COMPARATIVE EVALUATION OF SOME PHYSICAL AND CHEMICAL PROPERTIES OF TERMITE HILL SOIL, WORM CAST AND ALLUVIAL SOIL

By

YAHAYA, USMAN KEANA

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DEPARTMENT OF AGRICULTURAL AND BIO-RESOURCE ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

FEBRUARY, 2010.

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIO RESOURCES ENGINEERING.
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

FEBRUARY, 2010.

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 or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

17/02/2010

Yahaya Usman Keana

2004/18449EA

Date

CERTIFICATION

This project entitles "Comparative Evaluation of some Physical and Chemical Properties of Termite Hill Soil, Worm Cast and Alluvial Soil." By Yahaya Usman Keana meets the regulations governing the award of the degree 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.

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Date

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External Examiner

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Date

DEDICATION

I dedicate this project to the memory of my late Mother and sponsor, Hajiya Asamau Ladi who passed away during my final year of studies on 16th June 2009. May her gentle soul rest in peace (AMEEN).

ACKNOWLEDGEMENTS

First, I would like to thank God almighty for letting me pass through this academic struggle generally. Much thanks also to my project supervisor, Mr. P.A. Adeoye for the support and encouragement always. My late mother Hajiya Asamau Ladi, you deserve an endless thanks and may peace be upon you always.

Also, much thanks goes to the entire lecturers of Agric. and Bio-resources Engineering Department especially the H.O.D Dr A.A. Balami, may God bless you all.

Finally, i would like say thank you to all my friends in the department especially Benjamin Attah and Abubakar Ibrahim for your support always.

ABSTRACT

There are many different types of creatures that live on or in the topsoil. Each has a role to play. These organisms will work for the farmer's benefit if we simply manage for their survival. Consequently, we may refer to them as soil livestock. While a great variety of organism contributes to soil fertility, earthworms, termites and the various other soil-organisms merits particular attention. Some selected physical and chemical properties of termite hill soil, worm cast and alluvial soil which includes porosity, hydraulic conductivity, plasticity index, bulk density, pH, Nitrates, Sulphate and Phosphates have been able to indicate how the sample considered vary in their characteristics. It was seen that all samples considered contain some fertility before they are mixed that can be used for crop growth. It was also seen that worm cast soil has the highest fertility since it contains the highest sulphate, nitrate, phosphate and even organic matter followed by the alluvial soil and finally the termite hill cast which can be used to improve the soil hydraulic properties. Worm cast soil was seen to have a sulphate of 45mg/g, Nitrate of 41.3mg/g, and a phosphate of 41.3mg/g. Termite hill soil has a Sulphate of 22mg/g, a Nitrate of 16.5mg/g and sulphate of 22.9mg/g. The alluvial soil has a Sulphate of 39mg/g, Nitrate of 18.2mg/g and a sulphate of 59.0mg/g.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Soil widely varies in their characteristics and properties. In order to establish the interrelationship between their characteristics they require to be classified. Understanding the properties of the soil is important in respect of the optimum use they can be put to and for their best management requirement. The knowledge of properties of any engineering material is important to be able to use them in executing any useful project. This study takes us into knowing the different properties of termite hill soil, worm cast and alluvial soil. It is meant to compare their characteristics both physical and hydraulic, in order to know where they can suitably apply. These classes of soils are most often neglected or viewed with less importance; but for the purpose of this study, it can be seen what the different samples now represent in terms of properties and can easily be appropriately applied.

The activities of termite and worms upon the agricultural land have some merit and demerit depending on the view of individual or groups. Termite transports large quantities of materials from within the soil depositing it on the surface. Some of the termite hill moulds are about 5 meters tall and 7 meters in diameter. The earth movement activity of termite results in greater than normal content of the clay.

The productivity of agricultural land which is measured in terms of yield recovery depends on soil climatic conditions, pests, diseases, genetic potentials irrespective of the soil nutrient; the presence of humidified organic matter is of great importance in the formation and stabilization of soil structure. Amongst other soil invertebrates, earthworms are most abundant in soil minerals. They are found in almost all kinds of soil at different latitude except in arctic and Antarctic region. They form the highly mobile macroscopic soil invertebrates that help in mixing the soil. Though the soil organism comprises a very small percentage of total weight of soil with their rate of activity, they form the dominant factors in functioning of the soil system. Effect of earthworm activity on soil physico-chemical properties during the short period of favourable conditions, tropical worms have sufficient contributions in soil over. In most cases, immediately after the moon set showers large quantities of worm cast are observed on the soil surface. The mechanical breakdown of the plant litter and assimilating only 5 to 10 of the main job performed by many of these soil organism. It is also true that the faeces of these organisms provide more scope for the establishment of microbes than mechanically pulverized matter. The size and shape of the released cast is species specific but this cannot be considered as criteria for identifying worms. Because worm casts improve the physical, chemical and biological properties of soil, worms are used for recycling agricultural and municipal waste around countries like USA, Japan and Australia.

The alluvial soil on the other hand is formed when a soil carrying stream gradually loses its carrying capacity with decreasing velocity. In slowing down, a river does not have sufficient power to keep the large particles of soil suspended. These particles settle to the river bed. Further decrease in velocity causes smaller particles to settle. As the river becomes slow and sluggish (as in the lowlands where its gradient becomes small) it holds only the extremely fine particles in suspension. These particles are deposited finally at the mouth of the river, where they form deltas of fine grained soil. The deltas of rivers are alluvial deposits. Where swift mountains streams reach the floor of a flat valley, the sudden changes in grade, and the consequent slowing of the stream, often results in the deposition of an alluvial fan, another form of alluvial deposit. The action of running water tends to sort out the different sizes and weights of particles that are carried in suspension. Thus gravels and pebbles will be deposited farther upstream than the lighter sand fine silt will be carried farther downstream than sand. Deposits are also formed in the ocean, in lakes, and in other places by the settlement of sand, silt and other material.

The physical characteristics to be examined include the particle size, the particle shape, bulkiness, gradation, compactness, specific gravity, soil moisture, porosity. Although many conceptual model of soil assume that the experimental evidence indicates that the physical characteristics of soil aid in determining their engineering characteristics and are the basis of the system of soil classification used in general for the identification of soil types. Knowledge of these physical characteristic aid in determining the degree to which the local soil can be used in engineering project to support traffic loads or to serve as sub grade or foundation material. Particles making up the smaller soil fractions are directly non-spherical. The evidence has been compiled principally from ultra-microscopic observations of clay soils, the double refraction of clay particles, the layering of particles during deposition, the nature of clay crystals, and electron microscopy. The soil structure and its stability play an important role in a variety of process in the soil such as erosion, infiltration, root penetration, aeration or mechanical strength. Since all these process all have observable characteristics, soil structure is often evaluated by methods that correlate it to the properties of the process of interest. Soil structure can be evaluated by determining the extent of aggregation, the stability of the aggregates, and the nature of the pore space. These characteristics which significantly influence plant response to water management practices will change with tillage practices and cropping system.

