WATER INTAKE CHARACTERISTICS OF SOILS IN JAMILA VILLA FARM, MINNA NIGER STATE

BY

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

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DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

09/02/10

Popoola A. Stephen

Date

CERTIFICATION

This project entitled "water intake characteristics of soils in Jamila Villa farm, Minna, Niger State" by Popoola A. Stephen, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to God almighty who by His mercies and goodness has kept me till this day. To Him alone be all the Glory. Amen.

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ABSTRACT

This project report presents the water intake characteristics of soils in Jamila Villa farm, Minna, Niger State. The Gravimetric and infiltration test was performed in three different conditions of the soil. That is tilled, untilled and compacted soil. Double ring infiltrometer was used to study the infiltration characteristics of the soil on the farm and Horton's equation was adopted for the data analysis. From the analysis of data obtained the soil characteristics constant K was obtained for the tilled, non-tilled and compacted plots of the farm as; 0.038, 0.020 and 0.023. The soil intake characteristic equation of the farm for all the three conditions of the soils were calculated to be; $f = 9.0 + 111e^{-0.038t}$, $f = 1.56 + 74.04e^{-0.020t}$ and $f = 4.44 + 30.72e^{-0.023t}$. The cumulative infiltration Depth equation of soils are; $[F = 9.0t + 2921.05[1 - e^{-0.038t}]$, $[F = 1.56t + 3702[1 - e^{-0.020t}]$ and $[F = 4.44t + 1335.65[1 - e^{-0.023t}]$. This study enable the comparison of the parameters obtained from all the soil conditions of the location and the result will guide the farmer in designing a good and workable irrigation system in the future. The equations derived for all conditions in this site are used to attain an efficient condition of the farm site.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

The soil is an integral component of the hydrological cycle, directly influencing infiltration, storm runoff, evapotranspiration, interflow, and aquifer recharge. Understanding the nature of water movement in the soil and its quantification is essential to solving a variety of problems. Examples of such problems are: prediction of runoff from given precipitation events for the purposes of erosion control; sediment transport and flood control; estimation of water availability for plant growth; estimation of water recharge to the underlying aquifer; and assessment of the potential for aquifer contamination due to migration of water soluble chemicals present in the soil. Consequently, the study of soil-water movement has interested scientists from diverse disciplines such as soil science, hydrology, agriculture, civil engineering, and the environmental sciences for several years.

The use of soil models for the determination of contaminant cleanup levels, preliminary remediation goals (PRG), soil screening levels (SSL), and other related terms has proliferated in recent years. In providing technical support to various consultants, EPA Regional Offices, and the state agencies, it has become apparent that there exists a lack of guidance in the estimation of model parameters. In an attempt to address this problem, an EPA Issue Paper was prepared by Breckenridge *et al.* (1991), which was later published as a journal article (Breckenridge *et al.*, 1994). This paper discussed the techniques for characterizing soils for their chemical, physical, and hydraulic properties. It also provided a list of available field and laboratory measurement techniques and look-up methods for these parameters. Often these models utilize an over-simplified estimate of the infiltration rate, which may have very little basis in physics and actual site characteristics.

This document (Project work) presents the water intake characteristics of soils in Jamila Villa farm located at Brige, Pakororo local government area Minna, Niger State.

The study involves the performance tests and analysis of results of three selected plots of the major project area in the farm. To gain better insight into this study the following essential parameters are briefly described using the following terminologies;

1.1.1 Infiltration Rate: - This is the velocity at which water seeps into the soil profile (Sharma and Sharma, 2007). Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer-a relatively simple and accurate method. A metal 'infiltration ring' is pushed into the soil. Water is poured into the ring, and the rate at which the water soaks into the soil is measured. The rate of infiltration is affected by soil characteristics including ease of entry, storage capacity and transmission rate through the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles, and loosening soil through root action (Sharma and Sharma, 2007).

This is why forested areas have the highest infiltration rates of any vegetative types. The top layer of leaf litter that is not decomposed protects the soil from the pounding action of rain, without this the soil can become far less permeable. Other conditions that can lower infiltration rates or block them include dry plant litter that resists re-wetting, or frost. If soil is saturated at the time of an intense freezing period, the soil can become a concrete frost on which almost no infiltration would occur. Once water has infiltrated the soil it remains in the soil, percolates down to the ground water table, or becomes part of the subsurface runoff process.

1.1.2 Infiltration capacity: - The infiltration capacity is the maximum rate at which water can enter a particular soil. That is, the maximum rate that water can enter a soil in a given condition. Different soil types have different Infiltration capacities, for example sandy soils are free draining relative to clays, resulting in higher infiltration capacities. If the arrival of the water at the soil surface is less than the infiltration capacity, all of the water will infiltrate. If rainfall intensity at the soil surface occurs at a rate that exceeds the infiltration capacity, ponding begins and is followed by runoff over the ground surface, once depression storage is filled. This runoff is called Horton overland flow. High infiltration capacities will reduce run off and risks of water logging, However very high infiltration capacities, often found in sands, may mean some nutrients are lost from the root zone through leaching into deeper parts of the soil profile. Infiltration capacities can be altered by soil management practices. As infiltration is related to soil structure, any practice that degrades the structure of the soil will have an adverse effect on infiltration. Therefore, monitoring infiltration rates under different soil management regimes is a good indicator of how the practice will influence the rate at which water can move into the soil (Oosterbaan and Nijland, 1994).

The following parameters are determined to evaluate the intake characteristics of soil;

1. Infiltration rate of the soil.
2. Infiltration capacity of the soil.
3. Accumulated infiltration (accumulated infiltration dept)

The infiltration characteristics curves such as intake rate against time relationship, accumulated infiltration dept against time relationship were plotted to the graphical relationship of the parameters required in evaluating the intake characteristics of soils. The intake or infiltration characteristic of the soil is one of the dominant variables influencing irrigation and its knowledge is necessary for overall soil and water management. This is also useful to estimate catchments run-off models. From the above parameters, accumulated infiltration or cumulative infiltration depth means the total quantity of water that enters the soil in a given time.

1.2 Statement of the Problem

Establishment of Mechanized farm is cost effective and requires some level of skills or techniques. As a result of this, most farmers in Nigeria tends to economize beyond the required point in the aspect of spending on various important processes involve in farming. They often ignore the importance of water intake characteristics of soils on their farm land due to lack of orientation, thereby carrying out farming operations without ascertaining the infiltration rate of the soils so as to meet the water requirement of the proposed crop on the farm. Also, excavation for the construction of dam is done, leaving out the analysis of the water holding capacity of the soil. This is one of the reasons for over flooding and other problems associated with farm dams. The purpose of this study is to provide a guide in meeting the water requirement of crops and designing a good and workable irrigation system to the farmers.

1.2 Objective of the study

The objectives of this study are;

1. To study the water intake characteristics of the soil at a selected farm viz plot of the experiment site at Jamila Villa farm, Minna.
2. To develop the intake characteristics equation for the soils under conditions of ploughed soil, uncultivated soils, and compacted soils using the Horton's equation.
3 To develop water intake characteristics equation for the design of a workable irrigation system.

1.4 Justification of the project

Infiltration is one of the major components of the hydrologic cycle. Water that falls as precipitation may run over land eventually reaching streams, lakes, rivers and oceans or infiltrate through the soil surface, into the soil profile. Water that runs off over land causes erosion, flooding and degradation of water quality. Infiltration, on the other hand, constitutes the sole source of water to sustain the growth of vegetation, is filtered by the soil which removes many contaminants through physical, chemical and biological processes, and replenishes the ground water supply to wells, springs and streams (Oram, 2005). Infiltration is critical because it supports life on land on our planet. The ability to quantify infiltration is of great importance in watershed management. Prediction of flooding, erosion and pollutant transport all depend on the rate of runoff which is directly affected by the rate of infiltration. Quantification of infiltration is also necessary to determine the availability of water for crop growth and to estimate the amount of additional water needed for irrigation. Also, by understanding how infiltration rates are affected by surface conditions, measures can be taken to increase infiltration rates and reduce the erosion and flooding caused by overland flow. In order to develop improved hydrologic models, accurate methods for characterizing infiltration are required (Shirmohammadi, 1984). It is the goal of this study to carry out infiltration rate experiment, determination of soil's moisture contents, bulk density and porosity on the farm. The results obtained will guide the farm in designing a good and workable irrigation system in the future.

1.5 Scope of the Study

This study is restricted to the analysis of water intake characteristics of soils under the tilled, uncultivated and compacted soil conditions on the farm. This was achieve by the determination of the soil's bulk density, porosity, moisture contents and infiltration rate.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introductory note: - Infiltration data are commonly expressed graphically with the rate as the ordinate and time as the abscissa. Fig 2.1a represents a typical infiltration curve.

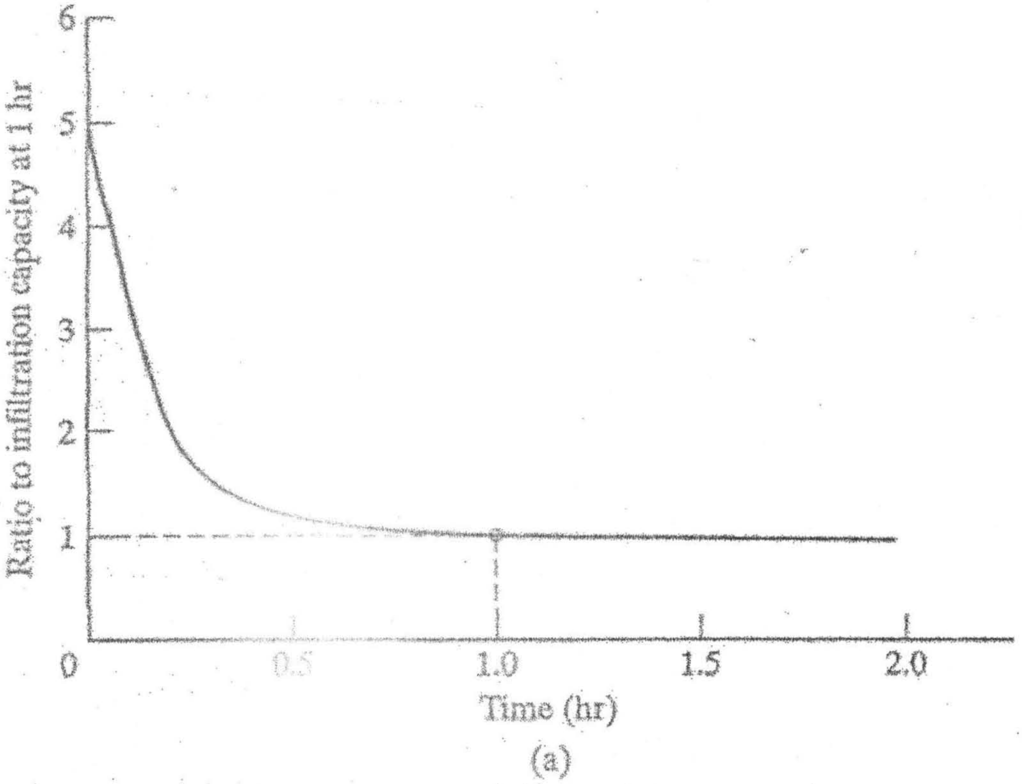


Fig. 2.1a

Here as usual, the potential capacity initially exceeds the rate of water application. However, as the soil pores are filled with water and surface seal takes place, the rate of water intake gradually decreases. It then normally approaches a constant value of which may be taking as the infiltration rate of soil.

