DETERMINATION OF HYDROLOGIC COEFFICIENTS FOR SANDY CLAY SOIL IN GIDAN KWANO CAMPUS IN DRY SEASON

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 AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

FEBRUARY, 2012.

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken, compiled 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 Information derived from personal communications, published and unpublished works were duly referenced in the text.

Akanbi Jonathan Seun

02-03-2012.
Date

CERTIFICATION

This is to certify that the project entitled "Determination of Hydrologic Coefficients of Disturbed and Undisturbed Sandy Clay Soil (Case Study of Gidan Kwano Campus of the Federal University of Technology, Minna, Niger State)" by Akanbi Jonathan Seun meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna. And is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This research work is dedicated to the almighty God, my dearest parents, Pastor & Mrs Akanbi, Mrs Nancy Gebadi, Princess Odunayo, Prince Caleb, Prince Ifeoluwa and Miss Joy Osemene and entire members of Christ Fishers Ministry Ilorin Kwara State, Nigeria.

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y profound gratitude also goes to my parents, Pastor & Mrs. Akanbi, who has contributed far o enough to my success although my educational career up to this stage.

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It is my earnest prayer that God will bless you ALL

ABSTRACT

There was need to estimate the amount of runoff that would occur after a storm event using a imple mathematical model, to save researchers and designers the cost and rigors of continuous ield experiment, especially in Nigeria. This was achieved by the determination of factors that irectly affect runoff, such as infiltration rate, moisture content, slope, storm intensity, time of torm event, soil surface condition, and also the type of soil. A rainfall simulator was used to be ble to have a replicate event if the need arises. A catchment area of $18m^2$ (6X3m) was used and en (10) replicate of the catchment area was investigated to have an accurate result. The type of oil used was found to be SANDY CLAY soil after a sieve analysis of the soil sample. The verage basic infiltration rate of the ten plots was found to be 1.3cm/hr using a double ring nfiltrometer. The average slope was found to 2.13^0 (3.65%) using the change in height method. The average moisture content for disturbed and undisturbed soil after the simulation was found o be 3.54% and 4.58% respectively using the gravimetric method

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CHAPTER ONE

INTRODUCTION

Background of Study

ecipitation (or rainfall), after satisfying the requirements of evapotranspiration, interception, iltration into the ground, and detention storage, drains off or flows off from a catchment sin as an overland flow (or surface runoff which includes precipitation falling on the stream stem too) into a stream channel (William *et al*, 2000). Some part of the infiltrating water oves laterally through the upper layers of the soil and returns to the ground surface as erflow or subsurface runoff at some place away from the point of infiltration into the soil. rt of the infiltrating water percolates deep into the ground and joins the ground water orage. When water table intersects the stream channels of the catchment basin, some ground ater may reach the surface or join the stream as ground water runoff, called base flow or y-weather flow (William *et al*, 2000). Thus, runoff from a catchment includes surface and bsurface runoff and base flow. The surface runoff starts soon after the precipitation and is e first to join the stream flow. Subsurface runoff is slower and joins the stream later obkaew, 2005). Depending upon the time taken by the subsurface runoff between the filtration and joining the stream channel, it may be termed as prompt subsurface runoff or elayed subsurface runoff. The groundwater runoff is the slowest in joining the stream hannel but, is responsible in maintaining low flows in the stream during dry season. Based n the time interval between the precipitation and runoff, the runoff is categorized as direct unoff (that enters the stream immediately after precipitation *i.e.,* surface runoff and ubsurface runoff) and base flow *i.e.,* ground water runoff (Perlman, 2011). Runoff thus is the esponse of a catchment to the precipitation reflecting the combined effects of the nature of ecipitation, other climatic characteristics of the region, and the physiographic characteristics the catchment basin (Perlman2011). Type, intensity, duration and areal distribution of ecipitation over the catchment are the chief characteristics of the precipitation that affect the eam flow.

ecipitation in the form of rainfall is quicker to appear as stream flow than when it is in the rm of snow. For the surface runoff to start, the intensity of rainfall (or precipitation) must ceed the infiltration capacity of the soil which decreases with the increase in the duration of nfall. It is, therefore, obvious that a longer duration rainfall may produce higher runoff even the intensity of rainfall is less but, of course, exceeding the infiltration capacity of the soil erlman2011).

eavy rainfalls in the downstream region of the catchment will cause rapid rise in the stream vels and early peaking of the discharge. A rare occurrence of uniformly distributed rainfall ay result in increased infiltration and, therefore, increased subsurface runoff and base flow sulting in slow rise in levels and delayed peaking of the discharge (Perlman2011).

urface runoff also known as excess rainfall and soil type of the environment of study ontribute immensely to the damming of water for agricultural and farming purpose.

.1 Problem Statement

is important to study and know the relationship of rainfall, runoff and drainage basin haracteristics. The establishment of a clear rainfall–runoff–drainage basin characteristics elationship is difficult due to the large number of variables which affect the process. It is ore difficult to estimate the impact of vegetation change on rainfall-runoff relations for large asins where the interactions between land use, climatic characteristics and underlying ydrological process are more complex and dynamic. Thus, to study the effects of storms and o replicate the conditions, many researchers have decided to the use of artificially simulated nfall. Simulated rainfall provides rapid results than natural rains. It can be conducted iciently from the stand point of time and labour. The storm characteristics can carefully be ntrolled and the approach is more adaptable for certain type of studies.

Aim and Objective

1. To determine the surface runoff and infiltration rate coefficients of disturbed and undisturbed sandy clay soils in Gidan Kwano campus of the federal university of technology, Minna, Niger State, Nigeria.
2. To develop an empirical mathematical model/equation using the Crammer rule capable of determining the Manning's coefficient for the various conditions of sandy clay soil in Gidan Kwano area of Niger State for a small watershed.
3. To determine the relative contribution of the various components such as infiltration, surface slope and roughness and watershed shape in the generation of runoff hydrograph predicted by the model or equation.

3 Justification of Study

oil erosion, downstream flooding and siltation has been the major caused of worry of atershed managers, particularly in Nigeria, due to high rates of deforestation, desertification, oil types and intense rainfall in some parts of the country. Knowledge of the volume and tes of runoff and the failure of farm structures to serve their lifespan. Generated in response rainfall is very important, if not quintessential, to predicting soil losses but information oncerning the extent causes, and control of water erosion in Nigeria still remains agmentary and limited. This can be partly ascribed to the dependence upon field runoff plots nder natural rainfall as the main data source (Lai, 2006; Roose, 2008).

4 Scope of Work

e to the failure of farm structures built on this farmland to serve its life's span, a model for determination of the manning's coefficient of sandy clay is to be developed. The project is ited to the determination of infiltration rate, time of concentration and moisture content of soil in context.

CHAPTER TWO

LITERATURE REVIEW

.0 Brief Introduction on Agriculture

an livelihood is dependent on so many factors, one of them being food and water which has basis on agriculture. Agriculture is be defined as the science that deals with the cultivating land, producing crops, and rearing of animals (livestock) for human consumption. Food oduction has a lot to do with the sustenance of the human population and its success is pendent on so many factors, of which the farms needed to plant the crops must be in good ndition and provided with every resources that will yield good result example of such being equate water for plant growth. In many instances farms are not close to source of water due vegetation location, for example in the northern part of Nigeria where rainfall is a scarce mmodity, there is need for irrigation farming for efficient and continuous production of od. This irrigation has to do with channeling of water through artificial means for water orage (motherlandnigeria.com/agriculture, (2002).

1.1. Definition of Hydrology

he scientific study of water related to this problem is hydrology and is defined as the science at deals with the characteristics, distribution and movement of water on and below the arth's surface and atmosphere. It has to do with the estimation of flow peaks, volumes, and me of distribution and concentration of storm water runoff (iSWM Design Manual-2006). ydrology as a course consist of phenomena such as rainfall intensity, surface runoff, routing, recipitation, condensation, infiltration, topography and so many others; all of this is ummarized by the Water Cycle concept (iSWM Design Manual-2006). Surface runoff also own as excess rainfall is so much important for the storage of water meant to be used for ricultural purpose especially farming. It is dependent on a lot of variable factors which are:

i. amount of rainfall and storm distribution;

ii. area size of drainage, orientation and shape;

iii. slope of terrain and stream channel(s);

iv. moisture condition;

v. Storage potential (ponds, wetlands, reservoirs, channels, etc.)

vi. Local drainage system characteristics.

