	0.442	26.53
100	19.90	16.30	3.60	43.40	0.434	26.04
120	25.70	19.90	5.80	49.20	0.410	24.60

TABLE B52 FALLOWED LAND

INFILTRATION RATES AT NORMAL SURFACE FOR JULY

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(cm)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.00	6.00	-	-	-	-
1	6.70	6.00	0.70	0.70	0.700	42.00
2	6.30	5.70	0.60	1.30	0.650	39.00
5	8.10	6.30	1.80	3.10	0.620	37.20
10	10.30	8.10	2.20	5.30	0.530	31.80
15	12.20	10.30	1.90	7.20	0.480	28.80
20	14.00	12.20	1.80	9.00	0.450	27.00
30	17.00	14.00	3.00	12.00	0.400	24.00
45	21.10	17.00	4.10	16.10	0.358	21.47
60	12.70	7.80	4.90	21.00	0.350	21.00
75	16.80	12.70	4.10	25.10	0.335	20.08
90	20.20	16.80	3.40	28.50	0.317	19.00
100	10.60	7.50	3.10	31.60	0.316	18.96
120	15.90	10.60	5.30	36.90	0.308	18.45

TABLE B53 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(cm)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.60	7.60	-	-	-	-
1	8.20	7.60	0.60	0.60	0.600	36.00
2	7.60	7.20	0.40	1.00	0.500	30.00
5	8.40	7.60	0.80	1.80	0.360	21.60
10	9.80	8.40	1.40	3.20	0.320	19.20
15	10.90	9.80	1.10	4.30	0.287	17.20
20	12.00	10.90	1.10	5.40	0.270	16.20
30	14.90	13.00	1.90	7.30	0.243	14.60
45	17.30	14.90	2.40	9.70	0.216	12.93
60	19.40	17.30	2.10	11.80	0.197	11.80
75	10.50	7.50	3.00	14.80	0.197	11.84
90	13.00	10.50	2.50	17.30	0.192	11.53
100	14.50	13.00	1.50	18.80	0.188	11.28
120	17.20	14.50	2.70	21.50	0.179	10.75

TABLE B54 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JULY

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(cm)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.40	7.40	-	-	-	-
1	7.90	7.40	0.50	0.50	0.500	30.00
2	9.30	8.90	0.40	0.90	0.450	27.00
5	10.30	9.30	1.00	1.90	0.380	22.80
10	12.00	10.30	1.70	3.60	0.360	21.60
15	13.40	12.00	1.40	5.00	0.333	20.00
20	14.60	13.40	1.20	6.20	0.310	18.60
30	16.70	14.60	2.10	8.30	0.277	16.10
45	19.50	16.70	2.80	11.10	0.247	14.80
60	20.90	19.50	2.40	13.50	0.225	13.50
75	9.30	20.90	3.70	17.20	0.229	13.76
90	12.30	9.30	3.00	20.20	0.224	13.47
100	14.10	12.30	1.80	22.00	0.220	13.20
120	17.10	14.10	3.00	25.00	0.208	112.50

TABLE B55 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(cm)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	6.00	6.00	-	-	-	-
1	6.70	6.00	0.70	0.70	0.700	42.00
2	7.00	6.70	0.30	1.00	0.500	30.00
5	7.60	7.00	0.60	1.60	0.320	19.20
10	8.40	7.60	0.80	2.40	0.240	14.40
15	8.00	7.40	0.60	3.00	0.200	12.00
20	8.50	8.00	0.50	3.50	0.175	10.50
30	9.60	8.50	1.10	4.60	0.153	9.20
45	10.90	9.60	1.30	5.90	0.131	7.87
60	12.10	10.90	1.20	7.10	0.118	7.10
75	13.30	12.10	1.20	8.30	0.111	6.64
90	14.40	13.30	1.10	9.40	0.104	6.67
100	15.10	14.40	0.70	10.10	0.101	6.06
120	17.60	16.10	1.50	11.60	0.097	5.80

TABLE B56 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JULY

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.20	7.20	-	-	-	-
1	8.10	7.20	0.90	0.90	0.900	54.00
2	7.40	7.10	0.30	1.20	0.600	36.00
5	8.10	7.40	0.70	1.90	0.380	22.80
10	9.00	8.10	0.90	2.80	0.280	16.80
15	9.90	9.00	0.90	3.70	0.247	14.80
20	10.70	9.90	0.80	4.50	0.225	13.50
30	12.10	10.70	1.40	5.90	0.197	11.80
45	14.00	12.10	1.90	7.80	0.173	10.40
60	15.70	14.00	1.70	9.50	0.158	9.50
75	17.20	15.70	1.50	11.00	0.147	8.80
90	19.60	18.20	1.40	12.40	0.138	8.27
100	20.40	19.60	0.80	13.20	0.132	7.92
120	21.90	20.40	1.50	14.70	0.123	7.35

TABLE B57 CULTIVATED LAND

A Elapsed Time	B Final Reading	C Initial Reading	D Water Intake (B-C)	E Cum. Water Intake (ΣD)	F Infiltration Rate (E/A)	G Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	7.80	7.80	-	-	-	-
1	8.90	7.80	1.10	1.10	1.10	66.00
2	8.80	7.90	0.90	2.00	1.000	60.00
5	11.20	8.80	2.40	4.40	0.880	52.80
10	14.20	11.20	3.00	7.40	0.740	44.40
15	16.60	14.20	2.40	9.80	0.653	39.20
20	18.60	16.60	2.00	11.80	0.590	35.40
30	21.80	18.60	3.20	15.00	0.50	30.00
45	24.80	21.80	3.00	18.00	0.400	24.00
60	17.00	8.50	8.50	25.50	0.442	26.50
75	22.70	17.00	5.70	32.20	0.429	25.76
90	25.70	12.70	3.00	35.20	0.391	23.47
100	17.00	12.40	4.60	39.80	0.398	23.88
120	23.40	17.00	6.40	46.20	0.385	23.10

TABLE B58 FALLOWED LAND

INFILTRATION RATE AT NORMAL SURFACE FOR JULY

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.50	8.50	-	-	-	-
1	9.10	8.50	0.60	0.60	0.600	36.00
2	8.60	8.10	0.50	1.10	0.550	33.00
5	9.70	8.60	1.10	2.20	0.440	26.40
10	11.30	9.70	1.60	3.80	0.380	22.80
15	12.50	11.30	1.20	5.00	0.333	20.00
20	13.70	12.50	1.20	6.20	0.310	18.60
30	15.60	13.70	1.90	8.10	0.270	16.20
45	18.10	15.60	2.50	10.60	0.236	14.30
60	20.10	18.10	2.00	12.60	0.210	12.60
75	21.90	20.10	1.80	14.40	0.192	11.52
90	13.80	11.10	2.70	17.10	0.190	11.40
100	15.30	13.80	1.50	18.60	0.186	11.16
120	18.10	15.30	2.80	21.40	0.178	10.70

TABLE B59 CULTIVATED LAND

A	B	C	D	E	F	G
Elapsed Time	Final Reading	Initial Reading	Water Intake (B-C)	Cum. Water Intake (ΣD)	Infiltration Rate (E/A)	Infil. Rate (Fx60)
(min)	(cm)	(cm)	(cm)	(cm)	(cm/min)	(cm/hr)
0	8.00	8.00	-	-	-	-
1	8.60	8.00	0.60	0.60	0.600	36.00
2	8.00	7.60	0.40	1.00	0.500	30.00
5	8.80	8.00	0.80	1.80	0.360	21.60
10	9.90	8.80	1.10	2.90	0.290	17.40
15	11.00	9.90	1.10	4.00	0.267	16.00
20	11.80	11.00	0.80	4.80	0.240	14.40
30	13.40	11.80	1.60	6.40	0.213	12.80
45	15.30	13.40	1.90	8.30	0.184	11.07
60	17.00	15.30	1.70	10.00	0.167	10.00
75	18.40	17.00	1.40	11.40	0.152	9.12
90	19.60	18.40	1.20	12.60	0.140	8.40
100	20.40	19.60	0.80	13.40	0.134	4.04
120	22.80	20.40	2.40	15.80	0.132	7.90

TABLE B60 FALLOWED LAND

APPENDIX C.

GRAPHS FOR DATA OBTAINED FROM THE FIELD

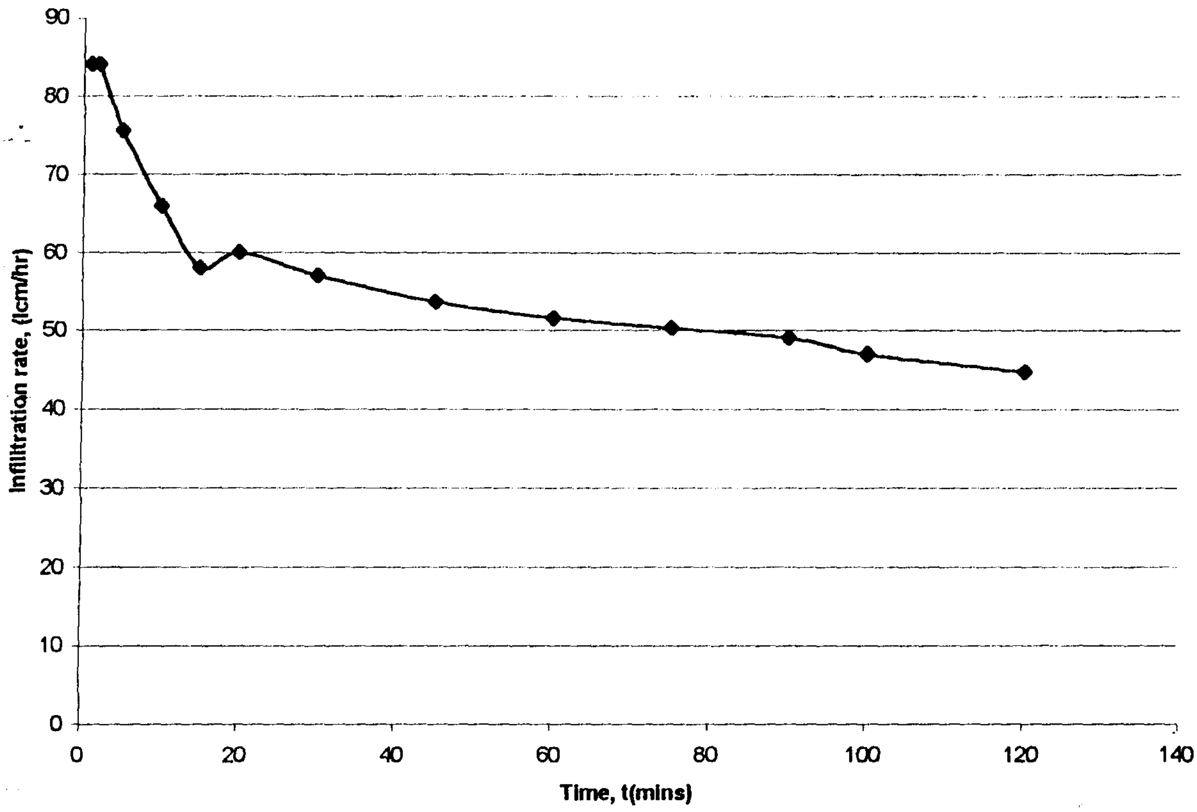

Fig. .1: Graph of infiltration rate against time for average of four replicates for cultivated land

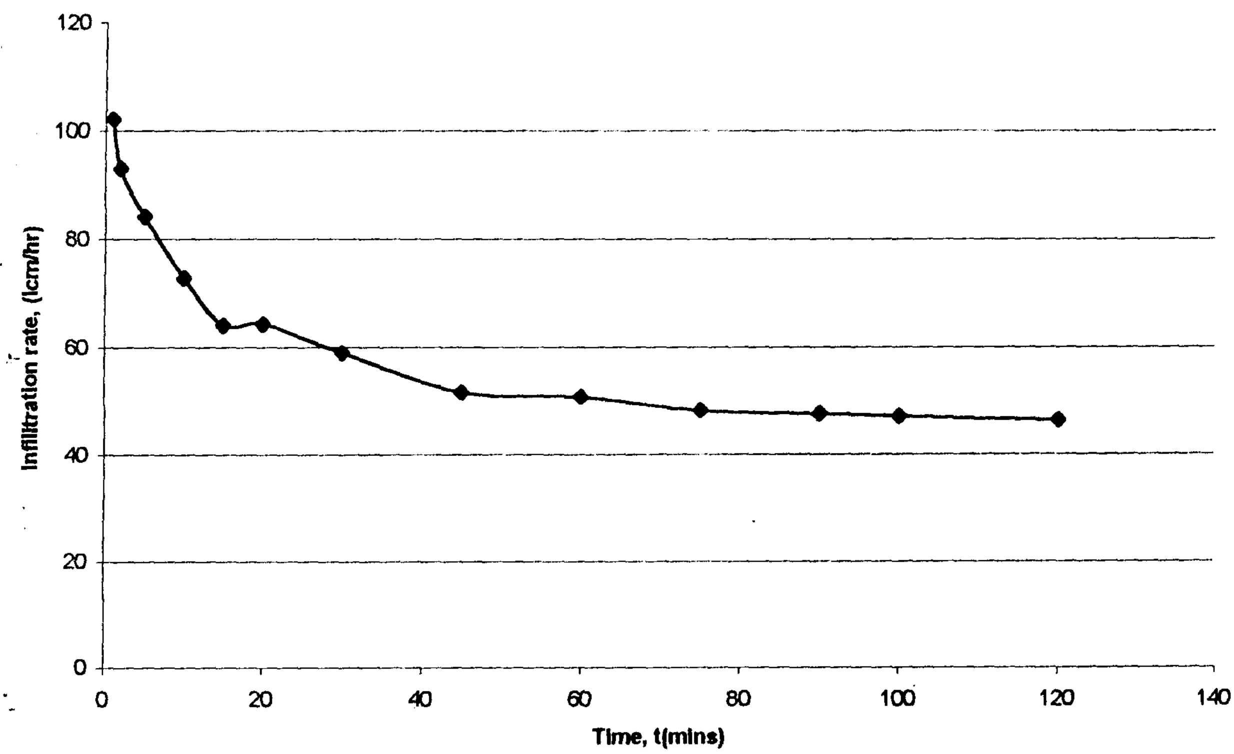

Fig. 2: Graph of infiltration rate against time for average of four replicates for fallowed land

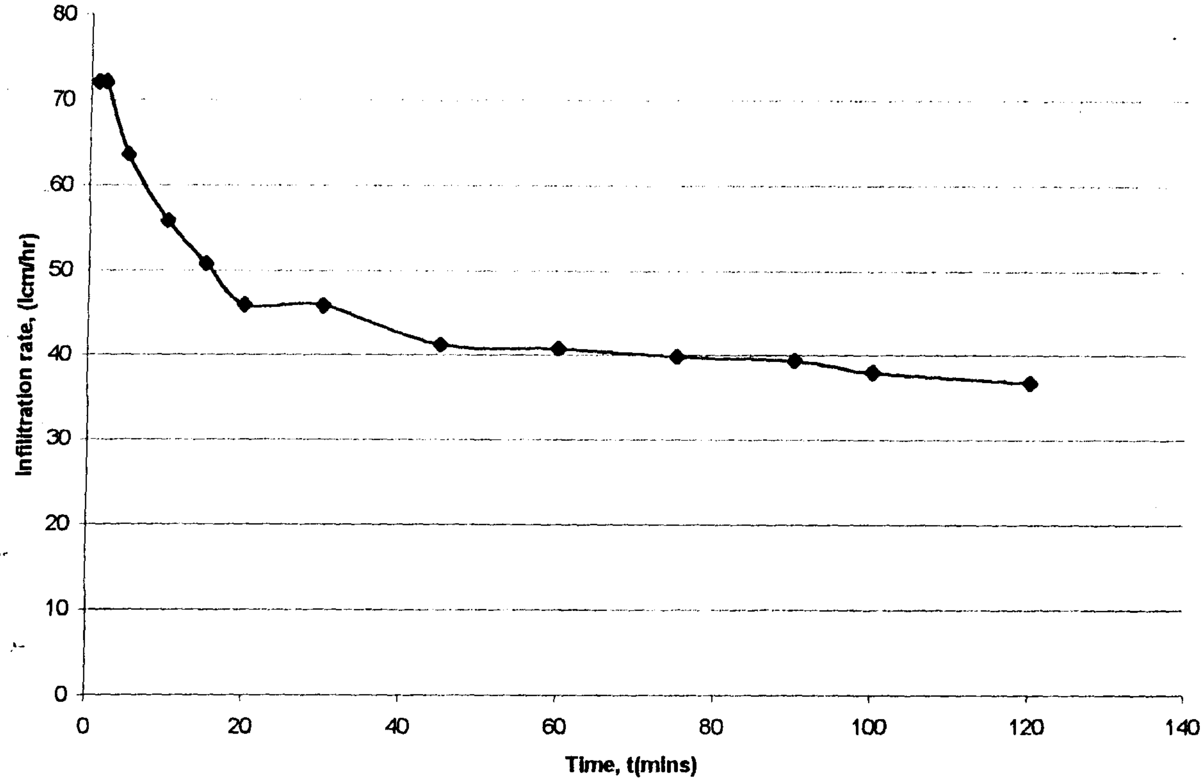

Fig. 3. Graph of infiltration rate against time for average of four replicates for cultivated land

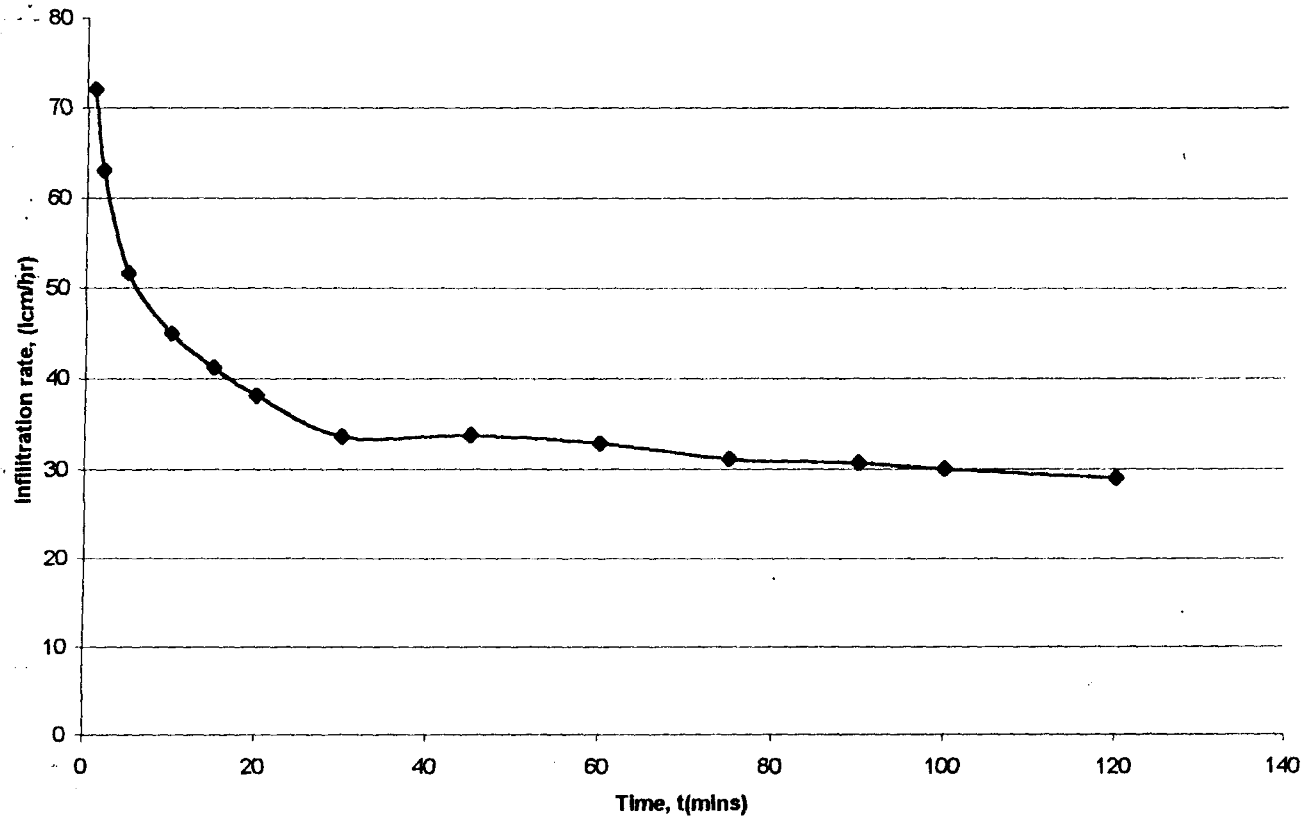

Fig. 4. Graph of infiltration rate against time for average of four replicates for fallowed land

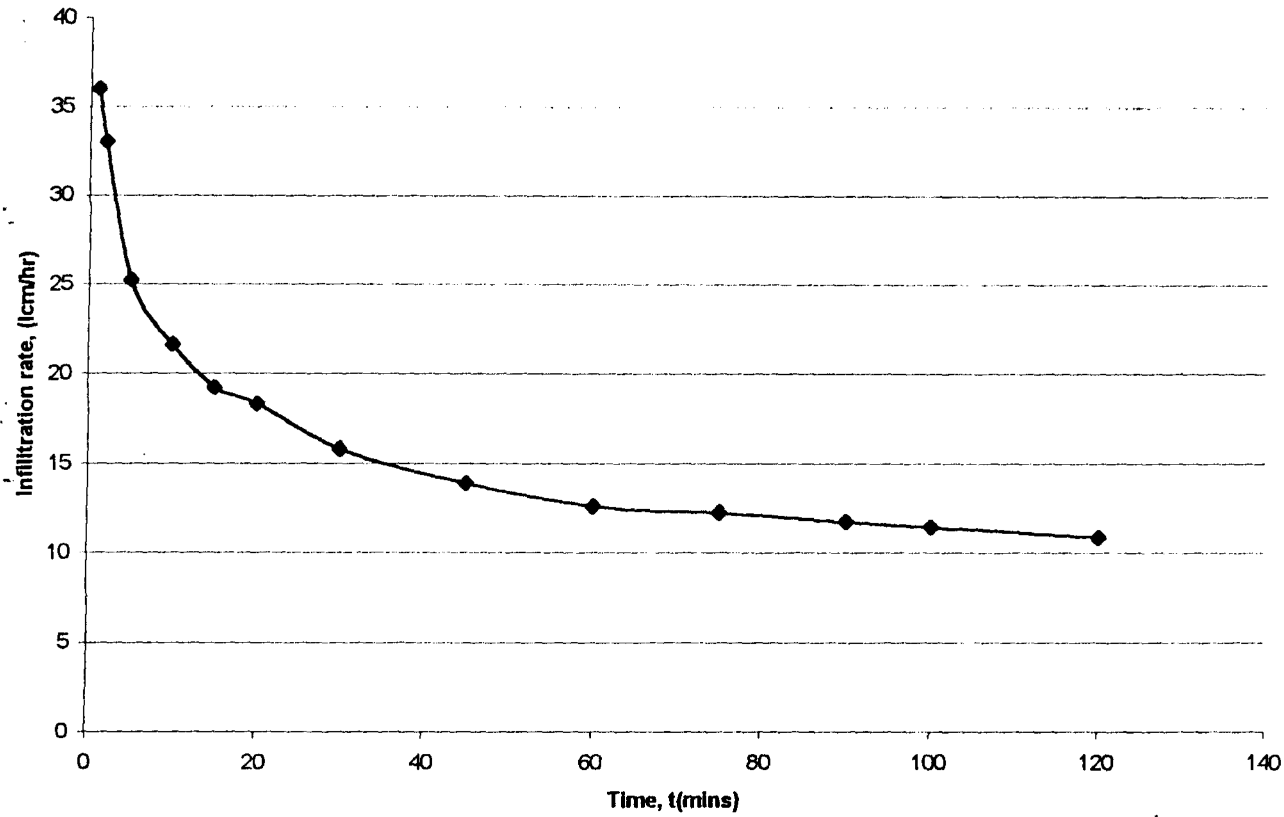

Fig. :5: Graph of Infiltration rate against time for average of four replicates for cultivated land

