ESTIMATION OF RUNOFF VOLUME AND SEDIMENT LOAD AT TUDUN FULANI FARM PLOTS (NIGER STATE)

BY

MAMOUDOU MOUSTAPHA

98/7713EA

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DEDICATION

This thesis is specially dedicated to ALMIGHTY ALLAH, the most merciful for granting me assistance to achieve my goal and to my beloved mother and father.

CERTIFICATION

This project titled "estimation of runoff volume and sediment load at Tudun Fulani farm plots (Niger State)" was carried out by Mamoudou Moustapha, under the supervision of Engr. (Dr). N.A. Egharevba and submitted to Agricultural Engineering Department, Federal University of Technology Minna

Engr. (Dr). N.A. Egharevba
(Project supervisor)

9/12/2003
Date

Eng. (Dr).D. ADGIDZI
(HOD)

5.12.03
Date

Emudiare
External supervisor

28/11/03
Date

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ABSTRACT

Field experiment were conducted in the year 2001 on an Alfisol in the southern guinea savanna zone of Nigeria cropped with maize to estimate the volume of runoff and sediment load resulting from no-tillage plus mulch plot (NT+M), disc tillage plus mulch (DT+M) plot and disc tillage without mulch (DT) plot. Mulching and tillage were applied to determine their effect on runoff and sediment production. The residue mulching (NT+M and DT+M) increased soil moisture content in the surface 20cm soil depth. The maize plants on DT plots have effect on the properties under investigation. NT+ M and DT+ M) plots generate less runoff and sediment than the DT plot. The soil analysis showed that the soil texture is sandy soil. Mulching increases water infiltration as expected, but it was apparent that the extra water was not retained. The implications of these findings on runoff and sediments in the southern guinea savanna are discussed.

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CHAPTER ONE

INTRODUCTION

Runoff is that portion of the precipitation that makes its way towards stream channels, lakes, or oceans as surface or subsurface flow. The term "runoff" usually means surface flow. Runoff occurs after precipitation has satisfied the demands of interception by foliage, infiltration, surface storage, and surface detention and channel detention. Interception by foliage may be so great as to prevent a light rain from wetting the soil. Interception by dense covers of forest or shrubs commonly amounts to 25 percent of the annual precipitation (Shwab, 1981). Interception also has a detention storage effect, delaying the progress of precipitation that reaches the ground only after running down the plant or dropping from the leaves. Runoff will occur only when the rate of precipitation exceeds the rate at which water infiltrates into the soil. After the infiltration rate is satisfied, water begins to fill the depressions, small and large, on the soil surface. As the depressions are filled over-land flow begins. The depth of water builds upon the surface until it is sufficient to result in runoff in equilibrium with the rate of precipitation, less infiltration and interception. The volume of water involved in the depth build-up is surface detention. As the flow moves into defined channels there is a similar build-up of water in channel detention. The volume of water in surface and channel detention is returned to runoff as the runoff rate subsides. The water in surface storage eventually goes into infiltration or is evaporated.

Runoff as a surface flow usually results into some type of erosion called water erosion. Erosion is one of the most important agricultural problems in the world. It is a primary source of sediments that pollute streams and fills reservoir. Water erosion is the removal of soil from the land by running water. In fact, it involves kinetic energy, which removes and transports the soil particles and the resisting force, which retards erosion. The particles are finally deposited at a site as the soil loss resulting from runoff. There are many types of water erosion such as: Interrills, rill, gully, and stream and channel erosion. Conversion structures and channels must be designed to handle natural flows of water from rainfall or melting snow. The engineer designing channels and structures to handle natural surface flow is concerned with peak rates of runoff, with runoff volumes and with temporal distribution of runoff rates and volumes. Methods of runoff estimation necessarily neglect some factors and make simplifying assumptions regarding the influence of others. The capacity to be provided in structures and channels is planned to carry runoff that occurs within a specified return period. It is often desirable to predict the total volume of runoff that may come from a watershed using runoff plot.

Total volume is of primary interest in the design of flood control reservoir. When surface water is to be stored in ponds or reservoirs, the total runoff volume for a period of several months should be considered. Usually the annual volume is of more interest than the runoff from a design storm. The annual runoff is often referred to as the water yield.

Soil losses vary considerably with the type of erosion, likewise there are several ways of estimating sediment loss. Sediment production downstream in a watershed may be estimated from the U.S.L.E and sediment delivery ratio. The soil loss equation estimates gross sheet and rill erosion, but does not account for sediments deposited en route to the place neither of measurement nor for gully or channel erosion downstream. The sediment delivery ratio is defined as the ratio of sediment delivered at a location in the stream system to the gross erosion from the drainage area above that point. This ratio varies widely with size of area, stiffness, density of drainage network, and many other factors. The sediment delivery ratio varies roughly as the inverse of the 0.2 power of the drainage area (Schwab, 1988).

Consequently this particular study aims to estimate runoff volume and sediment load, resulting from surface water flow in a farm (Tudun Fulani area).

1.1 Justification:

This study has enormous significance to Minna community, in the sense that it assesses the agricultural quality of their land and estimates the value of water resulting from surface flow. In consequence it serves as

(i) a basis to determine the suitability of the land to crop and plant cultivation in general.

(ii) Information on soil degradation in Minna due to water erosion, and

(iii) Baseline data on erosion at Minna which can be used for the design of erosion / runoff control structure.

1.2 Objectives

1.3 The aim of this study is:

i) To determine the runoff volume of the farm plots.

ii) To estimate the sediment load produced by runoff water for the study period.

iii) To relate the soil parameters to the production of runoff volume and sediment load.

CHAPTER TWO

LITERATURE REVIEW

2.1 PREVIOUS WORKS

Many scientists and engineers have done research on runoff, but their majority has been constructing on their effect on agricultural land. Agriculture being a means of survival for human beings, its affection by runoff concerns directly human life. That is why a great number of engineers have contributed a lot in runoff studies. Some of them have curried out their work on runoff process, the evaluation of runoff quantity, quality, damage etc, in order to find a way of handling it and making best use of it. In 1959 Braken Siek showed that the selection of runoff data for a water year rather than for a calendar year can greatly improve the reliability of results. The data for beginning the water year varies with geographical location, but in general it coincides with the season of maximum runoff (Boardmar et al 1990).

In 1974 U.S. army corps of engineers provided one of the earliest computer programs to use a basic rainfall-runoff mathematical relationship: STORM; storm water management computer programs use mathematical relationships to calculate runoff rates, rainfall excess, storage volumes and water quality. The program STORM was applied to two river basins: Palm Beach Gardens and Magnolia Ranch in 1975 at Ceconlo-Ckhatchee River to evaluate the mathematical relationships (Boardmar, 1990).

-The original work of Kuichling which is over 100years ago in an urban watershed showed that the ratio of runoff rate to precipitation rate is equal to the contributing area at a time into the storm when approximately the total impervious area was drained. Multiplying the runoff rate by this time results in a runoff volume {i.e., flow rate (L^3/t) x time (t) = volume (L^3) }and multiplying rainfall intensity by time and by area yields a rainfall volume[i.e., rainfall intensity (L/t) x time (t)x area (L^2)=volume (L^3)],or from Boardmar (1990).

$$\frac{Q}{i}=CA \quad \text{.......} \quad 2.1$$

Q = runoff rate $\frac{ft}{s}$

I = precipitation rate $\frac{in}{h}$

CA= contributing area

Integrating over time (T) gives: $\frac{Qt}{iAt}=C=\frac{R}{P}$ 2.2

R = runoff volume or rainfall excision

P= rainfall volume in

C =runoff coefficient

In 1889 Kuichling concluded that the ratio of $\frac{Q}{i}$ is the rational value that can be used for the design of urban sewer systems and the value of c is equal to the extent of the impervious surfaces divided by the total area assuming no drainage from the pervious surfaces (Boardmar 1990).

The presence or absence of surface vegetation, grazing animals and the timing ploughing operations may be particularly important in determining the magnitude of sediment production. The effect of land use on infiltration capacity and bulk density will be linked to measurements of surface Runoff and suspended sediment production from hill slope plots using rainfall-simulation experiments. The objective is to relate sediment production in surface runoff under controlled experimental conditions to stream sediments loads for monitored storm event, in small (headwater) drainage basins. The magnitude of storm sediment production at different catchment scales was examined and the potential links between hill slope sediment production and the stream sediment load explored in the context of catchment land use. Particular emphasis was placed on storm runoff, as a substantial proportion of non-point pollutants will be transported in overland flow associated with storm event (Cullen, 1982). In addition Dunne (1983) and Dunne and Black (1970) indicated the importance of localized (variable source) areas adjacent to the stream as contributions of storm runoff, as reported by Boardmar et al (1990).

Dao (1993) reported that the runoff volume from heavily grazed permanent grass land is at least double that from lightly grazed areas, and nearly twelve times greater than that of ungrased (temporary grass land area). According to Dao (1993) this is comparable with the result of MC Coll in 1979 that found that the runoff volume was seven times greater from grazed pasture when compared with ungrassed pasture.

According to larger (1977), Hormer and Mar (1982) as reported by Dao (1993) pollutants in storm water have a strong affinity to suspended solids transported during storm events, subsequently the removal of the pollutants. It had been indicated that large fractions of heavy metals, organic pollutants, and nutrients attach to solid particles, and most of the pollutants are associated with the smaller particle fractions, less than 100 μm in diameter. Settling of pollutant-saturated particles occurs as discrete individual particles and clusters of smaller particles fuse into large ones, thus accelerating their settling rates. In 1981 Whipple and Hunter concluded that settling rates of pollutants in runoff vary greatly and particle-size distributions cannot be transported into settling rates for absorbed constituents. Runoff water contains a wide variety of sediment particles that are different with respect to their specific gravity and how they absorb metals and other pollutants (Dao, 1993).

2.2 THEORY OF DETERMINATION OF THE REQUIRED PROPERTIES

2.2.1 ESTIMATION OF VOLUME OF RUNOFF

From Boardmar et al (1990), the volume of direct runoff from single storms is estimated from the following equation:

$R = P - L - G$ 2.3

Where R= direct runoff

P= precipitation

L= basin recharge

G= ground water accretion

It may be necessary to estimate monthly or annually stream flow from precipitation data. In estimating runoff volume for long periods the destination between direct and groundwater runoff is usually of no concern. The most accurate method of estimating long-term runoff is probably as a summation of storm runoff amounts. Over the period of a year, variation in antecedent conditions tends to average out, and the refinement, necessary in storm rainfall-runoff relations becomes less important. The seasonal distribution of precipitation may be important in determining the runoff. Scattered summer showers usually produce less runoff than general rains. Consequently, it may be necessary to use monthly or seasonal precipitation data as separate parameters in an annual rainfall-runoff relation.