ıe determination of runoff is very important to agriculture engineers, since it plays a major le in the design and construction of dams for irrigation farming. There are a number of npirical hydrologic methods that can be used to estimate runoff characteristics for a site or ainage sub basin; however, the following methods are commonly used:

- Rational Method;
- United States Geological Survey (USGS) and Tennessee Valley Authority (TVA) Regression Equations.
- Soil Conservation Service (SCS) Unit Hydrograph Method;
- Clark Unit Hydrograph;
- Water Quality Volume (WQv) Calculation; and
- Water Balance Calculations.

These methods were selected based upon their accuracy in duplicating local hydrologic estimates for a range of design storms and the availability of equations, monographs, and computer programs to support them, although they have their constraints and is shown the table below:

ethod	Size Limitations	Comments
ational	0 – 5 acres	Method can be used for estimating peak flows and the design of small site or subdivision storm sewer systems. Not to be used for storage design.
SGS Rural	0.36 mi^2 to 21,400 mi^2	Method can be used for estimating peak flows for all design applications in rural areas.
SGS Urban	2500 mi^2	Method can be used for estimating hydrographs for all design applications in urban areas.
TVA	> 0.36 mi^2	Method can be used for estimating peak flows for storm system design applications such as culverts, channels, etc.
SCS	0 – 2000 acres	Method can be used for estimating peak flows and hydrographs for all design applications.
Clark	See Comments	Method may not be applicable to very large drainage basins. Large drainage basins may need to be subdivided to overcome limitations of this method.
Water Quality	Limits set for each Structural Control	Method used for calculating the WQv.

United States Geological Survey (USGS), 2009.

1- Size limitation refers to the drainage basin for the storm water management facility (e.g., culvert, inlet).

2- There are many readily available programs (such as HEC-1) that utilize this methodology.

general, the rational method is recommended for small, highly impervious drainage areas ch as parking lots and roadways draining into inlets and gutters; and the USGS regression uations are recommended for drainage areas with characteristics within the ranges given for e equations (USGS, 2009).

i. The USGS equations should be used with caution when there are significant storage areas within the drainage basin or where other drainage characteristics indicate that general regression equations might not be appropriate; and

i. The TVA regression equations are used for storm water system design choosing the more conservative solution from between the results of the applicable USGS regression equation and the TVA regression equation.

1.2 Rainfall Estimation

any hydrologic analysis, the estimate of rainfall on a site for a given period of time can be uantified using the following characteristics:

i. *Duration (hours)* – Length of time over which rainfall (storm event) occurs;

ii. *Depth (inches)* – Total amount of rainfall occurring during the storm duration; and

ii. *Intensity (inches per hour)* – Rate of rainfall or depth divided by the duration the frequency of a rainfall event is the recurrence interval of storms having the same duration and volume (depth). This can be expressed either in terms of *exceedance probability* or *return period*.

iv. *Exceedance Probability* – Probability that a storm event having the specified duration and volume will be exceeded in one given time period, typically 1-year.

v. *Return Period* – Average length of time between events that have the same duration and volume (USGS, 2009).

Thus, if a storm event with a specified duration and volume has a 1% chance of occurring in any given year, then it has an exceedance probability of 0.01 and a return period of 100-years. A design storm event over 24-hours with a 1% chance of occurring in any given year is often referred to as the 100-year, 24-hour storm. This design storm would be developed based on assumptions regarding intensity and distribution of the storm over the specified timeframe (24-hours for this would be very unlikely that an actual storm event would match up with all of the design storm event assumptions)

2.1.3 Runoff determination

A popular approach for determining the peak runoff rate is the Rational Formula. The Rational Method considers the entire drainage area as a single unit and estimates the peak discharge at the most downstream point of that area. The Rational Formula follows the assumptions that:

i. the rainfall is uniformly distributed of the entire drainage area and is constant over time;

ii. the predicted peak discharge has the same probability of occurrence (return period) as the used rainfall intensity (I);

iii. peak runoff rate can be represented by the rainfall intensity averaged over the same time period as the drainage area's time of concentration (tc); and

iv. The runoff coefficient (C) is constant during the storm event.

When using the Rational Method some precautions should be considered:

i. in determining the C value (runoff coefficient based on land use) for the drainage area, hydrologic analysis should take into account any future changes in land use that might occur during the service life of the proposed facility;

ii. If the distribution of land uses within the drainage basin will affect the results of hydrologic analysis (e.g., if the impervious areas are segregated from the pervious areas), the basin should be divided into sub-drainage basins. The single equation used for the Rational Method uses one composite C and one tc value for the entire drainage area; and,

iii. The charts, graphs, and tables included in this section are given to assist the engineer in applying the Rational Method. The engineer shall use sound engineering judgment in applying these design aids and shall make appropriate adjustments dictate that these adjustments are appropriate.

2.1.4 Rational method equations

The Rational Method estimates the peak rate of runoff at a specific watershed location as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration, tc. The tc is the time required for water to flow from the most remote point of the basin to the location being analyzed.

The Rational Method is expressed in Equation below:

$$Q = CIA \qquad 2.1$$

Where:

Q = maximum rate of runoff (cfs)

C = runoff coefficient representing a ratio of runoff to rainfall

I = average rainfall intensity for a duration equal to the tc (in/hr)

A = drainage area contributing to the design location (acres)

Runoff Coefficient

The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the design engineer. While engineering judgment will always be required in the selection of runoff coefficients, typical coefficients represent the integrated effects of many drainage basin parameters.

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surfaces in the drainage areas by using percentages of different land uses. In addition, more detailed composites can be made with coefficients for different surface types such as rooftops, asphalt, and concrete. The composite procedure can be applied to an entire drainage area or to typical "sample" blocks as a guide to the selection of reasonable values of the coefficient for an entire area. It should be remembered that the Rational Method assumes that all land uses within a drainage area are uniformly distributed throughout the area. If it is important to locate a specific land use within the drainage area, then another hydrologic method should be used where hydrographs can be generated and routed through the drainage system. Using only the impervious area from a highly impervious site (and the corresponding high C factor and shorter time of concentration) can in some cases yield a higher peak runoff value than by using the whole site. Peak flow calculations can be underestimated due to areas where the overland portion of flow is grassy (yielding a longer tc) (UHHD, 2006).

Less frequent, higher intensity storms may require modification of the coefficient because infiltration and other losses have a proportionally smaller effect on runoff (Wright – McLaughlin Engineers, 1969). The adjustment of the Rational Method for use with major storms can be made by multiplying the right side of the Rational Formula by a frequency factor Cf. The Rational Formula for major storm events now becomes:

$$Q = C_f CIA \qquad 2.2$$

The rainfall intensity (I) is the average rainfall rate in in/hr for a selected return period that is based on a duration equal to the time of concentration (tc).

2.1.5 Time of Concentration

Use of the Rational Method requires calculating the time of concentration (tc) for each design point within the drainage basin. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I). The basin time of concentration is defined as the time required for water to flow from the most remote part of the drainage area to the point of interest for discharge calculations (UHHD, 2006). The time of concentration is computed as a summation of travel times within each flow path as follows:

$$t_c = t_{11} + t_{22} + t_m \qquad 2.3$$

Where:

t_c = time of concentration (hours)

t_t = travel time of segment (hours)

m = number of flow segments

Time of concentration calculations are subject to the following limitations:

1. The equations presented in this section should not be used for sheet flow on impervious land uses where the flow length is longer than 50 feet.
2. In watersheds with storm sewers, use care to identify the appropriate hydraulic flow path to estimate tc.

Two common errors should be avoided when calculating time of concentration. First, in some cases runoff from a highly impervious portion of a drainage area may result in a greater peak discharge than the calculated peak discharge for the entire area. Second, the designer should consider that the overland flow path does not necessarily remain the same when comparing redevelopment and post-development areas. Grading operations and development can alter the overland flow path and length. Selecting overland flow paths for impervious areas that are greater than 50 feet should be done only after careful consideration. For typical urban areas, the time of concentration consists of multiple flow paths including overland flow, shallow concentrated flow and the travel time in the storm drain, paved gutter, roadside ditch, or drainage channel (Knox County, 2006).

Overland Flow:

Overland flow in urbanized basins occurs from the backs of lots to the street, across and within parking lots and grass belts, and within park areas, and is characterized as shallow, steady and uniform flow with minor infiltration effects. The travel time (Tt) for overland flow over plane surfaces for distances of less than 300 lineal feet (100 feet for paved surfaces) can be calculated using Manning's kinematic solution (Knox county,2006), shown in Equation 2.4

$$T_t = \frac{0.07(nL)^{0.8}}{(P_2)^{0.5}S^{0.4}} \qquad 2.4.$$

Where:

Tt = travel time (hours)

n = Manning's roughness coefficient

L = flow length (ft)

P_2 = 2-year 24-hour rainfall (inches)

S = ground slope, (ft/ft)

Additionally, the SCS lag equation is an acceptable method for calculating the time of concentration for overland flow (T_c) based on watershed lag time (T_L). T_L is defined as the ime between the centers of mass of excess rainfall to the time of peak runoff (similar to an average flow time for a small homogeneous area) (Guo, 2006).