The hydraulic characteristics to be examined include the volumetric water content, available water content; bulk density, field capacity FC, saturated hydraulic conductivity, organic matter, permanent wilting point, field capacity, saturated hydraulic conductivity soil water retention capacity. The characteristics of soils and the vados zone include the estimation of the soil water retention and unsaturated hydraulic conductivity relations over a wide range of volumetric water content values. Although occasionally only specific data points are needed, parametric models for both hydraulic properties are preferred. The saturated hydraulic conductivity of the surface soil and sub-soil, final infiltration rate and soil holding capacity were recognised as the most critical hydraulic parameters based on their application in various water management activities and were selected for measurement.

Characterization of soils and the zone between surface and water table includes the estimation of the soil water retention and unsaturated hydraulic conductivity relations for a wide range of volumetric water content values. Although occasionally only specific data points are needed, parametric models for both hydraulic properties are preferred. The demand for these expressions is driven by their use in numeric models for simulating fluid flow and mass transport. These models do not necessarily require simple parametric expressions, but can instead use tables of values. However, the parametric models are generally well behaved for interpolation purposes and cause fewer numerical problems. The increasing availability of simulation models, their increasing ease of use and their ability to accurately predict flow and transport has created a need for parametric expressions that describe hydraulic relations for both near-surface soils and deep vadose zone.

Typically the soils to be characterized exhibit large variations in space and occasionally in time as well. Consequently, techniques need to be developed that allow a physical description of these variations with the least amount of effort. Although scaling techniques are useful in this respect, they generally require parametric models of the soil hydraulic properties. Also, indirect estimation techniques are becoming increasingly popular so that parameters of soil hydraulic functions, such as in the use of pseudo transfer functions to define land or soil quality indicators. A comprehensive evaluation of indirect estimation techniques is to be presented. The soil water retention function relates the energy state of the soil water content. If the soil pores are represented by an equivalent bundle of capillaries, with identical retention properties as real soil, a retention function provides the soil's pore-size distribution from which the unsaturated hydraulic conductivity function can be predicted.

1.2 Objectives of Study

The objectives of the study are:

1. To evaluate the physical and chemical characteristics of termite hill soil, worm cast and alluvial soil.

2. To compare the properties of each of the samples and ascertain if their mixture can bring any improvement in their individual properties.

1.3 Project Justification

The work will show the physical and chemical properties of the samples mentioned .Thus it will make it easy for any individual or group who intend to work on the samples of soil analyzed either for engineering construction or farming purposes. It is also meant to estimate the hydraulic function of the samples, i.e. the soil water retention and unsaturated hydraulic conductivity. To also check the properties of the sample under varied proportion of different additives. To classify soils and group them together in a meaningful manner, different systems of soil classification have been used from time to time. These systems have varied over a period of time having been drawn up to meet the requirements and the immediate purposes of their use as well as the knowledge of the soils which helps one to understand their genesis has developed the system.

1.4 Scope of the Study

This project focuses on the properties of both physical and chemical characteristics of the sample mentioned above. It is meant to compare the characteristics of termite hill soil, worm cast and alluvial soil. Also to see what the properties of the sampled mixtures will be if combined together and where they can suitably apply. Its major objectives are basically to test, compare and show the analysis of the samples. It does not intend to go further and plant with the result or try to apply the result for any construction purposes. The project has some limitations which includes the availability of the soil samples, like the worm cast clay is only common during the raining season and mostly around a river side or dams. The alluvial soil as well has to be obtained carefully else a mud or clay soil can be assumed or mistaken for the sample.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soil Properties

Soils are complex mixtures of minerals, organic compounds, and living organisms that interact continuously in response to natural and imposed biological, chemical, and physical forces." Physically, soil is made up of soil particles, air spaces which may be partially or fully filled with water, organic matter, and living organisms. Soils are grouped into textural classes depending upon the relative proportion of sand, silt, and clay composing them. Sand, silt, and clay are the basic particle size categories used for determining soil texture. The percentage of each within a given sample of soil can be determined through mechanical analyses which separate the soil particles into the relative size ranges. U.S. Dept. of Agriculture (USDA) textural classes are broken into particle size ranges as follows. Soil quality is evaluated using indicators that measure specific physical, chemical, and biological properties. Although it is useful to examine these aspects of soil quality individually, soil should be viewed as an integrated system rather than a collection of separate parts or processes.

Physical and chemical properties are shaped by biological activity, and biological activity is enhanced or limited by chemical and physical conditions. For this reason, specifically categorizing some soil indicators is difficult. For example, cation exchange capacity (CEC) could be classified as either a physical or a chemical property, and organic matter as either a chemical or a biological property. The best and most useful indicators of soil quality integrate the combined effects of several properties or processes.

2.1.2 Particle Size

The soil grading or the distribution of particle size is quantitatively determined by performing the particle-size analysis, also called mechanical analysis, which is carried out in two parts: sieve analysis and sedimentation analysis (Ibitoye 2008). The distribution of gravel and particle is determined by sieve analysis and that of silt and clay by sedimentation analysis which is also known as wet analysis. Depending on the type of soil and extend of particle-size distribution required, mechanical analysis may involve sieving and sedimentation or it may be restricted to either of them (Minasny and Hopsman 2004).

Important physical indicators of soil quality include those related to water storage and movement, soil structure, and soil or aggregate stability. Important chemical indicators include the presence and amounts of mineral elements and plant growth inhibiting substances. Biological indicators often refer to the amounts, types, and activities of soil organisms. A large, diverse, and active population of soil organisms may be the most important indicator of a healthy, high-quality soil. Yet, soil biological activity may be the most difficult indicator to satisfactorily measure and interpret.

Soil-quality indicators are limited to properties impacted by soil management. For this reason, some soil characteristics are not considered soil-quality indicators although they may influence soil use or productivity. Soil texture, topsoil depth, and slope or topography are examples of fixed soil properties that cannot be altered (except over long time periods or in extreme cases of erosion or sediment deposition). Although these characteristics clearly influence soil use or productivity, they are not used as soil-quality indicators.

Nevertheless, it is important to be knowledgeable about inherent soil properties because they often set limits on the maximum soil quality management practices can achieve. For example, soil texture refers to the relative amounts of primary mineral particles (sand, silt, clay) found in a soil. Coarse-textured sandy soils have proportionately larger sand particles, while fine-textured clayey soils have proportionately smaller clay particles. Soil texture is an unalterable soil property which strongly influences many soil-quality indicators, like drainage and water-holding capacity. But soil texture itself is not an indicator of soil-quality.

