HYDRAULIC PROPERTIES MODEL FOR PREDICTING SOIL WATER CHARACTERISTICS

BY

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NOVEMBER, 2006.

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A PROJECT SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING,
SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE,
NIGERIA.

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DECLARATION

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 Information derived from personal communication, published and unpublished works of others were duly referenced in the text.

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Mohammed, Jiya Mamman

9/1/2026
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Date

CERTIFICATION

This project entitled "Hydraulic Properties Model for Predicting Soill-Water Characteristics'' by Mohammed Jiya Mamman meets the regulations governing the award of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

.... 09-11-2006

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Date

DEDICATION

This work is specially dedicated to my parents, Alhaji Mohammed Tswanya and Mallama Amina Mohammed.

ACKNOWLEDGEMENTS

Special thanks are owned to Almighty ALLAH, the omnipotent, omnipresent, omniscient, the eternal, and master of the Day of Judgment for sparing my life in good health throughout my course of studies.

My unalloyed appreciation goes to my able supervisor Engr.Dr Nosa Anthony Egharevba for his untiring effort in going through this work and making necessary corrections.

I am indebted to Dr. Odofin of the Department of soil science Federal University of Technology Minna for his unique sacrifice in giving me all the necessary support and guidance to make this work see the light of the day.

My acknowledgments will not be complete without expressing my deep appreciation to my lecturers, starting from my Head of Department Engr. Dr Z.D Osunde, Prof. E.S.A Agisegiri, Engr. Dr M.G Yisa, Engr. Dr Alabadan, Engr.Dr O. Chukwu, Engr.P.A.Idah, Engr.Muhammad Bashir, Engr. Onuachu, Mrs. Hassana, Mr. Adeoye, Mr. Solomon, Mr. Olorunshogo, Mallam Isiaku, Mallam Suleman, Mr. Fabumi, for their moral support, care and inspiration. Also the support of other member of staff is highly acknowledged.

Finally my ample gratitude goes to my parent Alhaji Mohammed Tswanya and Mallama Amina Mohammed and other members of the family for their endurance, perseverance, kindness, moral and financial support and privilege given to me to attain this level of academic excellence.

ABSTRACT

This study compares laboratory measured soil water characteristics to an, American developed graphic computer programme (hydraulic properties model) which predicts soil water characteristics. Soil samples from four dug pits at different depths were obtained. Two pits at Chanchaga irrigation scheme and two pits at Federal University of Technology Minna Bosso Campus school farm, within the periods of June and July, 2006. The samples were analyzed and values for dependent and independent variables obtained. Percentage sand, percentage clay, percentage organic matter, percentage gravel, salinity and compaction are the independent variables, while wilting point, field capacity, available water, saturated hydraulic conductivity, saturation, and bulk density are the dependent variables. Salinity and percentage gravel were assumed to be zero, while compaction was assumed normal for the soils. The laboratory measured and model predicted values of the soil water characteristics were tested for significance using Chi-square method. The model predicted percentage saturation, field capacity, saturated hydraulic conductivity and bulk density were statistically in agreement with the same laboratory measured variables for the two sites. However, saturated hydraulic conductivity of pit two Chanchaga and Bosso sites were not statistically in agreement with the laboratory measured variables. The model predicted wilting point and available water for the two sites were also not statistically in agreement with laboratory measured variables.

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CHAPTER ONE

INTRODUCTION

Soil-plant-water relationship relate to the properties of soil and plants that affects the movement, retention, and use of water .Soil provides the room for water to be used by plants through the roots present in the same medium. Water as such and also as a carrier of large amount of nutrients, is required in large measure for the successful growth of crops. The rate of entry of water into the soil and its retention, movement and availability to plant roots are all physical phenomena. Hence, it is important to know the physical properties of soils in relation to water for efficient of irrigated agriculture.

The answer to a problem in soil Engineering is normally obtained by first determining the properties of the soil in question and then employing these properties to work out solutions. Since the soil at every site is different, the soil involved in each different problem must be evaluated. Often this evaluation can be from knowledge of the geology of the site or from experience with similar soils. Usually, however, the soil properties must be determined by laboratory or field test.

Broad interpretations of soil physical data are often difficult to quantify accurately because of the nature of the soil and/or the tests employed. As a general principle, as much information as possible should be used from projects already in operation, rather than the some what artificial results from the tests (Landon, 1991). Difficulties in interpretations of test results arise for a number of reasons, which include:

(a) the degree to which the soil sampled represents the natural soil under consideration: soil spatial variation, poor sampling techniques, and disturbance of natural soil conditions (especially of structure) can all contribute to the production of unrepresentative test results;

(b) The amount of external influence before or after sampling: many physical properties can be substantially altered by soil treatments such as cultivation practices or by factors such as a change in soil water content; test interpretations or comparisons, unless made under standard conditions, are therefore very difficult.

(c) Differences in methods used for testing: standard tests procedure varies considerably between countries and organizations and varies in particular between the use of laboratory and on-site testing.

From the view point of designing, as well as interpreting, a programme of soil physical measurements, the variability of soil properties is crucial. Soil physical measurements are therefore of very great importance for project planning and design.

A graphic computer programme developed by Saxton (1991) is used to estimate the hydrological water holding and transmission characteristics of an Agricultural soil profile layer using only the soil texture selected from within the ranges shown on the graphical soil textural triangle (Appendix G), the variation of soil water tension and conductivity with water content and the related water holding characteristics are estimated. The water characteristic values based on texture are further modified by additional soil variables of organic matter, salinity, gravel, and compaction whose values are selected using the slider bars for each variable.

In this study, physical properties of different samples from different points were laboratorilly measured and compared with this graphic computer programme predicted properties. In other words the laboratory measured values were compared with the computer programme predicted values.

1.1 Statement of the problem

Laboratory analysis in determining some soil water characteristics many be unavoidable, but laboratory determination of all the characteristics or parameters in planning for an irrigation system, consume a lot of time and energy.

Lack of standard laboratories, finance, and required technical know- how are hindering developments in agriculture, especially in the developing countries like Nigeria.

Study of this nature will reduce drudgery, cost of equipment, apparatus, reagents, save time, and assist in planning an efficient irrigation system at minimum cost.

1.2 Objectives of the Project

The objectives of this study are;

(1) To determine the soil water characteristics of the project locations (Bosso L.G.A and Chanchaga L.G.A)

(2) To compare the field measured values of the soil properties with hydraulic properties model predicted soil properties

(3) To validate the computer programme (model) under the moist Guinea savannah zone of Nigeria.

1.3 Justification of the Objectives.

In many African countries, like in Nigeria we do not have full information on water requirements of our major agricultural crops, so there is the important need for relevant studies on the physical properties of soils, water needs and their relationship to crops in the country. As a model for predicting soil - water characteristics, such studies will provide the vital information on the available water content of soil profiles as factors in soil classification and it suitability for crop growth

It's only with such information/data that we can plan and design effective irrigation system at a minimum cost.

It is a comparative study of laboratory measured soil- water characteristic values with model predicted values. Specially the study will attempt to establish whether;

(1) There is statistically significant difference between the laboratory measured soil-water characteristic values and the model predicted values;

(2) The model could be applied to Nigerian soils.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil-water and plant relationships

2.1.1 Water Relation to Soil

Pore spaces in soil are partly filled with soil air, liquid vapor and partly with liquid phase of soil water. Ghuman and Maurya (1980) gave the assertion that irrigation water become very necessary because of large amount of irrigation water would affect the suitability of soil for crop production. Water affects intensely many physical and chemical reactions of soil as well as plant growth. Soil serves as storage reservoir for water. The movement of water in the soil is complex because of the various state and directions water moves and also because of the forces that cause it to move. The movement of water from the surface and through the soil is called soil water intake. (Obiechefu, 1990).

2.1.2 Movement of water within the soils.

2.1.2.1 Hydraulic Conductivity

The hydraulic conductivity (or permeability) of soil, K, in cmh^{-1}, defines the volume of water which will pass through unit cross-sectional area of a soil in unit time, given a unit difference in water potential. The measurement is being made fore two purposes;

(a) For comparison of hydraulic conductivity rates of different soil horizons, particularly as a guide to water movement and possible drainage problems within soil profiles; and

(b) As a bases for in- field drainage design (Landon, 1984).

2.1.2.2 Saturated Hydraulic Conductivity

Conductivity is a constant referring to the flow of fluid through a saturated conducting medium, derived from empirical relationship by Darcy(1950) between the rate of flow of water through saturated columns of sand and the hydraulic head loss; This may be expressed as follows;

$$q = KAh / L$$

Where, q = is volume rate of flow across a plane normal to the direction of flow

K= hydraulic conductivity, which is the volume rate of flow through a sample of unit cross-sectional area under the influence of a unit hydraulic or head gradient.

A = cross-sectional area through which the flow takes place.

h = hydraulic head expressed in moving water from one side of the sample to another

L = the length of the sample in the direction of flow.

Conductivity values are related to textural and structural characteristics of a soil, by the F.A.O (1963) classification.

Soil with hydraulic conductivity values below 0.1m day^{-1} require excessively close drain and spacing and hence some artificial modification of subsoil water movement by moiling or sub- soiling is essential for practical and economical field drainage system. Hydraulic conductivity of 0.1 to 1.0m day^{-1} is the most critical for drainage design, and greatest accuracy in measuring k is required in this range.

In soils with abrupt horizon changes, corresponding changes in the hydraulic conductivity values can have serious effects on the movement of irrigation or drainage water within the profile. Landon (1984).

2.1.2.3 Soil Structure.

Soil structure refers to the arrangement of particles in a soil. In an thereby produces what is called a granular structure, which is desirable because permeability and water holding capacities are increased and clumped particles are more resistant to erosion.

Grading and compaction of soil during construction and excessive tillage with tractors destroy the natural structure, reduce permeability and increase runoff and erodibility.A good soil structure has ability of increasing soil aeration, water holding capacity, and facilitate microbial activity.Ezedima and Onazi(1986)

2.1.2.4 Soil Permeability

Soil permeability refers to the ability of soil to allow air and water to move through it. Soil texture, structure, and organic matter all contribute to permeability. Site with high permeable soils absorb more rainfall, produce less runoff, are less susceptible to erosion and support plant growth more successfully Landon (1984)

2.1.2.5 Moisture content.

There is the need to have basic knowledge on the capacity of soil to retain available irrigation water. Some soils produce crops despite the lapse of many days and some times weeks during their growing season, between periods of rainfall is an evidence of their capacity to store available water, since all growing plants require continuous water.

When designing irrigation and drainage systems the capacity of soil to store available moisture for the growing crops needs is of great importance. The term "soil moisture content" is used to refer to the water that may be evaporated from soil by heating to between 100°C and 11°C until there is no further weight loss. Gardner (1958) The methods of estimating moisture content include;

) Gravimetric method

) Tensometer method

) Pressure membrane and pressure plate method

) Neuron probe method

) Appearance and feel of the soil

(1) Using electrical properties

However for the purpose of this study, gravimetric method was used.

M.C = (%Volume v/v) = M.C (%by weight w/w ×B.D)

Where M.C = moisture content , B.D = Bulk density

i.e. M.C (%v/v) = (weight of water/weight of dry soil) × (weight of dry soil/Total Vol. of soil) (Landon, 1984)

2.1.2.6 Field Capacity (F.C)

The water content in the soil, 1-3days after water has been applied and drainage has largely ceased is defined as the field capacity. For practical purpose, the F.C is expressed as a percentage of the soil dry weight is considered a constant, for a soil sample at F.C then

F.C = Net weight (at F.C) – oven dry weight × 100)/oven dry weight

The F.C is lower in light than in heavy soils ranging roughly between five and twenty five to thirty percent. (Egharevba, 2002)

2.1.2.7 Bulk Density

This is the density of the bulk soil in its natural state, including both the particles and the pore space (Michael, 1978).Bulk density is divided into wet bulk density and dry bulk density. Wet bulk density of a soil is the mass of the soil including any water present in the soil per unit volume expressed as:

$D_w = M_T/V_T$

Where, MT = total mass of soil ,VT = total volume of soil and Dw = wet bulk density

In which dry bulk density is the mass of oven dry soil per unit volume of moisture soil expressed as Dd =Ms/Vt

Where Ms = mass of soil solid

Vt = total volume of the soil

Dd = dry bulk density

Wet bulk density, dry bulk density and moisture content of soil are related as follows

Ps = 110[e] / 100 +w

Where, Ps = dry bulk density

e = wet bulk density

w = moisture content of soil

Bulk density of soil is affected by the compaction, when a soil under goes compaction its bulk density increases.

2.1.2.8 Infiltration

Infiltration refers specially to entry of water into the soil surface. Infiltration capacity is the measure of the extent a given soil under specified condition can take in water, (Obiechefu, 1990).It is quantitatively found to be equal to the difference between the initial moisture content and the moisture content at saturation, (Okoro, 1978). Horton, (1940) defined infiltration capacity as the maximum rate which a given soil, when in a given condition can absorb rain as it fall.