2.1.1 Horton's Equation: - The infiltration process was thoroughly studied by Horton in the early 1930s. An outgrowth of his work, shown graphically in Fig. 2.1b,

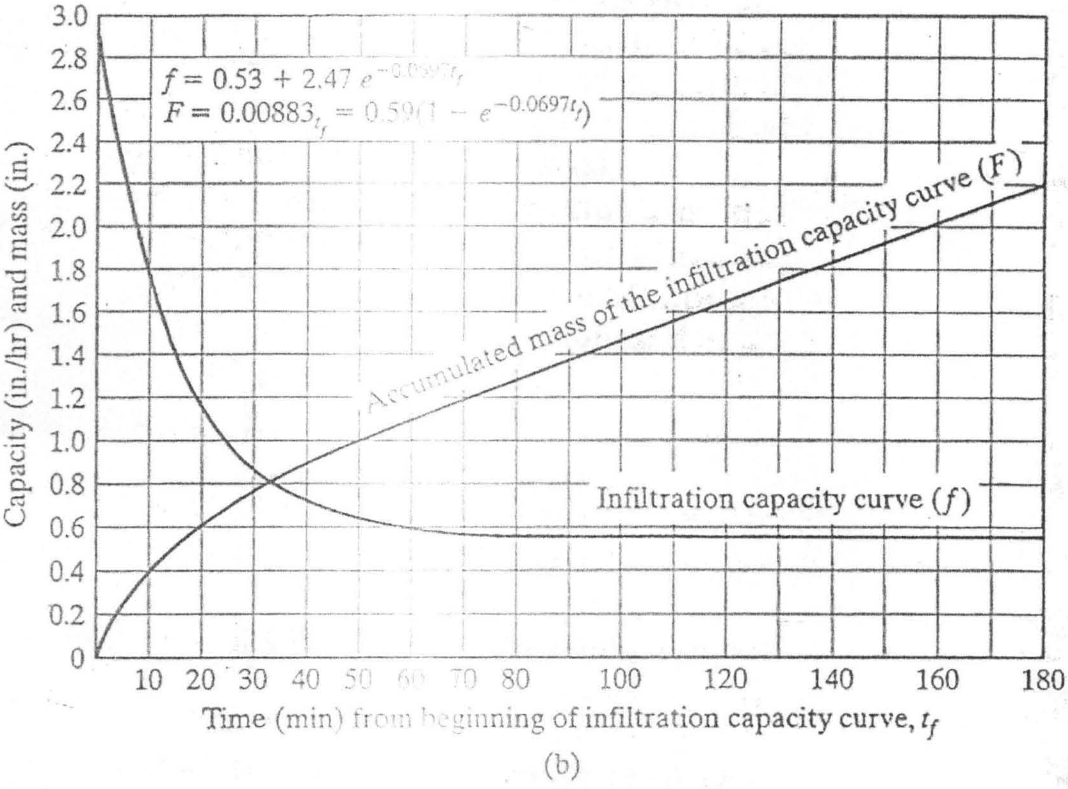


Fig. 2.1b: (a) Typical infiltration curve. (b) Infiltration capacity and mass curves for normal

was the following relation for determining infiltration capacity:

$$f_p = f_c + (f_o - f_c)\,e^{-kt} \quad \text{(Horton, 1940)} \qquad (2.1)$$

where :-

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

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

f_c = final or equilibrium capacity

f_o = the initial infiltration capacity

It indicates that if the rainfall supply exceeds the infiltration capacity, infiltration tends to decrease in an exponential manner. Although simple in form, difficulties in determining useful values for f_o and k restrict the use of this equation. The area under the curve for any time interval represents the depth of water infiltrated during that interval. The infiltration rate is usually given in inches per hour and the time t in minutes, although other time increments are used and the coefficient k is determined accordingly. By observing the variation of infiltration with time and developing plots of f versus t as shown in Fig. 2.1b, we can estimate fo and k. Two sets of f and t are selected from the curve and entered in Eq. 2.1. Two equations having two unknowns are thus obtained; they can be solved by successive approximations for f and k. . Typical infiltration rates at the end of 1 hr (f_1) are shown in Table 2.1.

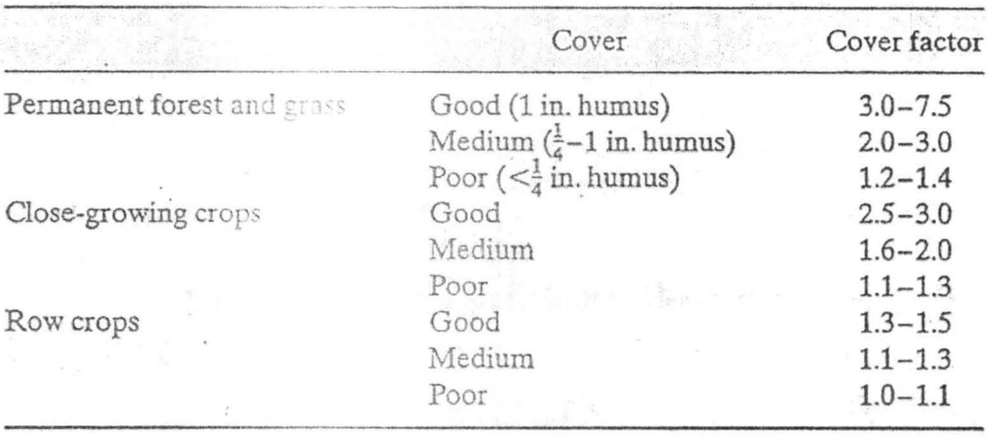
Table 2.1: Infiltration rates at the end of 1hour.

Soil group	f_1 (in./hr)	f_1 (mm/h)
High (sandy soils)	0.50–1.00	12.50–25.00
Intermediate (loams, clay, silt)	0.10–0.50	2.50–12.50
Low (clays, clay loam)	0.01–0.10	0.25–2.50

Source: After ASCE Manual of Engineering Practice, *No. 28.*

A typical relation between f_1 and the infiltration rate throughout a rainfall period is shown graphically in Fig. 2.1a; Fig.2.1b shows an infiltration capacity curve for normal antecedent conditions on turf. The data given in Table 2.1 are for a turf area and must be multiplied by a suitable cover factor for other types of cover complexes. A range of cover factors is listed in Table 2.2.

Table 2.2: Range of cover factors



	Cover	Cover factor
Permanent forest and grass	Good (1 in. humus)	3.0–7.5
	Medium ($\frac{1}{4}$–1 in. humus)	2.0–3.0
	Poor ($<\frac{1}{4}$ in. humus)	1.2–1.4
Close-growing crops	Good	2.5–3.0
	Medium	1.6–2.0
	Poor	1.1–1.3
Row crops	Good	1.3–1.5
	Medium	1.1–1.3
	Poor	1.0–1.1

Source: After ASCE Manual of Engineering Practice, *No. 28.*

Total volumes of infiltration and other abstractions from a given recorded rainfall are obtainable from a discharge hydro graph (plot of the stream flow rate versus time) if one is available. Separation of the base flow (dry weather flow) from the discharge hydrograph results in a direct runoff hydrograph (DRH), which accounts for the direct surface runoff, that is, rainfall less abstractions. Direct surface runoff or precipitation excess in inches uniformly distributed over a watershed can readily be calculated by picking values of DRH discharge at equal time increments through the antecedent conditions of turf areas, hydrograph and applying the formula;

$$P_e = \frac{(0.03719)(\Sigma\, q_i)}{A n_d} \quad \text{(Horton, 1940)} \qquad (2.2)$$

Where;

P_e = precipitation excess (in.)

q_i = DRH ordinates at equal time intervals (cfs)

A = drainage area (mi^2)

n_d number of time intervals in a 24-hr period

For most cases the difference between the original rainfall and the direct runoff can be considered as infiltrated water. Exceptions may occur in areas of excessive subsurface drainage or tracts of intensive interception potential. The calculated value of infiltration can then be assumed as distributed according to an equation of the form of Eq. 2.1 or it may be uniformly spread over the storm period. Choice of the method employed depends on the accuracy requirements and size of the watershed. To circumvent some of the problems associated with the use of Horton's infiltration model, some adjustments can be made. Consider Fig. 2.2. Note that where the infiltration capacity curve is above the hyetograph, the actual rate of infiltration is equal to that of the rainfall intensity, adjusted for interception, evaporation, and other losses. Consequently, the actual infiltration is given by:

$$f(t) = \min\,[f_p(t), i(t)] \quad \text{(Horton, 1940)} \qquad (2.3)$$

where $f(t)$ is the actual infiltration into the soil and $i(t)$ is the rainfall intensity. Thus the infiltration rate at any time is equal to the lesser of the infiltration capacity $f_p\ (t)$ or the rainfall intensity. Commonly, the typical values of f_0 and f_c are greater than the prevailing rainfall intensities during a storm. Thus, when Eq. 2.1 is solved for fp as a function of time alone, it shows a decrease in infiltration capacity even when rainfall intensities are much less than f_p. Accordingly, a reduction in infiltration capacity is made regardless of the amount of water that enters the soil. To adjust for this deficiency, the integrated form of Horton's equation may be used:

$$F(t_p) = \int_0^{t_p} f_p\,dt = f_c t_p + \frac{f_0 - f_c}{k}(1 - e^{-kt_p}) \quad \text{(Horton, 1940)} \qquad (2.4)$$

where F is the cumulative infiltration at time t_p as shown in Fig. 2.2.

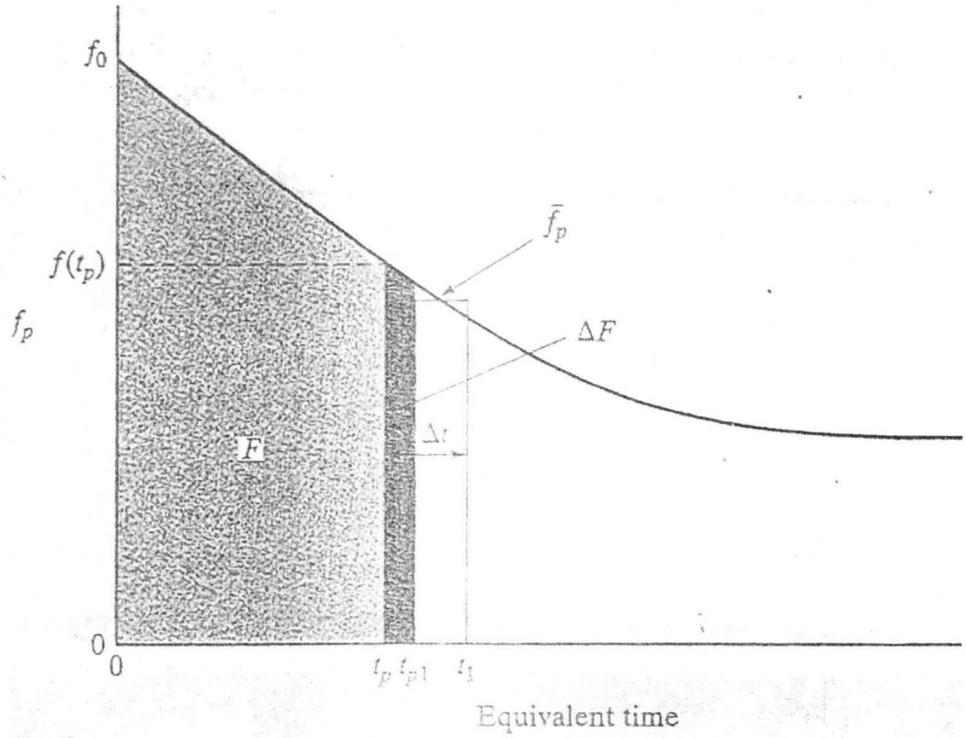


Fig. 2.2 Cumulative infiltration curve

In the figure, it is assumed that the actual infiltration has been equal to f_p. As previously noted, this is not usually the case, and the true cumulative infiltration must be determined. This can be done using:

$$F(t) = \int_0^t f(t)\,dt \quad \text{(Horton, 1940)} \qquad (2.5)$$

where $f(t)$ is determined using Eq. 2.5. Equations 2.4 and 2.5 may be used jointly to calculate the time t_p, that is, the equivalent time for the actual infiltrated volume to equal the volume under the infiltration capacity curve (Fig. 2.2). The actual accumulated infiltration given by Eq. 2.5 is equated to the area under the Horton curve, Eq. 2.4, and the resulting expression is solved for t_p. This equation:

$$F = f_c t_p + \frac{f_0 - f_c}{k}(1 - e^{-kt_p}) \quad \text{(Horton, 1940)} \qquad (2.6)$$

cannot be solved explicitly for $t_{p,}$ but an iterative solution can be obtained. It should be understood that the time t_p is less than or equal to the actual elapsed time t. Thus the available infiltration capacity as shown in Fig. 2.2 is equal to or exceeds that given by

Eq. 2.1. By making the adjustments described, f_p becomes a function of the actual amount of water infiltrated and not just a variable with time as is assumed in the original Horton equation. In selecting a model for use in infiltration calculations, it is important to know its limitations. In some cases a model can be adjusted to accommodate shortcomings; in other cases, if its assumptions are not realistic for the nature of the use proposed, the model should be discarded in favor of another that better fits the situation.

2.1.2 Kostiakov and Lewis: - Kostiakov (1932) and Lewis (1937) independently suggested the equation

$$I = Kt^n \tag{2.7}$$

For estimating infiltration rate

Where

I is the infiltration rate (mm/hr)

t is the infiltration time (hr)

k and n are constants for a particular soil and condition, n has negative sign by integrating equation 2.7 with respect to time, the depth (F) of water that would have infiltrated into the soil up to that time is obtained

$$F = I \& T$$

$$= Kt^n \& T$$

$$= \frac{Kt^{n+1}}{n+1} \tag{2.8}$$

That is, the cumulative infiltration F ifs the accumulated depth of water infiltrated during a given time period and is equal to the integral of the infiltration rate over the period

$$F(t) = \int_0^t f(t)dt \qquad (2.9)$$

And conversely, the infiltration rate is the time derivative of the cumulative infiltration

$$f(t) = \frac{df(t)}{dt}$$

Infiltration into unsaturated soil is defines by the differential equation;

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial Ó}{\partial z}\right) + \frac{\partial}{\partial z}(kg) \text{ (Klute, 1952)} \qquad (2.10)$$

Where

θ = the moisture content in volume of water per unit volume of soil

K= the unsaturated hydraulic conductivity (LT^{-1})

Ǿ = the capillarity potential (L)

g = gravitational constant (LT^{-2})

z = the co-ordinate in the vertical direction (L)

A general analytical solution to equation above cannot be obtained because both k and Ǿ are function of θ. Graphically solutions have been made and numerical solutions are practical with computer.