2.2.2 ESTIMATION OF SOIL LOSS

Soil loss may be expressed simply as a volume or weight lost from, or moved on a field (Spears and Frest, 1985). It is however more useful to express the loss as a rate in which the volume or weight of material lost from a rill or gully system is referred to an area and a unit of time usually a year. The unit of area may be the field or the catchments. An agricultural field may contain several catchments or may itself be part of a larger one. Field boundaries can be permeable or impermeable, and without checks during high-magnitude rainfall event, this can be difficult to establish. Some studies have quoted soil loss with reference to neither field nor catchments but the area on which riling occurred (e.g. Losses of soil by riling reach 195 that on parts of a field in north Norfolk; Evans and Nortcliff (1978). Although averaged over the whole field the loss is

11.8tha^{-1}. Use of the catchments as the unit of area is more meaningful in terms of geomorphologic explanation, however in an agricultural context it is often preferable to use the field as the basic area unit. Appreciation of spatial variation of rates within a field is of value in the discussion of conservation measures (Evans and Nortcliff, 1978). The relevant unit of time is the growing season. Soil loss can be expressed as

m^3 ha^{-1} yr^{-1}. Use of volumetric measuring of soil loss avoid the problem of varying bulk density ''soil loss'', or ''erosion rate'', refers to removal of soil from rill and gully systems. The soil may or may not be removed. Some may be stored within the field. Rills are defined as being small enough to be of no obstacle to tillage operation, whereas gullies are deep enough to interfere with normal tillage operations, but not to be obliterated by them (soil science society of America, 1987).

2.2.3 THEORY OF INFILTRATION

I) INFILTRATION RATE EQUATIONS

Infiltration refers to the entry of water into the soil from rainfall Or irrigation and, it is the first stage of water movement into the soil. It is necessary in any irrigation plan or for any run off problem to know the infiltration rate and the soil water content after infiltration. Researches on infiltration are categorized. The first is related to the water entry rate into the soil as measured in the field. The "intake rate" is represented in an empirical equation. Horton (1940) experimental equation is

$A= q_c +(q_0-q_c) \exp. (-Bt)$................................2.8

Where, q_0 is the initial intake rate, q_c the rate at steady state, the time, and B is a constant.

The intake characteristic of soil given by David (1943) is presented in equation 2.9.

$F_a =at^b + c$..2.9

Where, F_a =intake characteristic, a, b, α are constant, which are computed empirically (Michael, 1988).

To generate the required parameters from the infiltration thus the following equations are useful.

Average infiltration rate = (Dx60)/time..2.10

Accumulated infiltration depth = $D+D_i$ 2.11

Where Di is the depth and it is equal to the difference between initial reading on ruler and the reading after time interval t (minute) $D_i = R_1 - R_2$ where R_1 and R_2 are initial and final reading within the time intervals.

ii) RING INFILTRATION

This is a device used for measuring infiltration rate. They are usually about 25cm (250mm) deep and are formed of 2mm rolled steel. The inner cylinder from which the infiltration measurements are taken is usually 300mm in diameter. The outer cylinder that is used to form the buffer pond is 600mm diameter. The cylinders are installed 100mm deep in the soil. Care is taken to keep the installation depth of the cylinders the same in all experiments. This is achieved by marking the outside of the cylinders at the 100mm level and driving the cylinders up to the mark using a falling weight (Michael, 1988).

The infiltration rates are influenced by:

(i) cylinder diameter

(ii) thickness of cylinder

(iii) beveling of cylinder bottom

(iv) the method of driving the cylinder into the soil

(v) the installation depth

The experimental set up is As shown in fig (2.2) when the rings are in place, a step watch or the second hand of a wrist watch is used to note the instant 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 of water and the fractional volume in the jar, which is added last. Care is taken to fill container of water cylinder. The difference between the quantity of water added and the volume of water in the cylinder at the instant it reaches the desired point is taken as the time interval between the start of the filling and the first measurement.

After the initial reading point gauge measurements are made at frequent intervals of time. Water is quickly added after each measurement is taken to keep the level water head fairly constant. The buffer pond is replenished immediately after filling the inner ring pond. The results of reading obtained are used to produce a characteristic equation from a graph which similar to the one shown below (2.5) and the equation is similar to equation (2.6). The plan and side view of the infiltrometre is as shown in fig (2.2)

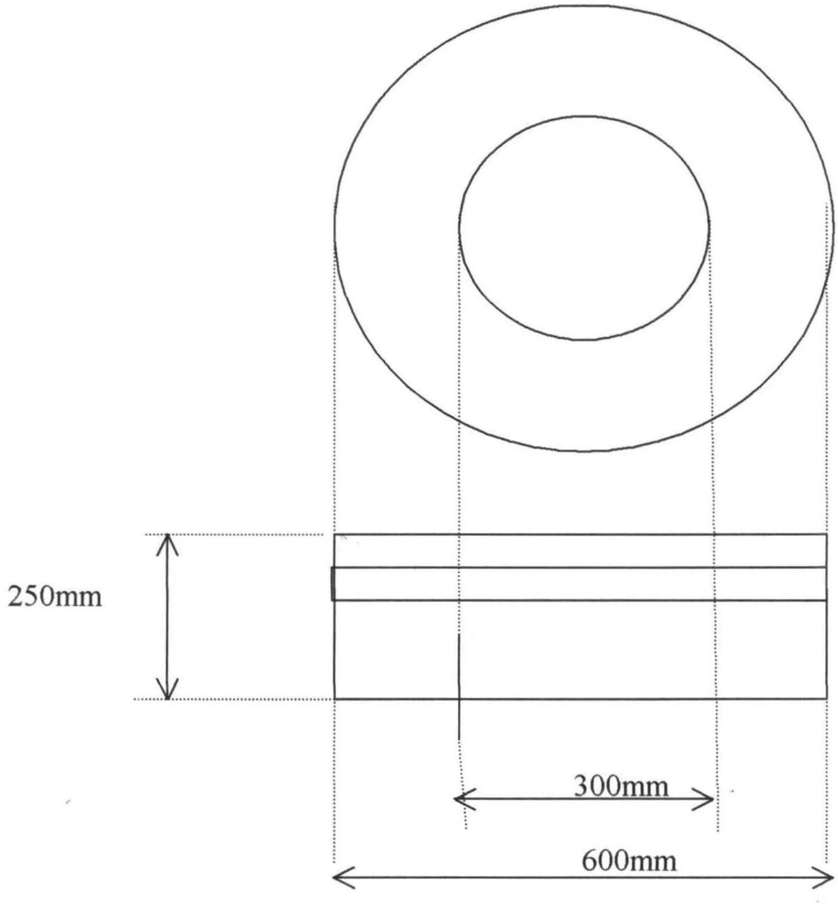

Fig 2.2 Plan and side view of the infiltrometer

2.2.4 PARTICLE SIZE ANALYSIS OF SOIL

Mechanical analysis is the determination of the size range of particles present in the soil expressed as a percentage of the totally dry weight.

Sieve analysis for particle sizes larger than 0.74mm in diameter is one shaking the soil sample through a set of sieves that have progressively smaller opening. This analysis permits to determine the different soil textural classes. The knowledge of soil texture is very important since it assist to estimate the relative resistance of soil to root penetration, the infiltration of water movement through the soil, the soil fertility. Equation and relationship requires in the analysis are given below:

(i) Percentage retained on sieve =(weight of soil retained x 100%)/total weight of soil.

(ii) Cumulative percentage retained on any sieve is given by 100-cumulative percentage retained.

2.2.5 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity, K, as applied to an aquifer, is define as the rate of flow of water in filter, per day through a horizontal cross sectional area of one square meter of the aquifer under a hydraulic gradient of one meter per meter at the prevailing temperature of water.

The rate of flow of ground water in response to a given hydraulic gradient is dependent upon the hydraulic conductivity of the aquifer (Mazunder, 1983).

$K = (A_l / A_t) \log (h_1 / h_2)$ 2.13

2.2.6 WATER TABLE

i) DESCRIPION

The boundary between the vadose zone and the zone of saturation is termed the water table (fig 2.). Its location is determined by the elevation to which water rises in umpumped well just penetrating the top of the zone of saturation. The water table is often described as a subdued replica of the surface topography. It is commonly higher under valleys, and a contour map of the water table in an area may look much like the surface topography. The water table is the surface of water body that is constantly adjusting itself toward an equilibrium condition. If there was no recharge to or outflow from the ground water in a basin, the water table could eventually become horizontal. Few basins have uniform recharge conditions at the surface. Some areas receive more rain than others. Some portions of the basin have more permeable soil. Thus, when intermittent recharge does occur, mound, and ridges from in the water table under the areas of greatest recharge. Subsequent recharge creates additional mounds, perhaps at other points in the basin, and the flow pattern is further changed. Superimpose upon this fairly simple picture the influence of lakes, streams and well and obtains a picture of water table constantly adjusting toward equilibrium. Because of the flow rates in most ground water systems this equilibrium is rarely before additional disturbances occur.

When water occurs, fissures, and caverns, the situation is somewhat different. Flow in large openings is usually found at about the same level anywhere within a system of interconnected openings. Water levels may vary considerably, however, between entirely separate openings in the same formation. Wells driven into such formations will yield little water unless they intersect one of the fissures or caverns.

Immediately or tension-saturated zone. In this region the space is completely filled with water, but capillary and molecular forces are significant so that the pressure in the water is less than atmospheric.

(i) **PIEZOMETER TUBE**:

The piezometre tube is a hollow tube that is placed into the soil with a water entry point at the plane where a measurement is desired. The other end of the tube extends virtually from the measurement point and is open to the atmosphere. If water in the soil is under positive pressure, it will enter the tube and rise to a height whose gravitational potential relative to the soil at the point of interest is equal to the tensiometre pressure potential of the soil water. (For practice, the reader may verify this using the equilibrium analysis.) Excluding unsaturated soil in which water would not enter the piezometer the tensiometer pressure potential in a saturated system is equal to the sum of the over burden and the hydrostatic pressure potentials. Thus, in a rigid soil, the water in the piezometer will rise to a height equal to the water table height. In a swelling soil, the height reached will exceed the height of the water table by an amount equal to the over burden potential head.