2.1.2.9 Soil Texture

This refers to the sizes and proportions of the particles making up a particular soil. Sand, silt, and clay are the three major classes of soil particles. Soil high in sand content are said to be coarse textured. Because water readily infiltrates into sandy soils, the runoff, and consequently the erosion potential, is relatively low. Soil with a high content of silt and clays are said to be fine textured or heavy. Clay, because of it thickness, bind soil particles together and makes soil resistant to erosion. Soils that are high in silt and fine sand, low in clay and organic matter are generally most erodible, well drained sandy and rocky soils are the least erodible. (Goldman, 1986)

2.1.2.10 Wilting Point

As water is extracted from the soil-water reservoir through evapotranspiration (E.T), the surface tension is increased. At about 15atm plants can no longer extract the water and wilt permanently. The soil-water at that time, on dry-weight bases is defined as the permanent wilting point (PWP) or simply wilting point (WP). Once this is reached, the soil-water reservoir is empty. (Egarevba, 2002)

Wilting point is estimated as hydraulic tension of 1500Kp (15bar) and dependent only on the texture and unaffected by salinity or gravel (Saxon, 1986)

2.1.2.11 Percolation

This is the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation rate is synonymous to infiltration rate with the quantitative provision of saturated or nearly saturated condition.

2.1.2.12 Matrix potential (ψm)

When soil is unsaturated and contains no gravitational water, the major movement of water is laterally from soil to plant roots. The important forces affecting water movement are adhesion and cohesion forces (Henry, 1990). Adhesion and cohesion effect are intensely affected by the size and nature of primary soil particles and pores. The resulting physical arrangement of surface and space, owing to the texture and structure is the soil marix.The interaction of the soil matrix with the water produces the matrix water potential.

2.1.2.13 Plant Available Water

This is the difference between the water content at field capacity and the permanent wilting point. Irrigation should be scheduled to maintain the water content of the soil between these two extremes.

Field capacity water content - Wilting point water content = plant available water. (Agvise Laboratories, 2006)

2.1.2.14 Porosity

This is an index of relative volume of pores. It is influenced by textural and structural characteristics of the soil (Michael, 1980)

Apart from quantity distribution, the tortuosity and continuity of pores are important features influencing aeration in soils, but they are less easily measured, and in most surveys only quantitative observations are made.

2.2 Assessing Crop Water Requirement

The quantity of water needed to irrigate a given land area depends on a number of factors, the most important being;

(1) Nature of crop

(2) Crop growth cycle

(3) Climatic conditions

(4) Type and condition of soil

(5) Land topography

(6) Field application efficiency

(7) Conveyance efficiency

(8) Water quality

The design of a small irrigation pump installation will need to take all this into account. The crop takes its water requirements from moisture held in the soil. Useful water for the crops varies between two levels, the permanent wilting point and field capacity.

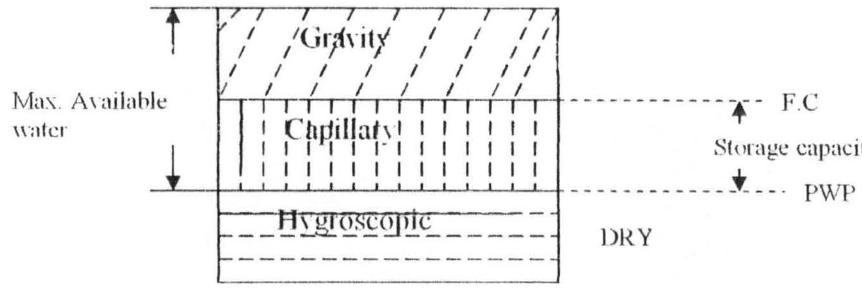

Fig 1.1 soil moisture quantities

2.2.1 Crop Growth as a Function of Soil Moisture

The rate of crop growth depends on the moisture content of the soil. There is an optimum growth rate condition in which the soil water content lies at a point some where between FC and PWP as below. However this point varies for different crops and for different stages of growth and so, it is not easy to adjust the irrigation intervals so that there is optimum crop growth.

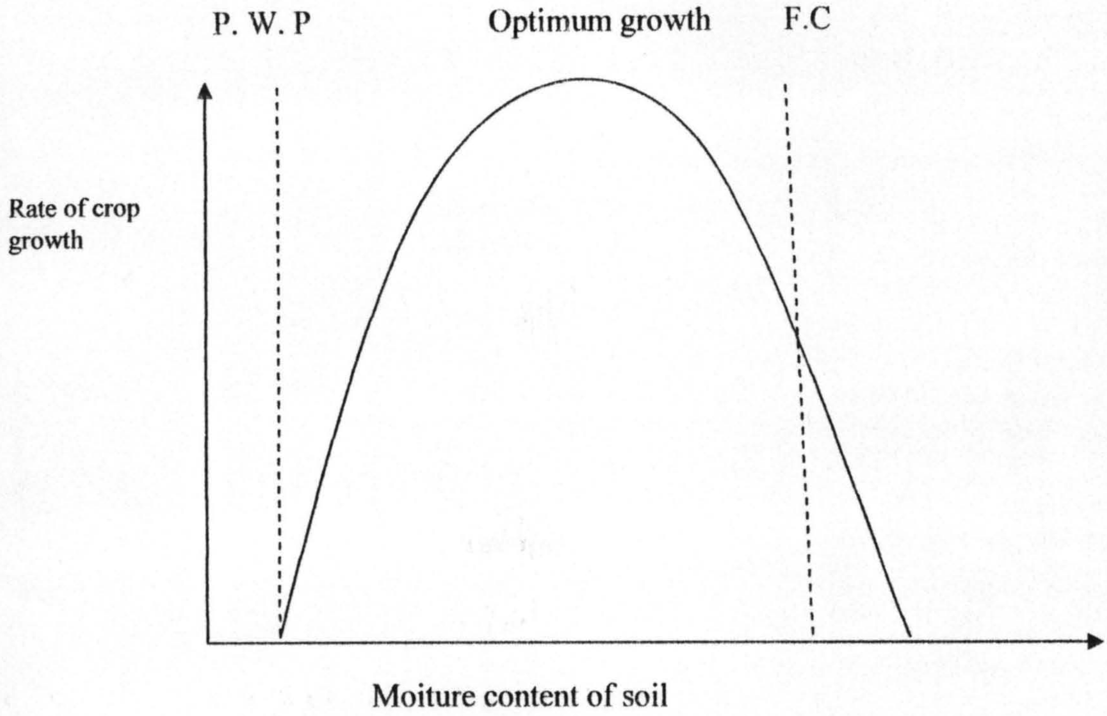

Fig 1.2 Rate of crop growth as a function of soil moisture content.

An estimation of the quantity of water that is required for irrigation can be usually obtained from local experts and agronomists. It involves several calculations stages (Doorenbos and Pruitt, 1977)

(1) Prediction methods, used to estimate crop water requirements (consumptive use), because of the difficulty of obtaining accurate field results measurements.

(2) The effective rainfall and ground water contribution to crops are subtracted from the crop water requirements to give the net requirement. Net irrigation water requirement equals crop water requirement minus effective rainfall water in the soil

(3) Field application efficiency and water conveyance efficiency are taken into account to give the gross pumped water requirement.

Gross water requirement (GWR) =Net water requirement (NWR) /System Design Efficiency.

Irrigation interval (peak) days =Net (peak) mm / Average ET (CU), mm/day.

2.3 Irrigation Schedule Model

An irrigation schedule model was developed in which the current and future soil contents are estimated (Hanks and Hill, 1980). When the soil water content drops to a specified level, the programme indicates that irrigation is needed. Estimated soil water (SW) content is determined by;

$Sw_2 = Sw_1 + Rain - E.T_C - Dp$

Where Sw1 and Sw2 are the beginning and end of total available soil water, and Dp, is the deep percolation or drainage out of the root zone and $E.T_C$ is the crop water requuirement. (Egharevba, 2002)

2.4 Salinity Effect on Soil Water

Soil salinity designates a condition in which the soluble salt content of the soil reaches a level harmful to the crops through the reduced osmotic potential of the soil solution and the toxicity of the specific ion. These soluble salts may be from those present in the original soil profile or transported to profile by irrigation water containing an unusual high concentration. Salinity largely affects the up take of water through increased water potentials; however it can also affect the hydrologic processes of infiltration and redistribution through chemical induced changes of structure and aggregation. Salinity affects soil water by adding osmotic potential to the soil matrix potential as seen by plant roots as they abstract soil water by osmosis. Matrix potential is a property of sol texture related to capillary tension and assumed constant as salinity changes. The net result is that while soil water content and matrix potential are not affected for hydrological budget consumption, plant up take and crop water stress are affected as a result of increased total water potentials and reduced plant available water

Saturation (SAT) and field capacity (FC) are physical properties of the soil matrix that are dependent only on the texture and are unaffected by salinity. Wilting point is the water content below which plants are unable to extract water from the soil, estimated as a total hydraulic potential of approximately 1500Kpa. As the salinity increases, the water content occurring at a total hydraulic potential of 1500Kpa will decrease since plant available water (PAW) is defined as the deference between field capacity and wilting point moisture contents, the decreased wilting point also decreases pant available water. Salinity is most often measured as electrical conductance (EC) of a saturated soil extract in ds/m (decisiemens per meter, equivalent to milimho/cm). The relationship between the measured resistance and the osmotic potential (ψo) at saturation has been given by $\Psi o = 36 \times EC$.Where, Ψo = osmotic potential in kPa and EC = Electrical conductivity in dS/m. (Saxon, 1986)

2.5 Compaction Effect on Soil Water

Soil profiles often have specific layers which have become more compact and dense than will be the mean for that particular soil texture as defined by the samples set used in the texture triangle estimates. This increased density often has obvious effect on the profiles hydrologic performance; particularly with regards to water conductivity as the soil pores are compacted smaller or closed. In the other regards, soils that have been tilled often have had increased porosity and lower densities established, although this is often a somewhat temporary condition as the soil re-compact under additional tillage and rainfall (Saxon, 1986)

2.6 Organic Matter Effect on Soil Water

Organic matter within a soil is decomposed plant and animal litter, it consist of colloidal particles. This kind of organic matter helps bind the soil particles together, improves soil structure and increases permeability and water-holding capacity.

Organic matter on the water holding and transmission of soil water has been studied for many years with varying results.

However, the reviews in recent years have shown some useful trends that were incorporated into this soil water hydrological model.

The data set from which the original relationships to estimate soil water characteristic had a generally low organic matter content averaging only 0.6%.This is the result having been collected throughout the depth of many soil profiles, thus only a small portion of the samples were from near surface horizons where organic matter will be expected to be higher. The analysis of this data showed little effect of organic matter on soil water; however this is likely the result of the fact that the content and the range of organic matter was law for a significant portion of the sample. With such a lower average and the generally known fact that organic matter does impact water holding characteristics, it is logical to make adjustment of the texture derived values, particularly for those horizons near the soil surface. It is not expected that these adjustments should be applied beyond the organic matter content of typical mineral-dominated agricultural soil, thus certainly not for soils that would generally be classified as highly organic or "peat" (Saxon, 1986).

Hillel (1998,) noted that is obvious that the shape and range of the soil-moisture characteristic curve depend strongly on soil texture. He further noted that the low, (<100kPa) of the matric suction curve depend mainly on the capillary effect the pore-size distribution, hence is strongly affected by soil structure. At higher and drier suction, water retention is increasingly influenced less by structure and more by texture. This suggests that the increase

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Areas

The study areas are Chanchaga irrigation scheme, in Chanchaga local government of Niger state, located between latitude 9°34'-9°37'N and longitude 6°36'-6°39'E Falade (2005) and Federal University of Technology Minna school farm, Bosso campus, longitude 8° -10° N and latitude 5° - 7°E in Bosso local government of Niger state.(Zahadi,2003)

3.2 Study Period

The study was carried out between the months of June and July 2006. The mean temperatures and evaporations of the two months were recorded as 31.5°C, 30.1°C and 3.0, 2.1 mm, respectively. The total rainfalls were 107.7 and 229.7mm for June and July. (Table D)

3.3 Materials and Methodology

The materials used include; core samplers, mallet, shovel, hoe, steel tape, etc. Two rectangular pits about 50m away from each other at two different sites, each of $2\times1\times1.5$m were dug using hoe and shovel. Five soil core samples were taken progressively at each 20cm downward. Ordinary soil samples at these depths were also taken for particle size analysis and wilting point water content determination. Water content at various levels, hydraulic conductivity and organic matter content were also measured from these two varieties of samples.

3.4 Laboratory Determined Parameters.

Independent variables

(1.) Sand (%wt)

(2.) Clay and

(3.) Organic matter

Dependent variables

(1.) Wilting point (% Vol.)

(2.) Field Capacity (% Vol.)

(3.) Saturation (%Vol.)

(4.) Available Water (% Vol.)

(5.) Saturated Hydraulic Conductivity (cm/hr)

(6.) Bulk Density (g/cm^3)

3.4.1 Saturated Hydraulic Conductivity Measurement.

Soil samples were collected from five different levels i.e.0-20, 20-40, 40-60, 60-80, and 80-100 depth in undisturbed form using core samplers and taken to the laboratory. The bottom end of the core samplers were sealed with a muslin sheet and completely saturated for a day by placing them in a basin filled with water to about 4cm. The experiment was set up by attaching another empty core sampler to the top of the filled core sampler with the aid of a cello- tape. They were then clamped to a retort stand vertically as shown below.