Where

S is the sorptivity of the soil

K is a constant

Then the instantaneous infiltration rate is;

$$f = \frac{dI}{dt} = \frac{1}{2}st^{-1/2} + K \text{ (Talsma, 1969)} \qquad (2.11)$$

From which it can be seen that f becomes steady and equal to k at times long enough for the first term to become negligible. Sorptivity is an important parameter in the description of both cumulative infiltration and the instantaneous infiltration rate. It is not a constant but becomes smaller as the initial water content (pressured uniform) increases. Talsma, (1969) worked out the optimum conditions for deriving s from data gained in the field from the standard ring – infiltrometer. As equation (2,4) shows, I should be plot on a straight line against $\sqrt{t}$, soon after the start of the experiment and before the processes represented by the second term contribute significantly for many soils the straight line plot of I vs. $t^{1/2}$ is limited to three minutes and up to 20 minutes. Sometimes, after the first application of the water Clothier and White (1986) applied the water to the surface through a porous plate, with hydrostatic pressure regulation, so that the matric potential at the soil surface is about -0,04m. Slight suction is sufficient to drain gross fissures and holes and markedly improves the estimate of s, particularly when it is to be used in calculations involving rain-fed infiltration. They isolate a short soil column by sculpturing it and enclosed it with a sorptivity tube, mode of clear perpex so that the wetting front could be seen. In sprinkler infiltrometers, excess water is sprayed or dripped unto the soil at a measured rate and the run-off from a central test plot within the sprayed area is collected and measured. The surrounding guard area is effective in preventing error from lateral movement. Natural rainfall can be used as the source of supply when surface run-off and precipitation data are available for rain storms of sufficient intensity and duration. Zegelin and white (1982) described the design of a field sprinkler. Infiltrometer, intended for use in constant flux experiments for a range of values of f_0 both smaller and larger k_0. They were able to verify that the expression for the time of incipient ponding, if $f_0 > k_0$; was calculated acceptably by the relation;

$$t_p = s^2/2f_0(f_0 - k_0).$$ (Talsma, 1969) (2.12)

Where

t_p= time of incipient ponding (sec.)

s = sorptivity

f_0 = infiltration capacity at the onset of infiltration.

K_0 = initial constant at f_0.

2.1.3 The Philip's Equation

Philip (1954) developed a theoretical solution for the dimensional vertical infiltration into soil profile surface moisture content of θ_0

$$Q = At^{1/2} + Bt + Ct^{3/2} + Dt^2 +$$ (Philip, 1954) (2.13)

Where the constants A, B, C etc functions of the properties $D(\theta)$, $K(\theta)$ and the initial and boundary conditions θ, θ_0. The first term ($At^{1/2}$) represents the effect of section (i.e. horizontal infiltration) and the remaining terms are effectively correction term to account for gravity (for small t, the first term will predominate. Philip suggested that if t were not too large the series could be truncated i.e.

$Q(t) = At^{1/2 + Bt}$. As the constants decrease for the terms with higher power of t, then the infiltration rate

$$f = \frac{dQ}{dt} \text{ is given by } f(t) = \frac{1}{2} At^{-1/2} + B.$$ (Philip, 1954) (2.14)

Note that as t → infinity ( ) f → $K_{sat,}$ which implies that B is equivalent to $K_{sat.}$ However the approximate form of equation holds for t "not too large" hence the theoretical values of B is different to $K_{sat.}$ In practice, the truncated equation is widely used in an empirical manner with A and B empirically determined and B corresponding to K_{sat}. The equation has 2 parameters compared with the 3 required by Horton's e equation but has a slight problem of an interminate $f(0)$. The equations were compared when on the same run-off model by Dandy and Lichty. Philip equation was easier to fit but the accuracy and sensitivity of the model were for both method.

2.1.4 Swatre

Infiltration and soil water transport in soils are simulated by a solution of the well known Richards equation, which combines the Darcy equation and the continuity equation:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} K(h)\left[\frac{\partial h}{\partial z} + 1\right] \quad \text{(Richards, 1931)} \qquad (2.15)$$

With

K = the hydraulic conductivity (m/s);

h = the pressure (matric) potential (m);

θ = the volumetric water content (m^3/m^3);

z = the gravitational potential or height above a reference level (m);

t = time (s)

Using the soil water capacity C (h) =dθ/dh (the slope of the soil water retention curve (h), the unsaturated flow equation is derived:

$$C(h)\frac{\partial h}{\partial t} = \frac{\partial}{\partial z} K(h)\left[\frac{\partial h}{\partial z} + 1\right] \quad \text{(Richards, 1931)} \qquad (2.16)$$

The Mualem/Van Genuchten equations (Mualem, 1976) and (Van Genuchten, 1980) can be used to predict the soil-water retention curves and the unsaturated hydraulic conductivity, which are needed to solve the equation above. However LISEM does not use these relations directly but requires the user to define the water retention curves and the K(h) curves as tables. The reasoning is that the measured curves hardly ever follow the Mualem-Van Genuchten relations exactly but usually derivate near saturation of the soil. Thus, for the catchments soil profile types are defined, and for each characteristic soil horizon, and for each horizon tables with the measured K-theta-h relations are required. The equations are solved by explicit linearisation using the so-called Thomas (tridiagonal) algorithm (Remson et al., 1971). The submodel operates with a variable time increment depending on pressure head changes. Swatre assumes that the nodes are not in the centre of the layers (as is common) but between the layers. The average hydraulic conductivity between the nodes can be calculated either as a arithmetic average (0.5*sum of Ki and Ki+1), or as the geometric average (sqrt(Ki*Ki+1)). The choice is made in the user interface. This has a large influence as the geometric mean favours the node with the lowest K value and the K(h) relationship is highly non-linear: compare 0.5*(1 + 0.01)=0.5005 with sqrt(1 * 0.01)=0.1.

2.1.5 Holtan Method

For areas without detailed knowledge of the soil physics, different model versions with empirical infiltration equations can be used, using Green & Ampt and Holtan (Green and Ampt (1911) and (Holtan, 1961). The Holtan model empirical (sub-) model is based on a storage concept. The main advantage of the model is the capability of recovery in soil infiltration capacity during periods of light or zero rainfall. The infiltration rate is expressed in terms of cumulative infiltration, initial soil water content and other soil variables

$$f = FC + A \text{ x}\left(\frac{S_t + DR - F}{TP \text{ x } DF}\right)^{P} \text{ (Holtan, 1961)} \qquad (2.17)$$

with:

f = infiltration rate (mm/h);

FC = infiltration rate at steady state (mm/h);

A = the maximum possible increase in infiltration rate over the steady state rate, FC (mm/h);

S_t = storage potential of the soil (mm) above the impeding strata: total porosity (TP) minus the antecedent soil water (ASM):

S = (1-ASM)*TP*DF;

DF = the effective depth to the impeding strata (control zone depth) (mm);

TP = total porosity (% volume);

ASM = antecedent soil moisture (% saturation);

DR = cumulative drainage (mm);

F = cumulative infiltration (mm);

P = dimensionless coefficient relating the rate of decrease in infiltration rate with increasing soil moisture content.

Huggins L. F and Monke E. J. introduced an expansion of the model, assuming a relationship between percolation (or 'drainage') and soil water content. Using both equations, the recovery of infiltration rate as the result of a temporary interruption in rainfall can be predicted. They assume drainage when soil moisture content in the control zone exceeds field capacity:

$$dr = FC \text{ x}\left(1 - \frac{S_t + DR - F}{(1-FP) \text{ x } TP \text{ x } DF}\right)^{3} \text{ (Huggins and Monke, 1968)} \qquad (2.18)$$

with:

dr = percolation or 'drainage' rate (mm/h);

FP = field capacity (% saturation).

The major advantage of the Holtan model over other infiltration equations is the use of cumulative infiltration instead of time as the independent variable. This offers several advantages in catchment-hydrology simulation. Using the Holtan equation, difficulties are not encountered in computing the infiltration rate at any time during a storm event, even when the water supply does not exceed the infiltration rate. Furthermore, because the Holtan model assumes a relationship between drainage and soil water content, the recovery of infiltration rate as the result of a temporary interruption in rainfall can be predicted. The major difficulty with the Holtan equation is the control zone depth (DF). Holtan suggested that the depth to the first impeding layer should be used. If no impeding layer exists, a value equal to 0.25 to 0.75 of the A-horizon is advised (Beasley & Huggins, 1982). Beasley and Huggins remarked that of all of the variables used in the ANSWERS model (Areal Non-point Source Watershed Environment Simulation), the DF is the least well defined and most arbitrary. Huggins and Monke found that the effective depth was highly dependent on both surface condition (crusting) and the cultural practices used in preparing the seed bed (Huggins and Monke, 1966). De Roo and Riezebos also demonstrated the influence of crusting on the DF variable (De Roo and Riezebos (1992). Huggins and Monke suggested that the DF for deep soils can be determined by the depth necessary for the hydraulic gradient to approach unity (Huggins and Monke, 1968). The control zone depth was computed for fallow soils from the initial soil water content (ASM), the soil porosity (TP), and the volume of water that had infiltrated (F) at the time the infiltration rate reached a constant value:

$$DF = \frac{F_{sat}}{(1-ASM)\,x\,TP} \quad \text{(Skaggs et al., 1969)} \qquad (2.19)$$

with:

F_{sat} = Cumulative infiltration (mm) at saturation.

A major disadvantage of this method however, is that the DF variable is made a fitted variable instead of being physically measurable as the depth to the first impeding layer. Nevertheless, with this method, Holtan's equation gave an excellent fit ($r^2 = 0.988$, obtained using non-linear regression) to their experimental data. The Holtan infiltration model incorporates a minimum infiltration capacity (FC), which equals the saturated conductivity (Ks) of the topsoil. Because the Ks is always larger than zero, the model always allows for infiltration, even when the soil profile is saturated. Thus, using this sub-model, only Hortonian overland flow is simulated. Saturation overland flow is not simulated. Using the Swatre-based sub-models and the Green/Ampt submodels, one can simulate saturated overland flow.

2.1.6 Green and Ampt: - Green W. H. and Ampt G. A first applied the Darcy equation to the wetted zone in the soil, assuming that a distinct wetting front exists. They produced a one dimensional infiltration equation used and adapted by many researchers. Generally the equation has the following form:

$$i = k\left(t + \frac{\Omega}{I}\right) \text{ and}$$

$$I - \Omega \ln\left(t + \frac{I}{\Omega}\right) = kt \text{ (Green and Ampt, 1911)} \qquad (2.20)$$

in which I = the infiltration rate (m/s), I = the accumulated infiltration over time (m), k = the hydraulic conductivity in the wetted zone (m/s), t = time since the start of the infiltration and W = potential head parameter (m). Note that k is not necessarily the saturated hydraulic conductivity but less (Li et al., 1976). According to Fok and Hansan, this parameter is defined as:

$$\Omega = (h_c + h_0)(\theta_w - \theta_i) \quad \text{(Fok and Hansan, 1966)} \qquad (2.21)$$

in which h_c = the average capillary suction head at the wetting front, h_o = the ponded head water level at the surface, q_w = the water content of the wetted zone (may be smaller than the porosity) and q_i = the antecedent moisture content. To get the infiltration rate at any time equation 2 of 2.20 has to be solved first for I and inserted into equation 1. This is usually done by iteration. Li et al. show that it is possible to use an explicit approximation by developing a power series expansion of the logarithmic term in equation 2. First the parameters are rewritten in their non-dimensional form:

$I^x = \frac{I}{\Omega}$; $t^x = \frac{kt}{\Omega}$ and $i^x = \frac{i}{k}$

By using these parameters the equations are now rewritten as:

$$i^{x=}\ t + \frac{1}{I^x}$$

and

$$I^{x-}\ln(1 + I^x) = t^x \quad \text{(Li et al., 1976)} \qquad (2.22)$$

Replacing the logarithmic term with a power series and dropping the higher order terms yields a quadratic function that can be solved simply by retaining the positive root:

$$I^x = 0.5\left[t^x + \sqrt{t^x\,(t^x + 8)}\,\right] \text{ (Li et al., 1976)} \qquad (2.23)$$

which can be rewritten in the dimensional form as:

$$dI = \frac{1}{2}\left[-(2I - kdt) + \sqrt{(2I - kdt)^2 + 8kdt(\Omega + I)}\right] \text{ (Li et al., 1976)} \qquad (2.24)$$

This is the relation used in LISEM whereby dI > 0 (if the solution is negative it has no meaning). The Green and Ampt model is very sensitive to the choice of Ksat and initial moisture content. The initial assumption that the wetting front moves down as a wet body parallel to the surface with a speed dictated by the Ksat is not correct. Many researchers therefore suggested "field" variables: a "field porosity or a field "Ksat", or a suction at the wetting front that is not the matrix potential at a given time but a more soil property.