CHAPTER THREE

3.0.MATERIALS AND METHODS

3.1 EXPERIMENTAL DESIGN:

The experiment was conducted on three different plots: in fact the plots were laid out in a randomized complete block design with three treatments. The treatments were:

No-tillage with mulches (NT+M),

Disc tillage with mulches (DT+M),

Disc tillage without mulches (DT).

The experiments were seasonal: treated maize seeds were grown in each plot from 9th may to 4th September 2001

. A miniplot was demarcated from each of the three plots for runoff collection

Three piezometer tubes were installed at different place of the site for water table measurement.

3.2.MEASURED PARAMETERS

-Runoff volume and sediment were collected from each miniplot and water table were measured from each piezometer tubes, after each rainfall, from 9th may to 4th September of the year 2001.

-Bulk density and particles size analysis experiments were carried out once

-Moisture content and infiltration rate experiments were conducted twice: one in rainy season and the other One in dry season.

-The hydraulic conductivity test was conducted using two different methods:

3.3 SITE DESCRIPTION AND PURPOSE

i) Runoff and sediments collection plot

Three sample plots are chosen for this experimental work, considering their different characteristic:

1- No tillage with mulch (NT+M) plot
2- Disc tillage with mulch (DT+M) plot
3- Disc tillage without mulch (DT) plot

The plot 1 and 2 were mulched with rice straw to increase infiltration of water, while plot number 3 had no mulch, treated maize seeds were hand sown, two seeds per hole at a spacing of 90cm x 40cm to give a plant population of 55,000 per ha. The period of growing was from 9th May to 4th September 2001, which is exactly the period of conduction of the experiment.

Bounds were constructed along the upper and lateral rides of each plot to prevent run on while permitting runoff. A miniplot (2.5mx2m) was demarcated from each of the three plots with 60cm high asbestos sheets inserted 20cm below and 40 cm above the ground surface for runoff and sediments collection. A collector drain bordering the lower side of each miniplot discharged runoff water and sediments load via a spout in a 320 liters tank installed in a pit just below ground level. Measurement was taken after each rain event.

ii)Installation of piezometer tubes for water table measurement.

These piezometer tubes were placed into different places of the site; each of them had a water entry point at the place where measurement was desired. The other end of the tube extended vertically from the measurement point and was opened to the atmosphere. If water in the soil was under positive pressure, it would enter the tube and rise to a height whose gravitational potential relative to the soil at the point of interest was equal to the tensiometer pressure potential of the soil water. (For practice, the reader may verify this using the equilibrium analysis.) Excluding unsaturated tensiometer pressure potential in a saturated system was equal to the sum of the over burden and the hydrostatic pressure potentials. Thus in a rigid soil, the water in the piezometer would rise to a higher equal to the water table height. In a swelling soil, the height reached would exceed the height of the water table by an amount equal to the over burden potential head

3.4 METHOD OF EXPERIMENTATION

3.4.1 DETERMINATION OF RUNOFF VOLUME AND SEDIMENT LOAD

The runoff and the sediment data were collected after each rainfall that's enough to produce the surface flow, from each of the three plots. Runoff was measured with one bucket, a graduated container of 1000milineters and a sponge. In fact bucket served to collect water from the tank, the graduated container is used to measure the volume of water collected and sponge to collect the smallest quantity of water remaining in the tank. The results of each miniplot are recorded separately: see chapter four. The sediments resulted at the bottom of the tank were collected with plastic containers, then transfer to the laboratory for drying in oven. The oven was set at a temperature of 105^0c for 24 hours. Finally the sediment would be collected from oven at constant weight, which used to be determined with a weighing balance. The recorded results of each miniplot were numbered and kept separate, for each rain event.

That was the procedure followed in determining runoff volume and the sediment load resulted after each rainfall, from 9th May to 4th September of the years 2001. At the end of the season cumulative runoff volume and cumulative sediment load, for each plot, were computed (results are found in chapter four: table n° 4.1 s

3.4.2 DETERMINATION OF BULK DENSITY

The black's gravimetric method was used to carry out the experiment. The following were the procedure steps.

Sample cores of equal dimensions and negligible weight differences were used. They were numbered from one to five:

Step 1:the sample core number one was coupled with an auger, the place was cleared before application of the coupled implement. The auger was forced into the ground by applying manual vertical force. The depth of entering of the implement did not exceed 20cm. Then the auger was removed, charged sample core was dissembled given the first soil sample. The same procedure was followed for the remaining sample cores, but for number two the collection was done at depth interval,[20cm, 40cm]. The sample core number three is collected at the interval[40cm, 60cm], the sample core number four at the depth interval[60cm, 80cm] and the sample core number five at the depth interval [80cm, 100cm].

Step two: the soil samples and the containers were weighted together. The difference in weight between the weight of the sample core containing the soil and its weight is known as the wet weight of soil.

Step three: the soil samples were transferred into oven for drying, the oven was set to a temperature of 105^0 c and for duration of 24 hours.

Step four: the dried samples were weighed again, the constant weight was recorded. This weight minus the weight of container is known as dry weight. The entire procedure is known as black's gravimetric method and it covers the determination of moisture content and wet and dry bulk densities.

Let W_C = weight of container (g)

V_c =volume of sample core (cm^3)

W_w = weight of wet soil (g)

W_d = weight of dry soil (g)

W_{wc} = weight of wet soil +weight of container

W_{dc} =weight of dry soil + weight of container

Therefore weight of wet soil = W_w =[W_{wc} –W_c][g]

Weight of dry soil = W_d = [W_{dc} –W_c][g]

Wet bulk density = W_w /V_c = weight of wet soil /volume of soil core [g/cm^3]

Dry bulk density = Wdc /V_c = weight of dry soil / volume of sample core [g/cm^3]

3.4.3 DETERMINATION OF MOISTURE CONTENT

The procedure described earlier in section 3.4.2 cover this experiment. After determination of wet and dry weights of the soil samples, the difference between them gave the amount of water in the soil sample. This is true assuming that the weight of air rids in the soil or pore was negligible. According to Gardner (1986)

$$M.C = \frac{\text{mass of wet soil-mass of dry soil}}{\text{Mass of dry soil}}$$

$$M.C = \frac{(W_w - W_d)}{W_d}\ 100\% = [g/\ g]\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

3.3.4 DETERMINATION OF INFILTRATION RATE

At the beginning of the experiment the required spot was found and cleared in a way that the structure of the soil surface was not disturbed. The double ring infiltrometer was then installed by placing the inner, smaller ring infiltrometer on the prepared spot. It is then forced into the ground up to a desired depth (10cm) such that the steel meter ruler reads (15cm) for the path on the surface. The outer ring was then installed around the inner ring making sure that inner ring was centrally placed within the outer ring. Using a graduated bucket, water was introduced in the rings, starting with the inner ring. Simultaneously, a pre-set stopwatch was on. The reading of the level of decrease of water within the inner ring was covered at given interval of time (see result table table4.1.c, table 4.1.b) after which the level is restored to its original level by filling with water first the inner ring then the outer ring. This is done at least for 2hours 20 minutes. The data are tabulated in the standard form in (table 4.1.c, table 4.1b). The values of accumulated infiltration and average infiltration rates are plotted as a function of elapsed time.

3.4.5 PARTICLE SIZE DISTRIBUTION

The experiment was carried out in a series of steps

Step 1: soil samples were collected from the following depth intervals: [0, 0.2m]; [0.20m, 0.40m]; [0.4m, 0.6m]; [0.6m, 0.8m], [0.8m, 1m] using a digger.

Step 2 the results of the collections were dried in oven set at 105^0 for 24 hours..

Step 3 the soil, samples were pound to obtain loosen soil materials, and the quantities designated for test were determined by weighing.

Step 4 the sieve analysis was carried out: it consisted of shaking the soil sample with sieve shaker. Soil sample was passed through set-graded sieves, each of standard mesh size, and fraction retained on each sieve was weighed. The finest sieve used in practice had a mesh opening of 0.074mm, which was slightly larger than the limiting particle diameter between fine sand and coarse silt. About 1000gr of distributed soil was adequate for sieve analysis. The results of sieve analysis are generally expressed in terms of percentage of total weight of soil passing different sieves. This percentage is referred to as percentage finer.

Percentage retained on sieve = (weight of soil retained x100%)/ total weight of soil

The results of particle size analysis are presented by semi –log known as particle size distribution. Particles diameters are plotted on the log scale and the corresponding percentage finer are plotted on this arithmetic scale.

3.4.6 DETERMINATION OF HYDRAULIC CONDUCTIVITY

Two methods were used for hydraulic conductivity determination: laboratory method and field method.

i) Laboratory method (fallen head permeameter test)

Five soil samples were collected according to the following depth: sample N^{o}1 at 0.20 m, sample N^{o}2 at 0.4 m, sample N^{o}3 at 0.6 m, sample at 0.8 m and sample N^{o}5 at 1 m. The samples were put into oven set at 105 °C for 24 hours. Each of the soil samples was pound to obtain loosely soil materials then carefully and separately packed to uniform packing of columns on which measurement was to be made. This is done to avoid special variable hydraulic conductivity. In filling columns short extension length was attached to the top of the column and above the top was filled by poring continuously but slowly while tamping to obtain uniform density. The material in the top extension was then removed leaving the bottom part of the measurement. The soil column was first weighed and put on a permeable bases such a wire gauge. To avoid difficulties from air bubbles, the water was desaerated and the medium was carefully saturated before testing. Water was conducted through a column from a variable head of water on the soil surface and was collected for measurement from an outlet chamfer attached to the base. The falling head permeameter is similar to the constant head permeameter except that instead of maintaining a constant head of water on the surface of the soil sample, no more water was added. The changing level of the head was observed as the water percolates through the sample. The Magnification of the rate of fall of the standard head was achieved by containing it in a tube of smaller cross sectional area A' than the cross-sectional area A of the soil sample.With the initial height of the water h_o at limit to falling to h_1 at t_1,according to Klute and Pirken(1986) the hydraulic conductivity is given by:

$$K = \frac{A' \times L \times Ln \frac{h_o}{h_1}}{A(t_1 - t_o)} \qquad \text{.....3.2}$$

ii) Field method (ring infiltrometer method)

Since the infiltrometer capacity (i.e. the steady infiltration rate that approached at large times when water infiltrates over the hole land surface) is identified with the hydraulic conductivity of saturated soil infiltration measurement into dry soil provide a mean of obtaining hydraulic conductivity values. To obtain the hydraulic conductivity of saturated soils, the rings were to be pressed into the soil to give a seal against leaks round the edge, when a small head of water was maintain on the soil surface within the ring. The cumulative infiltration was measured with time, and the steady rate-which was approached typical within 15 min for experimented soil was obtain from the result. There are several ways of obtaining the hydraulic conductivity from the infiltration data. According to Honolulu(1987)

$$K=\rho\, g\eta R^4 (\theta_0 - \theta_I)^2 /(\sigma^2)\ t^2 [-0.365+(0.133+I/R^3 ((\theta_0 - \theta_I))^{1/2}]^2 \qquad \text{.....3.3}$$

Where

I = total of infiltration up to time T

R = radius of the infiltration ring

θ_0 and θ_I = the saturated and initial water contents of soil

ρ,η a

nd σ equal to density, viscosity and surface tension , respectively, of water.