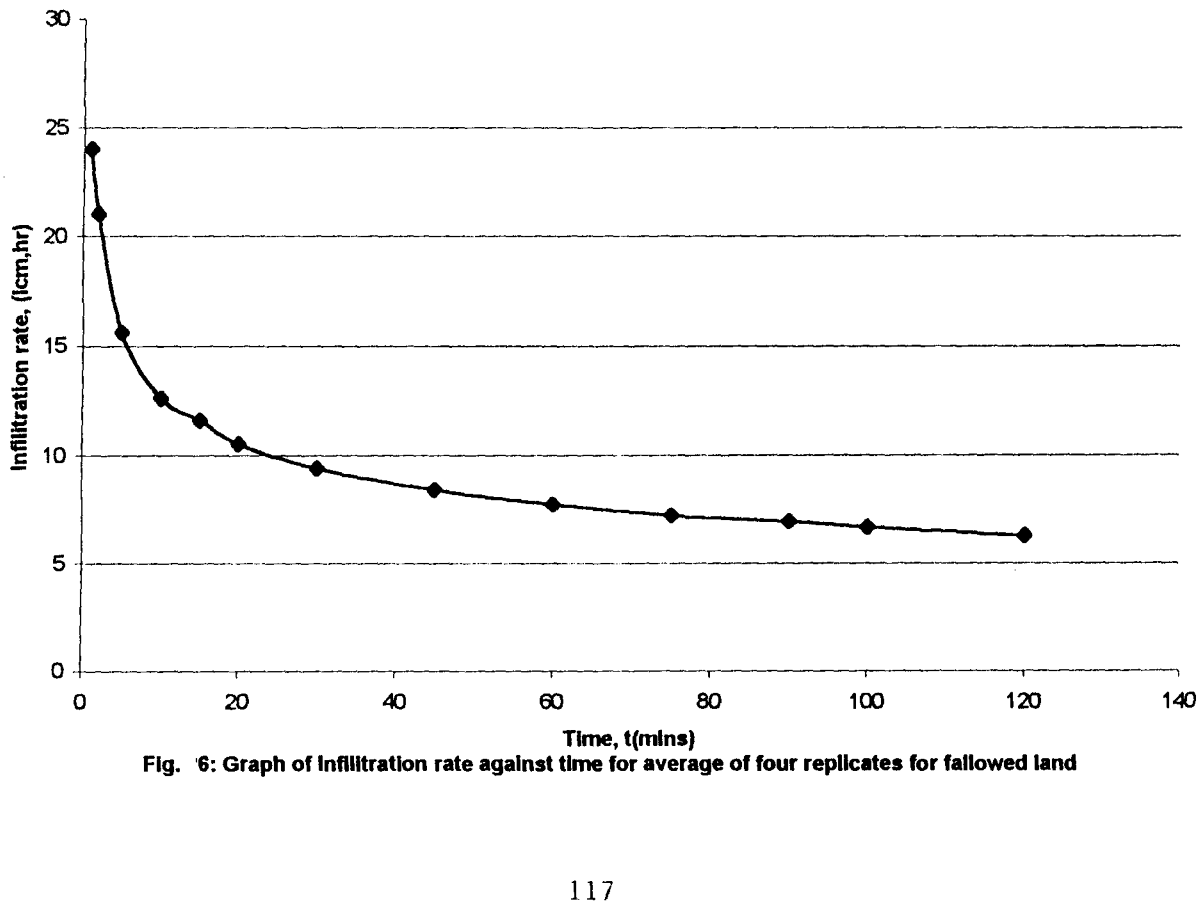

Fig. '6: Graph of Infiltration rate against time for average of four replicates for fallowed land

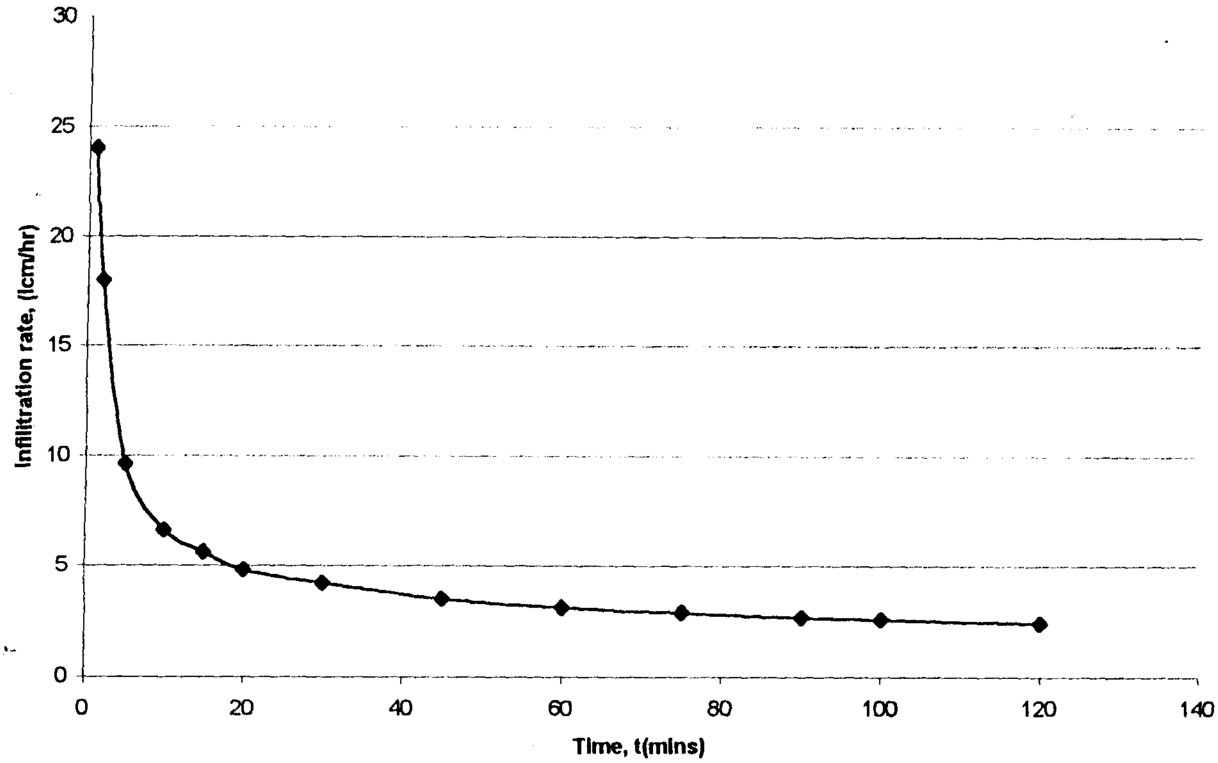

Fig. 7: Graph of Infiltration rate against time for average of four replicates for cultivated land

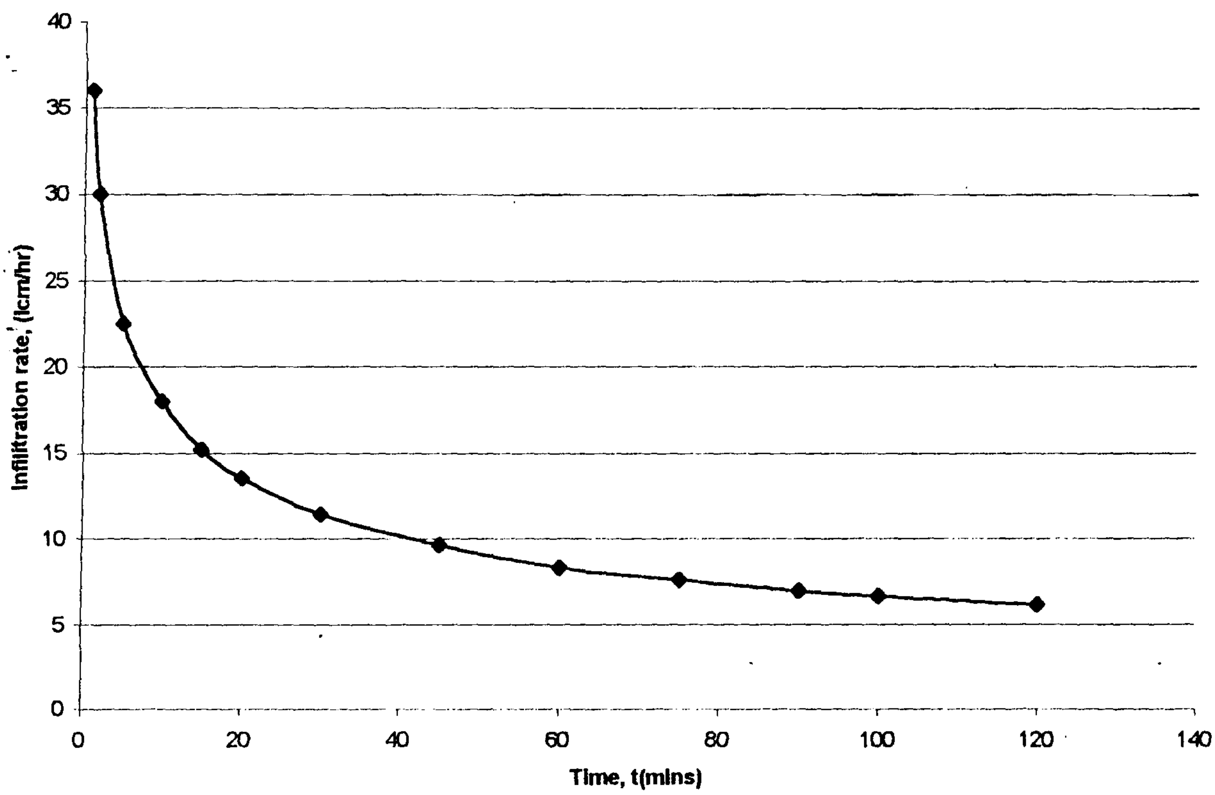

Fig. 8: Graph of Infiltration rate against time for average of four replicates for fallowed land

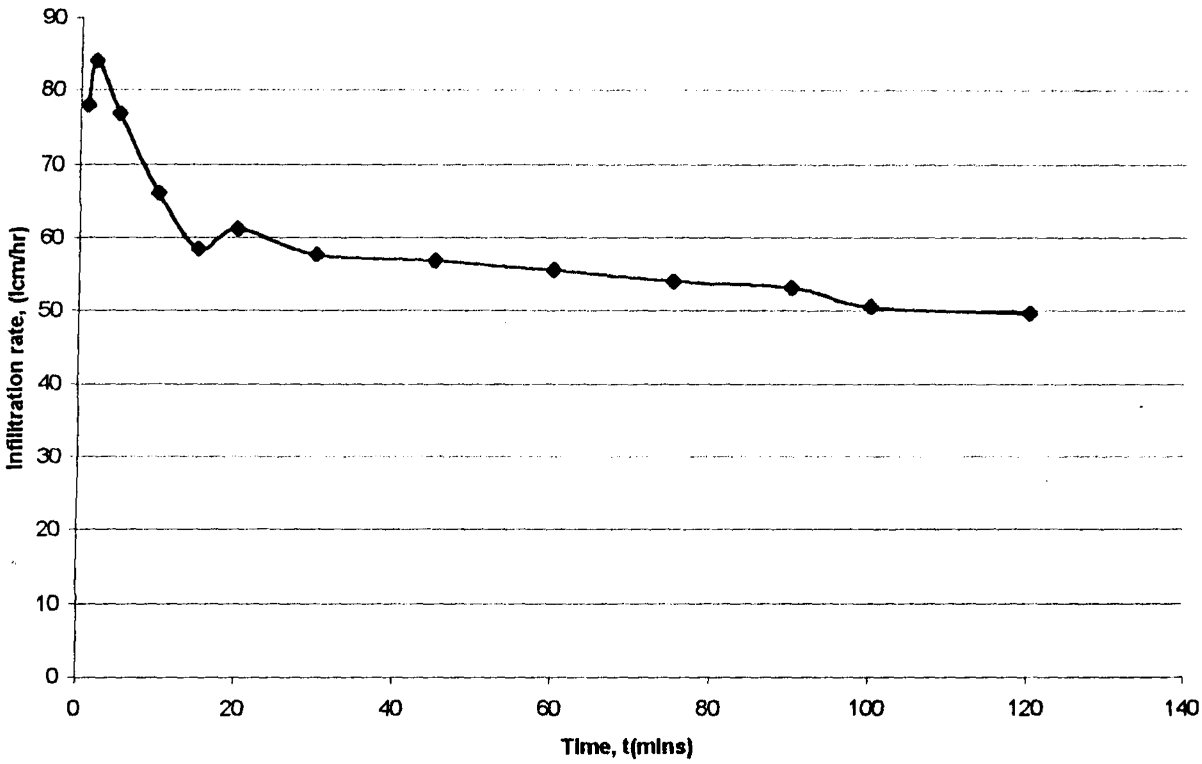

Fig. 9: Graph of infiltration rate against time for average of four replicates for cultivated land

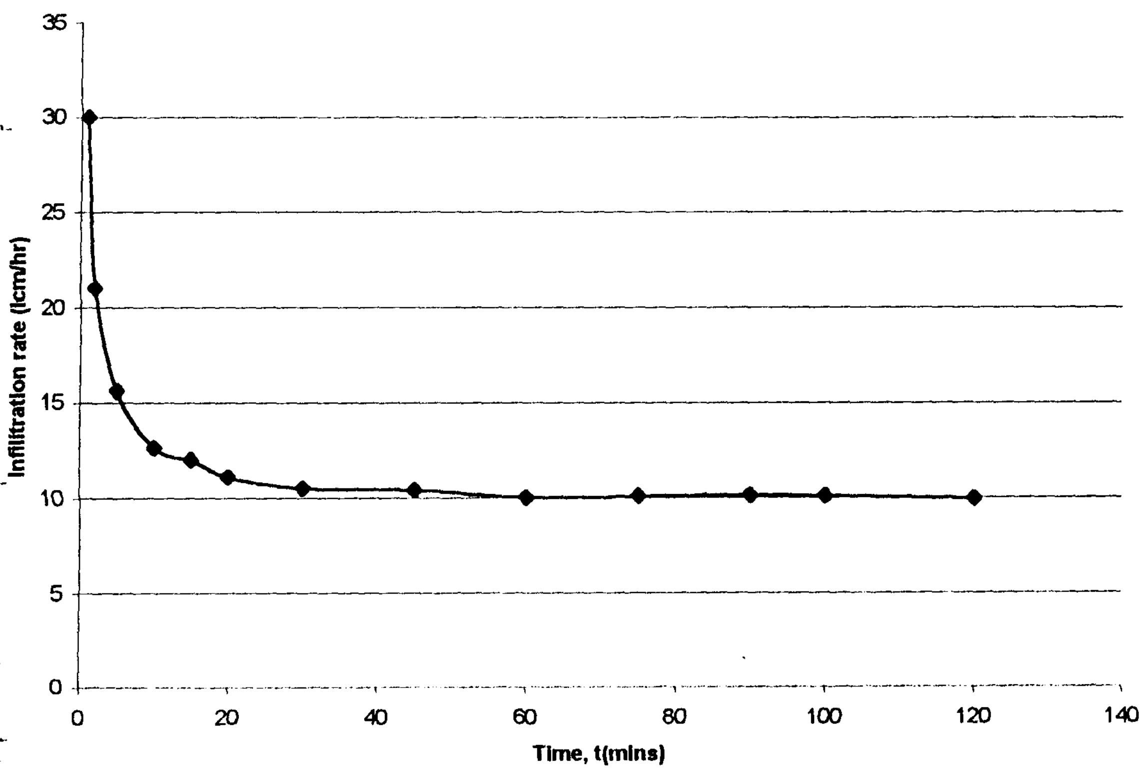

Fig. 10: Graph of infiltration rate against time for average of four replicates for fallowed land

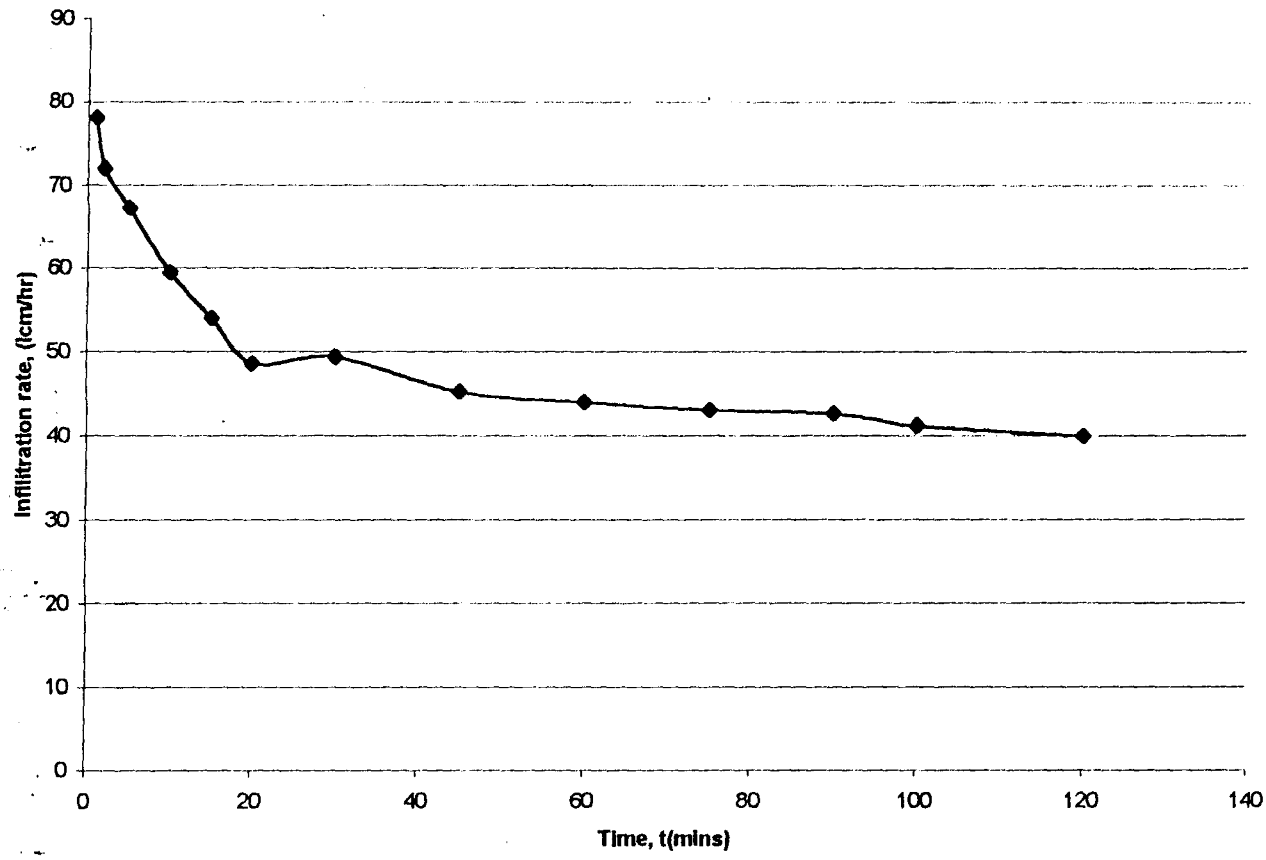

Fig. 11: Graph of Infiltration rate against time for average of four replicates for cultivated land

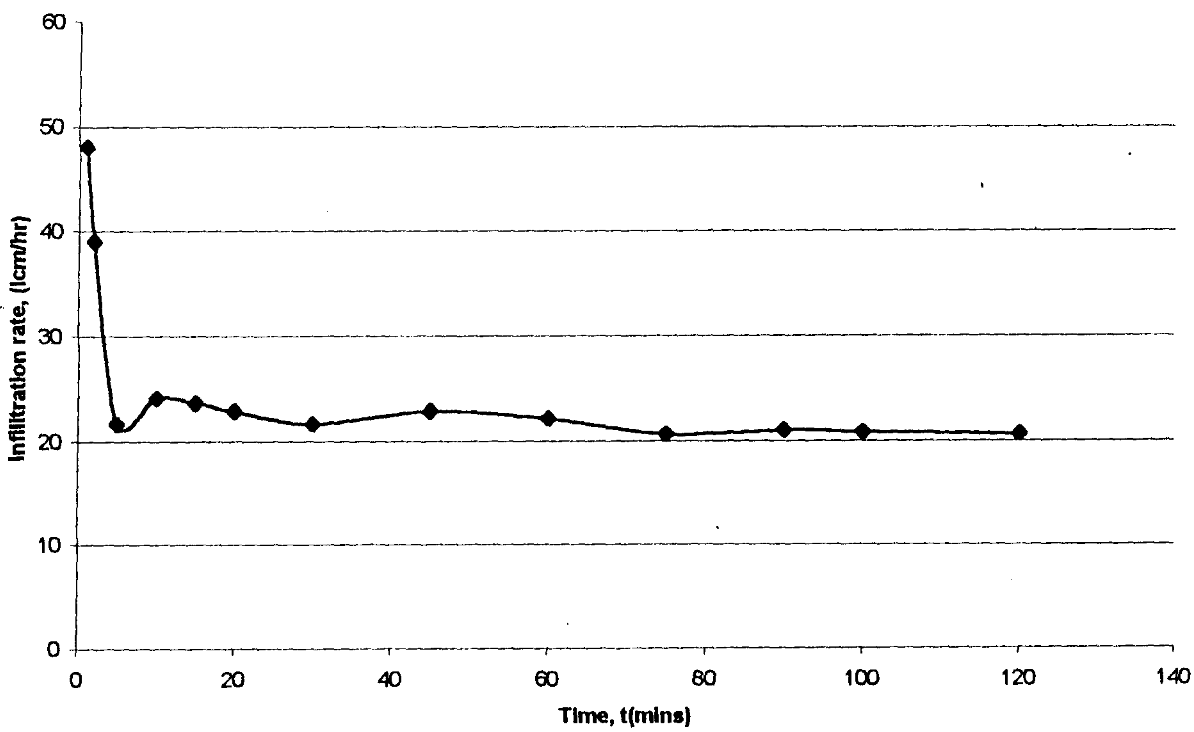

Fig. 12: Graph of Infiltration rate against time for average of four replicates for fallowed land

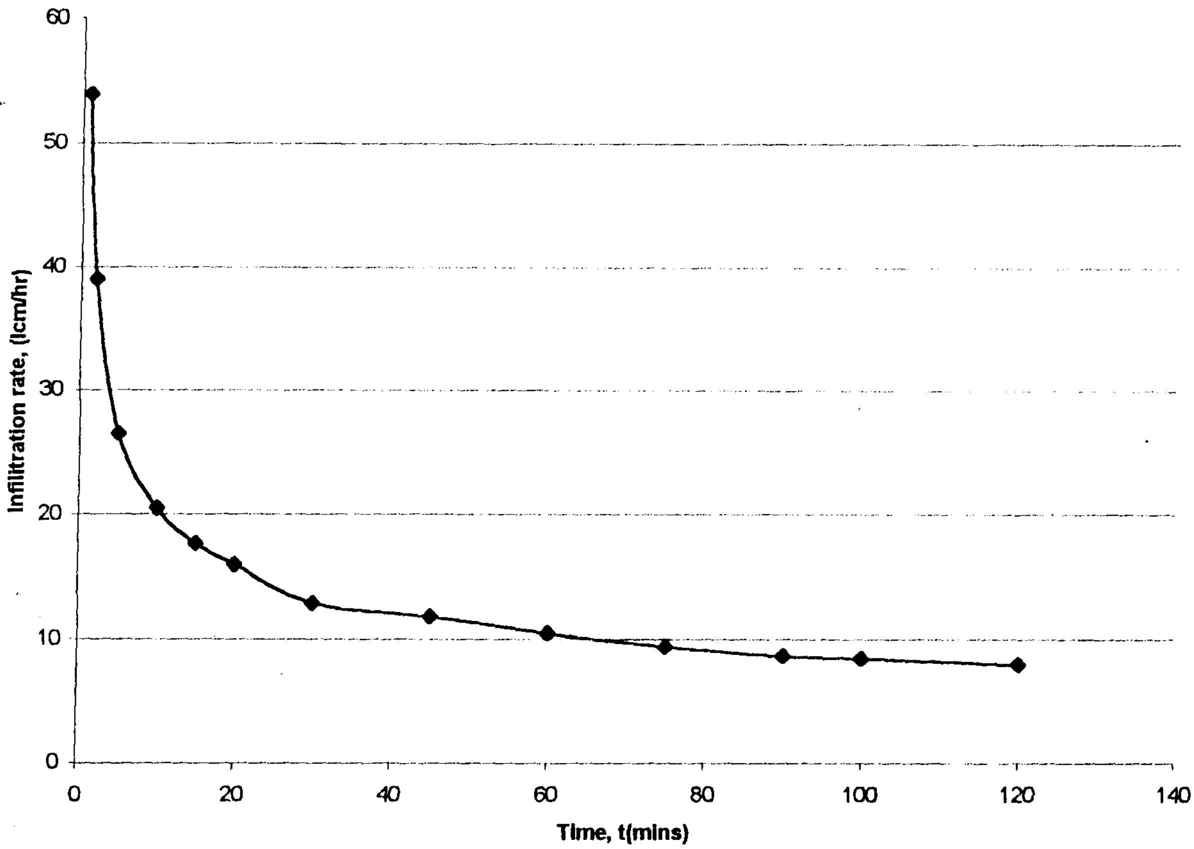

Fig. 13 Graph of Infiltration rate against time for average of four replicates for cultivated land