This means that in practice the Green and Ampt solution needs calibration, either by decreasing the Ksat values or the storage capacity of the soil. Subtraction of Ksat; the saturated hydraulic conductivity is subtracted from the net rainfall, simulating instant saturation in a simple way. This option can be used for testing and quick and dirty estimates.

2.2 **Measurement of Infiltration:** - The rate at which water can enter soil when not limited by the rate of supply of is measured in the field with water either ponded on the surface or failing on it as artificial or natural rain at a rate sufficient to cause run-off. It is expressed in m/s or some convenient multiple of these units and is called infiltration capacity (Hortan, 1940). It is a potential rate that is characteristics of the soil during bunder specified conditions. In particular, it varied with time during a test and with initial water content fig (2.2)Three method of estimating infiltration characteristics of soil includes:

1. The use of cylinder infiltrometers
2. Measurement of subsidence of free water in a large basing and
3. Estimating of accumulated infiltration from the water front advance data.

Among these methods the use of cylinder infiltrometer is most popular and adapted in this study. The method is described as follows. The infiltration characteristics of soils might be determined by pouring water in a metal cylinder installed on the field surface and observing the rate at which water level is lowered in the cylinder. In the earlier studies only a single cylinder was used and many of the data indicated a high degree of variability. The variability was mainly due to the uncontrolled lateral movement of water from the cylinder after the wetting front reached the bottom of the cylinder. After the initiation of infiltration, while the wetting front passes below the cylinder, a more or less divergence of flow will occur. The lateral movement of water from cylinder is minimized by ponding water in a guard cylinder of buffer area around which constructed and used for the study. Infiltration rate observed by cylinder infiltrometers are influenced by the cylinder diameter, thickness of cylinder, beveling of the cylinder bottom, the method of driving the cylinder into the soil and the installation depth. The variability of data caused by ring placement could be overcome greatly by leaving the cylinders in place over a long period during a series of measurement.

The cylinder are usually about 25-30cm deep and are formed of 2mm rolled steel. The inner cylinder, from which the infiltration measurement is taken is usually 30cmin diameter. The outer cylinder, which is used to form a buffed pond is about 60cm in diameter. The cylinders are installed about 10cm deep in the soil. Care is taken to keep the installation depth of the cylinders the same in all experiments. This can be accomplished by marking the outside and inside of the cylinders at the 10cm level and driving the cylinder into the ground by a falling weight type hammer striking on a wooden plant placed on top of the cylinder or by light blows with an ordinary hammer and using a short wooden plank to prevent damage to the edges of the metal cylinder.

The water level in the inner cylinder is read with the field type point gauge or hook gauge (sometimes an ordinary plastic scale placed in the inner cylinder or a manometer fixed to the outside of the cylinder are also used, but for accurate work a point gauge or hook gauge should be used). The point rod is set at the desired level to which water is to be added. Water is added to the inner cylinder from a container of known volume and a graduated jar. It is added by pouring water on a piece of folded juce malting. The malting is used to preventing puddling and seal of the surface soil. After filling the cylinder to about three-fourth of the desired level the matting is removed. A stop watch or the second's hand of a wrist watch is used to note the instant the addition of water begin and the time the water reaches the desired level. The total quantity of water added to the inner cylinder is determined by counting the number of full containers (Bambe, 1995).

2.3 **Factors Affecting Infiltration Rate:** - The movement of water into the soil by infiltration may be limited by any restriction to the flow of water through the soil profile. Although such restriction often occurs at the soil surface, it may occur at some point in the lower ranges of the profile. The most important items influencing the rate of infiltration has to do with physical characteristics of the soil line texture and soil particle size. Thus, the major factors affecting the infiltration of water into the soil are the initial moisture content, condition of the soil surface, hydraulic conductivity of the soil profile, texture, porosity, degree of swelling of soil colloids and organic matter, vegetative cover, duration of ponding water, irrigation or rainfall and viscosity of water. The antecedent soil moisture content had considerable influence on the initial rate and total amount of infiltration, both decreasing as the soil moisture content rises. The infiltration of any soil is limited by any restraint to the flow of water into and through the soil profile. The soiln layer with the lowest permeability either at the surface or below it, usually determines the infiltration rate. Infiltration rates are also affected by the porosity of soil which is changed by cultivation or compaction. Cultivation influences the infiltration rate by increasing the porosity of the surface soil and breaking up the surface seals. The effects of tillage on infiltration usually lasts only until the soil settle back to its formal condition of bulk density because of subsequent irrigation or ponding of water.

Infiltration rates are generally lower in soils of heavy texture than on soils of light texture. The influence of water depth over soil on infiltration rate was investigated by many workers. It has been established that in surface irrigation, increased depth increases initial infiltration slightly but the head has negligible effect prolonged irrigation. Infiltration rate are also influence by the vegetal cover (Horton, 1940) and (Green and Ampt,1911).

An infiltration rate on grass land is substantially higher than bare uncultivated land. Additions of organic matter increases infiltration rate substantially. The hydraulic conductivity of the soil profile often change during infiltration not only because of the puddling of the surface caused by reorientation of surface particles and washing of finer materials into the soil, viscosity of water influences infiltration. The high rate of infiltration in the tropics under otherwise comparable soil is due to the low viscosity of warm water.

2.4 Gravimetric Method of Obtaining Moisture Content, Bulk Density and Porosity.

2.4.1 Moisture Content: - Soil moisture content shall be determined gravimetrically as described in the method of soil analysis by driving a cylindrical sample core into the soil to entrap soil at different depths of 0 – 15cm, 15 – 30cm and 30 -45cm for each plot (Black,1965). The samples are weighed each in the sample can and they are placed in the oven at 105^0 C for 24 hours. The cans with soils are weighed and the difference in the wet weight to the dry weight of soil is the moisture content of the soil. The moisture content can be calculated by expressing it as percentage of dry weight is given below (Black, 1965).

$$\Theta g = \frac{Mw}{Ms} \text{ x } 100 \quad \text{(Black, 1965)} \tag{2.25}$$

Where

Θg = gravimetric water content percentage

Mw = weight of water

Ms = weight of soil after oven drying.

2.4.2 Bulk Density: - The soil bulk density was determined from the undisturbed core samples obtained by the Black's method. The bulk density can be calculated using the expression below;

$$(D.b) = \frac{Ms}{V} \quad \text{(Black, 1965)} \tag{2.26}$$

$$(B.D) = \frac{M}{V} \quad \text{(Black, 1965)} \tag{2.27}$$

Where

D.b = Dry bulk density in (g/cm^3)

Ms = weight of oven dried soil (g)

V = volume of core sampler (cm^3)

B.D = wet bulk density (g/cm^3)

M = total weight of the soil (g)

V = volume = TIr^{2}h (confirm it)

Where

r = radius of sample core

h = height of sample core

2.4.3 Porosity (n):- Porosity is the ratio of the volume of the void to the total volume of the soil. Void comprises of water and air and the total volume of the soil comprises of the volume of void and that of the soil gram

$$V = V_v + V_s \text{ (Black, 1965)} \qquad (2.28)$$

$$n = \frac{V_v}{V} \qquad (2.29)$$

The result obtained from the gravimetric experiment can be adopted as follows:

$$n = \left(1 - \frac{Db}{B.D}\right) \text{ x } 100 \text{ (Black, 1965)} \qquad (2.30)$$

Where

n = total porosity percentage

Db = dry bulk density (g/cm^3)

B.D = wet bulk density (g/cm^3)

2.5 Causes and Determination of Soil Compaction: - Constant action of movement of agricultural machines and equipments on soil cause a gradual compaction (elastic plastic and yield point). Compaction affects the soil surface and structure. Compaction causes a hard flat layer which has a negative effect on soil. On compacted soils, it is difficult for water to permeate below the layer there by causing soil erosion or water logging.

2.5.1 Determination of Soil Compaction: - The normal parameters to estimate the degree of soil compaction are maximum pressure of mechanical devices on soil Pk and normal stress (→ a depth of 0.5m). to determine the maximum pressure of wheel tractor on the soil, the following expression can be used

$$Pw = (K_2/K_1) \times PwAw \quad \text{(Bambe, 1995)} \qquad (2.31)$$

Where PWAV, average pressure of wheel tractor on hard surface, which is determined experimentally;

Pw = soil compaction

K_2 = coefficient of longitudinal unequal distribution of pressure on contact surface

K_1 = coefficient which depends on external diameter of tires

$K_1 = D$

$PwAw = \frac{Gk}{Ak}$

Gk = vertical load on tractor in (KN)

Ak = Area of contact surface of tire with soil in meter square

Horton's Equation:- In this study Horton's equation (2.1) shall be adopted to evaluate the intake characteristic of soil at the selected mechanized farm in Niger State. The equation (2.1) is integrated as follows to evaluate the accumulated depth of water infiltrated during a given time period.

$F = \int_0^t f dt$

$\int_0^t fc + (fo - fc)e^{-kt} dt$

$\int_0^t fcdt + \int_0^t (fo - fc)e^{-kt} dt$

$F = f_c t + (f_0 - f_c)[\frac{-1e^{-kt}}{k}]_0^t$

$F = f_c t + \frac{fo-fc}{k}[-e^{-kt} + e^0]$ (Horton, 1940) (2.32)

If $f_0 - f_c = a$

$F = f_c t + \frac{a}{k}[1 - e^{-kt} + e^0]$

$$F = f_c t + \frac{a}{k}[1 - e^{-kt}]$$

Where

F = Accummulated infiltration

f_c = the constant infiltration capacity as t approaches infinity.

f_0 = infiltration capacity at the on set of infiltration

k = a positive constant for a given soil and initial condition.

t = time.

In this study to determine the soil characteristic constant k, the Horton's equation (2.1) was transformed to equation of a straight line by taking the logarithm as follows;

Horton's equation (2.1)

$$f = f_c t\,(f_0 - f_c)\,e^{-kt}$$

To find the log on both sides

$$f = f_c t\,(f_0 - f_c)\,e^{-kt}$$

$$\log f = \log f_c + \log (f_0 - f_c) + \log e^{-kt}$$

$$\log f = \log + \log e^{-kt}$$

$$\log f = \log f_0 + k.t \log e$$

$$\log f = \log f_0 + K \log e.t \text{ (Horton, 1940)} \tag{2.33}$$

$$y = C + mx$$

Which is a straight line graph with the intercept;

$C = \log f_0$ and gradient

m = gradient

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introductory note

This chapter takes into account the procedure used to determine the soil moisture content and infiltration rate. They are discussed below;

The infiltration rate experiment is to determine the rate at which water goes or penetrates into the soil at known moisture, by obtaining the drop in height of water in the double ring infiltration at a fixed period of time.

3.1.1 Gravimetric Test Apparatus/Materials

Moisture can and lids

Sample core

Cutlass

Plank

Oven

Weighting Machine

3.1.2 Site Description

The geographical coordinate was just done recently and has not being submitted to the farm manager as at the time this experiment was conducted. Vegitationally, the site is located in the Sudan guinea savannah region and has basically the rainy, harmatta and dry season weather

3.1.3 Experimental Layout

The design of experiments was a randomized complete block (R.C.B) with three treatments. The tilled (T), Non-tilled (NT) and Tractor track (Tt); and with three replicates. The experimental layout is illustrated in Fig. 3.1

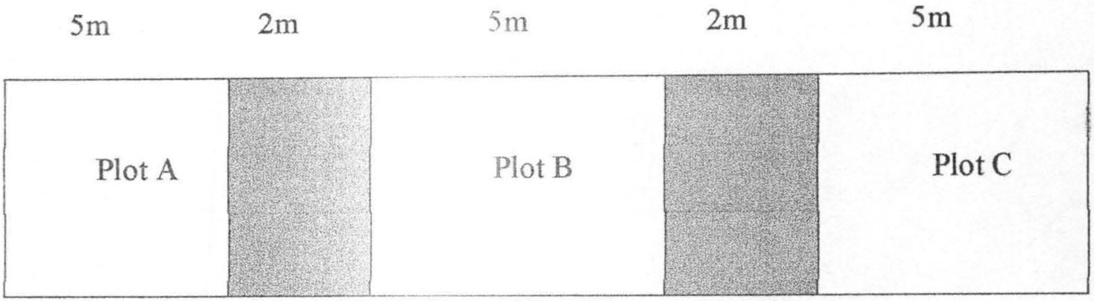


Fig. 3.1 Layout of the experiment showing treatments and plots.

Plot size was 5m x 5m and separated by (2 meter) alley between each other. Plots were marked out in 3 sites to correspond to the Tilled (T), Non-tilled (NT) and Tractor tracks (Tt). Other features of the sites are shown in table 3.1

Table 3.1 Features of the Tilled, Non-Tilled and Tractor tracks of the farm.