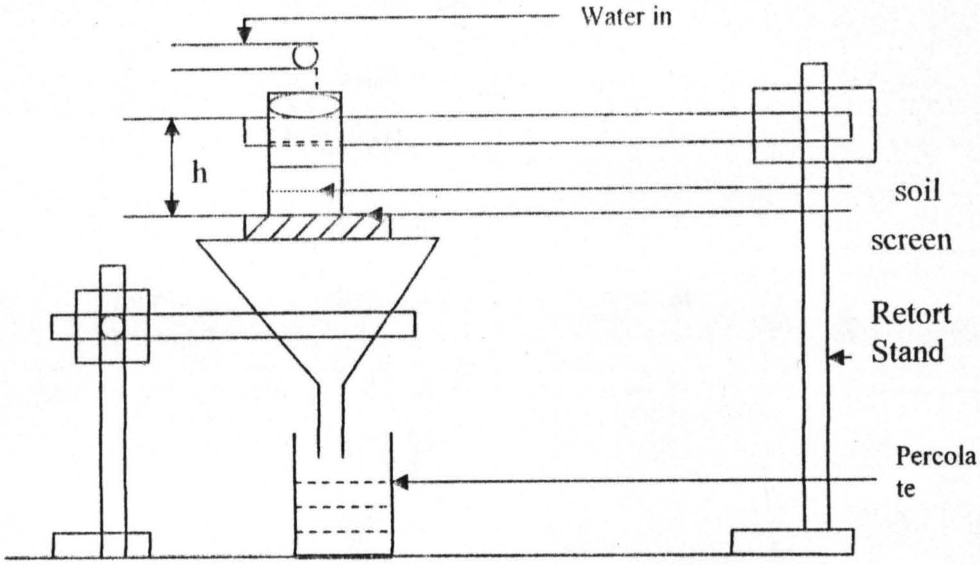

Fig1.2 Constant head method of hydraulic conductivity determination

Water was slowly introduced into the core cylinder and a constant head was maintained for one hour. Water was allowed to drain gradually through the soil sample into the graduated beaker. The volume of the percolate was measured. This was repeated for the remaining nineteen samples. The saturated hydraulic conductivity was determined as follow;

Saturated hydraulic conductivity =Vol of water per hr /Cross sectional area of the core.

3.4.2 Bulk Density Measurement.

Core samplers are commonly used take undisturbed soil samples. The cylinder of the core sampler, which has its cutting edge, is driven into the soil and uncompacted core obtained within the tube. The samplers were carefully trimmed at both ends. Empty labeled cans were weighed, they were then filled with soil core samples and weighed again and were oven dried at 105°C for about 24hrs, samples were again weighed.

Bulk density was determined as follow;

$\rho_b = Ms / Vs$

Where ρ_b =bulk density

Ms = mass of dry soil

Vs = Vol of soil

3.4.3 Water Content at Field Capacity Measurement

Soil core samples were completely saturated for a day and after they were suspended such that water is allowed to drain for two days. Weight of can and weight of can plus soil were taken. The samples were then oven dried at 105°C for 24hrs. Water content at field capacity was determined as follows;

Gravimetric water content = mass of water / Mass of oven dried soil

3.4.4 Water Content at Saturation Measurement.

Empty cans were weighed; completely saturated soil core samples were placed in them and then weighed again. The samples were oven dried at 105°C for 24hrs. Water content at saturation was determined as;

Gravimetric water content = mass of water / Mass of oven dried soil

3.4.5 Water Content at Wilting Point Measurement.

Ordinary fresh soil samples were air dried for a week. Weight of empty can plus weight of can plus soil were taken using a sensible weighing balance. The samples were oven dried at 105°C for twenty four hours. Water content at wilting point was determined as follows;

Gravimetric water content = Mass of water / Mass of oven dried soil

3.4.6 Available Water Content Measurement

Available water content = water content at field capacity – water content at wilting point.

3.4.7 The Graphic Computer Programme Use

Independent variable values of sand, clay, and organic matter are adjusted using the slider bar on the ruler. The adjustment of the slider bar on the on the rulers could be done starting from any independent variable. As the adjustments of the three independent variables are completed, the programme immediately predicts all the dependent variables including the textural class.

3.5 Determination of Organic Matter (Walkley black)

3.5.1 Procedure

1g of 0.5mm sieved soil was accurately weighed into 500mm conical flask in duplicate. 10ml of 1N $K_2Cr_2O_2$ solution was accurately pipette into each flask and swirl to gently disperse the soil.20ml of concentrated H_2SO_4 using automatic pipette was directly streamed into the suspension immediately. The flask was gently swilled until soil and reagent mix, then it was again vigorously swilled for one munite.The beaker was again rotated and allowed to stand on a sheet of asbestos for about 30 minutes.100mls of distilled water was added after standing for 30 minutes.3-5 drops of barium diphenylamine indicator was added.0.5N ferrous sulfate solution was used to titrate till end point was reached, which is greenish cast end point and it then changes to dark green, at this point, ferrous sulfate was added drop by drop until the colour changes sharply from blue to red and reflected right against a white background. A blank titration in the same manner was made without soil samples to standardize the dichromate. The results were calculated as follow;

$\%O.M = [(A-B) \times 0.3N] / W$

Where; A = Blank titer value

B = Sample titer value

0.3 = carbon conversion factor.

W = original weight of soil

N = normality of FeSO4 = 0.5

O.M = % O.C× 1.729

3.6 Determination of Particle Size Analysis by Hydrometer Method.

3.6.1 Procedure.

Two millimeter (2mm) air dried soil was served and 50g of the sample was weighed, 100ml of distilled water was added to the sample in a bottle and 5%sodium hexametaphosphate solution which serve as a dispersing agent was added. The mixer was placed in a shaker and shacked content was transferred quantitatively without loosing any particle into the sedimentation cylinder, up to 1liter marked with distilled water. The soil sample was disturbed with the aid of a plunger for proper soil suspention.The hydrometer reading was taken by immersing the hydrometer into the sample, and the stop clock was used to determine the reading. The temperature of the suspension was also taken by immersing the thermometer into the sample. The 40 second reading was taken to measure the percentage of silt and clay in suspension, while the two hours reading without disturb was taken to measure the percentage of clay in suspension. A blank sample was also prepared but without soil and the reading also obtained.

$C = R - RL + (0.36 \times T)$

Where C =corrected hydrometer reading

R = sample reading

RL = blank reading

T= temperature (°C)

0.36 = multiplication factor

% clay = $C \times 100/50$

% silt = C+ clay - % clay

% sand = 100 - % silt + clay

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Water Content at Saturation C-Pit 1

For normal soils like those in the tropics, water content at saturation decrease downward, because of the increase in clay content down the profile, this is reflected in pit one, water content at saturation decreases from 0 -60cm, though the clay content increases only from 0- 40cm.The decrease at 40 – 60 can be an error in the laboratory measurement or change in the nature of the soil (sandy) at that profile depth.

The increase in percentage saturation from 60 -100 cm as shown in the table 4.1 below is as a result of increase in sand content at these levels. The model predicted values for the percentage saturation has some degree of consistence with the laboratory measured values. From statistical analysis the predicted saturation values at 5% significance are accepted, since the table value at 5% significance and nineteenth degree of freedom is 30.14 which is greater than the Chi square value. (See Table 4.1 below and Appendix A&B)

Generally soils with high degree of saturation have less trafficability and floatation. This type of soil will require more drainage in cases of excess rain fall or irrigaton.The growth of non water loving crops is also hindered by these types of soils. From the table below it could be seen that the soil degree of saturation is just below 50% and so will not pose much treat of excess water to the plants or hinder floatation and trafficability.

Table 4.1 S, MS, OM, X^2 and particle size analysis values of C-Pit 1

Pd	S	MS	X^2	Sand	Clay	Silt	OM
0-20	37.5	47.7	2.2	59.1	31.6	9.3	0.5
20-40	36.2	48.8	3.3	59.1	36.6	7.3	0.8
40-60	35.3	45.4	2.3	63.1	25.6	11.3	1.2
60-80	37.8	45.3	1.2	69.1	25.6	5.3	0.3
80-100	41.4	47.7	0.4	69.1	27.6	3.3	0.3
			$\sum X^2 1 = 9.327$				

4.2 Water Content at Field capacity C-Pit 1

The field capacity decreases from 0 - 60 cm. This could be due to the lightness in the nature of the soil as a result of high sand and silt content. Field capacity is lower in light soils than in heavy soils, ranging from 5 and 25 – 30 (see literature review), it then increases from 60- 80 cm and then decreases. The model predicted field capacity show some level of consistence, however, the inconsistence in some values of field capacity to the laboratory measured values could be due to the fact that the prediction is dependent on the values of the laboratory measured independent variables. The statistical analysis showed that the field capacity is well predicted. (See Table 4.2 below and Appendix A&B)

Soils with good field capacity support plant more, especially when there is break in rain fall, so therefore will require less frequent irrigation. From the table below the field capacity could be said to be fair since it values are below 50% and therefore will require irrigation in cases of long break in rain fall.

Table 4.2 Fc, MFc, OM, X^2 and particle size analysis values of C-Pit 1

Pd	Fc	MFc	X^2	Sand	Clay	Silt	OM
0-20	34.5	27.2	2.0	59.1	31.6	9.3	0.5
20-40	33.2	28.2	0.9	59.1	36.6	7.3	0.8
40-60	32.3	24.1	2.8	63.1	25.6	11.3	1.2
60-80	34.8	23.5	5.4	69.1	25.6	5.3	0.3
80-100	33.1	24.2	3.3	69.1	27.6	3.3	0.3
		$\sum X^2 1=14.342$					

4.3 Water Content at Wilting Point C- Pit1

The laboratory measured wilting point increases from 0 -60 cm and then decreases at 80 -100 cm.The zero wilting point at 60 -80 cm indicates that the soil was completely dried during the period of one week exposure to atmospheric air. This could be as a result of high sand content, since water content at wilting point decreases with increase in sand and low clay content. The model predicted values are higher, though they both maintain the same matter of fluctuation down the profile. The statistical analysis showed that the lting points were not well predicted by the model. (See Table 4.3 below and Appendix &B).

Soils with low wilting point loss their water faster and therefore needs to be irrigated ore often for crop survival. Considering the model predicted values, the soil could be aid to be having high water content at wilting point, and therefore can support plant etter especially during breaks in rain fall

Table 4.3 Wp, MWp, OM, X^2 and particle size analysis values of C-Pit 1

Pd	Wp	MWp	X^2	Sand	Clay	Silt	OM
0-20	0.8	18.1	16.5	59.1	31.6	9.3	0.5
20-40	1.6	19.1	16.0	59.1	36.6	7.3	0.8
40-60	1.1	15.4	13.3	63.1	25.6	11.3	1.2
60-80	0.0	15.5	15.5	69.1	25.6	5.3	0.3
80-100	0.7	16.4	15.0	69.1	27.6	3.3	0.3
			$\sum X^2 1=76.377$				

4.4 Saturated hydraulic Conductivity C- Pit 1

The laboratory measured saturated hydraulic conductivity decreases from 0-40cm. The higher value at the upper part (0-20cm) is as a result of relatively high sand and relatively low clay. Conductivity increases with increase in sand and decrease with increase in clay. The lower value from 20-40cm is due to relatively high value of clay. The saturated hydraulic conductivity increases from 40-100cm; this is as a result of increase in sand low clay content, and lower organic matter content. However, it is difficult to co-relate ie laboratory measured values with the model predicted values, since the latter has igher values and manner of fluctuation differs. (See Table 4.4 below and Appendix \&B).The statistical analysis showed that the Saturated hydraulic Conductivity is well predicted since it chi^2 value is lower than the table value at 5% and 19th degree of freedom. Soil with hydraulic conductivity values below 0.1m day^{-1} require excessively close drain and spacing and hence some artificial modification of subsoil water movement by moiling or sub- soiling is essential for practical and economical field drainage system. Hydraulic conductivity of 0.1 to 1.0m day^{-1} is the most critical for drainage design, and greatest accuracy in measuring k is required in this range.

In soils with abrupt horizon changes, corresponding changes in the hydraulic conductivity values can have serious effects on the movement of irrigation or drainage water within the profile. Considering the table just below it could be seen that conductivity values are high, so therefore this soil will require more irrigation and less drainage.

Table 4.4 Sk, MSk, OM, X^2 and particle size analysis values of C-Pit 1

Pd	Sk	MSk	X^2	Sand	Clay	Silt	OM
0-20	28.0	19.0	8.4	59.1	31.6	9.3	0.5
20-40	13.2	22.0	3.5	59.1	36.6	7.3	0.8
40-60	12.7	24.0	5.3	63.1	25.6	11.3	1.2
60-80	15.1	26.0	4.6	69.1	25.6	5.3	0.3
80-100	26.5	21.0	1.4	69.1	27.6	3.3	0.3
			$\sum X^2 1=23.270$				

4.5 Bulk Density C-Pit 1

The laboratory measured bulk densities are the same from 0-60cm as the clay content increases from0-40, but decreases from 60-100cm as the sand content increases with increase in clay and the organic matter decreases at the same depth. Bulk density decreases with increase in sand, increases with increase in clay and also increases with increase in organic content. The laboratory measured values are not the same with the model predicted values, but nature of fluctuation of the values down the profile is closely related.

The percentage sand increases downward with the highest value of 69.12 from 60-100cm.The clay is highest at the depth of 20-40cm and is shown by the model predicted textural class as sandy clay (SC).The statistical analysis showed that the bulk density is well predicted since it calculated Chi^2 value is less than 30.14 Chi^2 table value. (See Table 4.5 below and Appendix A&B)

Bulk density is affected by compaction, the more the compaction the higher the bulk density, and therefore rate of infiltration is reduced and so the tendency for erosion will be high. Elements of compaction include heavy farm machinery and grazing animals Considering the table below it could be seen that the bulk density soil is normal.