2.1.3 Bulk Density

This is a property of powders, granules and other "divided" solids, especially used in reference to soil. It is defined as the mass of many particles of the material divided by the total volume they occupy. The total volume includes particle volume, inter-particle void volume and internal pore volume

Bulk density is not an intrinsic property of a material; it can change depending on how the material is handled. For example, a powder poured in to a cylinder will have a particular bulk density; if the cylinder is disturbed, the powder particles will move and usually settle closer together, resulting in a higher bulk density. For this reason, the bulk density of powders is usually reported both as "freely settled" and "tapped" density (where the tapped density refers to the bulk density of the powder after a specified compaction process, usually involving vibration of the container.)

The bulk density of soil depends greatly on the mineral make up of soil and the degree of compaction. The density of quartz is around 2.65g/cm^3 but the bulk density of a mineral soil is normally about half that density, between 1.0 and 1.6g/cm^3. Soils high in organics and some friable clay may have a bulk density well below 1g/cm^3

Bulk density of soil is usually determined on Core samples which are taken by driving a metal corer into the soil at the desired depth and horizon. The samples are then oven dried and weighed.

Bulk density = mass of oven dry soil/core volume

$$\rho = \frac{M_t}{V_t} \qquad 2.1$$

The bulk density of soil is inversely related to the porosity of the same soil. The more pore space in a soil the lower the value for bulk density. Cobbles, gravel sand, and silt particles cover a large range of size; however, they are all

bulky in shape. The term bulky is confined to particles that are relatively large in all three dimensions, as contrasted to platy particles, in which one dimension is small as compared to the other two. The bulky shape has the following four divisions listed in descending order of desirability: Angular-Sub angular-Surrounded-Rounded.

2.1.3 Soil Moisture

This is the quantity of the available water present in the soil; this can be estimated by the feel and appearance of the soil. Moisture affects coarse-grained soils much less than fine-grained soils (Tsytovich 1983). Capillary is practically nonexistent in gravels and in sand containing little fines. These soils, if they are above the ground water table, will not usually retain large amounts of water. The moisture content of soil vary amongst the different types of soils depending on its properties. The termite hill clay is usually dry except when the cast is newly made up. The worm cast clay is basically always moist due to the activities of the worms. The worms usually feed out of clay basically alluvial soil or pure at the bank of most rivers or dams. The alluvial soil has the most moisture since it is found and located mostly below the water surface after the water can no longer travel or transport the materials that contains the alluvial soil (Wildenschild 2001).

2.1.4 Porosity

The shape and arrangement of soil particles help determine porosity. Porosity or pore space is the amount of air space or void space between soil particles. Infiltration, groundwater movement, and storage occur in these void spaces. The porosity of soil or geologic materials is the ratio of the volume of pore space in a unit of material to the total volume of material.

A mathematical equation of porosity looks like this:

$$porosity(n) = {}^{v_{void}}/_{v_{total}} \qquad 2.2$$

Porosity is often expressed as a percentage of rock or soil voids of material, so multiply the answer by 100.

The arrangement or packing of the soil particles plays a role in porosity. In the diagrams to the left, the particles stacked directly on top of each other (cubic packing) have higher porosity than the particles in a pyramid shape sitting on top of two other particles (rhombohedral packing). Can you see the difference in pore space?

What could happen when smaller particles are mixed with larger particles? As the diagram shows, the smaller particles could fill in the void spaces between the larger particles, which would result in a lower porosity.

not all particles are spheres or round. Particles exist in many shapes and these shapes pack in a variety of ways that may increase or decrease porosity. Generally, a mixture of grain sizes and shapes, results in lower porosity.

One important point to remember is that the diameter size of the grain does not affect porosity. Remember, porosity is a ratio of void space to total volume. A room full of ping pong balls would have the same porosity as a room full of basketballs, as long as the packing or arrangement is similar. The total porosity of a porous medium is the ratio of the pore volume to the total volume of a representative sample of the medium. Assuming that the soil system is composed of three phases -- solid, liquid (water), and gas (air) where V_s is the volume of the solid phase, V_l is the volume of the liquid phase, V_g is the volume of the gaseous phase, $V_p = V_l + V_g$ is the volume of the pores, and $V_t = V_s + V_l + V_g$ is the total volume of the sample, then the total porosity of the soil sample, p_t, is defined as follows:

$$p_t = \frac{v_p}{v_t} = \frac{v_l + v_g}{v_s + v_l + v_g} \qquad 2.3$$

Porosity is a dimensionless quantity and can be reported either as a decimal fraction or as a percentage. Coarse-textured soil materials such as gravel and sand tend to have a lower total porosity than fine-textured soils such as silts and clays. The total porosity in soils is not a constant quantity because the soil, particularly clayey soil, alternately swells, shrinks, compacts, and cracks.

The part of the soil that is not solid is made up of pores of various sizes and shapes-sometimes small and separate, sometimes consisting of continuous tubes (Lambe 1984). Soil scientists refer to the size, number and arrangement of these pores as the soil's porosity. Porosity greatly affects water movement and gas exchange. Well-aggregated soils have numerous pores, which are important for organisms that live in the soil and require water and oxygen to survive. The transport of nutrients and contaminants will also be affected by soil structure and porosity.

This is usually expressed as a percentage and is also referred to as percentage voids. By the above definition, if the voids of an element of soil mass are represented by 1 (unity) or if the voids are represented by n, the total volume should be represented by 1. The figure below represents diagrammatically the elements of soil mass or of soil element in terms of e and n respectively.

$$porosity = \frac{e}{1+e} \qquad 2.4$$

The soil that is more porous amongst the samples in content is the termite hill soil. It usually very loose and free when broken from the cast. The worm cast is less porous compared to the termite hill clay. The alluvial soil is most porous as it appears as sandy when dried considerably.

2.2 Hydraulic Properties

It is important to have an accurate estimate of the physical and hydraulic characteristics of soils. The objective of classifying soils is to arrange them into groups and according to their properties and behaviour. If the group to which a soil belongs to is determined, it would be possible to predict its behaviour(Singh 1997).

2.2.1 Residual Water Content.

This is the amount of water available in the soil after the major water content have been removed. This could be due to the pressure the soil had undergone or rather the type of soil make up and formation.

2.2.2 Volumetric Water Content

Soil water content indicates how much water is present in the soil. It can be used to estimate the amount of stored water in a profile or how much irrigation is required to reach a desired amount of water content sensors provide a tool to measure the water content using hand-held sensors or installing the water content sensors into the soil for long-term measurement.

