

**MINERALOGY AND COMPRESSION
CHARACTERISTICS OF AGRICULTURAL SOILS
IN SELECTED PARTS OF EKITI STATE**



BY



OLORUNFEMI, MICHAEL ADEBUSUYI
(AGE/98/0287)

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CERTIFICATION

This is to certify that this work was carried out by **OLORUNFEMI, MICHAEL ADEBUSUYI** (AGE/98/0287) in the Agricultural Engineering Department, Federal University of Technology, Akure, in partial fulfilment of the requirements for the award of Master of Engineering in Agricultural Engineering (Soil and Water Engineering Option), Federal University of Technology, Akure. It has not been submitted elsewhere for the award any other degree or diploma.



Engr. (Dr.) A.E. Ajayi
Supervisor

30.12.09

Date



Prof. L.A.S Agbetoye
H.O.D

7/1/10

Date



DEDICATION

This project is dedicated to Almighty God, my parents, Adekemi and all that contributed to the realization of my dream.

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ABSTRACT

Landlocked States in Nigeria are daily faced with the reality of the need for rapid agricultural development for socio-economic transformation. The magnitude of the need for most of the States requires massive mechanisation of the agricultural production process and this comes with its attendant environmental problem. Thus it is desirable that a pre-investment investigation be carried out on soils for sustainable development. In this study, the mineralogy of agricultural soils in selected parts of Ekiti State, Southwest Nigeria were investigated from washed salt-free, freeze-dried, fine clay fraction of samples from the sites using x-ray diffractogram. The selected parts included: Oye-Ekiti, Ire-Ekiti and Ikere-Ekiti. The chemical compositions were determined using standard procedures. The load bearing (support) capacity at different moisture content were established from the plot of pre-compression (pre-consolidation) pressure at varying moisture regimes. The relationship between load support capacity and soil mineralogy for soil was thereafter examined. The result showed that the mineralogy of the studied sites were Ikere – Oxisols, Ire – Inceptisols, and Oye – Ultisols. Moisture retention capacity ranges in the studied sites were generally low viz Ikere; 0.05 - 0.20 kg/kg, Ire A horizon; 0.05 - 0.23 kg/kg; Ire B horizon; 0.03 - 0.35 kg/kg, Oye A horizon; 0.05 - 0.20 kg/kg, and Oye B horizon; 0.10 - 0.25 kg/kg. Load Support capacity (500kPa) were highest in Ultisols samples from Oye B-Horizon and the Oxisols from Ikere. It can be concluded that most samples from agricultural sites in Ekiti State would support mechanisation of the farming process. However, due to the low moisture retention ranges, shallow depth and the thinness of the A- Horizon, mechanisation process should be carefully handled in order not to destroy the soil structurally. Experience from literature suggest that such soil need more preparatory steps, with medium size implement to avoid losing soil layer above the preconsolidation pressure, when natural recovery will be impossible and degradation will be rapid. This study has laid a good foundation for large-scale estimation of soil workability data for similar soil types in Southwest Nigeria. It appears that soil trafficability in cultivation could be inferred from the compression and mineralogy characteristics.



CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Soils are complex assemblies of solids, liquids and gases, with the solid component accounting for about 50% of the volume, gases and liquid; typically water, makes up the remaining 50%. The soil solid component, consists of about 45% minerals (inorganic component) and 5% organic matter (Sparks, 1995). The inorganic component (90% of the solid component), are known to include both primary and secondary minerals ranging in size from clay size colloid to gravel and rocks.

Minerals are natural inorganic compounds with definite physical, chemical and crystalline properties influencing the physical and chemicals properties of the different soil type.

In crop production, forestry and other field of agricultural practices, soil is the major media. The well being of the soil in terms of fertility, structural stability, friability, tillability, trafficability, moisture retention capacity, among other factors determines the success or otherwise of agricultural ventures. A number of these factors are influenced by the management modules used by man on the soil.

Poor soil management practices have contributed largely, to the loss of several million hectares of agricultural soil in soil structure degradation worldwide (Sparks, 1995). Soil structure degradation alter the physical and mechanical configuration of such soils, resulting in, an increase in the soil bulk density and soil strength (Dias Junior *et al.*, 1999); decrease in the total porosity, size and continuity of the pores (Servadio *et al.*, 2001), restriction in root penetration due to the insufficient root turgor pressure to overcome the soil mechanical resistance (Gysi, 2001), limitation in nutrient uptake, water infiltration and redistribution, gas exchange, seedling emergence and root development (Bicki and Siemens, 1991; Durr and Aubertot, 2000). Generally, all these changes will result in decreased yields (Radford *et al.*, 2001; Dauda and Samari,

2002), increased erosion susceptibility, increased power requirement for tillage and ultimately compaction of the soil layers.

Soil compaction has been identified as one of the major problems causing soil degradation (Canillas & Salokhe, 2002). According to Soane, (1986) and Hakansson and Voorhess (1998), it affects the physical, chemical and biological properties of soil and has been considered as one of the main causes of agricultural soil degradation worldwide.

In the developed countries, this problem is viewed more seriously with a trend towards larger and heavier agricultural machinery (Brannack and Dexter, 1979). In Nigeria and many other developing countries in the tropics, mechanization of agriculture is increasing and gaining popularity. Although the intensity of traffic and weight of vehicles involved may be less, the low structural stability of tropical soils and the high erosivity of the rainfalls may make soil-compaction problems more serious. Yet only few studies have been reported from this zone on soil compaction (IITA, 1984). Hence, Ekiti State been an agrarian state was selected for this research on mineralogy and compression characteristics of agricultural soils.

The strength of nations is measured in her ability to sustainably feed its citizens. In achieving this, sustainable management of the natural resources play a key role. Sustainable agricultural practice which has sustainable productivity as its objective is being threatened by the aggravated declining quality of soil as a resource caused largely by improper management.

Soil, which has often been described as "man's most important heritage" (Jules, 2002), without doubt, is the backbone of agricultural productivity. The greatness of nations can be measured in terms of their skill and persistence in producing agricultural products. Thus, a study that could guide in the sustainable use and development of soil is paramount to agricultural productivity, particularly in Nigeria, where there are dearth of precise, research based description of the current status of our soil and the effect of man activities on it.

1.2 OBJECTIVES OF THE STUDY

The specific objectives of this study are:

- (i) to determine the dominant secondary minerals in some selected agricultural soils in Ekiti State, Nigeria;
- (ii) to establish the load bearing capacity models of the various soil types;
- (iii) to investigate possible relationship between the soil load bearing capacity (management factor) and soil mineralogy (historical factor)

1.3 RESEARCH JUSTIFICATION

Soil is an irreplaceable natural resource and should therefore be properly managed. Its proper management form the basis of sustainable agricultural productivity. In achieving the goal of sustainable management, there must be baseline characteristics which must be determined on the basis of, reproducible universal parameters, which could be monitored over time, to determine a shift in the positive or negative over time. One of such parameters is the preconsolidation pressure and moisture retention behaviour. In Ekiti State, as in many other parts of Nigeria and other sub-Saharan African countries, there are not many documented research results on the mineralogy and susceptibility of agricultural soils to compaction. Thus, this study will be filling the knowledge gap and would enhance agricultural mechanization programme for Ekiti State, Nigeria. It will establish a reference Bearing Capacity Model for soil in the study area.

CHAPTER TWO

LITERATURE REVIEW



2.1 SOIL

Soil means different things to different people. To many people, it is dirt that needs to be washed from clothes and swept out of the rooms. To the geologist, soil is the unconsolidated, weathered part of the earth's mantle, an insignificant, small fraction of its total volume. To the civil engineer, it is the medium for the support of structures and a construction material. To the agriculturist, soil is that part of the earth crust in which the roots of plants grow (Jules, 2002). A modern definition of soil relates to the earth's surface layer exploited by plant roots (Paul and Clark, 1989). It is a vital, living component of the environment that could be manipulated to influence crop performance.

Soil consist of mineral particles of various sizes and shapes with varying chemical characteristics, together with plant roots, the living soil population, and an organic matter component in various stages of decomposition. Soil gases, soil water, and dissolved minerals complete the soil habitat (Sparks, 1995). An understanding of the soil fabric requires knowledge of the spatial arrangements. This relates to the size and shape of the components. The relative dimensions of components of the soil matrix range from 2mm or greater for macroaggregates to fractions of a micrometer for bacteria and colloidal particles (Paul and Clark, 1989). Enzymatic and other molecular reactions occur at size dimensions, at least another order of magnitude smaller (Hakansson and Voorhess, 1998).

The major gases in the soil atmosphere are those found in the atmosphere, namely, Nitrogen (N), Oxygen (O₂), and Carbon dioxide (CO₂) (Paul and Clark, 1989). Gases arising from biological activity, such as Nitrogen Oxides, may at times be present, because of their high reactivity with soil components and their susceptibility to biological activity. They are usually transitory. In well aerated soils, the O₂ content seldom falls below 18 to 20% and CO₂ seldom rises above 1 to 2% (Donahue *et al*,

1977). However, given a clay texture and high moisture content coupled with high microbial activity, CO₂ content of the soil atmosphere may reach as high as 10% (Paul and Clark, 1989). The carbon of soil organic matter (SOM) is composed of 10 to 20% carbohydrates, primarily of microbial origin; 20% nitrogen-containing constituents, such as amino sugars and amino acids; 10 to 20% aliphatic fatty acids, alkanes, etc; with the rest of the carbon being aromatic (Paul and Clark, 1989).

When soil is misused, crops become less productive. When handled with due consideration for its biological and physical nature, it can continue to yield crops throughout countless generations of cultivation and use. According to Black (1968), soil has 3 primary functions in sustaining plant life. These are

- (i) It supplies mineral elements, serving both as a medium of exchange and as a place of storage.
- (ii) It supplies water and serves as a storage reservoir.
- (iii) It serves as a medium within which the roots of terrestrial plants, as well as those of many plants, anchor themselves.

One might ask whether soil is really necessary for plant growth. Hydroponics – the soil-less cultivation of plant with nutrient solutions alone or with sand or gravel, is practiced today on a limited scale (Abel, 2005). The United States Armed Services use hydroponic gardens to provide fresh vegetables for personnel on isolated islands in the Pacific Ocean where soil is not available. Even though it is possible to maintain a limited agriculture without soil, the massive production of plant materials that the world requires cannot be accomplished economically without soil under present economic conditions.

2.2 SOIL FORMATION

Soil is formed through weathering process which, result from all the interacting forces that affect the parent rock materials, air and water movement of particles, and the composition and fate of living organisms that inhabit it (Cruickshank, 1972).

Weathering is one of the most important geomorphologic processes, occurring when the rocks and sediments in the top meters of the earth's crust are exposed to physical,

chemical and biological conditions much different from those prevailing at the time the rocks were formed (Andrew, 1995).

In general two main types of weathering are recognized. Mechanical or physical weathering involves the breakdown or disintegration of rock without any substantial degree of chemical change taking place in the minerals that make up the rock mass. It incorporates such processes as frost and salt weathering and may also be achieved by organic or biological means like root wedging. Chemical weathering, in which biological processes may play a major role, involves the decomposition or decay of rock minerals through such processes as hydration, hydrolysis, oxidation and reduction, carbonation and chelation (Andrew, 1995). In most part of the world, both types of weathering may operate together though in differing proportions, and one may accelerate the other. For instance, the physical disintegration of a rock will expose a greatly increased surface area to chemical attack.