This equation can only be used during the early stage of infiltration when $I < R^3 (\theta_0 - \theta_I)$.

If the unit of length is the centimeter and unit of time is the second

g= acceleration due to gravity, $\rho\, g\eta/\sigma^2 = 0.00187\ cm^{-3}.s$ to give the of K in centimeters per second.

3.4.6 WATER TABLE MEASUREMENT

The piezometer tube was installed in the way explained (section 2.2.9 (ii)). The measurement was done as follow:

A long metal bar of small cross sectional area was inserted in the tube, a mark was put at a point of the metal bar found at the surface level. After removing it from the tube, the water table depth was obtained by measuring the length of the metal bar between the marked point and the wet parts of the bar. In fact that so-called water table depth is the distance between the level of the water table and the soil surface.

When the soil infiltration rate is high, the surface runoff decreases and the water table will increase, considering the soil water balance of the area.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 RESULT OF SOIL ANALYSIS

Table 4.13 shows the results of bulk density test. These results vary from depth to depth. It can be seen that the wet bulk density has no significant relationship with the depths. Table 4.13 also shows that the wet bulk density is greater than the dry bulk density. The bulk density of soil from 0-100cm depth was in-between 1 and 1.5 g/cm. Table 1.4.a represents the result of soil moisture contents test. It shows that the moisture content of the soil in the rainy season is greater than that of the dry season. The least moisture content recorded in rainy season experiment is found to be greater than the greatest value of moisture content recorded in dry season. This resulted from lack of rainfall in the dry season. In table 4.14 are presented the results of the cylinder infiltrometer test carried out in dry season. The average infiltration rate decreases as time increases while the cumulative infiltration increases with increase in time. More details about it are presented in figure 4.6 and figure 4.7. Table 4.14 and Table 4.15 presents the rate of infiltration in the rainy season. It can be observed that the rate of infiltration in the rainy season is much lower than that recorded in the dry season. The variation of average infiltration rate and cumulative infiltration with respect to time in rainy season experiment is lower than the one in dry season experiment. This was due to the high humidity of soil in rainy season.

Table 4.16, Table 4.17, Table 4.18, Table 4.19 and Table 4.20 respectively show the particle size analysis at depths[0 to 0.20m],[0.20 to 0.40m],[0.4 to 0.60m],[0.60 to 0.80m] and[0.80, 1m]. Figures4.1, 4.2, 4.3, 4.4, 4.5 show plots of diameters of the grain particles against the percentage passing the set of sieves. The analyses showed that the soil being studied is a sandy soil.

From the hydraulic conductivity test conducted using laboratory method, the following results were obtained: the Table 4.1 showed the resulted hydraulic conductivity at the depth[0, 20cm], Table 4.2 showed the hydraulic conductivity obtained from the soil at the depth[20, 40cm], Table 4.3 showed the hydraulic conductivity at the depth [40, 60cm], the Table 4.4 showed the hydraulic conductivity at the depth[60, 80cm], Table 4.5 showed hydraulic conductivity at the depth[80, 100cm]. The obtained values of hydraulic conductivity ranged between 10^{-7} and 10^{-4}m/s. According to Marshal (1988), soils that have hydraulic conductivity within that range have fine texture with stable aggregates. They can therefore be used for growing crops including those under irrigation that are largely within this range. The Table 4.6 presents the result of hydraulic conductivity test that was carried out with ring infiltrometer. The depth of infiltration was determined in time intervals of two minutes. After a cumulative elapsed time of 15mn the infiltration rate became constant and the experiment ended. The value of hydraulic conductivity was determined by calculation under table 4.1.0. It also ranges between 10^{-7} and 10^{-3} m/s. It can be seen that both the laboratory and field methods approximately showed the same results.

Table 4.1 hydraulic conductivity k_1 at depth interval[0, 20cm] using fallen head permeameter method

Test No	Time t_1 (sec)	Time t_2 (sec)	Time (t_1 -t_2)	Hydraulic conductivity K1 (cm/s)
1	7	12	5	4.4×10^{-3}
2	6	12	6	3.7×10^{-3}
3	6	13	7	3.2×10^{-3}
4	5	11	6	3.7×10^{-3}
5	6	12	6	3.7×10^{-3}
Average time	6	12	6	$3.7.10^{-3}$ cm/s

Hydraulic conductivity K

$K=A'L/A\ (t_1-t_0)\times\ln\ (H_0/H_1)$

A'= area of capillary

A =area of soil test

H_0=initial height of water

H_1=final height of water

Area of capillary $A'=\pi d^2/4$

Diameter of capillary is 0.5cm

$A' = \pi\times(0.5)^2/4 = 0.19cm^2$

Area of the soil $A = \pi\times10^2/4 = 78.54cm^2$

$$K_1 = \frac{(0.196\text{x } 13)}{(78.54\text{x}6)} \ln (100/50)$$

$K_1 = 3.7\text{x}10^{-3}\text{cm/s}$

This method was applied to the soil samples collected from depth intervals [20cm, 40cm]; [40cm, 60cm]; [60cm, 80cm]; [80cm, 100cm] and the following hydraulic conductivity values were respectively obtained.

$K_2 = 9.77\text{x}10^{-4}\text{cm /s}$

$K_3 = 7.028\text{x}10^{-4}$ cm/s

$K_4 = 5.62\text{x}10^{-4}\text{cm/s}$

$K_5 = 1.022\text{x}10^{-3}\text{cm/s}$

Table 4.2 Hydraulic conductivity k2 at depth interval[20, 40cm] using fallen head permeameter method

Test No	**Time t_1 (sec)**	**Time t_2 (sec)**	**Time (t_1 -t_2)**	**Hydraulic conductivity K2 (cm/s)**
1	13	35	22	10.22x10^{-4}
2	12	35	23	9.77x10^{-4}
3	12	36	24	9.36x10^{-4}
4	12	36	24	9.36x10^{-4}
5	13	36	23	9.77x10^{-4}
6	13	36	23	9.77x10^{-4}
Average time	12	36	23	9.77x10^{-3}cm/s

Table 4.3 Hydraulic conductivity k3 at depth interval[40, 60cm] using fallen head permeameter method .

Test No	Time t_1 (sec)	Time t_2 (sec)	Time (t_1 -t_2)	Hydraulic conductivity`K3 (cm/s)
1	14	45	31	7.253×10^{-4}
2	15	47	32	7.028×10^{-4}
3	15	47	32	7.028×10^{-4}
4	15	47	32	7.028×10^{-4}
5	15	47	31	7.253×10^{-4}
6	16	47	32	7.028×10^{-4}
verage time	15	47	32	7.103×10^{-4}

Table 4.4 Hydraulic conductivity k4 at depth interval [60,80cm] using fallen head permeameter method .

Test No	Time t_1 (sec)	Time t_2 (sec)	Time (t_1 -t_2)	Hydraulic conductivity K4 (cm/s)
1	19	59	40	5.62×10^{-4}
2	19	59	40	5.62×10^{-4}
3	18	58	40	5.62×10^{-4}
4	18	58	40	5.62×10^{-4}
5	19	59	40	5.62×10^{-4}
Average time	19	59	40	5.62×10^{-4}cm/s

Table 4.5 Hydraulic conductivity k5 at depth interval [80, 100cm] using fallen head permeameter method

Test No	Time t_1 (sec)	Time t_2 (sec)	Time (t_1 -t_2)	Hydraulic conductivity K5 (cm/s)
1	13	35	22	$1.022x10^{-3}$
2	13	35	22	$1.022x10^{-3}$
3	13	34	21	$1.070x10^{-3}$
4	13	35	22	$1.022x10^{-3}$
Average time	13	35	22	$1.034x10^{-3}$

Table 4.6 Hydraulic conductivity determination using ring infiltrometer method

Time (min)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Depth (cm)	6	12	13	11	10.87	10.64	10.43	10.99	10.35	10.11	10.11	10	10	10	1

-Analysis of Table 4.6 results

D= cumulative depth

D=6+12+13+11+10.87+10.64+10.43+10.99+10.15+10.11+10.11+10+10+10+10

=165.65

I = total volume of infiltration = $D \times \pi \times R^2 = 165x3.14 \times (15)^2 = 117031.725cm^3$

$\rho.g\eta/\sigma^2 = 0.00187\ s/cm^3$

T = cumulative time = 15 min = 900 seconds

R = radius of infiltrometer = 15 cm

K6 = hydraulic conductivity =?