2.2.3 Available Water content

Soil can process and contain considerable amount of water. They cake in water, and will keep doing so until they are full, or the rate which at which they can transmit water into, and through the pores is exceeded. Some of this water will steadily drain through the soil (vial gravity) and end up in the waterways and streams. But much of it will be retained, away from the influence of gravity, for use of plant and other organisms to contribute to land productivity and soil health.

The spaces that exist between soil particles, called pores, provide for the passage and retention of gasses and moisture within the soil profile. The soil's ability to retain water is strongly relate to particle size; water molecules hold more tightly to the fine particles of a soil than to coarser particles of a sandy soil, so clays generally retain more water . Conversely, sands provide easier passage or transmission of water through the profile. Clay type organic content and soil structure also influence soil water retention (Chairman and Murphy 1977)

2.2.4 Bulk Density

Bulk density is a measure of the weight of the soil per unit volume (g/cc), usually given on an Oven-dry (110°) basis. Variation in bulk density is attributable to the relation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil. Most mineral soil has bulk densities between 1.0 and 2.0. Although bulk densities are seldom measured, they are important in quantitative soil studies, and measurement should be encouraged. Such data are necessary, for example, in calculating soil moisture movement within a profile and rates of clay formation and carbonate accumulation. Even when two soils are compared qualitatively on the basis of their development for purposes of stratigraphic correlation, more accurate comparisons can be made on the basis of total weight of clay formed from 100g of parent material than on percent of clay alone.

Bulk Density= Weight/Volume

2.2.5 Saturated Hydraulic Conductivity

The hydraulic conductivity of a soil is a measure of the soil's ability to transmit water when submitted to a hydraulic gradient. Hydraulic conductivity is defined by Darcy's law, which, for one-dimensional vertical flow, can be written as follows:

$$U = -K\frac{dh}{dz} \qquad 2.5$$

where U is Darcy's velocity (or the average velocity of the soil fluid through a geometric cross-sectional area within the soil), h is the hydraulic head, and z is the vertical distance in the soil. The coefficient of proportionality, K, in Equation 5.1 is called the hydraulic conductivity. The term coefficient of permeability is also sometimes used as a synonym for hydraulic conductivity. On the basis of the equation above, the hydraulic conductivity is defined as the ratio of Darcy's velocity to the applied hydraulic gradient. Hydraulic conductivity is one of the hydraulic properties of the soil; the other involves the soil's fluid retention characteristics. These properties determine the behaviour of the soil fluid within the soil system under specified conditions. The hydraulic conductivity depends on the soil grain size, the structure of the soil matrix, the type of soil fluid, and the relative amount of soil fluid (saturation) present in the soil matrix. The important properties relevant to the solid matrix of the soil include pore size distribution, pore shape, specific surface, and porosity. In relation to the soil fluid, the important properties include fluid density, and fluid viscosity. For a subsurface system saturated with the soil fluid, the hydraulic conductivity, K, can be expressed as follows (Bear 1972):

$$K = \frac{kpg}{\mu} \qquad 2.6$$

where k, the intrinsic permeability of the soil, depends only on properties of the solid matrix, and μ called the fluidity of the liquid, represents the properties of the percolating fluid. The hydraulic conductivity, K, is expressed in terms of length per unit of time (lT^{-1}), the intrinsic permeability, k, is expressed in l^2, and the fluidity, $g/$, in $l^{-1}T^{-1}$. By using the values of saturated hydraulic conductivity in soils vary within a wide range of several orders of magnitude, depending on the soil material Saturated hydraulic conductivity is a quantitative measure of a saturated soil's ability to transmit water when subjected to a hydraulic gradient. It can be thought of as the ease with which pores of a saturated soil permit water movement.

In Darcy's law, saturated hydraulic conductivity is a constant (or proportionality constant) that defines the linear relationship between the any two variables. It is the slope of the line showing the relationship flux and hydraulic gradient. If the same hydraulic gradient is applied to two soil, the soil from which the greater soil at the same hydraulic gradient. The soil with the steeper slope (the sandy soil) has the higher hydraulic conductivity. Hydraulic conductivity (or slope "k") defines the proportional relationship between flux and hydraulic gradient, or in this case of in directional flow in saturated soil. Saturated hydraulic conductivity (ks) is a quantitative expression of the soil's ability to transmit water under a given hydraulic gradient. There are two broad categories of determining hydraulic conductivity:

- Empirical approach by which the hydraulic conductivity is correlated to soil properties like pore size and particle size (grain size) distributions, and soil texture
- Experimental approach by which the hydraulic conductivity is determined from hydraulic experiments using Darcy's law

The experimental approach is broadly classified into:

- Laboratory tests using soil samples subjected to hydraulic experiments
- Field tests (on site, in situ) that are differentiated into:
    - small scale field tests, using observations of the water level in cavities in the soil
    - large scale field tests, like pump tests in wells or by observing the functioning of existing horizontal drainage systems.

Determination by experimental approach

There are relatively simple and inexpensive laboratory tests that may be run to determine the hydraulic conductivity of a soil: constant-head method and falling-head method.

2.2.5.1 Constant-head method

The constant-head method is typically used on granular soil. This procedure allows water to move through the soil under a steady state head condition while the quantity (volume) of water flowing through the soil specimen is measured over a period of time. By knowing the quantity Q of water measured, length L of specimen, cross-sectional area A of the specimen, time t required for the quantity of water Q to be discharged, and head h, the hydraulic conductivity can be calculated:

$$Q = Avt \tag{2.7}$$

where v is the flow velocity. Using Darcy's Law:

$$v = Ki \tag{2.8}$$

and expressing the hydraulic gradient i as:

$$i = \frac{h}{L} \tag{2.9}$$

where h is the difference of hydraulic head over distance L, yields:

$$Q = \frac{AKht}{L} \tag{2.10}$$

Solving for K gives:

$$K = \frac{QL}{Ath} \quad 2.11$$

2.2.5.2 Falling-head method

The falling-head method is very similar to the constant head methods in its initial setup; however, the advantage to the falling-head method is that can be used for both fine-grained and coarse-grained soils. The soil sample is first saturated under a specific head condition. The water is then allowed to flow through the soil without maintaining a constant pressure head

$$K = \frac{2.3aL}{At} \log\left(\frac{h_1}{h_2}\right) \quad 2.12$$

2.2.5.3 Augerhole method

There are also in-situ methods for measuring the hydraulic conductivity in the field. When the water table is shallow, the augerhole method, a slug test, can be used for determining the hydraulic conductivity below the water table. The method was developed by Hooghoudt (1994)

an augerhole is perforated into the soil to below the water table

1. water is bailed out from the augerhole
2. the rate of rise of the water level in the hole is recorded
3. the K-value is calculated from the data as :

$$K_h = C(H_0 - H_t)/t \quad 2.13$$

Cumulative frequency distribution (lognormal) of hydraulic conductivity (X-data)

where: K_h = horizontal saturated hydraulic conductivity (m/day), H = depth of the water level in the hole relative to the water table in the soil (cm), Ht = H at time t, Ho = H at time t = 0, t = time (in seconds).

where: r = radius of the cylindrical hole (cm), h' is the average depth of the water level in the hole relative to the water table in the soil (cm).