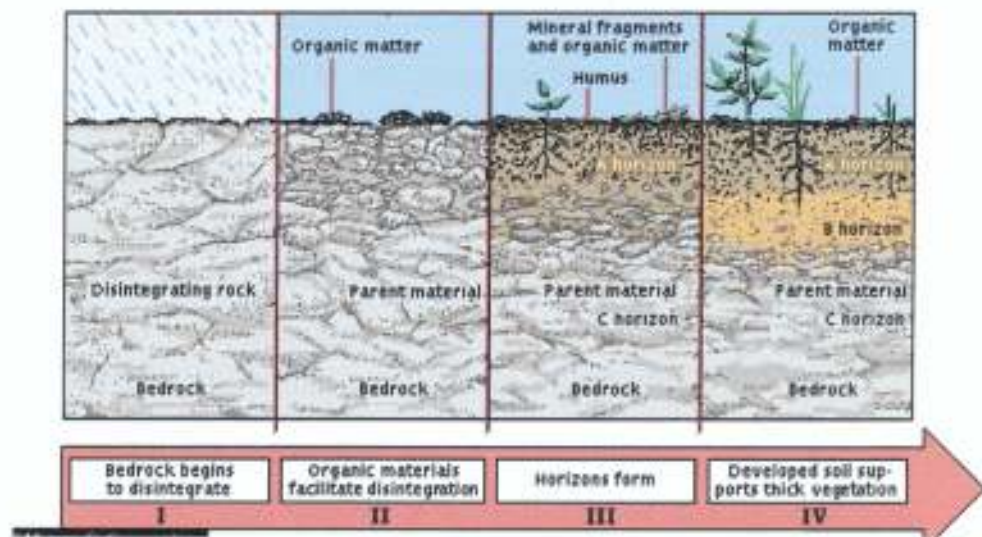


Fig. 2.1: Stages of Soil Formation.
Source: Encarta 2005 Edition.

Rocks vary enormously in their physical and chemical properties. Similarly the weathered materials (soils) derived from different rocks are themselves very different. The fact remains, however, that much of the material composing most soils has been derived from the underlying rock; no matter how long a soil has been in process of formation, the original "raw material" must therefore have some effect on its ultimate

nature (Spark, 1995). This explains the need for specified soil management practices for different soil formations.

The mineral fraction of soil is made up of a combination of sand, silt, and clay particles. These particles do not fit together tightly, but are surrounded by open pore spaces. This open space is important because it allows soil to hold air and water. Spaces between the particles are filled with air in dry soil, water in saturated soil, or both in moist. When the soil is pressed, there will be gradual expelling of the air and water, but the rate will depend on the bonding strength with the mineral content of the soil solid component. This is while soil mineralogy may have some influence on compression characteristic of soil.

2.2.1 THE SOLIDS IN SOIL

The solid in soil are minerals and organic matter. Minerals can be either primary or secondary. Quartz and feldspar are primary minerals. The clays are secondary minerals. Rocks are mixture of minerals. Igneous rocks are formed from molten magma. Sedimentary rocks are cemented accumulations of minerals materials. Common sedimentary rocks include limestone, sand stones, quartzite, and shale. Metamorphic rocks include slate (hardened shale) and marble (hardened limestone). The various rocks and minerals decompose and weather to form soil minerals. These soil minerals may be small versions of primary minerals (sand is usually small quartz rocks) or may be secondary minerals (as is the case with most clays). Soil minerals are mostly O, Si, and Al (Spark, 1995, Shaw et al., 2002).

2.2.2 PRIMARY MINERALS

They are formed at high temperature and pressure, under reducing conditions without free oxygen. These minerals are mainly present in soils as sand and silt particles. They are not crystallized and decomposed from molten lava. The primary minerals on the earth cooled from a molten mass, and have not changed chemically since the day they came inexistence. Several distinct soil minerals are recognized as detailed in Table 2.1 (Spark, 1995; Encarta, 2005; Shaw et al., 2002).

Table 2.1: Soil Primary Minerals

Primary minerals	Chemical formulae	Importance
Quartz	SiO_2	Abundant in sand and silt
Feldspar	$(\text{Na,K})\text{AlO}_2[\text{SiO}_2]_3$ $\text{CaAl}_2\text{O}_4[\text{SiO}_2]_2$	Abundant in soil that is not leached.
Mica	$\text{K}_2\text{Al}_2\text{O}_5[\text{Si}_2\text{O}_5]_2\text{Al}_4(\text{OH})_4$ $\text{K}_2\text{Al}_2\text{O}_5[\text{Si}_2\text{O}_5]_3(\text{Mg,Fe})_6(\text{OH})_4$	Sources of K in most temperate zones
Amphibole	$(\text{Ca,Na,K})_{2-3}(\text{Mg,Fe,Al})_5(\text{OH})_2[\text{Si,Al}_4\text{O}_{11}]_2$	Easily weathered to clay minerals
Pyroxene	$(\text{Ca,Mg,Fe,Ti,Al})(\text{Si,Al})\text{O}_3$	Easily weathered
Olivine	$(\text{Mg, Fe})_2\text{SiO}_4$	Easily weathered
Epidote	$\text{Ca}_2(\text{Al,Fe})_3(\text{OH})\text{Si}_3\text{O}_{12}$	Highly resistant to chemical weathering
Tourmaline	$\text{NaMg}_3\text{Al}_6\text{B}_3\text{Si}_6\text{O}_{27}(\text{OH,F})_4$	Highly resistant to chemical weathering
Zircon	ZrSiO_4	Highly resistant to weathering
Rutile	TiO_2	Highly resistant to weathering

Source: Encarta 2005 edition

2.2.3 SECONDARY MINERALS

They are formed at low temperature and pressure through oxidation. They are the weathering product of primary minerals, either through alteration of their structure or through re-precipitation. Secondary minerals are usually present in soil as clay particles. These minerals are formed by precipitation or recrystallization of elements that were released by the weathering of primary minerals (Spark, 1995).

2.2.4 SOIL ORGANIC MATTER

Soil organic matter is composed of decomposing residues; by-products formed by organisms responsible for decomposition of residues, the micro-organism themselves, and the more resistant soil humates. Residues of plants differ in phenolic content and in the proportion of lignin to cellulose and protein (Paul and Clark, 1989). Microbial attack of carbohydrates and proteins results in the production of microbial products, while the production of SO_4^{2-} and NH_4 as well as CO_2 depend on the Carbon(C): Nitrogen (C/N) and Sulphur : Phosphorus (S/P) ratios.

2.3 PHYSICAL PROPERTIES OF SOIL

Physical properties refer to characteristics described by physical measurements such as length, mass, and temperature. These properties often are the most important for

determining the limitations and practical uses for a unit of land. Can the soil support trees, aquatic plants and desert shrubs? Can the soil withstand vehicle traffic/tractor weight, or will it fail under stress? A complete answer to these questions requires a thorough knowledge of the physical properties of the soil (Dias Junior, 2003; Dias Junior *et al.*, 2007). These properties include texture, structure, bulk density and porosity, colour and temperature (Donahue *et al.*, 1977, Olufayo, 1997).

2.3.1 SOIL TEXTURE

The term soil texture refers to the size of the individual mineral particles (Baver, 1972). These mineral particles of the soil can be arranged according to size from very coarse to very fine. The proportion of the different sizes of particles making up a soil determines its texture (ASAE Monograph, 1980). These textural groups, as measured by effective particle diameter are primarily referred to as: Gravel, Sand, Silt, and Clay. Example of the textural classification system commonly used for soil evaluations associated with selecting farm irrigation systems is the one developed by the United State Department of Agriculture (USDA). The size range of the particles and their textural groups are presented in Table 2.2.

Table 2.2: Size range of particles associated with soil textural groups.

Textural Group	Particle Size (mm)
Gravel	>2.0
Sand	
Very Coarse Sand	1.0 – 2.0
Coarse Sand	0.5 – 1.0
Medium Sand	0.25 – 0.5
Fine Sand	0.10 – 0.25
Very Fine sand	0.05 – 0.10
Silt	0.002 – 0.05
Clay	<0.002

Source: ASAE monograph (1980)

The coarse materials such as sands and gravels are usually composed of many small particles cemented together either chemically or by a matrix material. These are bound relatively firmly and present only a single outer surface. The physical and chemical properties of these coarse materials do not differ greatly from those of their parent materials (Foth, 1978).

Silt particles, which are smaller than Sand particles are more or less unweathered, but their surfaces are coated with a clayey matter. The properties of silt are therefore somewhat intermediate between those of sand and clay (Baver, 1972). The clay, the smallest of the soil particles, shows distinct chemical and physical properties (Foth, 1978). Clays colloids are viscous and gelatinous when moist but hard and cohesive when dry (Jules, 2002). Clays are composed of particles called "micelles", which are formed from the parent materials by a crystallization process. They are merely finely divided rock, with internal as well as external surfaces, and tend to be held together by chemical linkages or ions between the plates (Baver, 1972). A colloid is a small, insoluble, non-diffusible particle, larger than a molecule but small enough to remain suspended in a fluid medium without settling (Foth, 1978; Spark, 1995) and is present in most soils as organic colloidal particles as well as inorganic colloidal particles of clays.



Fig. 2.2: Soil classification according to textural triangle.

Source: *Handbook of Agricultural Engineering, ASAE 1999.*

Soil texture affects the retention of water and the rate of water infiltration (Jules, 2002). Coarse soils permit the rapid infiltration and percolation of water, so that there is no surface runoff even after a heavy rain. In contrast, clay soils are so finely textured that very little water penetrates to lower levels, especially after the surface clays becomes wet and expand. Coarse soils however exhibit low water retention

capacity. Soil texture has some effect on compaction, although compaction can be a problem to one degree or another in almost all soil types. Soils made up of particles of about the same size compact less than soil with a variety of particle sizes. Smaller particles can fill the pores between larger particles making for a more dense soil.

A dry soil, which has friction between the soil particles, is not easily compacted. Water acts as lubricant between the particles, making the soil easier to compact. However, as soil water content increases, a point is reached where most pore spaces in the soil are filled with water, not air. Water cannot be compressed, so water between the soil particles carries some of the load on the soil, resisting compaction. Therefore, a very wet soil will not compact as much as a moderately moist soil.

2.3.2 SOIL STRUCTURE

Soil structure refers to the gross arrangement of the soil particles into aggregates (USDA, 1957). Particles of coarse grained soils tend to function as individuals, while the aggregated particles of fine – textured soils tend to form granules. The size and shape of these particle groups and their stability is defined as the soil structure.

A soil may have either a simple or a compound structure. Sand and gravels, (examples of soils with a simple structure) have very little cohesion, plasticity, and consistency the latter been the resistance of the particles in the soil to separation. Simple – structured soils are usually composed of materials that are relatively resistant to weathering, such as quartz sand. They are also said to have a single – grain structure. Most agricultural soils have a compound structure; their particles aggregate, or stick together. Several distinct sizes of compound structures are recognized as detailed in Table 2.3.