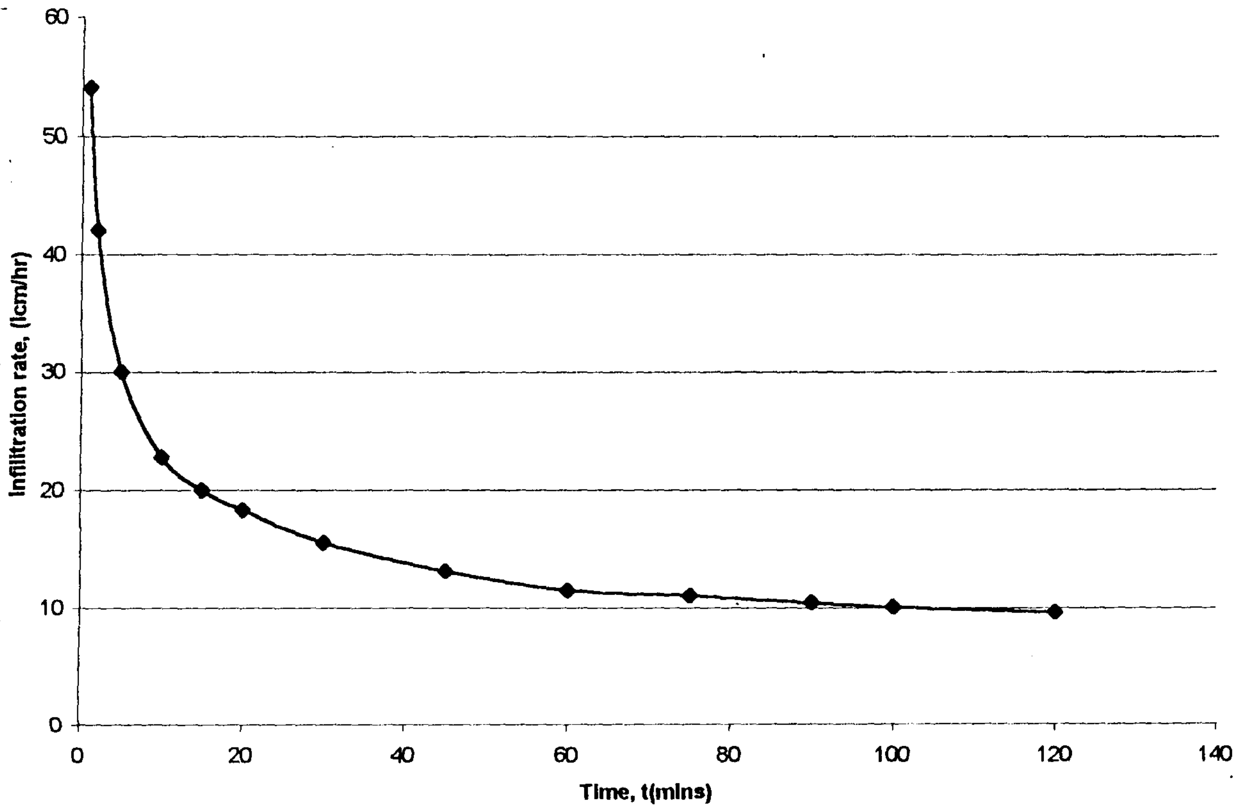

Fig. 14 Graph of Infiltration rate against time for average of four replicates for fallowed land

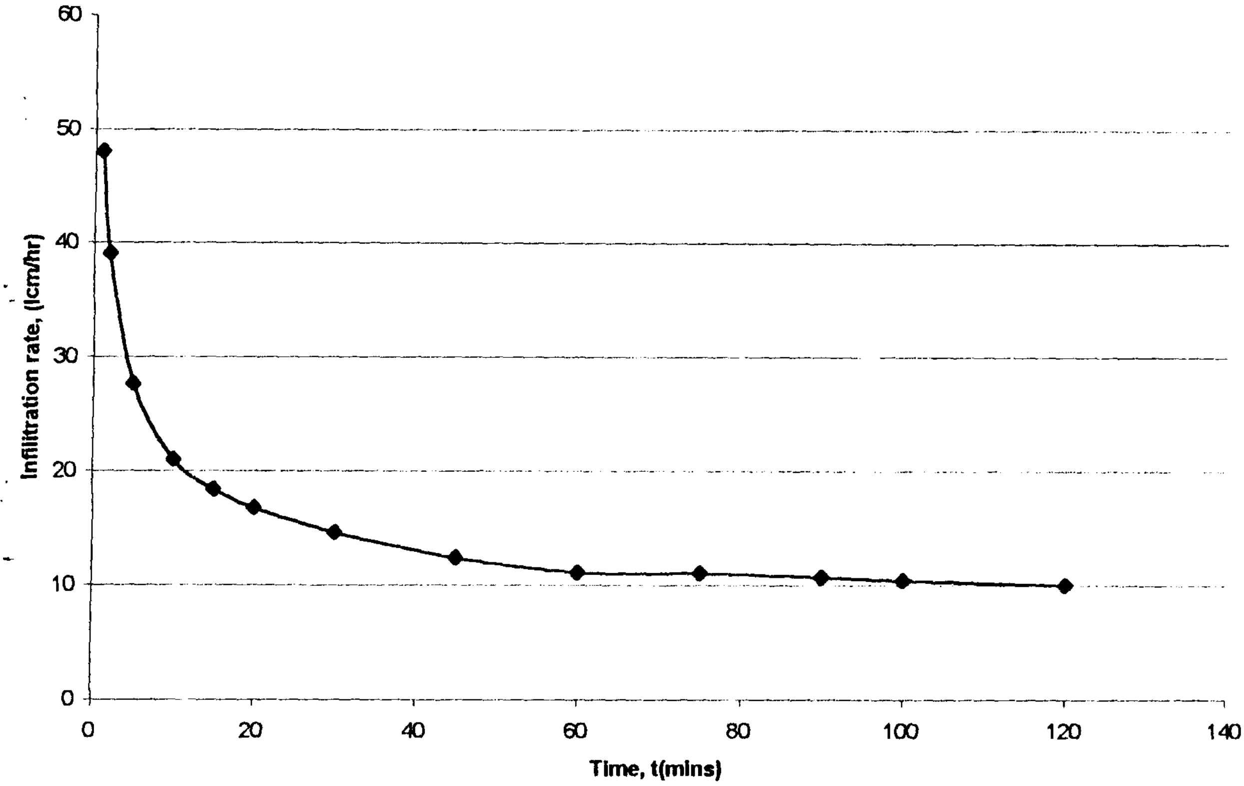

Fig. 15 Graph of Infiltration rate against time for average of four replicates for cultivated land

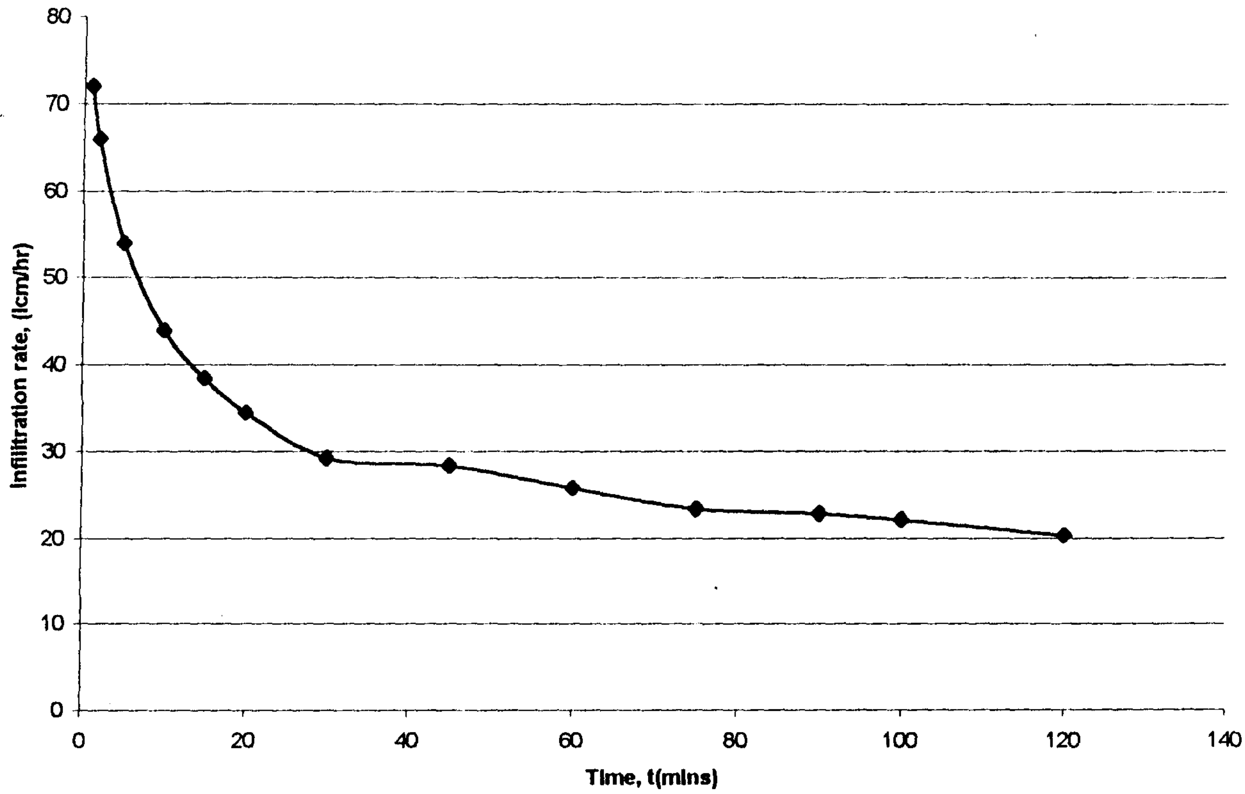

Fig. 16. Graph of Infiltration rate against time for average of four replicates for fallowed land

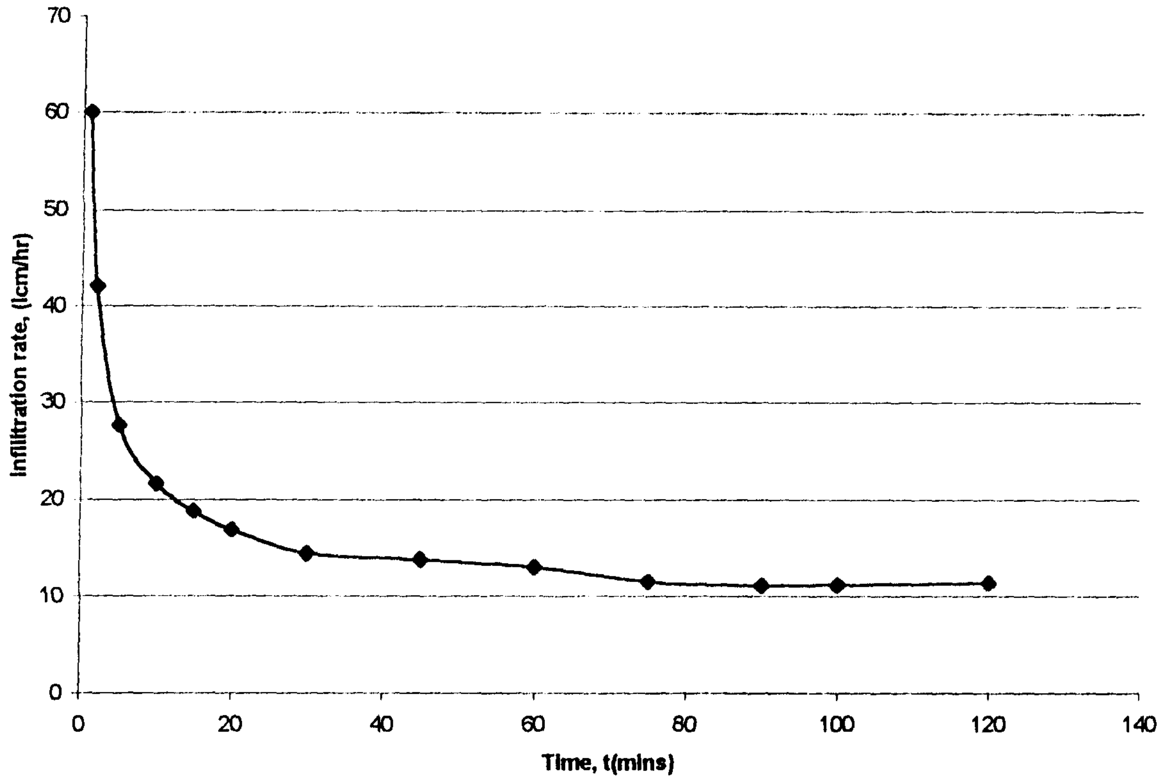

Fig.17 : Graph of Infilitration rate against time for average of four replicates for cultivated land

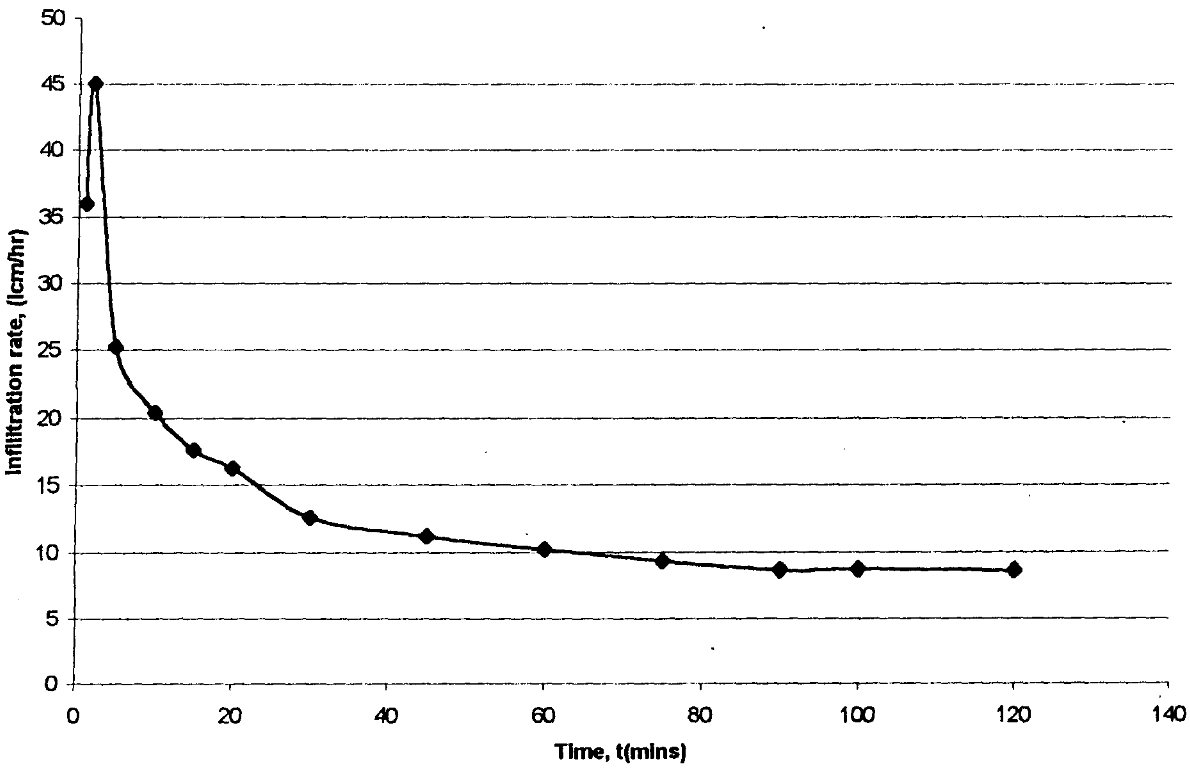

Fig. 18: Graph of Infilitration rate against time for average of four replicates for fallowed land

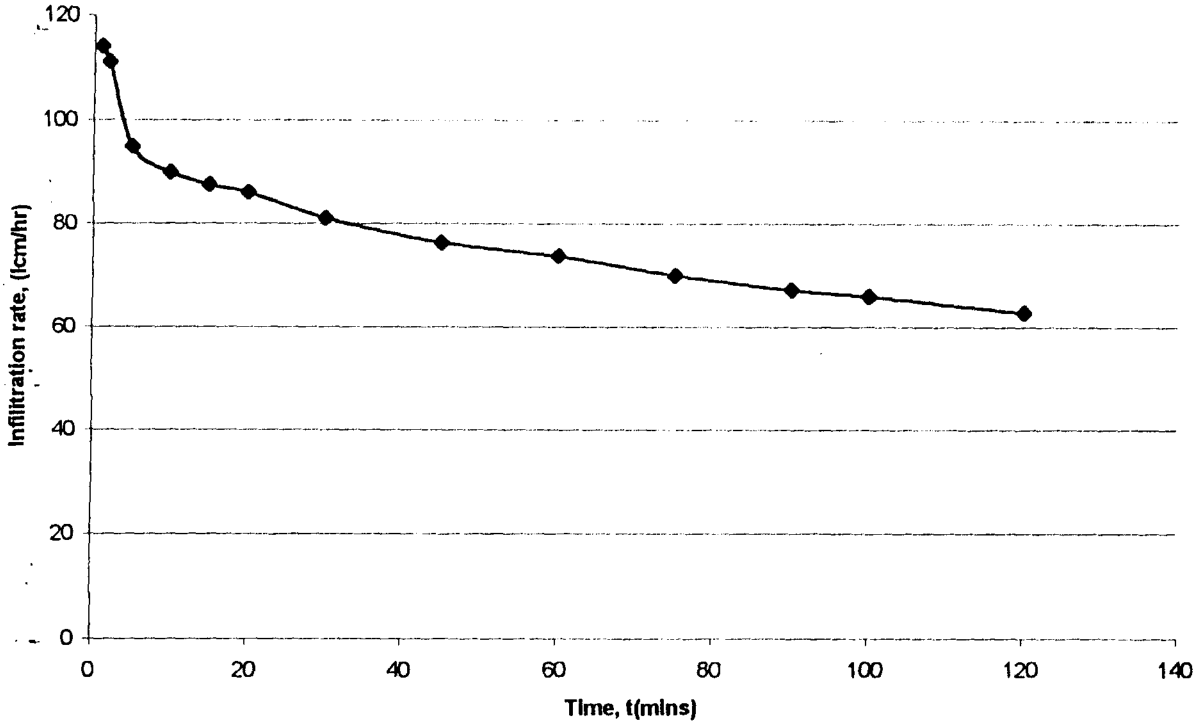

Fig.19: Graph of Infiltration rate against time for average of four replicates for cultivated land

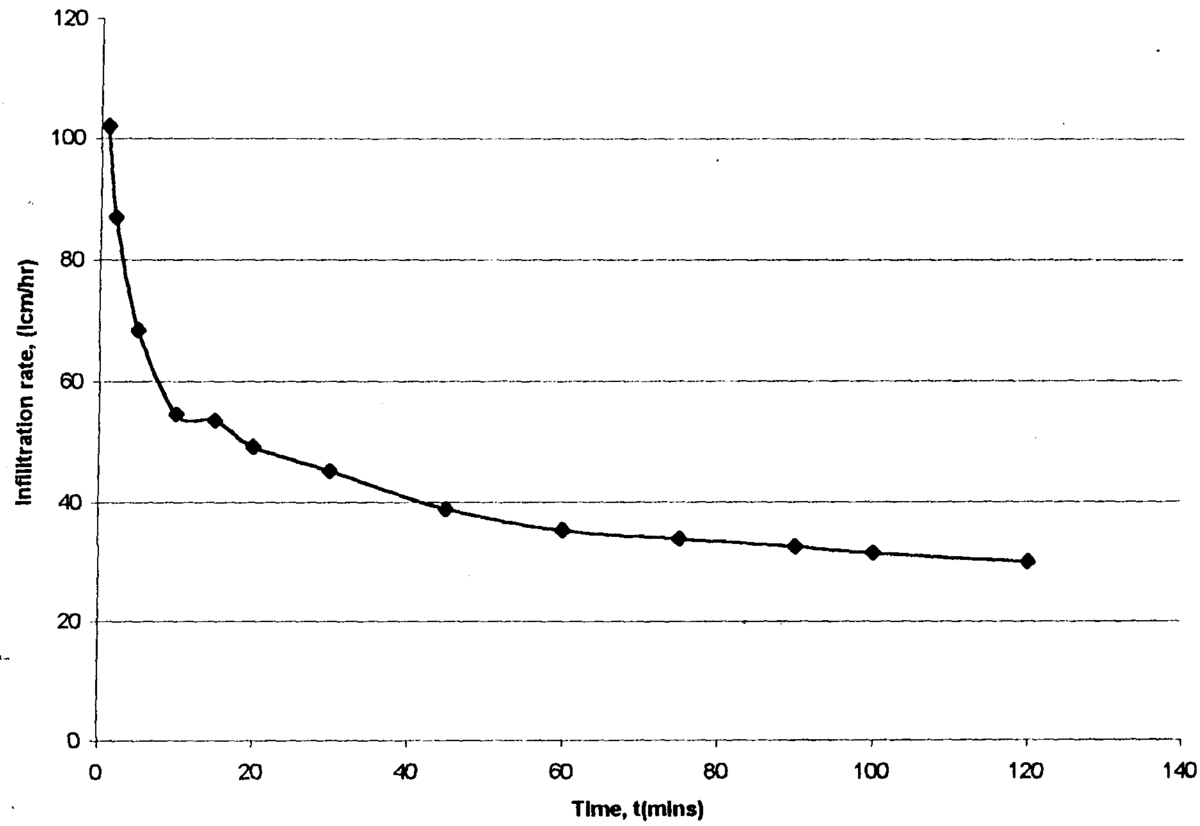

Fig.20 Graph of Infiltration rate against time for average of four replicates for fallowed land

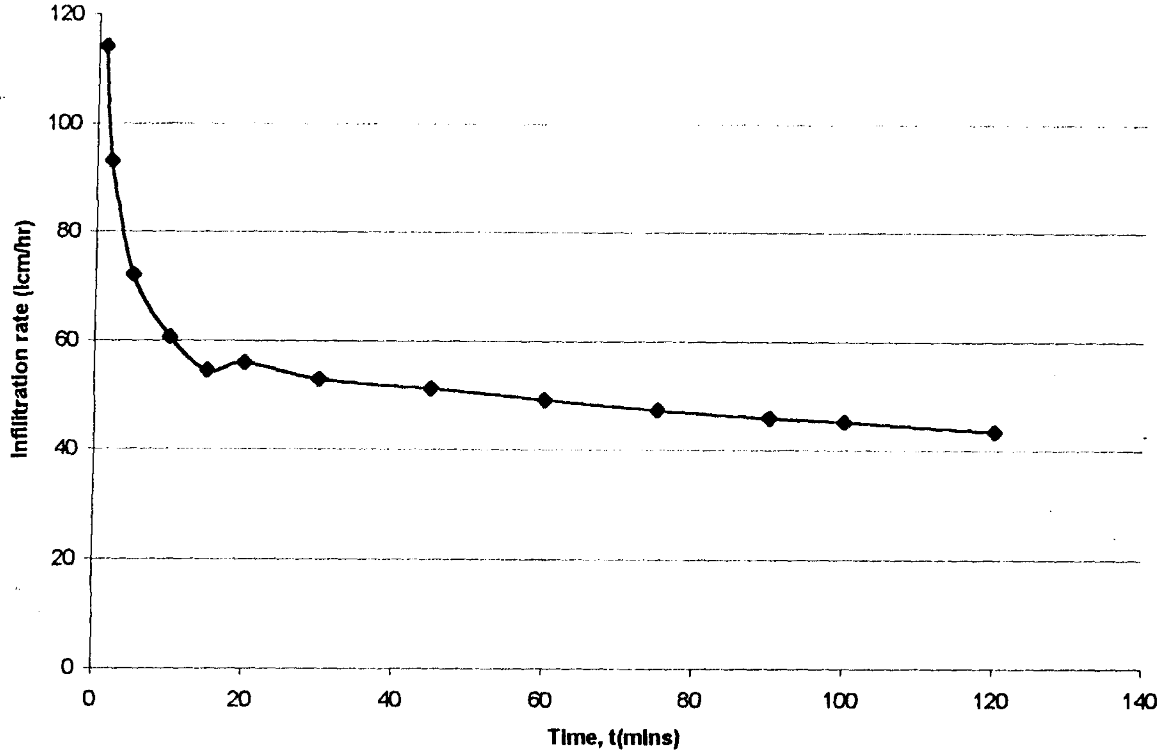

Fig. 21: Graph of Infiltration rate against time for average of four replicates for cultivated land