The picture shows a large variation of K-values measured with the auger hole method in an area of 100 ha. The ratio between the highest and lowest values is 25. The cumulative frequency distribution is lognormal and was made with the Cum Freq program.

2.2.6 Shrinkage Ratio/ Limit

The shrinkage limit of a soil is defined as the maximum calculated water content, at which a reduction in water content will not cause a decrease in the volume of the soil mass.

The shrinkage limit, S can be calculated from the data obtained in the volumetric shrinkage

Determination by the following formula:

$$S = W - \frac{v - v_0}{w} x100 \qquad 2.14$$

where:

S = shrinkage limit;

w = water content of wet soil, in percentage of the mass of oven-dried soil;

v = volume of wet soil pat;

vo = volume of oven-dried soil pat.

w = mass of oven dried soil pat.

2.2.7 Plasticity Index

Plasticity index (PI) is the numerical difference in moisture content between the liquid and plastic limits. This is the lowest water content determined in accordance with a procedure at which the soil remains plastic. The plasticity index of a soil is the range in water content, expressed as a percentage of the mass of the oven-dried soil, within which the material is in a plastic state. It is the numeral difference between the liquid limit and plastic limit of the soil. This is the property of the fine-grained portion of a soil that allows it to be deformed beyond the point of recovery without cracking or changing volume appreciably. Some minerals on the other hand are plastic no matter how fine the particles or how much water is added. All clay minerals on the other hand are plastic and can be rolled into thin threads at a certain moisture content without crumbling.

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid limit and the plastic limit.

The plastic limit (PL) is the water content where soil starts to exhibit plastic behaviour. A thread of soil is at its plastic limit when it is rolled to a diameter of 3 mm or begins to crumble. To improve consistency, a 3 mm diameter rod is often used to gauge the thickness of the thread when conducting the test.

The liquid limit (LL) is the water content where a soil changes from plastic to liquid behavior. The original liquid limit test of Atterberg's involved mixing a pat of clay in a little round-bottomed porcelain bowl of 10-12cm diameter. A groove was cut through the pat of clay with a spatula, and the bowl was then struck many times against the palm of one hand.

Casagrande subsequently standardized the apparatus and the procedures to make the measurement more repeatable. Soil is placed into the metal cup portion of the device and a groove is made down its center with a standardized tool. The cup is repeatedly dropped 10mm onto a hard rubber base during which the groove closes up gradually as a result of the impact. The number of blows for the groove to close for 13 mm (½ inch) is recorded. The moisture content at which it takes 25 drops of the cup to cause the groove to close is defined as the liquid limit. Another method for measuring the liquid limit is the Cone Penetrometer test. It is based on the measurement of penetration into the soil of a standardized cone of specific mass. Despite the universal prevalence of the Casagrande method, the cone penetrometer is often considered to be a more consistent alternative because it minimizes the possibility of human variations when carrying out the test.

2.2.8 Plasticity index

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 tend to have little or no silt or clay.

2.2.9 Liquidity index

The liquidity index (LI) is used for scaling the natural water content of a soil sample to the limits. It can be calculated as a ratio of difference between natural water content, plastic limit, and plasticity index:

$$L_i = {W - P_L}/{L_l} - P_l \qquad 2.15$$

where W is the natural water content.

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The test to determine the shrinkage limit is ASTM International D4943. The shrinkage limit is much less commonly used than the liquid limit and the plastic limit.

2.2.10 Soil Water Retention Capacity.

This is the property of the soil that enables it to hold or retain water for a period of time. This is observed when the soil molecules is bonded more evenly. The retention of excess water in the soil may occur in an opening in the soil. Plasticity is a property of the fine-grained portion of a soil that allows it to be deformed beyond the point of recovery without cracking or changing volume appreciably. Some minerals, such as quartz powder, cannot be made plastic no mat-ter how fine the particles or how much water is added. All clay minerals, on the other hand, are plastic and can be rolled into thin threads at certain moisture content without crumbling. Since practically all fine-grained soils contain some clay, most of them are plastic. The degree of plasticity is a general index to the clay content of a soil.

The term fat and lean are sometimes used to distinguish between highly plastic and slightly plastic soils. For example, lean clay is only slightly plastic, whereas fat clay is highly plastic. In engineering practice, soil plasticity is determined by observing the different physical states that a plastic soil passes through as the moisture conditions change. The boundaries between the different states, as described by the moisture content at the time of change, are called consistency limits or Atterberg limits.

The liquid limit (LL) is the moisture content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil. Above this value, the soil is presumed to be a liquid and behaves as such by flowing freely under its own weight. Below this value, it deforms under pressure without crumbling, provided the soil exhibits a plastic state.

The plastic limit (PL) is the moisture content at an arbitrary limit between the plastic and semisolid state. It is reached when the soil is no longer pliable and crumbles under pressure. Bet-ween the liquid and plastic limits is the plastic range. The numerical difference in moisture con-tent between the two limits is called the plasticity index (PI). The equation is:

$$PI = LL - PL \qquad 2.16$$

It defines the range of moisture content within which the soil is in a plastic state.

The shrinkage limit is the boundary in moisture content between the solid and the semisolid states. The solid state is reached when the soil sample, upon being dried, finally reaches a limiting or minimum volume. Beyond this point, further drying does not reduce the volume but may cause cracking.

2.3 Evaluating Soil Quality

Physical, Chemical, and Biological Indicators of Soil Quality

Soil quality is evaluated using indicators that measure specific physical, chemical, and biological properties. Although it is useful to examine these aspects of soil quality individually, soil should be viewed as an integrated system rather than a collection of separate parts or processes.

Physical and chemical properties are shaped by biological activity, and biological activity is enhanced or limited by chemical and physical conditions. For this reason, specifically categorizing some soil indicators is difficult. For example, cation exchange capacity (CEC) could be classified as either a physical or a chemical property, and organic matter as either a chemical or a biological property. The best and most useful indicators of soil quality integrate the combined effects of several properties or processes.

Important physical indicators of soil quality include those related to water storage and movement, soil structure, and soil or aggregate stability. Important chemical indicators include the presence and amounts of mineral elements and plant growth inhibiting substances. Biological indicators often refer to the amounts, types, and activities of soil organisms. A large, diverse, and active population of soil organisms may be the most important indicator of a healthy, high-quality soil. Yet, soil biological activity may be the most difficult indicator to satisfactorily measure and interpret.

