EFFECT OF SIAM WEED (*Chromolaena odorata*, L.M. King & Robison) ON COMPACTION OF DIFFERENT AGRICULTURAL SOILS

BY

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CERTIFICATION

This is to certify that this project work was carried out by Mr. Babalola, Olorunfemi Ade, in the Department of Agricultural Engineering, Federal University of Technology, Akure and that to the best of my knowledge it has not been submitted elsewhere for the award of a degree or diploma.

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DEDICATION

This project work is dedicated to God Almighty, my parents, my wife and loving children. Thanks so much for your concern always.

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O.A. Babalola

ABSTRACT

The effect of incorporation of fresh Siam weed (*Chromolaena odorata,* L.M. King & Robison*)* into six different agricultural soil samples on the magnitude of compaction and penetration resistance was investigated in a laboratory experiment in the Federal University of Technology, Akure. The magnitude of compaction in terms of cone penetration resistance was measured at different levels of addition of fresh Siam weed (thereby varying the organic matter content), number of blows of proctor's hammer and moisture content of the soil.

Siam weed was incorporated into six different soil samples thereby raising their organic matter content to between 1.7 and 14% dry mass basis of the soil. The samples of soil were obtained from Okitipupa, Ode Irele, Ondo, Igbara-Oke, Owo and Oke-agbe, towns noted for tractor tillage operations in Ondo State. The samples were analysed in the laboratory to classify them appropriately using the USDA classification system. For the determination of compaction strength, the fresh *Chromolaena* was incorporated into the soil samples before compacting using 10, 20, 30 and 40 blows of proctor hammer at moisture content levels ranging from1.1 to 21.2% dry basis. The data obtained was analyzed statistically using ANOVA.

Results from the study show that the penetration resistance (an index of compaction) of the six soil samples were influenced significantly by addition of fresh *Chromolaena.* For all the soil types, the compaction strength decreased with increase in fresh Siam weed addition, with the compaction strength increasing to maximum at about 10% dry basis, and subsequently decreasing with further increase in soil moisture content The penetration resistance of the soil decreased with increase in

moisture content levels in all soil types. Furthermore, the addition of fresh Siam weed as organic material during tillage operation is recommended because it will reduce soil compaction. However, heavy tillage machinery should not be used at 10% moisture content and above, as it will cause higher compaction on such soils.

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INTRODUCTION

1.1 Background to the Studies

Technological advancement in soil tillage makes it imperative that more vehicles are used in crops production. In a fully mechanized agricultural system different types of agricultural machinery are used for different operations. These include, soil tillage, fertilizer application, planting, weeding, application of herbicides and ameliorating chemical, moving portable irrigation equipment, harvesting and moving primary processing equipment. The unknown traffic set up by these operations, has been shown to cause soil deterioration, usually known as soil compaction.

In developed countries, this problem is viewed more seriously with a trend towards large and heavier agricultural machinery while in Nigeria and other developing countries, soil compaction problems have just being reported because of an increase in the usage of farm machinery in recent years. Soil compaction studies was therefore started at Nsukka, Nigeria in 1983 by Anazodo and Onwualu (1984). The first part of their study evaluated the effect of repeated passes of different tractors on some soil properties. Soil compaction in the field land reduced by decreasing tractor tyre-soil contact pressure, controlling farm traffic and addition of organic matter to the soil.

During harvesting of any crop, the surface of the soil is compacted by tractors, specialsed machineries, and trailers used to carry off the produce. The situation most at risk are where crops are harvested late in the year when soils are wet and soft, and where large weights of crops has to be lifted and carried off the field. Root crops such as potatoes and Sugar beets (in the temperate regions) as well as yam, cassava, sweet potato and cocoyam which are widely grown in the tropical countries have to be extracted from the soil but they contain a high content of water. However, there is less risk where cereals are harvested, as this is normally done under dry soil conditions and yields rarely exceed 10 t/ha. The effect of surface compaction under wheel track are reduced water infiltration, erosion and reduced penetration of tillage implements. One practical solution is the use of tines, deep enough to go across the main line of tracks (Batey, 1988).

Over-compaction in the sub-soil i.e. below normal depth of ploughing and tillage normally arises from the use of heavy pressure applied in wet and thus, soft conditions and also in areas where multiple passes occur such as on headlands used for turning and near field exits loosening compacted layers below the normal depth of ploughing (sub-soiling) has been known to give beneficial results for a century.

The Nigeria population is increasing at alarming rate, the use of heavy machines and implement is inevitable in order to increase crop production. The need therefore arises to adopt farming practices that will alleviate the problems of soil compaction from agricultural implements. The available information on local organic materials that can be incorporated into agricultural soils before compaction will therefore help in solving compaction problems, not only in Ondo State of Nigeria but also in places where soils of similar texture, are being used for agricultural production. Siam weeds which are found plentifully in Ondo State of Nigeria may have a great effect in alleviating this problems if incorporated into soil.

1.2 Scope of the Project

The study was conducted in Ondo State with particular emphasis on six locations with different soil classifications. The six locations are the places where tillage operations are carried out with tractors in the State. Ondo State is situated approximately between latitude $6^0 45'$N and $7^0 15'$N Longitude $4^0 53'$E and $5^0 10'$E with tropic rainforest belt of Nigeria as shown Fig. 1. It is hoped that the work could be expanded in future to cover larger arrears within the Ondo State ecosystem, and in Nigeria as a whole.

1.3 Objectives of the Project

(a) To determine the compaction strength of samples of selected agricultural soils where tractor based tillage operations are carried out in Ondo State and at various levels of fresh Siam weed addition.

(b) To determine the penetrometer resistance of the selected agricultural soil samples

(c) To evaluate the effect of moisture content on the compaction strength of the agricultural soil samples.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil Compaction

2.1.1 Definition of Soil Compaction

Soil compaction is the compression of soil due to expulsion of air from the voids. According to Godwin (1992), compaction is the increase in dry bulk density resulting from load applied for short period of time by machinery and equipment. This leads to destruction of large pores and orientation of soil particles. Soil compaction can be defined as densification of unsaturated soil due to reduction in air volume without change in mass wetness (Hillel, 1971).

The degree of compaction of a soil is measured in terms of dry density, which is defined as the mass of solids per volume of soil as shown in equation (1) below.

$$Y_d = \frac{Y}{1+W} \qquad (1)$$

Where;

Y_d – dry density, kPa

Y = Bulk density, kg/m^2

W = Water content, %

The dry density of a given soil after compaction depends on the water content and compaction effort. The compaction characteristics of soil can be investigated by means of standard Laboratory test.

2.1.2 Soil Tillage

Before someone can understand compaction we should first look into tillage very carefully. Tillage according to F.A.O (1993), is a generic term and broadly used.

It embraces all operations of seedbed preparation that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth. It includes mechanical methods founded on conventional techniques of ploughing and harrowing, weed control using chemical herbicides and growth regulation. It also involves fallowing with an aggressive cover crop that can be easily controlled for direct seeding through its residue mulch. Odigboh (1991), however defined tillage as the operation of tilling the land, involving the mechanical manipulation of soil for any purpose, especially the of changing the soil conditions for crop production.

In general, tillage has been defined as the mechanical practice of modifying the state of the soil in order to provide condition favourable for plant growth. It involves breaking, stirring, turning of conditioning the soil surface thereby altering the physical condition of the soil to create optimum conductive environment for plant growth (Lal, 1995)

Tillage has been an important aspect of technological development in the evolution of agriculture, in particular food production. According to Kepner *et al.* (1978) the objectives of tillage include, development of desirable soil structure for a seedbed or root bed, management of plant residues, incorporation and mixing of fertilizer and other soil amendments or pesticides into the soil, control of weeds and removal of unwanted crops, increased infiltration rate, erosion control, establishment of a specific surface configurations for planting, irrigation drainage and harvesting and compaction reduction.

Development of desirable soil surface for seed bed or root bed is usually done to allow rapid infiltration and good retention of water, provision of adequate air capacity and exchange within the soil and minimizing resistance to root penetration. The type of seedbed required is dependent on the types of crop and method of establishment. During tillage operation, the soil is exposed to the atmosphere and hence to the changes of temperature and humidity brought about by wind, sun, rain e.t.c, therefore further aeration and tillage production is achieved. Tillage operation promotes effective management of plant residues, incorporation and mixing of fertilizer and other soil amendments or pesticides into soil. Thorough mixing of trash is desirable for good tillage and decomposition. Primary cultivation is an appropriate point in crop cycle to start on the process of weed control, with effective weed control at this stage it will reduce the requirement for subsequent weed measure. In dry land farming system where catchments of seasonal rains is important "Opening up" the soil prior to the rains is sometimes done with the objective of increasing the infiltration rate. This can be done in the dry conditions before rain, or at the end of the growing season when reasonable moisture is still left soil to make operation easier and less power requirement.

A certain amount of land forming is associated with cultivation, because land forming is done in-between or in association with cultivation operations (Carruthers, 1992). Such operation include ridging, and seedbed making.

2.1.3 Tillage Techniques and Systems

For the transformation of the soil from its initial state into that required, it may be necessary to perform one or combination of the following basic cultivation operations;

(a) Form or destroy soil aggregates

(b) Alter the clod size distribution

(c) Rearrange the soil particles and aggregates by loosening, compacting, pudding, inverting, mixing.

(d) Transform the soil surface by either smoothing moving of forming.

Tillage is usually classified into Primary and Secondary, although there is no clear-cut between the two (Kepner *et al.*, 1987). Primary tillage operations constitute the initial major soil-working operation. Its major objectives are to reduce soil strength, cover plant materials and rearrange aggregates. It results in the inverting, lifting, pulverizing and inverting of the soil with relatively deep penetrating tools, leaving a rough surface texture. Secondary Tillage operation usually follows primary tilalge opertion, it is usually designed to create refined soil condition before seeding.

It results in the pulverization, leveling and making firm the soil in order to prepare a good seedbed or root bed and to control weeds, mix and chop trash and conserve moisture. Other tillage operations exists which are normally required after secondary tillage to create the best surface configuration or till for the crop to be planted are ridging, channeling e.t.c.

Tillage systems generally include the following conventional tillage operations: minimum tillage, stubble tillage, listing, deep tillage, zero tillage and strip tillage.

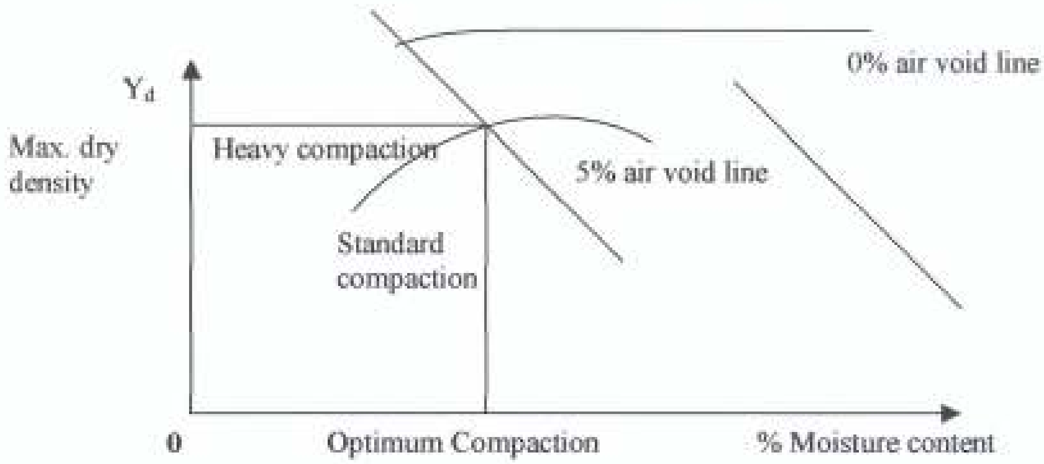


Figure 2.: Graph to show curves of dry density and moisture content of both standard and heavy compactions.

2.1.4 Factors Influencing Soil Compaction

Proctor in the Sixteen Century identified four variables influencing soil compaction namely, Dry unit weight (*Y_d*), water content (*W*), compactive effort energy and soil type. The effect of increasing the compactive effort can be investigated using the results of modified and standard of proctor test. With increasing compactive efforts, the maximum dry density increase and the optimum moisture content decreases as in Figure 2. If the maximum density is plotted versus the log of the compactive effort (Figure 2) the increase in maximum dry density with compactive effort is less pronounced from well-graded coarse-grained soil than fine grained soil. It should be noted however, that if water content is appreciably above, proctor would no longer assist in obtaining a significantly higher density.

The trend of water-dry density relationship for practically all type of soils is similar at low water contents, the particles develop large and large films around them.

A thick water film around the particle tends to lubricate them and make movement easier. The particle comes closer together on application of pressure. The dry weight thus increase in water content till it reaches a stage where water start occupying the space that could have been occupied by soil grains. Thus, the water at the stage hinders the closer packing of grains and reduces dry unit weight (Manfred, 1990).

The effect of increasing the compactive effort varies with type of soil. For coarse-grained soil the result of standard modifies compaction shows that it is less compacted than fine-grained soil because of large voids between its grains. Fine-grained soil is more compacted because of tiny voids between the particles (Manfred, 1990).

2.1.5 Field Compaction

Soil compaction is desirable in civil engineering contracts or works where soil is used as construction materials. Compaction of soil is carried out to improve the soil properties and technique specified by the engineer.