The following equations can be used to determine T_c:

$$T_c = 1.67T_L \qquad \textbf{2.5}$$

Where:

T_C = time of concentration of overland flow portion of flow path (hours)

T_L = NRCS lag time (hours)

$$T_L = \frac{L^{0.8}\ (S+1)^{0.7}}{1900{W_S}^{0.5}} \qquad \textbf{2.6}$$

Where:

T_L = SCS lag time (hours)

L = flow length for sheet flow over the surface (feet)

S = potential maximum soil retention (inches) = 1000/CN-10

Ws = average ground surface slope as a percentage (%)

2.1.6 SOIL

Soil classifications are based on the distribution and behavior of fine-grained (passing No. 200 sieve) and coarse-grained (retained No. 200 sieve) soil constituents, as described in ASTMD 2487 and D 2488 of 2009. These procedures employ visual examination and simple manual tests to identify soil characteristics, which are then included in the material description. For example, estimates of grain-size distribution by visual examination indicate whether the soil is fine-grained or coarse-grained. Manual tests for dry strength, dilatancy, toughness, and plasticity indicate the type of fine-grained soil. Organics are generally identified by their color, odor, and spongy feel. The general descriptive sequence for soil materials is listed below. As a minimum, the first seven items should be included on the exploration logs (ASTM, 2009).

i. Soil Name
ii. USCS Designation
iii. Color
iv. Plasticity
v. Moisture
vi. Consistency/Relative Density
vii. Texture
viii. Cementation
ix. Structure
x. Other Constituents/Characteristics (unit weight, sensitivity, etc.)
xi. Origin

2.1.7 Soil Type

To describe a soil, the Soil Engineer should determine whether the soil is predominantly fine or coarse grained. A mixed-grained soil, which contains both fine and coarse-grained constituents, is categorized by determining its predominant engineering behavior. The procedures for describing and classifying fine-grained and coarse-grained soils are as follows:

i. Fine-grained Soils - Fine-grained soils are described by their engineering behavior considering characteristics such as dilatancy, dry strength, toughness, dispersion, and plasticity. The index tests used to determine these characteristics are described in

ASTMD 2488. Examples of soil descriptions based on index tests are shown on Figure 9-3. Figure 9-4 summarizes the sub classification order for fine-grained soils. For example, a soil that contains 80% fine-grained constituents (medium dry strength, slow dilatancy, medium toughness, low plasticity) and 20%sand would be described as "clayey silt with some sand (ASTM, 2009).

ii. Coarse-grained Soils - Coarse-grained soils are described based on an estimation of particle-size distribution. Where no constituent exceeds 50% of the total sample, the coarse-grained constituent having the largest percentage becomes the primary constituent. If the soil contains no discernable fines, then the soil is described as "clean." Where the secondary or additional constituent is fine-grained, the term "clay" or "silt" is selected based on the predominant plasticity characteristics from index tests. For example, a soil with 48%sand, 42%gravel, and 10%fine-grained constituents (non plastic, low dry strength) would be described as "gravelly sand with some silt." (ASTM, 2009)

iii. Organics - Organics can generally be identified by their distinctive dark color and by their spongy feel. Fresh, wet organic soils usually have a distinctive odor of decomposed organic matter. This odor can be made more noticeable by heating the wet sample. The estimated percent and type of organic material present should be included as part of the visual sample description. The percentage of organics or any other constituent in a sample can be estimated visually by comparing the sample to standardized volume percentage charts. Based on the percentage of organics present, the material classification is as follows: Peat 50 to 100% Primary Constituent (ASTM, 2009)

CHAPTER THREE

.0 MATERIALS AND METHODS

.1 Study Area

The Federal University of Technology permanent site is known to have a total land mass of eighteen thousand nine hundred hectares (18,900 ha) which is located along kilometer 10 Minna – Bida Road, South – East of Minna under the Bosso Local Government Area of Niger State. It has a horse – shoe shaped stretch of land, lying approximately on longitude of 06^0 28’ E and latitude of 09^0 35’ N. The site is bounded at Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga. The entire site is drained by rivers Gwakodna, Weminate, Grambuku, Legbedna, Tofa and their tributaries. They are all seasonal rivers and the most prominent among them is the river Dagga. The most prominent of the features are river Dagga, Garatu Hill and Dan Zaria dam (Musa, 2003).

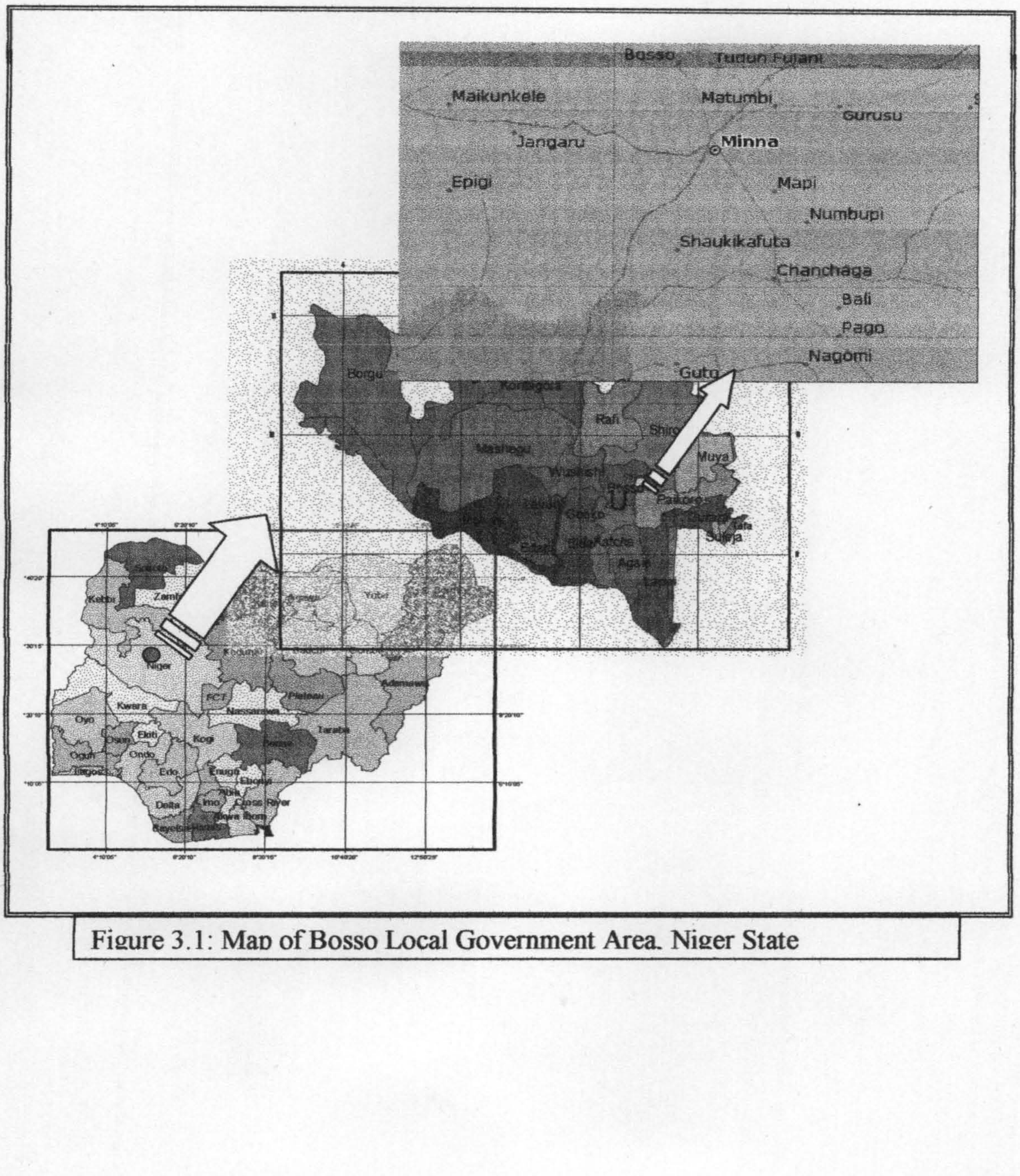
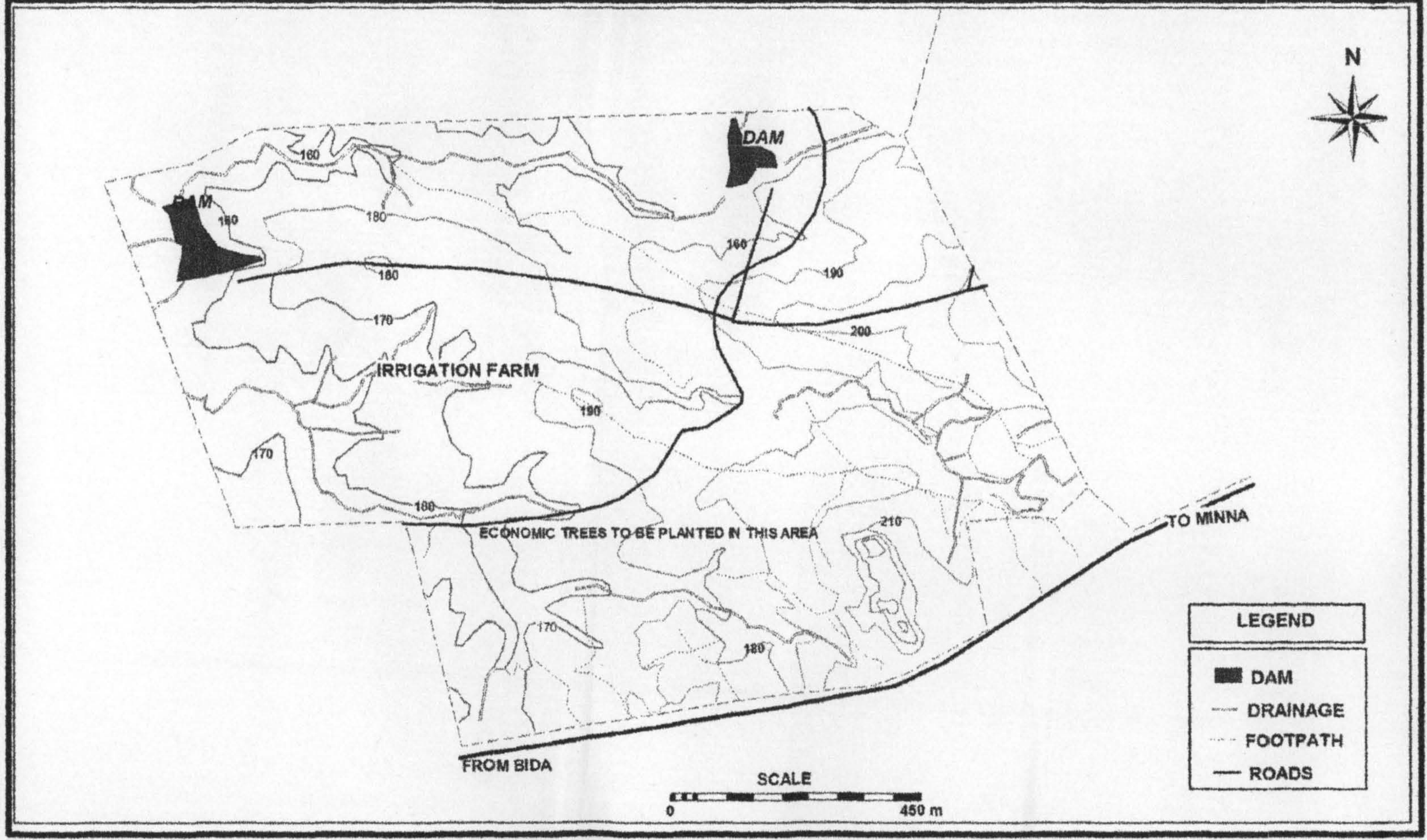