Soil-quality indicators are limited to properties impacted by soil management. For this reason, some soil characteristics are not considered soil-quality indicators although they may influence soil use or productivity. Soil texture, topsoil depth, and slope or topography are examples of fixed soil properties that cannot be altered (except over long time periods or in extreme cases of erosion or sediment deposition). Although these characteristics clearly influence soil use or productivity, they are not used as soil-quality indicators.

Nevertheless, it is important to be knowledgeable about inherent soil properties because they often set limits on the maximum soil quality management practices can achieve. For example, soil texture refers to the relative amounts of primary mineral particles (sand, silt, clay) found in a soil. Coarse-textured sandy soils have proportionately larger sand particles, while fine-textured clayey soils have proportionately smaller clay particles. Soil texture is an unalterable soil property which strongly influences many soil-quality indicators, like drainage and water-holding capacity. But soil texture itself is not an indicator of soil-quality.

2.4 Alluvial Soil

The alluvial soil is formed when a soil carrying stream gradually loses its carrying capacity with decreasing velocity. In slowing down, a river does not have sufficient power to keep the large particles of soil suspended. These particles settle to the river bed. Further decrease in velocity causes smaller particles to settle. As the river becomes slow and sluggish (as in the lowlands where its gradient becomes small) it holds only the extremely fine particles in suspension. These particles are deposited finally at the mouth of the river, where they form deltas of fine grained soil. The deltas of rivers are alluvial deposits. Where swift mountains streams reach the floor of a flat valley, the sudden changes in grade, and the consequent slowing of the stream, often results in the deposition of an alluvial fan, another form of alluvial deposit. The action of running water tends to sort out the different sizes and weights of particles that are carried in suspension. Thus gravels and pebbles will be deposited farther upstream than the lighter sand fine silt will be carried farther downstream than sand. Deposits are also formed in the ocean, in lakes, and in other places by the settlement of sand, silt and other material.

2.3 Worm Cast

Worm castings are 100% natural, with a healthy, earthy odor and the appearance of coffee grounds. The casting slowly release nutrients needed for healthy plant growth and increased production rates for fruits and vegetables. It allow plants to quickly and easily absorb essential nutrients and trace minerals. This is possible because Earthworms grind and uniformly mix the nutrients into simple forms, which are easily absorbed by the surrounding plant life.

The productivity of agricultural land which is measured in terms of yield recovery depends on soil climatic conditions, pests, diseases, genetic potentials irrespective of the soil nutrient; the presence of humidified organic matter is of great importance in the formation and stabilization of soil structure. Amongst other soil invertebrates, earthworms are most abundant in soil minerals. They are found in almost all kinds of soil at different latitude except in arctic and Antarctic region. They form the highly mobile macroscopic soil invertebrates that help in mixing the soil. Though the soil organism comprises a very small percentage of total weight of soil with their rate of activity, they form the dominant factors in functioning of the soil system. Effect of earthworm activity on soil physico-chemical properties during the short period of favourable conditions, tropical worms have sufficient contributions in soil over. In most cases, immediately after the moon set showers large quantities of worm cast are observed on the soil surface. The mechanical breakdown of the plant litter and assimilating only 5 to 10 of the main job performed by many of these soil organism. It is also true that the faeces of these organisms provide more scope for the establishment of microbes than mechanically pulverized matter. The size and shape of the released cast is species specific but this cannot be considered as criteria for identifying worms. Because worm casts improve the physical, chemical and biological properties of soil and are as well used for recycling agricultural and municipal waste around some countries.

CHAPTER THREE

Materials and Methods

3.1 Description of the site

The studies are done in Minna, Niger State of Nigeria. The area lies between longitudes 6^0E and 7^0E and the latitudes 9^0N and 10^0N. According to Wright (1989), the residual soil in this area is under laid by a granite basement and is surrounded to the north and south by the older basement rocks of the Precambrian to upper cambrian age and Illo-group formation to the north-west. The area is drained by several rivers which are tributaries of River Niger. Rainfall in this area varies considerably from station to station. The maximum rainfall per year varies from 1000mm to 1500mm for different locations.

3.2 Material Description

3.2.1 Termite Hill Soil

The termite hill soil used for this research work was obtained from around Bosso Area in Bosso local Government Area of Niger State at Lattitude 9°39' N andLongitude 6°35'E. The soil sample was air dried, crushed and passed through a 2mm Stainless steel screen. All the foreign materials inside it were hand picked and was packaged for laboratory analysis.

Plate 1. Termite hill

3.2.2 Worm cast clay

The worm cast clay used for this work was obtained from the bank of Bosso Dam in the same local Government area . They were handpicked along the bank of the river (Plate 1.). They were air dried to appreciable moisure content after which they were crushed. Foreign materials inside it were removed and were then packaged for analysis.

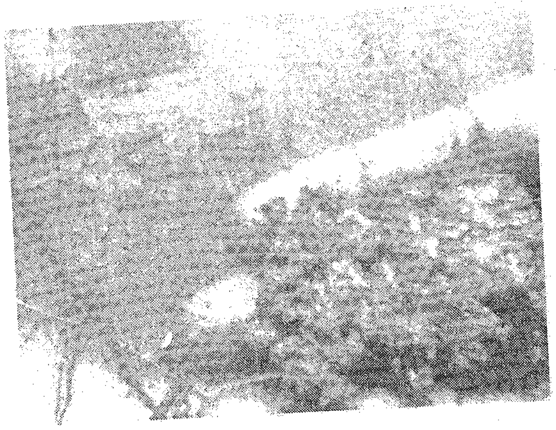

Plate 2: Worm cast being picked along the River Bank.

3.2.3 Alluvial soil

The alluvial soil used for this work was obtained also from Bosso Dam at Bosso Local Government of Niger State at Latitude 9°39' N and Longitude 6°35'E. A hand auger was used to obtain samples of the soil. The soil was obtained from a particular flood plain that has already been drained into the dam. The samples collected were sun dried and crushed. Foreign material inside it was removed by hand and was then packaged for analysis.

3.3 Samples Identification

Sample A: 100% worm cast

Sample B: 100% Termite hill soil

Sample C: 100% Alluvial soil

Sample D: 50% worm cast and 50% Termite hill soil

Sample E: 50% Termite hill soil and 50% alluvial soil

Sample F: 50% alluvial soil and 50% worm cast.

3.4 Chemical properties Determination

The United States Soil Conservation Agency (USSCA, 1998) soil analysis method was adopted for chemical properties determination while other physical properties were determined as explained below.