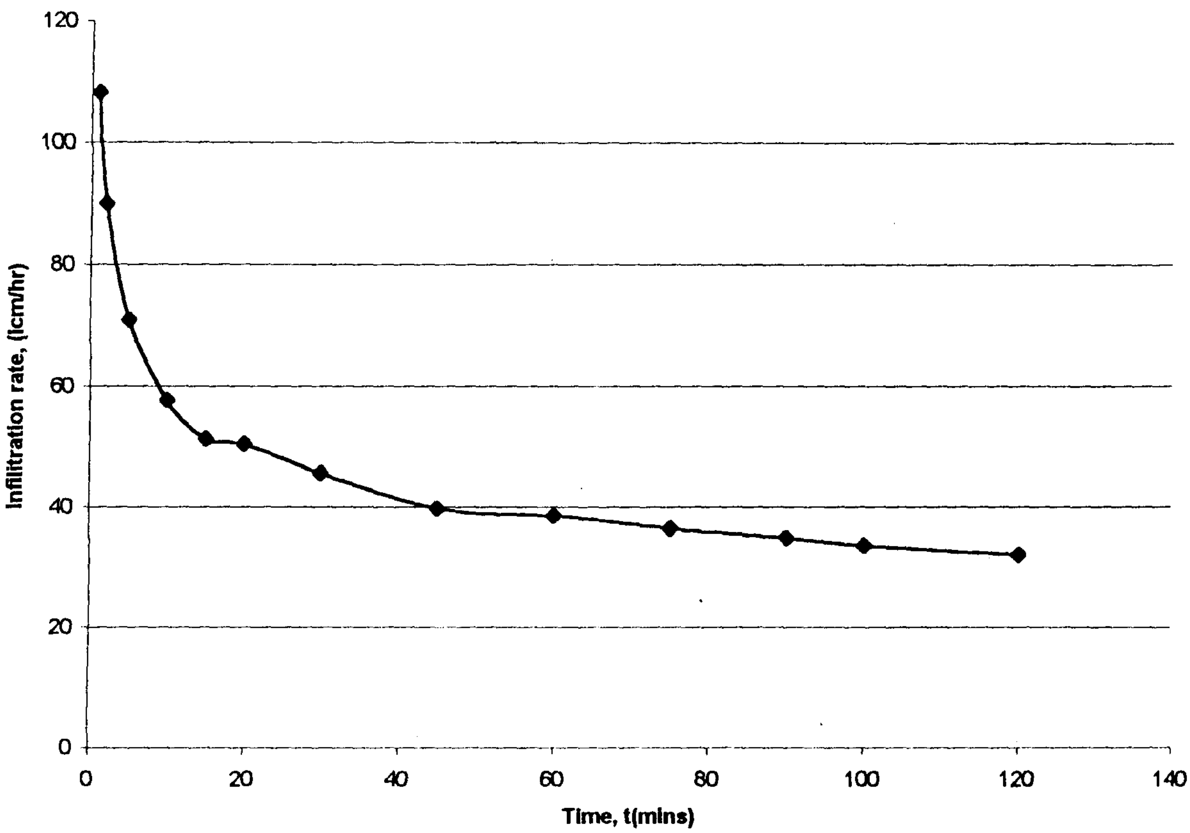

Fig. 22: Graph of Infiltration rate against time for average of four replicates for fallowed land

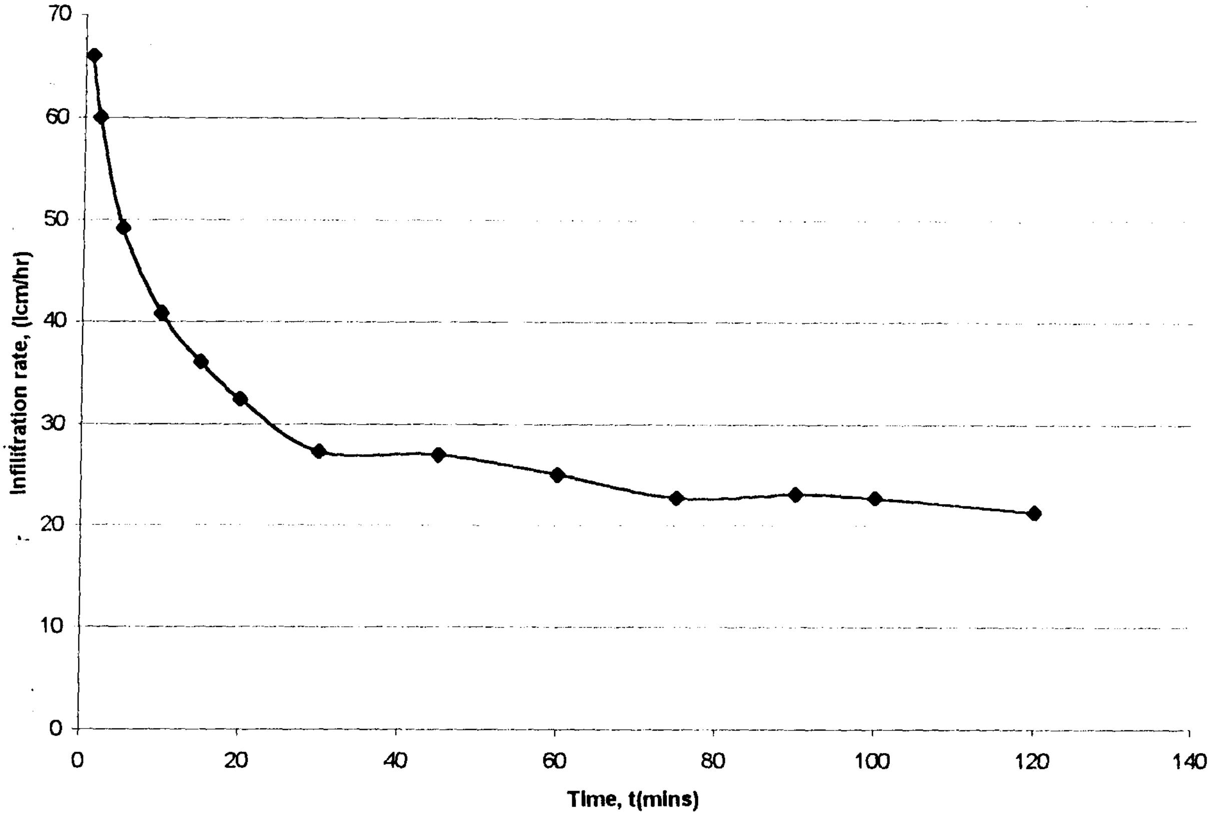

Fig23 : Graph of Infilitration rate against time for average of four replicates for cultivated land

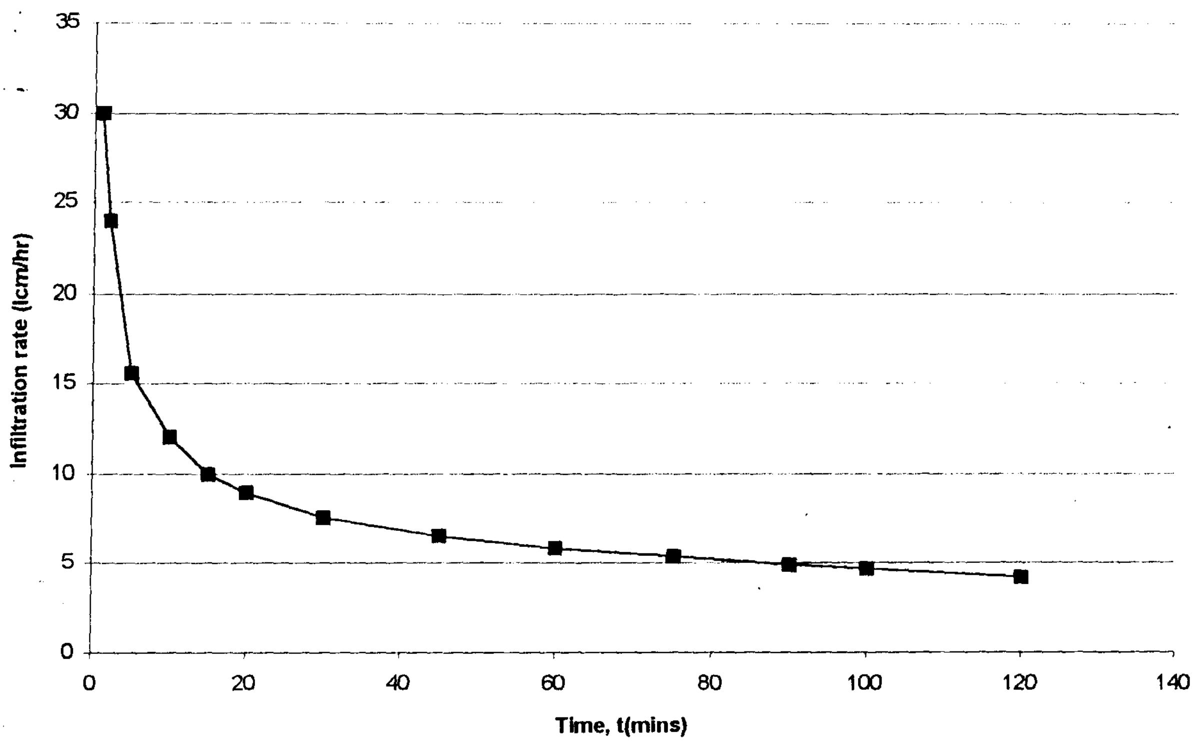

Fig.24: Graph of infiltration rate against time for average of four replicates for fallowed land

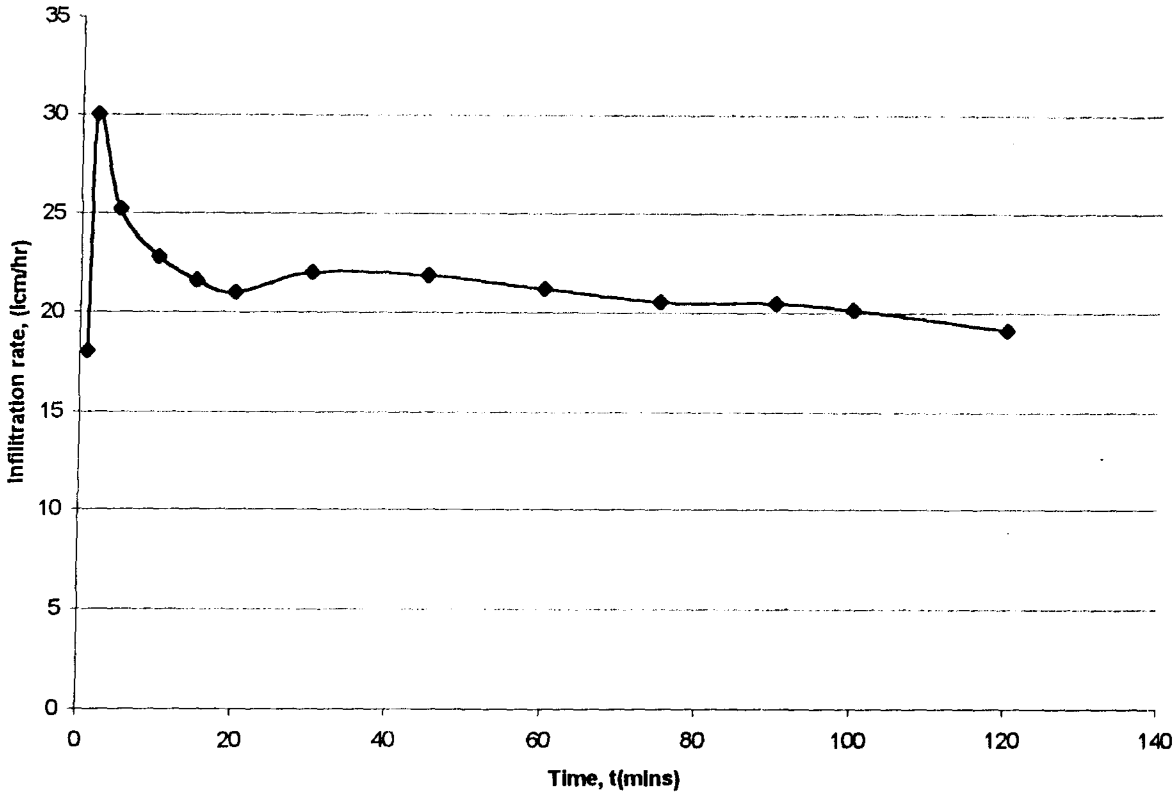

Fig. 25 Graph of Infiltration rate against time for average of four replicates for cultivated land

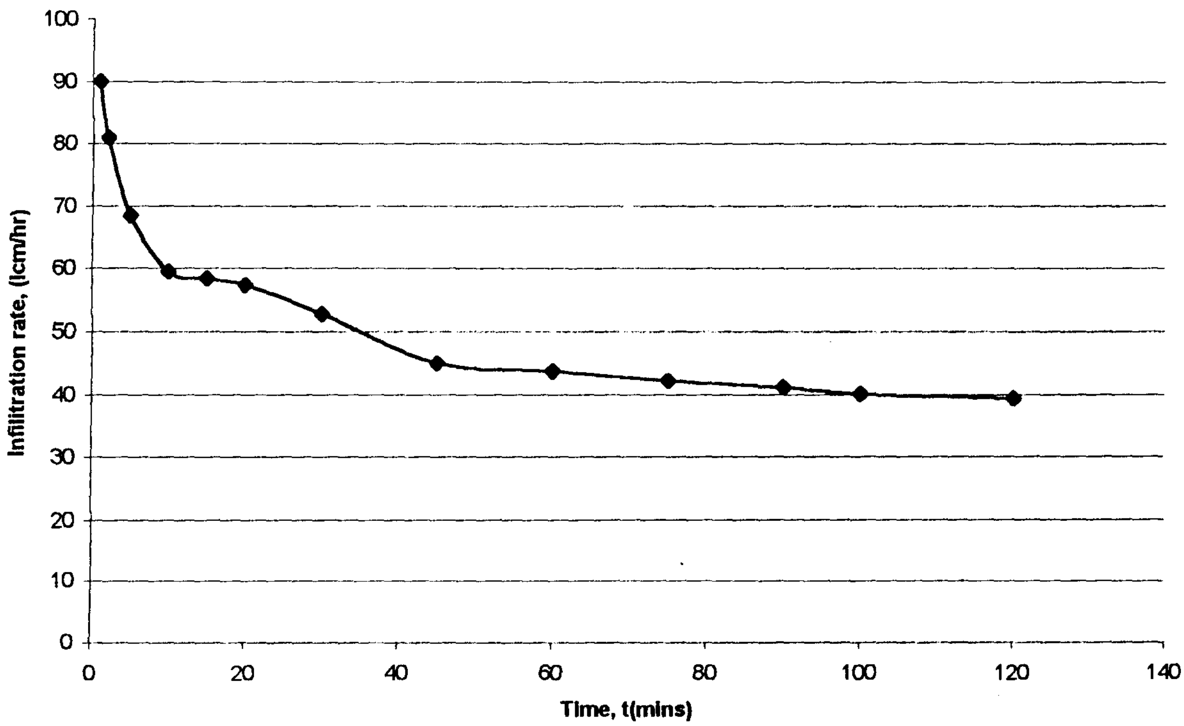

Fig. 26 Graph of Infiltration rate against time for average of four replicates for fallowed land

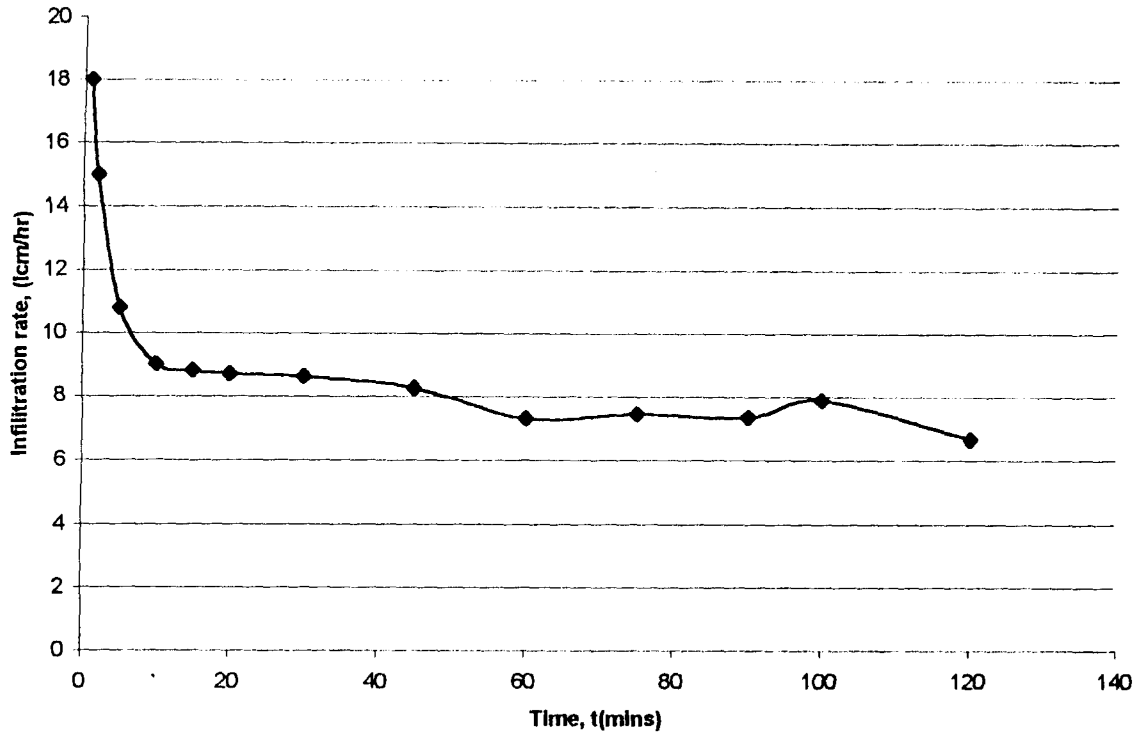

Fig.27 Graph of Infilitration rate against time for average of four replicates for cultivated land

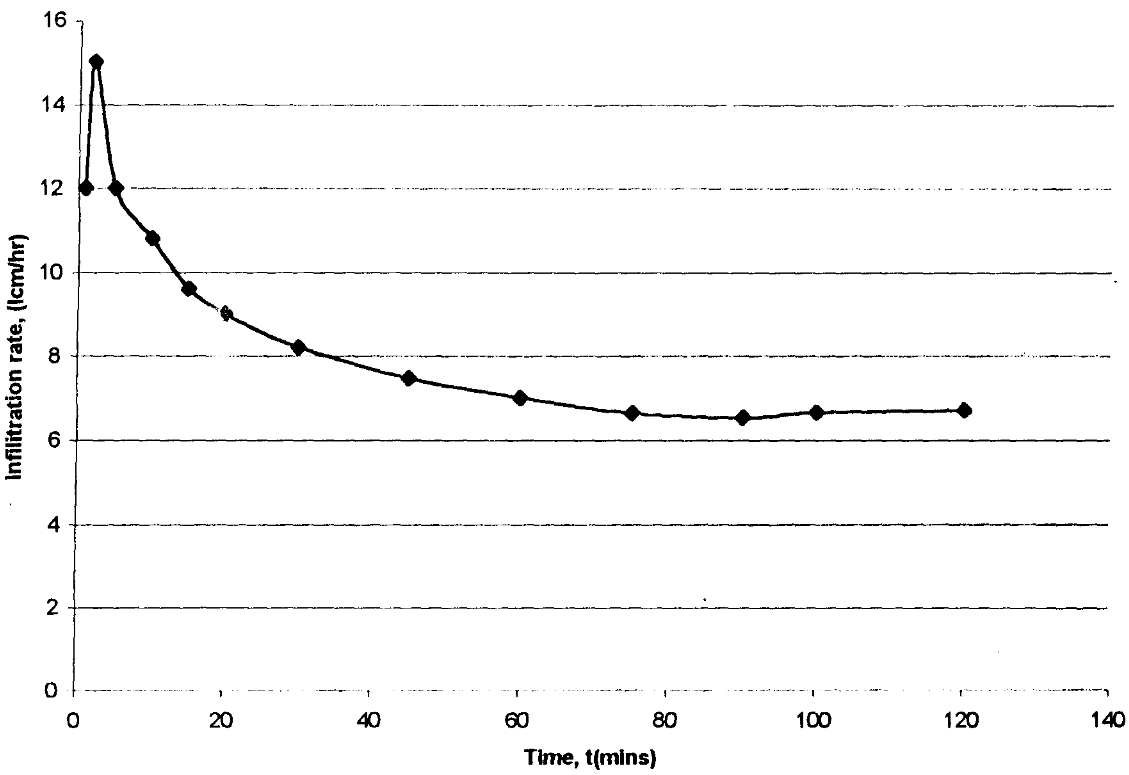

Fig28 Graph of Infilitration rate against time for average of four replicates for fallowed land

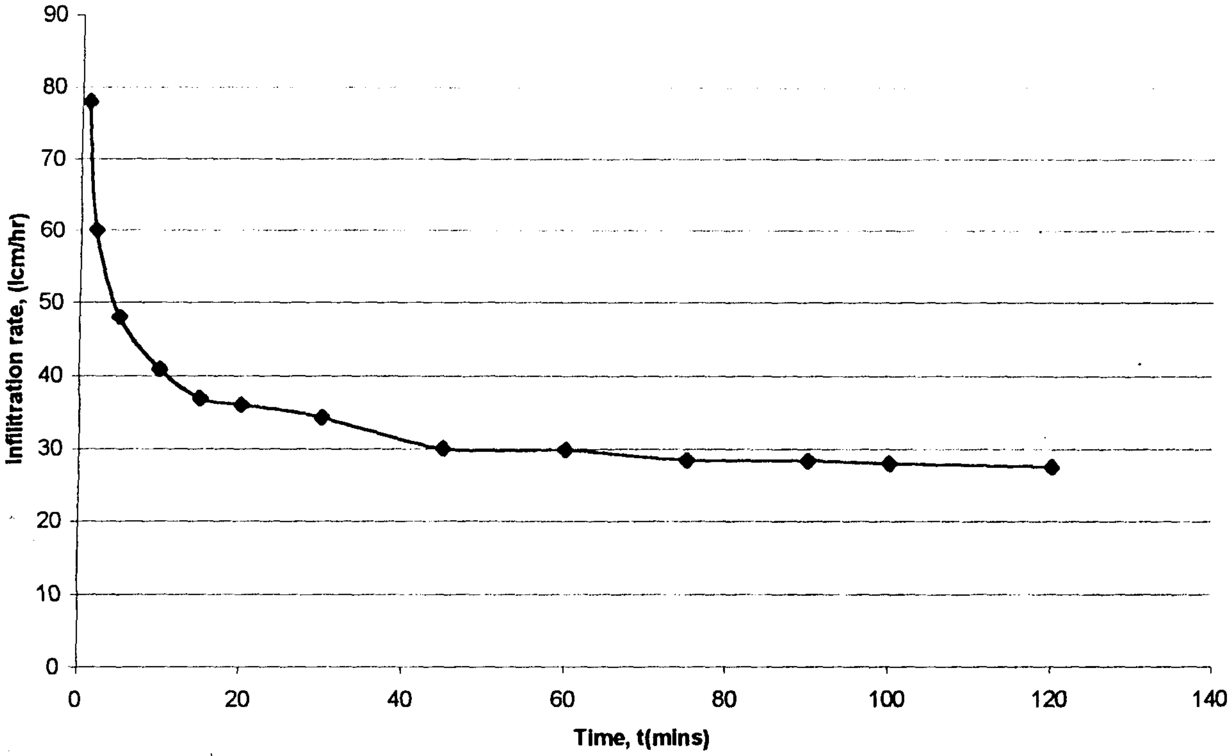

Fig.29 Graph of infiltration rate against time for average of four replicates for cultivated land