θ_o = saturated water content

θ_1 = initial water content

$\theta_o = 560$ g

$\theta_1 = 215$ g

According to Youngs(1991) The Equation used for determination of hydraulic conductivity k6 is:

$$K6 = \frac{\rho g \eta (\theta_o + \theta_I)^2}{\sigma^2 t^2} \left\{ -0{,}365 + \left\{ 0{,}133 + \frac{I}{\boxed{R^2(\theta_0 - \theta_I)}} \right\}^{1/2} \right\}^2 \quad \text{..........................4.1}$$

$$K\,6 = \frac{94.66 \times 119025}{900^2} \left\{ 0.365 + \left[0.133 + 0.000117952 \right]^{\frac{1}{2}} \right\}^2$$

$k6 = 0.194 \times 10^{-2}$ cm / s

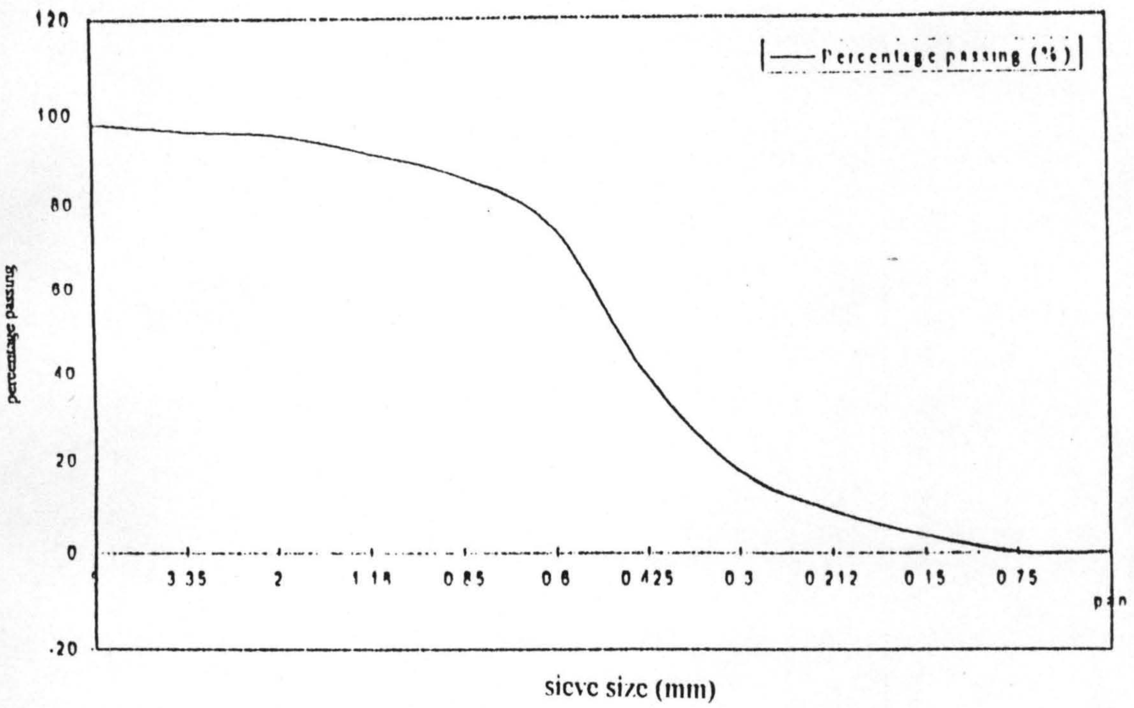

Figure 4.1: particle size analysis(o-o.20)

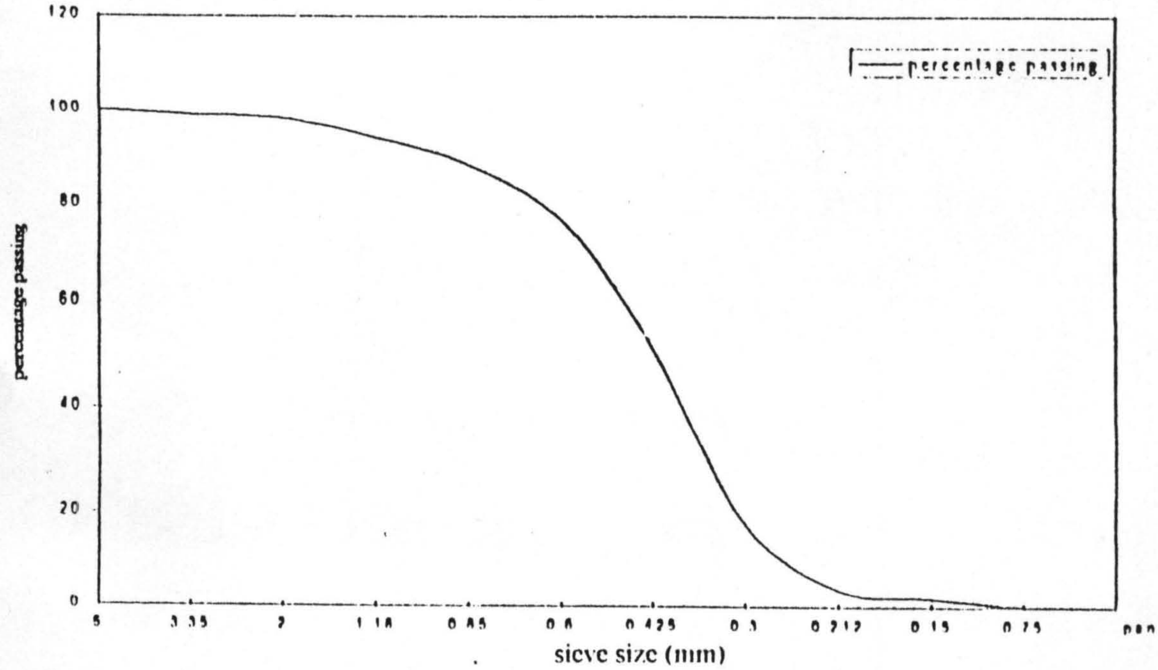

Figure 4.2. particle size analysis (0.20-0.40)

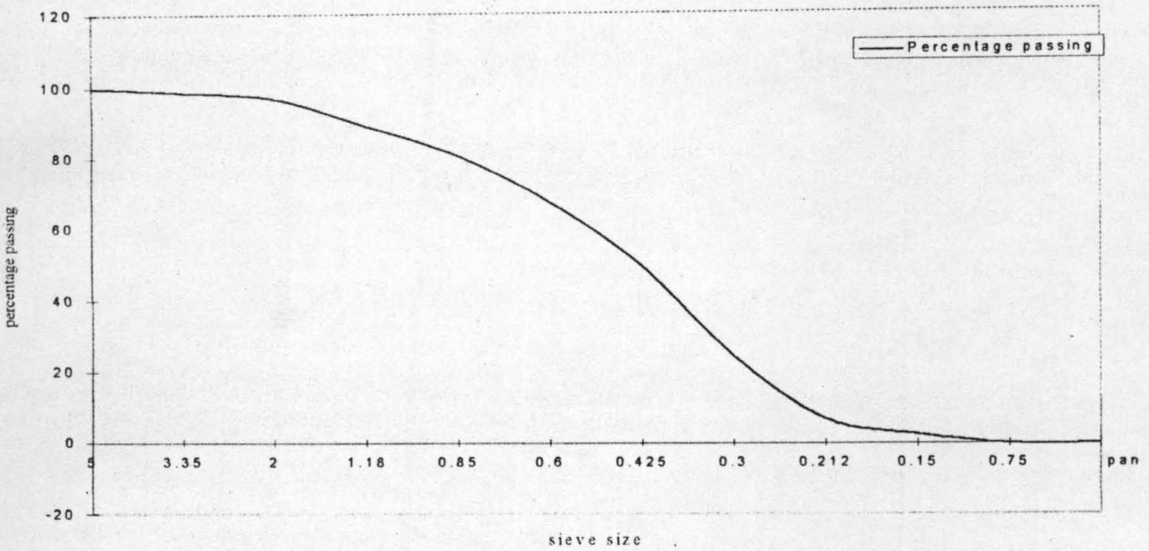

Figure 4.3: particle size analysis(0.40-0.60)

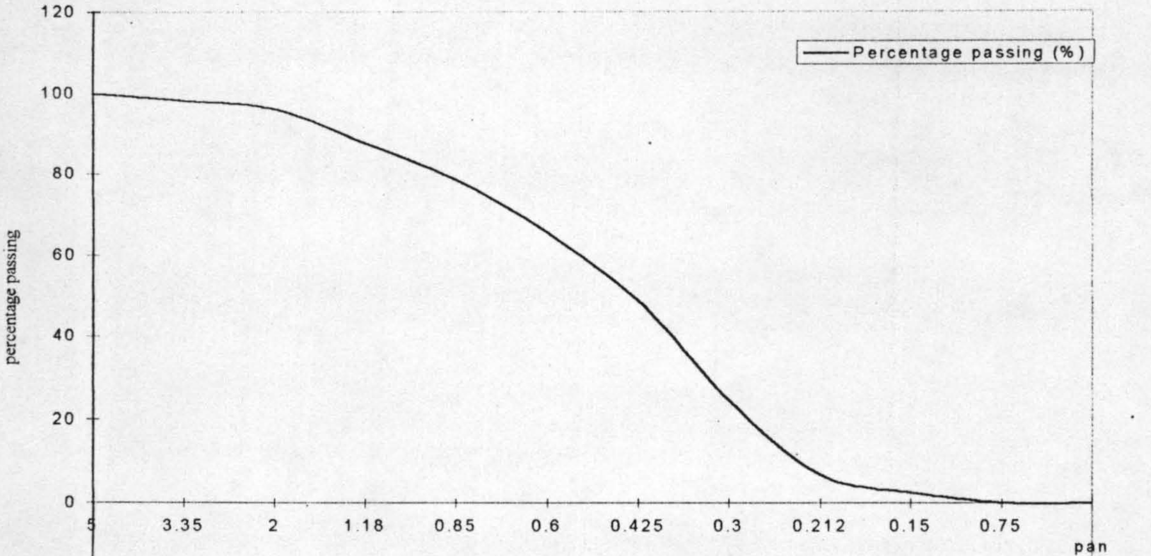

Figure 4.4: particle size analysis(0.60-0.80)