The most common examples are sub-base of a road where the compaction may be in situ or an embankment where soil is brought frequently from a cutting being constructed elsewhere. Back full below ground construction is another example where soil may have to be compacted. Compaction is carried out by rolling or tramping, which causes compression of the soil by expelling air from voids.

The soil compaction is undesirable in agricultural production because it alters the soil structure and reduces the water transmission of soil (Warkentin, 1971). These changes result in reduction in the germination of crops, retarded root development and reduce crop yield for many soil types and condition (Soane *et al.*, 1982; Frost, 1988).

Compaction of agricultural field result mainly from, cultivation or soil tillage, farm traffic, Animal (Livestock husbandry) rainfall and human being.

Farm traffic causes more compaction than others. Under natural conditions in certain soil type, hard pans or compact horizons are recognized in soil profile. These hard layers of soil may be genetically induced or developed due to improper tillage practice.

In recent years, the increase in mechanization and the use of heavy machines and implements have created a serious problem of artificial soil compaction. The compact soil layers are at the bottom of the zone of ploughing is termed the plough sole. Since all agricultural implements may create some kind of sole under favourable soil conditions, these have been named on the implement used i.e the plough soil, sub-soiler sole, due harrow sole e.t.c

The last one is caused by the tractor tyres and vehicular traffic. The farm traffic effect on compaction of agricultural field has been well studied (Dawkins, 1983; Ohu, 1985, Frost, 1988). Soil compaction in the field can be reduced by decreasing tractor tyre-soil contract pressure (Read, 1983) and controlling farm traffic (Ohu, 1985).

The long-term effect of mouldboard and Chisel ploughing, ridging and reduced-till planting tillage treatment on soil properties are fully understood in conventional tillage system involving the mould board plough, occurrence of plough soles have been recognized for decades and soil water problems in such instance may be resolved by sub-soiling (Martin, 1976).

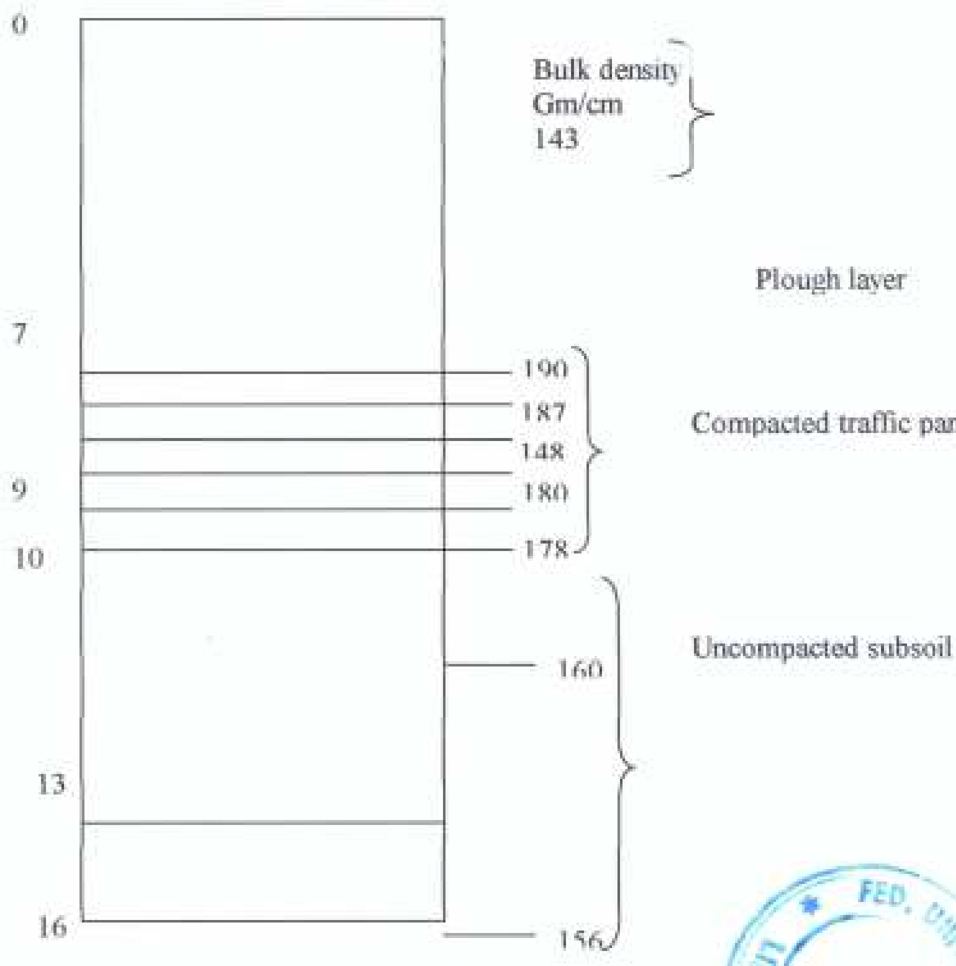
Increased worldwide demand for food and fuel will necessitate a change in tillage and increased residue cover. This practice is not unique to the Midwestern region of the United States. Reduced tillage systems were introduced in Europe in the late 1960s and yield problem occur due to the formation of compacted layer in the soil where these systems were practiced (Spoor, 1982).

Much of the equipment used in no-till seeding in United Kingdom is large and heavy, so that the soil may be penetrated in dry autumn months. According to Spoor (1982), evidence suggest that the uses of heavy equipment on soil where there is little or no soil loosening may be detrimental to soil structure and the effects of compaction are long lasting.

Over a long period, tillage operations have detrimental effects on surface soil granules. In the first place, by mixing and stirring the soil, tillage generally hasten the oxidation of organic matter from soils. Secondly tillage operations especially those involving heavy equipment, tend to break down the stable soil aggregates. Compaction occurs from repeated running over field with heavy farm machines. An indication of the effect of such traffic upon bulk density is given in figure 3 below. This explains the increased interest in techniques of drastically reducing tillage operation where possible.

2.2 Physical Properties of Soil

Various physical forces interact in the development of soils. The resulting effect renders characteristic properties to soils, which can be described, in physical terms. Examples of such properties are texture and structure. According to Biswas and Mukherjee (1987), two very important physical properties of the soil are soil texture and soil structure. These properties have a considerable impact on anchorage, root penetration, drainage, aeration, movement and retention of moisture, availability of plant nutrients and chemical and biological characteristics of soil. These properties also determine the relative ease with which an agricultural implement moves in different soil as well as its compacting effect.



Figures 3: Effect of tillage on bulk density

(*Source: Brady, 1990*)

2.2.1 Soil Texture

Soil texture refers to the relative proportion of particles of various sizes in a given soil mass. Soil texture cannot be altered because it is a basic property of the soil.

The three broad and fundamental groups of soil textural class are sand, silt and clays. These soil fractions contribute to the consistence and strength of the soil and their packing determines bulk density.

Many of the important soil properties are related to texture. Texture affects water retention and release characteristics of soils, its nutrient supply to plant (Biswas and Mukherjee, 1987) and the workability of soils (Baver, 1972). In an experiment to describe water retention by soils, Biswas and Mukherjee (1987) showed that at the same suction, water is higher in clay, lower in loam soil and lowest in sandy soil. For this reason, even for a small amount of rainfall, water is available to the plants on coarse textured soils but this may not be so in fine textured soil. Hence, at the same moisture content, water is more available to plants in coarse textured soils than in the fined textured soil. Also, water infiltration is move in coause-textured soil as compared with fine textured soil, hence plants, which require fine good drainage, will thrive well in a coarse rather than in fine the soils positive impact on fine textured soil. Tillage has little impact on coarse textured soil but it has a profound positive impact on fine textured soils (Donahue and Miller, 1992).

2.2.2 Soil Structure

Soil structure has to do with the physical condition of a soil material as expressed by the size, shape and arrangement of soil particles and associated voids. It includes both the primary particles, which form compound (Secondary) particles and the secondary particles themselves (Dexter, 1976). Soil structure modifies the influence of texture with regard to moisture an air relationship, ability of plant nutrients, action of microorganism and root growth (Foth, 1984). According to

Bradfield and Jameson (1951), soil conditions and characteristics such as water movement, heat transfer, aeration, bulk density and porosity are influenced by structure. In valuation of soil structure, the agriculturists interest is associated with tilth, (Baver, 1972). The important physical changes imposed by the farmer in ploughing, cultivating, draining, liming and manuring his land are structural his land are structural rather than textural soil structure has a direct bearing on case of cultivation the necessary implements, the applied methods and production casts. A good and efficient soil tillage tries to create strong and stable aggregates resist the impact of rain drop, improves the infiltration and water holding capacity, thus improving soil structure.

Soil structure influences plant growth rather indirectly (Biswas and Mukherjee, 1987). This is so because formation of structural clods leads to formation of an array of pores of various shapes and sizes. These pores are the controlling factors governing water, air and temperature in soil, which in turn govern plant growth, one of the best examples of the effect of soil structure on plant growth is the emergence of seedlings on seedbed, (Biswas and Mukherjee, 1987). Successful seed germination depends upon careful preparation of the seedbed. The soil on the seedbed should have a crumb structure so that the beds are soft and porous and roots of the seedling can penetrate easily. For seedbed, it is accepted that an aggregate size range of 1 to 5mm is required (Russel, 1973). In general it is a fact that the better the soil structure, the higher is the yield, other factors of crop production being optimum.

The moisture content of the soil affects the magnitude of power required to operate the mixture. It affects a number of soil characteristics such as cohesion, adhesion, deformation and other soil strength properties (Godwin, 1984). The most convenient way of considering the effect of soil moisture is not in terms of soil moisture content but in terms of the soil consistency states. Soil could be in cemented (hard) friable plastic or liquid state.

Soil compaction also has a great influence on soil productivity and implement performance. According to Anazodo *et al.* (1987), soil compaction increases the bulk density of the soil and soil resistance, which also increase the draught and energy requirement for soil bread up. The amount of compaction varies with soil moisture content, soil type and the size and type of external loading. Increase in soil compaction changes the permeability of the soil, loss in porosity and may inhibit root penetration (Ohu and Folorunso, 1989). Soil compaction also reduces penetration by tillage implements, reduce the area covered/unit time and leads to increase in energy and power requirements.

2.3 Soil Density

The physical properties of a soil are determined by the composition and stability of the soil separates and peds, their volume and weight. Their relationship with soil organic matter is of particular significance in agriculture and engineering. For instance fine textural soils have more weight per volume than coarse textured ones. The addition of organic matter to either of the textural classes will reduce their densities but increase porosity. The density of a soil can be expressed either as particle density or as bulk density.

2.3.1 Particle Density (P_d)

It is described as mass of soil per unit volume of the soil i.e the mass of soil solid per unit volume of the soil. And it is expressed in g/cm^3.

$$P_d = \frac{\text{Wt. of Soil Solid}}{\text{Vol. of Soil}} \quad \text{g/cm}^3 \qquad (2)$$

For many mineral soils, the particle density is usually given in average of 2.6 g/cm^3 but can range from 2.6.89 g/cm^3 to 2.89 g/cm^3 (Ghidyal *et al.*, 1987). The variation can be due to organic matter or mineralogical content of the soil. Accurate determination of particle density is made with the use a specific gravity bottle called pycnometer. Particle density is not affected by fineness and arrangement of solid particles. Its value decreases with increasing amount of organic matter because the latter weighs less than the mineral solids.

2.3.2 Bulk Density (Y)

Bulk density is the weight of oven dry soil to the volume of the soil. Mathematically it can be expressed as.

$$Y = \frac{\text{Wt of oven dry soil}}{\text{Vol. of the soil sample}} \quad \text{g/ cm}^3 \qquad (3)$$

When bulk density of soil is being considered it should be taken into account that the density of the soil material themselves and their structure play a vital role.

Therefore a loose porous soil has a smaller bulk density that a compacted soil even though the density of individual particles in the two soils may be the same.

The bulk density of a soil is smaller than its particle density. The mean value for sand is 1.7 g/cm^3 and that for peat is 0.5 g/cm^3 (Ghilday *et al.*, 1987).

Bulk density is altered by soil management and cropping practices. Dry density is the ratio of bulk density to a whole number plus moisture content in decimal (1 + M.C).

$$\gamma_d = \frac{Y}{1 + M.C} \qquad (4).$$

2.3.3 Hydraulic Conductivity

Hydraulic conductivity measures the ability of the soil to conduct water. Therefore, the hydraulic conductivity depends on both the nature of the soil and the fluid properties. The soil characteristics, which affect the hydraulic conductivity, are related to pore geometry i.e the total porosity, the pore size distribution and tortuosity of soil pores. Therefore, soils containing straight and uniform popes channels of large diameter, will have a higher conductivity than those containing non-uniform pores of smaller sizes, for a soil column of length *L*, containing capillaries of length *Le*, the tortuosity can be defined as;

$$T = L_e/L \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where

T = tortuosity,

L = actual path length (cm),

L_e = length of soil column (cm).

Tortuosity can be evaluated from the measurement of the electrical resistivity while the heavy clays, which have finer pores, will have hydraulic conductivity lower than coarse textured soil because of the dray exerted by the wall of channel on the viscous fluid. The liquid is closer to the walls of soil particle in fine pored soils than macro pored soil.