Figure 3.1: Map of Bosso Local Government Area, Niger State

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA PERMANENT SITE FARM



3.1.1 Vegetation and Land Use

Minna falls within the semi-wood land or tree forest vegetation belt with derived dry grass or shrub land known as the southern guinea savannah. This is also known as the transition belt, which lies between the savannah grass/shrub land of the north and the rain forest of the south. Due to intensive fallow type of agricultural practice and grazing of the land, the area is dominated by stunted shrubs; interspersed with moderate height tree and perennial foliage. Similarly, due to human activities and land use abuse which is characteristic of most expanding urban centre in Nigeria, the site is fast losing its remaining tree species to development. Along some river course and lowland areas, the vegetation is more wooded and resembles some forest affinities. The area is still being used as farm and grazing land by the residents of Minna and her environs (Musa 2003).

3.1.2 Climate

3.1.2.1 Rainfall

Minna generally is known to experience rainfall from the month of May to the month of October and on rear occasions, to November. It is known to reach its peak between the months of July and August. Towards the end of the rainfall season, around October, it is known to be accompanied by great thunder storms (Musa, 2003).

3.1.2.2 Temperature

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

3.1.3 Soils of the Area

The major soil found in this area is the sandy loam type with a sparse distinction of the sandy–clay soil and sandy soils. This has so far encouraged the residents of Minna metropolis and neighboring villagers to use the land for agricultural activities such as farming and grazing by the nomadic cattle rearers (Musa, 2003).

3.2 Field Topography and Configuration

This information requires that a surveying instrument be used to measure elevations of the principal field boundaries (including dykes if present), the elevation of the water supply inlet (an invert and likely maximum water surface elevation), and the elevations of the surface and subsurface drainage system if possible. These measurements need not be comprehensive or as formalized as one would expect for a land-leveling project (Oyebode, 2010).

The field topography and geometry measurement requires placing a simple reference grid on the field, usually by staking, and then taking the elevations of the field surface at the grid points to establish slope and slope variations. Usually one to three lines of stakes placed 20-30 meters apart or such that 5-10 points are measured along the expected flow line will be sufficient. The survey establishes the distance of each grid point from the field inlet as well as the field dimensions (length of the field in the primary direction of water movement as well as field width).

3.3 Infiltration measurement

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

Water was collected from the nearby storage tank using buckets. The water was therefore poured into the infiltrometer compartments simultaneously and as quickly as possible. As soon as the buckets are emptied, the water level from the inner cylinder was read from the float (rule) and the local time was noted. Repeated readings were taken at intervals of 0 minute, 1 minute, 2 minutes, 5 minutes, 10 minutes, 15 minutes, 20 minutes 30 minutes, 45 minutes, 60 minutes, 75 minutes, 90 minutes, 100 minutes and finally at 180 minutes.

3.3.1 Description of the Infiltrometer Equipment

The infiltrometer rings were rolled iron sheet of 12-guage steel and the diameters of the inner and outer rings were 300 mm and 600mm, respectively as suggested by Bambe (1995) and also by Swartzendruber and Oslo (2001). They both have a height of 250mm and the bottom ends of the ring were sharpened for easy penetration into the soil (Oyebode, 2010).

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

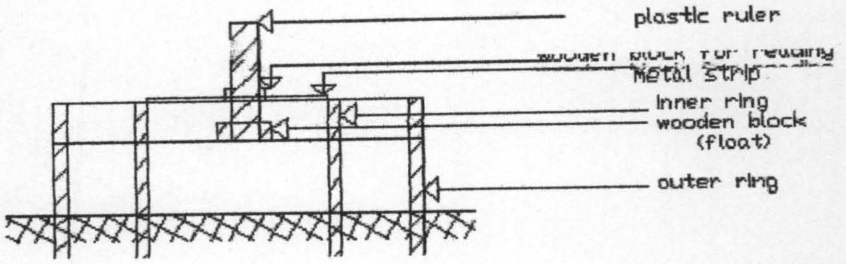


Figure 3.3: A Dissected Double Ring infiltrometer.

3. 4 Runoff Plots and Site Set-up

The exact size of each plot was the estimated size of the catchment planned for the study. Smaller dimensions were avoided, since the results obtained from very small plots are rather misleading.

Care was taken to avoid sites with special problems such as rills, cracks or gullies crossing the plot. These would drastically affect the results which would not be representative for the whole area. The gradient along the plot was regular and free of local depressions.

During construction of the plots, one out of the two plots was undisturbed and the other plot was thoroughly disturbed. A disturbed plot is one in which the structure of the soil has been changed sufficiently that test of structural properties of the soil will not be representative of in-situ conditions only properties of the grains (e.g grain size distribution, atterberg limits, and possibly the water content) can be accurately determined. An undisturbed plot is one where the condition of the soil in the plot is close enough to the condition of the soil in-situ to allow tests of structural properties of the soil to be approximate to the properties of the soil in-situ. Care was taken not to disturb or change the natural conditions of the plots such as destroying the vegetation or compacting the soil for the undisturbed soils while for the disturbed soils, every form of shrubs present on the plots were removed and the plot completely cleared of grasses.