Features	Tilled	Non-Tilled	Tractor Tracks
Types of farming operation done	Plowing	No farming operation	Tractor movement
Period operation last perform	3 weeks	2 years	1 week
Surface Configuration	Rough	Smooth with cracks	Compacted with smooth surfaces

The sample core is made of steel iron and it is beveled at an end.

The size of the sample core is 6.5cm diameter by 6.4cm in height.

3.1.4 Procedure.

The sample cores are placed on the soil (0-15cm) and driven in by applying force from weight. When the core is filled with soil, it is gently removed by placing a cutlass under the sample core; so as to prevent the soil in the core from falling off. After removing the sample core from the soil, the soil transferred into the moisture can and covered immediately to avoid moisture loss or gain by evaporation or condensation.

The cans are placed in a cool place after been filled with soil. The same procedure is repeated for 15-30, and 30-45 soil depth.

The cans are all covered with their lids after filling it it with soil.

All the samples are taken gently in a container into the laboratory, where an electronic weighing machine is used measure the weight of the cans and the soil.

The cans are all labeled and weighed before being taking to the field. The cans are labeled in this way: for the tilled soil cans we have:

T1, 0-15,	T1, 15-30	T1, 30-45cm
T2, 0-15	T2, 15-30	T2, 30-45cm
T3, 0-15	T3, 15-30	T3, 30-45cm

This shows that for plot one of the tilled soils, T1 is used to signify the first plot, T2 signifies the second and T3 signifies the third plot. The same method is used to label the cans used for the Non-Tilled and Tractor track in plot B and C.

The cans containing soil after being weighed are placed in the oven for 24 hours at a temperature of 105^0c. After 24 hours, the oven is switched off and opened for the cans to cool a little before it is being weighed again and recorded. Empty can from the oven are re-weighed to make sure that the can were properly weighed.

3.1.5 Plot Description

3.1.5.1 The Tilled Plot

It is an area that has always been cultivated for the past years and crops are planted on it.

It is to show the effect of infiltration on this soil. The soil had been tilled before this experiment was carried out. The tillage operation done on the plot is ploughing. It makes the soil loose and allows for easy percolation of water during the experiment.

3.1.5.2 The Non-Tilled Plot

Due to the effect of continuous farming operation on the soil, by machine(s) is selected where the soil is almost loses its natural state for a long time without any machine – soil relationship. Border between fields are normally used for this experiment. This will give room for comparism of the effect of machine operation on the soil and non machine operation on the soil.

3.1.5.3 The Tractor Tracked Plot

This is an area where there has always been a constant machine traffic travel which the area experienced soil compaction. The essence of this is to know the effect of soil compaction on the soil as regard its rate of infiltration.

3.1.5.4 Crop Residue on Surface

This is the amount of plant that remains on the soil from the last season up to the present time before the experiment. The feature of the plot is shown the table 3.1

In this study, Horton's equation was adopted to develop the intake characteristics equation for the soils encountered. The infiltration rate and accumulated infiltration depth equation shall represent the observed decrease of infiltration rate with time.

The choice of the Horton's equation for this study is due to the fact that the Horton's equation has the consideration for the accumulated depth equation and it has the easiest formula for calculating the infiltration depth.

3.2 The Jamila Villa Farm

3.2.1 Introduction Note

The Jamila Villa farm is owned and operated by the present Niger state governor, Dr Muazu Aliyu Babangida (Talban-Minna) with the aim to improve and increase food supply for the Nigerlite and its environ. It is a dairy farm.

The farm was established in 2007. It is sited at Brige, Pakororo local government area of Minna.

The farm is divided into three parts namely; the crop production, Animal production and milling units.

3.2.2 Location

The Farm is located at Brige village, Pakororo local government, Minna Niger State.

3.2.3 Rainfall

There is no specific rainfall data for the location yet but rainfall is normally from March to October with its peak around July/august.

3.2.4 Crop Grown

The crops grown in farm are maize which is used as feeds for the cattle, Banana Mango, Orange (Citrus fruits).

3.2.5 Topography

The area of the land is not regular. The area used for growing crop is flat but some areas are sloppy. Drains are provided at the edges of the farm for convenience of excess water

3.2.6 Cultural Practice

The farm has a land mass of 800 hectares. The farming operations in the area are ploughing done with a disc harrow. Planting is done by a mechanic planter while fertilizer application is done manually. Herbicides are applied with a hand sprayer. The harvesting of the maize after its maturity is done manually. The citrus and other fruit crop are still in their growing stage.

3.2.7 Soil Type

The type of soil found in this area loamy clay soil. It is blackish grey in colour with a sticky nature and it has boulders and cracks after high moisture loss

It has a high percentage of clay and it is water retaining type soil.

3.3 Determination of Soil Bulk Density (B.D) and Porosity.

The soils in the sample core are poured into cans with lids. Weighed and placed in the oven to dry for 24 hours at a temperature of 105^0C. The readings are recorded for all plots and treatments.

The samples are weighed again after 24hours and the readings were also recorded. The data obtained for Bulk density and Porosity were recorded in table 3.2 and equation (2.26) is used for the calculations.

Table 3.2: Bulk Density and Porosity of the soil for Plot A, Plot B, and Plot C

	BULK DENSITY (g/cm^3)			POROSITY (g/cm^3)		
			PLOT A (TILLED)			
Depth (cm)	A	B	C	A	B	C
0 – 15	0.59	0.61	0.75	77.74	76.98	71.70
15 -30	0.53	0.73	0.63	80.00	72.45	76.23
30 – 45	0.64	0.56	0.69	75.85	78.87	73.96
Average	0.59	0.63	0.69	77.74	76.23	73.96
			PLOT B (NON-TILLED)			
0 – 15	0.56	0.56	0.61	78.87	78.87	76.98
15 -30	0.58	0.56	0.58	78.11	78.87	78.11
30 – 45	0.69	0.66	0.53	73.96	75.09	80.00
Average	0.61	0.59	0.57	76.98	77.74	78.49
			PLOT C (TRACTOR TRACKED)			
0 – 15	0.67	0.60	0.62	74.72	77.36	76.60
15 -30	0.65	0.40	0.60	75.47	84.91	77.36
30 – 45	0.58	0.51	0.75	78.11	80.76	71.70
Average	0.63	0.50	0.65	76.23	81.13	75.47

The sample core has a diameter of 6.5cm.The radius of the core 3.25cm, the height of the core is 6.4cm.This core is used for all the experiment. This gives the same volume of samples for all the experiment

Table 3.3a Gravimetric Test Field Analysis Of Jamila Villa Farm

	Fresh weight in gram- Weight of Can (26.11g)			Dry weight in gram - Weight of Can (26.11g)		
			PLOT A (TILLED)			
Depth (cm)	A	B	C	A	B	C
0 – 15	149.58	149.93	181.13	125.93	129.62	158.74
15 -30	124.79	175.77	148.12	113.02	154.40	132.86
30 – 45	146.59	132.51	161.61	136.49	118.89	145.46
Average	140.32	152.74	163.62	125.15	134.30	145.69
			PLOT B (NON-TILLED)			
0 – 15	136.76	135.18	141.39	119.26	118.02	128.79
15 -30	136.67	137.72	137.07	123.54	119.03	123.75
30 – 45	161.87	155.33	126.07	146.40	140.72	112.04
Average	145.10	142.74	134.84	129.73	125.92	121.53
			PLOT C (TRACTOR TRACKED)			
0 – 15	167.33	146.88	144.25	142.86	127.42	130.54
15 -30	154.49	096.52	138.60	137.84	084.23	127.26
30 – 45	135.29	120.21	174.00	122.43	107.53	158.13
Average	152.37	121.20	152.28	134.38	106.39	138.64

Table 3.3b: Moisture Content of the soil in Jamila Villa Farm

	Difference in weight in gram			Moisture content in percent %		
			PLOT A (TILLED)			
Depth (cm)	A	B	C	A	B	C
0 – 15	23.65	20.31	22.39	18.78	15.67	14.11
15 -30	11.77	21.37	15.26	10.41	13.84	11.49
30 – 45	10.10	13.62	16.15	07.40	11.46	11.10
Average	15.17	18.43	17.93	12.20	13.66	12.23
			PLOT B (NON-TILLED)			
0 – 15	17.50	17.66	12.60	14.67	14.54	09.78
15 -30	13.13	18.69	13.32	10.63	15.70	10.76
30 – 45	15.47	14.61	14.03	10.57	10.38	12.52
Average	15.37	16.82	13.32	11.96	13.54	11.02
			PLOT C (TRACTOR TRACKED)			
0 – 15	24.47	19.46	13.71	17.13	15.27	10.50
15 -30	16.65	12.29	11.34	12.08	14.59	08.91
30 – 45	12.86	12.68	15.87	10.50	11.79	10.04
Average	17.99	14.81	13.64	13.24	13.88	09.82

3.4 Infiltration Rate Apparatus/Materials

Stop watch or wrist watch

Measuring jug

2 cylinders

Ruler

Plank

Weight

Drum and bucket

In performing this experiment a double ring infiltrometer was constructed. The two cylindrical rings have a height of 250mm and the outer diameter is 600mm.The diameter of the inner cylinder is 300mm.the cylinders were constructed using galvanized flat sheet of 1.5mm thickness.

3.5 Infiltration Rate Methodology

Plots for the experiments were leveled by removing grasses and debris just at the surface. Care was taken so that the surface structure of the plot is not destroyed. The double ring infiltrometer was placed on the selected plot.

First the inner ring is placed on the soil. The ring is then inserted into the soil by placing a plank across the ring and taped gently until the ring has gone into the soil within a depth of 100-150mm. The inner ring has a ruler attached to the inner side. This allows for the reading of the water level as infiltration progresses

For the tilled soil the inner ring is installed at a depth 130mm due to the loose nature of the soil to avoid water seepage for non-tilled and compacted plots has their rings inserted to a depth of 130mm as well.

After the installation of the inner ring, the outer ring was also installed in the same manner to a depth of 150mm.during the installation of the outer ring, care was taken to centralize the distance between the two rings. The depth is re-checked with a ruler to ensure a perfect level before commencing the experiment fully. The distance between the two rings is also measured with a ruler as well. A drum of water was placed close to the experimental site for constant water use. A small quantity of grass is placed in the inner and outer ring of the infiltrometer to avoid puddling when pouring water in the rings. water was measured with a four liter capacity can and the watch was set at zero reading, after the infiltrometer was set at zero reading, after the infiltrometer was put in place, water was powered into the inner ring and simultaneously the watch was started.

The inner ring was filled up to a level of 20cm reading on the ruler in the inner cylinder. This implies that 20cm of the ruler is used as the reference point. When the inner ring has been filled up to the reference point, the water level in the inner ring was maintained in the outer ring. On the tilled plot, the readings were taken every 2minutes because of the high infiltration rate of the loose soil. After percolation was very high at the initial point of the experiment. For the non tilled and compacted soil the reading were taken every 5minutes on of the soil. The readings vary depending on the type of soils and moisture content of the soil. The time reference point also varies depending on the location. After every reference time expires, a reading is taken and the rings are filled back to the reference water level taking cognizance of the inner ring.

The experiment continues for some time until when a constant reading value is obtained for about 3 to 5 times. For every experiment infiltration rate reading was no less than an hour but not more than 2hours 30minutes. After every experiment the rings were removed and taken to another plot. The data obtained are shown in tables 3.4 to 3.6. Three replicates were taken on each site.