Hydraulic conductivity is also affected by air bubbles, which may block the pore passages. When the soil is allowed to saturate with water it is possible to replace all the air by water and some of the air is trapped in the pores. This trapping of air bubbles obstructs the flow of water, since the capacity of water to dissolve air depending upon the temperature changes.

Table 1: Solubilty of gases in water

Tempertature, °C	Solubilty of gases		
	N	O_2	CO_2
0	0.0294	0.0694	3.346
20	0.0190	0.0434	1.688
50	0.0122	0.0266	0.781
90	0.0038	0.0079	0.062

Source: 0' Neal (1952)

2.4 Soil Consistency

Consistency is the resistance of the soil to deformation or rupture and is determined by the cohesive and adhesive properties of the entire soil mass. Whereas, structure deals with shape, size and distinction of natural soil aggregates, consistency deals with strength and nature of force between particles. Consistency of the soil is important for tillage and traffic consideration.

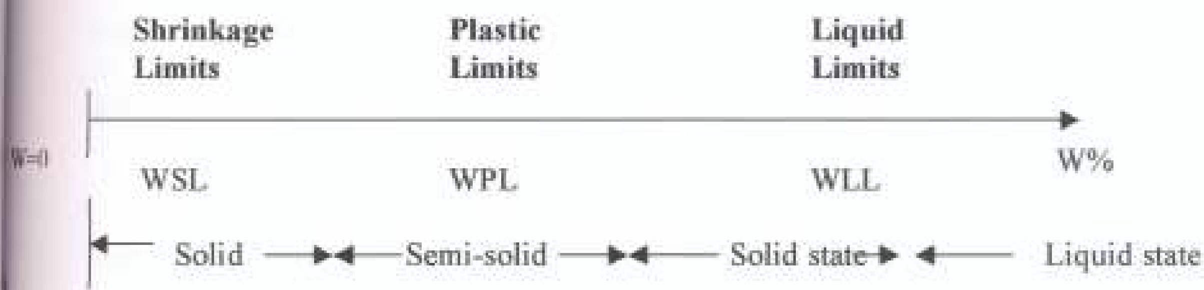
2.4.1 Consistency Limit

As moisture is removed from a fine-grained soil, it passes through a series of states namely; liquid, plastic, semi-solid and solid. The moisture content of soil at points where it passes from one stage to the next is known as consistency limit. These limits are defined as;

(a) ***Liquid Limit (LL):*** The minimum moisture content at which the soil will flow under it own weight

(b) ***Plastic Limit (PL):*** The minimum moisture content at which the soil can be rolled into a thread 3mm diameter without breaking up.

(c) ***Shrinkage Limit (SL):*** The maximum moisture content at which further loss of moisture does not cause a decrease in volume of soil.



Where: WSL = Moisture content Shrinkage limits
WPL = Moisture content plastic limits
WLL = Moisture content liquid limits

Figure 4: Consistency limit of soil. (*Source: Smith, 1978*).

2.5 Organic Matter

Soil organic matter may be defined as any living or dead plant and animal materials in the soil. Organic matter is often confused with humus. Humus is substance left after soil organisms have modified organic materials to rather stable group to decay product.

2.5.1 Sources of Soil Organic Matter

The original source of the soil organic matter is plant tissue. Under natural conditions, the tops and roots of trees, shrubs, grasses and other native plants annually supply large quantities of organic residue.

Animals usually are considered as secondary source of organic matter. As they attack the original plant tissues, they contribute waste products and leave their own bodies as their life cycles are consummated. Certain forms of animal life, especially the earthworms, termites and ants also play important role in the translocation of soil and plant residues.

2.5.2 Composition of Plant Residues

The moisture content of plant residues is high, varying from 60 to 90% (Nyle, 1984). On weight basis, the dry matter is mostly carbon and oxygen with less than 10% hydrogen and inorganic elements. However, on an elemental basis, hydrogen predominates. In representative plant residues, there are 8 hydrogen atoms fro every 3.7 carbon atoms and 2.5 oxygen. These 3 elements dominate the bulk of organic tissues in the soil (Nyle, 1984).

Other elements such as sulfur, phosphorus potassium, calcium and magnesium are particular significant.

2.5.3 Types of Organic Materials

There are many type of organic materials that can be added onto soil such as farm yard manure, peat nut, green manure, compost and straws. The straws are of many origins such as maize chaff, groundnut haulm, millet straw, and Guinea Corn straw e.t.c. Fresh leaves and shrubs such as Siam weed are important sources of organic matter in the soil and they are therefore referred to as organic materials.

2.5.4 Relationship between Organic Matter and Soil Compaction

The incorporation of organic materials into soils help to improve the physical and hydraulic conductivity properties of soil (Hafez, 1974; Ohu, 1985; Ekwue 1990).

Many researchers noted that the incorporation of organic materials to soil before compaction help to alleviate the problem of compaction in agricultural soils (Greenland, 1977; Im, 1978; Ekwue, 1990; Ohu; 1991; Babalola, 1999). Research into the mechanism, control and management of soil compaction has been extensive (Cruse and Gupta, 1991; Raper, 1994; Soane *et al.*, 1981).

Surface residues have been shown to reduce machine-induced soil compaction in forest soil. Bulk density differences caused by logging traffic on skid trails projected by decaying vegetative matter were shown to be less than half those observed on major trails that had been stripped of organic cover (Miles, 1978).

Although detached crop residues on the surface of, or incorporated into the soil after little resistance to machine induced compaction, living and to lesser extent, dead roots have a marked effect on soil strength characteristics. Apart from acting as a physical network, roots are active sources of organic exudates, which are likely to be effective agents in stabilizing aggregates (Soane, 1990). Waldron (1977) demonstrated the effectiveness of alfalfa, barley and yellow pine roots in increasing soil shear strength. The roots of rice plants have also been shown to produce significant increases in soil shear strength (Hunter, 1991). Increased soil shear resistance due to nest reinforcement results from the trenching, slipping breaking of roots of various sizes (Waldrn and Dakessian, 1981). The strength of soil increases proportionally to the concentration, or cross sectional area of root fiber in the soil (Wasterlund, 1989).

However, by far the most common cause of soil compaction in modern agriculture is the effect of machinery imposed on the soil by wheels, tracks and soil engaging tools. These effects can be reduced by the incorporation of organic matter such as farm yard manure, green manure, compost, roots, straws and surface residues.

2.5.5 Siam Weed (Chromolaena odorata L.M. **King & Robinson***)*

Chromolaena is a prominent weed in West Africa and especially its distribution which is considered to be troublesome to farmers. Many names were given to *Chromolaena* in West Africa because of its importance, distribution and the forceful way it established such as 'Sekou Toure Ma' in Benin Republic, 'Archeapong' in Togo, 'Rawlins' in Ghana, 'Bokasa' in Central Africa Republic, 'Lantanna Di Ngoubabi' in Congo and 'Independence Plant' in Cote D'Ivoire. In South West Nigeria, it is nicknamed 'Akintola' after the Premier of defunct Western Region of Nigeria who forcefully regained his seat.

Chromolaena helps in controlling spear grass as well as improving the fertility of the soil and reducing the fallow period of land (Ojeniyi, 1995). As fallow specie, *Chromolaena* provides large large quantities of of nutrient rich humus which improves the structure and nutrient content of the soil. A four-year fallow of *Chromolaena* is judged adequate by farmers to return the fertility of arable soil in South Western Nigeria. All farmers recognize the weed as very effective in restoring soil fertility. In Cote, D'Ivoire farmers hesitate to eliminate *Chromolaena* totally from their fields because their crops yields seems to be higher when it is present. They recognized that *Chromolaena* protects soil from erosion and control nematode infestation. The top growth of *Chromolaena* fallow vegetation contributes 22 to 67 kg N/ha whereas *Impereta cylindrica* is poor in terms of Nitrogen contribution.

The N, P and K contents of *Chromolaena* were 2.5, 0.7 and 2.5% and the equivalent values of Pennisetum were 2.0, 0.7 and 1.8%. Ojeniyi (188) applied cow dung, cowpea top, *Chromolaena* and *Pennisetum* at 20 t/ha to coffee seedlings and their residual effect on maize was determined. The highest dry matter yield was produced in soils treated with *Chromolaena. Pennisetum* showed the highest P and K residuals. Maize grown with *Chromolaena* residue had the highest leaf N content. Ojeniyi and Adetoro (1993) studied the effect of *Chromolaelna* mulch on soil physical conditions and performance of three crops of okra. The mulch significantly increased the soil moisture content, root length, crop growth and pod yield of okra. It was implied that farmer could improve yield of okra significantly through the use of *Chromolaena* mulch. Falade and Ojeniyi (1997) and Awodun and Ojeniyi (1998) in their field studies conducted at Akure South West Nigeria found that *Chromolaena* mulch was highly effective in improving nutrient contents, maize root growth and yield.

2.6 Cone Index

Cone index is the measure of penetration resistance of soil. The penetrometer is a common instrument for assessing compaction, mechanical or soil strength (Soane *et al.*, 1981). The interactions among soil compaction, strength, moisture are retention, aeration and root growth have been studied by among others, including Klute *et al.* (1969) and Keys (1974). In many of the studies of root penetration in compact media, soil resistance has been characterized by means of penetrometers of various types. Soil penetrometer resistance readings can give an indication of compacted layers and relative resistance to root penetration (Voorhees *et al.*, 1975). Soil penetrometer resistance values between 2.1 and 2.8 MPa_{s} impedes cotton (*Grossypium hursatun*, L) root growth (Tollner and Simonton, 1989). According to Babalola (1991) penetration resistance of agricultural soils decreases linearly with increasing moisture content. Major factors affecting the penetration resistance are manure content, soil density, soil type, soil strength, base diameter and apex angle and surface roughness of the cone (Gill, 1968).

2.7 Soil Classification

Before someone can classify soil properly, a perimeter survey should be undertaken which enable us to select a base line. These are the operation guidelines set to classify soil;

(a). The traverse should be cut along the topography or along the slope and perpendicular to baseline at predetermined distance depending on the type of survey to be carried out whether it is reconnaissance survey, semi-detailed and detailed survey.

(b). The sampling points are located along the traverses and these sampling points will be at predetermined distances e.g. (2 chain apart). Dig chisel holes on the sampling points bringing out the soil layer by layer until colour changes or mass of stone content are noticed until 76 cm depth hole arm is reached.

©. Bring out soil from different layers, a break in layer is determined by massiveness of the root, stoniness. Inspect 5the soil and classify to give the

Series/Association name following the criteria earlier indicated such as vegetation, colour, feeling, parent rock, laboratory tests etc.

(d). The early soil surveyors gave the name of the towns or locations where the different soils were first encountered and described them such as Iwo, Egbeda, Ondo and Benin associations. These names can be allotted to a soil someone has just described, depending on whether the characteristics tally. Therefore, the name of soil associations is not location specific.

2.7.1 Soil Classification of Ondo State

Soils in Ondo state can be classified using USDA textural classification system into the following:

(a). Okitipupa Area: It belongs to the order of ULTISOL. Texture is Sandy loam with composition as sand 74.8%, Silt 8.7%, Clay 16.5% and Organic matter 2.9%. Okitipupa soils are derived from coast plain sand overlying consolidated brown sandstone. It is acidic in Nature. The area is classified into Benin association.

(b). Akure/Owo Area: This soils in this area belongs to the order of ALFISOL. Texture ranges from gravelly or sandy at the upper surface and subsoil layers varies from sand loam to sandy clay or clay. It consist of sand 65.0%, Silt 16.0%, Clay 19.0 and Organic matter 1.2%. The area is classified as Egbeda association.

©. Ondo Area: It belongs to the order of ALFISOL. The texture ranges from loose clayey sand for top soil to sandy clayey or very clayey sand in the subsoil. It consist Sand 62.5 %, Silt 20.0%, Clay 17.3% and Organic matter 3.5%. Ondo soils are classified into Ondo association.

(d). Akoko Area It belongs to the order of ALFISOL. The texture is Sandy loam humic very clayey sand at the surface merging into sandy clay subsoil.It consist of sand 68.4%, Silt 20.5%, Clay 10.1% and Organic matter The area is classified into Iwo association.

The soil classification of Ondo state is presented in Figure1b.