Table 2.3: Sizes of compound structured soils

Structural Type	Aggregate Diameter (mm)
Columnar	>250
Blocky	5 – 25
Granular	3 – 5
Crumbly	1 – 3
Massive	Completely puddle or compacted

Source: Jules (2002)



Fundamentally, soil structure is developed by wetting and drying, freezing and thawing, and combinations of these conditions. The primary function of organic matter in the soil is to add stability to soil aggregates and serve as a cushion against the effects of tillage. Good soil structure is very important for agricultural soils (Jules, 2002). This is because the soil structure influences the ease of root penetration, the infiltration rate, aeration, and the movement of water in the soil, all of which are essential to crop production (ASAE Monograph, 1980). For good crop production, the maintenance of a good soil structure is recognized as being equally important as maintaining a good chemical balance (Golchin and Asgari, 2008)

Thus, in mechanized agriculture, it will be necessary to synchronize the scheduling of various farm operations, vehicular movements, with moisture content of the soil as it affects the load bearing capacity of the soil. This measure will guide against soil structure degradation resulting from compaction and consequent losses of productivity in areas under intense traffic (Dias Junior *et al.*, 2005; Ajayi *et al.*, 2008).

2.4 SOIL RESOURCES IN NIGERIA

Soil constitutes an important resource in Nigeria where majority of her inhabitants are engaged in agriculture. Although a great diversity of specific soil type abounds in the country, yet the great majority of the soils in the country are nutrient deficient (Olu *et al.*, 1986). The problems of phosphorus deficiency, aluminium toxicity, drought stress and low inherent fertility are common. Most of the soils are acidic, compacted and leached. These soil problems constitute great threat to soil resources and agricultural productivity in Nigeria, which lies within the tropical soils.

2.5 SOIL COMPACTION

Soil compaction arises from an imbalance between the forces (pressures) exerted by soil tillage or wheel traffic and the bearing capacity of the soil (Tijink, 1990). Understanding the compressive behaviour of soil is essential to predict the alterations that might occur in soil structure when submitted to stress caused by agricultural implements.

2.6 TYPES OF SOIL COMPACTION

There are several forces, natural and man-induced, that compact a soil. This force can be high such as that from a tractor, combine harvester or tillage implement, or it can come from something as small as a rainfall impact. Listed below are several types of soil compaction and their causes.

2.6.1 Naturally Dense Soils

Most dense soils have high clay content in some parts of the soil profile. Soils that are dense by nature cannot be easily "un-compacted". Enormous amounts of sand and silt would be needed to do so. Attempts to mix sand and clay layers in river bottom soils and seas shore soils have had varying degrees of success. Tillage offers only a short lived solution in these soils. Prevention of additional compaction is the best management strategy in naturally dense soils (Donahue et al., 1990).

2.6.2 Surface Crusting

Soils are sensitive to surface crusting caused by rainfall impact. Excessive or high intensity of rainfall compacts the soil. Crop residue or vegetative cover is the best means to prevent surface crusting and soil sealing in all soils. (Donahue et al., 1990) Soils without residue cover form a dry surface crust that is difficult for emerging seedlings to penetrate.

2.6.3 Tillage Pan

Tillage implements that shear the soil, such as mould board ploughs, disks and sweep-type tools, have a tendency to cause soil compaction. When continuously operated at the same depth, tillage implements orient soil particles in the same direction, creating a layer of compacted soil. This compaction is typically referred to as a tillage or plough pan. The potential to cause a tillage pan is greater under wet soil conditions than under dry conditions. It is difficult for roots and water to penetrate a tillage pan. A tillage pan effectively reduces the rooting depth to the depth of tillage, which is usually between 13cm to 21cm.

2.6.4 Vehicle Induced Compaction

This form of compaction can be divided into two types namely:

- (a) Shallow compaction
- (b) Deep compaction

Shallow compaction

This is defined as any compaction occurring within the normal tillage zone. For some producers this may be 12.7cm deep and for others it may be 25.4cm deep. Shallow compaction is related to the pressure applied to the surface of the soil. (Donahue *et al.*, 1990).

Deep Compaction

This is compaction that occurs below the normal tillage zone. It is caused by weight of force applied to the soil, and is mostly affected by the maximum axle weight.

2.6.5 Compaction from Cultural Practices

Excessive tillage tends to break down soil aggregate resulting in poor soil structure and higher potential for compaction. Tillage hastens breakdown of the organic matter that is needed for good soil structure. Crop sequences, residue production and residue management can all affect soil structure and compaction potential. Practices that leave surface residue undisturbed help increase or maintain a good organic matter level, which favours good soil structure and reduces the potential for compaction (Donahue *et al.*, 1990).

2.7 EFFECT OF ORGANIC MATTER ON SOIL COMPACTION

Soil response to compaction is also influenced by organic matter content (McBride and Watson, 1990; Soane, 1990). The susceptibility to compaction decreases as soil organic content increases (O' Sullivan, 1992). However, the effect of organic matter on the reduction of soil compressibility seems to be dependent on soil moisture at the time of load application (Soane, 1990). It was also reported that there is significant decrease in the strength of the soil at any level of compaction, for low concentration of organic matter (Olu *et al.*, 1986). At such level, the presence of organic matter would be associated with a decrease in bulk density of the soil and increased pore spaces. However, increase in the concentration of organic matter within a soil volume had been reported to increase soil strength which reduces the susceptibility of the soil to compaction (Olu *et al.*, 1986; Zhang *et al.*, 1997). This happens because, with higher organic matter, more moisture would be required to initiate the flow of the soil unlike when the organic material concentration is low.

2.8 EFFECT OF SOIL MOISTURE

The water lost by the soil represents the soil moisture content in the moist samples (Brady, 1984). The most common means of expressing soil water content is the mass or volume of water associated with a given mass or volume of soil solids. Soil moisture could be measured from a number of techniques including tensiometry, electrical conductivity, neutron and gamma ray attenuation (Brady, 1984).

Soil moisture has been widely recognized as a determinant of soil compressibility (Soane, 1990; O' Sullivan 1992). Soil compressibility is defined as the resistance against volume decrease when soil is subjected to a mechanical load, which has been described by the shape of the soil compression curve (Horn and Lebert, 1994). The differences in the soil susceptibility to compaction seems to be related to the mechanism whereby a decrease in soil water content increases the number of contacts between particles, which is directly dependent on soil texture (McNabb and Boersma, 1993; Harte, 2000). Crystalline clay minerals may lose more water from the external surface than noncrystalline minerals. As a result, the number of contacts between particles increases at a faster rate in the former than in the later as the soils dried. (McNabb and Boersma, 1993).

2.9 EFFECT OF BULK DENSITY

The soil compression behaviour is also affected by soil bulk density. Soil deformation occurs when some individualized (crystals) or grouped (domains) particles are able to separate and move in relation to each other. This movement is restricted by friction forces and by the bonds existing between particles. The denser the soil and the more intricate the particle arrangement, the smaller the pore space available for particle movement is and the higher the friction forces between them are. Thus, displacement and rearrangement of solid particles to closer positions (deformation) becomes more difficult as bulk density increases (Paz and Guterif, 2000).

2.10 EFFECT OF AGRICULTURAL MECHANIZATION ON SOIL

Man as a power unit is very inefficient and ineffective. He is limited to about 0.075kW continuous out-put and is therefore worth almost nothing as a primary source of power (Barger *et al.* 1963). For the farmer to receive an adequate return for his labour, he must be an efficient producer (Igbeka, 1991). This efficiency can only be achieved if there is proper use of materials and effective utilization of power through mechanization. Agricultural mechanization encompasses the use of hand-and animal-operated tools and implements as well as motorized equipment to reduce human efforts. It improves timeliness and quality of various farm operations and stands as the only measure for achieving sustainable agricultural productivity (Igbeka, 1991).

To achieve a fully mechanized agricultural production system, different types of agricultural machinery are used for different operations. These include, soil tillage, fertilizer application, planting, weeding, application of herbicides, pesticides and soil ameliorating chemicals, moving portable irrigation equipment, harvesting and moving primary processing equipment (Onwualu and Anazodo, 1989). The unknown traffic set up by these operations has been shown to cause soil deterioration, usually referred to as soil compaction (Wolf and Hadas, 1984).

The magnitude of soil compaction problems resulting from increased use of large machinery and more intensive cultivation and their consequences on crop production, has not been much researched in the tropics as in the temperate regions (Hakansson *et al.* 1988). However, the implementation of numerous large mechanized land development programs is inevitable consequence of attempts to increase food production rapidly. Yet the conclusions drawn from a critical appraisal of previously implemented large-scale agricultural development schemes in the tropics are far from encouraging (Abdulmumin, 1997; ICID and CIID, 1999).



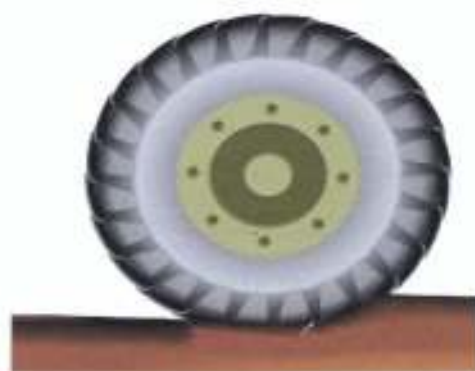


Fig 2.3: Soil Subjected to High Axle Load

Failure of large-scale mechanized agricultural schemes in Africa, Latin America and tropic Asia has been attributed to many factors, including socio-economic conditions and poor infra-structure (ICID and CIID,1999), insufficient baseline data to enable adequate planning for resource development and management (Bauer,1978), and erratic rains. In addition to these exogenous factors, the ability of the soil to sustain economic yields under mechanized farming system is obviously an important factor and need to be adequately assessed.

The importance of soil factors is basic to all planning. An important endogenous soil factor is the problem of soil compaction and its effects on soil and sativa environmental degradation and on crop production. Thus, the necessary skill to own and run a farm successfully should not be taken for granted. This accounts to a large extent, for the failure of many commercial farming projects. It takes more than available land, favourable weather and desire to make money to succeed in farming.

2.11 EFFECT OF COMPACTION ON TROPICAL CROPS

Considerable evidence exists to show that soil compaction, originating either from anthropogenic or natural causes, exert an enormous impact on the establishment, growth and yield of food and cash crops in tropical regions where south western Nigeria is located .The dominant crops here vary from Rice (*oryza sativa*), Maize (*zea mays*), Cowpea (*vigna unguiculata*), Yam (*dioscoreaceae*) and Cassava (*manihot*

esculenta). Soybean (*glycine max*) production is also expanding gradually in the tropics due to its vast potential as a source of edible oil and animal feed (Kayombo and Lal, 1994).