The two project sites had a dimension of 6 X 3m each on vary slope measurements. The plots were prepared in March of 2011. Around the edge of each plot, long plywood which does not leak was placed, following the direction of the slope in a rectangular pattern to permit only runoff delivery and sediment within the experimental plot. The plywood extends 20cm above the ground surface and 10cm below the ground surface. A broad collector 1.2m long and 30cm wide was placed at the base of each of the plots to collect all the runoff and sediment produced during the simulated rain event. On the collector are spouts (15cm in diameter) through which runoff delivery empties into a collecting tank (250 liters) installed in pits just below ground level. Placed over the spout is a mesh to collect the sediment.

The plots were categorized into the disturbed and undisturbed soils for the various types of soils available within the Federal University of Technology, Minna Niger State. Records of rainfall depth for each storm were taken using a locally constructed rain-gauge.

3.5 Method of Measurement

3.5.1 Runoff Delivery and Sediment Load

After each simulated rainfall event, runoff and sediment load produced are channeled through the collector placed at the lower end of the plot. The sediment loads trapped on the collector by the mesh placed over it were scooped off into a soil bag. Sediments channeled into the tank were allowed to settle after which the runoff volume was determined. The clear water was collected with a bucket and measured with a graduated container. The sediment collected at the bottom of the tank plus the sediment collected on the collector were taken for oven drying to a constant weight. The sediment weights were determined after oven drying using a weigh balance. The sample weight divided by the area of the experimental plot gives the total soil loss from the plot. The total amounts of water collected in the container were measured and the volume was compared with the total simulated rainfall intensity within the plot area.

3.5.2.1 Soil Analysis

Soil samples were collected from each plot using a hand auger. The auger was position vertically upright on the soil surface. The handle was turned clockwise until the cylinder was full. It was lifted from the hole and the content emptied into a container. The samples were taken at a depth of 20cm. The samples were labelled before taking the next sample point.

3.5.2.2 Particle Size Analysis

The hydrometer method was used for the particle size determination. A sample (50 grams) of air dry soil was weigh into a 250ml beaker. 100ml of dispersing agent (sodium pyrophosphate solution) is added to the soil sample, mixed and allowed to soak for at least 30 minutes. The suspension is mixed for about 3 minute with a mechanical stirrer before transferring the content into a sedimentation cylinder and filled to mark with distilled water. A hand stirrer was inserted into the sedimentation cylinder to mix the content thoroughly and the time of completion of stirring was noted. A hydrometer is carefully lowered into the suspension and reading was taken after 40 seconds (R_{40}). The sands settles in about 40 seconds (silt and clay remains in suspension) and a hydrometer reading taken 40seconds determined the grams of silt and clay remaining in suspension. The hydrometer was removed and the temperature of the suspension was taken using a thermometer. The suspension was disturbed. Two hour after the final mixing of the suspension sand and silt would have settled (only clay remains in suspension). Another hydrometer and temperature reading was taken (R_{2hrs}). A blank sample containing 100ml of dispersing agent and 1 liters of distilled water was measured into a cylinder. The hydrometer was lowered into the solution carefully and readings were taken after 40 seconds (R_a) and readings after two hours (R_b). After the hydrometer readings have been obtained, the soil water mixture is poured over a screen to remove the entire sand fraction. The separated soil Percentage is calculated from

$$\% \text{ Sand} + \text{loamy} = \frac{(\text{Reading after forty seconds} - R_a) + R_c}{\text{Weight of soil}} \text{ X } 100 \qquad 3.22$$

$$\% \text{ loamy} = \frac{(R_{2hrs} - R_b) + R_d}{\text{weight of soil}} \times 100 \qquad 3.23$$

Where

R_a= 40 sec, blank hydrometer reading

R_b= 2 hr, blank hydrometer reading

R_c = 40sec (Temperature × 0.360)

R_d = 2 hr correction factor (temperature × 0.36)

W = weight of soil sample used.

3.5.2.3 Soil Textural Class

The textural class was determined from the particle size analysis. After determining the distribution of sand, silt and clay from the particle size analysis, the soil was assigned a textural class based on the textural triangle. Within the textural triangle is various soil textures which depends on the relative proportion of soil particles.

3.5.3 Moisture Content

The weight of a clean and well labelled can was taken using a weigh balance. Soil clod was added into the can after which the weight was taken. The difference in weight between the weight of can plus clod and the weight of the can is the wet weight of the soil. The can containing the clod were taken to the laboratory for oven-drying to a constant weight at 104 ^{0}C. The can was removed from the oven, allowed to cool for several hours. After cooling the weight of the can containing the soil was taken. Weight of the dry soil is the difference in weight between the weight of the can plus soil after oven drying and the weight of the can. The moisture content was calculated as:

$$\%\,MC = \frac{\text{loss in weight}}{\text{weight of soil after drying}} \times 100 \qquad 3.24$$

$$MC = \frac{W_w - W_d}{W_d} \times 100\,\% \qquad 3.25$$

Where

W_w= weight of wet soil (g)

W_d=weight of dry soil (g)

3.5.4 Bulk density measurement

Core sampler is commonly used to take undisturbed soil samples. The cylinder of the core sampler, which has it cutting edge, is driven into the soil and uncompacted core obtained within the tube. The samplers were carefully trimmed at both ends. Empty labelled cans were weighed, they were then filled with soil core samples and weight again and were oven dried at 110°C for about 24hrs, and samples were again weighed.

Bulk density was determined as follows;

$\rho_b = Ms/Vs$

Where;

ρ_b= bulk density (g/cm^3).

Ms = mass of dry soil (g).

Vs = volume of soil (cm^3).

CHAPTER FOUR

DISCUSSION OF RESULT

4.1 Properties of sandy clay soil

4.1.1 Analysis of soil characteristics

The characteristics of the soil were analyzed in order to obtain the soil properties for the various land cover types. The analyzed soil was collected some centimeters below the test plot used. Each soil type has different properties and specific ranges in soil particle sizes.

Based on the USDA and FAO Classification, sand as a soil separately consist of mineral soil particles that are 0.05m to 2mm in diameter, silt as a soil consist of mineral soil particles that are 0.002mm to 0.05mm in diameter, clay as a soil separately consists of mineral soil particles that are less than 0.002mm in diameter. The content of sand, silt and clay affects the physical behavior of soil. Particle size is important is important for engineering agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification. The textural classification of soil shown in Table 4.1.It was observed that at a depth of 0-20cm, the composition of the soil was 49% sand, 6% silt and 45% clay which gave a sandy clay soil type. At a dept of 20-110cm, it was observed that varying percentages of sand, silt and clay were gotten which gave a result of clay soil.

4.1.3 Bulk density of sandy clay soil

The bulk density of sandy clay soil is the measure of the weight of soil (oven dried) per unit volume. The volume is measured when the soil is at field moisture capacity. The bulk density was determined by sampling soil 5-cm depth with core sampler measuring ranging between 90-95cm^3. The soil sample was oven-dried for 24 hours at 105°C. Determination of the bulk density is as calculated below (Gordon *et al.* 1993). The results of the bulk density at varying depths are presented in Table 4.1 which ranges between 1.23264 and 1.31392 which implies that as the bulk density increases, the surface runoff reduce.

Table 4.1 Textural properties of representative soil units in Gidan Kwano and its average corresponding bulk density

Horizon	Depth (cm)	% sand	% silt	% clay	Soil type	Bulk Density (g/cm^3)
O	0-20	49	6	45	Sandy Clay	1.31392
A	20-50	39	5	56	Clay	1.26192
B	50-75	34	16	50	Clay	1.26896
C	75-110	24	20	56	Clay	1.23264

4.2 The Slope

The slope of the area under study is a function of the length and gradient. It was observed that increase in soil loss occurs more when the slope is steeper than with slope length. Topography plays a major role in predicting time of concentration has been seen to important especially in areas of low topography. The time of concentration increases to infinity when slope decreases to zero. The slope topographical factor depends on both the length and gradient of slope of the area under study.

Table 4.2: Average slope (degree) of the various types of soil areas

Plot No	Undisturbed Sandy Clay	Disturbed Sandy Clay
1	3.17	2.17
2	2.13	2.13
3	2.00	2.00
4	2.17	2.17
5	2.17	2.17
6	2.73	3.83
7	2.00	2.00
8	2.00	2.00
9	2.17	2.17
10	2.00	3.00
Average slope (degree)	2.25	2.36

4.3 Time of concentration

The time of concentration is defined as the time required for water to flow from the most remote part of the drainage area to the point of interest for discharge calculations. The time of concentration is computed as a summation of travel times within each flow path as follows:

$$t_c = t_{t1} + t_{t2} + t_m \qquad \textbf{4.1}$$

Where:

t_c = time of concentration (hours)

t_t = travel time of segment (hours)

m = number of flow segments

The maximum time of concentration for disturbed sandy clay soil is 51.11minutes while the minimum is 43.25minutes,hence the average time of concentration is 46.53min.For undisturbed, the maximum is 48.10min and the minimum is 39.25min.