Table 4.5 ρb, Mρb, OM, X^2 and particle size analysis values of C-Pit 1

Pd	Pb	M ρb	X^2	Sand	Clay	Silt	OM
0-20	1.5	1.4	0.0	59.1	31.6	9.3	0.5
20-40	1.5	1.4	0.0	59.1	36.6	7.3	0.8
40-60	1.5	1.5	0.0	63.1	25.6	11.3	1.2
60-80	1.4	1.5	0.0	69.1	25.6	5.3	0.3
80-100	1.4	1.4	0.0	69.1	27.6	3.3	0.3
			$\sum X^2 1=0.0$				

4.6 Water Content at Saturation, and F.C C-Pit 2

The laboratory measured water content at saturation is highest at 40 -60cm, likewise the model predicted and it is lowest at 20-40 for both. This is due to the high sand and relatively low silt content. From statistical analysis the predicted saturation values at 5% significance are accepted, since the table value at 5% significance and nineteenth degree of freedom is 30.14 which is greater than the Chi square value. (See Table 4.6 below and Appendix A&B).

The laboratory measured field capacity is highest 60-80cm. This is due to relatively high clay content. It is lowest at 20-40cm.This is due to high sand content and relatively low clay. The statistical analysis showed that predicted saturation is within the range of acceptance, while FC calculated Chi^2 value is just close to table value of 30.14 (See Table 4.6 below & Appendix A&B

Table 4.6 S, MS, OM, Fc, MFc, X^2 and particle size analysis values of C-Pit 2

Pd	S	Ms	X^2	Fc	Mfc	X^2	OM	Sand	Silt	Clay
0-20	40.3	47.8	1.2	37.7	24.8	6.7	1.2	69.1	11.3	25.6
20-40	41.2	47.2	0.8	36.9	24.5	6.3	1.0	69.1	11.3	25.6
40-60	43.2	48.9	0.7	39.2	27.7	4.8	0.9	63.1	3.3	33.6
60-80	41.4	45.8	0.4	40.0	25.2	8.7	0.1	65.1	5.3	29.6
80-100	40.9	47.0	0.8	38.9	25.9	6.5	0.5	63.1	7.3	29.6
			$\sum X^2 2= 3.823$			$\sum X^2 2=32.970$				

4.7 Wilting Point Saturated Hydraulic Conductivity and Bulk Density C-Pit 2.

The laboratory measured wilting point is highest at 80-100cm. this is as a result of relatively low sand and relatively high clay content. The model predicted wilting point is highest at 40-60cm. This could be as a result of high clay content

The higher values of laboratory measured saturated hydraulic conductivity at the depth of 20-40cm & 60-80cm are as a result of high sand content and relatively low clay content. However the model predicted values are not consistent with the laboratory measured values, since the former decreases from 0-80cm and then increases from 80-100cm. The laboratory measured saturated hydraulic conductivity is lowest at 80-100cm.This due to relatively high clay, silt, and organic. Bulk density is highest at 60-80cm as a result of high clay. The laboratory measured and model predicted textural classes are all the same (SCL). The statistical analysis showed that only bulk densities are within the acceptable range. Wilting point and Saturated Hydraulic Conductivity are not. (Table4.7)

Table 4.7 Wp, MWp, SK, MSk, ρb, Mρb, OM, X^2 and particle size analysis values of C-Pit 2

Wp	Mwp	X^2	Sk	Msk	X^2	Pb	Mρb	X^2	OM	Sand	Silt	clay
0.9	15.9	14.2	45.7	55.0	1.6	1.3	1.4	0.0	1.2	69.1	11.3	25.6
1.7	15.8	12.6	104.3	46.0	73.9	1.4	1.4	0.0	1.0	69.1	11.3	25.6
1,2	19.1	16.8	18.5	24.0	1.3	1.4	1.4	0.0	0.9	63.1	3.3	33.6
0.5	17.1	16.1	139.3	14.0	1121.4	1.4	1.4	0.0	0.1	65.1	5.3	29.6
2.3	17.2	12.9	4.1	21.0	13.6	1.4	1.4	0.0	0.5	63.1	7.3	29.6
	$\sum X^2 2 = 72.531$			$\sum X^2 2 = 1211.720$			$\sum X^2 2 = 0.0$					

4.8 Water Content at Saturation and Wilting Point B-Pit 1

The laboratory measured water content at saturation is highest at 60-80cm as a result of relatively low clay high sand and relatively low silt and lowest at 80-100cm, due to high clay, relatively high silt and high organic content, however the model predicted saturation is highest at 0-20cm and lowest at 60-80cm.

The laboratory measured wilting points are zero. This indicates that the soil was completely dried during a week of exposure to atmospheric air. However, this is not reflected in the model predicted values. The statistical analysis showed that water content at predicted saturation is within the range of acceptance, while predicted wilting is not, since it Chi^2 value is greater than the table value of 30.14. (See Table 4.7 below and Appendix A&B)

Table 4.8 S, MS, Wp, MWp, OM, X^2 and particle size analysis values of B-Pit 1

Pd	S	Ms	X^2	Wp	Mwp	X^2	OM	Sand	silt	Clay
0-20	48.1	54.9	0.8	0.0	22.1	22.1	2.7	51.8	8.6	39.6
20-40	40.8	54.8	3.6	0.0	20.5	20.5	2.7	47.8	16.6	35.6
40-60	49.4	53.8	0.4	0.0	22.2	22.2	2.4	37.8	22.6	39.6
60-80	60.8	50.1	2.3	0.0	16.2	16.2	2.0	63.8	10.6	26.6
80-00	37.6	50.4	3.3	0.0	17.0	17.0	2.1	63.8	8.6	27.6
			$\sum X^2 1= 10.314$			$\sum X^2 1=98.0$				

4.9 Field Capacity, Saturated Hydraulic Conductivity and Bulk Density B-1

The laboratory field capacity increases from 0-40cm and then decreases from 40-100cm,the increase in field capacity at 0-40 is due to the reduction in sand at the same profile depth, while the decrease from 40-100 is due to the increase in sand and decrease in clay along the same profile depth. The model predicted values flow the same manner of fluctuation.

The laboratory measured saturated hydraulic conductivity is highest at 60-80cm. This is due to the high sand and the relatively low clay content and silt. However, the model predicted is highest at 20-40cm and lowest at 40-60cm.

The laboratory measured bulk density is highest at 20-40cm where the clay content is relatively high. The model predicted values at this depth are the same from 0-60cm and then from 60-100cm.Athough there is some degree of variation between the values of the laboratory measured and the model predicted values, the range of difference is almost the same. The statistical analysis showed that predicted field capacity and bulk density are within the range of acceptance, while predicted saturated hydraulic conductivity is not since the latter Chi^2 value is greater than the table value of 30.14. (See Table 4.9 below and Appendix A&B)

The percentage sand is highest at 60-100cm. The textural class at this pit for both model predicted and laboratory determined are uniform.

Table 4.9 Fc, MFc, OM, Sk, MSk, ρb, Mρb, X^2 and particle size analysis values of B-Pit 1

	Fc	Mfc	X^2	Sk	Msk	X^2	ρb	Mρb	X^2	OM	Sand	silt	Clay
0	32.6	31.9	0.0	2.9	90.0	84.3	1.6	1.2	0.1	2.7	51.8	8.6	39.6
40	39.8	32.2	1.8	0.9	130.0	128.2	1.7	1.2	0.2	2.7	47.8	16.6	35.6
-60	35.1	34.7	0.0	5.7	61.0	50.1	1.3	1.2	0.0	2.4	37.8	22.6	39.6
-80	33.6	26.5	1.9	6.6	105.0	92.2	1.6	1.3	0.1	2.0	63.8	10.6	26.6
-100	27.4	27.0	0.0	5.0	87.0	77.3	1.7	1.3	0.1	2.1	63.8	8.6	27.6
	$\sum X^2 2$= 3.722				$\sum X^2 2$= 432.130				$\sum X^2 2$= 0.472				

4.10 Water Content at Saturation, Field Capacity and Wilting Point B-Pit2

The depth of 40-60cm recorded the highest value for both laboratories determined and model predicted water content at saturation however the sand content is relatively low but relatively high clay content.

The laboratory measured field capacity increases from 40-100cm, just as the sand increases from 40-100cm. It also decreases from 0-40cm as the sand increases. This trend of fluctuation is also reflected in the model predicted values of field capacity. The statistical analysis showed that the predicted water content at saturation and field capacity are within the range of acceptance since their Chi2 values are less than the table value of 30.14 at 5% significance and 19^{th} degree of freedom. (See Table below and Appendix)

The wilting point also decreases with increase in sand for both laboratory measured and model predicted. (See Table 4.10 below and Appendix A&B)

The bulk density is highest at the depth of 60-80cm with highest clay content and relatively low sand. The textural classes at this pit are the same.Satistical analysis also showed that the bulk density is well predicted while the wilting is not. . (See Table 4.10 below and Appendix A&B)

Table 4.10 S, Ms, Fc, MFc Wp, Mwp, OM, X^2 and particle size analysis values of B-Pit 2

	S	M s	X^2	Fc	Mfc	X^2	Wp	Mwp	X^2	Om	Sand	Silt	clay
	46.5	52.8	0.8	31.5	28.3	0.4	1.2	17.4	15.1	2.5	63.8	8.6	27.6
)	44.7	52.4	1.1	28.3	27.8	0.0	1.0	10.7	8.8	2.7	65.8	18.6	25.6
)	53.3	54.9	0.1	34.0	32.5	0.1	1.0	21.3	19.4	2.9	47.9	14.6	37.6
0	38.0	53.3	4.4	28.1	31.3	0.3	3.8	22.0	15.1	2.3	55.8	4.6	39.6
00	43.5	50.0	0.9	24.0	26.0	0.2	0.7	16.3	14.9	2.1	69.8	4.6	25.6
		$\sum X^2 1= 7.167$			$\sum X^2 1=4.634$				$\sum X^2 1=171.200$				

4.11 Saturated Hydraulic Conductivity and Bulk Density B-Pit 2

The laboratory measured saturated hydraulic conductivity decreases from 0-80cm and then increases from 80-100cm; this is as a result of the similar trend of fluctuation in the sand, silt, clay, and organic matter content. The increase in Saturated Hydraulic Conductivity at 80-100cm depth is as a result of increase in sand content and decrease in the clay content at this depth. (See Table 4.11 below)

The bulk density is highest at the depth of 60-80cm with highest clay content and relatively low sand. The textural classes at this pit are the same.Satistical analysis showed that the bulk density is well predicted while the Saturated Hydraulic Conductivity is not. (See Table 4.11below and Appendix A&B)

Table 4.11 Sk, MSk, ρb. Mρb, OM, X^2 and particle size analysis values of B-Pit 2

Pd	Sk	Msk	X^2	Pb	Mρb	X^2	OM	Sand	Silt	clay
0-20	6.4	169.0	156.4	1.5	1.3	0.1	2.5	63.8	8.6	27.6
20-40	3.2	195.01	188.7	1.5	1.3	0.0	2.7	65.8	18.6	25.6
40-60	2.6	110.0	104.9	1.5	1.2	1.1	2.9	47.9	14.6	37.6
60-80	1.5	53.0	50.0	1.7	1.2	0.1	2.3	55.8	4.6	39.6
80-100	29.8	104.0	52.9	1.5	1.3	0.0	2.1	69.8	4.6	25.6
		$\sum X^2 2=552.930$				$\sum X^2 2=1.314$				

4.12 Available Water

The values obtained for all the available water for all the pits depends on the values of the field capacity and the wilting point, it fluctuates as the field capacity and wilting point fluctuates, since available water is field capacity – wilting point. (A.W α F.C & W.P) (See Tables 4.12 below).