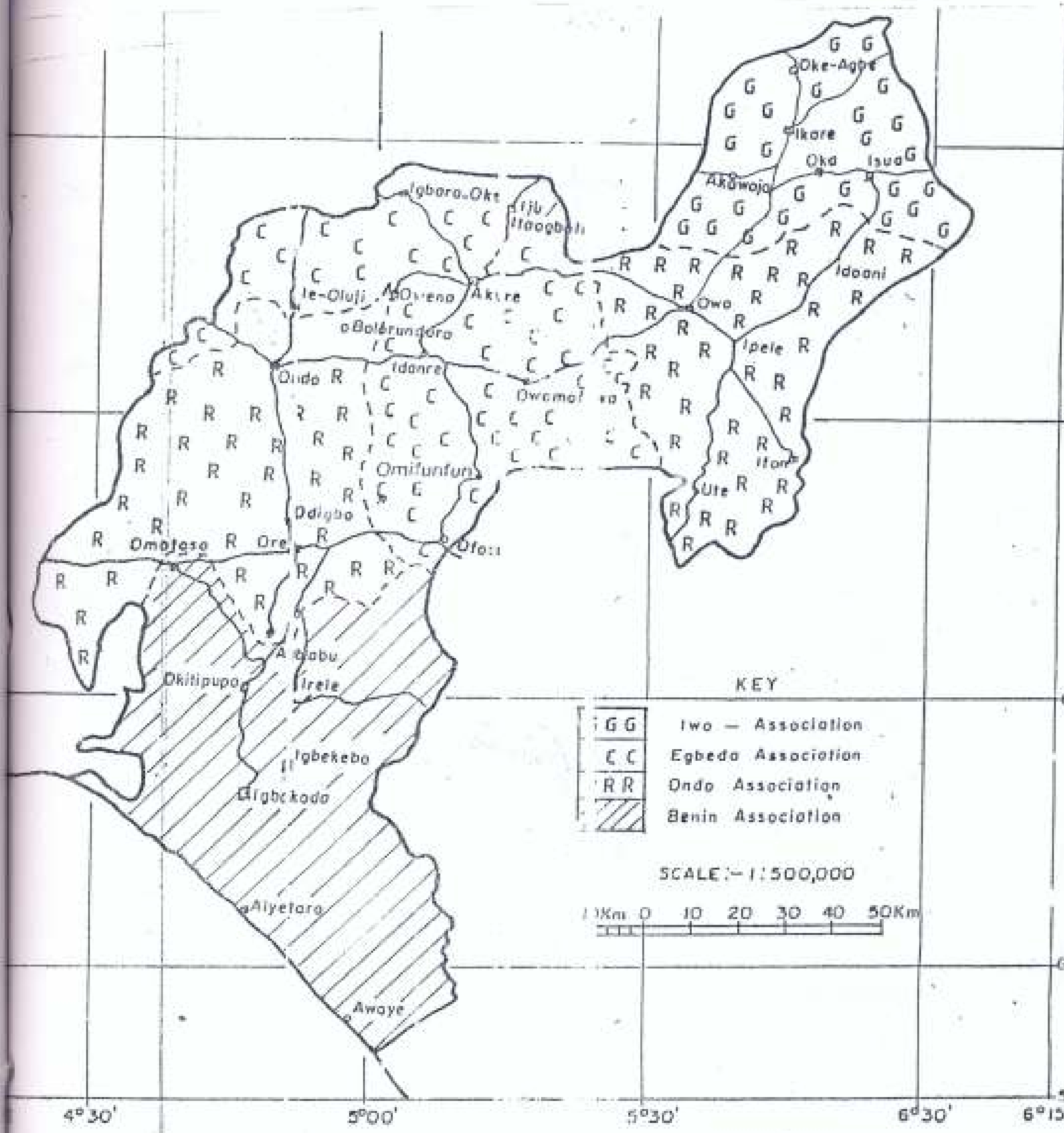


Fig. 1b: Soil Map of Ondo State.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

Soil samples were taken from six locations is Ondo state namely Okitipupa, Ode Irele, Owo, Ondo, Igbara-Oke and Okeagbe (Figure 1b). In these locations tractor based tillage operations are carried out by farmers, especially in the farms owned by the State Ministry of Agriculture, Local Government Councils and Private individuals under the Government supported Agricultural Development programme.

3.2 Sampling and Sample Collection

Samples of soil were taken with cutlass and trowel at a depth of 45 cm using systematic sampling method at 10 m apart for sampling points Each location was replicated 4 times. Soil tests were conducted in the laboratory of the Department of Applied Geology, School of Mines and Earth Sciences, Federal University of Technology, Akure.

3,3 Materials and Equipment:

The materials used for the tests include

1. Shear vane tester: it was used to measure soil compaction in cohesion (kPa). It is made of two parts;

   (a) Long cylindrical steel part which can be screwed into the circular body of the instrument and the other end is varied, which facilitate it to penetrate the soil to enable measurement.

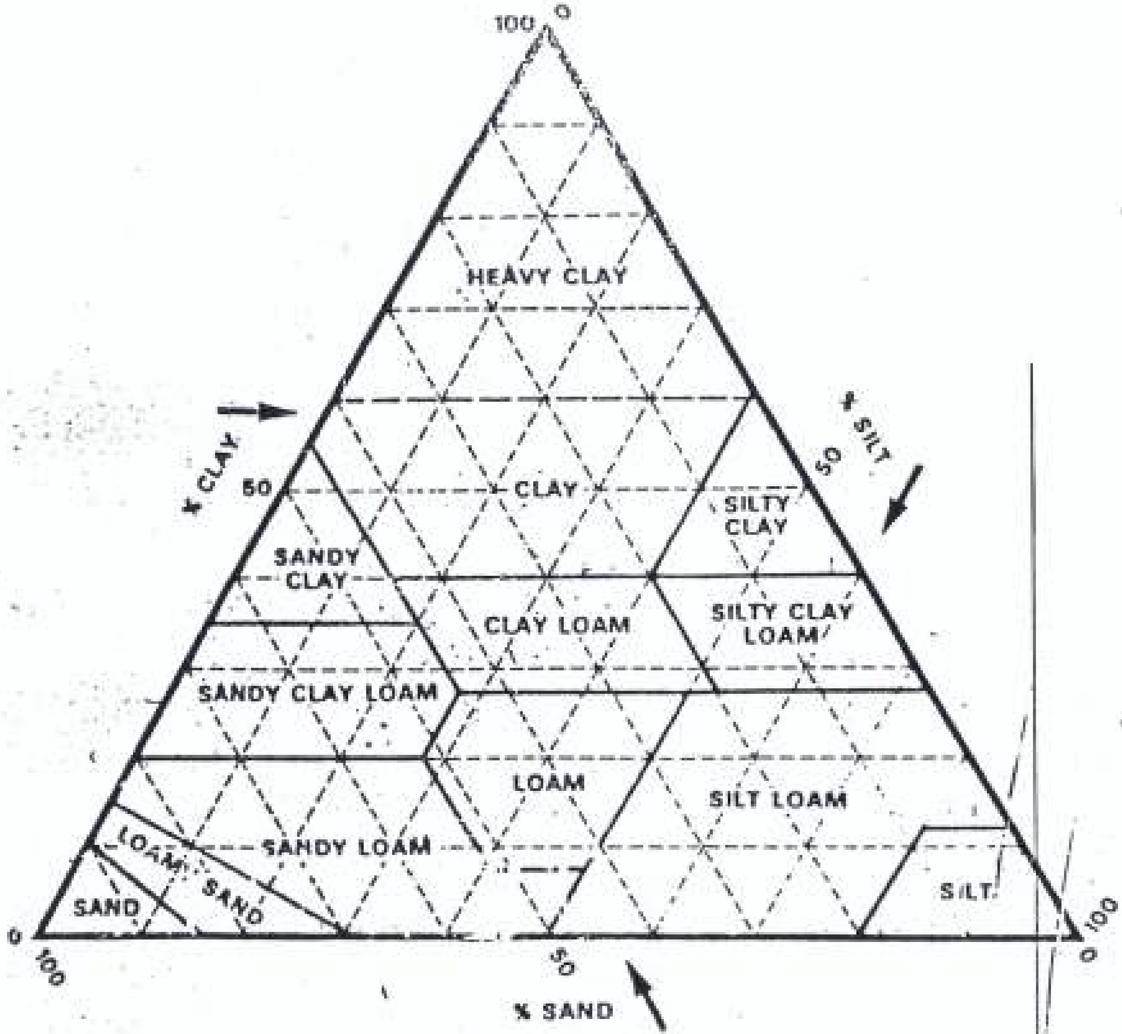


Figure 5: Soil Textural Triangle.

(b) The circular part consist the main body of the instrument and it is graduated part, which measure cohesion from 0 to 140 kPa. IT can easily be used both in the laboratory and for field experiment.

2. Oven (*Gallenkamp B.S.*) It is made of rectangular metal body. It measures from 1 to 250^{0}c. This is the only means of drying soil samples in the laboratory.

3. Hand penetrometer (ASIMD 1558). It has a T-handle metal part. It is a spring type penetrometer which is used in laboratory and in the field when controlling soil compaction in compliance with ASIM 1558. Direct reading is done in kg on sliding rod. The instrument is supplied with seven needles of known cross-sectional areas. It is simple to sue and easy to carry. It weighs 8kg.

4. Proctor's mould: it is made of cylindrical metal hollow object with 11.6cm in height and a diameter of 101.2 cm and contain 944cm^3 volume. It holds volume of soil to be compacted. It is easy to work with and rigid.

5. Oven Cans: These are empty peak milk cans which lids are removed to hold soil sample for purpose of dry in the oven. It is light and occupies small specie.

6. Soil Tray: This is made of metal sheet measure 60 x 40 cm. It enables the soil to be prepared that is removal of pebbles, roots and breaking of soil lumps before packing into mould for compaction.

7. Chisel: Ti is made of metal bar of 2cm wide and 15 cm long with a wooden handle. It enables easy removal of compacted soil from the mould.

8. Rubber hammer; It is made of rubber head and wooden handle. It is used for breaking soil lumps in the tray into smaller particles before packing into mould.

Weighing Machine: Two types of weighing machines were used

a. Semi-automatic weighing machine: Measure by mechanical means, measures from range 0 – 500kg. It is used to measure soil before compaction.

b. Stanton (4000g): It measures by electrical means. It measures from 0 to 4000g.. It is sensitive to measure small soil samples to determine moisture content of soil while oven dry.

9. Proctor Hammer: This consist of cylindrical metal with 4cm in diameter and 45cm long, with one open end and the other end partially close to allow passage of small rod which carry a metal of 2.5kg inside the hollow pipe and with a handle outside the pipe. It is used for oil compaction in the mould.

3.4 Determination of Soil Textural Classes

The textural classes of the six samples of soil collected selectively from Ondo State were determined suing hydrometer method. Each sample was sieved through 2mm mesh and 50gm of each sample was measured into the flask, 5gm of sodium hexametal phosphate (cagon) was dissolved into 100 ml of water in each soil sample in each flask.

The soil samples were agitated through meachnical shaker and then poured into 1000 ml measuring cylinder. Hydrometer is placed in each cylinder containing different soil sample and water is added to make solution in each cylinder to 1000 ml. The content of each cylinder is shaken and their hydrometer and temperature readings were taken at 40 sec and 2 hrs respectively.

The stem of hydrometer reads directly in gm of soil/litre of solution. To correct the hydrometer reading for temperature, 0.36g/litre was added of every 1^0c above 20^0c while 0.36 g/litre was subtracted of every 1^0c below 20^0c.

$$\% \text{ silt + clay} = \frac{\text{corrected 40 sec. Hydrometer reading X 100}}{\text{dry weight of soil}} \quad (6)$$

$$\% \text{ clay} = \frac{\text{corrected 2hrs hydrometer reading X 100}}{\text{dry weight of soil}} \quad (7)$$

% Sand + Silt + Clay = 100

% Silt = (Silt + Clay)-Clay

% Sand = 100 – Silt + Clay).

By using the USDA textural classification system, soil samples were classified with the textural triangle as in Figure 5.

3.5 Determination of Soil Organic Mater

Walkey-Black method was used to determine the soil organic mater. The Walkey-Black procedure measure active or decomposable organic matter in the soil. Oxidizable matter in the soil samples is oxidized by chromium ions and the reaction is facilitated by the heat generated when 2 volumes of tetra-oxo-sulphate VI acid (H_2S0_4) acid are mixed with I volume of tetra-oxo-chromate solution ($K_2Cr_20_7$). The excess of chromium ion ($Cr_20_7^{2}$) is determined by titration with standard Iron II tetra-sulphate IV salt solution $FeS0_4$) and the quantity of substance oxidized is calculated from the amount of chromate ion ($Cr_20_7^{2-}$) reduced using orthphenanthroline ferrous complex indicator (ferrin) which gives a colour change from orange to dark-green to light green and finally to maroon red.

In wet oxidation method, all organic carbon is oxidized. Some resistant groups such as ring compound are only slightly attacked. It is assumed that an average of 75% of the organic carbons is attacked and the amount calculated from the titration is multiplied by 100/75 (1.33) to give% organic (corrected), charcoal, diamond and graphite not included, Walkey (1934). It is assumed that soil organic matter contain 58% (1.72).

3.6 Determination of Moisture Content

Gravimetric method was used to determine the soil moisture content. Each sample of soil is put into a container, weighted, oven dried, and weighed again after drying. Drying is done at 105-110^{0}c to constant weight for 24 h.

The mass of water content (Q_m) is the decimal that equals the weight of water divided by weight of oven-dried soil. The mass of water percentage (P_m) is calculated on the basis of dry weight using the formula.

$$\text{Mass of water content } (Q_m) = \frac{\text{Mass of water}}{\text{Mass of oven dry soil}} \quad (8)$$

$$\text{Mass percentage of water } (P_m) = Q_m \times 100 \quad (9)$$

3.7 Compaction Procedure

3.7.1 Change in Organic Matter Content Level

The highest organic matter of the original soil was 3. 09% (Table 1). The soil organic matter content was increased by adding fresh Siam weed. This enabled the organic matter content to vary from 1.17 to 14% on dry mass basis of the soil, before subjecting them to compaction.

3.7.2 *Changing of Moisture Content Level*

The moisture content has a great influence on compaction strength of the soil. The soils were compacted at moisture content levels ranging from 1.09 to 21.2% moisture content on proportion by dry mass basis of the soil, before subjecting them to compaction.