Table 3.4: The Jamila Villa Farm Field Data

	PLOT A (TILLED)					
Time (Min)	Water Level Reading (cm)	Difference (cm)	Water Level Reading (cm)	Difference (cm)	Water Level Reading (cm)	Difference (cm)
0	20.00	0.0	20.00	0.0	20.00	0.0
2	15.90	4.1	16.00	4.0	16.10	3.9
4	16.40	3.6	17.40	3.6	16.50	3.5
6	16.90	3.1	17.80	3.2	16.70	3.3
8	17.00	3.0	17.00	3.0	16.90	3.1
10	17.00	3.0	17.20	2.8	17.20	2.8
12	17.20	2.8	17.20	2.8	17.20	2.8
14	17.40	2.6	17.30	2.7	17.40	2.6
16	17.40	2.6	17.30	2.7	17.40	2.6
18	18.10	1.9	18.10	1.9	17.60	2.4
20	18.20	1.8	18.10	1.9	17.90	2.1
22	18.20	1.8	18.20	1.8	18.10	1.9
24	18.20	1.8	18.20	1.8	18.20	1.8
26	18.30	1.7	18.30	1.7	18.30	1.7
28	18.30	1.7	18.40	1.6	18.40	1.6
30	18.30	1.7	18.40	1.6	18.40	1.6
32	18.40	1.6	18.50	1.5	18.40	1.6
34	18.40	1.6	18.50	1.5	18.50	1.5
36	18.60	1.4	18.60	1.4	18.60	1.4
38	18.60	1.4	18.60	1.4	18.60	1.4
40	19.00	1.0	18.90	1.1	18.80	1.2
42	19.01	0.9	19.20	0.8	19.00	1.0
44	19.01	0.9	19.20	0.8	19.20	0.8
46	19.03	0.7	19.40	0.6	19.30	0.7
48	19.03	0.7	19.40	0.6	19.40	0.6
50	19.04	0.6	19.50	0.5	19.50	0.5

52	19.04	0.6	19.60	0.4	19.50	0.5
54	19.04	0.6	19.60	0.4	19.50	0.5
56	19.05	0.5	19.60	0.4	19.60	0.4
58	19.05	0.5	19.60	0.4	19.60	0.4
60	19.05	0.5	19.70	0.3	19.70	0.3
62	19.06	0.4	19.70	0.3	19.70	0.3
64	19.06	0.4	19.70	0.3	19.80	0.2
66	19.06	0.4	19.70	0.3	19.80	0.2
68	19.06	0.4	19.70	0.3	19.80	0.2
70	19.06	0.4	19.70	0.3	19.80	0.2
72	19.06	0.4	19.70	0.3	19.80	0.2
74	19.06	0.4	19.80	0.2	19.80	0.2

Table 3.5: The Jamila Villa Farm Field Data

			PLOT B (NON-TILLED)			
Time (Min)	Water Level Reading (cm)	Difference (cm)	Water Level Reading (cm)	Difference (cm)	Water Level Reading (cm)	Difference (cm)
0	20.00	0.0	20.00	0.0	20.00	0.0
5	14.00	6.0	13.00	7.0	14.00	6.0
10	14.10	5.9	14.00	6.0	15.00	5.0
15	14.30	5.7	14.10	5.9	15.50	4.5
20	14.40	5.6	14.20	5.8	16.50	3.5
25	14.50	5.5	14.40	5.6	16.50	3.5
30	14.60	5.4	14.60	5.4	17.00	3.0
35	15.00	5.0	14.90	5.1	18.40	2.6

40	15.30	4.7	15.10	4.9	18.60	2.4
45	15.60	4.4	15.20	4.8	18.80	2.2
50	15.90	4.1	15.30	4.7	18.80	1.2
55	16.50	3.5	15.50	4.5	19.00	1.0
60	16.70	3.3	16.20	3.8	19.20	0.8
65	16.80	3.2	16.40	3.6	19.30	0.7
70	16.80	3.2	16.60	3.4	19.30	0.7
75	16.80	3.2	16.80	3.2	19.40	0.6
80	17.00	3.0	17.00	3.0	19.40	0.6
85	17.40	2.6	17.20	2.8	19.50	0.5
90	17.40	2.6	17.40	2.6	19.50	0.5
95	17.80	2.2	17.60	2.4	19.50	0.5
100	18.00	2.0	17.60	2.4	19.60	0.4
105	19.20	0.8	17.80	2.2	19.60	0.4
110	19.50	0.5	18.20	1.8	19.60	0.4
115	19.50	0.5	18.20	1.8	19.70	0.3
120	19.60	0.4	18.40	1.6	19.70	0.3
125	19.60	0.4	18.60	1.4	19.80	0.2
130	19.60	0.4	18.80	1.2	19.80	0.2
135	19.70	0.3	19.20	0.8	19.80	0.2
140	19.70	0.3	19.40	0.6	19.80	0.2
145	19.80	0.2	19.60	0.4	19.90	0.1
150	19.80	0.2	19.70	0.3	19.90	0.1

155	19.80	0.2	19.80	0.2	19.90	0.1
160	19.90	0.1	19.80	0.2	19.90	0.1
165	19.90	0.1	19.80	0.2	19.90	0.1
170	19.90	0.1	19.80	0.2	19.90	0.1
175	19.90	0.1	19.80	0.2	19.90	0.1
180	19.90	0.1	19.80	0.2	19.90	0.1

Table 3.6: The Jamila Villa Farm Field Data

	PLOT C (TRACTOR TRACKED)					
Time (Min)	Water Level Reading (cm)	Difference (cm)	Water Level Reading (cm)	Difference (cm)	Water Level Reading (cm)	Difference (cm)
0	20.00	0.0	20.00	0.0	20.00	0.0
5	17.00	3.0	16.70	3.3	17.50	2.5
10	18.00	2.0	17.00	3.0	18.00	2.0
15	18.20	1.8	17.30	2.7	18.50	1.5
20	18.50	1.5	17.50	2.5	18.50	1.5
25	18.50	1.5	17.50	2.5	18.70	1.3
30	18.70	1.3	18.00	2.0	18.90	1.1
35	18.70	1.3	18.40	1.6	18.90	1.1
40	18.90	1.1	18.40	1.6	19.10	0.9
45	19.10	0.9	18.60	1.4	19.10	0.9

50	19.10	0.9	18.80	1.2	19.20	0.8
55	19.20	0.8	19.20	0.8	19.20	0.8
60	19.30	0.7	19.20	0.8	19.20	0.8
65	19.30	0.7	19.40	0.6	19.30	0.7
70	19.40	0.6	19.40	0.6	19.30	0.7
75	19.50	0.5	19.50	0.5	19.40	0.6
80	19.50	0.5	19.50	0.5	19.40	0.6
85	19.50	0.5	19.50	0.5	19.50	0.5
90	19.60	0.4	19.60	0.4	19.50	0.5
95	19.70	0.3	19.60	0.4	19.60	0.4
100	19.70	0.3	19.60	0.4	19.60	0.4
105	19.70	0.3	19.60	0.4	19.60	0.4
110	19.70	0.3	19.60	0.4	19.60	0.4
115	19.70	0.3	19.60	0.4	19.60	0.4
120	19.70	0.3	19.60	0.4	19.60	0.4

The photographs taken during the experiment on the farm are shown in plate 3.1-3.4 (See page 49-50).

Plate 3.1 Installation of the Infiltrometer

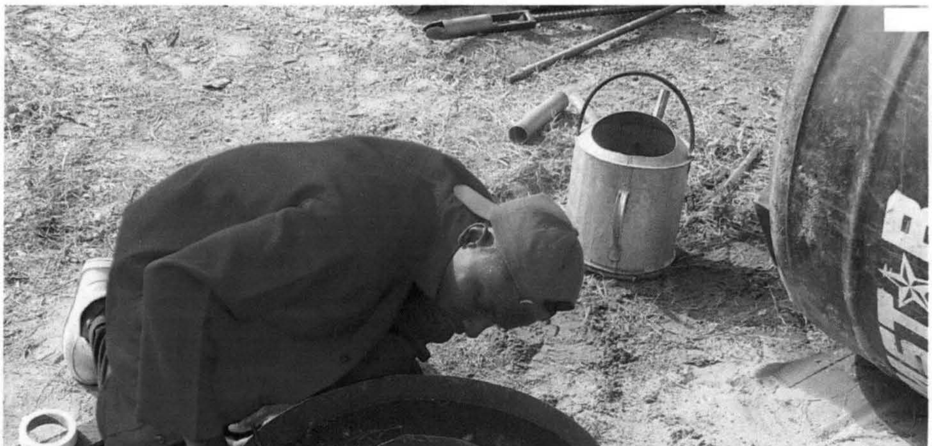


Plate 3.2 Ponding of water in the Infiltrometer

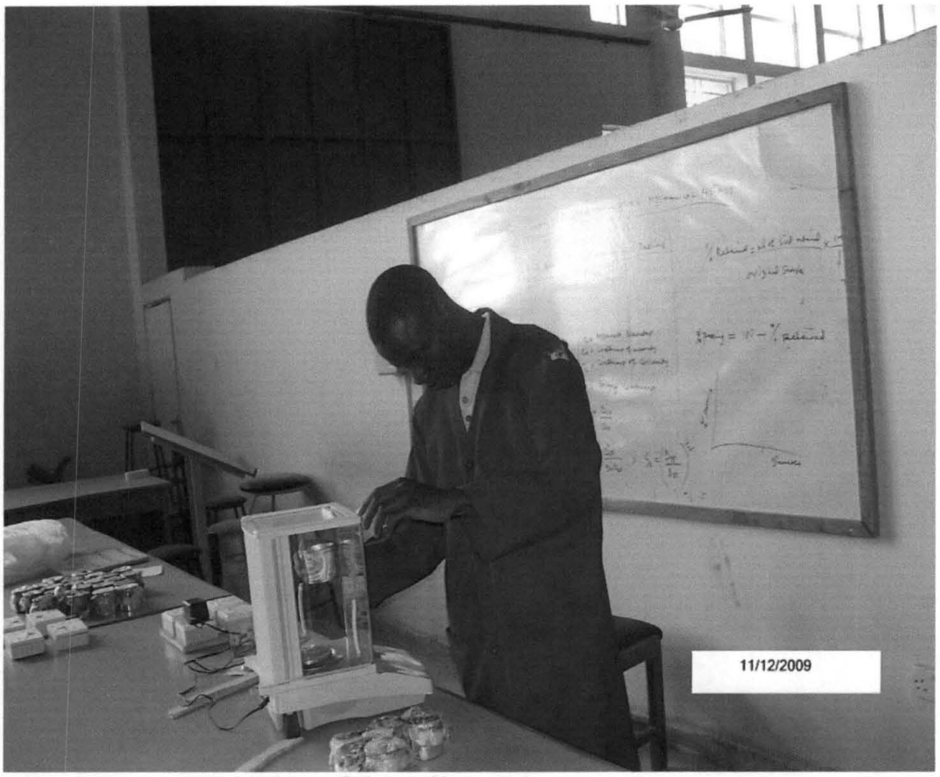


Plate 3.3 Weighing of the soil samples

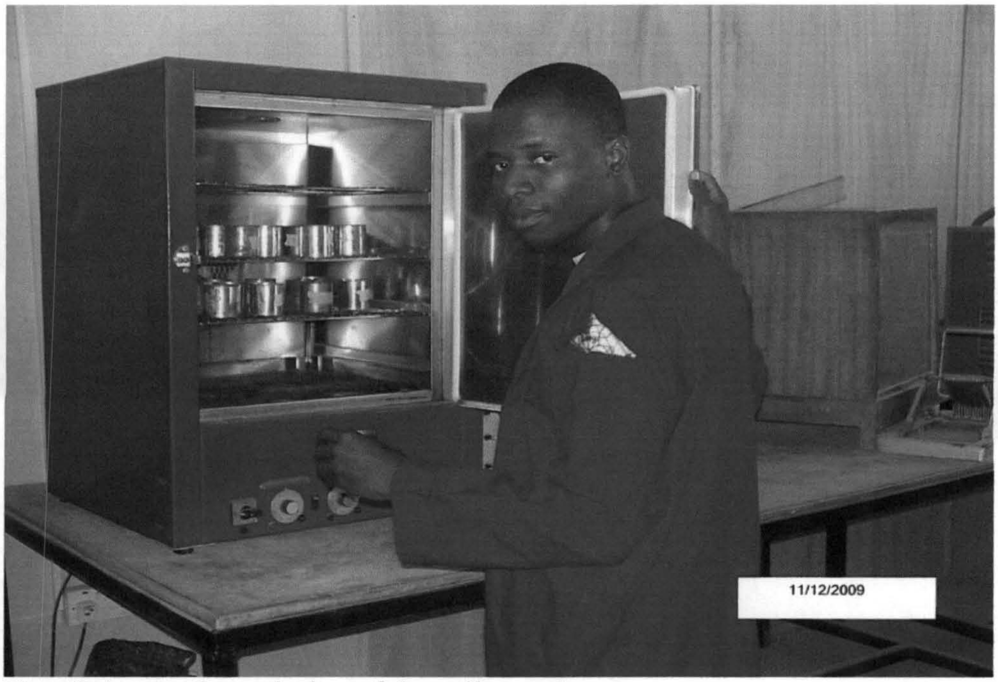


Plate 3.4 Oven drying of the soil samples

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

In this chapter all the values obtained from the infiltration test was computed and analyzed. Result and tables are presented in tables 4.1-4.3 the following parameters were determined viz:

-the average infiltration depth in cm

-the average infiltration rate in cm/hr and

-the accumulated infiltration depth in cm/hr

All the values presented in these tables 4.1 to 4.3 were computed using experimental data given in tables 3.4-3.6. (See page 44-48). Average infiltration depth, Average infiltration rate and Accumulated Depth were thus calculated and presented below (see details on page 73).