The statistical analysis showed that the predicted available water for all the pits is not within the range of acceptance. This is as a result of very low laboratory measured water content at wilting point values obtained, and high model predicted values as the case may be. (See Tables 4.12 below and Appendix A&B)

Table 4.12 Fc, MFc, Wp. MWp, X^2 and Aw values of C-Pit 1

Pd	Fc	Mfc	X^2	Wp	Mwp	X^2	Aw	Maw	X^2
0-20	34.5	27.2	2.0	0.8	18.1	16.5	33.7	9.0	67.7
20-40	33.2	28.2	0.9	1.6	19.1	16.0	31.6	9.0	56.7
40-60	32.3	24.1	2.8	1.1	15.4	13.3	34.2	9.0	70.6
60-80	34.8	23.5	5.4	0.0	15.5	15.5	43.8	9.0	134.5
80-100	33.1	24.2	3.3	0.7	16.4	15.0	32.4	9.0	61.1
		$\sum X^2 1= 14.342$			$\sum X^2 1= 76.377$			$\sum X^2 1= 390.460$	

Table 4.12 Fc, MFc, Wp. MWp, X^2 and Aw values of C-Pit 2

Pd	Fc	Mfc	X^2	Wp	Mwp	X^2	Aw	Maw	X^2
0-20	37.7	24.8	6.7	0.9	15.9	14.2	36.7	9.0	85.5
20-40	36.9	24.5	6.3	1.7	15.8	12.6	35.3	9.0	76.7
40-60	39.2	27.7	4.8	1.2	19.1	16.8	38.0	9.0	93.4
60-80	40.0	25.2	8.7	0.5	17.1	16.1	39.5	8.0	124.
80-100	38.9	25.9	6.5	2.3	17.2	12.9	36.6	9.0	84.8
		$\sum X^2 2=32.97$			$\sum X^2 2=72.53$			$\sum X^2 2=464.48$	

Table 4.12 Fc, MFc, Wp. MWp, X^2 and Aw values of B-Pit 1

Pd	Fc	Mfc	X^2	Wp	Mwp	X^2	Aw	Maw	X^2
0-20	32.6	31.9	0.0	0.0	22.1	22.1	32.2	10.0	50.8
20-40	39.8	32.2	1.8	0.0	20.5	20.5	39.8	12.0	64.5
40-60	35.1	34.7	0.0	0.0	22.2	22.2	35.1	12.0	44.4
60-80	33.6	26.5	1.9	0.0	16.2	16.2	33.6	10.0	55.7
80-100	27.4	27.0	0.0	0.0	17.0	17.0	27.4	10.0	30.1
		$\sum X^2 1=3.722$			$\sum X^2 1=98.0$			$\sum X^2 1=245.354$	

Table 4.12 Fc, MFc, Wp. MWp, X^2 and Aw values of B-Pit 2

Pd	Fc	Mfc	X^2	Wp	Mwp	X^2	Aw	Maw	X^2
0-20	31.5	28.3	0.4	1.2	17.4	15.1	30.3	11.0	33.9
20-40	28.3	27.8	0.0	1.0	10.7	8.8	27.3	11.0	24.2
40-60	34.0	32.5	0.1	1.0	21.3	19.4	32.1	11.0	40.3
60-80	28.1	31.3	0.3	3.8	22.0	15.1	24.3	9.0	25.9
80-100	24.0	26.0	0.2	0.7	16.3	14.9	23.3	10.0	17.6
		$\sum X^2 2=4.634$			$\sum X^2 2=73.20$			$\sum X^2 2=141.908$	

4.13 Textural Class

The laboratory measured and model predicted textural classes of B-Pit1, B-Pit 2 and C-Pit 2, are the same. The laboratory measured and model predicted textural classes of C-Pit1 are also the same except those at 20-40cm depth. The clay loam texture at 40-60cm B-Pit 1 is as a result of the highest clay content at this level. The laboratory measured values of sand, clay; silt and organic matter dictate the textural classes. (See Tables 4.13-4.16 below and Appendix A&B)

Table4.13 Textural classes and particle size values of C-Pit1

OM	Sand	Silt	clay	Tc	Mtc
0.5	59.1	9.3	31.6	Scl	Scl
-0.8	59.1	7.3	36.6	Scl	Sc
1.2	63.1	11.3	25.6	Scl	Scl
0.3	69.1	5.3	25.6	Scl	Scl
0.3	69.1	3.3	27.6	Scl	Scl

Table4.14 Textural classes and particle size values of C-Pit2

OM	Sand	Silt	clay	Tc	Mtc
1.2	69.1	11.3	25.6	Scl	Scl
1.0	69.1	11.3	25.6	Scl	Scl
0.9	63.1	3.3	33.6	Scl	Scl
0.1	65.1	5.3	29.6	Scl	Scl
0.5	63.1	7.3	29.6	Scl	Scl

Table15 Textural classes and particle size values of B-Pit1

OM	Sand	Silt	clay	Tc	Mtc
2.7	51.8	8.6	39.6	Sc	Sc
2.7	47.8	16.6	35.6	Sc	Sc
2.4	37.8	22.6	39.6	Cl	Cl
2.0	63.8	10.6	26.6	Scl	Scl
2.1	63.8	8.6	27.6	Scl	Scl

Table16 Textural classes and particle size values of B-Pit1

OM	Sand	Silt	clay	Tc	Mtc
2.5	63.8	8.6	27.6	Scl	Scl
2.7	65.8	18.6	25.6	Scl	Scl
2.9	47.9	14.6	37.6	Scl	Scl
2.3	55.8	4.6	39.6	Scl	Scl
2.1	69.8	4.6	25.6	Scl	Scl

Pd = profile depth

S = laboratory measured volumetric water content at saturation, (%)

Ms = model predicted volumetric water content at saturation, (%)

$X^2 = [(O-E)^2/E]$

Wp = laboratory measured volumetric water content at wilting point, (%)

Mwp = model predicted volumetric water content at wilting point, (%)

Sk = laboratory measured saturated hydraulic conductivity (cm/hr)

Msk = model predicted saturated hydraulic conductivity (cm/hr)

ρb = laboratory measured bulk density (g/cm^3)

Mρb = model predicted bulk density (g/cm^3)

Aw = laboratory measured volumetric available water (%)

Maw = model predicted volumetric available water (%)

OM = organic matter (%)

Tc = laboratory measured textural class

MTc = model predicted textural class

C-Pit1 = Chanchaga pit 1

C-Pit2 = Chanchaga pit 2

B-pit 1 = Bosso pit 1

B-pit 2 = Bosso pit 2

4.14 General Comment on the two sites

The soils of the two sites have relatively high laboratory measured values of saturation, except B- pit 2, and therefore will require less but frequent irrigation. It also has high field capacities which indicate ability to hold more water to sustain crops. The water content at wilting point is also high as predicted by the model, this indicate a good support for plants especially during rain break. The saturated hydraulic conductivities for Chanchaga site are high, this shows good permeability. However, the conductivities of Bosso site are low, and therefore the soil here may require more drainage. (Refer to table 4.1)

Considering the information available from the statistical data, it could be seen that there is no much difference in the sites soil profiles ability to hold water, except for few cases. This could be approximated from the geological nature of the soils during the field work. This could also be seen from the model predicted and laboratory measured textural classes.

Organic matter content which support soil structure building and water holding capacity of soils vary slightly from each other.

C- Pit 2 was discovered to have high alluvium deposition progressively down the profile to about 1.3m; this could be as a result of the river ingress, over flow, or flood.

C- Pit 1 could be visualized during the field work to be sandy progressively down the profile, only that there was colour variation as you go down the profile.

Bosso site was Fatima in nature. The upper parts look clayey i.e. from 0-80cm and sandy clay at the lowest part i.e. from 80-100cm.

The sharp difference between the laboratories determined wilting point and model predicted wilting point, can be as a result of high clay content of the soil as determined in the laboratory. This high clay content value supplied to the model made it predict high water content at wilting point. However the laboratory measured value of water content at wilting point were very low.

CHI square statistical method was used to test for the significance of the data obtained.

CHAPTER FIVE

5.0 Conclusion and Recommendation

5.1 Conclusion

It is obvious from the statistical analysis that the model predicted water content at saturation, field capacity, saturated hydraulic conductivity, and bulk density are within the range of acceptance for Chanchaga Pit1 and Chanchaga Pit 2 except field capacity of Chanchaga Pit 2.While the predicted wilting point, and available water content are not within the range of acceptance. Also the same variable are within the range of acceptance for Bosso Pit1 and Bosso Pit 2 except wilting point, available water and saturated hydraulic conductivity that are not within the range of acceptance.

Considering the two sites, it could be estimated from the statistical analysis that the model predicted correctly for 50% of the dependent variables and 99% of the textural class. The model is therefore a good predictor for the correctly predicted variables and not for others.

Based on this research work the model can only be applied to predict correctly for those variables that statistically have no significant difference between their laboratory measured values and model predicted values.

5.2 Recommendation

In the application of this model to these research areas, the following are recommended:

(1) For those variables that were not statistically within the range acceptance, the laboratory measured values should be used to calibrate for them or as a control such that for example if the predicted field capacity values are higher or lower than the laboratory

measured values, the predicted values could be adjusted to those of the laboratory measured values, so that when ever the model is been applied to any soil, values could either be added to or subtracted from the predicted values.

(2) Since this study was carried out only in wet season more research should be carried out in both seasons to see whether there will be much variation in the values obtained in both seasons.

(3) More research should be carried out on different soils from different areas to see how perfect the model could be on different type of soils and areas of this country.

(4) The samples obtained for laboratory analysis should be analyzed in different laboratories by different experts or several times, so as to make the data obtained more reliable.

(4) Compaction, gravel, and salinity of the soil in question should also be field/laboratory measured instead of been assumed.

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There is no significant difference between the laboratory measured water content at saturation and the model predicted water content at saturation.

For volumetric water content at wilting point.

Decision.

$X^2wp = \sum [(O-E)^2/E] = 76.378$

76.378>30.14, Ho is rejected

H1 is accepted.

Interpretation

There is significant difference between the laboraratory measured volumetric water content at wilting point and model predicted.

For volumetric water content at field capacity.

$X^2 = \sum [(O-E)^2/E] = 14.342$

14.342<30.14, Ho is accepted.

H1 is rejected.

Interpretation.

There is no significant difference between the laboratory measured volumetric water content at field capacity and the model predicted.

For saturated hydraulic conductivity.

Decision.

$X^2 = \sum [(O-E)^2/E] = 23.271$

23.271<30.14, Ho is accepted.

H1 is rejected.

Interpretation

There is no significant difference between laboratory measured values of saturated hydraulic conductivity and the model predicted.

For bulk density

Decision

$X^2\rho b = \sum [(O-E)^2/E] = 0.0517$

0.0517<30.14, Ho is accepted

H1 is rejected

Interpretation.

There is no significant difference between the laboratory measured bulk density values and model predicted bulk density values.

For volumetric available water.

$X^2 = \sum [(O-E)^2/E] = 854.94$

854.94>30.14, Ho is rejected

Hi is accepted.

Interpretation.

There is significant difference between the libratory measured volumetric water content values and model predicted values.

Chanchaga pit 2

For volumetric water content at saturation.

Decision.

$X^2sat. = \sum [(O-E)^2/E] = 3.823$

3.823< 30.14, Ho is accepted.

H1 is rejected.

Interpretation.

There is no statistically significant difference between the laboratory measured saturation values and model predicted saturation values.

For volumetric water content at field capacity.

Decision.

$X^2 = [(O-E)^2/E] = 32.97$

32.97>30.14, Ho is rejected.

H1 is accepted

Interpretation

There is statistically significant difference between the laboratory measured field capacity values and model predicted field capacity values.

For volumetric water content at wilting point

Decision.

X^2 WP =. $[(O-E)^2/E]$=72.531

72.531>30.14, Ho is rejected.

H1 is accepted.

Interpretation.

There is statistically significant difference between the laboratory measured water content at wilting point values and model predicted wilting point values.

For saturated hydraulic conductivity.

Decision.

X^2sat.k =. $[(O-E)^2/E]$=1211.71

1211.71>30.14, Ho is rejected

H1 is accepted.

Interpretation.

There is statistically significant difference between the laboratory measured saturated hydraulic conductivity values and model predicted saturated hydraulic conductivity values.

For bulk density.

Decision.

$X^2\rho b$=. [(O-E)^2/E]=0.0517.

0.0517< 30.14, Ho is accepted.

H1 is rejected.

Interpretation.

There is statistically significant difference between the laboratory measured bulk density values and model predicted bulk density values.

For volumetric available water.

Decision.

X^2Aw=. [(O-E)^2/E]=854.94

854.94>30.14, Ho is rejected.

Hi is accepted.

Interpretation

There is statistically significant difference between the laboratory measured available water values and model predicted available water values.

Bosso pit 1

For volumetric water content at saturation.

Decision.

X^2sat. =. [(O-E) ^{2} /E]=10.314

10.314< 30.14, Ho is accepted.

H1 is rejected

Interpretation.

There is statistically no significant difference between the laboratory measured water content at saturation values and model predicted values.

For volumetric water content at field capacity.

Decision.

X^2FC =. [(O-E) ^{2} /E]=3.722

3.722< 30.14, Ho is accepted

H1 is rejetected

Interpretation.

There is statistically no significant difference between the laboratory measured water content at field capacity values and model predicted values.

For volumetric water content at wilting point

X^2WP =. [(O-E) ^{2} /E]=98.00

98.00>30.14, Ho is rejetected **,** H1 is accepted

Interpretation.

There is statistically significant difference between the laboratory measured water content at wilting point values and model predicted water content at wilting point values.

For saturated hydraulic conductivity

Decision.

X^2sat.k =. [(O-E) ^{2} /E]=432.13

432.13>30.14, Ho is rejected

H1is accepted.

Interpretation.

There is statistically significant difference between the laboratory measured saturated hydraulic conductivity values and model predicted saturated hydraulic conductivity values.

For bulk density.

Decision.

$X^2\rho b$ =. [(O-E) ^{2} /E]=0.472.

0.472< 30.14, Ho is accepted.

H1 is rejected.

Interpretation.

There is statistically significant difference between the laboratory measured bulk density values and model predicted bulk density values.

For volumetric available water.

Decision.

X^2Aw =. [(O-E) ^{2} /E]=464.48

464.48>30.14, Ho is rejected.

H1 is accepted.

Interpretation

There is statistically significant difference between the laboratory measured available water values and model predicted available water values

Bosso pit 2

For volumetric water content at saturation.

Decision.

X^2sat. =. [(O-E)^2/E]=7.166

7.166< 30.14, Ho is accepted.; H1 is rejected

Interpretation.

There is statistically no significant difference between the laboratory measured water content at saturation values and model predicted values.

For volumetric water content at field capacity.

Decision.

X^2FC =. [(O-E)^2/E]=0.921

0.921< 30.14, Ho, accepted; H1, rejetected

Interpretation.