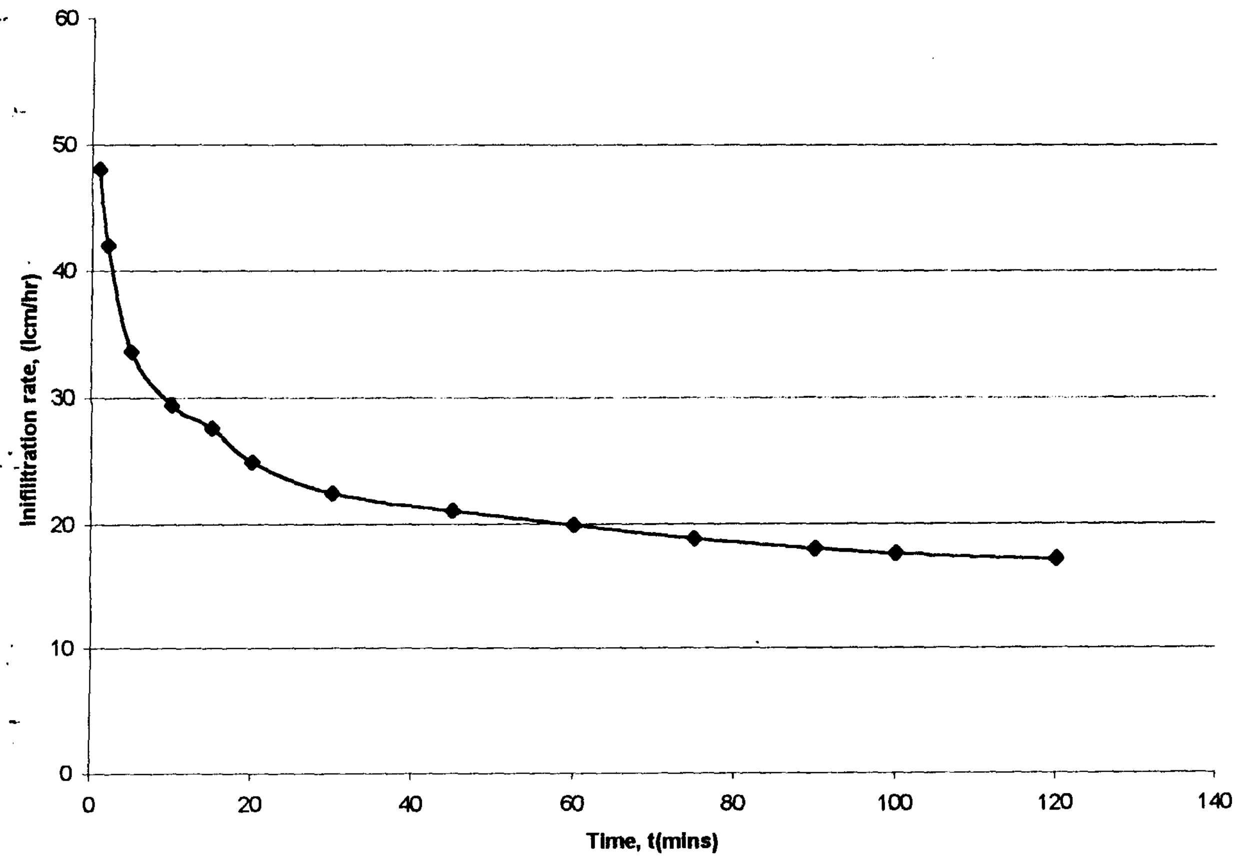

Fig.30Graph of infiltration rate against time for average of four replicates for fallowed land

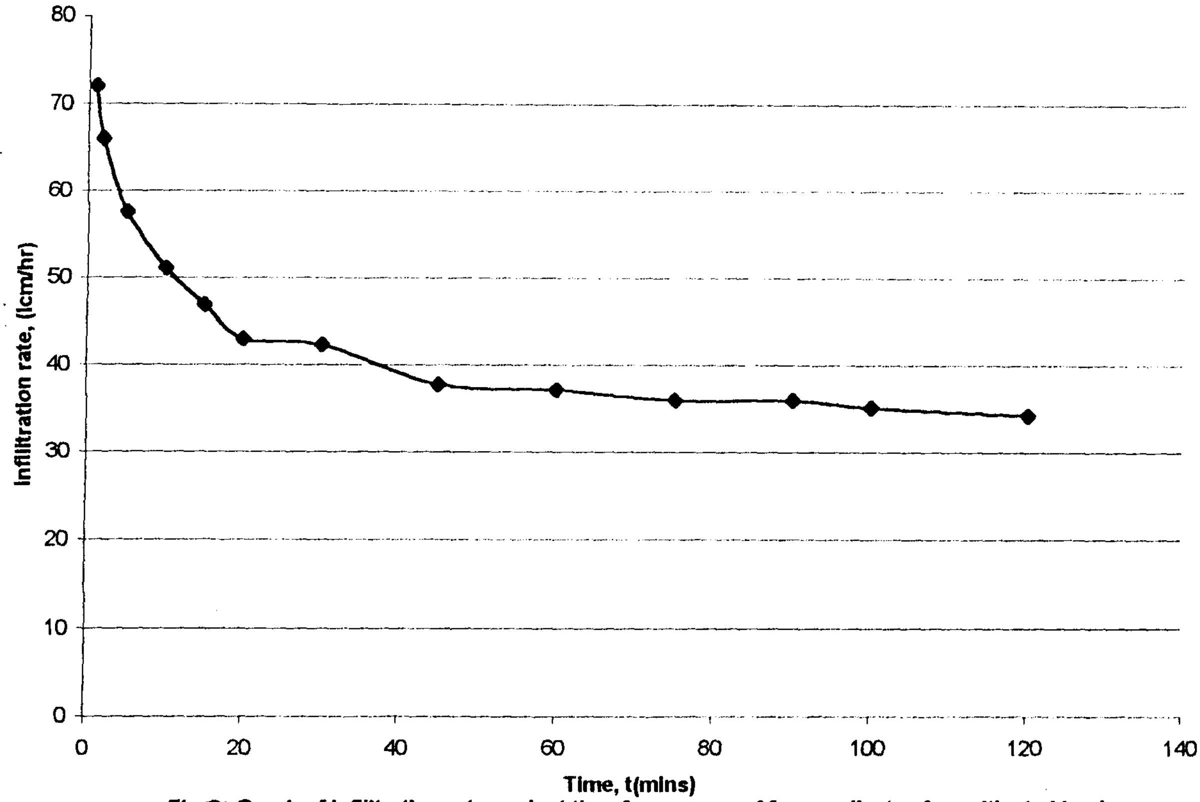

Fig.31 Graph of Infiltration rate against time for average of four replicates for cultivated land

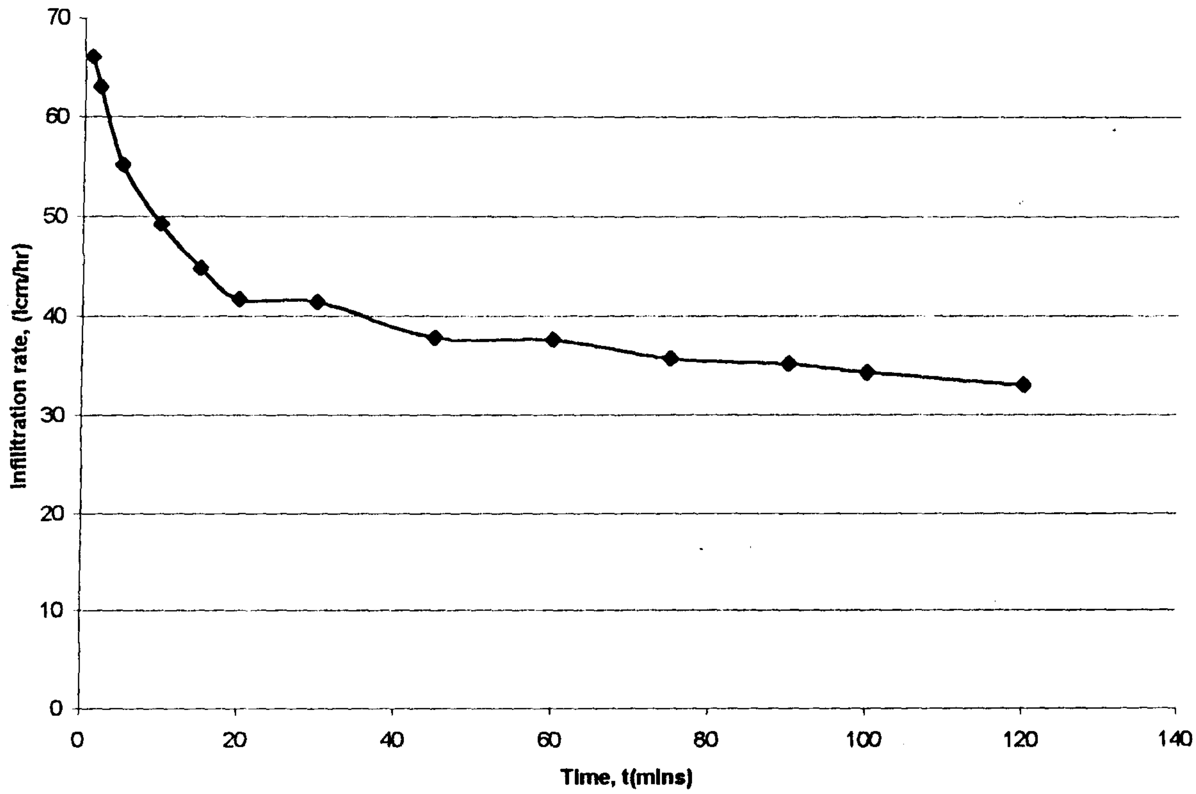

Fig.32 Graph of Infiltration rate against time for average of four replicates for fallowed land

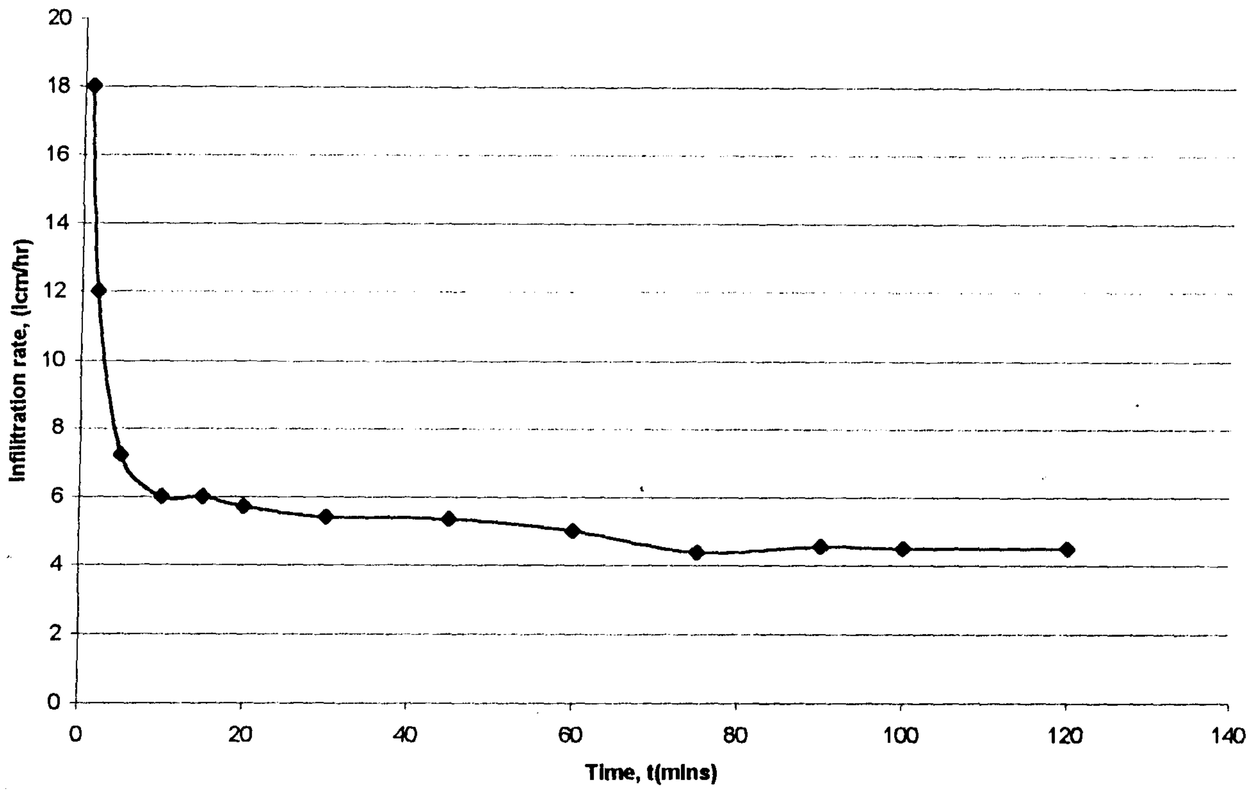

Fig.33 Graph of Infilitration rate against time for average of four replicates for cultivated land

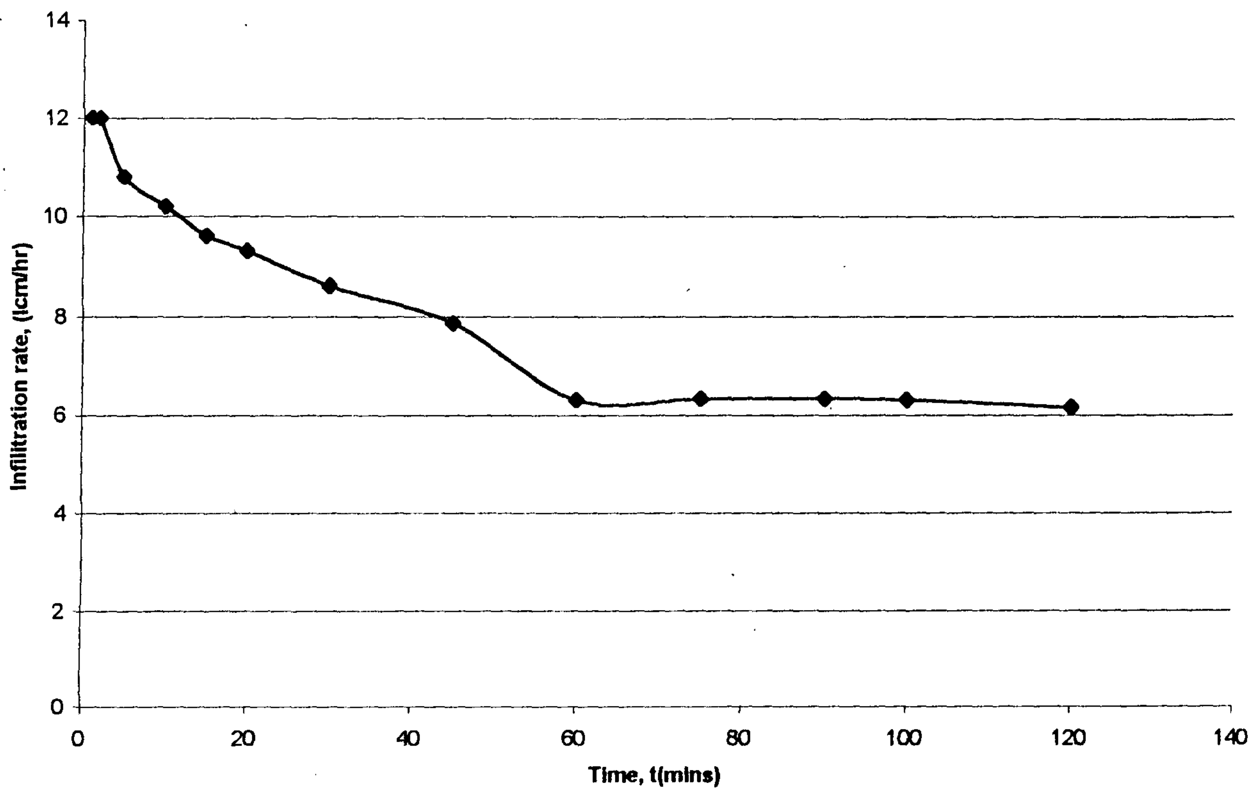

Fig.34. Graph of Infilitration rate against time for average of four replicates for fallowed land

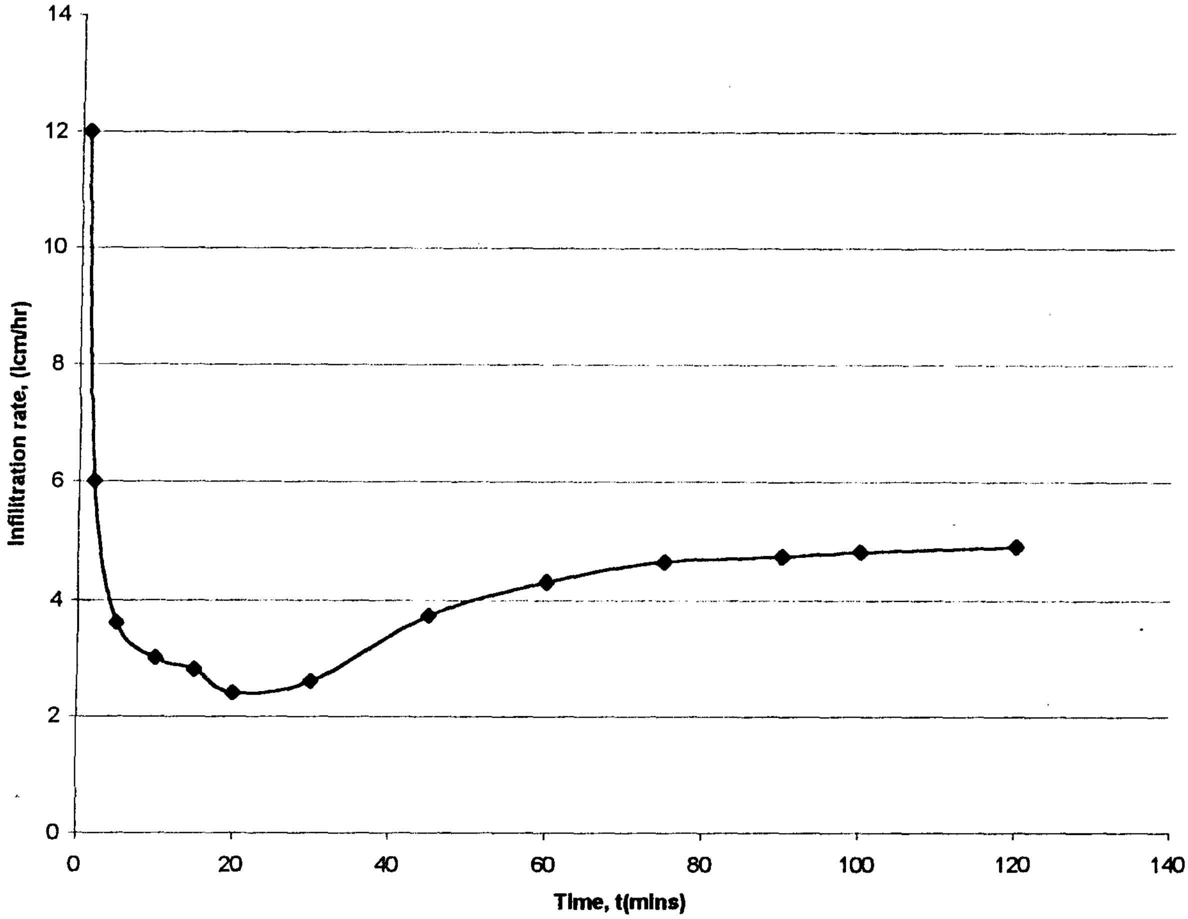

Fig. 35 Graph of Infiltration rate against time for average of four replicates for cultivated land

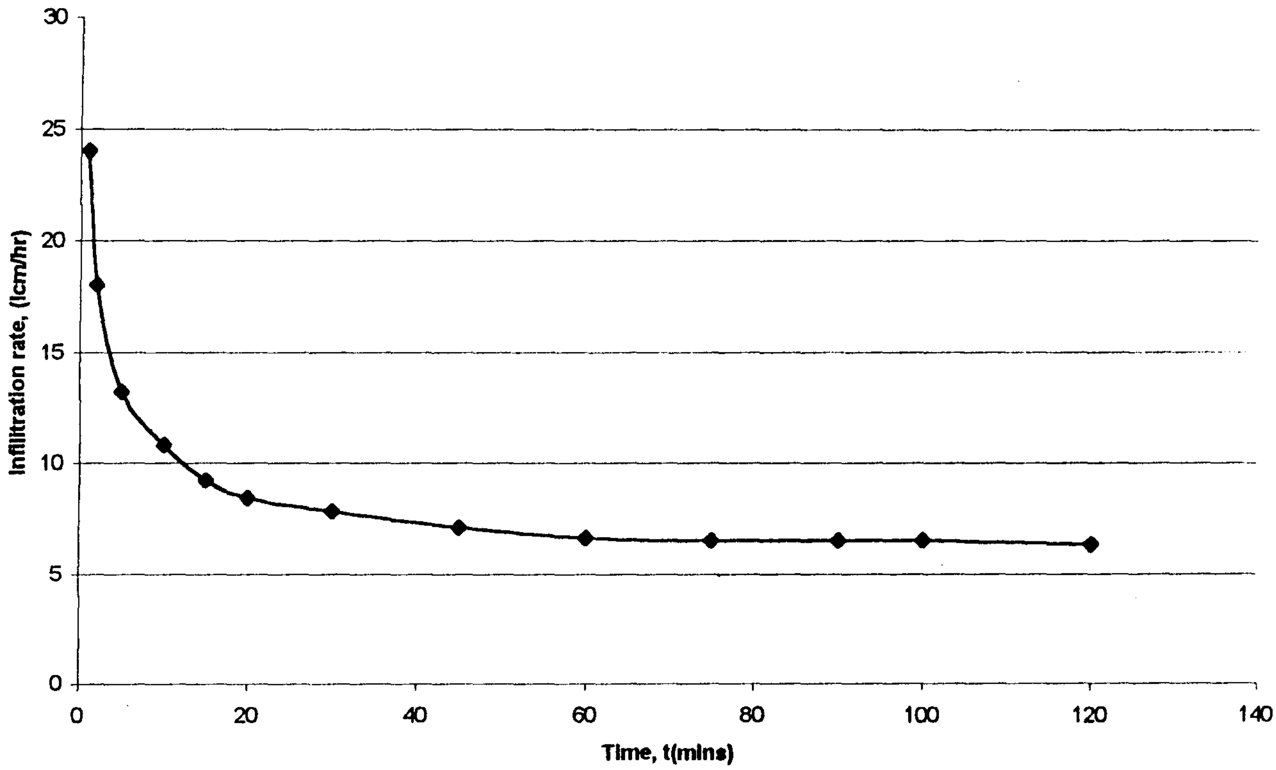

Fig. 36 Graph of Infiltration rate against time for average of four replicates for fallowed land

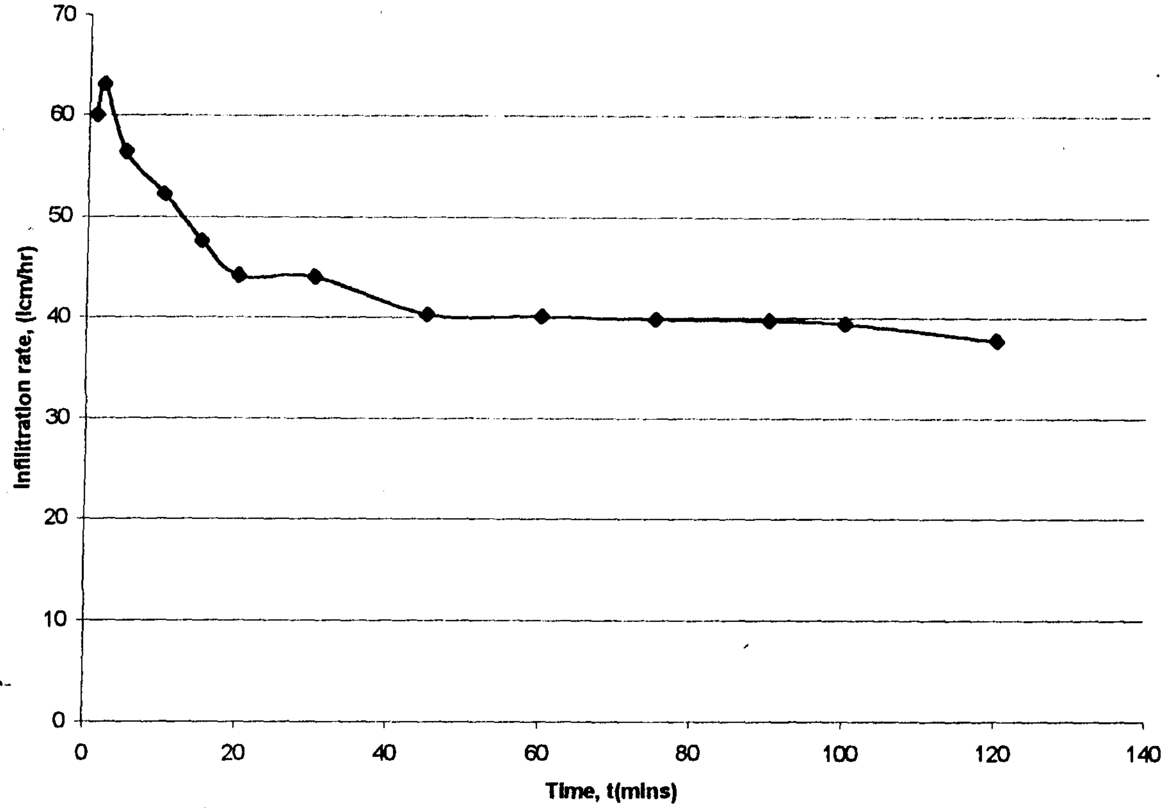

Fig.37: Graph of infilitration rate against time for average of four replicates for cultivated land