Rice which constitutes the important staple food of about half the world's population (Olorunfemi, 2007), are of two types. Paddy rice is grown under puddled irrigated conditions, and upland rice is grown in unpuddled rain fed conditions. Many studies on paddy rice grown in coarse-textured soils indicate that moderate soil compaction enhances better establishment of root growth, and produces higher grain yields due to a more favourable soil bulk density profile, a lower infiltration rate and higher surface retention of water (Ogunremi *et al.*, 1986a). Similar responses to compaction have been reported in upland rice for some soils (Kar *et al.* 1986), although in most instances soil compaction decreases seedling emergence, and causes stunted shoot and root growth.

Experiments conducted in eastern Africa have shown that the germination and early growth of maize are severely restricted on untilled and shallow-tilled naturally compacted soils (Macartney *et al.*, 1971). The poor crop performance is attributed to restricted root growth. Mechanical land clearing and continuous mechanized farming causes significant deterioration of soil physical properties as compared to manual clearing or no-tillage, and consequently leads to reduced maize growth in tropical soils (Lal, 1985a; Ojeniyi, 1990). Soil compaction resulting from mechanical land clearing considerably reduces maize grain yield compared to land cleared by manual methods (Alegre *et al.*, 1986). Kayombo and Lal (1986a) reported that a 4-pass treatment reduced emergence, plant height, leaf number, leaf area index and root growth of maize more on ploughed than on no-till plots in three consecutive growing seasons on an Alfisol in south western Nigeria. The problem of soil compaction in plough-based systems is greatly accentuated by motorized farm operations and vehicular traffic (Lal, 1985a).

Adequate development of cassava root tubers depends on a high total porosity and the ability of soil to accommodate voluminous tubers. Loose soil is obviously advantageous for cassava tuber development because roots first penetrate the soil and then enlarge to bulking. The adaptation of cassava to drought is partly explained by

the ability of its feeder roots to penetrate deep into the soil and extract water (Ezumah, 1983). Compacted soils decrease the tuberous root/feeding root ratio and reduce yields. In addition, the adverse effects of soil water stress on plant growth and dry matter yield of cassava are accentuated if the cassava root system development is restricted by high bulk density. Pre-plant field traffic consisting of 4 roller passes (452 Kpa) has been shown to reduce plant height, leaf number, shoot dry weight and fresh tuber yield in both no-till and ploughed plots on an Alfisol in South-Western Nigeria (Kayombo and Lal, 1986b). Table 2.2 shows beneficial effect of minimal compaction on yield.

Table 2.4: Response of cassava tuber yield to soil compaction

Roller Treatment	Tillage	Cassava Tuber yield (Mg ha ⁻¹)	Tubers/Plant (Number)
0	No tillage	18.4	9.1
2	No tillage	16.3	9.5
4	No tillage	9.7	5.6
0	Ploughed	20.6	11.2
2	Ploughed	24.1	12.8
4	Ploughed	12.7	7.2

Source: Soane & Ouwerkerk (1994)

2.12 SOIL PRECONSOLIDATION PRESSURE

The preconsolidation pressure is the pressure that divides the soil compression curves into region of small, elastic and recovered deformation, secondary compression curve and a region of plastic and unrecoverable deformation – virgin compression curve (Holtz and Kovacs, 1981). The maximum stress previously sustained by a soil is an indicator of the soil strength (Defossez and Richard, 2002). Soil compaction which occurs due to removal of air – filled porosity is a relevant factor in soil deformation analysis. An assessment of the influence of compaction on soil physical properties is necessary in agricultural research and it usually involves the monitoring of variations in soil structure, bulk density, porosity, water content, air permeability, pore size distribution, etc under loading and unloading. Thus, in agriculture, application of stress greater than the soil preconsolidation pressure should be avoided in order to avoid unrecoverable soil deformation (Defossez and Richard, 2002).

Considering the fact that soil preconsolidation pressures indicate the soil strength and maximum stress that should be applied to a soil in order to avoid soil degradation and ensure soil structure sustainability (Dias Junior *et al.* 1999), it is therefore apparent that a reduction in the soil preconsolidation pressure value may be used as an indicator of soil structure recovery.

The bearing capacity model (BCM), which is the adjustment of soil preconsolidation pressure as a function of moisture content or suction, may be used also to detect the soil structure changes through time due to the Below Ground Biological Diversity (BGBD) management. In addition, the bearing capacity model has different uses in agriculture and environment quality studies. The uses include the estimation of maximum pressure that should be applied to the soil in order to avoid soil compaction, evaluation of traffic effect on soil structure, assessment of natural alleviation of soil structure after a compaction event and determining the natural soil mechanical resistance of the soil horizons that may impair the sustainable soil uses through time.





CHAPTER THREE

MATERIALS AND METHOD

3.1 DESCRIPTION OF THE STUDY AREA

The samples used in this study were all collected from sampling pits in some selected agriculture belt of Ekiti State, Southwestern Nigeria. Agro-Ecologically, most part of Ekiti State falls under the Rainforest and Secondary Forest classification. In the transition zone of Ekiti State, that is, area adjoining Kogi and Kwara States, the vegetation is dominantly derived Savanah. Climatologically, the studied site is sub-humid zone (Jagtag and Alabi, 1997), with mean annual rainfalls ranging between 1200mm and 1350mm.

In this study, soil samples were collected from three locations noted for subsistence agriculture, but with great potential for large scale agriculture due to the availability of large expanse of land. The selected sites were in Oye Ekiti, Ire Ekiti and Ikere Ekiti. All the selected sites have similar climatological and ecological condition with samples collected under natural vegetation. Detail descriptions of the sampling locations are presented in Table 3.1.

Table 3.1: Description of sampling sites.

Site	Ring Nomenclature & Horizon (A&B)	Location Name	Lat & long	Elevation (M)	Others
1	EK1-EK17 (A) EK18-EK34 (B)	Oye-Ekiti	Lat.5.20'696" Long.7.48'114"	550	Previously cropped
2	EK35-EK51 (A) EK52-EK68 (B)	Oge Village, Ire Ekiti	Lat 5.21'895" Long.7.43'853"	428	Virgin Land
3	EK69-EK85 (A)	Ikere-Ekiti	Lat.5.13'757" Long.7.27'541"	385	Hilly Land basement

At Oye and Ire Ekiti, undisturbed core samples were collected in both the A (10-20cm) and B (70-80cm) horizons. At Ikere, sample could not be collect at the B-horizon, due to the existence of a hard pan at about 65cm depth

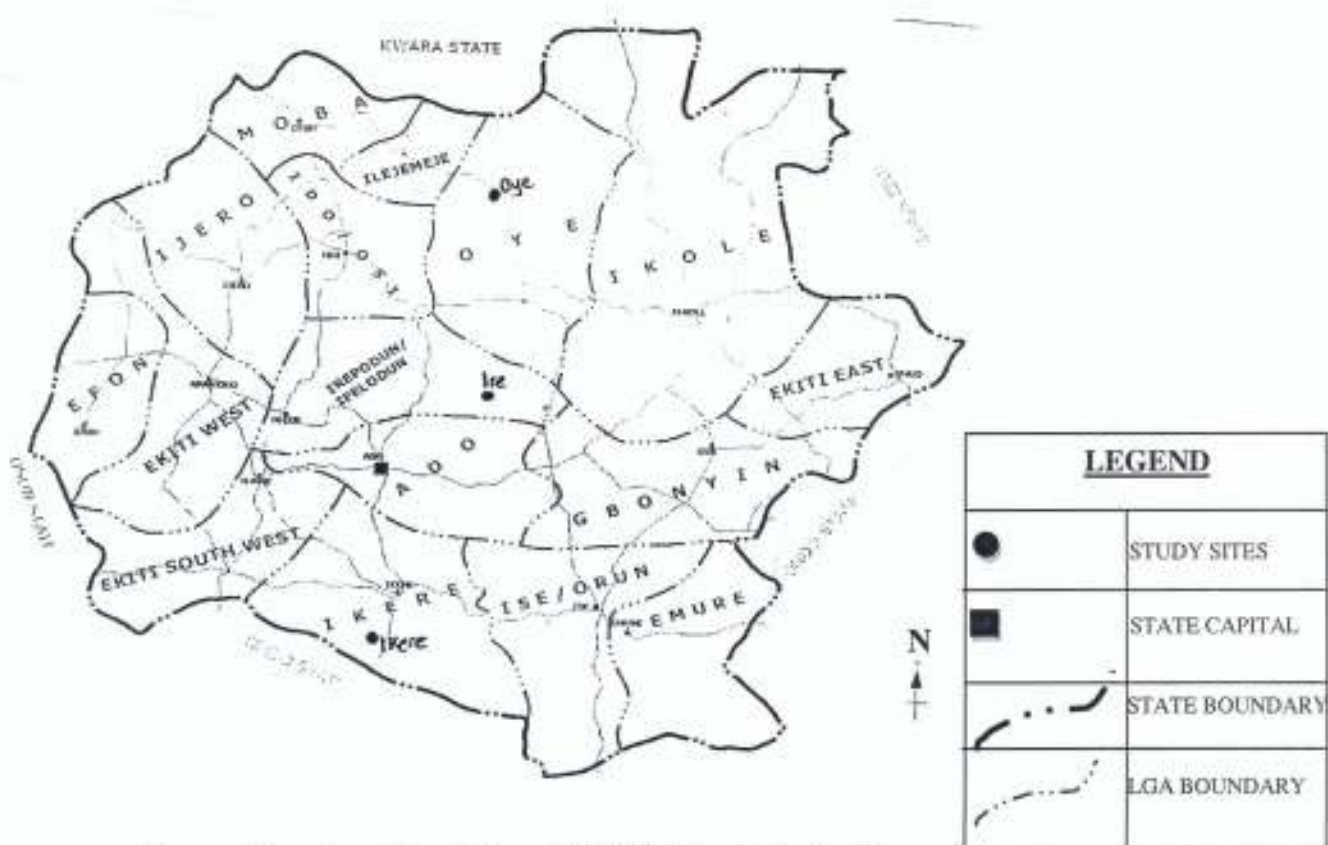


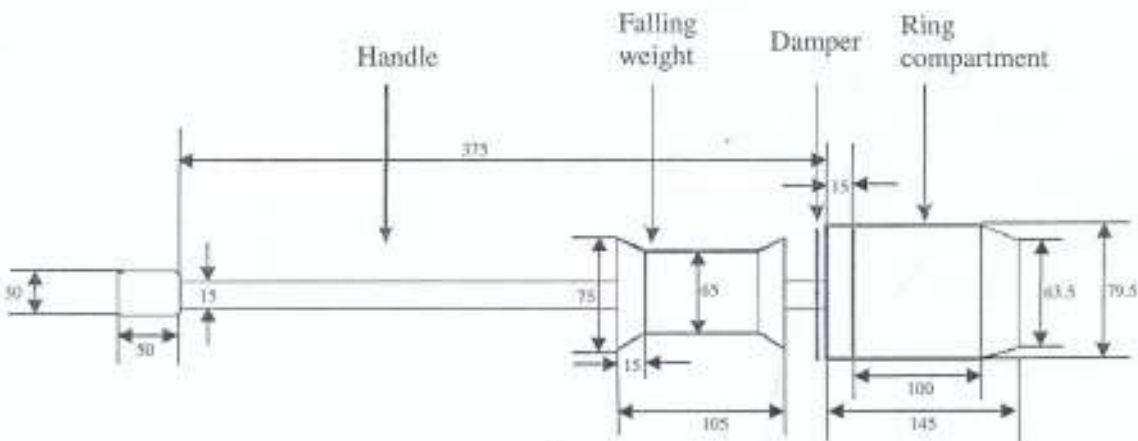
Figure 3.1: Location Map of Ekiti State & Study Sites

3.2 MATERIALS

For the collection of field samples in this study and in the laboratory analysis, the materials used include, Falling Weight Soil sampler (Uhland Amostrador), Handheld Geographical Positioning System (GPS), Weighing Balance, Vernier Calliper, Cylindrical rings, Hoe, Knife, Measuring tapes, Munsell Soil Colour Charts, Handheld Penetrometer, Paraffin Wax, Digital camera, Distilled Water, Sodium Hydroxide (Noah), Pipette, Conical flask, Potassium Chloride (KCl), Pressure Chamber, Ceramic Plates, Metal Sieve Set, and Consolidometer.