The average time for 0.25m^3 container to be filled up for each plot considered for this research work for clay soil in dry season is shown in table 4.5 below.

Table 4.3 Average time for a 0.25 m^3 container to be filled up for each plot observed under sandy clay type of soil condition during the dry season

Plot No	Undisturbed Sandy Clay	Disturbed Sandy Clay
1	48.10	51.11
2	44.23	47.28
3	47.45	50.35
4	46.37	48.22
5	42.28	47.18
6	40.47	43.57
7	38.55	42.55
8	43.28	46.45
9	42.38	45.38
10	39.25	43.25
Average T_d (Mins)	43.24	46.53

Where Td is the Time taken to fill a drum of 0.25 m^3 capacity

4.4 Infiltration Rate

The processes involved in agricultural development entail identifying the constraints affecting agricultural production and subsequently putting in place solutions which may be technical or management to such a problem. It is essential to investigate the issue of poor infiltration of water into some soils in places where major or even minor construction of agricultural projects are to be carried out within the country. Thus, soil compaction and its effects on crop growth has been the focus of researches carried out in the past decade.

Table 4.4a and 4.4b presents the infiltration rate for disturbed and undisturbed soils for the sandy clay soil of the plots on which the experiment is being carried out within the Gidan Kwano campus of the Federal University of Technology, Minna while table 4.4c and 4.4d presents the regression analysis of infiltration rate of sandy clay soil and regression analysis of cumulative infiltration of the soil under test respectively.

Generally, infiltration rate shows a sharp decline with time from the start of application of water. A constant rate is approached after a sufficiently large time; this is referred to as the steady-infiltration rate as observed in Table 4.4a and 4.4b respectively. The infiltration rate was being measured using the double ring infiltrometer on all the areas were the soil type of study was collected.

The double-ring infiltrometer consisting of two concentric rings; the rate of fall of water was measured in the inner ring while a pool of water was maintained at approximately the same level in the outer ring to reduce the amount of lateral flow from the inner ring. Three double-ring infiltrometer were set up at each site. The diameters of the inner rings were 300 mm and the outer diameters were 600 mm. Rings were 250 mm deep and were made from 12-guage steel with sharpened bottom edges; they were driven into the ground to 50 mm depth. In areas where grasses exited they were cut to near soil level and a pad was placed inside the inner ring to prevent puddling; care was taken while cutting the grasses of where the infiltration test was to be conducted so as not to uproot them. The inner and outer edges were tamped to seal possible cracks in the soil. The minimum water level was kept within the range of 20 mm and 50 mm depth; the height difference between the inner and outer rings was kept to a minimum.

It was observed that there is a difference in the suction head of the soil; thus when the infiltration rate was been carried out, the top layer of the soil became wetter than the lower layers. Due to the difference in the suction head, downward forces (due to the suction head or capillary effect and pressure head or moisture gradient from the saturated top layer) with the gravity force will act on the water and force the water to infiltrate into the soil. At the start of the infiltration, the downward forces are large compared with the flow resistance of the soil thus water enters the soil rapidly. As the time of infiltration increases, the resistance that is caused by swelling of the various soil particles and entrapped air increases. Therefore, there is not much difference between the values of downward forces and thus the rate of infiltration reduces. When the downward forces and resistance have equalized, the rate of infiltration becomes constant and stabilizes. The results presented in Tables 4.4a to 4.4d shows that the infiltration rate varies from one soil to another. The sandy soil had the highest rate of infiltration rate of 24 cm/hr for dry seasons while disturbed loam soil had the lowest infiltration rate for dry season. The soil properties and slope may be contributing factors.

Table 4.4 and 4.5 shows that the basic intake rate is almost similar within the soil profiles representing this zone and the values of infiltration rate ranged from 8.40 to 20.40 cm/hr while the cumulative infiltration ranging between 9.60 and 11.43 cm. This period is classed as the high infiltration period as the moisture content for the various soils were extremely low thus giving room for high rate of water intake. Though, in some of the soils, it was observed that water intake rate reached its climax under 3 hours which could be as a result of the nature of the underlay of soil and the shallow depth of the water table. Such was observed in undisturbed sandy loam soil and disturbed clay soil.

Table 4.4a Average Cumulative infiltration of sandy clay types of soils under the disturbed and undisturbed condition during the dry season

Time (Mins)	Undisturbed Sandy Clay	Disturbed Sandy Clay
0	0.00	0.00
1	3.10	1.00
2	5.50	2.50
5	7.00	4.35
10	9.10	6.90
15	11.00	8.45
20	13.10	10.55
30	15.10	12.80
45	17.20	15.05
60	18.00	17.75
75	19.30	18.85
90	20.00	19.75
100	20.20	20.05
120	21.00	20.90
150	21.40	21.15
180	21.40	21.15
Average cumulative infiltration	13.90	12.58

Table 4.4b Average Cumulative infiltration of the various types of soils under the disturbed and undisturbed condition during the dry season

Time (Mins)	Undisturbed Sandy Clay	Disturbed Sandy Clay
0	23.50	24.00
1	20.40	23.00
2	18.00	21.50
5	16.50	19.65
10	14.40	17.10
15	12.50	15.55
20	10.40	13.45
30	8.40	11.20
45	6.30	8.95
60	5.50	6.25
75	4.20	5.15
90	3.50	4.25
100	3.30	3.95
120	2.50	3.10
150	2.10	2.85
180	**2.10**	**2.85**

Table 4.4c Regression analysis of Infiltration rates for sandy clay soils of Gidan Kwano

Type of Soil and condition of soil		Seasonality values of R^2	Seasonality equation of the form Y = Mx +C
Soil	Condition	Dry	Dry
Sandy Clay	Undisturbed	0.715	$Y = -0.104X + 15.51$
	Disturbed	0.771	$Y = -0.119\ X\ 18.16$

Table 4.4d Regression analysis of cumulative infiltration for the various soils of Gidan Kwano

Soil		R^2	
Soil	Condition	Dry	Dry
Sandy Clay	Undisturbed	0.715	$Y = 0.104X + 7.984$
	Disturbed	0.771	$Y = 0.119X + 5.838$

4.5 Moisture Content

The critical moisture content of the soils was determined by collecting the wet soil samples at the start of the surface runoff. This was derived by weighing the samples, after which they were being placed inside electric oven at a temperature of about 104-105° Celsius. At the sites where the soil samples were collected and taken to the standardized plots, the observed moisture content are presented in Tables 4.8. The moisture content samples were collected between 0 and 60 mm depth. It was observed that during the dry season, the moisture content was lower when compared with that of the wet season.

It was observed that the difference in the soil moisture content during the wet and dry season may be due to the lost of moisture through evapotranspiration. The water percolates to the various underground water bodies around the study area; the soil becomes drier and in some cases caked to form a hard clod. Another factor that influences the moisture level is the degree of slope of the study area which aids the surrounding water bodies, steeper slopes usually experience a rapid movement of water provided where there final destination is not saturated; and does not experience any form of water logging or the soils are not tightly packed together which reduces the rate of movement of water to the barest minimum. Other possible effect may come from the surrounding farm lands which have been heavily compacted as a result of the various forms (vehicular and human) of movement which might have created a hard pan in some of these areas or the presence of an underlying rock in some of the study areas which do not allow the passage/infiltration of water to move down the soil profile but horizontally or even above the soil surface as surface runoff. This played a very important role in the determination of the model for the various soils considered.

Plot No	Undisturbed Sandy Clay	Disturbed Sandy Clay
1	4.26	4.93
2	4.15	3.96
3	4.90	4.20
4	4.78	3.87
5	4.77	4.02
6	4.72	4.38
7	5.42	3.43
8	5.04	3.98
9	4.13	3.90
10	3.59	4.62
Average Mc	4.58	3.54

4.6 Developing Manning-Nigeria Coefficients

With reference to the model develop in 1986 by Papadakis and Kazan from the Navier-Stokes equations, and the reason for this adoption is to establish and allow the simulation of sheet flow over the surface of the land. . The overall slope of the land was fixed at 3% with a standard length of 6m to imitate the situation explored in the problem statement.

The model discussed above has the following variables of

i. length of the watershed,

ii. surface roughness (usually Manning's n),

iii. slope of the watershed, and

iv. Rainfall intensity.