3.7.3 *Measurement of Shear Strength of the Soil*

At each moisture levels, the soil samples were subjected to 10, 20, 30 and 40 blows of a standard proctor hammer of mass (2.5 kg) in a mould of 10.2cm in diameter and 11.6cm in height (volume 944cm^3) following proctor compaction procedure (Lambe, 1951). The compaction effort of 10, 20, 30 and 40 blows estimated by using Joseph (1992) equation below

$$CE = \frac{a \times b \times c \times h}{R} = kJ/m^3 \quad (10)$$

Where CE = compaction effort (kJ/m^3)

a. = mass of the soil (kg) ranging from 1.8 to 3kg

b. = number of blows

c. = mass of hammer (kg)

h. = height of dropping of hammer (m)

R = volume of the mould (m^3)

This provides a nominal compaction energy (Kilo-Joules) to the soil (Joseph, 1992). The equivalent static compaction effort of the 10, 20, 30 and 40 blows were estimated by using above equation and cohesion measure with shear vane tester at 5 cm and 10 cm depth in the mould.

3.7.4 *Measurement of Penetration Resistance of the Soil*

The soil samples were subjected to 10, 20, 30 and 40 blows of a standard proctor hammer (2.5 kg) in a mould of volume 944 cm following compaction procedure (Lambe, 1951). The equivalent static compaction effort of 10, 20, 30 and 40 blows were estimated by using equation 10.

$$\frac{A \times b \times c \times h}{R} = kg/m^3 \qquad (10)$$

These were obtained to be 21.0, 42.0, 631 and 84.1 kg/m^3 but with moisture content ranging from 5 to 21.1% at deterrent levels. The cone index was taken at depth of 5 cm and 10 cm and 10 cm respectively. The bulk densities of the soil samples were determined by using initial moisture content of each soil sample on dry mass basis with volume of the mould (944 cm^3). This is by using equation below

$$Y = \frac{\text{Wt. of oven dry soil}}{\text{Volume of the soil}} \qquad (11)$$

Also result of each parameter investigated was replicated twice and the value was used in statistical model generation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

Table 2 shows the physical characteristics of the soil samples, which were obtained by particle analyses. It also contains the organic matter content in the original soil samples, which was determined by Walky-Black method. The compaction levels of the soil, which were assessed through the measurement of the resistance of the soil samples to penetration by cone penetrometer (at depths 5 and 10 cm) at different levels of soil moisture content, and at different levels of fresh Siam weed addition (and therefore different levels of organic material) are presented in Tables 3 to 14.

The results presented in Tables 3 to 14 were subjected to statistical analyses using ANOVA at 5% significance level. The summary tables of the analyses are presented in Appendix…

Table 2: Measured physical properties of the soil samples

S/No	Organic Matter Content %	%, Sand	% Clay	% Silt	Moisture content %(d.b)	Location	Soil Class	Soil Associa-tion
A	3.0	66	23	11	1.5	Okitipupa	Sandy loam	Benin
B	1.74	68	23	9	1.3	Ode-Irele	Sandy loam	Benin
C	2.04	54	23	23	2.1	Igbara-Oke	Sandy clay loam	Egbeda
D	1.17	64	25	11	1.2	Ondo	Sandy clay loam	Ondo
E	2.39	56	29	15	2.6	Oke-Agbe	Sandy Clay loam	Iwo
F	1.39	56	31	19	0.9	Owo	Sandy loam	Egbeda

Table 3a: Effect of moisture content on strength of Okitipupa sandy loam soil without organic matter at 10 blows of proctor's hammer

Moistures Content level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	11.5	24.5	18.0
5.0	25.0	32.5	28.8
7.5	39.0	43.5	41.5
10.0	49.5	60.0	54.8
12.5	20.5	26.5	23.5
15.0	14.5	18.5	16.5
17.5	11.5	14.5	13.0

Table 3b: Effect of moisture content on strength of Okitipupa sandy loam soil without organic matter at 20 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.6	17.0	26.5	21.8
5.0	21.0	28.0	24.5
7.0	24.0	36.5	30.3
10.0	29.0	41.5	35.3
12.5	26.0	38.5	32.3
15.0	25.5	21.5	18.5

Table 3c: Effect of moisture content on strength of Okitipupa sandy loam soil without organic matter at 30 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.6	20.5	26.5	23.5
5.0	35.0	45.0	40.0
7.5	44.5	56.0	50.3
10.0	49.5	61.5	55.5
12.5	24.0	34.5	29.3
15.0	15.5	21.5	18.5
17.5	13.0	16.5	14.8

Table 3d: Effect of moisture content on strength of Okitipupa sandy loam soil without organic matter at 40 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.6	24.5	34.5	29.5
5.0	33.5	43.5	38.3
7.5	45.5	56.5	51.0
10.0	63.5	76.5	70.0
15.0	25.0	33.0	29.0
17.5	18.5	21.0	20.0

Table 3e: Effect of moisture content and organic matter on strength of Okitipupa sandy loam soil at 10 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.6	3.1	9.5	13.50	13.8
5.0	4.0	11.5	15.0	15.0
7.5	6.0	12.5	20.5	17.8
10.0	8.0	16.0	24.8	20.5
12.5	10.0	15.5	23.3	19.3
15.0	12.0	14.5	18.3	16.0
17.5	14.0	11.5	18.5	15.0

Table 3f: Effect of moisture content on strength of Okitipupa sandy loam soil without organic matter at [illegible] blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.6	3.1	17.5	25.5	21.5
5.0	4.0	20.5	31.0	25.8
7.5	6.0	40.5	51.0	45.5
10.0	8.0	43.5	60.0	51.8
12.5	10.0	20.0	32.0	26.0
15.0	12.0	16.5	27.5	22.0
17.5	14.0	11.5	18.5	15.0

Table 3g: Effect of moisture content on strength of Okitipupa sandy loam soil without organic matter at 30 blows of proctor's hammer

istures ntent level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
6	3.1	20.5	26.5	23.5
0	4.0	32.5	38.5	35.5
5	6.0	40.5	50.5	45.5
0.0	8.0	56.0	61.0	58.5
2.5	10.0	28.0	38.5	33.3
5.0	12.0	19.5	315	25.5
7.5	14.0	14.5	18.5	16.5

Table 3h: Eff[illegible] [illegible]ture content and organic matter on strength of Okitipupa sandy loam soil at 40 blows of proctors hammer

Moistures kPa Content level %	organic matter level %	cohesion kPa at 5cm depth	cohesion kPa at 10cm depth	Average Cohesion
1.6	3.1	24.5	34.5	29.5
5.0	4.0	30.5	38.5	34.5
7.5	6.0	40.5	46.5	[illegible]3.5
10.0	8.0	53.5	59.5	56.5
12.5	10.0	30.0	37.5	33.8
15.0	12.0	24.5	20.5	19.5
17.5	14.0	18.5	20.5	19.5

Table 4a: Effect of Moisture content on strength of Ode-Irele sandy loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	11.5	24.0	17.8
5.0	25.5	38.5	32.0
7.5	45.5	56.0	50.3
10.0	59.0	69.0	64.0
12.5	22.5	37.0	30.0
15.0	17.0	25.5	21.3
17.5	13.0	18.5	15.8

Table 4b: Effect of moisture content on strength of Ode Irele sandy loam without organic matter at 20 blows of proctor's hammer.

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	27.5	39.0	33.3
5.0	47.0	38.5	32.0
7.5	68.5	70.0	69.3
10.0	74.5	83.0	78.8
12.5	33.0	52.0	42.5
15.0	24.0	41.5	32.8
17.5	17.5	31.5	24.5

Table 4c: Effect of moisture content on strength of Ode Irele sandy loam without organic matter at 30blows of proctor's hammer.

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.5	39.5	50.0	44.8
5.0	56.5	65.5	60.8
7.5	70.5	79.5	75.0
10.0	87.0	93.0	90.0
12.5	54.5	61.0	57.8
15.0	48.0	53.5	50.8
17.5	26.5	34.5	30.5

Table 4e: Effect of moisture content on the strength of Ode-Irele sandy loam without organic matter at 10 blows at proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	1.2	11.5	24.5	18.0
5.0	4.0	25.0	32.5	28.8
7.5	6.0	39.0	43.5	41.5
10.0	8.0	49.5	60.0	54.8
12.5	10.0	20.5	26.5	23.5
15.0	12.0	14.5	18.5	16.5
17.5	14.0	11.5	14.5	13.0

Table 4f: Effect of moisture content on the strength of Ode-Irele sandy loam without organic matter at 20 blows at proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	1.2	28.0	38.5	33.3
5.0	4.0	41.0	56.0	48.5
7.5	6.0	60.0	68.0	64.0
10.0	8.0	72.5	78.5	75.3
12.5	10.0	28.0	43.0	35.5
15.0	12.0	17.5	35.5	26.5
17.5	14.0	14.5	24.0	19.3

Table 4g: Effect of moisture content on the strength of Ode-Irele sandy loam without organic matter at 30 blows at proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	1.2	39.5	50.0	44.8
5.0	4.0	56.5	65.0	60.8
7.5	6.0	70.5	76.5	73.5
10.0	8.0	87.0	93.0	90.0
12.5	10.0	54.5	61.0	57.8
15.0	12.0	48.0	53.5	50.8
17.5	14.0	26.5	34.5	30.5

Table 4h: Effect of moisture content on the strength of Ode-Irele sandy loam without organic matter at 40 blows at proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	1.2	52.0	72.5	62.5
5.0	4.0	75.5	84.5	80.0
7.5	6.0	95.0	105.0	100.0
10.0	8.0	107.0	120.0	113.5
12.5	10.0	44.5	52.0	48.3
15.0	12.0	32.5	38.5	35.5
17.5	14.0	24.0	26.5	25.3

Table 5a: Effect of moisture content on the strength of Igbara Oke sandy clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.2	12.0	24.0	18.0
5.0	32.0	43.5	37.8
7.5	48.0	52.2	50.3
10.0	54.0	66.5	60.3
12.5	25.0	32.0	28.5
15.0	15.0	22.5	18.8
17.5	11.5	15.5	13.5

Table 5b: Effect of moisture content on the strength of Igbara Oke sandy clay loam without organic matter at 20 blows of proctor hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.2	22.5	32.0	27.3
5.0	47.5	52.5	50.0
7.5	54.0	63.0	58.5
10.0	59.0	69.5	64.3
12.5	33.5	40.5	37.0
15.0	24.5	32.5	28.5
17.5	18.0	23.0	20.5

Table 5c: Effect of moisture content on the strength of Igbara Oke sandy clay loam without organic matter at 30 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.2	34.5	43.0	38.8
5.0	61.0	72.0	66.5
7.5	68.5	78.0	73.3
10.0	74.5	84.0	79.3
12.5	45.5	53.0	49.3
15.0	34.5	41.5	38.0
17.5	27.5	32.5	30.0

Table 5d: Effect of moisture content on the strength of Igbara Oke sandy clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2	44.5	52.0	48.3
5.0	77.5	38.5	32.0
7.5	82.0	88.5	85.3
10.0	88.5	93.5	91.0
12.5	62.5	69.0	65.8
15.0	48.0	52.0	50.0
17.5	37.5	415	39.5

Table 5f: Effect of moisture content on the strength of Igbara Oke sandy clay loam without organic matter at 20 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.3	1.7	22.5	32.0	27.3
5.0	4.0	36.5	48.5	42.5
7.5	6.0	54.5	56.0	55.3
10.0	8.0	57.5	62.2	60.0
12.5	10.0	30.0	39.0	34.5
15.0	12.0	20.5	27.5	24.0
17.5	14.0	16.0	25.0	20.5

Table 5g: Effect of moisture content on the strength of Igbara Oke sandy clay loam without organic matter at 30 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.2	1.7	34.5	43.0	38.8
5.0	4.0	56.5	58.0	57.5
7.5	6.0	62.5	68.5	65.5
10.0	8.0	66.5	71.5	69.0
12.5	10.0	42.5	48.0	45.3
15.0	12.0	30.5	37.0	33.8
17.5	14.0	29.0	31.0	30.0

Table 5h: Effect of moisture content on the strength of Igbara Oke sandy clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
1.2	1.7	44.5	52.0	48.3
5.0	4.0	71.5	68.0	69.8
7.5	6.0	73.5	78.5	76.0
10.0	8.0	77.5	82.5	80.0
12.5	10.0	58.0	64.0	61.0
15.0	12.0	43.5	48.5	46.0
17.5	14.0	23.0	39.0	31.0

Table 6a: Effect of moisture content on the strength of Ondo sandy clay loam soil without organic matter at 10 blows of proctors hammer.

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	18.5	34.5	26.5
5.0	48.5	51.5	50.0
7.5	55.5	63.5	59.5
10.0	68.5	72.5	70.5
12.5	38.5	50.5	44.5
15.0	30.0	45.5	38.0
17.5	22.5	32.5	27.3

Table 6b: Effect of moisture content on the strength of Ondo sandy clay loam soil without organic matter at 30 blows of proctors hammer.