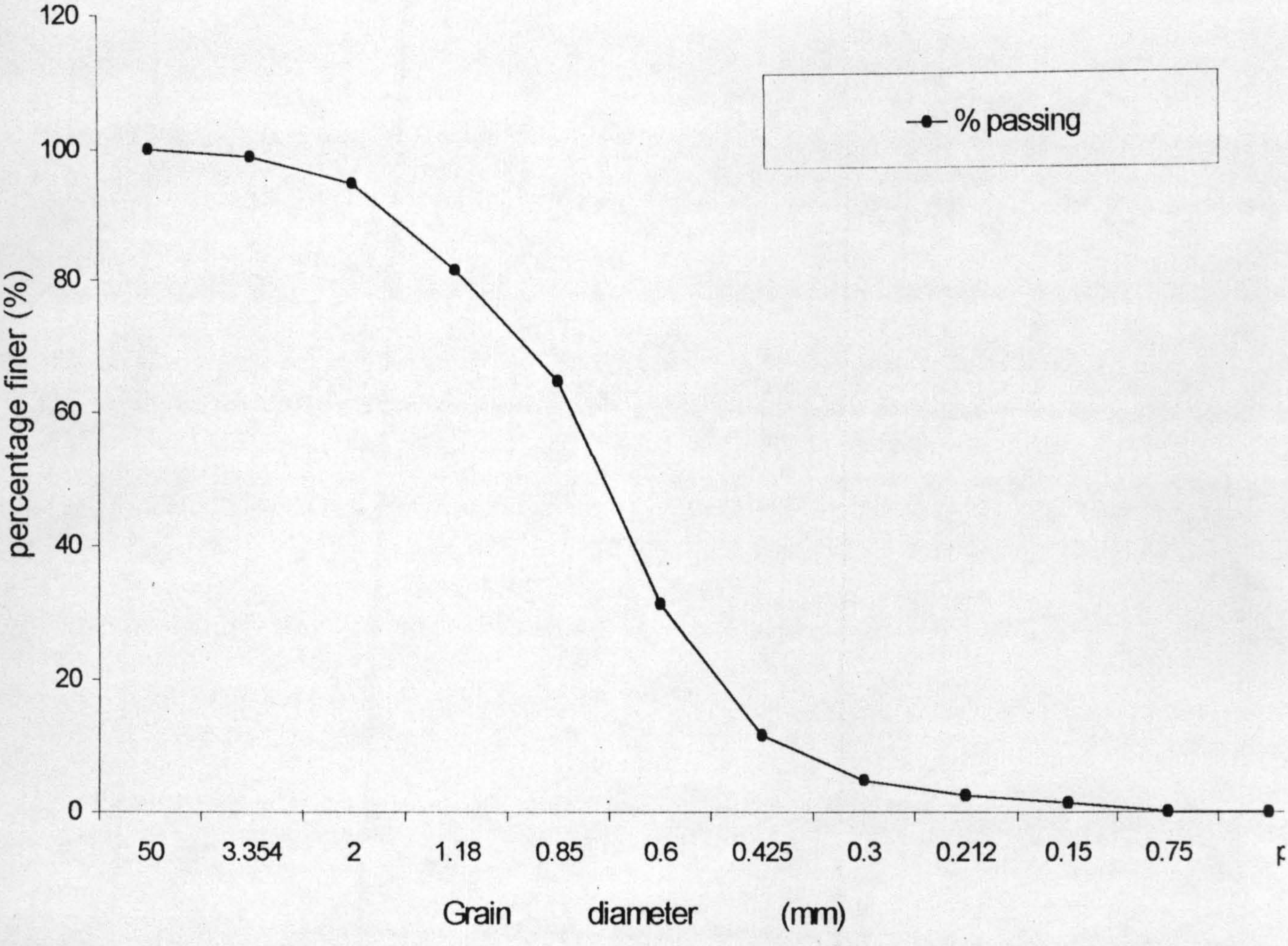

Figure 4.5: Particle size analysis at interval] 0.80, 1.00 m]

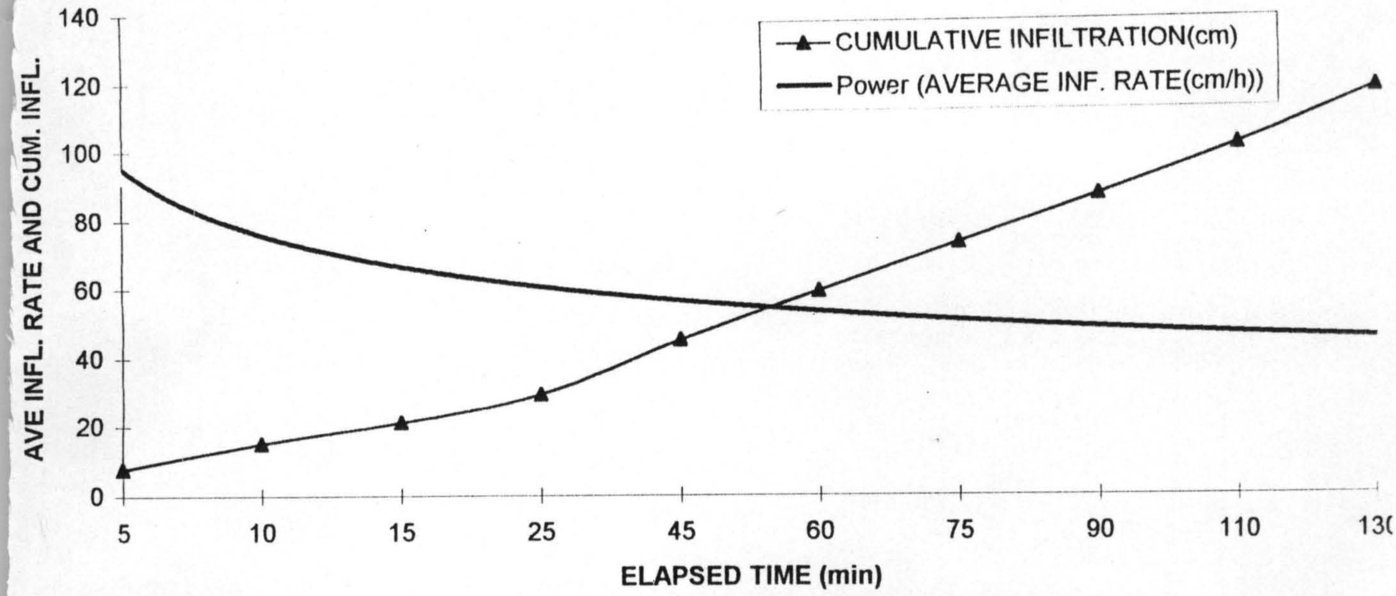

FIGURE 4.6: CYLINDER INFILTRATION TEST (RAINY SEASON)

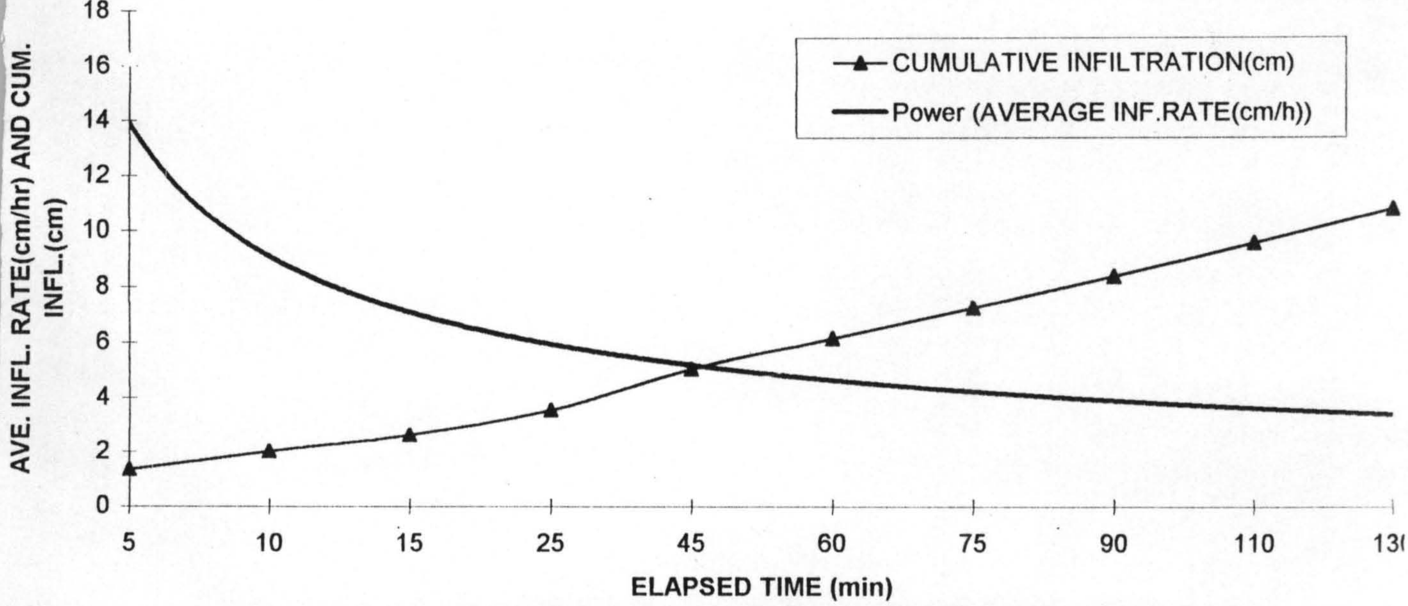

FIGURE 4.7: CYLINDER INFILTROMETER TEST(DRY SEASON)

4.2 WATER TABLE LEVELS

The piezometer P_3 had the lowest water table because it was located in a depression area. Its recharge period started on July with its peak being reached on September due to the high rainfall recorded at that period. The level of the water table reduces from October and continues up to November. For piezometer P_2 and P_1 the same trend of reduction was observed, but the levels of the water table in these cases were higher compared with the level in the case of P3. This is due to the fact that the piezometer P3 is located at a higher point. So P_1 and P_2 have respectively their peaks as 77 cm and 55.25 cm. All the piezometers had their maximums discharge on November. This can be explained by the minimum amount of rainfall recorded at that period.

Table 4.7 Monthly water Table depth at three piezometer points during the study period.