Table 4.1: Data Analysis of the Infiltration Test Taken at Jamila Villa Farm,

PLOT A (TILLED)

Time (Min)	Average Infiltration Depth (cm)	Average Infiltration Rate (cm/hr)	Accumulated Depth (cm)
0	0.00	000.00	00.00
2	4.00	120.00	04.00
4	3.57	107.10	07.57
6	3.20	096.00	10.77
8	3.03	090.90	13.80
10	2.87	086.09	16.67
12	2.80	084.00	19.47
14	2.63	087.90	22.10
16	2.63	087.90	24.73

18	2.07	062.10	26.80
20	1.93	057.90	28.73
22	1.83	054.90	30.56
24	1.80	054.00	32.36
26	1.70	051.00	34.06
28	1.63	048.90	35.69
30	1.63	048.90	37.32
32	1.57	047.10	38.89
34	1.53	045.90	40.42
36	1.40	042.00	41.82
38	1.40	042.00	43.22
40	1.10	033.00	44.32
42	0.90	027.00	45.22
44	0.83	024.90	46.05
46	0.67	020.10	46.72
48	0.63	018.90	47.35
50	0.53	015.90	47.88
52	0.50	015.00	48.38
54	0.50	015.00	48.88
56	0.43	012.90	48.31
58	0.43	012.90	49.74
60	0.37	011.10	50.11
62	0.33	009.90	50.44
64	0.30	009.00	50.74
66	0.30	009.00	51.04
68	0.30	009.00	51.34
70	0.30	009.00	51.64
72	0.30	009.00	51.94
74	0.27	008.10	52.21

Table 4.2: Data Analysis of the Infiltration Test Taken at Jamila Villa Farm

PLOT B (NON-TILLED)			
Time (Min)	Average Infiltration Depth (cm)	Average Infiltration Rate (cm/hr)	Accumulated Depth (cm)
0	0.00	00.00	00.00
5	6.30	75.60	06.30
10	5.63	67.56	11.94
15	5.37	64.44	17.30
20	4.97	59.64	22.27
25	4.87	58.44	27.14
30	4.60	55.20	31.74
35	4.23	50.76	35.97
40	4.00	48.00	39.97
45	3.80	45.60	43.77
50	3.33	39.96	47.10
55	3.00	36.00	50.10
60	2.63	31.56	52.73
65	2.50	30.00	55.23
70	2.43	29.16	57.66
75	2.33	27.96	59.99
80	2.20	26.40	63.19
85	1.97	23.64	65.16
90	1.90	22.80	67.06
95	1.70	20.40	68.95
100	1.60	19.20	70.36
105	1.13	13.56	71.49
110	0.90	10.80	72.39
115	0.87	10.44	73.26
120	0.77	09.24	74.03
125	0.67	08.04	74.70

130	0.60	07.20	75.30
135	0.43	05.16	75.73
140	0.37	04.44	76.10
145	0.23	02.75	76.33
150	0.20	02.40	76.53
155	0.16	01.92	76.69
160	0.13	01.56	76.82
165	0.13	01.56	76.95
170	0.13	01.56	77.08
175	0.13	01.56	77.21
180	0.13	01.56	77.34

Table 4.3: Data Analysis Of The Infiltration Test Taken At Jamila Villa Farm

PLOT C (TRACTOR TRACKED)			
Time (Min)	Average Infiltration Depth (cm)	Average Infiltration Rate (cm/hr)	Accumulated Depth (cm)
0	0.00	00.00	00.00
5	2.93	35.16	02.93
10	2.33	27.96	05.26
15	2.00	24.00	07.26
20	1.83	21.96	09.09
25	1.77	21.24	10.86
30	1.47	17.64	12.33
35	1.33	15.96	13.66
40	1.20	14.40	14.86

45	1.07	12.84	15.93
50	0.97	11.64	16.90
55	0.80	09.60	17.70
60	0.77	09.24	18.47
65	0.67	08.04	19.14
70	0.63	07.56	19.77
75	0.53	06.36	20.30
80	0.53	06.36	20.83
85	0.50	06.00	21.33
90	0.43	05.16	21.76
95	0.37	04.44	22.13
100	0.37	04.44	22.50
105	0.37	04.44	22.87
110	0.37	04.44	23.24
115	0.37	04.44	23.61
120	0.37	04.44	23.98

The graph for the Average infiltration rate versus ponding time, infiltration rate versus accumulated depth and plot of log f versus ponding time for the all the plots (Tilled, Non-tilled and Compaction soils) are also given below (see figures 4.1-4.3).

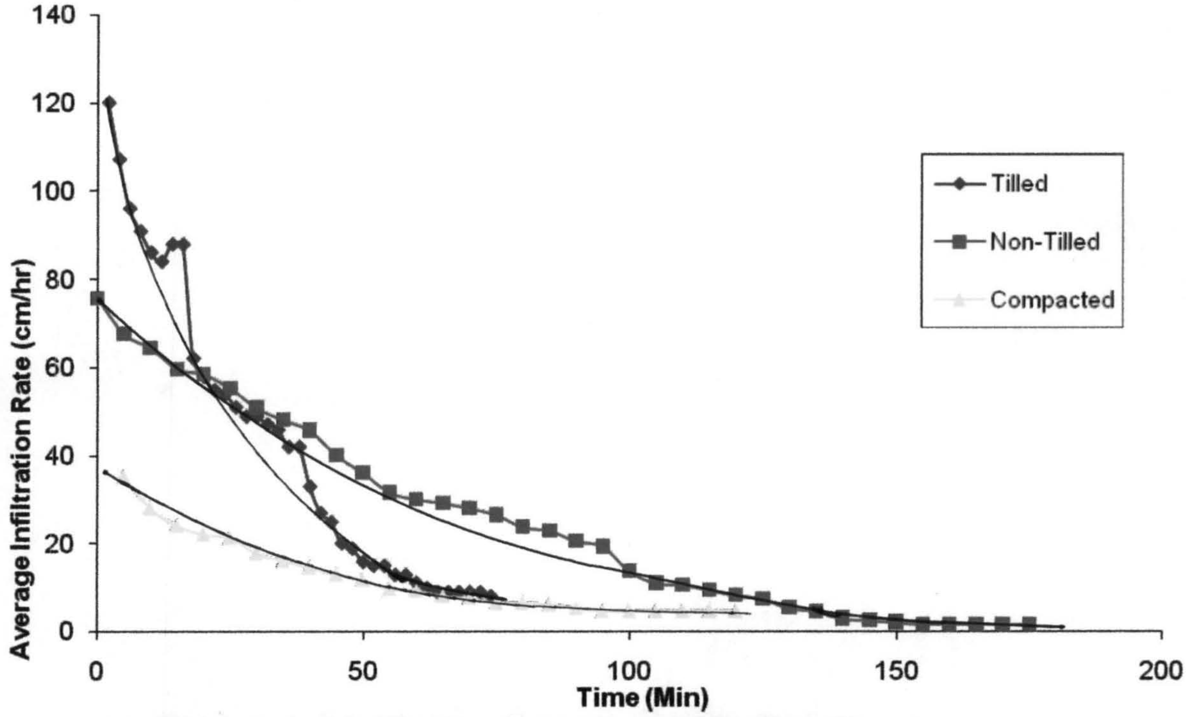


Fig 4.1: Average Infiltration Rate Versus Ponding TIme for Tilled, Non -Tilled and Compacted Soil

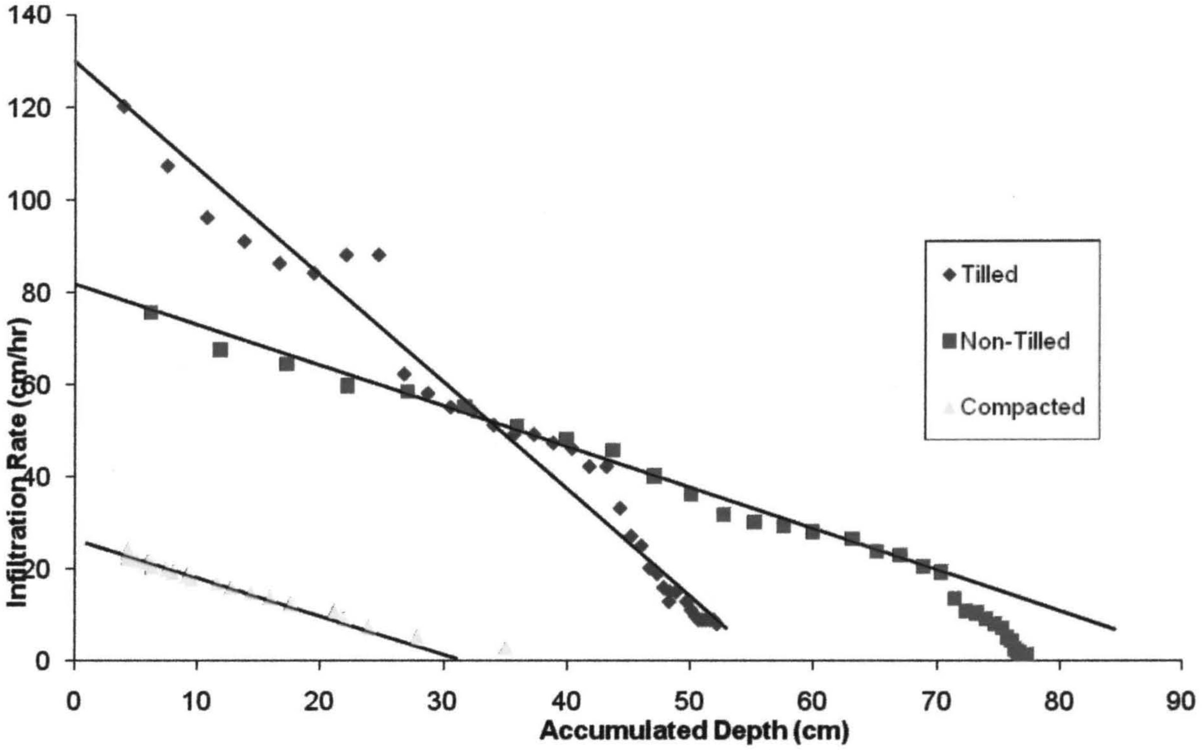


Fig 4.2: Infiltration Rate Versus Accumulated Depth

SLOPES (M);

For Tilled Soil; M = 0.8/48 = -0.0167

For Non-Tilled Soil; M = 0.75/86 = -0.0087

For Compacted Soil; M = 0.65/66 = -0.0099

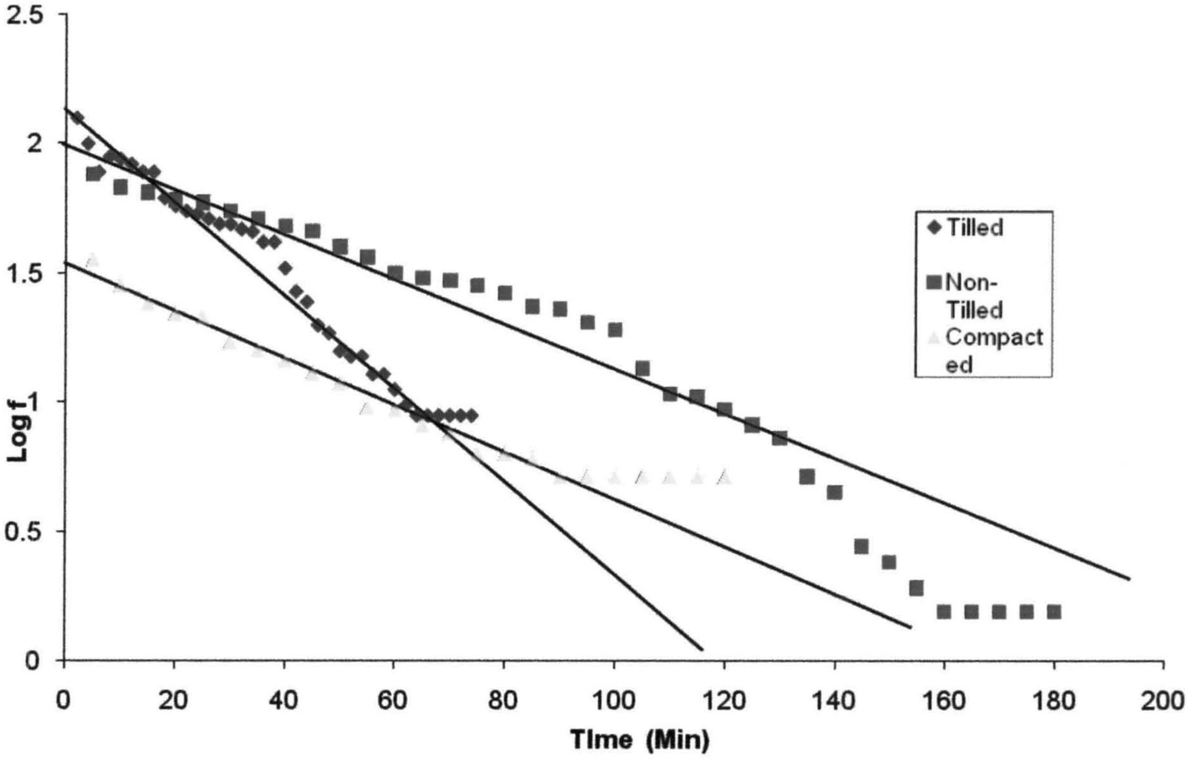


Fig 4.3: Plot of Log f Versus POnding TIme

The analysis of the field data of various experiments from selected farms sites are presented below

4.1.1 Soil characteristic constant k

The soil characteristic constant k of the three farms of study is determined as follows see table 4.4

Table 4.4 the values of k for the tilled untilled and compacted fields

TILLED	UNTILLED	COMPACTED
0.038	0.020	0.023

The samples of the calculations of this results above is given in appendix c

4.1.2 Infiltration depth rate equation f

The infiltration depth rate equation for each soil at the stated conditions is given as follows.