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	44.0	51.0	47.5
5.0	62.5	69.0	65.8
7.5	67.5	72.5	70.0
10.0	80.5	89.5	85.0
12.5	55.5	60.5	58.0
15.0	50.5	58.5	54.5
17.5	39.5	44.0	41.8

Table 6c: Effect of moisture content on the strength of Ondo sandy clay loam soil without organic matter at 40 blows of proctors hammer.

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	55.5	74.0	64.8
5.0	74.0	80.5	77.3
7.5	78.5	84.5	81.5
10.0	95.0	102.5	98.8
12.5	67.5	72.5	70.0
15.0	63.5	69.5	66.5
17.5	50.5	54.5	52.5

Table 6d: Effect of moisture content on the strength of Ondo sandy clay loam soil without organic matter at 40 blows of proctors hammer.

Moistures Content level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	68.0	73.5	70.8
5.0	87.0	97.5	92.3
7.5	92.5	105.0	98.8
10.0	108.0	113.5	111.0
12.5	78.5	85.5	82.0
15.0	72.5	75.5	74.0
17.5	59.5	65.5	62.5

Table 6e: Effect of moisture content on the strength of Ondo sandy clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	2.0	18.0	34.0	26.0
5.0	4.0	44.5	47.5	46.0
7.5	6.0	48.5	57.0	52.8
10.0	8.0	59.5	64.5	62.0
12.5	10.0	34.0	48..0	41.0
15.0	12.0	27.0	40.5	33.8
17.5	14.0	20.0	32.0	26.0

Table 6f: Effect of moisture content on the strength of Ondo sandy clay loam without organic matter at 20 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	2.0	44.0	50.5	47.3
5.0	4.0	55.5	60.5	58.0
7.5	6.0	63.5	69.5	66.5
10.0	8.0	72.5	79.5	76.0
12.5	10.0	50.0	57.5	54.0
15.0	12.0	45.5	52.0	48.8
17.5	14.0	34.0	43.5	38.8

Table 6g: Effect of moisture content on the strength of Ondo sandy clay loam without organic matter at 30 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	2.0	55.5	61.0	58.3
5.0	4.0	65.5	71.0	68.3
7.5	6.0	75.5	79.5	77.5
10.0	8.0	84.5	90.5	87.5
12.5	10.0	61.5	68.0	64.8
15.0	12.0	57.5	62.5	60.0
17.5	14.0	42.0	54.5	48.3

Table 6h: Effect of moisture content on the strength of Ondo sandy clay loam without organic matter at 40 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.1	2.0	68.0	73.5	70.8
5.0	4.0	79.5	82.5	81.0
7.5	6.0	84.0	89.0	86.5
10.0	8.0	98.0	103.5	100.8
12.5	10.0	73.5	78.0	75.8
15.0	12.0	68.0	71.5	69.8
17.5	14.0	59.0	67.0	63.0

Table 7a: Effect of moisture content on the strength of Oke agbe sandy clay loam without organic matter at 10 blows of proctor's hammer.

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.6	27.5	36.0	31.8
5.0	54.0	67.5	60.5
7.5	71.5	83.0	77.3
10.0	85.0	94.0	89.5
12.5	45.5	50.5	47.5
15.0	35.0	43.0	39.0
17.5	26.0	34.0	30.0

Table 7b: Effect of moisture content on the strength of Oke agbe clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.6	47.0	55.0	51.0
5.0	72..0	85.5	78.5
7.5	89.0	93.0	91.0
10.0	97.5	115.5	106.5
12.5	56.5	60.5	58.5
15.0	48.0	52.5	50.3
17.5	36.0	42.0	39.0

Table 7c: Effect of moisture content on the strength of Oke agbe sandy clay loam without organic matter at 30 blows of proctor's hammer.

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.6	60.0	69.0	64.5
5.0	94.0	105.5	99.5
7.5	102.0	112.5	107.3
10.0	119.5	130.0	124.8
12.5	68.5	72.5	70.5
15.0	58.5	64.5	61.5
17.5	47.5	52.5	50.5

Table 7e: Effect of moisture content on the strength of Oke agbe sandy clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.6	2.4	27.5	36.0	31.8
5.0	4.0	52.0	58.5	55.3
7.5	6.0	62.5	72.0	67.3
10.0	8.0	75.0	82.5	78.8
12.5	10.0	40.5	48.5	44.5
15.0	12.0	32.0	37.5	35.0
17.5	14.0	20.5	24.5	22.5

Table 7f: Effect of moisture content on the strength of Oke agbe sandy clay loam without organic matter at 20 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.6	2.4	47.0	55.0	51.0
5.0	4.0	68.0	74.0	71.0
7.5	6.0	79.5	85.5	82.5
10.0	8.0	87.5	91.5	89.5
12.5	10.0	52.5	62.5	57.5
15.0	12.0	40.5	47.5	44.0
17.5	14.0	31.5	39.0	35.3

Table 7g: Effect of moisture content on the strength of Oke agbe clay loam without organic matter at 30 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.6	2.4	60.5	68.5	64.5
5.0	4.0	80.5	89.0	84.8
7.5	6.0	92.5	98.0	95.3
10.0	8.0	101.0	107.5	104.3
12.5	10.0	63.0	68.5	65.8
15.0	12.0	52.5	56.0	54.3
17.5	14.0	41.5	47.0	44.3

Table 7h: Effect of moisture content on the strength of Oke agbe clay loam without organic matter at 40 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
2.6	2.4	78.0	87.5	82.3
5.0	4.0	95.5	102.5	99.0
7.5	6.0	105.0	110.5	107.8
10.0	8.0	115.5	121.0	118.3
12.5	10.0	71.5	79.0	75.3
15.0	12.0	61.5	68.0	64.8
17.5	14.0	52.0	58.0	55.0

Table 8a: Effect of moisture content on the strength of Owo sandy clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
0.9	31.0	39.0	35.0
5.0	52.0	58.5	55.3
7.5	62.0	69.0	65.5
10.0	72.5	80.5	76.5
12.5	45.0	52.0	48.5
15.0	39.5	45.5	42.5
17.5	27.5	34.5	31.0

Table 8b: Effect of moisture content on the strength of Owo sandy clay loam without organic matter at 20 blows of proctor's hammer

Moistures Content level %	cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
0.9	43.0	51.0	47.0
5.0	62.0	69.0	65.5
7.5	72.0	83.0	77.5
10.0	85.5	89.5	87.5
12.5	58.5	61.5	60.0
15.0	50.5	56.5	53.5
17.5	38.0	41.5	39.8

Table 8c: Effect of moisture content on the strength of Owo sandy clay loam without organic matter at 30 blows of proctor's hammer

Moistures Content level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
0.9	56.5	62.5	59.5
5.0	76.5	87.5	82.0
7.5	89.5	96.5	93.0
10.0	98.0	100.5	99.3
12.5	68.5	72.5	70.5
15.0	61.0	65.5	63.3
17.5	48.5	54.0	61.3

Table 8d: Effect of moisture content on the strength of Owo sandy clay loam without organic matter at 40 blows of proctor's hammer

Moistures Content level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
0.9	72..5	83.5	78.0
5.0	94.5	105.5	100.0
7.5	102.0	105.0	103.5
10.0	111.5	115.0	113,3
12.5	79.5	83.5	81.5
15.0	70.5	75.5	73.0
17.5	60.0	65.0	62.5

Table 8e: Effect of moisture content on the strength of Owo clay loam without organic matter at 10 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
0.9	1.4	43.0	51.0	47.0
5.0	4.0	60.5	65.0	63.0
7.5	6.0	69.0	73.5	71.3
10.0	8.0	75.5	78.5	77.0
12.5	10.0	52.5	58.5	55.5
15.0	12.0	44.5	49.0	46.8
17.5	14.0	33.5	37.0	35.3

Table 8g: Effect of moisture content on the strength of Owo clay loam without organic matter at 30 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
0.9	1.4	56.5	62.5	59.5
5.0	4.0	69.0	73.5	71.3
7.5	6.0	78.5	82.5	80.5
10.0	8.0	115.5	121.0	118.3
12.5	10.0	62.0	65.5	63.8
15.0	12.0	53.5	59.0	56.3
17.5	14.0	40.0	45.5	42.8

Table 8h: Effect of moisture content on the strength of Owo clay loam without organic matter at 40 blows of proctor's hammer

Moistures Content level %	Organic Matter Level %	Cohesion kPa at 5cm depth	Cohesion kPa at 10cm depth	Average Cohesion kPa
0.9	1.4	72.5	83.0	78.0
5.0	4.0	86.0	90.5	88.3
7.5	6.0	93.0	94.0	93.5
10.0	8.0	96.5	101.0	98.8
12.5	10.0	70.5	78.5	74.5
15.0	12.0	64.5	68.0	66.3
17.5	14.0	52.5	60.5	56.5

Table 9a: Effect of moisture content, compaction and depth on penetration resistance of Okitipupa sandy loam soil at 10 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
6.0	1.852	1980.7	1868.6	0.30	11	50.0	13	59.1
12.0	1.975	1994.8	1781.1	0.40	6	27.3	8	36.4
18.0	2.112	1997.5	1692.8	0.45	4	18.2	6	27.3

Table 9b: Effect of moisture content, compaction and depth on penetration resistance of Okitipupa sandy loam soil at 20 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
6.0	1.852	1989.1	1876.5	0.35	19	86.4	25	113.6
12.0	1.975	1994.7	1781.0	0.40	14	63.6	17	77.3
18.0	2.112	2005.6	1699.7	0.50	9	40.9	12	54.5

Table 9c: Effect of moisture content, compaction and depth on penetration resistance of Okitipupa sandy loam soil at 30 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
6.0	1.852	2044.0	1928.3	0.65	23	104.5	27	122.7
12.0	1.975	2050.0	1830.3	0.70	18	81.8	24	109.1
18.0	2.112	2061.7	1747.2	0.80	13	59.1	18	81.8

Table 9d: Effect of moisture content, compaction and depth on penetration resistance of Okitipupa sandy loam soil at 40 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
6.0	1.852	2092.3	1973.9	0.90	29	131.8	32	145.5
12.0	1.975	2108.5	1882.6	1.00	21	95.5	27	122.7
18.0	2.112	2121.3	1797.7	1.10	15	68.2	21	95.5

Table 10a: Effect of moisture content, compaction and depth on penetration resistance of Ondo sandy loam soil at 10 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.0	1.830	1935.7	1809.1	0.30	19	86.4	23	104.5
14.0	1.993	1966.9	1725.4	0.40	12	54.5	15	68.2
21.0	2.112	2101.4	1736.7	0.50	5	22.7	8	36.4

Table 10b: Effect of moisture content, compaction and depth on penetration resistance of Ondo sandy loam soil at 20 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.0	1.830	1970.9	1842.0	0.50	25	113.6	30	136.4
14.0	1.993	2012.4	1765.3	0.65	9	40.9	13	59.1
21.0	2.112	2101.4	1768.9	0.70	6	27.3	9	40.9

Table 10c: Effect of moisture content, compaction and depth on penetration resistance of Ondo sandy loam soil at 30 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.0	1.830	2026.3	1893.7	0.80	34		36	
14.0	1.993	2050.2	1798.4	0.85	18		22	
21.0	2.112	2180.7	1802.2	0.90	8		13	

Table 10d: Effect of moisture content, compaction and depth on penetration resistance of Ondo sandy loam soil at 40 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.5	1.854	1996.2	1857.9	0.55	19	86.4	31	140.9
12.2	1.945	2001.3	1783.7	0.56	12	54.5	12	54.5
18.6	2.160	2083.4	1756.7	0.75	5	22.7	10	45.5

Table 11a: Effect of moisture content, compaction and depth on penetration resistance of Irele sandy loam soil at 10 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
8.0	1.860	1922.6	1780.2	0.29	12		16	
16.0	1.050	1972.7	1700.6	0.38	9		13	
22.0	2.210	1987.3	1628.9	0.45	6		10	

Table 11b: Effect of moisture content, compaction and depth on penetration resistance of Irele sandy loam soil at 20 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
8.0	1.860	1981.7	1834.9	0.40	22	100.0	27	122.7
16.0	1.050	2017.6	1739.3	0.64	10	45.5	15	68.2
22.0	2.210	2035.2	1662.2	0.71	7	31.8	12	54.5

Table 11c: Effect of moisture content, compaction and depth on penetration resistance of Irele sandy loam soil at 30 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
8.0	1.860	2037.1	1886.2	0.80	28	127.3	32	145.5
16.0	1.050	2058.1	1774.2	0.85	13	59.1	17	77.3
22.0	2.210	2073.6	1699.7	0.91	9	40.9	16	72.7

Table 11d: Effect of moisture content, compaction and depth on penetration resistance of Irele sandy loam soil at 40 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.5	1.854	1996.2	1857.9	0.55	19	86.4	31	140.9
12.2	1.945	2001.3	1783.7	0.56	12	54.5	12	54.5
18.6	2.160	2083.4	1756.7	0.75	5	22.7	10	45.5

Table 12a: Effect of moisture content, compaction and depth on penetration resistance of Igbara oke sandy loam soil at 10 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	Cone Index depth=5cm kPa	Cone Index depth=10cm kg	Cone Index depth=10cm kPa
8.0	1.851	1940.4	1796.7	0.30	16	72.7	21	95.4
12.0	1.970	1980.6	1768.3	0.45	11	50.0	14	63.6
18.0	2.100	1997.9	1693.1	0.50	7	31.8	10	45.6