3.3 COLLECTION OF SOIL SAMPLES

Undisturbed core soil samples were collected at the three different locations earlier described. The selected sites represent geographically similar ecological conditions, but also present the range of soil that had been associated with different types of parent materials in Ekiti state.



NOTE: All dimensions in mm

Figure 3.2: Uhland Soil Sampler (*Amostrador*)

Eighty-five undisturbed soil samples (85) were collected with the aluminium cylindrical ring in the A and B-horizons. Prior to this sampling, the height and internal diameter of the rings were measured using the Vernier Calliper, and their weights using digital weighing balance to facilitate the computation of samples moisture content and field bulk density in the laboratory.

The sampling pits (1m x 2m x 1m) were dug very carefully to avoid soil compaction during digging process, after which the Uhland sampling device was pushed carefully into the soil using the falling weight. These samples were collected randomly in each pit to ensure good representation.



Plate 3.1: Sampling Pit at Oye Ekiti Site

At Oye-Ekiti site, which is a fallowing ground (previously cropped land), seventeen soil samples were collected at the A-horizon and same number of samples collected at B-horizon. At Oge village, the Ire-Ekiti site (on a virgin land), 17 samples were also collected at the A-horizon, but the B-horizon samples were collected at 70cm depth to avoid the stony hardpan below that depth. In addition, 17 samples were collected at Ikere- Ekiti at the base of a hilly land within the A-horizon.

At each point, the collected undisturbed soil samples, which have some soil on the top and bottom of the cylindrical metal ring, were wrapped with paraffin wax (to retain the soil initial moisture level), until compressibility and other tests were performed. All identification for the soil samples such as site number, ring nomenclature, and other pertinent data were recorded on the data sheet.



Plate 3.2: Undisturbed Soil Sample in Cylindrical Metal Ring.



Plate 3.3: Soil Sample Wrapped in Paraffin Wax.

3.4 LABORATORY EXPERIMENTAL PROCEDURE

In the laboratory, the soil samples collected were carefully trimmed to the size of the respective rings, (whose inner diameter, height and weight had been previously measured) using wire saw and knife.



Plate 3.4: Post Consolidometry Drying of Soil Samples

3.4.1 Field Moisture Content

The disturbed soil samples scraped near the intact soil cores were used among other things to determine the level of drying (under natural condition) or saturation (by capillary) of the samples during preparation for compressibility test. The remaining disturbed soil samples were later air-dried and passed through 2mm mesh sieve and used for other standardize tests.

3.4.2 Soil pH

The soil pH was measured in distilled water and 1N KCL using 1:1 mass soil to solution ratio. The cation exchange capacity (CEC) was determined as being the sum of the electric charge of Ca^{2+} , Mg^{2+} and Al^{3+} extracted with 1N KCL, of K^+ & Na^+ extracted with 0.05 N HCL, and of H^+ & Al^{3+} extracted with a tampon solution of Ca $(\text{CH}_3\text{COO})_2$ and CH_3OOH at pH 7.0. Other parameters monitored in the samples include soil colour, plastic and liquid limits.

3.4.3 Particle Size Determination

The particle size distribution was determined using the pipette method after dispersing with 1N NaOH while particle density was determined using 95% hydrated alcohol with 20g of air-dried soil material in 50ml pycnometer.



Plate 3.5: Particle Size Determination

3.4.4 Compressibility and Pre-consolidation Pressure Determination

In determining the compressibility of soil samples, two samples each of the prepared soil cores were saturated by capillary with distilled water, and equilibrated to 1 atm, 0.02 atm and 0.06 atm on ceramic plate inside a pressure chamber. Other samples were adjusted to different moisture content between saturation and about 5% moisture content. For lower moisture content, the cores were first equilibrated at a matrix potential of 100 kPa and air dried at room temperature until desired moisture content was attained. Two other samples were left at natural field moisture content.



Plate 3.6: Sample Saturation Process

For the test, bottom porous stone is fitted into the base of the consolidometer, with a filter paper placed over it. The ring with the undisturbed soil sample was then placed on the porous stone with another filter paper placed on its top before placing the top porous stone, after which the loading plate was positioned. These undisturbed soil samples at different moisture contents were then subjected to uniaxial compression test using pneumatic S-450 Terraload floating ring consolidometer (Durham Geo Enterprises, USA).

The undisturbed soil samples were kept within the coring cylinders, which were placed into the compression cell, and afterward subjected to pressures of 25, 50, 100, 200, 400, 800 and 1600 kPa respectively. Assouline *et al.* (1997) has shown that Oxisols reach equilibrium at these pressures. Each pressure was applied until 90% of the maximum deformation was reached and then the pressure increased to the next level. Having applied all the different pressures, the applied pressure and the dial indicator were removed and the apparatus disassembled. Then, the wet soil samples oven dried to constant weight in 24 hours at 105 - 110°C and these weights (i.e. dry weight of the soil samples plus the corresponding ring) were thus recorded in the data sheet. Measurement and analysis of data were carried out at the laboratories of: Federal University of Lavras, Lavras, MG, Brazil; Department of Agricultural



Plate 3.7: Multi Step Consolidometer

3.4.5 Determination of 90% Maximum Deformation

The 90% of maximum deformation was determined by drawing a straight line through the data points of the initial part of the curve obtained when dual readings were plotted versus square root of the time, until this line intercepts the Y-axis (dual readings). A second straight line was drawn from this intersection with all the abscissas 1.15 times as large as corresponding values on the first line. The intersection of this second line and the laboratory curve is the point corresponding to 90% consolidation (Taylor, 1948; Assouline *et al.*, 1997; Dias Junior and Pierce, 1995).

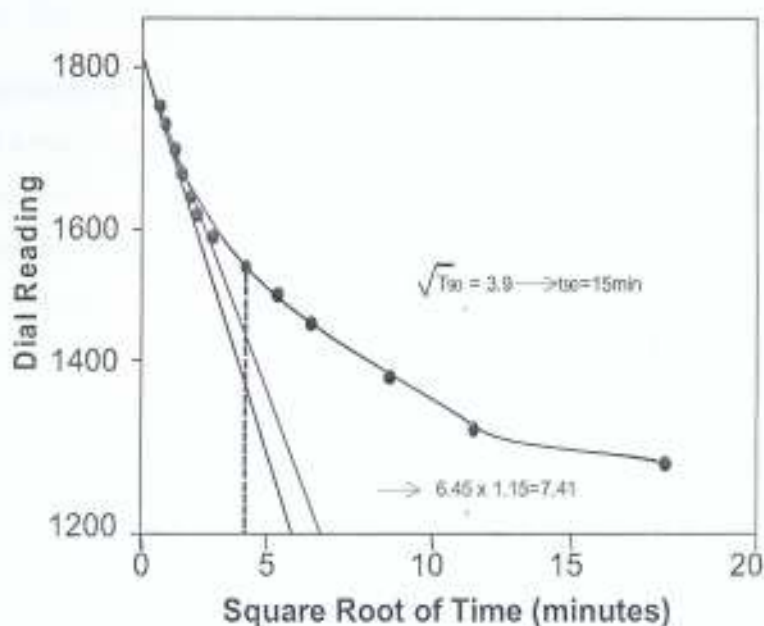


Fig.3.3: Curve of square root of time versus dial reading.

Source: *Dias Junior and Pierce (1995)*.

3.5 Bearing Capacity Model

In obtaining the load bearing capacity model of the soil under study, the stress versus strain data were first used to construct the soil compression curves. From these, the preconsolidation pressures (σ_p) were determined following the procedure of Dias Junior and Pierce (1995).

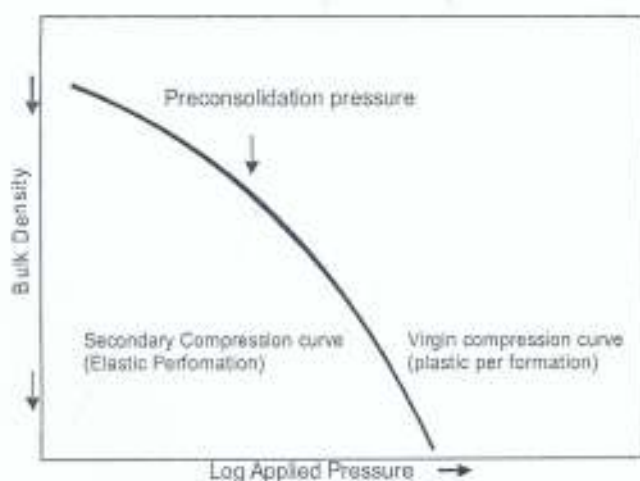


Fig.3.4: Soil Compression Curve

Source: *Dias Jr and Pierce (1995)*.

The preconsolidation pressures values were therefore plotted against its moisture content and a regression line fitted from an exponential function in the form 10^{a+bu} (Dias Jr and Pierce, 1995). The regression line obtained gives the load bearing capacity model of the soil under study and it represents the adjustment of preconsolidation pressures to varying moisture content. The regression analyses were accomplished using the software sigma plot 10.0 (Jandel Scientific). Statistical comparison of the regression lines for the study sites was also carried out.



CHAPTER FOUR

RESULTS AND DISCUSSION



4.1 Physical and Chemical Properties of Soils

The physical attributes of the soil samples from the various sites are presented in Table 4.1. The result of the particle size analysis when plotted on the Soil Textural Triangle showed that the soil in both the A and B horizon of the samples collected at Ire were uniformly Sandy Clay Loam. Similarly, the sample collected at the A-horizon of Oye was Sandy Clay, while the B-horizon sample was Clay. The Ikere sample is also classified as a Clay Soil.

Relatively, sand particles were high in all the sample analysed, while the silt proportion was generally low. This largely account for the high infiltration rate, but low infiltration capacity in soil from the study area. The combination of these factors with the high intensity storm pattern in the study area could account for the dominance of Hortonian overland flow (infiltration excess) in the runoff mechanism (Ajayi *et al.*, 2008).