There is statistically no significant difference between the laboratory measured water content at field capacity values and model predicted values.

For volumetric water content at wilting point

X^2WP =. [(O-E)^2/E]=73.20

73.20>30.14, Ho, rejetected

H1, accepted

Interpretation.

There is statistically significant difference between the laboratory measured water content at wilting point values and model predicted water content at wilting point values.

For saturated hydraulic conductivity

Decision.

X^2sat.k =. [(O-E)^2/E]=552.93

55.93>30.14, Ho, rejected; H1, accepted.

Interpretation.

There is statistically significant difference between the laboratory measured saturated hydraulic conductivity values and model predicted saturated hydraulic conductivity values.

For bulk density.

Decision.

X^2ρb =. [(O-E)^2/E]=1.315

1.315< 30.14, Ho, accepted.

H1, rejected.

Interpretation.

There is statistically significant difference between the laboratory measured bulk density values and model predicted bulk density values.

For volumetric available water.

Decision.

X^2Aw =.[(O-E)^2/E]=141.908

141.908>30.14, Ho, rejected.

Hi, accepted.

Interpretation

There is statistically significant difference between the laboratory measured available water values and model predicted available water values

APPENDIX B

Statistical tests tables for laboratory measured and model predicted values of dependent variables are shown below;

Table B1 Chi square test for independent variables Chanchaga pit 1

Pd	S	Ms	X^2	Fc	Mfc	X^2	Wp	Mwp	X^2	Sk	Msk	X^2	Pb	Mρb	X^2	Aw	Maw	X^2
0-20	37.5	47.7	2.2	34.5	27.2	2.0	0.8	18.1	16.5	28.0	19.0	8.4	1.5	1.4	0.0	33.7	9.0	67.7
20-40	36.2	48.8	3.3	33.2	28.2	0.9	1.6	19.1	16.0	13.2	22.0	3.5	1.5	1.4	0.0	31.6	9.0	56.7
40-60	35.3	45.4	2.3	32.3	24.1	2.8	1.1	15.4	13.3	12.7	24.0	5.3	1.5	1.5	0.0	34.2	9.0	70.6
60-80	37.8	45.3	1.2	34.8	23.5	5.4	0.0	15.5	15.5	15.1	26.0	4.6	1.4	1.5	0.0	43.8	9.0	134.5
80-100	41.4	47.7	0.4	33.1	24.2	3.3	0.7	16.4	15.0	26.5	21.0	1.4	1.4	1.4	0.0	32.4	9.0	61.1
	$\sum X^2 1= 9.327$			$\sum X^2 1= 14.342$				$\sum X^2 1= 76.377$			$\sum X^2 1=23.270$			$\sum X^2 1= 0.0$			$\sum X^2 1= 390.460$	

Table B2 Chi-squared test for independent variables Chanchaga Pit 2

Pd	S	Ms	X^2	Fc	Mfc	X^2	Mp	Mwp	X^2	Sk	Msk	X^2	Pb	Mρb	X^2	Aw	Maw	X^2
0-20	40.3	47.8	1.2	37.7	24.8	6.7	0.9	15.9	14.2	45.7	55.0	1.6	1.3	1.4	0.0	36.7	9.0	85.5
20-40	41.2	47.2	0.8	36.9	24.5	6.3	1.7	15.8	12.6	104.3	46.0	73.9	1.4	1.4	0.0	35.3	9.0	76.7
40-60	43.2	48.9	0.7	39.2	27.7	4.8	1.2	19.1	16.8	18.5	24.0	1.3	1.4	1.4	0.0	38.0	9.0	93.4
60-80	41.4	45.8	0.4	40.0	25.2	8.7	0.5	17.1	16.1	139.3	14.0	1121.4	1.4	1.4	0.0	39.5	8.0	124.1
80-100	40.9	47.0	0.8	38.9	25.9	6.5	2.3	17.2	12.9	4.1	21.0	13.6	1.4	1.4	0.0	36.6	9.0	84.8
	$\sum X^2 2= 3.823$				$\sum X^2 2= 32.970$			$\sum X^2 2= 72.531$			$\sum X^2 2= 1211.720$			$\sum X^2 2= 0.0$			$\sum X^2 2= 464.48$	
	$\sum X^2 1,2= 13.151$				$\sum X^2 1,2= 47.32$			$\sum X^2 1,2= 148.909$			$\sum X^2 1,2= 1234.99$			$\sum X^2 1,2= 0.0$			$\sum X^2 1,2= 854.94$	

Table B3 Chi squared test for independent variables Bosso pit 1

Pd	S	Ms	X^2	Fc	Mfc	X^2	Wp	Mwp	X^2	Sk	Msk	X^2	Pb	Mρb	X^2	Aw	Maw	X^2
0-20	48.1	54.9	0.8	32.6	31.9	0.0	0.0	22.1	22.1	2.9	90.0	84.3	1.6	1.2	0.1	32.2	10.0	50.8
20-40	40.8	54.8	3.6	39.8	32.2	1.8	0.0	20.5	20.5	0.9	130.0	128.2	1.7	1.2	0.2	39.8	12.0	64.5
40-60	49.4	53.8	0.4	35.1	34.7	0.0	0.0	22.2	22.2	5.7	61.0	50.1	1.3	1.2	0.0	35.1	12.0	44.4
60-80	60.8.	50.1	2.3	33.6	26.5	1.9	0.0	16.2	16.2	6.6	105.0	92.2	1.6	1.3	0.1	33.6	10.0	55.7
80-100	37.6	50.4	3.3	27.4	27.0	0.0	0.0	17.0	17.0	5.0	87.0	77.3	1.7	1.3	0.1	27.4	10.0	30.1
			$\sum X^2 1=$ 10.314			$\sum X^2 1=$ 3.722			$\sum X^2 1=$ 98.0			$\sum X^2 1=$ 432.130			$\sum X^2 1=$ 0.472			$\sum X^2 1=$ 245.345

Table B4 Chi squared test for independent variables Bosso pit 2

Pd	S	M s	X^2	Fc	Mfc	X^2	Wp	Mwp	X^2	Sk	Msk	X^2	Pb	Mρb	X^2	Aw	Maw	X^2
0-20	46.5	52.8	0.8	31.5	28.3	0.4	1.2	17.4	15.1	6.4	169.0	156.4	1.5	1.3	0.1	30.3	11.0	33.9
20-40	44.7	52.4	1.1	28.3	27.8	0.0	1.0	10.7	8.8	3.2	195.01	188.7	1.5	1.3	0.0	27.3	11.0	24.2
40-60	53.3	54.9	0.1	34.0	32.5	0.1	1.0	21.3	19.4	2.6	110.0	104.9	1.5	1.2	1.1	32.1	11.0	40.3
60-80	38.0	53.3	4.4	28.1	31.3	0.3	3.8	22.0	15.1	1.5	53.0	50.0	1.7	1.2	0.1	24.3	9.0	25.9
80-100	43.5	50.0	0.9	24.0	26.0	0.2	0.7	16.3	14.9	29.8	104.0	52.9	1.5	1.3	0.0	23.3	10.0	17.6
	$\sum X^2 2= 7.167$				$\sum X^2 2= 4.634$			$\sum X^2 2= 73.2$			$\sum X^2 2= 552.930$			$\sum X^2 2= 1.314$			$\sum X^2 2= 141.908$	
	$\sum X^2 1,2= 17.481$				$\sum X^2 1,2= 4.634$			$\sum X^2 1,2= 171.200$			$\sum X^2 1,2= 985.060$			$\sum X^2 1,2= 1.7866$			$\sum X^2 1,2= 387.262$	

Table B5 Laboratory measured and model Predicted soil water characteristics Chanchaga Pit 1

Pd	S	Ms	Fc	Mfc	Wp	Mwp	Sk	Msk	Pb	Mρb	Aw	Maw	Om	Sand	silt	clay	Tc	Mtc
0-20	37.5	47.7	34.5	27.2	0.8	18.1	28.0	19.0	1.5	1.4	33.7	9.0	0.5	59.1	9.3	31.6	Scl	Scl
20-40	36.2	48.8	33.2	28.2	1.6	19.1	13.2	22.0	1.5	1.4	31.6	9.0	0.8	59.1	7.3	36.6	scl	Sc
40-60	35.3	45.4	32.3	24.1	1.1	15.4	12.7	24.0	1.5	1.5	34.2	9.0	1.2	63.1	11.3	25.6	scl	Scl
60-80	37.8	45.3	34.8	23.5	0.0	15.5	15.1	26.0	1.4	1.5	43.8	9.0	0.3	69.1	5.3	25.6	scl	Scl
80-100	41.4	47.7	33.1	24.2	0.7	16.4	26.5	21.0	1.4	1.4	32.4	9.0	0.3	69.1	3.3	27.6	scl	Scl

Table B6 Laboratory measured and model Predicted soil water characteristics Chanchaga Pit 2

Pd	S	Ms	Fc	Mfc	Wp	Mwp	Sk	Msk	Pb	Mρb	Aw	Maw	Om	Sand	silt	clay	Tc	Mtc
0-20	40.3	47.8	37.7	24.8	0.9	15.9	45.7	55.0	1.3	1.4	36.7	9.0	1.2	69.1	11.3	25.6	scl	Scl
20-40	41.2	47.2	36.9	24.5	1.7	15.8	104.3	46.0	1.4	1.4	35.3	9.0	1.0	69.1	11.3	25.6	scl	Scl
40-60	43.2	48.9	39.2	27.7	1.2	19.1	18.5	24.0	1.4	1.4	38.0	9.0	0.9	63.1	3.3	33.6	scl	Scl
60-80	41.4	45.8	40.0	25.2	0.5	17.1	139.3	14.0	1.4	1.4	39.5	8.0	0.1	65.1	5.3	29.6	scl	Scl
80-100	40.9	47.0	38.9	25.9	2.3	17.2	4.1	21.0	1.4	1.4	36.6	9.0	0.5	63.1	7.3	29.6	scl	Scl

Table B7 Laboratory measured and model Predicted soil water characteristic Bosso Pit1

Pd	S	Ms	Fc	Mfc	Wp	Mwp	Sk	Msk	Pb	Mρb	Aw	Maw	Om	Sand	silt	clay	Tc	Mt
0-20	48.1	54.9	32.6	31.9	0.0	22.1	2.9	90.0	1.6	1.2	32.2	10.0	2.7	51.8	8.6	39.6	sc	Sc
20-40	40.8	54.8	39.8	32.2	0.0	20.5	0.9	130.0	1.7	1.2	39.8	12.0	2.7	47.8	16.6	35.6	sc	Sc
40-60	49.4	53.8	35.1	34.7	0.0	22.2	5.7	61.0	1.3	1.2	35.1	12.0	2.4	37.8	22.6	39.6	cl	Cl
60-80	60.8	50.1	33.6	26.5	0.0	16.2	6.6	105.0	1.6	1.3	33.6	10.0	2.0	63.8	10.6	26.6	scl	Scl
80-100	37.6	50.4	27.4	27.0	0.0	17.0	5.0	87.0	1.7	1.3	27.4	10.0	2.1	63.8	8.6	27.6	scl	Scl

Table B8 Laboratory measured and model Predicted soil water characteristics Bosso Pit2

pd	S	Ms	Fc	Mfc	Wp	Mwp	Sk	Msk	Pb	Mρb	Aw	Maw	Om	sand	silt	Clay	Tc	Mt
0-20	46.5	52.8	31.5	28.3	1.2	17.4	6.4	169.0	1.5	1.3	30.3	11.0	2.5	63.8	8.6	27.6	scl	Scl
20-40	44.7	52.4	28.3	27.8	1.0	10.7	3.2	195.01	1.5	1.3	27.3	11.0	7	65.8	18.6	25.6	scl	Scl
40-60	53.3	54.9	34.0	32.5	1.0	21.3	2.6	110.0	1.5	1.2	32.1	11.0	2.9	47.9	14.6	37.6	scl	Scl
60-80	38.0	53.3	28.1	31.3	3.8	22.0	1.5	53.0	1.7	1.2	24.3	9.0	2.3	55.8	4.6	39.6	scl	Scl
80-100	43.5	50.0	24.0	26.0	0.7	16.3	29.8	104.0	1.5	1.3	23.3	10.0	2.1	69.8	4.6	25.6	scl	Scl

APPENDIX C

Table C1 Determination of water content at saturation.Chanchaga Pit 1

Profile Depth (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Bulk density (g/cm^3)	Soil. water Content (g/g)	Available Water (cm/cm)
0-20	25.0	209.8	172.7	147.7	1.5	0.3	0.22
20-40	25.4	209.7	173.8	148.4	1.5	0.2	0.21
40-60	24.7	203.7	168.6	143.8	1.5	0.2	0.23
60-80	24.5	198.8	162.1	137.7	1.4	0.3	0.31
80-100	24.1	199.3	159.2	135.1	1.4	0.3	0.24

Table C2 Determination of water content at wilting point.Chanchaga Pit 1

Profile Depth (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil. water Content (g/g)	Available Water (%)
0-20	25.1	113.3	112.8	87.7	$5.5*10^{-3}$	0.55
20-40	25.5	110.1	109.3	83.8	$1.1*10^{-2}$	1.1
40-60	25.0	128.8	128.1	103.0	$7.3*10^{-3}$	0.73
60-80	24.9	103.8	103.2	78.0	$7.2*10^{-3}$	0.72
80-100	24.5	110.9	110.5	86.0	$4.9*10^{-3}$	0.49