The model is expressed as:

$$T_c = kL^a n^b S^{-y} i^{-z} \qquad \textbf{4.2}$$

Where T_c is the time of concentration, *L* is the watershed length, *n* is Manning's n, *S* is the watershed slope, and *i* is the rainfall intensity. k is a constant and a, b, y, z are exponents. This equation exhibits a linear correlation of the logarithms of the variables involved. It was observed that the antecedent soil moisture had a strong influence on the surface runoff travel time for the two seasons considered. Using the above model as the baseline model, Cahill and Li (2005) added the antecedent soil moisture variable to create a new model. It is expressed as:

$$T_c = kL^a n^b \theta^{-x} S^{-y} i^{-z} \qquad \textbf{4.3}$$

The included variable Θ is the soil moisture and x is a exponent of Θ. It was observed that the above equation was more complicated than the Saint-Venant equations (the Saint-Venant equations are a simplification of the Navier-Stokes equations). The empirical mathematical method and Crammer's rule was adopted to determine the various exponents for the Manning-Nigeria coefficient. Details of the mathematical calculation are attached in the appendix.

Using the FAA Equation that

$$T_c = 1.8(1.1 - c)\left(\frac{L^{0.5}}{S^{0.33}}\right) \qquad Take\ C\ to\ be\ (0 - 1) \tag{4.4}$$

From the above equation, the new time of concentration was arrived at.

The model developed for this study is stated below as:

$$T_c = 0.938L^{0.878}n^{0.324}\theta^{-0.222}S^{-0.049}i^{-0.075} \tag{4.5}$$

where T_c is the time of concentration in minutes, L is the watershed length of the study area in meters, n is Manning-Nigeria's n, θ is the antecedent soil moisture in percent, S is the watershed slope, and i is the rainfall intensity in mm/hr.

From equation 4.3, making n our subject of formula we have that

$$n^{0.324} = \frac{T_c}{0.938L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075}} \tag{4.6}$$

Thus making n the subject of the formula from the above equation 4.4, the formula now becomes:

$$Logn = \frac{LogT_c - 0.938Log(L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075})}{0.324} \tag{4.7}$$

Equation 4.5 above was used to determine the Manning-Nigeria coefficient for sandy clay soils considered in this study and then compared with the model developed by Cahill and Li (2005) and Kerby (1959). The model developed by Cahill and Li (2005) states that

$$T_c = 0.951\,.\,L^{0.5}\,.\,n^{0.326}\,.\,\theta^{-0.459}\,.\,S^{-0.053}\,.\,i^{-0.674} \tag{4.8}$$

Making n the subject of the formula from equation 4.6, we now have

$$Logn = \frac{LogT_c - 0.951Log(L^{0.5}\theta^{-0.459}S^{-0.053}i^{-0.674})}{0.326} \tag{4.9}$$

But the model developed by Kerby in 1959 states that $T_c = \frac{0.83(nL)^{0.467}}{\sqrt{S}}$ thus making n the subject of formula; we cross multiply to now have

$$T_c \times S^{0.5} = 0.83(nL)^{0.467} \qquad \textbf{5.0}$$

Making n the subject of the formula from the above equation we now have n to be

$$\left(\frac{LogT_c + 0.5LogS + 0.081}{0.467}\right) - Log\,L = Logn \qquad \textbf{5.1}$$

Based on the data's collected from the field, the equation 4.7 and 4.9 were used to obtain the manning's Nigeria coefficient for sandy clay soil in Gidan Kwano campus of the Federal University of Technology Minna, Niger state. This new model obtain is far more better than the formal because, all data's involve and used are for Nigerian settings and Nigeria soil which makes it more reliable than the foreign coefficient. The manning Nigeria coefficients for sandy clay soil are tabulated below

Table 4.8 Manning Nigeria coefficients of sandy clay soil

		Manning-Nigeria Model	Cahill and Li Model	Kerby's Model
Type of soil	Condition of Soil	Dry	Dry	Dry
Sandy clay	Undisturbed	0.09	59.57	18.71
	Disturbed	0.11	58.21	23.01

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Components such as precipitation, infiltration and surface runoff contributions were used in the generation of runoff hydrograph predicted by the model and equations generated.

Sandy clay soil within the Federal University of Technology Minna was observed to have an average infiltration rate of 13.9cm/hr and 12.58cm/hr for undisturbed and disturbed condition of soil. This is a clear indication that the rate of movement of water into the soil is gradual and steady. This is in conformity with the works of Musa and Egherveba (2009) and that of Ahenaku (2010). It can therefore be concluded that the infiltration capacity for sandy clay soils within FUT Minna is relatively stable over the dry season.

The developed model, gave a good description of the hydrologic parameters for sandy clay soil within FUT Minna. It can also be concluded that this model can be applied to similar properties in other parts of Niger State. The NRSC best calculates the time of concentration for the study area as its covers the entire study area of the various plots within a short period of time.

The calculated time of concentration for time lag equation can be used as one of the parameters in determining the values of n (manning's coefficient).

5.2 RECOMMENDATION

To put this practical research work into use, the following are required or recommended:

1. Samples obtained should be tested or analyzed in different laboratories by different professionals and should be carried out several times, so as to make sure that the data obtained is more reliable.
2. All data's should be purely obtained from field and laboratory and should not be assumed in any case in order to get accurate result.
3. Basically, since the research work was carried out during the dry season, it's important to carry out similar research work during the raining season to see if there would be similarities or differences in the proposed result.
4. All research work (field) should be carried out within a maximum of a week to ensure accuracy of result.

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APPENDICES

```
> k := 0.935
                              k :=0.935
> t := ln(9.0)
                          t :=2.19722457
> b1 := k·(a·ln(22.90) + b·ln(0.0086) − y·t − x·ln(142.30) − c
      ·ln(22.90)) = ln(13.42)
          b1 :=2.927613012a − 4.446853526b − 2.054404979y
              − 4.635671567x − 2.927613012c = 2.596746132

> b2 := k·(a·ln(22.90) + b·ln(0.0086) − y·t − x·ln(131.67) − c
      ·ln(22.30)) = ln(13.51)
          b2 :=2.927613012a − 4.446853526b − 2.054404979y
              − 4.563079371x − 2.902788544c = 2.603430152

> b3 := k·(a·ln(22.90) + b·ln(0.0086) − y·t − x·ln(165.80) − c
      ·ln(21.10)) = ln(12.58)
          b3 :=2.927613012a − 4.446853526b − 2.054404979y
              − 4.778581397x − 2.851070292c = 2.532108251

> b4 := k·(a·ln(22.90) + b·ln(0.0086) − y·t − x·ln(220.30) − c
      ·ln(45.80)) = ln(13.26)
          b4 :=2.927613012a − 4.446853526b − 2.054404979y
              − 5.044315887x − 3.575705625c = 2.584751985

> b5 := k·(a·ln(22.90) + b·ln(0.0086) − y·t − x·ln(235.50) − c
      ·ln(41.10)) = ln(13.43)
          b5 :=2.927613012a − 4.446853526b − 2.054404979y
              − 5.106699704x − 3.474467594c = 2.597491011

> with(LinearAlgebra) :
          >
             A := [[2.927613012, −4.446853526, −2.054404979, −4.635671567,
                 −2.927613012],
                 [2.927613012, −4.446853526, −2.054404979, −4.563079371,
                 −2.902788544],
                 [2.927613012, −4.446853526 , −2.054404979, −4.778581397,
                 −2.851070292],
                 [2.927613012, −4.446853526, −2.054404979, −5.044315887,
                 −3.575705625],
                 [2.927613012, −4.446853526 , −2.054404979, −5.106699704,
                 −3.474467594]]
```

```
A := [[2.927613012 -4.446853526 -2.054404979 -4.635671567
    -2.927613012],
    [2.927613012 -4.446853526 -2.054404979 -4.563079371
    -2.902788544],
    [2.927613012 -4.446853526 -2.054404979 -4.778581397
    -2.851070292],
    [2.927613012 -4.446853526 -2.054404979 -5.044315887
    -3.575705625],
    [2.927613012 -4.446853526 -2.054404979 -5.106699704
    -3.474467594]]

> c1 := Determinant(A);
                          c1 := -1.17104520510^-9

>
  A1 := [[2.596746132 -4.446853526 -2.054404979 -4.635671567
    -2.927613012],
    [2.603430152 -4.446853526 -2.054404979 -4.563079371
    -2.902788544],
    [2.532108251 -4.446853526 -2.054404979 -4.778581397
    -2.851070292],
    [2.584751985 -4.446853526 , -2.054404979 -5.044315887
    -3.575705625],
    [2.597491011 -4.446853526 , -2.054404979 -5.106699704
    -3.474467594]]

        A1 := [[2.596746132 -4.446853526 -2.054404979 -4.635671567
            -2.927613012],
            [2.603430152 -4.446853526 -2.054404979 -4.563079371
            -2.902788544],
            [2.532108251 -4.446853526 -2.054404979 -4.778581397
            -2.851070292],
            [2.584751985 -4.446853526 -2.054404979 -5.044315887
            -3.575705625],
            [2.597491011 -4.446853526 -2.054404979 -5.106699704
            -3.474467594]]

> c2 := Determinant(A1);
                          c2 := -1.02825425010^-9

          c2
> aii := ---
          c1
                          aii := 0.878065377:
```

```
>
  A2 := [[2.927613012,2.596746132,-2.054404979,-4.635671567,
    -2.927613012],
    [2.927613012,2.603430152,-2.054404979,-4.563079371,
    -2.902788544],
    [2.927613012,2.532108251,-2.054404979,-4.778581397,
    -2.851070292],
    [2.927613012,2.584751985,-2.054404979,-5.044315887,
    -3.575705625],
    [2.927613012,2.597491011,-2.054404979,-5.106699704,
    -3.474467594]]
```

```
          A2 := [[2.927613012,2.596746132,-2.054404979,-4.635671567,
              -2.927613012],
              [2.927613012,2.603430152,-2.054404979,-4.563079371,
              -2.902788544],
              [2.927613012,2.532108251,-2.054404979,-4.778581397,
              -2.851070292],
              [2.927613012,2.584751985,-2.054404979,-5.044315887,
              -3.575705625],
              [2.927613012,2.597491011,-2.054404979,-5.106699704,
              -3.474467594]]
```

```
> c3 := Determinant(A2);
                              c3 := -3.8 10^-10
> aiii := c3/c1
                              aiii := 0.324496439
>
  A3 := [[2.927613012,-4.446853526,2.596746132,-4.635671567,
    -2.927613012],
    [2.927613012,-4.446853526, 2.603430152,-4.563079371,
    -2.902788544],
    [2.927613012,-4.446853526, 2.532108251,-4.778581397,
    -2.851070292],
    [2.927613012,-4.446853526,2.584751985,-5.044315887,
    -3.575705625],
    [2.927613012,-4.446853526 , 2.597491011,-5.106699704,
    -3.474467594]]
```

```
          A3 := [[2.927613012,-4.446853526,2.596746132,-4.635671567,
              -2.927613012],
              [2.927613012,-4.446853526,2.603430152,-4.563079371,
              -2.902788544],
              [2.927613012,-4.446853526,2.532108251,-4.778581397,
              -2.851070292],
              [2.927613012,-4.446853526,2.584751985,-5.044315887,
              -3.575705625],
              [2.927613012,-4.446853526,2.597491011,-5.106699704,
              -3.474467594]]
```

```
> c4 := Determinant(A3);
```