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
P1	77.5	91.1	77	133.6	168
P2	54.5	59.4	54.25	89.6	121.5
P3	40	36.8	29.75	64.8	110.75

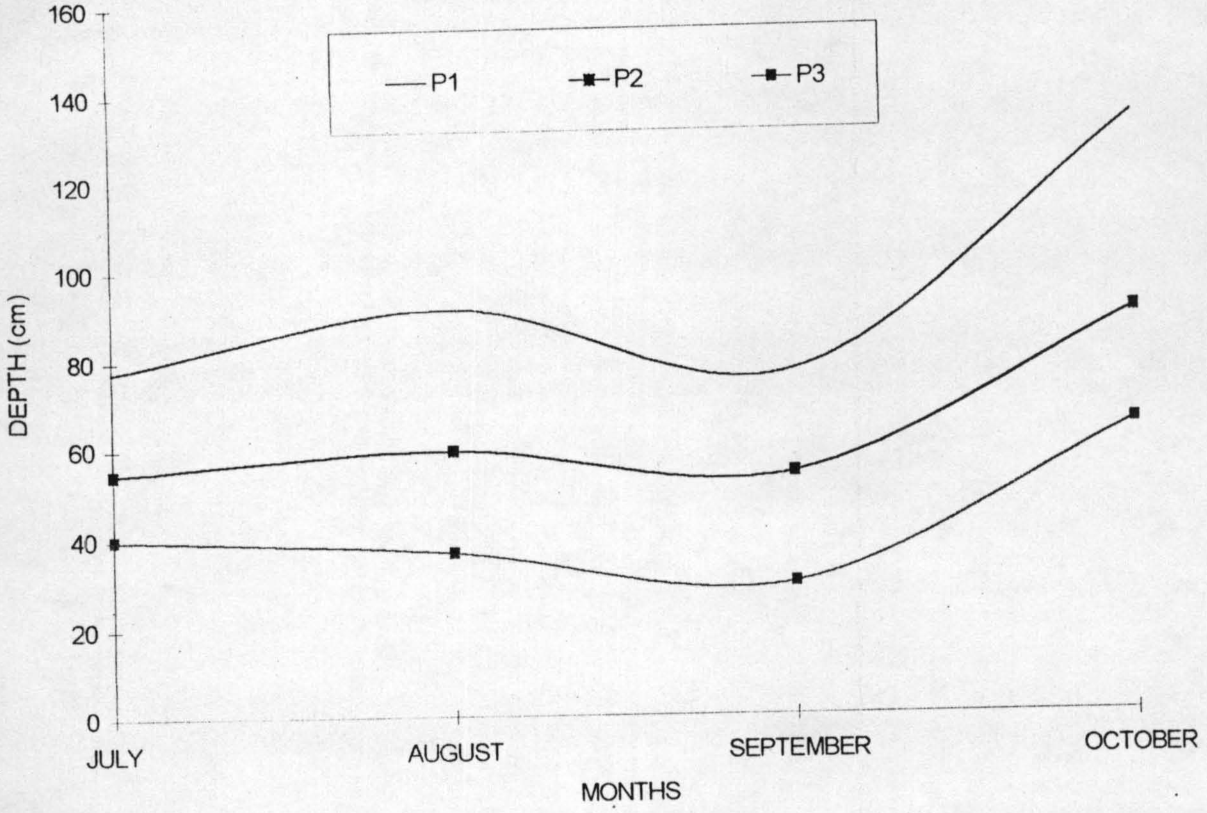

Figure 4.8: Depth of water table at three piezometer points during study period

4.3 RUNOFF AND SEDIMENTATION DATA

The table 4.8 showed the runoff results of the assigned season for each month.

From the graph (in figure 4.9), it can be observed that the curves of the three treatment showed the same fluctuation. That means the minimum runoff values of the season were recorded in May. From that month there was an increase of runoff recorded up to the following month (June). From June the runoff recorded started decreasing up to the end of the assigned period. This general variation of the runoff records resulted from the rainfall variation, which also had its lowest records in May and its maximum records in June. But the three treatments had different records throughout the period. At the beginning, the records of the three treatments were presented as follow:

DT+M> DT>NT+M. After that period the treatment DT was the greatest followed by NT+M treatment then DT+M.

For DT the low record at the beginning is due to Tillage carried out in the plot. It increased infiltration of water resulting from rainfall. Then the successive rainfalls consolidated the soil aggregate. That is why the infiltration reduced and runoff records consequently became the greater. Another reason why this phenomenon was observed was that the plot was cleared in such a way that there was no obstacle for the flow of water. The lowest runoff was recorded for DT+M treatment because tillage and mulch increase infiltration and therefore decrease runoff. The NT+M treatment records a lower runoff value than in the case of DT because mulch increased the infiltration rate. But the recorded runoff value there is greater than that of the DT+M, because the structure of NT+M plot was not disturbed while that of DT+M was disturbed by tillage.

Table 4.9 shows the sediment load resulted from each of the season. Figure 4.10 shows a plot of months against sediment load. It can be seen that the sediment production increases from May to June and decreases from June to September. The comparison of the curves in figure 4.9 and figure 4.10 shows that the two (2) phenomenons approximately have the same behaviour. This shows how closely related the sediment production is to the runoff.

Table 4.1 shows that the values of hydraulic conductivity of soil ranged between 10^{-7} and 10^{-4} m/s. Table 4.13 shows that the bulk density values range from 1 to 1.5 g/cm^3. According to Marshall (1988) soil with hydraulic conductivity and bulk density within this range is good for crop production and irrigation.

The high amount of runoff produced shows the necessity of constructing conservation structures in that area. The amount of sediment is information required in order to provides best solutions to erosion damages.

Table 4.8 Runoff volume (averages for the assigned months of the season ($10^6 mm^3$))

	MAY	JUNE	JULY	AUGUST	SEPTEMBER
NT+M	2.76	47.11	19.502	19.13	11.075
DT+M	7.48	34.276	20.008	15.513	9.72
DT	4	18.385	64.084	56.681	30.845

Table 4.9 Sediments loss (averages for assigned months of the season (10^3 g)

	MAY	JUNE	JULY	AUGUST	SEPTEMBER
NT+M	24.8	423.5	175.3	171.9	0.0995
DT+M	36.8	168.8	98.58	76.4	0.0478
DT	69.1	1872.8	1107.3	979.4	0.5329

Table 4.10 Summary of Runoff and Sediment loss results

NT+M	661.19×10^6	12.70%	6300.2
DT+M	528.53×10^6	10.20%	2634.6
DT	1701.67×10^6	32.72%	29405.1

Table 4.11 Rainfall a month (mm) at the experimental site.

Month										
Year	J- M	A	M	J	J	A	S	O	N–D	Total
2001	Nil	94.6	152.0	305.7	433.0	648.6	148.7	31.4	Nil	1,414.0

Sources: Meteorological Station, Upper Niger River Basin Development Authority Minna – 2001

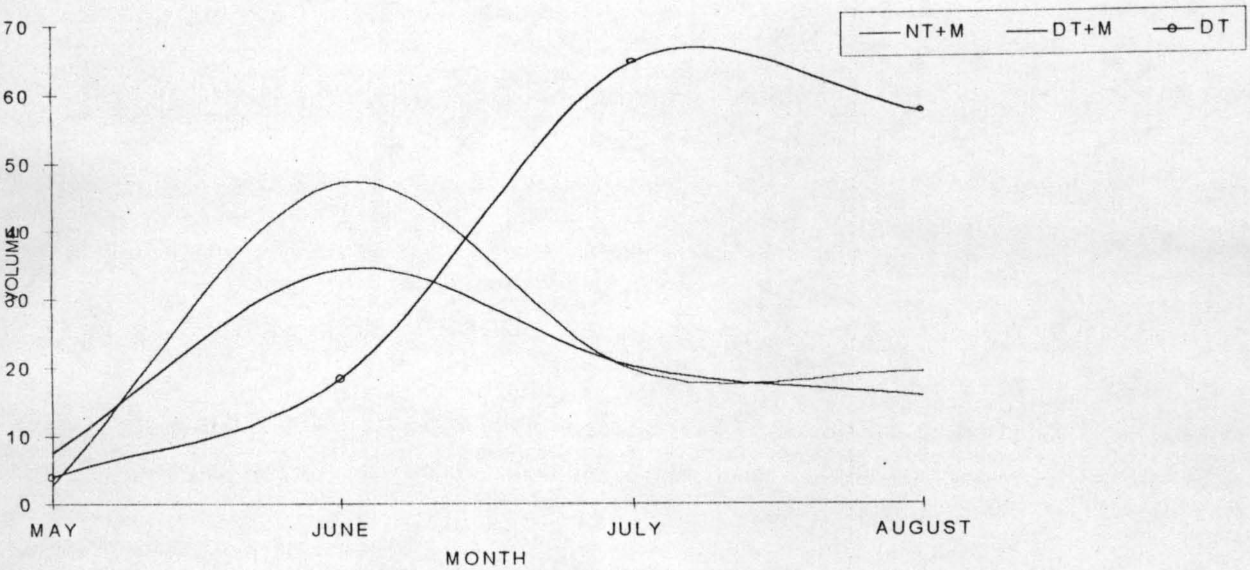

Figure 4.9:RUNOFF VOLUME (AVERAGE PER MONTHS OF THE SEASON)

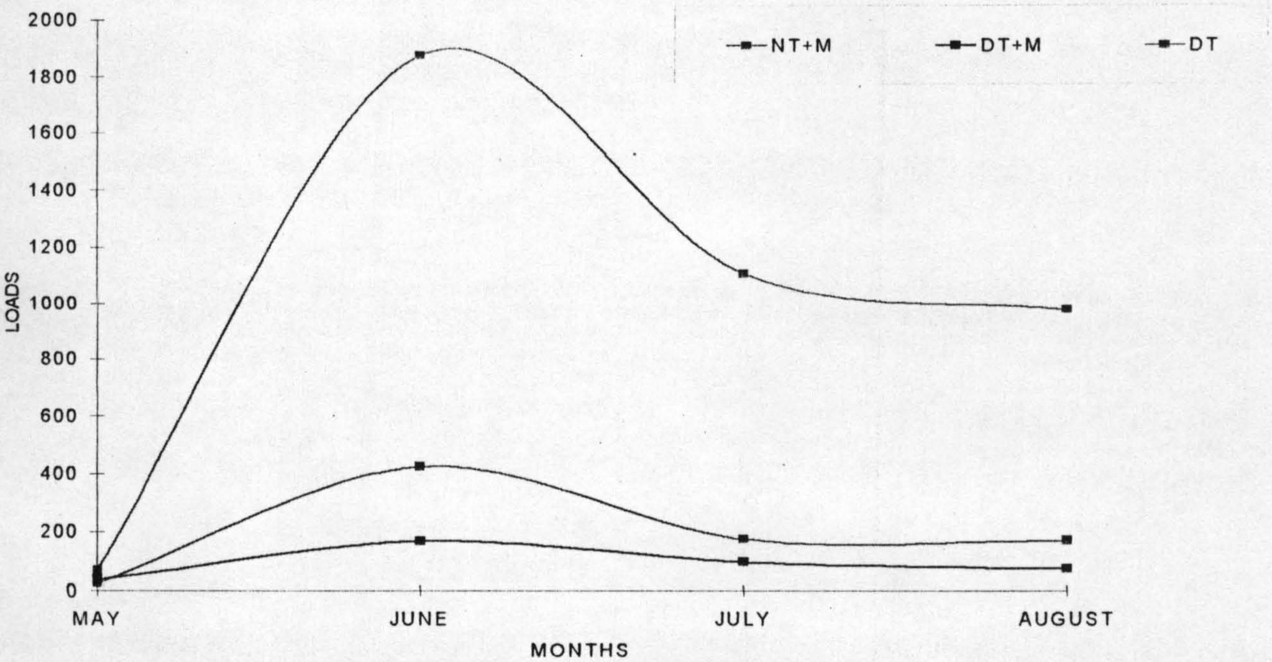

Figure 4.10: SEDIMENTS LOAD (AVERAGES FOR MONTH OF THE SEASON

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

After the completion of this project work, the following results were obtained: the runoff values of 32.72%, 10.20% and 12.70% were respectively measured for the soil treated with disc tillage, soil treated with disc tillage and mulch and finally soil treated with mulch only.