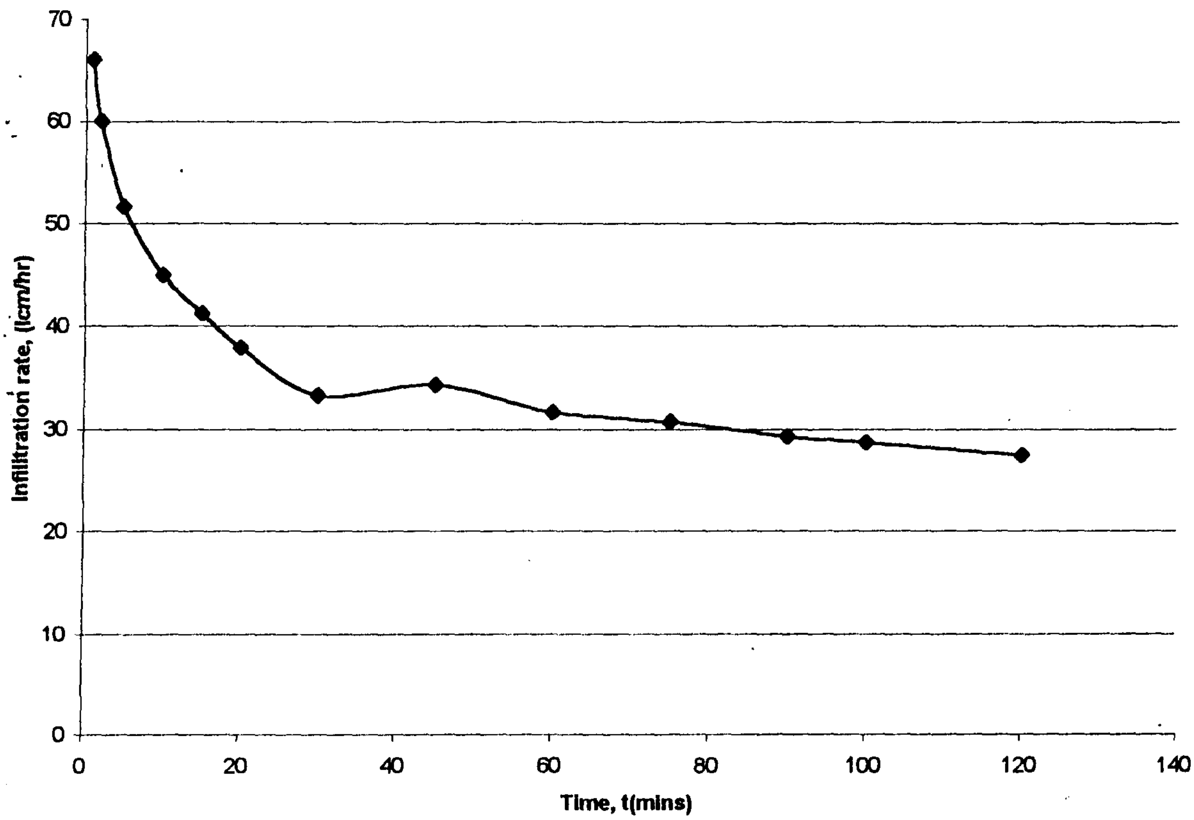

Fig. 38 Graph of infilitration rate against time for average of four replicates for fallowed land

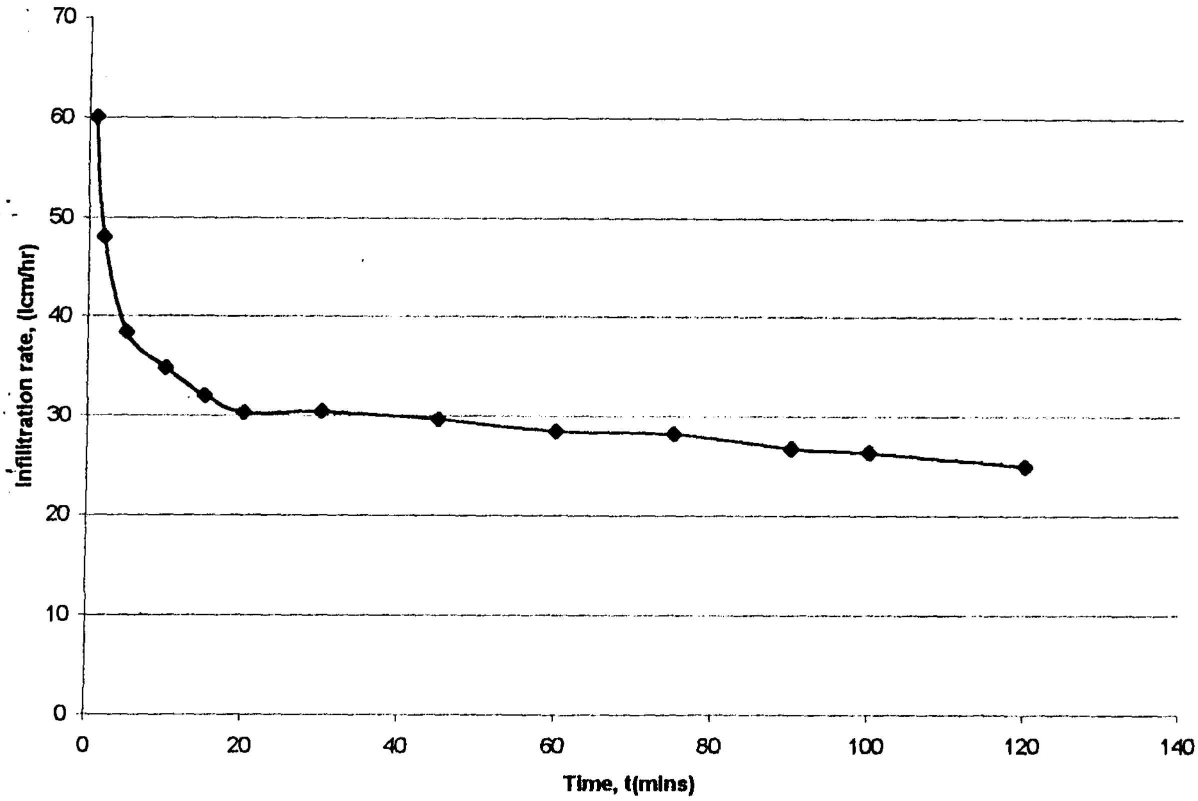

Fig. 39 Graph of infiltration rate against time for average of four replicates for cultivated land

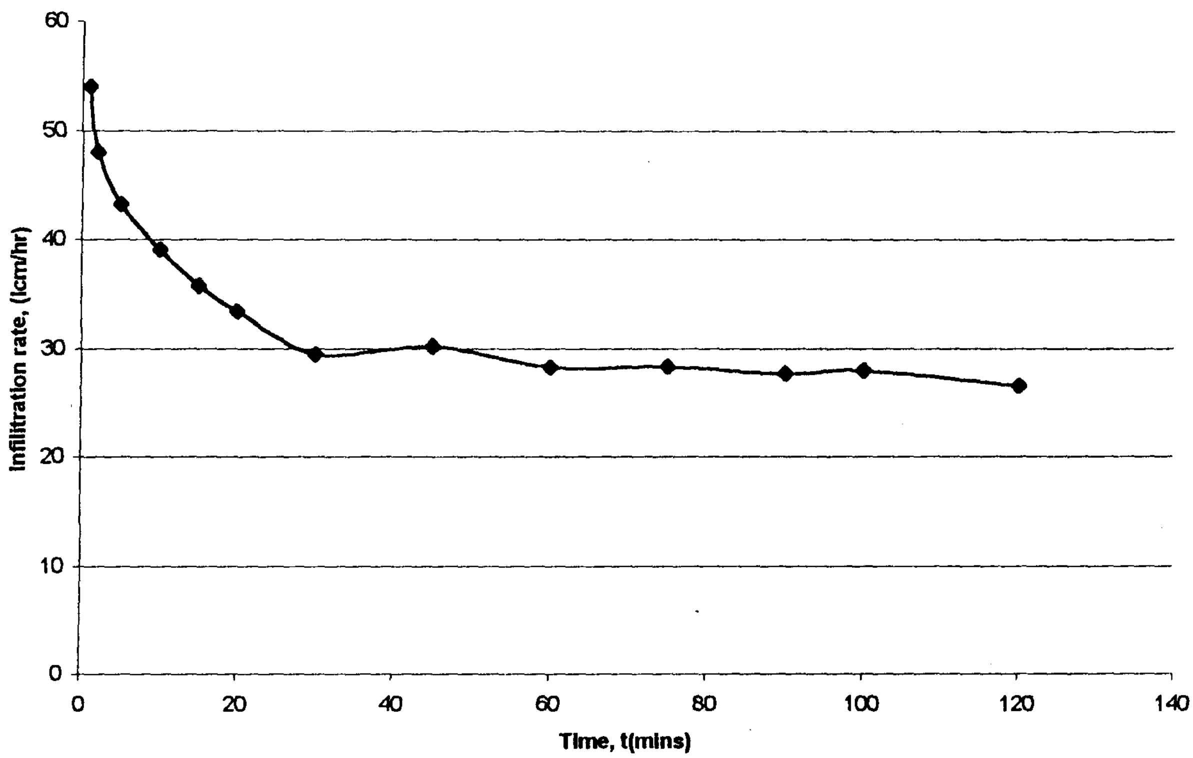

Fig. 40 Graph of infiltration rate against time for average of four replicates for fallowed land

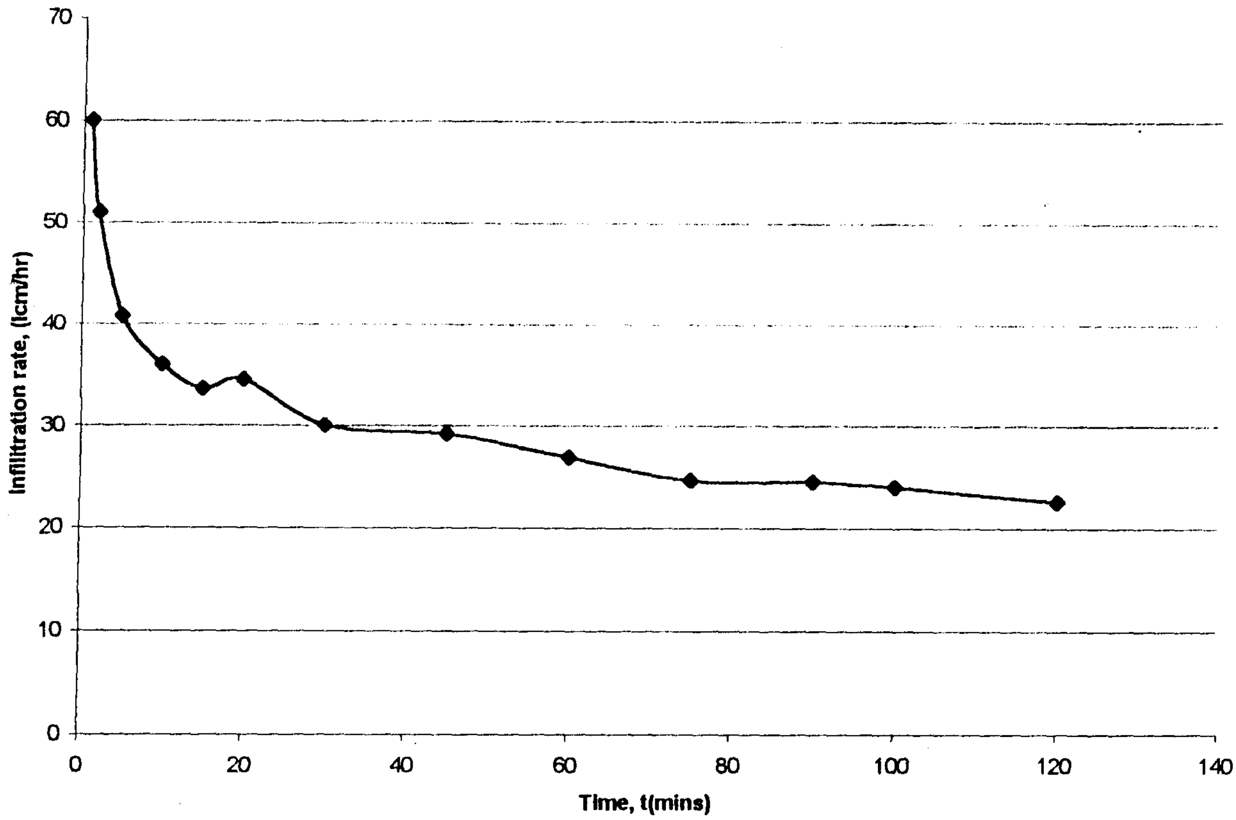

Fig.41 Graph of Infiltration rate against time for average of four replicates for cultivated land

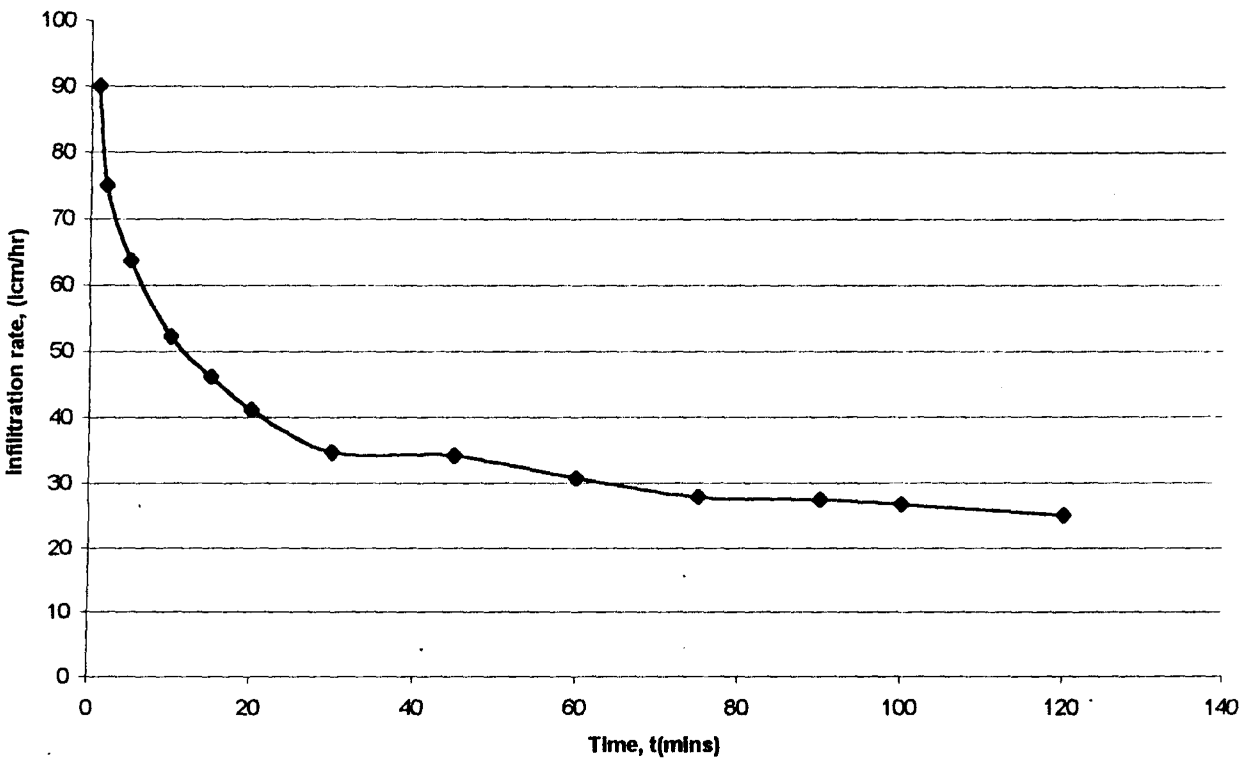

Fig.42 Graph of Infiltration rate against time for average of four replicates for fallowed land

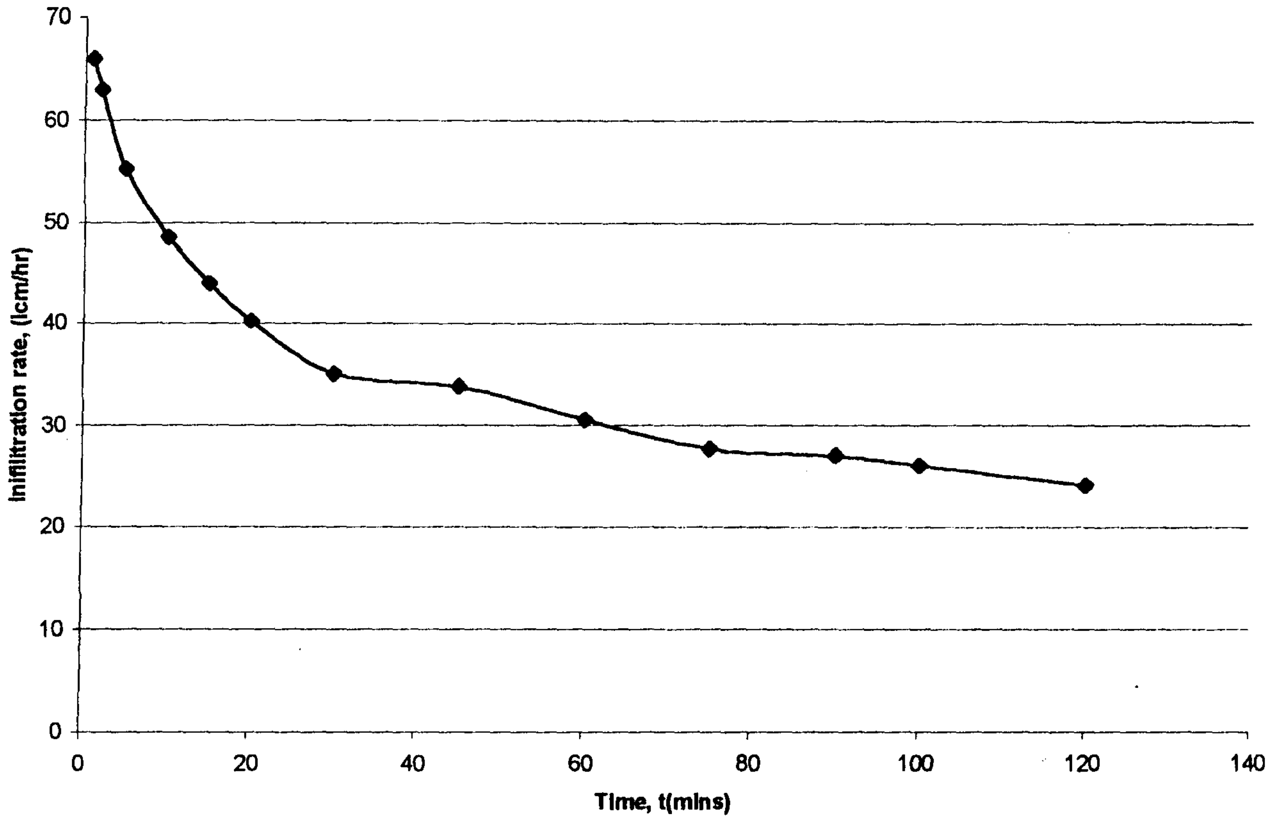

Fig. 43 Graph of Infiltration rate against time for average of four replicates for cultivated land

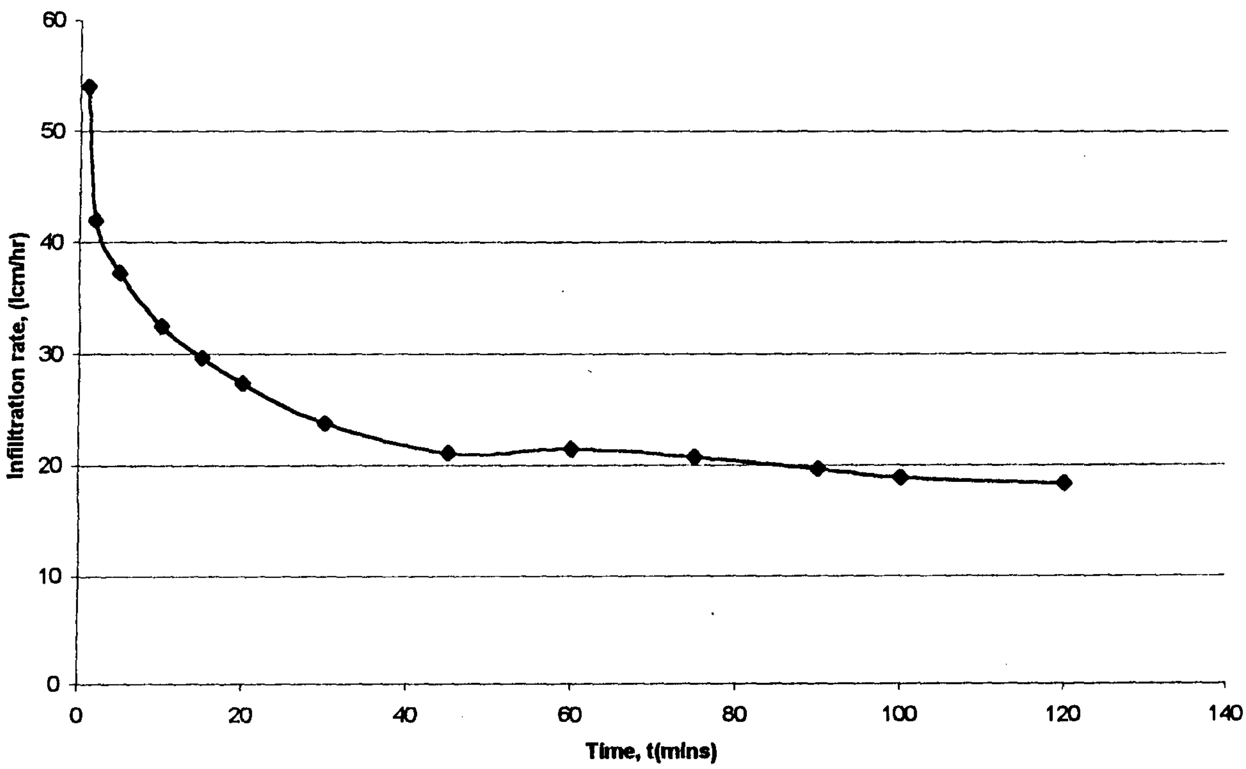

Fig. 44 Graph of Infiltration rate against time for average of four replicates for fallowed land

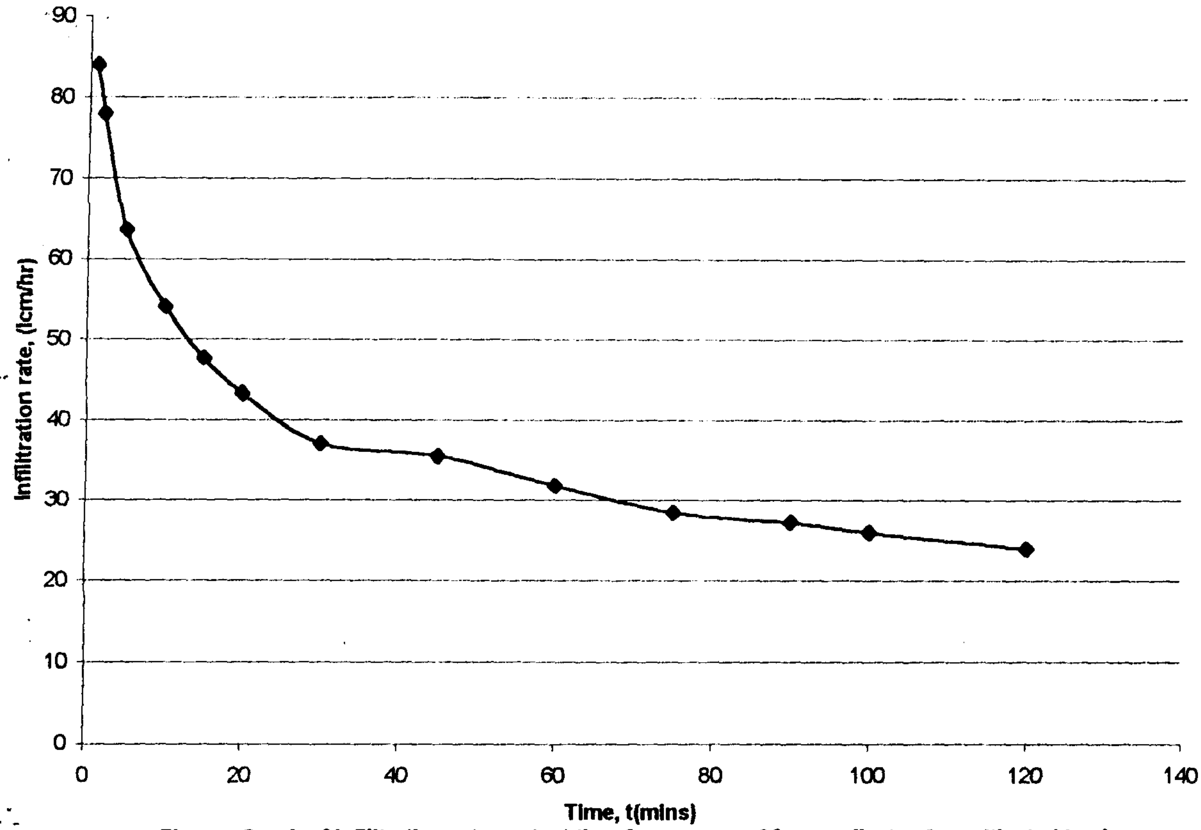

Fig. 45 Graph of Infiltration rate against time for average of four replicates for cultivated land