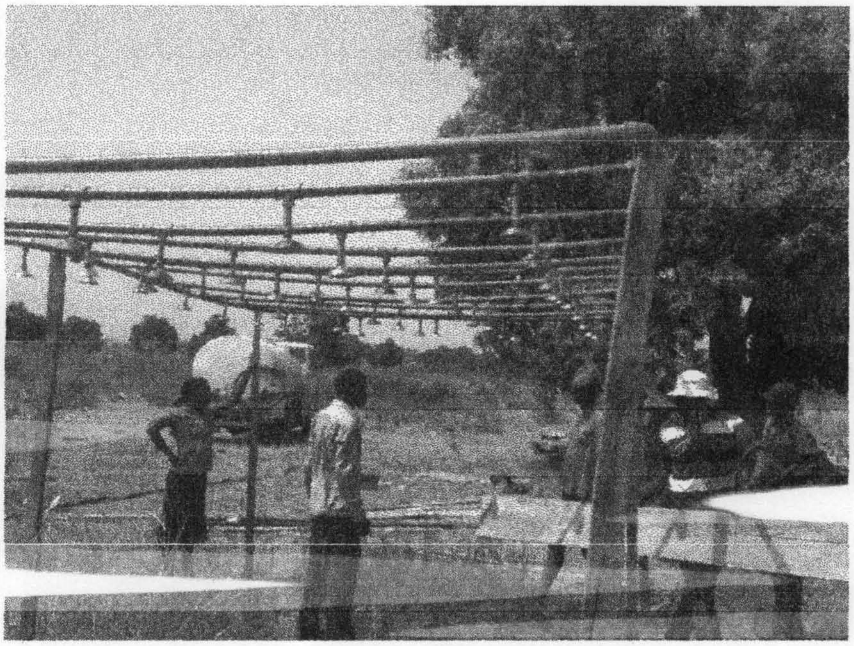
```
                                c4 := 2.6 10^-10
> aiii := c4/c1
                                aiii := -0.222023879
/
>
    A4 := [[2.927613012-4.446853526-2.0544049792.596746132
      -2.927613012],
      [2.927613012-4.446853526, -2.0544049792.603430152
      -2.902788544],
      [2.927613012-4.446853526, -2.0544049792.532108251
      -2.851070292],
      [2.927613012-4.446853526-2.0544049792.584751985
      -3.575705625],
      [2.927613012-4.446853526, -2.0544049792.597491011
      -3.474467594]]
                  A4 := [[2.927613012-4.446853526-2.0544049792.596746132
                    -2.927613012],
                    [2.927613012-4.446853526-2.0544049792.603430152
                    -2.902788544],
                    [2.927613012-4.446853526-2.0544049792.532108251
                    -2.851070292],
                    [2.927613012-4.446853526-2.0544049792.584751985
                    -3.575705625],
                    [2.927613012-4.446853526-2.0544049792.597491011
                    -3.474467594]]

> c5 := Determinant(A4);
                                c5 := 5.8552260210^-11
> aiv := c5/c1
                                aiv := -0.0499999999
>
    A5 := [[2.927613012-4.446853526-2.054404979-4.635671567
      2.596746132],
      [2.927613012-4.446853526, -2.054404979-4.563079371
      2.603430152],
      [2.927613012-4.446853526, -2.054404979-4.778581397
      2.532108251],
      [2.927613012-4.446853526-2.054404979-5.044315887
      2.584751985],
      [2.927613012-4.446853526, -2.054404979-5.106699704
      2.597491011]]

> c6 := Determinant(A5);
                                c6 := 8.78283903410^-11
```

> $av := \frac{c6}{c1}$ $A5 := [[2.927613012 - 4.446853526 - 2.054404979 - 4.635671567$
$2.596746132],$
$[2.927613012 - 4.446853526 - 2.054404979 - 4.563079371$
$2.603430152],$
$[2.927613012 - 4.446853526 - 2.054404979 - 4.778581397$
$2.532108251],$
$[2.927613012 - 4.446853526 - 2.054404979 - 5.044315887$
$2.584751985],$
$[2.927613012 - 4.446853526 - 2.054404979 - 5.106699704$
$2.597491011]]$

$$av := -0.0749999999$$

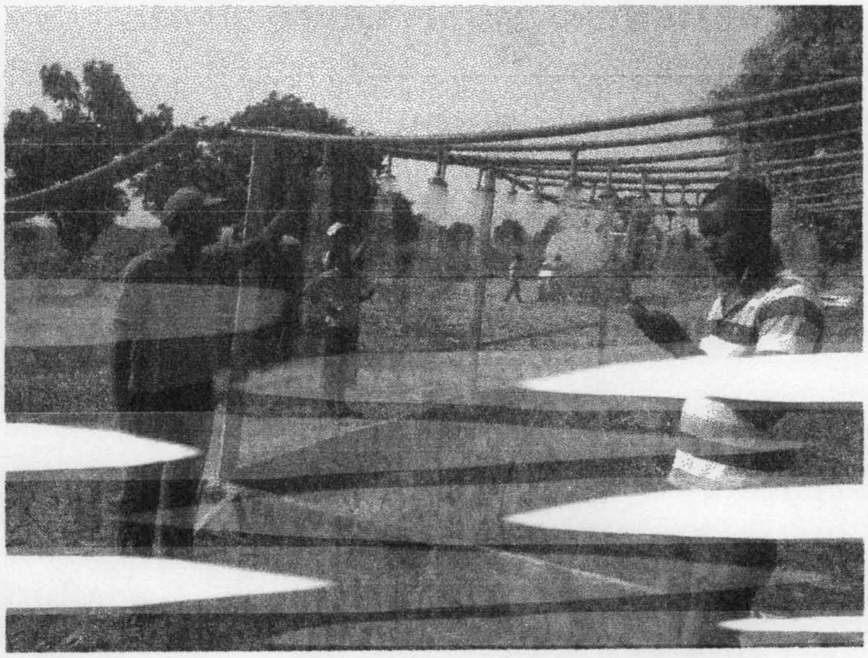
>

PLATE



SETTING UP OF MATERIAL FOR SIMULATION

SITE DURING SIMULATION I



SITE DURING SIMULATION II