3.5 Porosity

Danielson and Sutherland (1986) method of porosity determination was adopted. On the basis of the definition of total porosity, a soil sample could be evaluated for total porosity by directly measuring the pore volume (V_p) and the total volume (V_t). The total volume is easily obtained by measuring the total volume of the sample. The pore volume can, in principle, be evaluated directly by measuring the volume of water needed to completely saturate the sample.

A 500ml beaker was filled with the dry sample and was placed on a flat workplace. Then another beaker of 500ml was filled with water. Then the water was slowly poured from the second beaker into the sample until the water level reached the top of the soil. At this point the soil has reached the saturation and cannot hold any more water. Then the quantity of water left in the second beaker and the one that has been held in the pore spaces of the soil samples were calculated and was then used to calculate the porosity using equation.

3.6 Bulk Density Determination

The clod method of bulk density determination was adopted. Bulk density is defined as the ratio between the mass of oven dried soil to the total volume of soil i.e. the volume of soil particles and the volume of pores.

Materials

1- Paraffin kept in a container t at a temperature between 60 and 70 °C.

2- Oven with 100 –110 °C temperature control.

3- A balance of precision of ±0.01 g.

4- Desiccators that contains active desiccant such as magnesium per chlorate or calcium sulfate).

5- Coarse mesh wire pan.

6- 100 or 200 ml beaker.

Procedure

Obtain a soil clod. Dry the clod in the air.

Weigh the air-dry clod. Record this weight as M_{sa}.

Place the soil clod in the wire pan, and then dip the clod and the wire pan in the melted Paraffin. Take the pan out of the paraffin container and drain the excess. Allow the Paraffin to solidify on the clod surface.

Weigh the Paraffin coated clod. Record this weight as M_{pa}.

Fill the beaker partly with water. Determine the weight of the filled beaker.

Place the Paraffin coated clod in the beaker. Determine the weight of the filled beaker plus the coated clod. The difference in weight between step 6 and 5 is the weight of the Paraffin coated soil sample in water. Record this difference as M_{spw}.

To obtain correction for the soil water content. Break the soil clod open. Take a sample dry it in the oven at 105 ^{0}C, and determine the soil moisture content on weight basis. Record the soil moisture content as θ_d. (Refer to *Measurement of soil moisture content by gravimetric method* module).

3.7 Hydraulic Conductivity

Constant falling head method of determination developed in 1856 by a French engineer called Henry Darcy.

The hydraulic conductivity is the coefficient of proportionality in Darcy's law, however; it is the important soil property involved in the behavior of water flow in soils. It is defined as the ability of saturated soil, or porous medium, to transmit water. Hydraulic conductivity can be measured by maintaining a constant head above a disturbed or undistributed soil sample, measuring the water flux, and then solving Darcy's law for the hydraulic conductivity. Several data points are usually needed for reliable measurement.

Materials

1- Soil core sampler.

2- Plastic cylinders of diameter equal to the diameter of inner cylinder of the soil core sampler.

3- Plastic tubing as available.

4- Two frits or porous plates.

5- Two rubbers plug.

6- Funnel.

7- Stand.

8- Two or three clamps.

9- Water source.

10- Graduate cylinder.

11- Stop watch.

12- Miscellaneous items such as filter paper or a piece of cloth to cover the lower end of the soil sample.

Procedure

1- Measure the diameter (*D*) of the inner cylinder of the core sampler. Calculate the cross sectional area (*A*)

2- Acquire undisturbed soil sample according to the procedure given in the *bulk density* module.

3- Cover one end of the soil core sample with a piece of cloth. Soak the lower end in water for 16 hours or until the sample is completely saturated.

4- Fix a rubber stopper to the bottom of a short cylinder. Place a frit or porous plate on the top of the rubber stopper. Make sure that the frit rests at but not beyond the top of the cylinder.

5- Remove the soil sample core from water and quickly connect its lower part to the cylinder prepared in step 3, using a rubber band or waterproof tape.

6- Extend the upper end of the soil core sample by connecting it to an empty cylinder, using a rubber band or waterproof tape.

7- Slip a frit or porous plate into the empty cylinder and place it on the top of the sample. Plug the empty cylinder with a rubber stopper. If necessary use a spring to fix the porous plate in place.

8- Fix the whole assembly to the stand. Fix the funnel above the soil sample. Use the plastic tubing to connect the funnel to the soil sample as shown in figure 1

9- Run water into the funnel, eventually the water will reach the top of the funnel. To maintain a constant head, allow the water excess to drain from a hole in funnel's side (figure 1.7.1). Adjust the water supply accordingly.

3.8 Organic Matter Determination

Ignition Method was used for this.

In this lab you will measure the total organic matter content by the ignition method. This is achieved by reducing the mineral portion of the soil to ashes, and converting the organic matter to $CO_{2(g)}$, that evolves out from the soil sample. Thus, the organic matter content is the difference in weight between the soil sample and the mineral ashes. It should be noted, however, that the ignition method is only approximate, more accurate methods involve measuring the total C content, and multiply the resultant values by conversion factors ranging from 1.73 – 2.0.

Materials

1- Ring stand
2- Ceramic triangle
3- Burner
4- Ceramic crucible
5- Soil sample

6- A balance of precision of ±0.1 g.

7- Desiccator

Procedure

1- Set up a ring stand with a ceramic triangle and burner. Place clean ceramic crucible in the triangle and heat until read hot for 2 minutes. Then turn off the burner and allow crucible to cool.

2- Weigh the cool crucible to the nearest 0.1 g. Record this reading as the crucible weight in grams.

3- Place enough air-dry soil into the crucible to fill it to the nearest 1/3. Record this reading as the weight of (crucible + soil) in grams.

4- Take an equal quantity of soil to determine the soil moisture content by weight, θg.

5- Set crucible on burner and gradually heat with burner until the ceramic glows red. Then continue to keep it red-hot for 1-2 hours. Stir the soil occasionally with a glass rod. Take care not to loose any of the soil material.

6- After ignition is complete turn off the burner and cool the crucible in a desiccators. Reweigh the cooled crucible of soil and record this measurement as the weight of the (crucible + ash) in grams.

3.9 Plasticity Index Determination

The Hand Rolling Method was used for this determination.

Apparatus

1. Dish—A porcelain evaporating dish, or similar mixing dish about 115 mm in diameter.
2. Spatula—A spatula or pill knife having a blade about 75 mm in length and about 20 mm in width.

3. Surface for Rolling—A ground glass plate or piece of smooth, unglazed paper on which to roll the sample.

Methods

Select a 1.5- to 2.0-g portion from the mass of soil taken in accordance with Section 4. Form the selected portion into an ellipsoidal mass.

Use one of the following methods to roll the soil mass into a 3-mm diameter thread at a rate of 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again.