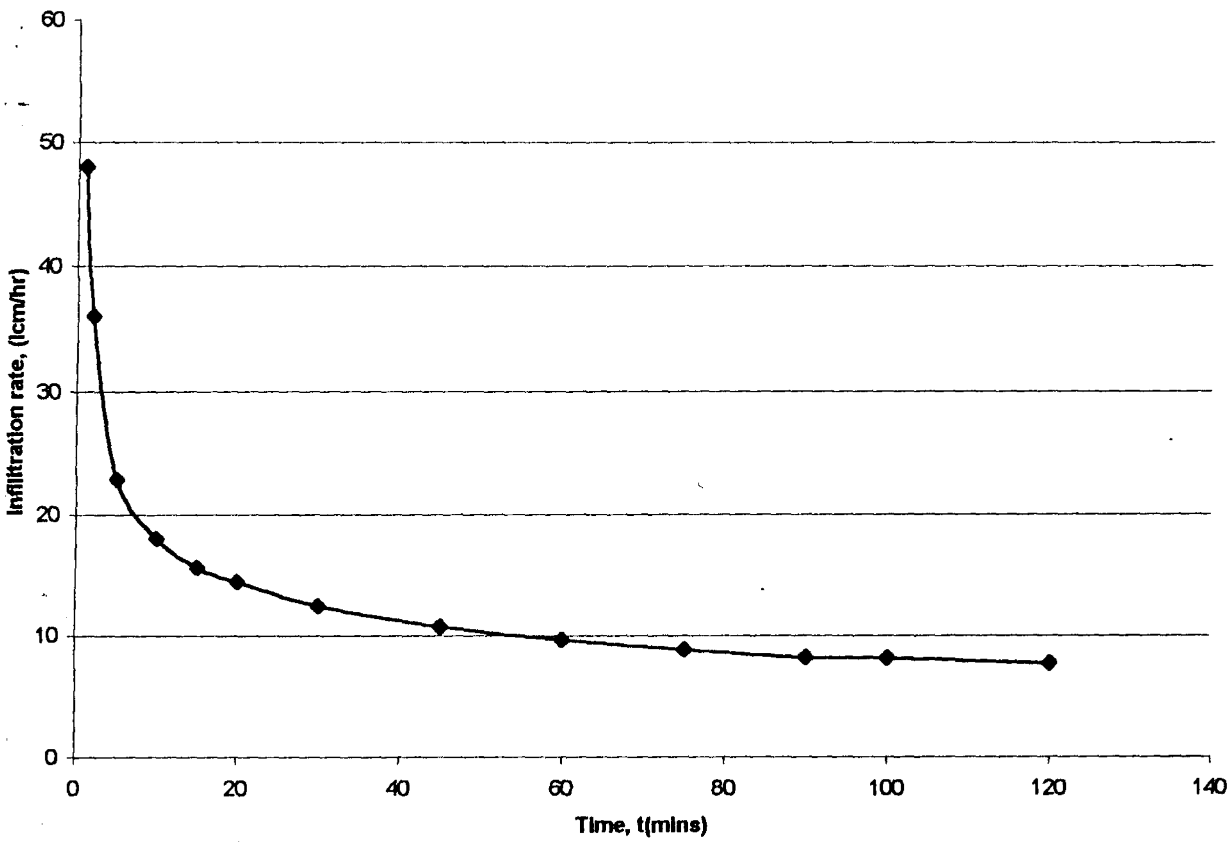

Fig. 46 Graph of Infiltration rate against time for average of four replicates for fallowed land

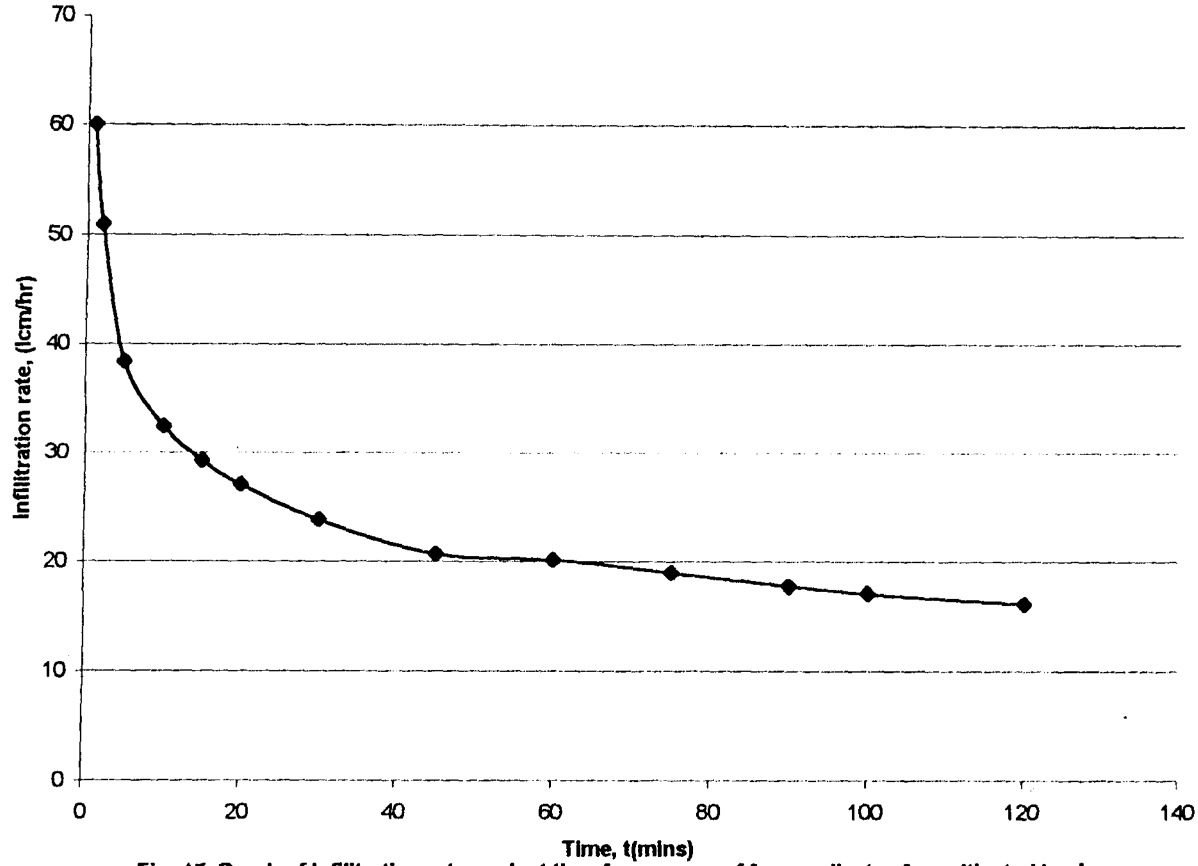

Fig. 47 Graph of infiltration rate against time for average of four replicates for cultivated land

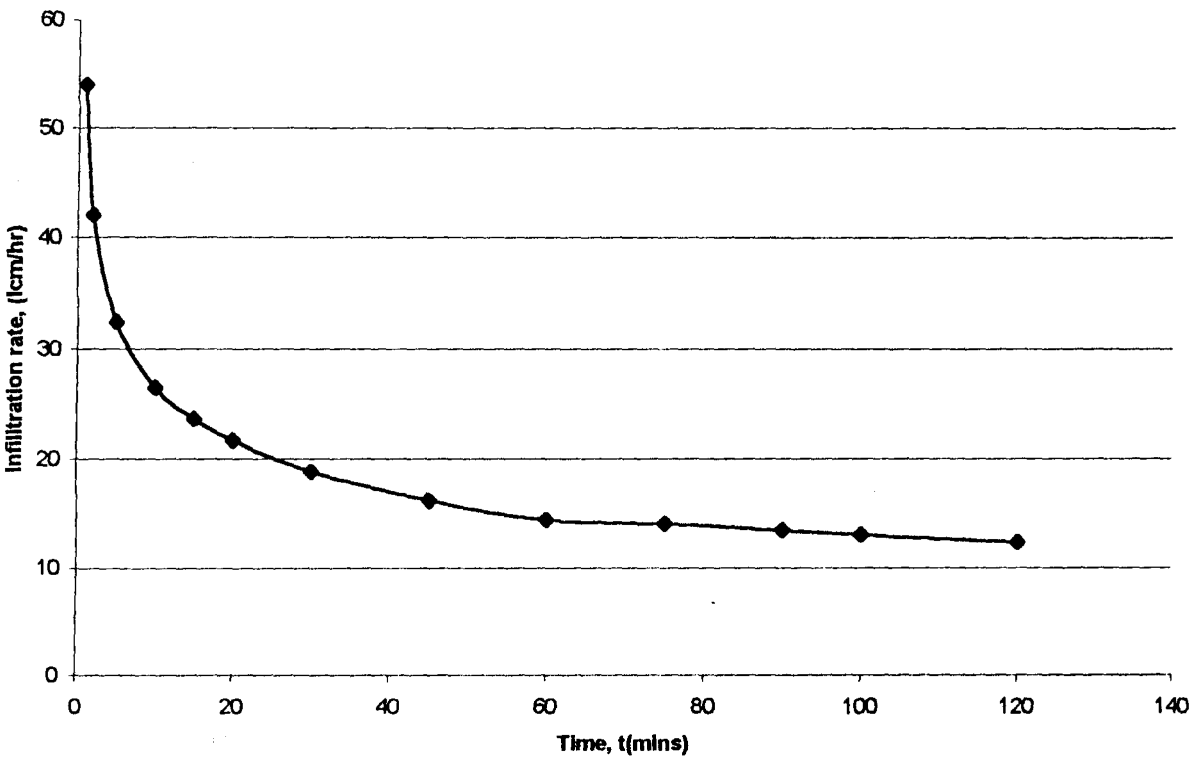

Fig. 48 Graph of infiltration rate against time for average of four replicates for fallowed land

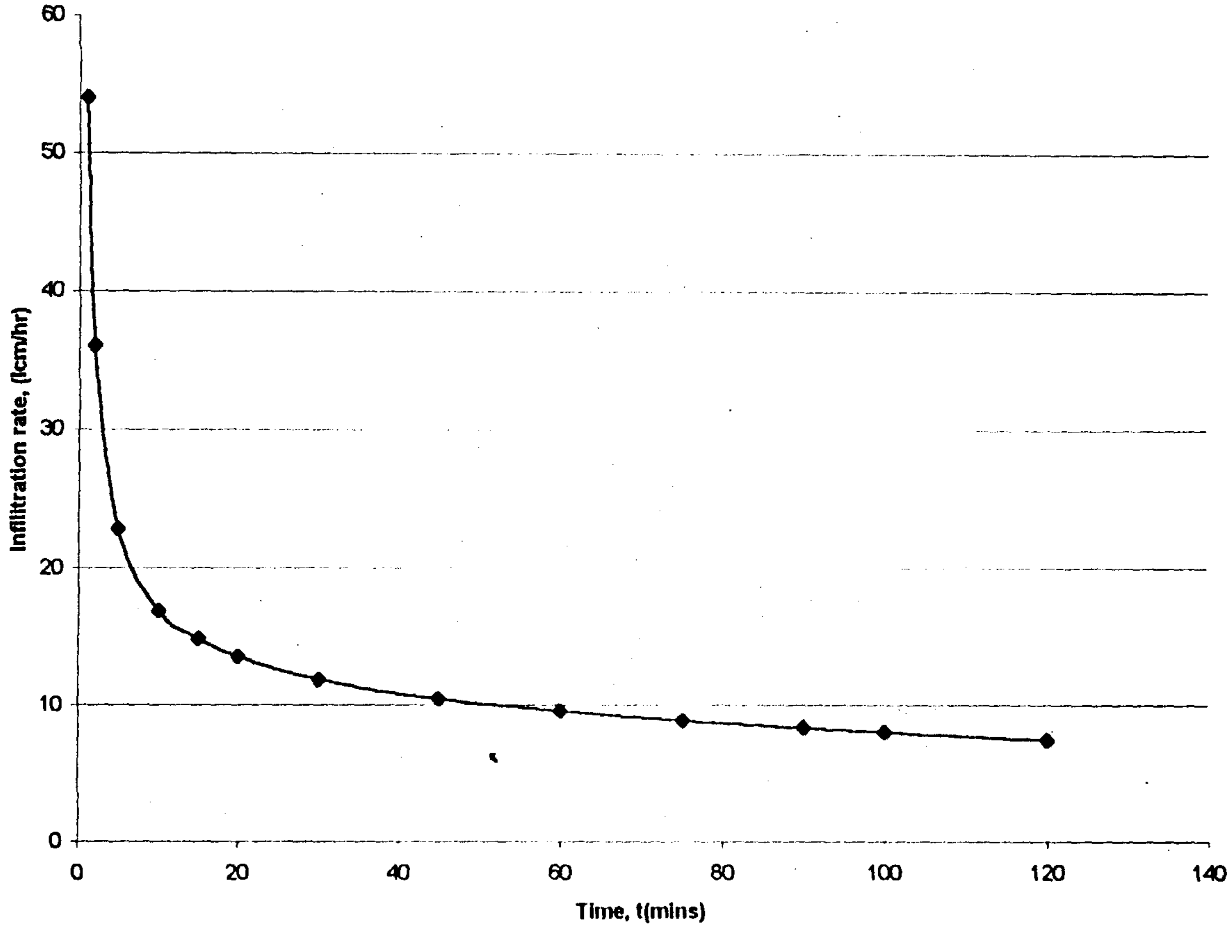

Fig. 49. Graph of Infiltration rate against time for average of four replicates for cultivated land

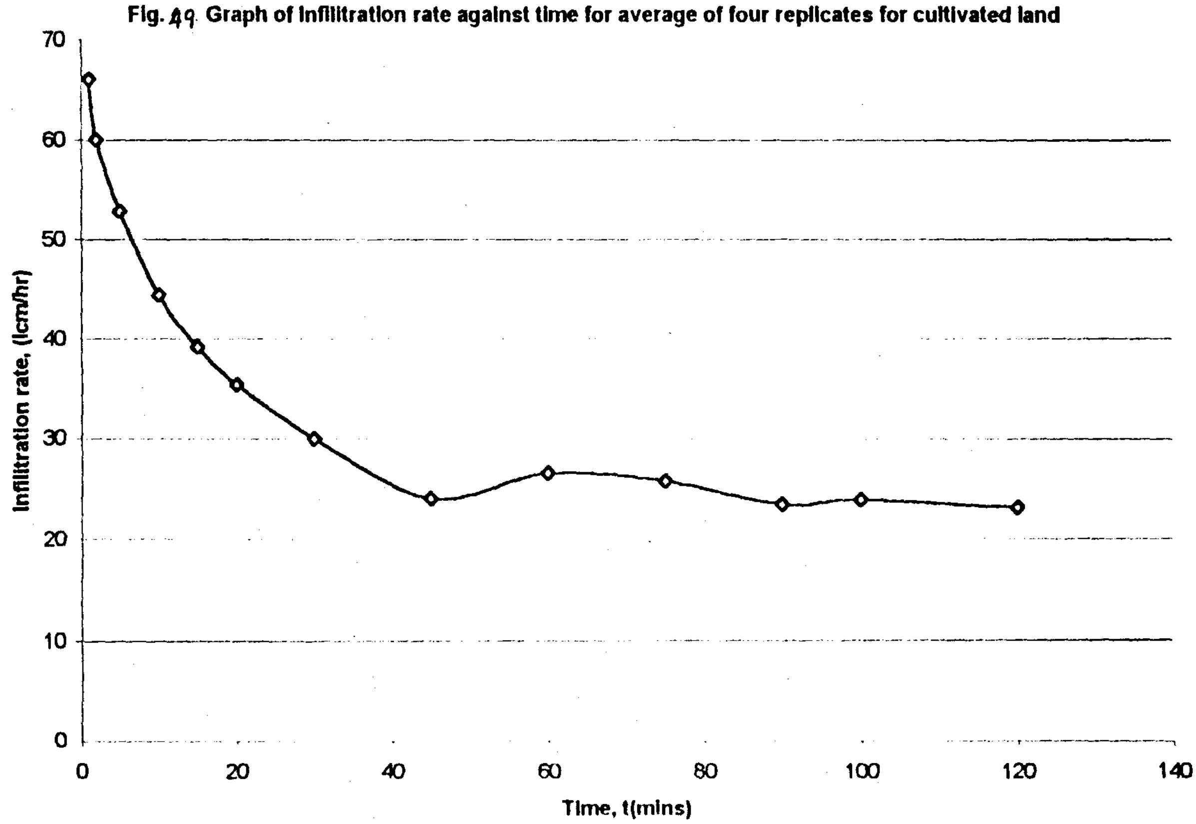

Fig.50: Graph of Infiltration rate against time for average of four replicates for fallowed land

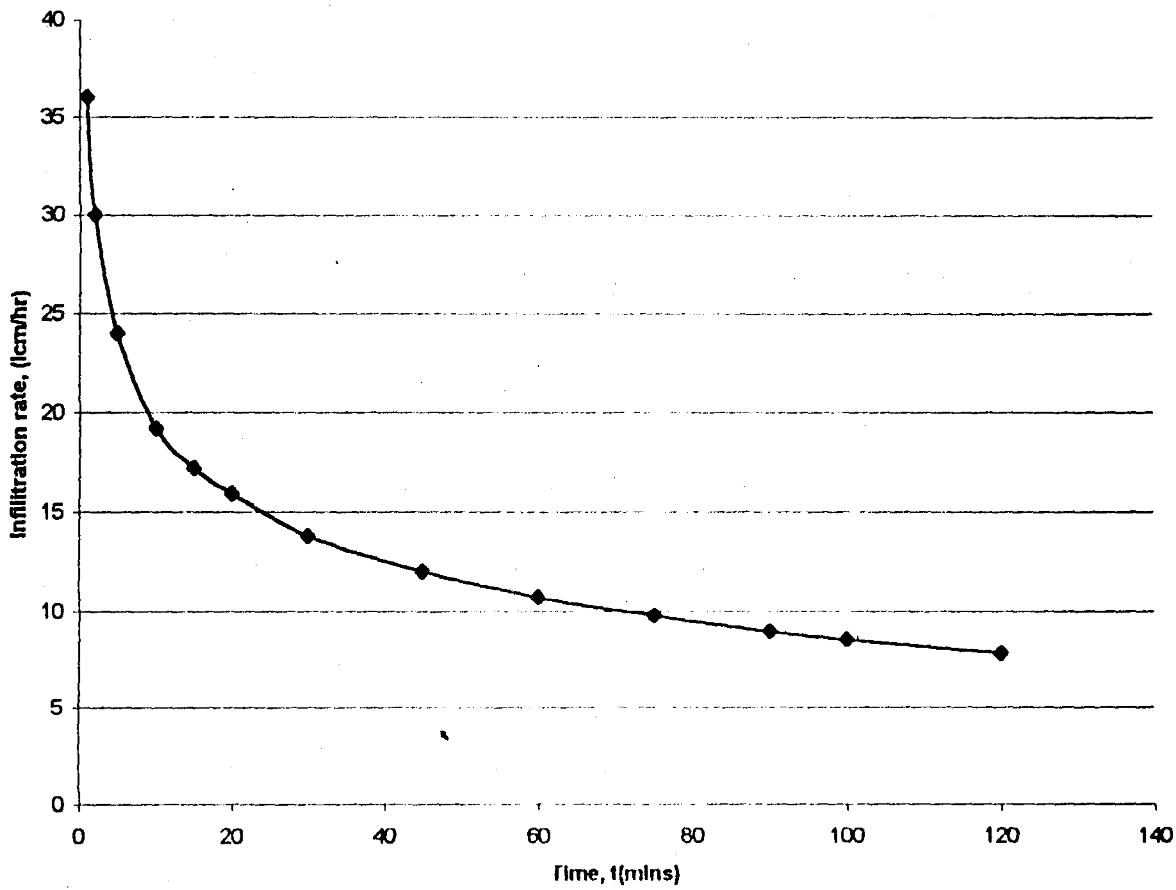

Fig.51 Graph of infiltration rate against time for average of four replicates for cultivated land

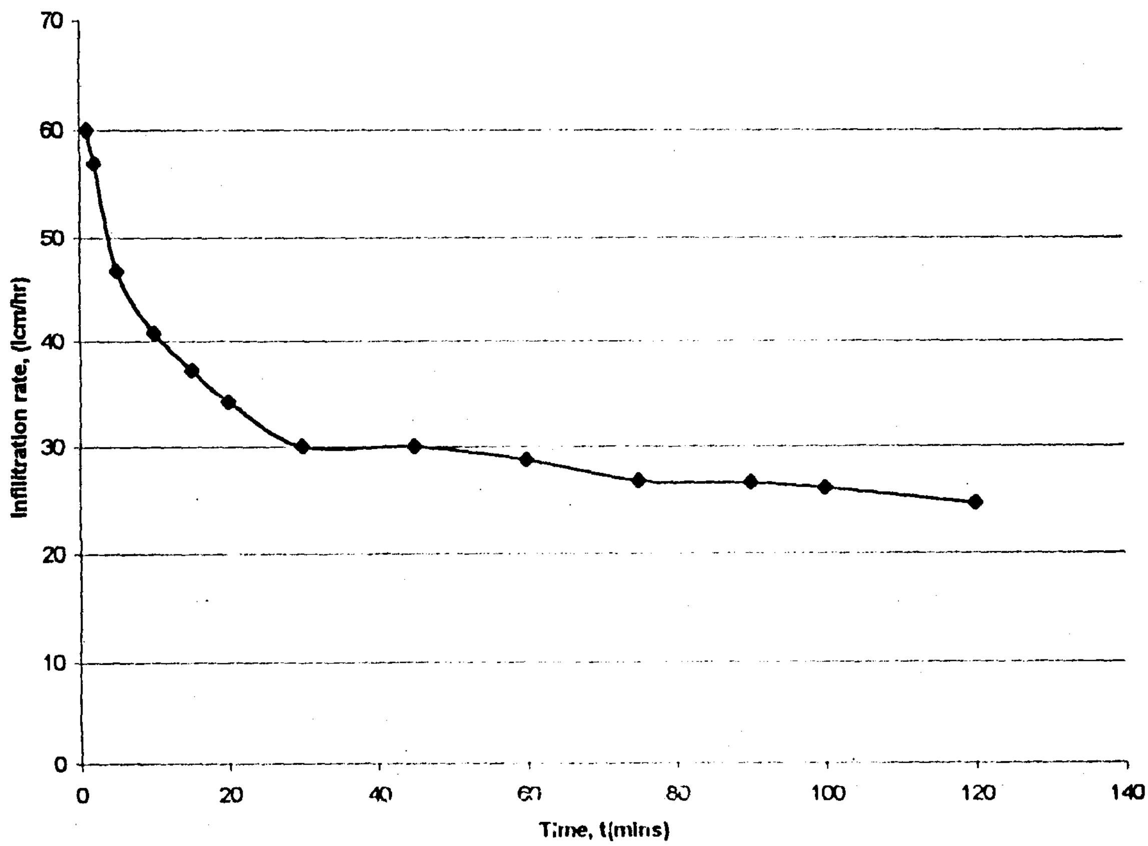

Fig. 52 Graph of infiltration rate against time for average of four replicates for fallowed land