Table C3 Determination of water content at field capacity.Chanchaga pit 1

Profile Depth (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil. water Content (g/g)	Available Water (cm/cm)
0-20	24.4	208.8	173.9	149.5	0.23	23
20-40	24.9	208.1	174.9	149.9	0.22	22
40-60	24.7	195.1	162.3	137.8	0.24	24
60-80	26.1	201.8	166.5	140.4	0.32	32
80-100	25.0	195.9	163.2	138.2	0.24	24

Table C4 Organic Carbon/Organic matter determination.Chanchaga Pit 1

Profile Depth (cm)	Initial reading (cm^3)	Final readings (cm^3)	Volume used (cm^3)	Organic Carbon (%)	Organic Matter (%)
0-20	0.00	19.50	19.50	0.26	0.45
20-40	19.50	37.90	18.40	0.42	0.78
40-60	0.00	20.50	20.50	0.105	0.18
60-80	20.50	40.70	20.20	0.15	0.26
80-100	0.00	20.00	20.00	0.18	0.31

Table C5 Determination of Saturated Hydraulic Conductivity.Chancaga pit 1

Profile depth (cm)	Volume of water collected (cm^3)	Saturated Hydraulic Conductivity (cm/hr)	Time (hr)
0-20	550.0	28.00	1
20-40	259.0	13.19	1
40-60	249.0	12.68	1
60-80	296.0	15.07	1
80-100	520.0	26.48	1

Table C5 Determination of particle size. Chanchaga Pit 1

Lab. No	Profile Depth (cm)	40 sec. readings	Temp (°C)	2hr readings	Temp. (°C)	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	0-20	7.00	29	2.00	30	59.12	9.28	31.6	Scl
2	20-40	7.00	29	3.00	30	59.12	7.28	33.6	Scl
3	40-60	5.00	29	2.00	30	63.12	11.28	25.6	Scl
4	60-80	2.00	29	1.00	30	69.12	5.28	25.6	Scl
5	80-100	2.00	29	0.00	30	69.12	3.28	27.6	Scl

Table C6 Determination of water content at saturation. Chanchaga Pit 2

ofile epth m)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Bulk density (g/cm^3)	Soil. water Content (g/g)	Available Water (cm/cm)
20	24.2	190.8	151.6	127.4	1.30	0.31	0.28
-40	24.9	204.0	164.1	139.2	1.42	0.29	0.26
-60	25.1	199.4	157.3	132.3	1.35	0.32	0.28
-80	24.5	200.5	159.5	135.0	1.38	0.30	0.28
-100	25.7	199.4	161.7	136.0	1.39	0.28	0.25

Table C7 Determination of water content at wilting point.Chanchaga Pit 2

file th (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil. water Content (g/g)	Water content (%)
	25.8	106.8	106.2	80.4	$7.2*10^{-3}$	0.72
	25.5	123.2	122.8	97.2	$4.6*10^{-3}$	0.46
)	25.1	123.7	122.8	97.7	$8.6*10^{-3}$	0.86
	24.1	121.8	121.6	97.4	$3.7*10^{-3}$	0.37
0	25.2	106.7	105.4	80.2	$1.7*10^{-2}$	1.70

Table C8 Determination of water content at field capacity.Chanchaga Pit 2

Profile Depth (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil. water Content (g/g)	Water content (%)
0-20	25.1	198.8	160.1	134.9	0.29	29
20-40	25.7	210.9	172.3	146.7	0.26	26
40-60	24.8	195.6	157.3	132.7	0.29	29
60-80	25.1	206.3	166.1	150.0	0.28	28
80-100	25.5	200.2	163.2	138.7	0.27	27

Table BC9 Determination of Saturated Hydraulic Conductivity.Chancaga pit 2

Profile depth (cm)	Volume of water collected (cm^3)	Saturated Hydraulic Conductivity (cm/hr)	Time (hr)
0-20	897	45.67	1
20-40	2048	104.28	1
40-60	363	18.48	1
60-80	2735	139.26	1
80-100	81	4.12	1

able C10 Organic Carbon/Organic matter determination.Chanchaga Pit 2

Profile Depth (cm)	Initial reading (cm^3)	Final readings (cm^3)	Volume used (cm^3)	Organic Carbon (%)	Organic Matter (%)
0-20	21.20	37.70	16.50	0.71	1.22
20-40	0.00	17.40	17.40	0.57	0.99
40-60	17.40	35.10	17.60	0.54	0.93
60-80	35.10	52.00	16.90	0.65	1.12
80-100	0.00	19.20	19.20	0.31	0.54
Blank	0.00	21.20	21.20		

Table C11Determination of particle size. Chanchaga Pit 2

Lab. No	Profile Depth (cm)	40 sec. readings	Temp (°C)	2hr readings	Temp. (°C)	Sand (%)	Silt (%)	Clay (%)	Textural Class
	0-20	2.00	29	-1.00	30	69.1	11.28	25.6	Scl
	20-40	2.00	29	-1.00	30	69.1	11.28	25.6	Scl
	40-60	8.00	29	3.00	30	63.1	3.28	33.6	Scl
	60-80	7.00	29	1.00	30	65.1	5.28	29.6	Scl
	80-100	8.00	29	1.00	30	63.1	7.28	29.6	Scl
	Blank	-3.00	29	-3.00	30				

Table C12Determination of water content at saturation. Bosso Pit 1

Profile Depth (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Bulk density (g/cm^3)	Soil. water Content (g/g)	Water content (%)
0-20	24.92	223.62	177.22	152.3	1.55	0.31	31
20-40	24.91	227.69	188.21	163.3	1.66	0.24	24
40-60	24.57	200.09	152.07	127.5	1.30	0.38	38
60-80	24.39	222.39	181.84	157.45	1.60	0.26	26
80-100	23.99	227.72	191.68	167.69	1.71	0.22	22

Table C13 Determination of water content at wilting point. Bosso Pit 1

ofile pth)	Wt of can (g)	Wt of can +Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil. water Content (g/g)	Water content (%)	Available Water (cm/cm)
)	25.12	150.21	148.37	123.25	$1.49*10^{-2}$	1.49	0.20
0	25.49	162.45	160.42	134.93	$1.51*10^{-2}$	1.51	0.19
)	24.99	145.39	142.68	117.69	$2.3*10^{-3}$	2.3	0.25
)	25.06	143.19	142.25	117.19	$8.02*10^{-3}$	0.80	0.20
0	24.51	164.26	163.38	138.87	$6.34*10^{-3}$	0.63	0.15

Table C14 Determination of water content at field capacity.Bosso Pit 1

Profile Depth (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil. water Content (g/g)	Water content (%)
0-20	24.58	209.22	176.71	152.13	0.21	21
20-40	25.20	218.93	181.93	156.14	0.24	24
40-60	25.80	204.06	204.06	141.48	0.27	27
60-80	26.38	214.91	214.91	156.1	0.21	21
80-100	25.39	209.01	209.01	158.4	0.16	16

Table C15 Determination of Saturated Hydraulic Conductivity.Bosso pit 1

Profile depth (cm)	Volume of water collected (cm^3)	Saturated Hydraulic Conductivity (cm/hr)	Time (hr)
0-20	56.0	2.85	1
20-40	18.0	0.92	1
40-60	112.0	5.70	1
60-80	129.0	6.57	1
80-100	98.0	4.99	1

Table C16 Organic Carbon/Organic matter determination.Bosso Pit 1

Profile Depth (cm)	Initial reading (cm^3)	Final readings (cm^3)	Volume used (cm^3)	Organic Carbon (%)	Organic Matter (%)
0-20	0.00	13.00	13.00	1.56	2.70
20-40	13.00	26.20	13.20	1.53	2.65
40-60	26.20	40.30	14.10	1.40	2.41
60-80	0.00	15.80	15.80	1.14	1.97
80-100	15.80	31.10	15.30	1.2	2.10
Blank	0.00	15.40	23.40		

Table C17 Determination of particle size Bosso Pit 1

Lab. No	Profile Depth(cm)	40 sec. readings	Temp (°C)	2hr readings	Temp. (°C)	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	0-20	12.0	28	7.0	30	51.84	8.56	39.60	Sc
2	20-40	14.0	28	5.0	30	47.84	16.56	35.60	Sc
3	40-60	19.0	28	7.0	30	37.84	22.56	39.60	Cl
4	60-80	6.0	28	0.0	30	63.84	10.56	25.60	Scl
5	80-100	6.0	28	1.0	30	63.84	8.56	27.60	Scl
	Blank	-2.0		-2.0					

Table C18 Determination of water content at saturation. Bosso Pit 2

ile h	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Bulk density (g/cm^3)	Soil. water Content (g/g)	Water content (%)	Available Water (%)
	23.90	216.83	171.07	147.17	1.50	0.31	31	0.21
)	24.76	215.19	170.64	145.88	1.49	0.30	30	0.18
)	25.16	224.64	171.00	145.84	1.48	0.37	36	0.22
)	24.34	222.84	186.19	161.85	1.65	0.23	23	0.15
0	24.94	215.08	172.41	147.44	1.50	0.29	29	0.16

Table B9 Determination of water content at wilting point. Bosso Pit 2

Profile Depth cm)	Wt of can (g)	Wt of can +Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil.water Content (g/g)	Water content (%)
-20	25.79	139.52	138.62	112.83	7.98^{*-3}	0.80
0-40	24.79	141.81	140.69	115.9	9.66^{*-3}	0.66
)-60	25.15	148.83	147.20	122.05	1.34^{*-2}	1.34
-80	24.21	120.40	118.23	94.02	2.31^{*-2}	2.30
-100	25.31	184.59	183.81	158.5	24.92^{*-3}	0.49

Table C20 Determination of water content at field capacity.Bosso Pit 2

Profile Depth (cm)	Wt of can (g)	Wt of can + Wt of wet soil (g)	Wt.of Oven dried soil +can (g)	Wt.of Oven dried soil (g)	Soil. water Content (g/g)	Water content (%)
0-20	25.37	205.53	173.55	148.18	0.21	21
20-40	25.73	212.13	182.14	156.41	0.19	19
40-60	24.95	206.67	172.38	147.43	0.23	23
60-80	25.10	218.10	189.43	164.33	0.17	17
80-100	24.52	166.24	146.10	121.58	0.16	16

Table C22 Determination of Saturated Hydraulic Conductivity.Bosso pit 2

Profile depth (cm)	Volume of water collected (cm^3)	Saturated Hydraulic Conductivity (cm/hr)	Time (hr)
0-20	125.0	6.37	1
20-40	63.0	3.21	1
40-60	50.0	2.55	1
60-80	29.0	1.48	1
80-100	586.0	29.84	1

Table C23 Organic Carbon/Organic matter determination.Bosso Pit 1

Profile Depth (cm)	Initial reading (cm^3)	Final readings (cm^3)	Volume used (cm^3)	Organic Carbon (%)	Organic Matter (%)
0-20	31.10	44.80	13.70	1.46	2.50
20-40	0.00	12.90	12.90	1.58	2.70
40-60	12.90	25.20	12.30	1.67	2.88
60-80	25.20	37.70	12.50	1.31	2.26
80-100	0.00	15.40	15.40	1.2	2.10
Blank			23.40		

Table C24 Determination of particle size Bosso Pit 1

Lab. No	Profile Depth (cm)	40 sec. readings	Temp (°C)	2hr readings	Temp. (°C)	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	0-20	6.0	28	1.0	30	63.84	8.56	27.60	Scl
2	20-40	5.0	28	0.0	30	65.84	8.56	25.60	Csl
3	40-60	14.0	28	6.0	30	47.84	14.56	37.60	Sc
4	60-80	10.0	28	7.0	30	55.84	4.56	39.60	Sc
5	80-100	3.0	28	0.0	30	69.84	4.56	25.60	Scl
	Blank	-2.0		-2.0					