Hand Rolling Method—Roll the mass between the palm or fingers and the ground-glass plate (or a piece of paper laying on a smooth horizontal surface) with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The thread shall be further deformed on each stroke so that its diameter reaches 3 mm, taking no more than two minutes. The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

Calculation:

Calculate the plastic limit, expressed as the water content in percentage of the mass of the ovendrysoil, as follows:

$$Plastic\ \lim it = \frac{mass\ of\ water}{mass\ of\ oven-dry\ soil} x100$$

Calculate the plasticity index of a soil as the difference between its liquid limit and its plastic Limit, as follows:

Plasticity Index = liquid limit – Plastic limit

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

The results of the physical and chemical analysis of the samples are presented in the tables 1and 2 below

Table 4.1: Results of the Physical and Chemical Analysis of the Samples.

	Sample A A100% WC	Sample B 100%THS	Sample C 100%AS	Sample D 50%WC ,50%THS	Sample E 50%THS, 50%AS	Sample F 50%AS, 50%WC
pH	8.9	6.5	7.3	6.6	7.4	6.5
SO_4^{2+} (mg/g)	45	22	39	25	19	52
NO_3^- (mg/g)	19.6	16.5	18.2	14.3	15.4	23.4
PO_4^{2-} (mg/g)	41.3	22.9	59.0	30.1	31.2	43.8
Ca^{2+} (mg/g)	344.2	350.6	333.9	231.9	230.9	345.8
K^+ (mg/g)	320.0	320.8	243.3	265.9	321.9	333.2
Porosity	0.23	0.46	0.34	0.67	0.46	0.55
Hydraulic Conductivity (m/day)	0.35	0.62	0.46	0.81	0.48	0.47
Organic matter (g/kg)	550	211	345	367	280	569
Plasticity index	0.23	0.56	0.69	0.44	0.89	0.44

WC- Worm Cast, THS- Termite Hill Soil, AS- Alluvial Soil

Table 4.2: Results of Bulk Density Determination for the Samples

Sample Description	Weight of clod/g	Weight of waxed clod/g	Volume of waxed clod/ cm^3	Volume of wax/cm^3	Bulk density g/cm^3
A	10.38	11.87	10.00	1.66	1.245
B	11.74	13.98	11.00	2.49	1.380
C	11.81	13.14	10.00	1.48	1.386
D	9.58	11.18	9.50	1.78	1.241
E	14.38	16.79	11.00	2.61	1.714
F	11.74	13.98	11.01	2.49	1.381

4.1 Discussion of the Results

4.1.1 Hydrogen ion Concentration (pH)

From the results of the analysis, it can be observed that all the samples have the pH that fall within the allowable limit of USSCA, 1998. What can be deduced from this is that worm cast and other soil samples can be used for agricultural activities without undergoing any liming process since they are not toxic or acidic. Similar assertion has been given by Hudson,(2003) that worm cast and alluvial can be used to reclaim any acidic soil where liming agent is not available because they have inherent liming properties.

4.1.2 Nitrates, Sulphates and Phosphates

These are the indices that can be indirectly used to measure the fertility of any given soil samples. From the results in table 1, it can be seen that worm cast recorded the highest of all the parameters over all other samples. Significant improvement was however recorded when alluvial soil and worm cast were mixed together. This advantage can be exploited in subsistence agriculture where the samples can be mixed at equal proportion or at proportion that depends on their availability. This if done will improve their fertility and can be used to grow arable crops or vegetable. The cost of fertiliser will be saved and will not be in any way toxic to the consumers. Termite hill soil recorded the lowest but its own fertility can also be improved by mixing it with any of the other samples. Beasley, (1991) recorded something similar to this when he used a combination alluvial worm cast and termite hill to grow cucumber. He realised more yield on a combination of alluvial and worm cast than any other combinations

4.1.3 Porosity and Hydraulic Conductivity

These two parameters are linearly related. A porous soil will have a high hydraulic conductivity. Termite hill soil recorded the highest porosity and hydraulic conductivity. This may be attributed to its highest sandy content. Since sand soil is very coarse, it will be very porous. This property can be exploited in agriculture for a crop that needs a well drained and porous soil like yam,*(Dioscorea sp).* If the soil to be used is not too porous to allow good propagation of yam. Some quantity of termite hill clay can be mixed with it together with worm cast. Greenland and Lal (1988) experimented this on a tropical soil by using a combination of termite hill clay worm cast and another sandy soil to grow, water yam *(Dioscorea alata).*They were able to conclude that termite hill soil is not as useless as people think they are because they can be added to some non- porous soil to improve their hydraulic conductivity.

4.1.4 Bulk Density

This also depends on porosity to some extent. Because if the air space in a particular soil is high, the soil samples will be light in weight. Perhaps that is why alluvial soil that is very high in clay content recorded the highest bulk density. A bulky soil can also be made a bit porous by mixing it with a little worm cast. This will make it to be lighter and can then be used for agricultural activities.

4.1.5 Percentage Organic Matter

Worm cast recorded the highest organic matter content. This can simply be attributed to the activity of earthworm inside the soil. Agriculturally, a soil that is high in organic matter will be very fertile, it can then be concluded here that worm cast is much richer in plant nutrient than other two samples. But since worm cast is not so abundant to be used for extensive agricultural activities, it can be mixed with alluvial soil or termite hill soil and then be used to grow arable crops. Brady, (1998) experimented this and concluded that worm cast in the absence of inorganic fertiliser can be added to an impoverished soil to improve its fertility.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The project study provides us opportunity to study some physical and chemical properties of termite hill soil, worm cast and alluvial soil. It can be concluded from the study that all the three samples before they are mixed contain some fertility that can be used by crops. Worm cast has the highest level parameters that are needed by crops. For instance, it contains highest quantity of sulphates, nitrates, phosphates and even organic matter content. Though termite hill soil is seen by many as not having any advantageous value, the study has shown that it can be used to improve the porosity of a poorly drained soil. This can be exploited for crops that need a well drained soil. If worm cast that is high in all the nutrients needed by crops is to be used for such a plantation, it should be mixed with some portion of termite hill soil to improve its hydraulic conductivity.

5.2 Recommendations.

Since the stated aims and objectives has been achieved in this project work by evaluating the physical and chemical properties of the three samples and also by checking if their mixture can bring about any improvement on their properties, it is therefore recommended that;

1. The percentage of the mixture be varied further to know the optimum percentage that will contain highest level on nutrient and hydraulic conductivity. It can also be experimented further and be subjected to statistical analysis that will then come up with an equation. The equation will henceforth

be used to know the appropriate mixture of worm cast, termite hill soil and alluvial soil needed to achieve a stated objective.

2. The results of this can also be experimented on the field by using the soil and the mixture to plant some crops. The yield can then be compared to the results of this work to know what is needed further to make the three soil samples under study more useful.

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