Table 4.1: Particle size distribution of the soil

Soil Label	Clay (%)	Sand (%)	Silt (%)	Textural Classification	Silt/Clay Ratio
Oye A	35.8	45.3	18.9	Sandy Clay loam	0.53
Oye B	55.0	34.5	10.5	Clay	0.19
Ire A	31.0	55.7	13.3	Sandy Clay loam	0.42
Ire B	27.3	59.3	13.4	Sandy Clay loam	0.49
Ikere	45.1	38.7	16.2	Clay	0.37

The chemical properties of the soil samples presented in Tables 4.2a & b indicate that the samples are acidic. The data also indicate proportion of potassium, phosphorous and calcium in the soil. The chemical constituent of soil has been reported to influence the compression characteristic (Baumgartl and Kock 2004) in Ajayi, 2007.

Another factor that has been observed to influence the compressive behaviour of soil is the organic matter content. It was observed that the effect of the organic material on strength characteristics depends on the concentration of the organic material, the moisture status of the soil sample and the particle size distribution. Organic content in the soil influence soil particle density (Ajayi, 2007). In the entire studied sample, the organic matter contents were low, thus, the effect on the strength attributes will be minimal. In theory, low soil particle densities indicate high organic content. Low organic content in the soil reduces its infiltration capability, resulting in reduced moisture content in the soil.

Table 4.2a: Chemical Properties of the Soil Studied

Soil label	pHw H ₂ O	P	K	Ca ²⁺	Mg ²⁺	Al ³⁺	H+Al	SB	CEC	T
		mg/dm ³								
eA	5.4	0.9	42	1.7	1	0.4	3.6	2.8	3.2	6.4
eB	5.6	0.9	22	2.1	0.7	0.3	2.9	2.9	3.2	5.8
A	6.1	0.6	56	5.3	1.6	0	1.5	7	7	8.5
B	6.2	0.4	69	4.7	2.1	0	1.7	7	7	8.7
re	5.7	0.9	67	3.9	1.1	0	1.7	5.2	5.2	6.9

The samples collected at the A horizon in Oye (Oye A) was observed to have a high concentration of Manganese (Mn) and Iron (Fe), whereas within the soil, minerals such as Calcium (Ca), Magnesium (Mg) and Zinc (Zn) were very low.

Table 4.2b: Chemical Properties of the Soil Studied Continue

V	M	ISNa	OM	P-rem	Zn	Fe	Mn
	%		dag/kg	mg/l		Mg/dm ³	
43.8	12	0.0	1.4	16.9	1.2	90.4	109.1
49.7	9	0.0	0.8	4.1	0.5	76.8	40.2
82.4	0	0.0	0.9	30.3	0.6	73.4	31.3
80.4	0	0.0	0.6	24.3	0.6	99.5	42.6
75.3	0	0.0	1.4	26.8	1.5	98.1	55.4

V= base saturation indices; M=aluminum saturation indices, OM=Organic matter P-rem=remaining phosphorus pHw= pH in water, SB= sum of exchanges bases (Ca²⁺+Mg²⁺+K⁺+ Na⁺); CEC = cation exchange capacity, T = cation exchange capacity at pH of 7.0

The result also showed that Fe was well distributed compared to Mn in all the sites except at Oye A-horizon where Mn exceeded Fe in proportion. Moreover, chemical

properties such as V (base saturation indices), K, Ca^{2+} are highly distributed at both A and B horizons in Ire, and Ikere A-horizon samples while, Al^{3+} was completely absent. Oxides of Ca, Al and Fe act as binding agent in soil when they hydrate and harden. It is therefore expected that their presence and concentration in the samples will influence the binding characteristic of the soil aggregates into larger ones at the appropriate soil moisture level.

4.2 LOAD BEARING CAPACITY MODEL

The representative load bearing capacity curve for the study sites are presented in Figs 4.1a - 4.1e. The models attenuate the influence of soil moisture on the load support capacity of soils. It is clear that in all the studied samples, the load support capacity reduces as the moisture content increases. . It was observed that the strength of the soil samples reduces although not linearly, with increases in the moistures content of the soil. This observation was consistent with results from several studies on the strength of soil samples (Peng *et al.*, 2004; Pereira *et al.*, 2006; Dias Junior *et al.*, 2007; Ajayi, 2007).

The models also showed the dynamism of load support of the different soil horizon. Discrepancies were observed in the behaviour of models constructed with samples collected at different depths of the same site (sample collection pit). The difference was more obvious in the model constructed for samples from Ire A and B horizon. The behaviour however is traceable to the difference in moisture retention capability and physical behaviour of the soil. For example, while the load bearing capacity of the A-horizon stopped at less than 0.25kg/kg moisture content, that of B-horizon exceeded 0.3kg/kg moisture content.