Table 12b: Effect of moisture content, compaction and depth on penetration resistance of Igbara-Oke sandy loam soil at 20 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	Cone Index depth=5cm kPa	Cone Index depth=10cm kg	Cone Index depth=10cm kPa
8.0	1.851	1977.6	1831.1	0.50	26	118.2	31	140.9
12.0	1.970	2025.9	1808.8	0.60	12	54.5	15	68.2
18..0	2.100	2031.1	1721.3	0.70	8	36.4	12	54.5

Table 12c: Effect of moisture content, compaction and depth on penetration resistance of Igbara Oke sandy loam soil at 30 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	Cone Index depth=5cm kPa	Cone Index depth=10cm kg	Cone Index depth=10cm kPa
8.0	1.851	2012.4	1863.3	0.70	32	145.5	37	168.2
12.0	1.970	2063.9	1842.8	0.80	15	68.2	21	95.4
18.0	2.100	2069.8	1754.1	0.85	9	40.9	15	68.2

Table 12d: Effect of moisture content, compaction and depth on penetration resistance of Igbara oke sandy loam soil at 40 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	Cone Index depth=5cm kPa	Cone Index depth=10cm kg	Cone Index depth=10cm kPa
8.0	1.851	2046.5	1894.9	0.9	34	154.5	39	177.3
12.0	1.970	2093.2	1868.9	0.95	17	77.3	23	104.5
18.0	2.100	2098.4	1778.3	1.00	10	45.5	17	77.3

Table 13a: Effect of moisture content, compaction and depth on penetration resistance of Oke agbe sandy loam soil at 10 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.5	1.854	1952.7	1816.5	0.30	19	86.4	24	109.1
12.2	1.945	1960.4	1747.2	0.45	12	54.5	17	773.2
18.6	2.160	2083.4	1756.7	0.75	5	22.7	10	45.5

Table 13b: Effect of moisture content, compaction and depth on penetration resistance of Oke agbe sandy loam soil at 20 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.5	1.854	1996.2	1857.9	0.55	19	86.4	31	140.9
12.2	1.945	2001.3	1783.7	0.56	12	54.5	12	54.5
18.6	2.160	2083.4	1756.7	0.75	5	22.7	10	45.5

Table 13c: Effect of moisture content, compaction and depth on penetration resistance of Oke agbe sandy loam soil at 30 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.5	1.854	2040.2	1897.9	0.70	33	150.0	35	159.1
12.2	1.945	2042.7	1820.6	0.85	17	77.3	21	95.5
18.6	2.160	2113.0	1781.6	0.90	8	36.4	13	59.1

Table 13d: Effect of moisture content, compaction and depth on penetration resistance of Oke agbe sandy loam soil at 40 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m^3	Dry density kg/m^3	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.5	1.854	2067.2	1923.0	0.90	35	159.1	38	172.7
12.7	1.945	2081.8	1855.4	1.05	18	81.8	30	90.9
18.6	2.160	2163.9	1824.5	1.15	9	40.9	15	68.2

Table 14a: Effect of moisture content, compaction and depth on penetration resistance of Owo sandy loam soil at 10 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m³	Dry density kg/m³	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
8.0	1.860	1955.0	1810.2	0.35	11	50.0	15	68.2
14.0	1.995	1978.0	1735.1	0.40	6	27.3	7	40.9
21.1	2.120	2021.9	2021.9	1696.1	4	18.2	7	31.8

Table 14b: Effect of moisture content, compaction and depth on penetration resistance of Owo sandy loam soil at 20 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m³	Dry density kg/m³	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
8.0	1.860	1990.7	1843.2	0.60	18	81.8	24	109.1
14.0	1.995	2014.4	1767.0	0.65	13	59.1	17	77.3
21.1	2.120	2047.4	1690.0	0.70	9	40.9	13	59.1

Table 14c: Effect of moisture content, compaction and depth on penetration resistance of Owo sandy loam soil at 30 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m³	Dry density kg/m³	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
8.0	1.860	2023.7	1873.8	0.75	23	104.5	30	136.4
14.0	1.995	2042.4	1791.7	0.80	18	81.8	25	113.6
21.1	2.120	2091.3	1726.9	0.85	12	54.5	17	77.3

Table 14d: Effect of moisture content, compaction and depth on penetration resistance of Owo sandy loam soil at 40 blows of proctor's hammer.

Moisture Content %d/b	Mass of Soil kg	Bulk Density kg/m³	Dry density kg/m³	Sinkage cm	Cone Index depth=5cm kg	kPa	depth=10cm kg	kPa
7.5	1.854	2067.2	1923.0	0.90	35	159.1	38	172.7
12.7	1.945	2081.8	1855.4	1.05	18	81.8	30	90.9
18.6	2.160	2163.9	1824.5	1.15	9	40.9	15	68.2

4.2 DISCUSSION

Table 2 shows that the particle size analysis as well as the percentage of organic matter in the original soil as determined in the laboratory. The soils were arranged in order of increasing clay content representing different textural classifications i.e. sandy loam, sandy loam, sandy clay loam, sandy clay loam, sandy clay loam and sandy loam. Table 2 also shows the moisture contents of soil samples on dry mass basis.

The effects of Siam weed addition; moisture content and number of blows of proctor hammer on the magnitude of compaction strength of the selected soil samples were determined. The data obtained from the experiment were analyzed statistically wind ANOVA at 5% level of significance (Table 16-25 in the appendix)

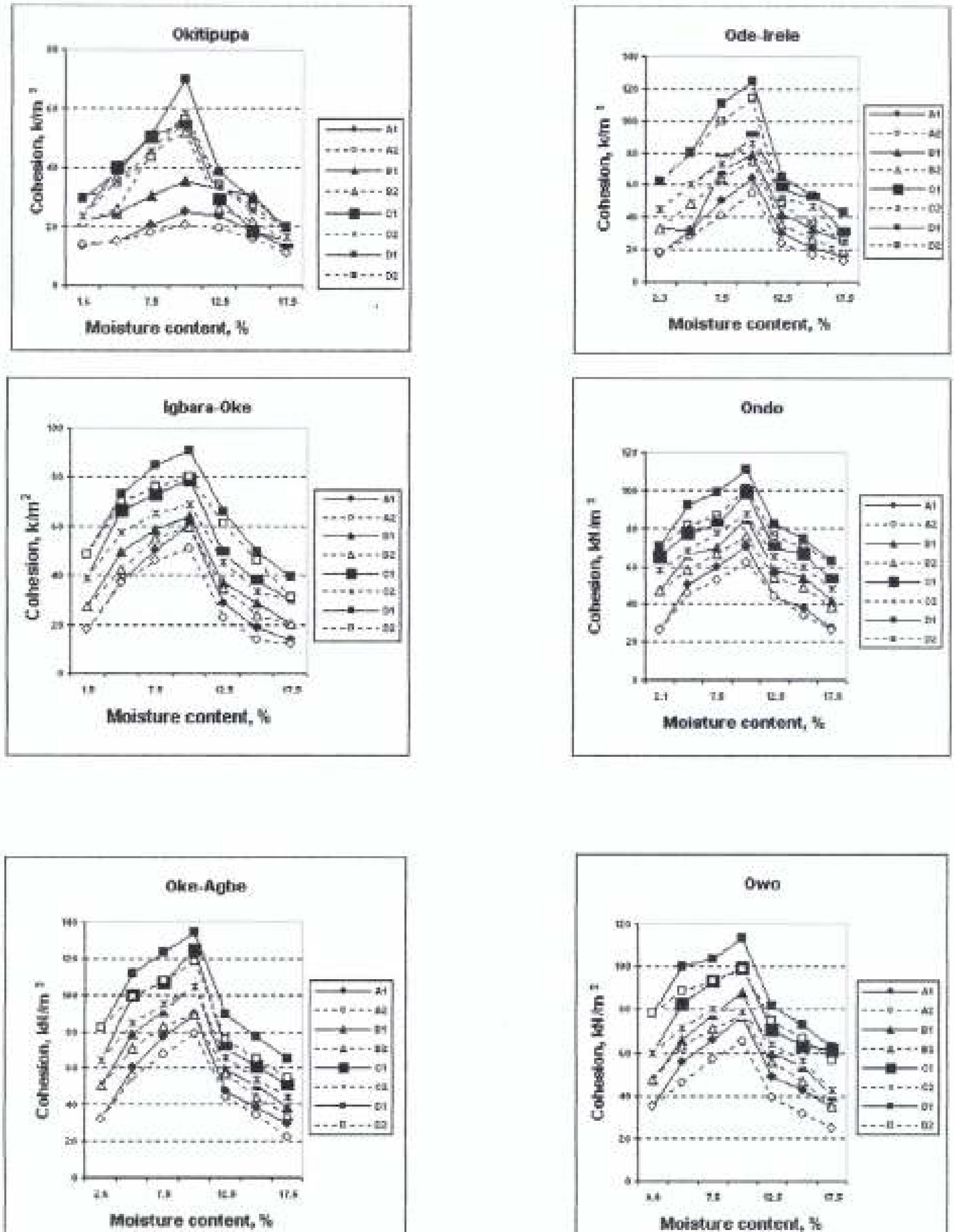
Figure 6 shows that the compaction of the soil as measured by the cone penetrometer resistance of the soil is affected by, moisture content, number of blows of proctor hammer and addition of fresh Siam weed on soil types. At all blows of proctor hammer, higher values of soil cohesion were obtained for all soils without addition of *Chromolaena*. The addition of fresh *Chromolaena* increased the organic matter content of the soil samples thereby reducing their bulk density. Owo soil samples had the highest values of soil cohesion.

Furthermore, Figure 6 shows that compaction level of the soil increases with increase in moisture content up to a maximum, after which further increase in soil moisture content led to decrease in the value of soil cohesion. This observation is in agreement with the assertion by Anazodo *et al.* (1987) that the magnitude of soil compaction varies with soil moisture content, soil type, size and external loading.

Figure 6 shows that the cohesion, moisture content, depth, with or without organic material added at any compaction level reach the maximum at 10% moisture content and later decreased, which means heavy machinery should not be used at 10% moisture content level in the sandy clay loam and sandy loam in order to avoid higher compaction influence where such soil is being mechanized for agricultural purposes and farm road construction. The variation of penetration resistance, moisture content level at different depths at any compaction level of soil types as shown on Tables 9-14. It shows that penetration resistance decreased linearly with increasing in moisture content level and also increased with the depth of soil in the mould.

The values of soil cohesion obtained for Okitipupa (Benin association), Ode Irele (Benin association are lower than those obtained for Owo (Egbeda association), Ondo (Ondo association and Oke agbe (Egbeda association) because the former are coarse-grained soils while the latter are fine grained. Similar results have been obtained by Manfred (1990) which stated that for coarse-grained soil, using standard modified compaction procedure, the magnitude of compaction of coarse-grained soil is less than that of fine grained.

At any given level of compaction, the magnitude of soil cohesion decreased with increase in Siam weed content at all the moisture content levels (Figs. 6 & 7). This is in agreement with the results obtained by different researchers, who noted that the incorporation of organic materials to the soil before compaction helps to alleviate the problem of compaction of agricultural soils (Greenland, 1977; Im, 1978;Ekwue, 1990; Ohu, 1991; Babalola, 1999).



A = 10 blows B = 20 blows C = 30 blows D = 40 blows 1 = Without Siam weed 2 = With Siam w

Figure 5: Effect of addition of Siam weed and moisture content on the compaction Strength of different agricultural soils