From the Horton equation

$f = fc + (fo+fc)\ e^{-kt}$

Table 4.5 Infiltration Rate Equations

TILLED	UNTILLED	COMPACTED
$f = 9.0 + 111e^{-0.038t}$	$f = 1.56 + 74.04e^{-0.020t}$	$f = 4.44 + 30.72e^{-0.023t}$

4.1.3 Cumulative Infiltration Depth Rate Equation

The equation for the cumulative infiltration depth of each site and soil conditions are given as follows

From the equations $F = f_c t - \frac{fo-fc}{k}[1-e^{-kt}]$

Table 4.6 Cumulative Infiltration Depth Equation

TILLED	UNTILLED	COMPACTED
$F=9.0t + 2921.05[1-e^{-0.038t}]$	$F=1.56t + 3702[1-e^{-0.020t}]$	$F=4.44t+1335.65[1-e^{-0.023t}]$

4.1.4 The initial infiltration capacity, final capacity and time.

These are other parameters obtained from the analysis. The table below shows the values of the parameters used in deriving the f and F equation-see table 4.5 and 4.6

Table 4.7 Initial infiltration capacity, final capacity and time.

TILLED			UNTILLED			COMPACTED		
Time	fo	fc	Time	fo	Fc	Time	fo	Fc
74	120.00	9.0	180.00	75.60	1.56	120.00	35.16	4.44

Soil moisture determination and measurement. The following parameters were obtained from the soil analysis carried out on the field and in the laboratory. The result of the soil moisture content of the farm are presented in tables 3.2-3.3

From the average soil moisture content percentage given a table 3.2-3.3. It can be observed that soil moisture difference of various depths the evaporation of water due to different weather condition. The soil moisture increases with an increase in the difference in weight obtained from the fresh and dry weight of soil samples an average is obtained for every plot in different depths.

The average bulk density obtained increases with decrease in the average moisture percentage. The average porosity is observed to increase as the bulk density decreases

4.2 Discussion of Results

In the discussion of result the following limitations must be observed

1. the moisture depth was carried out at a depth of 0-15cm, 15-30cm, 30-45cm.
2. the volume of the sample cup used is 212.37cm$^{3.}$
3. a double ring infiltrometer of 30cm inner diameter and 60cm outer diameter was locally constructed and used with a thickness of 0.15cm.
4. the time of refilling the inner and outer cylinder after every reading varies with about 2seconds.
5. depth of installation of cylinders at different sites varies but it is assumed that the experiment are subjected to the same conditions for all plots.
6. the soil moisture, texture and other properties varies at different plots under different conditions.
7. The condition of the soil vary due to the history and cultural practices on the soil.
8. The calibration could not be done due to the fact that a standard infiltrometer could not be secured for the experiment.

The limitations mentioned above will no doubt affect the results of the experiments obtained. The results showed that the infiltration rate is higher in tilled soil than the non tilled soil or compacted tractor tack soils. This is attributed to the loss nature of the tilled soil and void spaces being created, the undisturbed nature of soil in the untilled soil and the increased soil strength in compacted soil. This will affect the water that will infiltrate into the soil at a given time, the rate of run off will be high in soil of low infiltration and hence proper drainage is needed to curtail water logging problems.

The graphs of average infiltration rate versus ponding time at different conditions have their points scattered. a curved slope is obtained in this graph. From this graph it is observed that the scattered point is due to the difference in the soil bulk density, porosity and moisture. The value of the graphs for the tilled soil is higher than that of non tilled and compacted soil.

The graphs of the infiltration rate versus accumulated depth have the same pattern but different values. This is due to the difference in moisture percentage bulk density and the different texture of soil. The physical properties and chemical properties of soil also varies. The points of the graph are scattered but the points falling on the best straight line is plotted. The high clay percentage of farm makes the infiltration rate low in this farm. The infiltration rate is higher on tilled soil than non- tilled and compacted.

The semi log graph of log *f* versus ponding time has scattered points too, the points along the best straight line is plotted for this graphs

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the results obtained so far the following conclusions were drawn;

i the infiltration characteristics equations were obtained for the different conditions of the soils. The soil characteristics constant K, for the tilled, non-tilled and compacted soils are; 0.038, 0.020 and 0.023. The infiltration rate equations f, are $f = 9.0 + 111e^{-0.038t}$ for tilled, $f = 1.56 + 74.04e^{-0.020t}$ for non-tilled and $f = 4.44 + 30.72e^{-0.023t}$) for compacted soil. While the cumulative infiltration depth equations are; $F=9.0t+ 2921.05[1-e^{-0.038t}]$, $F=1.56t + 3702[1-e^{-0.020t}]$ and $F=4.44t+1335.65[1-e^{-0.023t}]$ for different soil conditions as stated above. The values are varies for the different soil conditions due to their texture differences.

ii from the characteristic equations derived, the design of any irrigation system should consider these equations, before implementing the design. Soil characteristic equations should equally be derived for other soils to be considered for any irrigation system

iii an intake characteristic equation was developed for the use of the design of a workable and efficient irrigation system for the farm of study

From the experiments carried out so far and the results obtained the different characters of soils under different condition has given an idea of what one will expect if an irrigation system is introduced on these sites

5.2 Recommendations

The compacted area in the field should be reduced to the minimum area due to its negative effect infiltration rate. Although this cannot be completely eradicated but measures can be taken to reduce and guide against compaction

These are;

i Implements with wide width of coverage should be used to reduce the number of machine travel on a field

ii There should be paths for machine movement to guide against random movement of machine on the field

iii The use of very heavy machines should be reduced and appropriate machine should be used for the best suited operation

iv Since the effect of compaction is adverse the use of manure and deep tillage should be encouraged in mechanized fields.

It will be of advantage to always till the soil before any planting season so that the soil will accumulate enough moisture to meet the management allowable deficiency for different crops to be grown. This is due to the fact that infiltration rate is higher in tiled soil. A good drainage system is also essential for all the types of soil encountered to prevent erosion

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APPENDICES

APPENDIX A

Formulae used in the computation of parameters

(a) Hortons equation (1940)

(b) $f = f_c t\ (f_0 - f_c)\ e^{-kt}$ (hortons,1940) 1

where

f = Infiltration capacity or the maximum rate at which soil under a given condition can take water through its surface (LT^{-1})

fc = The constant infiltration capacity as t approaches infinity

fo = Infiltration capacity at the onset of infiltration

k = A positive constant for a given soil and initial condition

t = Time

(b) Infiltration rate equation from $f = f_c t\ (f_0 - f_c)\ e^{-kt}$ (hortons, 1940) 1

finding log on both sides

$f = f_c t\ (f_0 - f_c)\ e^{-kt}$

$\log f = \log f_c + \log (f_0 - f_c) + \log e^{-kt}$

$\log f = \log + \log e^{-kt}$

$\log f = \log f_0 + k.t \log e$

$\log f = \log f_0 + K \log e.t$ 2

$y = C + mx$

Slope = $m = - k \log e$

Intercept = $c = \log fo$

Y axis = t

Slope $m = \frac{y2 - y1 \text{ diffrence in the y axis}}{X2 - x1 \text{ difference in the x axis}}$

(c) Accumulated infiltration equation

$F = \int_0^t f dt$

$= \int_0^t fc + (fo - fc)e^{-kt}\, dt$

$= \int_0^t fc dt + \int_0^t fc\ (fo - fc)e^{-kt}\, dt$

$F = fct + (fo - fc)\ (-1/k\ e^{-kt})\,{}^{t}_{0}$

$F = fct + \frac{(fo - fc)}{k}\ [-e^{-kt} + e^{0}]$ (4a)

If $fo - fc = a$

$f = fct + a/k\ [-e^{-kt} + e^{0}]$

$f = fct + \frac{a}{k}\ [1 - e^{-kt} + e^{0}]$

$f = fct + \frac{a}{k}\ [1 - e^{-kt}]$ (4b)

(d) Gravimetric water content percentage equation

$Qg = \frac{Mw}{Ms}$ x 100 (%) (Black, 1965) (5)

Qg = gravimetric water content percentage

Mw = weight of water minus weight of can

M s =weight of soil after oven drying minus weight of can

(e) Bulk density equation

B.d (Db) $\frac{Ms}{v}$ (g/cm^3) (Black, 1965) (6)

Ms = weight of soil after oven drying

V = volume of sample core = $\prod r^2 h$

B.d (Db) = bulk density dry base

(f) Total porosity equation

$Tp = 1 - \frac{Bd}{Dp}$ (Db) x100 (g/cm^3) (Black, 1965) (7)

Tp = total porosity %

B.d*(Db) bulk density dry base (g/cm^3)

Particle density is 2.65$(g.cm^3)$

Other formula

For the gravimetric test

(i) Moisture difference

Moisture difference = (wet base weight of soil sample-weight of can)-(weight of dry soil-weight of can)

(ii) Average depth (cm) = $\frac{\text{sum of all the depth replications}}{\text{number of replications}}$ (Bambe, 1995)

(iii) Average rate (cm/hr) = $\frac{\text{average depth x 60}}{\text{time difference interval}}$ (Bambe, 1995)

(iv) Accumulated infiltration depth (cm) = addition of initial depth and the present reading (Bambe, 1995).

APPENDIX B

Samples for calculations of parameters

Appendix B1

(i) Gravimetric water content percentage for the one replicates of 0-15cm depth of the tilled soil

$Qg = \frac{Mw}{Ms}$ x 100 (Black, 1965)

Parameters are defined in appendix A

$\frac{149.58-26.11}{125.93-26.11} x\ 100$ (See table 3.3b)

$\frac{23.65}{125.93} x\ 100$

18.78%

(ii) Bulk density

B.d (Db) $\frac{Ms}{v}$ (g/cm^3) (Black, 1965)

This calculation shows the bulk density for the 0-15cm depth of the tilled soil is;

B.d(Db) = $\frac{125.93}{212.37}$ (See table See table 3.2)

0.59 g/cm^3

Where volume = V= $\prod$ x r^2 x h

= $\prod$ x 3.25^2 x 6.4 (See page 39)

= 212.37cm^2

(iii) Total porosity

Total porosity for the tilled soil at 0-15 depth

$1 - \frac{0.59}{2.65} x\ 100$ (See table 3.2)

77.74 g/cm^3

APPENDIX B2

Calculation pertaining to other equations

All calculations in this section will be with respect to the experiment of the first experiment on tilled soil on the farm

(I) Moisture difference = $\frac{149.68-26.11\ (wet\ soil-can)}{125.93-26.11\ (dry\ soil-can)}$ (See table 3.3a)

23.65 gram

(ii) Moisture content percentage

$= \frac{\text{moisture difference}}{\text{dry weight}}\ x\ 100$ (See table 3.3b)

=23.65/125.93 x 100

=18.78

(ii) Average depth = $\frac{4.0 + 6.3+2.93}{3}$ (See table 3.4)

= 4.0 g/cm^3

(iv) Average infiltration rate = 4.0 x 60/2 (See table 3.4)

= 120 cm/hr

(v) Accumulated infiltration= 0.00 + 4.0

= 4.0 + 3.57

= 7.97cm… (See table 3.4)

Slope

The slope for tilled soil is calculated

M = 0.8/48

= -0.0167

Infiltration rate for the 5 minutes of infiltration on non-tilled plot

$f = fc + (fo + fc)\, e^{-kt}$ ((hortons,1940)

From equation

$F=1.56 + (75.6 - 1.56)e^{-0.020t}$ (See table 4.5)

At 5minutes

$=1.56 + (75.6 - 1.56)e^{-0.020 \times 5}$

$= 1.56 + 27.24$

$= 28.80$cm/hr

$f= 28.80$ for 5 minutes of infiltration

Accumulated infiltration for plot b at minutes

$F = fct+ \frac{fo-fc}{K} [1-e^{-kt}]$

From the equation

$F=1.56\, t + \frac{(75.6 - 1.56)}{0.020} [1-e^{-0.020t}]$ (See table 4.6)

At 5 minutes of infiltration

$= 7.8 + 352.43$

$F= 360.23$cm/hr

Interpolation

YD = C x D - X2) / (X1-X2) x (Y1-Y2) + Y2

X1=the increment of the table above the desired value

X2=the reading in table for X1

X2= the increment of the table below the desired value

Y2= the reading in table for X2

Xb=the number at which the desired reading is found

APPENDIX C

Determination of the value of k for plot A, B, and C

From the graph slope m = - k log e

M = - 0.4343k

For tilled plot

M = - 0.4343k

$K = \frac{-0.0167}{0.4343} = 0.038$ (See page 58)

For non-tilled plot

$K = \frac{0.0087}{0.4343} = 0.020$ (See page 58)

For Compacted plot

$K = \frac{-0.0099}{0.4343} = 0.023$ (See page 58)