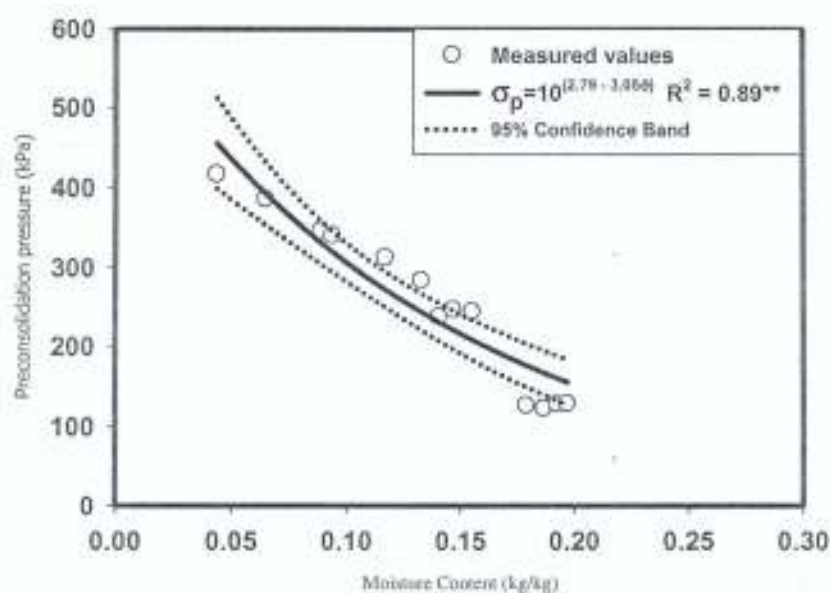


Fig.4.1a: Load Bearing Capacity model for Oye A-horizon

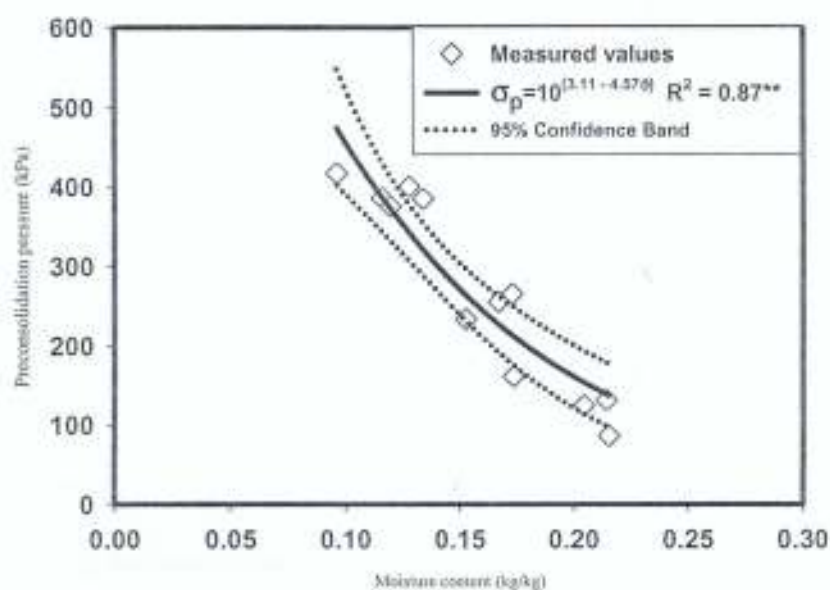


Fig.4.1b: Load Bearing Capacity model for Oye B-horizon

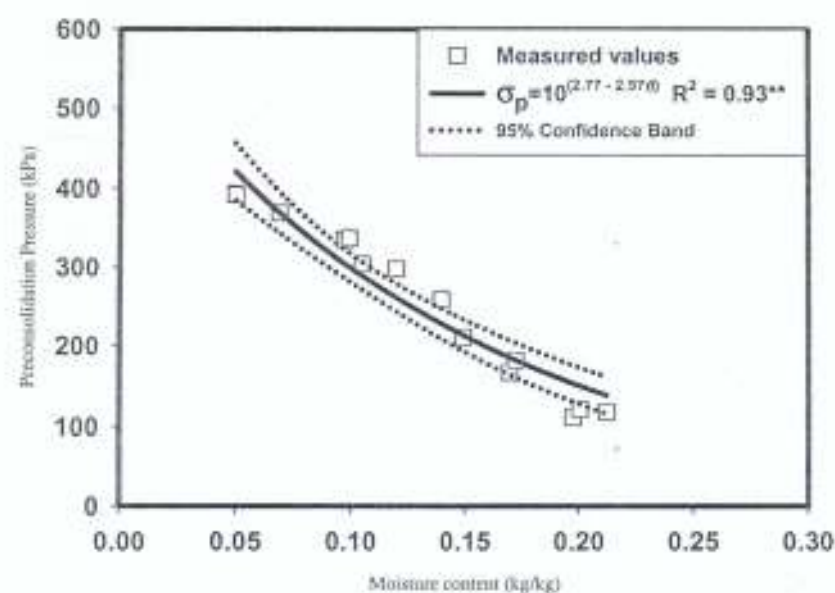


Fig.4.1c: Load Bearing Capacity model for Ire A-horizon

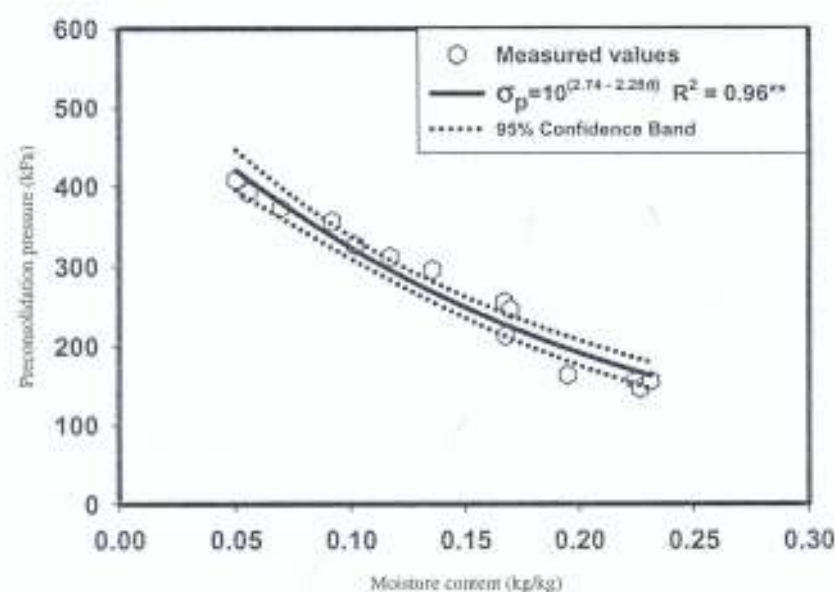


Fig.4.1d: Load Bearing Capacity model for Ire B-horizon

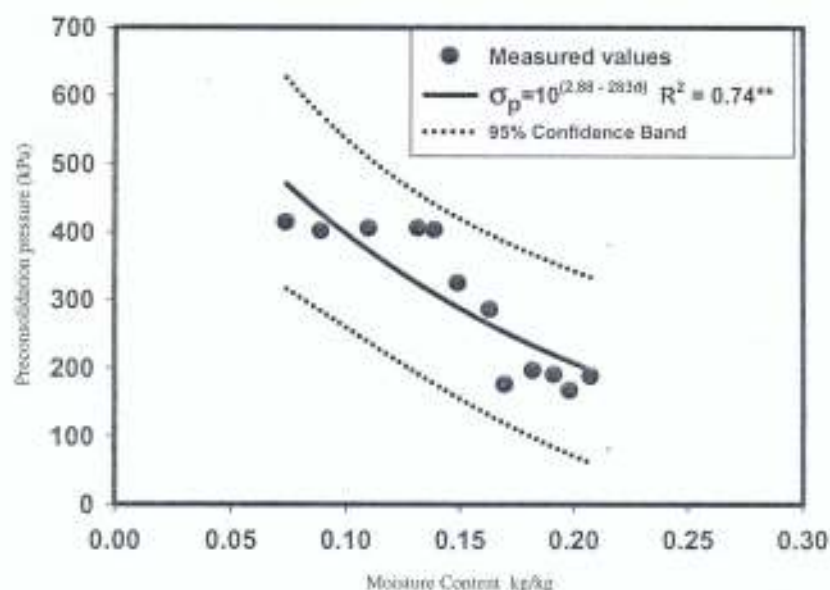


Fig.4.1e: Load Bearing Capacity model for Ikere A-horizon

At low soil moisture content, the load bearing capacity of the soils increased with increasing moisture content. This increase in soil load bearing capacity is as a result of increased cohesion between the soil particles, occasioned by the gradual increase of the moisture content and this possibly justifies why soils with high bulk density and low porosity have higher strength at lower moisture content. Thus, cohesiveness of the soil particle would only continue to a certain moisture level, associated with the structure and clay content of the soil (Reatto *et al.*, 2007). Having exceeded this level, further addition of water would result in decreased strength, thus creating greater pore water pressure when external stresses are applied.

These models also gave hint of the water holding capacity of the different sites samples studied and showed the effect of organic matter on water holding capacity of the soil samples. All the samples have relatively low water holding capacity. The 34% Upper limit of soil moisture that would still support external load record at Ire B-horizon was the highest and this may not be unconnected with hardpan experienced at the horizon.

The lower values of pre-consolidation pressure in the samples collected at Ire site compared to others suggest that the incidence of organic matter (Tables 4.1 & 4.2a-b)

could modify the compression characteristics of soils, thereby shifting the bearing capacity curve, and altering the ability to withstand pressure from external load. Low concentration of organic matter in the samples resulted in significant decrease in the strength at any compaction level. This happens because, with higher organic matter, more moisture would be required to initiate the flow of the soil unlike when the organic matter concentration is low. Also, at optimum moisture content, organic materials acting as binders, improve the infiltration characteristic of the soil thereby, reducing compaction susceptibility. This accounts for better load bearing characteristic noticed in Oye and Ikere samples. Thus, organic matter has significant effect on the bearing capacity of a typical soil sample.

The various particles dominance within the soil structure influences the compaction susceptibility to external stresses. Dominance of clay in samples from Oye B-horizon and Ikere A-horizon improved their load bearing capacity at moderate moisture content. The pre-consolidation pressure of well above 400kPa was recorded for the two horizons at 0.1kg/kg moisture content. According to Ajayi (2007), dominance of clay in a soil could mean low porosity and higher bulk density depending on the clay mineralogy. These two conditions would translate to low storage space for water depending on the soil structure. Hence it could be deduced that effect of organic matter on compression characteristics depend on the concentration of organic material, moisture status of the soil sample and particle size distribution.

4.3 MOISTURE RETENTION

The moisture retention curve of different soils used for this study is presented in Figure 4.2. Highest water retention at all the matric potentials were recorded in the samples collected at Oye while the lowest were from samples collected at Ire. Water retention reduces with increasing matric potential in all the samples.

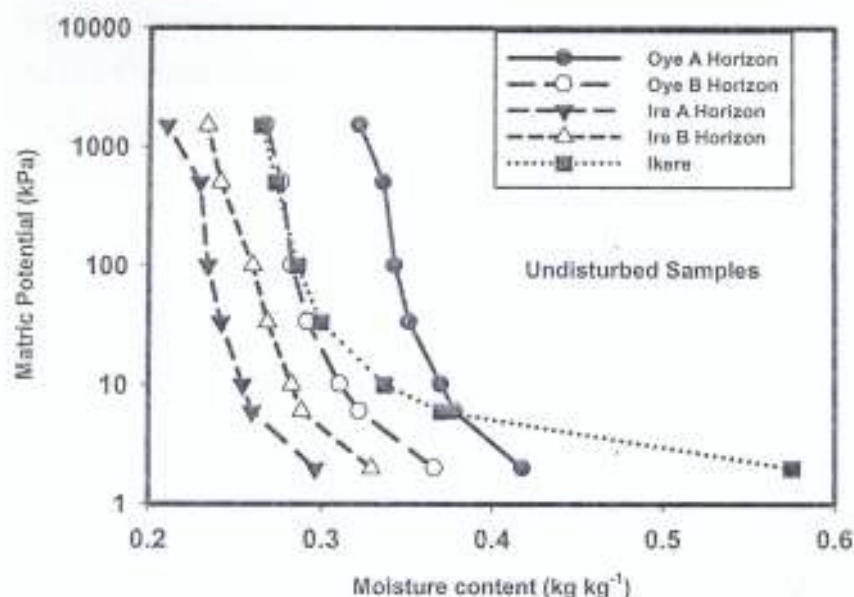


Fig. 4.2: Moisture retention curve for the studied samples

The average values of moisture retained with the soil layers at the different matric potential reduces in the direction of increasing sand content. This was similarly observed by Reatto *et al* (2007). The samples collected from Ikere were observed to specifically retain more water at 3kPa. The observation could be attributed to the clay mineralogy which influences the specific surface area of the soil. Moisture retention in the sample however normalizes at about 8kPa. This observation has direct implication on the strength and trafficability of the soil during the wet seasons. In the days following rainfall event, the water level of the soil will remain very high except there is an adequate drainage provision. The use of heavy equipment that may subject the soil to pressure above the preconsolidation pressure must be completely avoided to forestall a permanent damage to the soil structure. It was evident that the hydraulic stress created during this period would be very high.

4.4 SOIL MINERALOGY AND SOIL STRENGTH

The X-ray diffractograms (XRD) of clay particle fractions of the soil samples describing their respective mineralogical constituents are shown in Figures 4.3a - 4.3e. The Secondary minerals held mostly within the clay fraction were studied in a diffractogram. Quartz was also found as secondary minerals in samples from Oye A

& B horizons, and Ikere A-horizon. The secondary minerals in the samples were aluminosilicate minerals such as kaolinite; $\text{Si}_4\text{Al}_4\text{O}_{10}(\text{OH})_8$, oxides and hydroxide of Al and Fe such as Gibbsite; $\text{Al}(\text{OH})_3$, Goethite; FeOOH . Others included: Mica and VHE. Since these minerals are found mostly within clay particles, they are referred to as clay minerals.