APPENDIX D

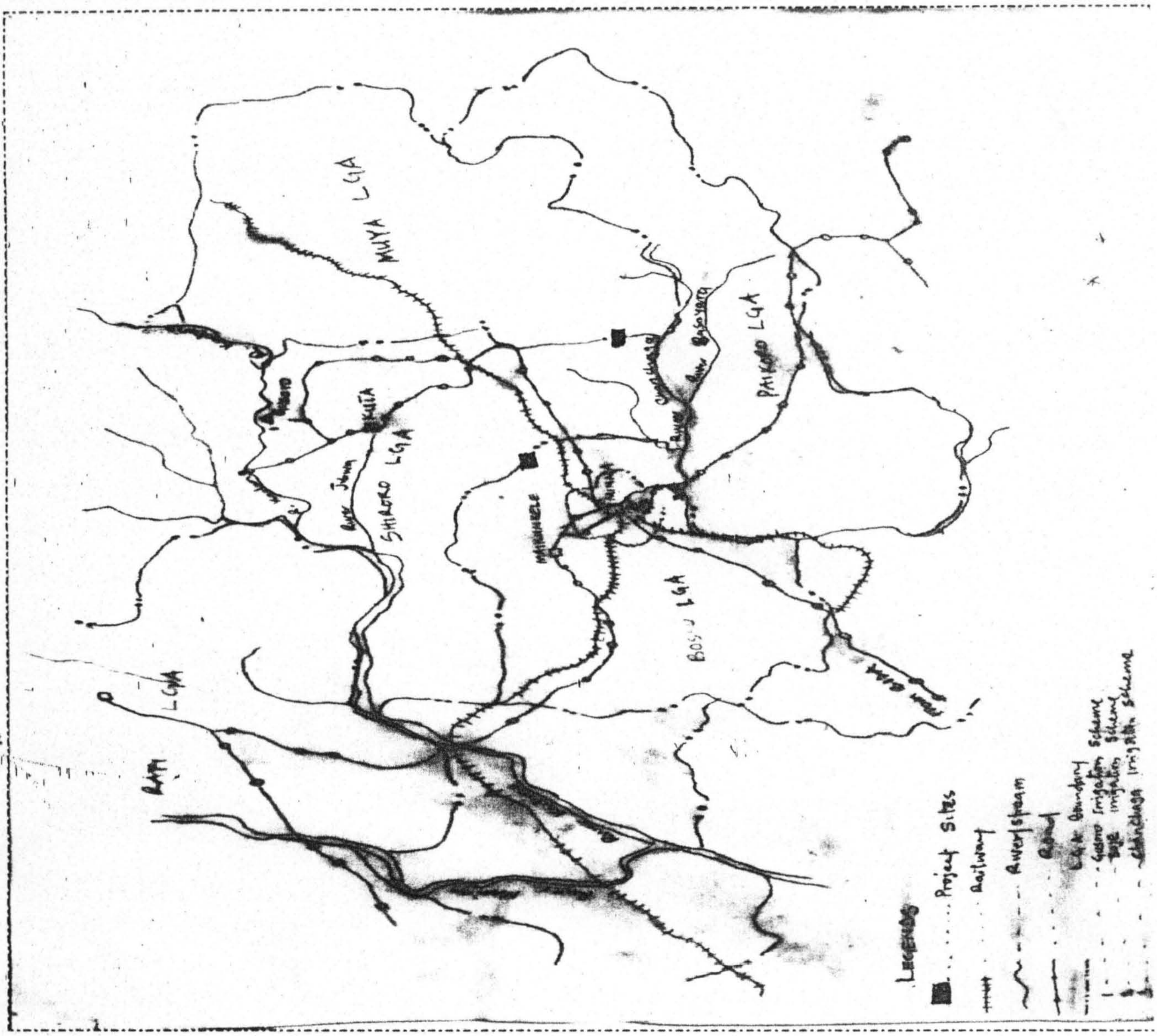
Table D Mean Temperature, Rain fall and Evaporation of Jan. – July, 2006.

Month	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
Temp.(°C)	35.7	37.7	35.6	38.4	32.0	31.5	30.1
Rain.(mm)	11.2	0.0	TR	29.9	195.0	107.0	229.7
Evap.(mm/day)	8.7	10.3	10.1	9.7	3.6	3.0	2.1

Source: Meteorological Station Minna Airport, Niger State

APPENDIX E

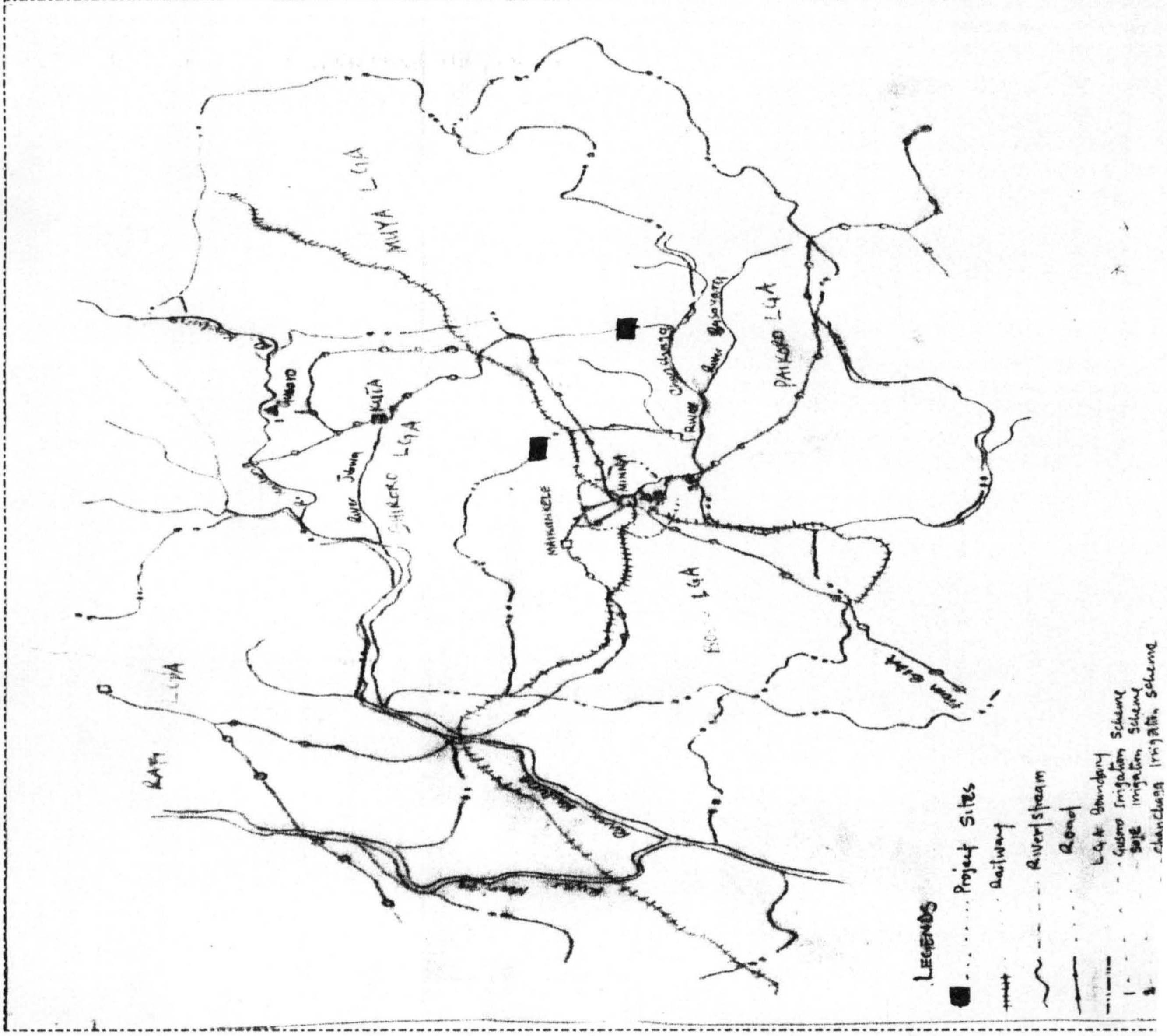
Map showing the locations of Study Areas



■ APPX. Points of sampling

APPENDIX E

Map showing the locations of Study Areas



■ APPX. Points of sampling

APPENDIX F

Appendix F Percentage Points of the Chi-Square Distribution

Degrees of freedom	Probability of a larger value of χ^2								
	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
1	0.000	0.000	0.016	0.102	0.455	1.32	2.71	3.84	6.63
2	0.020	0.103	0.211	0.575	1.386	2.77	4.60	5.99	9.21
3	0.115	0.352	0.584	1.213	2.366	4.11	6.25	7.81	11.34
4	0.297	0.711	1.064	1.923	3.357	5.38	7.78	9.49	13.28
5	0.554	1.145	1.610	2.675	4.351	6.63	9.24	11.07	15.09
6	0.872	1.635	2.204	3.455	5.348	7.84	10.64	12.59	16.81
7	1.239	2.167	2.833	4.255	6.346	9.04	12.02	14.07	18.47
8	1.646	2.733	3.490	5.017	7.344	10.22	13.36	15.51	20.09
9	2.088	3.325	4.168	5.899	8.343	11.39	14.68	16.92	21.67
10	2.558	3.940	4.865	6.737	9.342	12.55	15.99	18.31	23.21
11	3.053	4.575	5.578	7.584	10.341	13.70	17.27	19.67	24.72
12	3.571	5.226	6.304	8.438	11.340	14.84	18.55	21.03	26.22
13	4.107	5.892	7.042	9.299	12.340	15.98	19.81	22.36	27.69
14	4.660	6.571	7.790	10.165	13.339	17.12	21.06	23.68	29.14
15	5.229	7.261	8.547	11.036	14.339	18.25	22.31	25.00	30.58
16	5.812	7.962	9.312	11.912	15.338	19.37	23.54	26.30	32.00
17	6.408	8.672	10.085	12.792	16.338	20.49	24.77	27.59	33.41
18	7.015	9.390	10.865	13.675	17.338	21.60	25.99	28.87	34.80
19	7.633	10.117	11.651	14.562	18.338	22.72	27.20	30.14	36.19
20	8.260	10.851	12.443	15.452	19.337	23.83	28.41	31.41	37.57
22	9.542	12.338	14.041	17.240	21.337	26.04	30.81	33.92	40.29
24	10.856	13.848	15.659	19.037	23.337	28.24	33.20	36.41	42.98
26	12.198	15.379	17.292	20.843	25.336	30.43	35.56	38.88	45.64
28	13.565	16.928	18.939	22.657	27.336	32.62	37.92	41.34	48.28
30	14.953	18.493	20.599	24.478	29.336	34.80	40.26	43.77	50.89
40	22.164	26.509	29.051	33.660	39.335	45.62	51.80	55.76	63.69
50	27.707	34.764	37.689	42.942	49.335	56.33	63.17	67.50	76.15
60	37.485	43.188	46.459	52.294	59.335	65.98	74.40	79.08	88.38

APPENDIX G

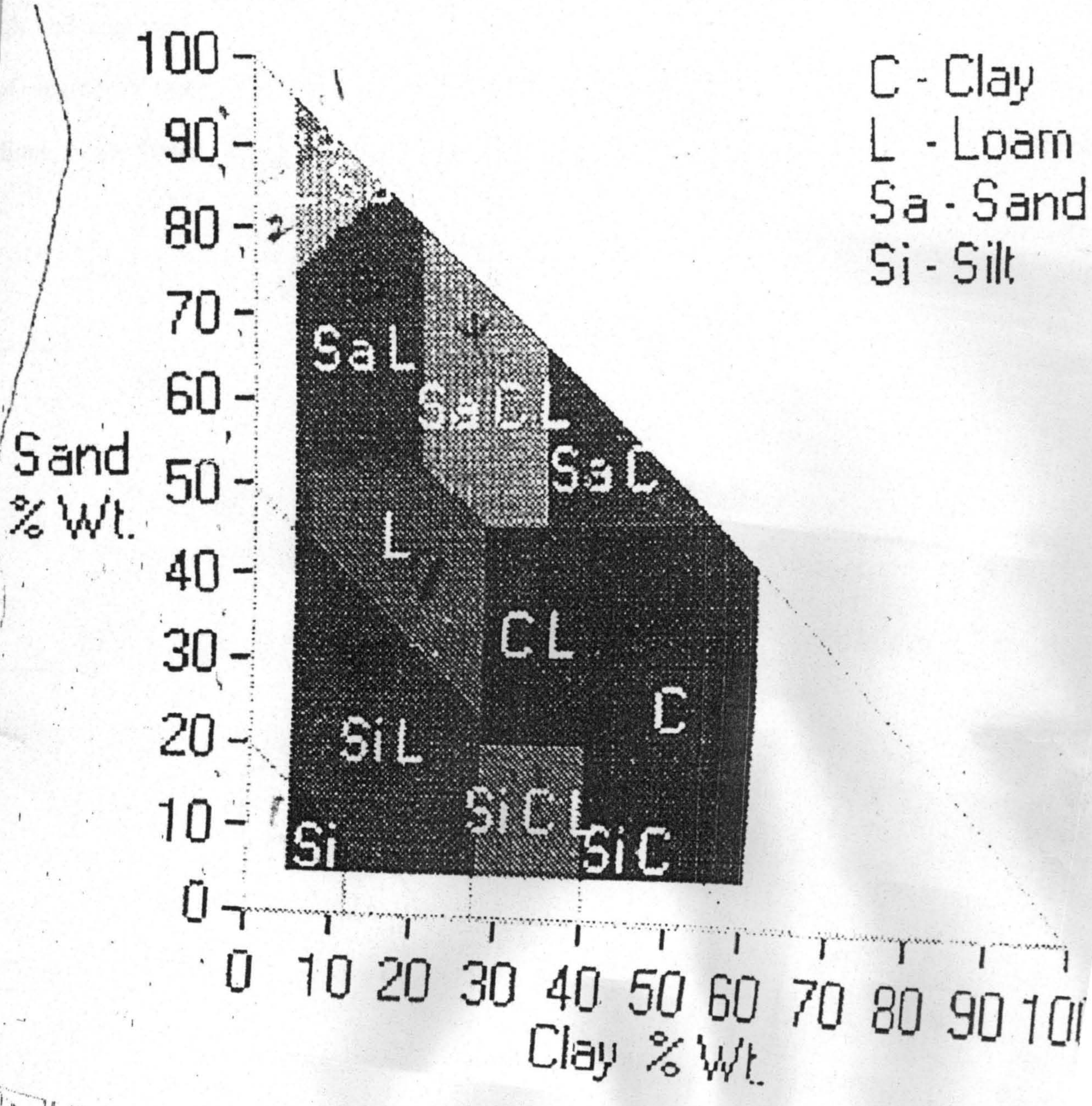


Fig G Textural Triangle