It can be seen that the runoff values change with respect to the treatment undergone by the soil. On the other hand, the sediment load production is observed to be dependent on the nature of the soil and runoff. A soil with a high value of bulk density, moisture content and high water table can then be said to have a great potentiality of runoff production.

Sediment load production depends on how tightly the soil particles are cemented together. Thus the loser the soil the more it generates sediment load.

5.2 RECOMMENDATIONS:

-This monitoring of runoff and sediment load production should be continued in order to have a better understanding of the project.

-The investigation can be extended to other types of soil and at different locations in Niger State to know more about the soil quality, provide solution to erosion problem and find out the suitability of the land to crop production.

-Considering drinking water problem in Minna town, the investigation on runoff should emphasis on the production and treatment of runoff water in conservation structures. Therefore more period of research is required at various locations to establish the water conservation potentiality.

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APPENDIX 1: Tables of results of soil analysis

Table 4.12: Soil moisture content

	Dry season experiment							Rainy season experiment				
ber	1	2	3	4	5		Soil samples No	1	2	3	4	5
ht of oil	164.45	144.23	197.1	203.95	194.83		Weight of wet soil (g)	161.011	146.6	178.67	153.3	203.64
ht of oil	163.67	139.89	183.18	188.9	178.8		Weight of dry soil (g)	140.5	129.72	156.49	132.55	161.88
ht of r (g)	0.78	4.34	13.92	15.05	16.03		Weight of water (g)	20.511	16.88	22.18	20.75	31.76
ture ent	0.47	3.1	7.59	7.96	8.96		Moisture content (%)	12.31	10.46	12.13	13.06	16.28

Table 4.13 Bulk density

th)	Weight of wet soil (g)	Weight of dry soil (g)	Moisture content (%)	Wet bulk density (g/cm3)	Dry bulk density (g/cm3)
20	161.011	140.5	12.31	1.22	1.05
- 40	146.6	129.72	10.86	1.1	1
- 60	178.67	156.49	12.13	1.35	1.18
- 80	153.3	132.55	13.06	1.15	1
- 100	103.64	171.88	16.28	1.5	1.3

Table 4.14 Data of cylinder infiltrometer tests (dry season)

SED TIME (min)	5	10	15	25	60	75	90	110	130
H (m)	7.7	7.2	6	8	13.8	13.8	138	14.6	14.6
AGE RATE (cm/h)	92.4	86.4	72	48	55.2	55.2	55.2	43.8	43.8
LATIVE INFILTRATION (cm)	7.7	14.9	20.9	28.9	58.6	72.4	86.2	100.2	115.4

Table 4.15 Data of cylinder infiltrometer test (rainy season)

PSED TIME (min)	5	10	15	25	45	60	75	90	110	130
TH (m)	1.3	0.65	0.62	0.9	1.5	1.1	1.1	1.1	1.2	1.2
RAGE RATE)	16.62	7.8	7.44	5.4	4.5	4.4	4.4	4.4	3.6	3.6
U.INFILT. (cm)	1.3	2	2.62	3.52	5.02	6.12	7.22	8.32	9.52	10.72

Table 4.16 Grain size distribution at interval[0, 0.20m]

ieve ize mm)	Weight of sieve sample (g)	Weight of sieve (g)	Weight of sample (g)	Percentage retaining (%)	Cumulative retaining (%)	Percentage passing (%)
5	479.86	498.8	18.94	1.894	1.894	98.106
3.35	472.22	487.43	15.21	1.521	3.415	96.585
2	420.46	430.4	9.94	0.994	4.409	95.591
1.18	391.47	431.64	40.17	4.017	8.426	91.574
0.85	359.17	413.6	54.43	5.443	13.869	86.131
0.6	336.95	455.74	118.79	11.879	25.748	74.252
0.425	329.74	679	349.26	34.926	60.674	39.326
0.3	316.6	532.22	215.62	21.562	82.236	17.764
0.212	304.64	392.55	87.91	8.791	91.027	8.973
0.15	396.63	347.97	51.4	5.134	96.161	3.839
0.75	297.79	334.23	36.44	3.644	99.805	0.195
pan	308.72	310.8	2.08	0.208	100	0

Table 4.17 Grain size distribution at interval [0.20, 0.40 m]

Sieve size (min)	Weight of sieve sample (g)	Weight of sieve (g)	Weight of sample (g)	Percentage retaining (%)	Cumulative retaining (%)	Percentage passing (%)
5	479.86	479.86	0	0	0	100
3.35	472.22	481.44	9.22	0.922	0.922	99.078
2	420.46	429.72	9.26	0.926	1.848	98.152
1.18	391.47	433.5	42.03	4.203	6.051	93.949
0.85	359.17	414.98	55.81	5.581	11.632	88.368
0.6	336.95	452.14	115.19	11.519	23.151	76.849
0.425	329.74	585.92	256.18	25.618	48.769	51.231
0.3	316.6	651.66	35.06	3.506	82.275	17.725
0.212	304.64	444.08	139.44	13.944	96.219	3.781
0.15	396.63	321.5	24.87	2.487	98.706	1.294
0.75	297.79	308.75	10.96	1.096	99.802	0.198
pan	308.72	307.3	1.54	0.154	100	0

Table 4.18 Grain size distribution at interval[0.40, 0.60m]

eve ze ım)	Weight of sieve sample (g)	Weight of sieve (g)	Weight of sample (g)	Percentage retaining (%)	Cumulative retaining (%)	Percentage passing
5	479.86	479.86	0	0	0	100
3.35	472.22	485.77	13.55	1.355	1.355	98.645
2	420.46	438.28	17.82	1.782	3.137	96.863
1.18	391.47	469.34	77.87	7.787	10.924	89.076
0.85	359.17	443.16	83.99	8.399	19.323	80.677
0.6	336.95	468.82	131.87	13.187	32.51	67.49
0.425	329.74	510.78	181.04	18.104	50.614	49.386
0.3	316.6	566.26	249.66	24.966	75.58	24.42
0.212	304.64	480.5	175.86	17.586	93.166	6.834
0.15	396.63	340.32	43.69	4.369	97.535	2.465
0.75	297.79	322.02	24.23	2.423	99.958	0.042
pan	308.72	309.11	0.39	0.039	100	0

Table 4.19 Grain size distribution at interval [0.60,0.80m]

ieve ze nm)	Weight of sieve sample (g)	Weight of sieve (g)	Weight of sample (g)	Percentage retaining (%)	Cumulative retaining (%)	Percentage passing (%)
5	479.86	479.4	0	0	0	100
3.35	472.22	470.4	17.12	1.712	1.712	98.288
2	420.46	442.46	22	2.2	3.912	96.088
1.18	391.47	474.76	83.29	8.329	12.241	87.759
0.85	359.17	449.92	90.81	9.08	21.322	78.678
0.6	336.95	467.68	130.73	13.073	34.395	65.605
0.425	329.74	496.64	166.9	16.69	51.085	48.915
0.3	316.6	560.82	244.22	24.422	75.507	24.493
0.212	304.64	481.2	176.56	17.656	93.163	6.837
0.15	396.63	339.45	42.82	4.282	97.445	2.555
0.75	297.79	322.47	24.68	2.468	99.913	0.087
pan	308.72	309.7	0.98	0.098	100	0

Table 4.20 Grain size distribution at interval[0.80,1.00m]

Sieve size (mm)	Weight of sieve sample (g)	Weight of sieve (g)	Weight of sample (g)	Percentage retaining (%)	Cumulative retaining (%)	Percentage passing (%)
50	479.86	479.86	0	0	0	100
3.354	472.22	485.83	13.61	1.361	1.361	98.639
2	420.44	461.6	41.14	4.114	5.475	94.525
1.18	391.47	526.16	134.69	13.469	18.944	81.056
0.85	359.17	525.68	166.51	166.51	35.595	64.405
0.6	336.95	669.84	332.89	33.289	68.884	31.116
0.425	329.74	526.3	196.58	19.658	88.542	11.458
0.3	316.6	383.99	67.39	6.739	95.281	4.719
0.212	304.64	326.78	22.14	2.214	97.495	2.505
0.15	296.63	307.47	10.84	1.084	98.579	1.421
0.75	297.79	310.49	12.7	1.27	99.849	0.151
pan	308.72	309.98	1.26	0.126	100	0

Table 4.21: Depths of water table measured per week(cm)

Date	P1	P2	P3
18/7/2001	67	48	0
26/7/2001	88	61	40
3/8/01	85.5	59	37
7/8/01	106	58	36
14/8/2001	112	70	57
18/8/2001	81	58	26
27/8/2001	71	52	28
1/9/01	86	60	40
6/9/01	58	43	11
10/9/01	86	59	35
24/9/2001	78	55	33
1/10/01	105	67	47
8/10/01	123	79	60
15/10/2001	137	88	65
22/10/2001	147	100	70
29/10/2001	156	114	82
5/11/01	168	119	97
12/11/01	W.T.below Piezometer depth	124	102
19/11/2001	W.T.below Piezometer depth	W.T.below Piezometer depth	112
26/11/2001	W.T.below Piezometer depth	W.T.below Piezometer depth	132

SITE FREE HAND SKETCH