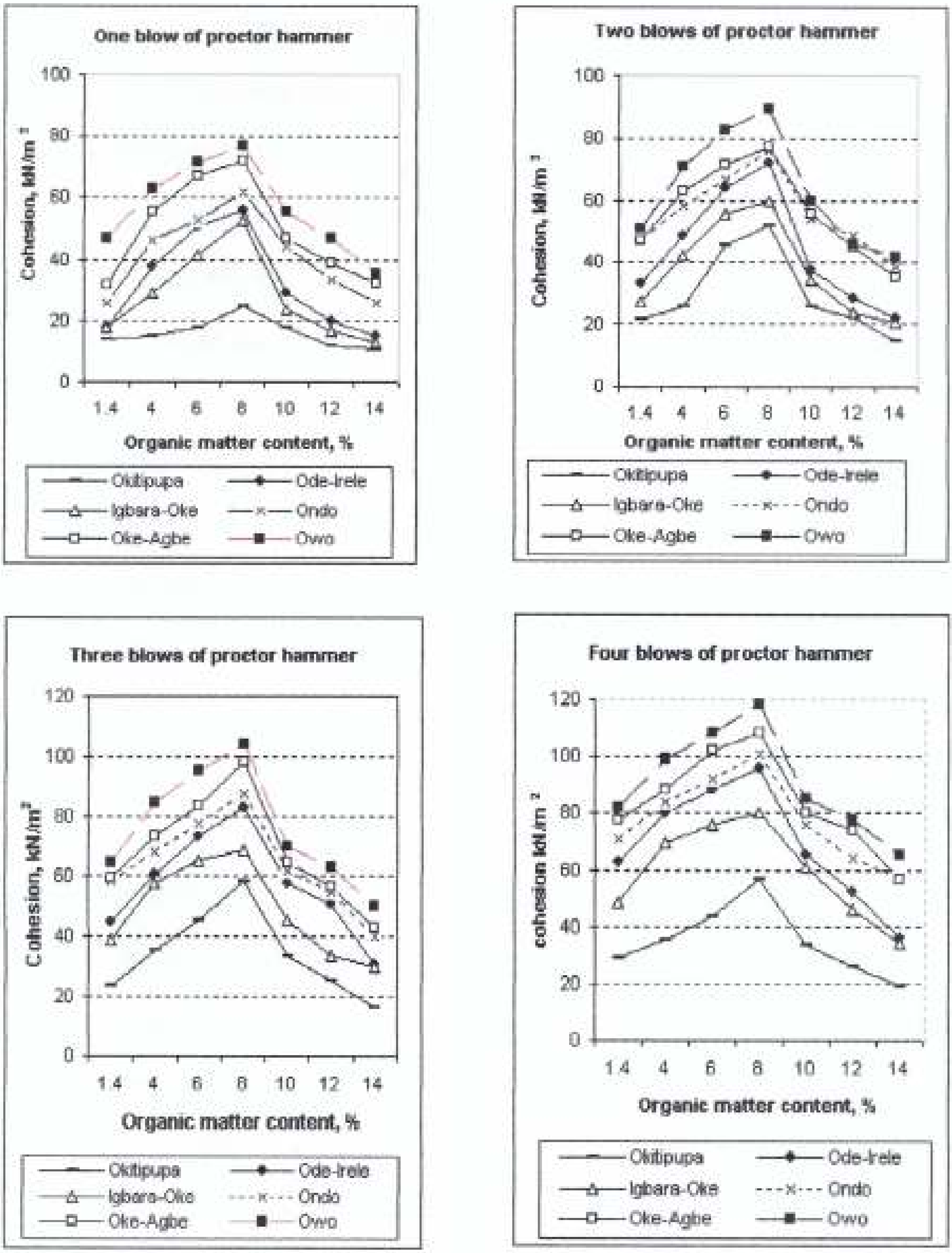


Fig. 7: Effect of addition of fresh Siam weed on the compaction of different soils at different number of blows of proctor's hammer

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

In this study, the effect of addition of Siam weed (*Chromolaena odorata*) as suitable organic material for reducing compaction strength of selected agricultural soils during tillage operations, has been investigated. The following conclusions are made;

1. The compaction of the soil as measured by the cone penetrometer resistance of the soil is affected by, moisture content, number of blows of proctor hammer and addition of fresh Siam weed on soil types.
2. At all blows of proctor hammer, higher values of soil cohesion were obtained for all soils without addition of *Chromolaena. i.e* Cohesion decreases with increase in organic matter of soil at a given moisture content.
3. Optimum values of soil cohesion were obtained in all soil types at moisture content of 10% at all compaction levels (blows of proctor hammer)
4. Penetration resistance increases with depth in all soil types in the mould.
5. The addition of fresh Siam weed as organic material during tillage operation is recommended because it will reduce soil compaction. However, heavy tillage machinery should not be used at 10% moisture content and above, as it will cause higher compaction on such soils.

5.2 RECOMMENDATIONS

For efficient agricultural production, the following suggestions are recommended;

1. Siam weed (*Chromolaena odorata*) should be incorporated into soil during tillage operation to reduce compaction by tractor and other machinery.
2. The use of other plants or mixture of plants as organic materials for incorporation into the soil before compaction by vehicular traffic to know their effects should be investigated.
3. More soil samples should be brought into focus under this study from various parts of Ondo state.
4. Measurement of shear and drag force of tillage implements in soils, which have been previously tilled with organic material incorporated and those ones without organic material added.
6. Other means of compacting soil samples other than the use of proctor hammer, which induced drudgery should be investigated.

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APPENDIX I

TABLE 16: Summary And ANOVA of Okitipupa sandy loam soil at 10,20,30 and 40 blows of proctor hammer at 5% significant difference

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
okiti10	7	128.4	18.34286	20.01619
okiti20	7	175.3	25.04286	24.12952
okiti30	7	228.4	32.62857	243.709
okiti40	7	276.3	39.47143	275.9057

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1763.894	3	587.9648	4.171735	0.016308	3.008786
Within Groups	3382.563	24	140.9401			
Total	5146.457	27				

APPENDIX II

TABLE 17: Summary And ANOVA of Ode-Irele Sandy loam soil at 10,20,30 and 40 blows of proctor hammer at 5% significant difference.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Irele10	7	222.4	31.77143	277.0924
Irele20	7	283.3	40.47143	257.539
Irele30	7	387.5	55.35714	473.1262
Irele40	7	469.9	67.12857	455.7924

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5167.501	3	1722.5	4.70516	0.010115	3.008786
Within Groups	8786.1	24	366.0875			
Total	13953.6	27				

APPENDIX III

TABLE 18: Summary And ANOVA of Igbara-Oke Sandy Clay Loam at 10,20,30 and 40 blows of proctor hammer at 5% significant difference.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
igbara10	7	316.8	45.25714	262.0629
igbara20	7	421.4	60.2	216.34
igbara30	7	506.7	72.38571	245.8614
igbara40	7	595.4	85.05714	312.3329

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6072.89	3	2024.297	7.811314	0.000828	3.008786
Within Groups	6219.583	24	259.1403			
Total	12292.47	27				

APPENDIX IV

TABLE 19: Summary And ANOVA of Ondo Sandy Clay Loam Soil at 10,20,30 and 40 blows of proctor hammer at 5% significant difference.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
ondo10	7	195.9	27.98571	228.8781
ondo20	7	302.1	43.15714	413.2262
ondo30	7	409.7	58.52857	383.5424
ondo40	7	460.4	65.77143	959.2924

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5934.153	3	1978.051	3.986119	0.019477	3.008786
Within Groups	11909.63	24	496.2348			
Total	17843.79	27				

TABLE 20: Summary And ANOVA of Okeagbe Sandy Clay Loam Soil at 10,20,30 and 40 blows of proctor hammer at 5% significant difference.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Agbe10	7	381.7	54.52857	589.059
agbe20	7	476.8	68.11429	652.4914
agbe30	7	581.9	83.12857	805.159
agbe40	7	678.5	96.92857	861.319

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7081.241	3	2360.414	3.246754	0.039521	3.008786
Within Groups	17448.17	24	727.0071			
Total	24529.41	27				

[illegible]

LE 21: Summary And ANOVA of Owo Sandy Loam Soil at 10,20,30 and 40 blows of proctor hammer at 5% significant difference.

va: Single Factor

MMARY

Groups	Count	Sum	Average	Variance
10	7	351.5	50.21429	256.7381
20	7	430.8	61.54286	282.6029
30	7	518.7	74.1	318.29
40	7	629.3	89.9	481.4533

VA

urce of Variation	SS	df	MS	F	P-value	F crit
ween Groups	6099.221	3	2033.074	6.073208	0.00316	3.008786
hin Groups	8034.266	24	334.7611			
l	14133.49	27				

APPENDIX VII

TABLE 22: Summary And ANOVA of Owo,Okeagbe,Ondo, Igbara, Okiti pupa and Ir... Soil at 10 blows of proctor hammer at 5% significant difference

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
owo10	7	351.5	50.21429	256.7381
agbe10	7	381.7	54.52857	589.059
ondo10	7	195.9	27.98571	228.8781
igbara10	7	316.8	45.25714	262.0029
okiti10	7	128.4	18.34286	20.01619
irele10	7	283.3	40.47143	257.539

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6684.573	5	1336.915	4.96904	0.001404	2.477165
Within Groups	9685.76	36	269.0489			
Total	16370.33	41				

APPENDIX VIII

TABLE 23: Summary And ANOVA of Owo,Okeagbe,Ondo,Igbara,Okitipupa and Irele Soil at 20 blows of proctor hammer at 5% significant difference.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
owo20	7	430.8	61.54286	282.5629
agbe20	7	476.8	68.11429	652.4914
ondo20	7	302.1	43.15714	413.2262
igbara20	7	421.4	60.2	216.34
okiti20	7	175.3	25.04286	24.12952
irele20	7	283.3	40.47143	257.539

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9278.65	5	1855.73	6.030681	0.000378	2.477165
Within Groups	11077.73	36	307.7148			
Total	20356.38	41				

APPENDIX X

TABLE 25: Summary And ANOVA of Owo,Okeagbe,Ondo,Igbara,Okitipupa and Irele Soils at 30 blows of proctor hammer at 5% significant difference

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
owo40	7	629.3	89.9	481.4533
agbe40	7	678.5	96.92857	881.316
ondo40	7	460.4	65.77143	959.2924
Igbara40	7	595.4	85.05714	312.3329
okiti40	7	276.3	39.47143	275.0057
irele40	7	469.9	67.12857	465.7924

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15455.49	5	3091.098	5.542754	0.000604	2.477165
Within Groups	20076.57	36	557.6826			
Total	35532.06	41				

APPENDIX IX

TABLE 24: Summary And ANOVA of Owo,Okeagbe,Ondo,Igbara,Okitipupa and Irele Soils at 30 blows of proctor hammer at 5% significant difference

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
owo30	7	518.7	74.1	318.29
agbe30	7	581.9	83.12857	805.159
ondo30	7	409.7	58.52857	383.5424
Igbara30	7	506.7	72.38571	245.8614
okiti30	7	228.4	32.62857	243.709
irele30	7	387.5	55.35714	473.1262

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11316.96	5	2263.391	5.49881	0.000734	2.477165
Within Groups	14818.13	36	411.6147			
Total	26135.08	41				

Appendix XI

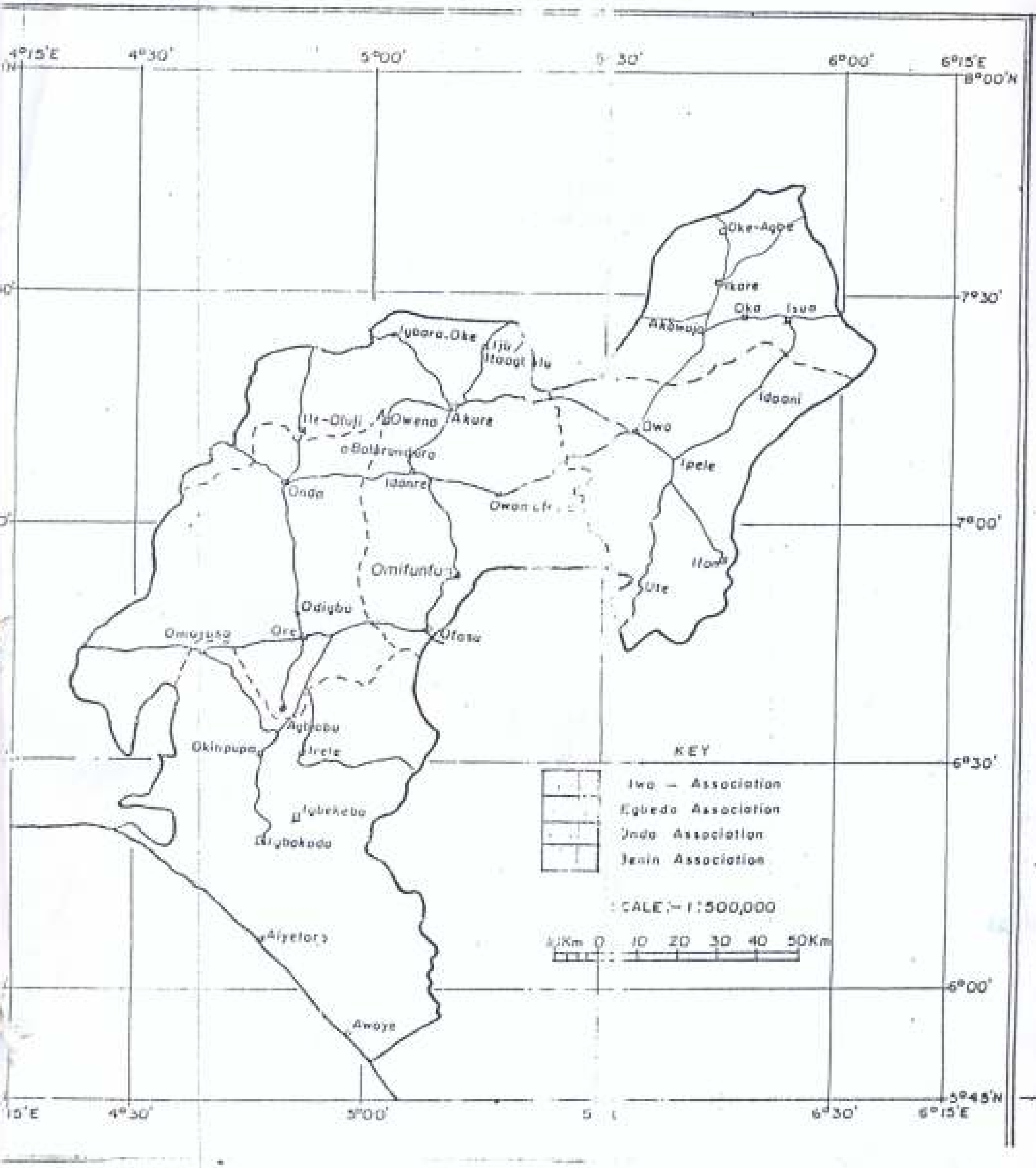

Fig 1: Map of Ondo State