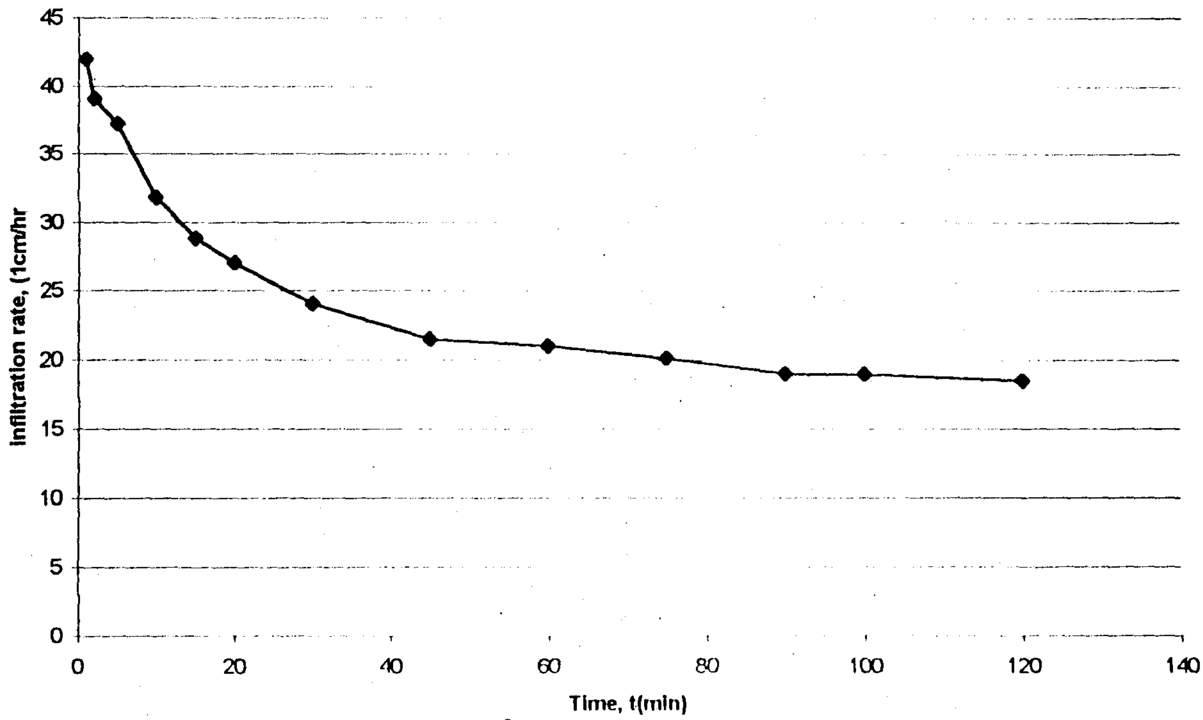

Fig. 53: Graph of Infiltration rate against time for average of four replicates for cultivated land

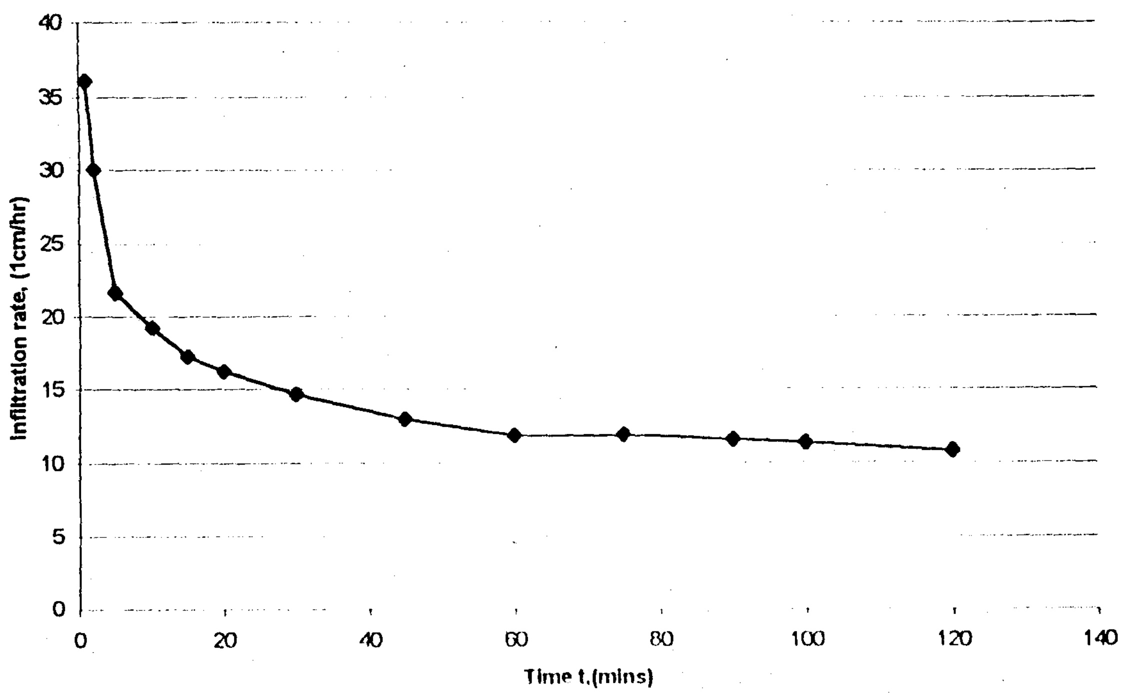

Fig 54: Graph of Infiltration rate agaist time for average of four replicates for fallowed land

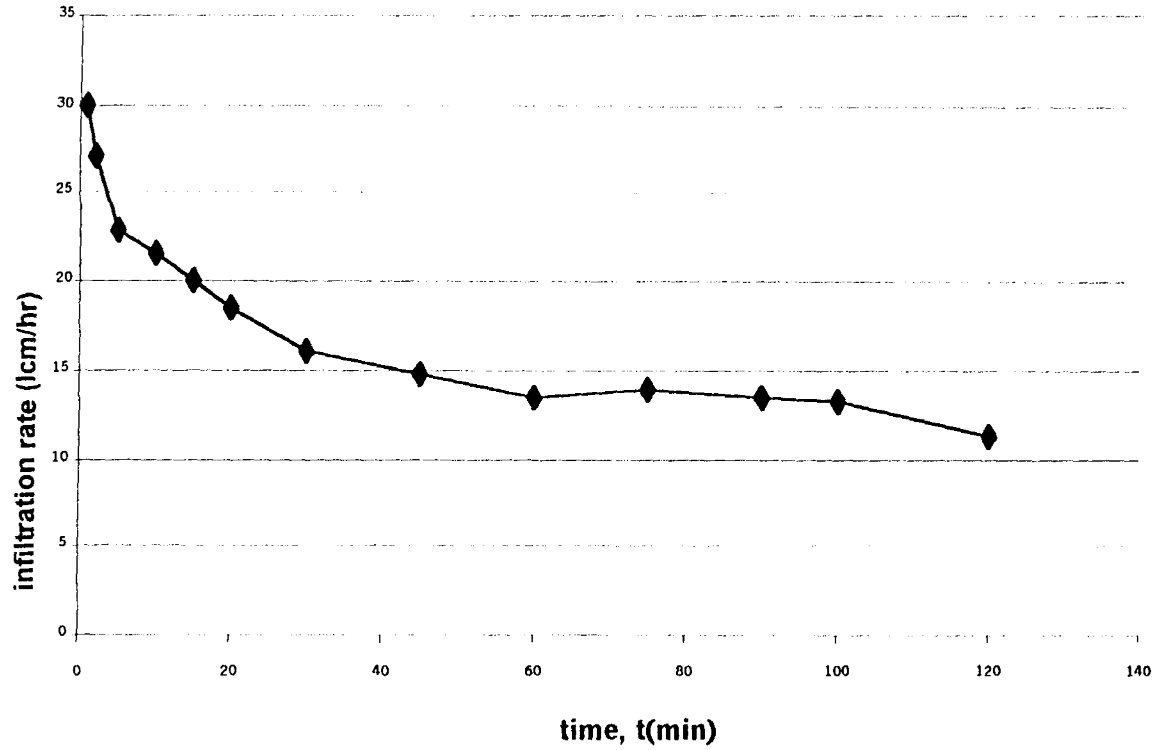

Fig55:Graph of infiltration rate against time for average of four replicates for cultivated land

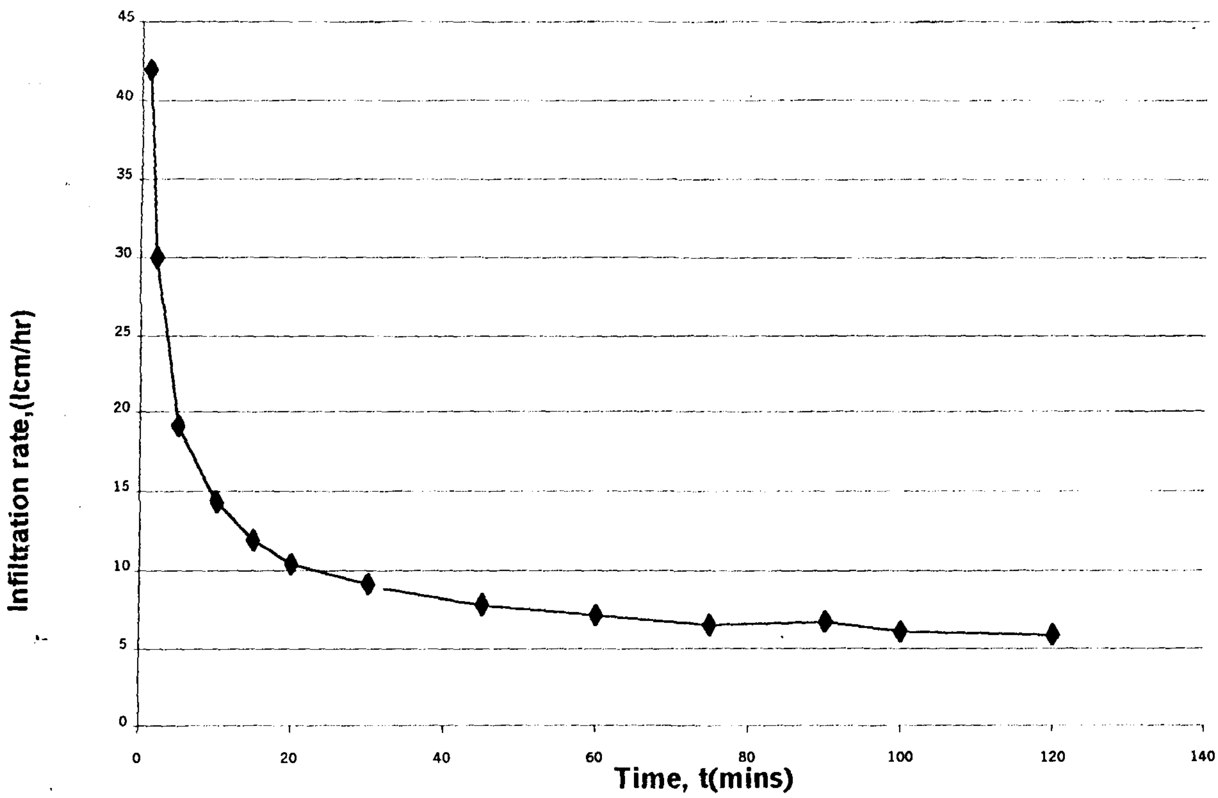

Fig 56 :Graph of infiltration rate against time of average of four replicates for fallowed land

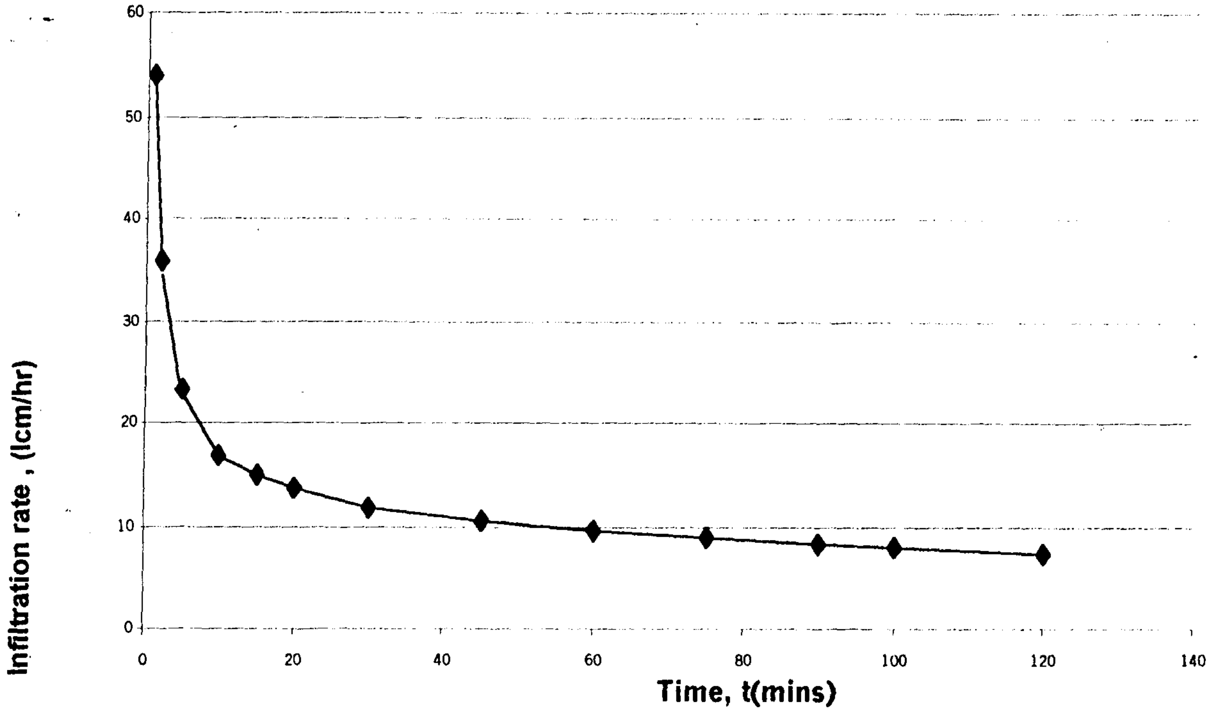

Fig57 Graph of infiltration rate against time for average of four replicates for cultivated land

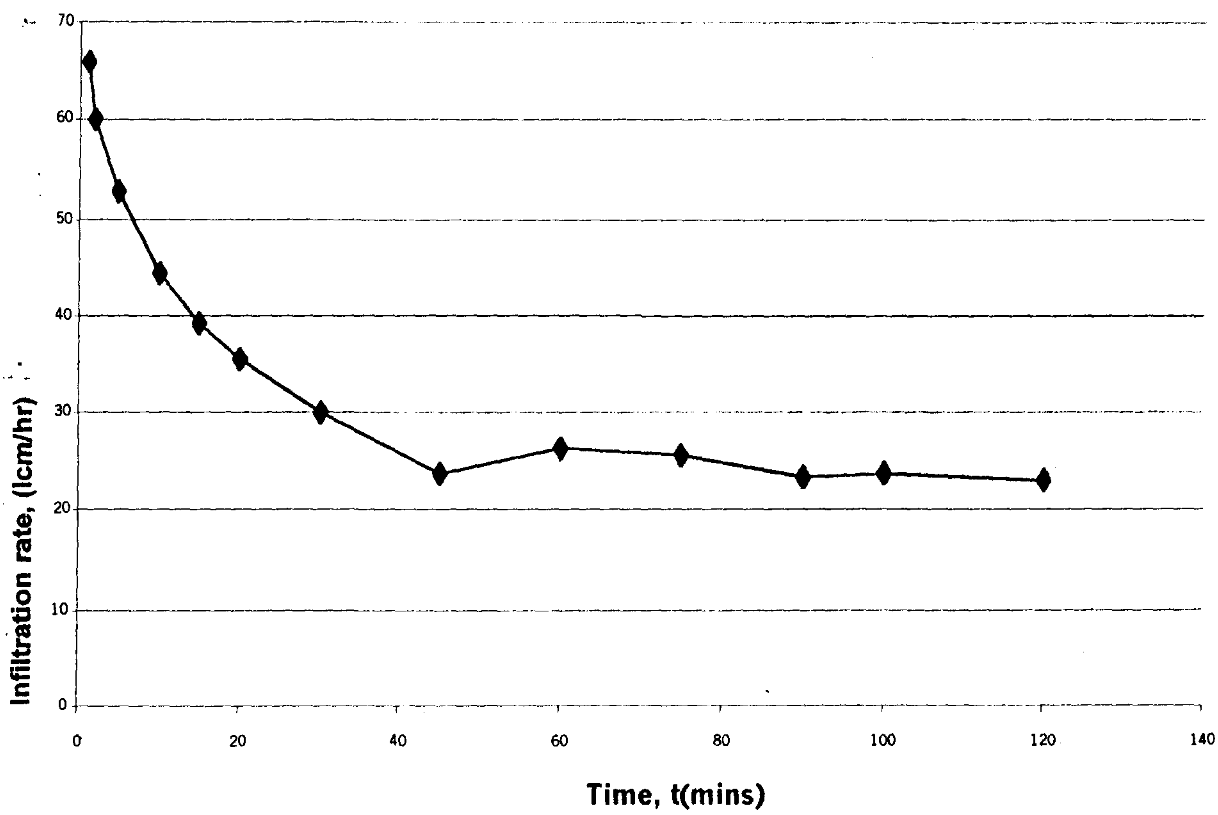

Fig58 :Graph of infiltration rate against time of average of four replicates for fallowed land

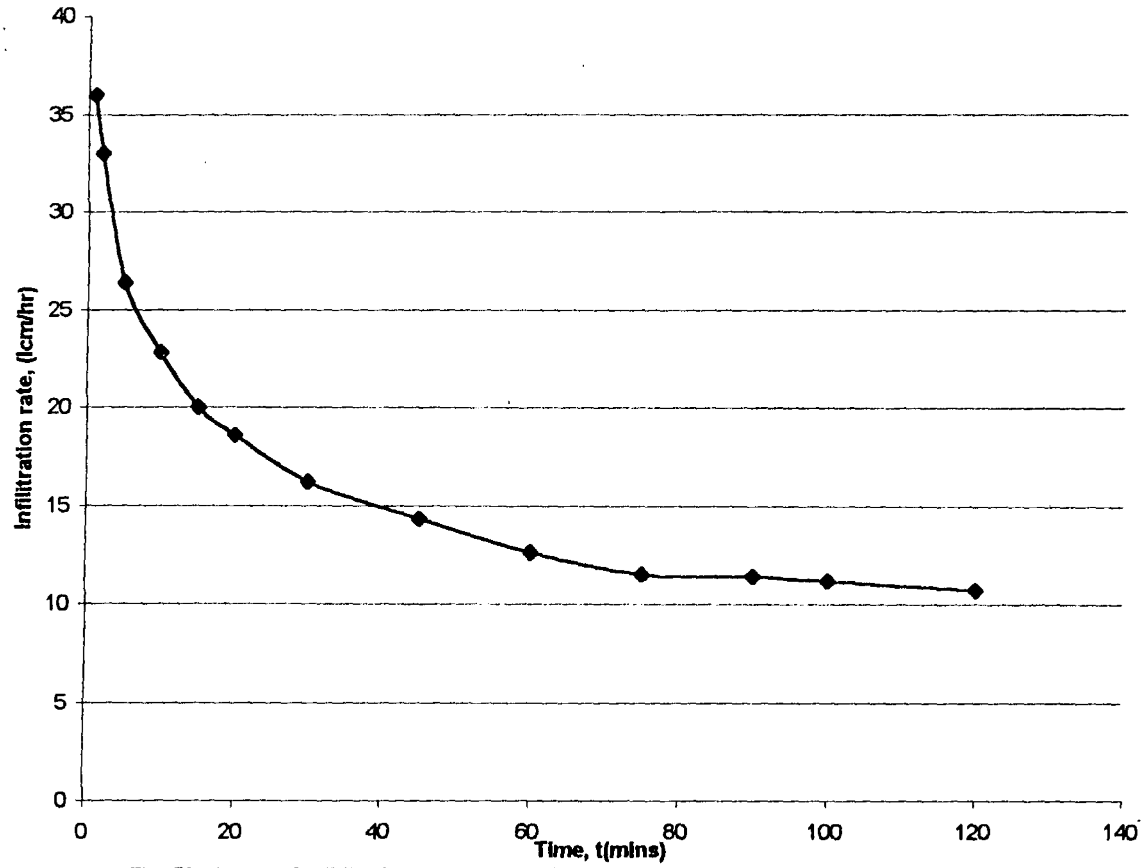

Fig. 59: Graph of infiltration rate against time for average of four replicates for cultivated land

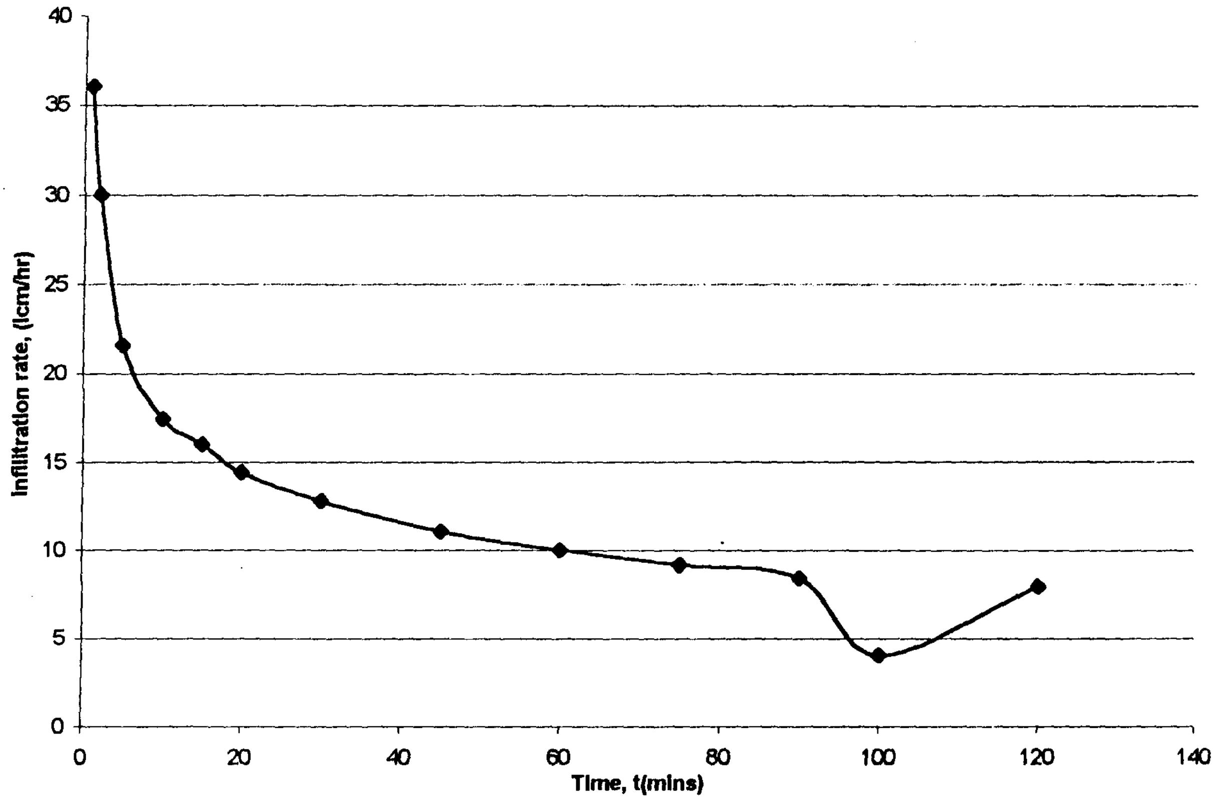

Fig. 60: Graph of infiltration rate against time for average of four replicates for fallowed land

APPENDIX D.

LOCATION OF TESTED SITES MARKED A, B AND C.

LOCATION: A

From point A at the edge of the tributary into the dam, a bearing of 208^0NE was taken to site 27 which has a distance of 762.5m between them. Using site 27 as a reference point to heat some of the surrounding point we have the

1. The bearing of site 30 from site 27 is 88^0NE with a distance of 1712.5m between them.
2. The bearing of site 29 from site 27 is 148^0NE with a distance of 1125m between them.
3. The bearing of site 28 from site 27 is 193^0NE with a distance of 725m between them.
4. The bearing of site 17 from site 27 is 243^0NE with a distance of 637.5m between them.
5. The bearing of sit 26 from site 27 is 278^0NE with a distance of 880m between them.
6. The bearing of site 25 from site 27 is 308^0NE with a distance of 975m between them.

LOCATION B:

From B on the hill the bearing to site 5 is 282^0NE with a distance of 775m between them.

1. Therefore, using site 5 as our reference point, the bearing of site 5 to site 4 is 165^0NE and the distance between them is 925m.
2. The bearing of site 3 from site 5 is 242^0NE with a distance of 1225m between them.

3. The bearing of site9 of from site 5 is 294^{0}NE with a distance of 1550m between them.

4. The bearing of site 8 from site 5 is 309^0 with a distance of 1000m between them.

5. The bearing of site 6 from site 5 is 15^{0}NE with a distance of 662.5m between them.

6. The bearing of site 7 from site 5 is 29^0 with a distance of 1250m between them.

LOCATION C:

From point C, a bearing of site 14 was taken to be 130^{0}NE which will serve as our reference point to leave all others. The distance between them is given as 937.5m.

1. The bearing of site 13 from site 14 is 141^{0}NE with a distance of 962.5m between them.

2. The bearing of site 12 from site 14 is 103^{0}NE with a distance of 1312.5m between them.

3. The bearing of site 15 from site 14 is 73^{0}NE with a distance of 900m between them.

4. The bearing of site 19 from site 14 is 28^{0}NE with a distance of 825m between them.