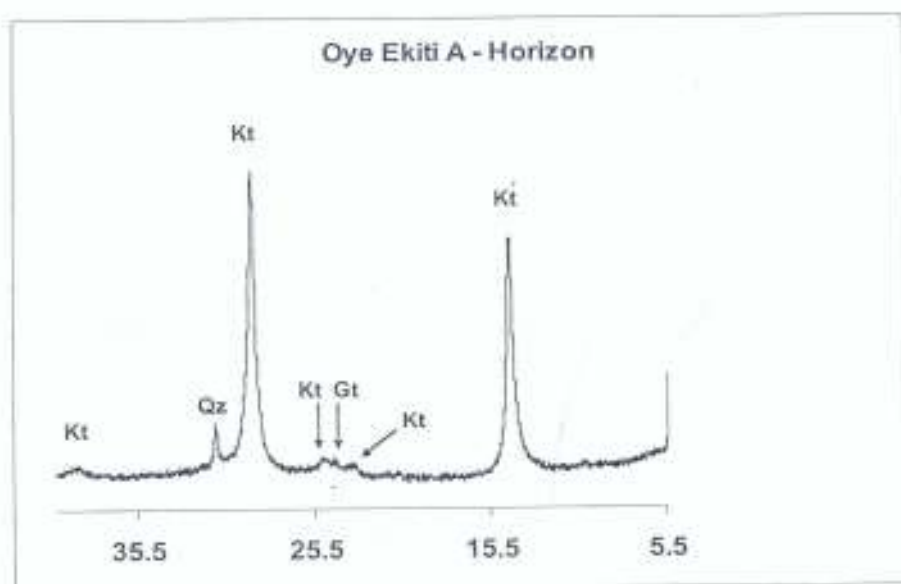


Figure 4.3a: XRD for fine Clay fraction of samples from Oye A Horizon

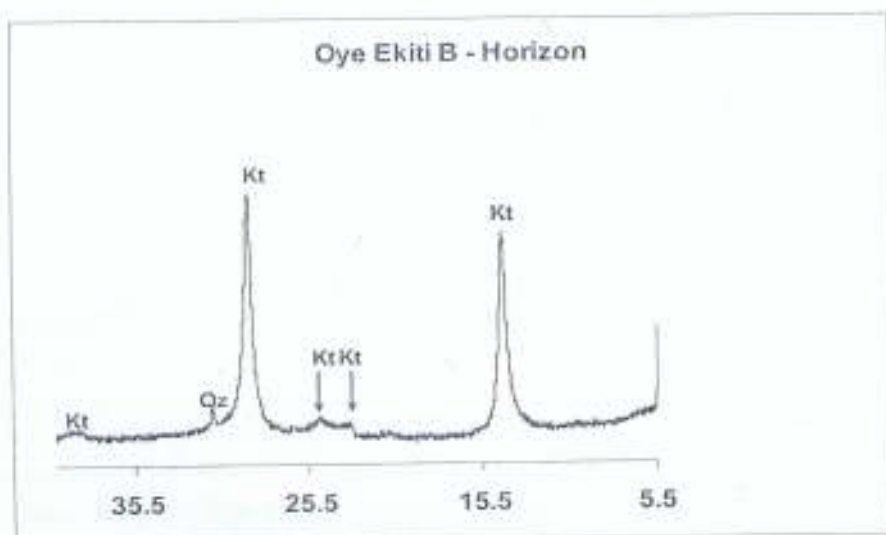


Figure 4.3b: XRD for fine Clay fraction of samples from Oye B Horizon

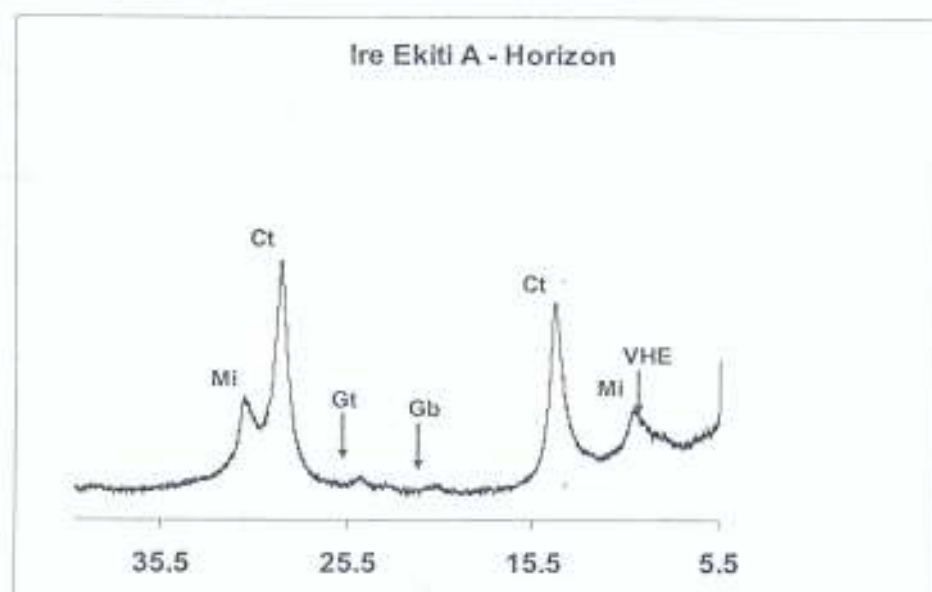


Figure 4.3c: XRD for fine Clay fraction of samples from Ire A Horizon

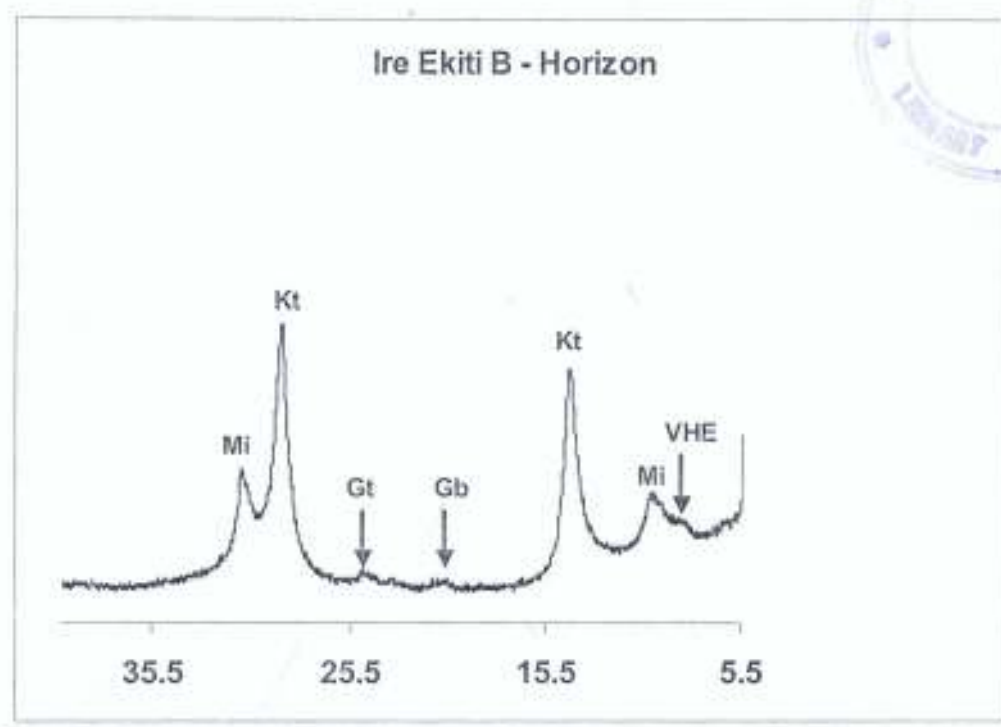


Figure 4.3d: XRD for fine Clay fraction of samples from Ire B Horizon

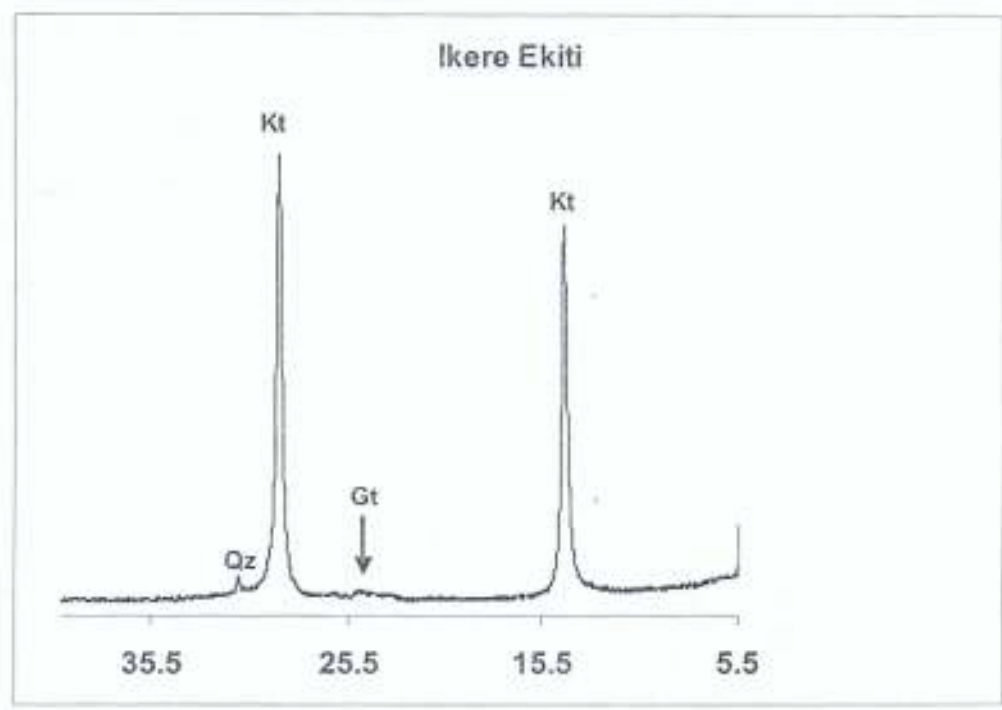


Figure 4.3e: XRD for fine Clay fraction of samples from Ikere A Horizon

KEY: Qz=Quartz, Kt=Kaolinite, Gt=Goethite, Mi=Mica, Gb=Gibbsite

Clay minerals are assemblages of tetrahedral and octahedral sheets arranged in unique format depending among other things on the oxides levels, parent materials and soil age (Spark, 1995). Arrangements of these minerals sheets affect the structure of the soil, and consequently the strength attributes of the soil samples (Jones et al., 2003).

The soil type from mineralogy analysis for Oye Ekiti, Ire Ekiti and Ikere Ekiti could be described as Ultisol, Inceptisol and Oxisol respectively. Predominant soils of the tropics are Oxisols (22.5% of the area in the tropics), Aridisols (18.4%), Alfisols (16.2%), Ultisols (11.2%), Entisols (8.2%), and Inceptisols (8.3%) and others (15.2%) (van Wambeke, 1992).

Ultisol collected at Oye-Ekiti was from a wide range of parent materials. Kaolinite, goethite and a few quartz-interlayered types of clay were common in the fraction, with low base saturation and very low calcium content. Oxisol from Ikere site was dominated by kaolinite with little goethite and quartz. The composition of the clay

fraction suggests that, it is kaolinite- a dioctahedral kaolin. The oxisol sample showed high resistance to compaction but the soil turned slippery at high moisture content. According to Lal (1979) oxisols and ultisols are highly weathered, have low CEC, low plant nutrient reserves, and low plant-available water capacity. Inceptisol collected at Ire-Ekiti also have kaolinite and goethites as part of its constituent added to these are mica and gibbsite. The hardpan noticed at depth 55cm of the inceptisol sample pit depict soil of minimal development with distinctive horizon, which accounts for the clear difference in compression characteristics of its A and B horizons.

Furthermore, kaolinite sheets have a face-to-face arrangement, and are interlocked and stacked by hydrogen bonding, thus, there are no interlayer spaces. This arrangement, results in a platy (prismatic) soil structure with high bulk density and low porosity (Jones et al., 2003; Ajayi *et al.*, 2008). The rich presence of oxide in the clay fraction, facilitate the cementation and that explains the high load support capacity of the sample from Ikere and Oye B-horizon at moderate moisture content.

The presence of gibbsite in the clay minerals of sample from Ire-Ekiti (Inceptisol) hinders the face-to-face arrangement of the kaolinite sheets. The gibbsite and other oxides acted rather as a wedge between the kaolinite sheets, thereby producing a granular and single grained structure respectively in the soil sample. Consequently the soil of Ire-Ekiti have lower load bearing capacity compared to the platy structure from a face-to-face arrangement noticed in Ikere and Oye samples. Another contributory factor to lower load bearing capacity of Ire-Ekiti sample was the prevalence of the sand particle in the soil sample which inhibit the cohesiveness of the kaolinite plates resulting in a weakly developed blocky soil structure which get weaker in strength, as moisture content increases.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSIONS

Undisturbed soil samples were collected at three study sites in Ekiti State. The particle size distribution and chemical properties of the soil samples were determined. Load bearing capacity model constructed from the measurements of the preconsolidation pressure of soil samples at different moisture content were compared. The X-Ray Diffractogram obtained was used to identify the clay particle minerals of each soil sample. The result showed that soil mineralogy influence soil compression characteristics as, it was observed that clay particle mineralogy has significant effect on soil structure and consequently the load bearing capacity of the soil samples.

The soils from the study sites were identified as Ultisol, Inceptisol and Oxisol. The oxisol and ultisol were dominated by kaolinite, which formed a face-to-face arrangement resulting in a platy soil structure with high bulk density, and low porosity that facilitated high compression resistance characteristics. The presence of gibbsite and high proportion of sand particle fraction in the inceptisol reduced its load bearing capacity and water retention ability. Generally, the load bearing capacities of all the samples were relatively low at the moisture level where field agriculture operations take place. Experience from literature suggest that such soil need more preparatory steps, with medium size implement to avoid losing soil layer above the preconsolidation pressure. The result explained how mineralogy of soil influences its compression characteristics, moisture retention and load bearing capacity.

5.2 RECOMMENDATIONS

In order to decide what land use system to recommend for any region it is necessary to consider not only the ecological requirements of the crop to be grown but also the appropriate technologies to be used by farmers. However, the methodology adopted in this study is useful in taking decision on agricultural soils in any region of Nigeria.

Thus the following are recommended:

1. The study should be adopted for other agricultural soils within the region of study for better soil management skill.
2. The study should be carried out in other regions of Nigeria to obtain accurate localized results for excellent agricultural operations and planning.

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