EFFECT OF FARM TRACTOR TYRE INFLATION PRESSURE AND TRAFFIC ON SOIL PHYSICAL PROPERTIES

By

ADU EMMANUEL ADEYEMI
MATRIC NO: 2004/18429EA

BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUREMENTS FOR THE AWARD OF BECHELOR OF (B.ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCE ENGINEERING FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

FEBRUARY 2010

EFFECT OF FARM TRACTOR TYRE INFLATION PRESSURE AND TRAFFIC ON SOIL PHYSICAL PROPERTIES

By

ADU EMMANUEL ADEYEMI

MATRIC NO: 2004/18429EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE.

FEBRUARY 2010

DECLARATION

I, ADU EMMANUEL ADEYEMI of the Department of Agricultural and Bioresource Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna, do hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university of institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text

.... 19/02/2018
ADU EMMANUEL ADEYEMI   Date

CERTIFICATION

This project entitled "Effect of Farm Tractor Tyre Inflation Pressure and Traffic on soil Physical Properties" by Adu Emmanuel Adeyemi meets the regulations governing the award of the degree of Bachelor of engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation

17/2/10

Mallam Adamu Halilu
Supervisor

Date

17/02/10

Engr. Dr.A. A. Balami
Head, Department of Agricultural/Bioresources Engineering

Date

9/2/2010

External Examiner

Date

DEDICATION

I dedicate this research paper work to God Almighty for His help towards me, making this study possible and successful.

ABSTRACT

A single wheel tyre tractor facilitated at National Centre for Agricultural Mechanization, Idofian, Kwara State, Nigeria was used to investigated the relationship between tractor tyre inflation pressure and the number of tyre passages on soil physical parameters. The relationship between inflation pressure and slippage was also studied. A tractor (Tak 90, four wheel drive) with no implement mounted with rear tyres size as 18.4-30 and front tyres size as 12.4-24 with both being radial ply was tested on sandy-loam soil. The experiment was conducted on a land previously cleared mechanically so as to get a condition of filed that will be encountered normally during cultivation to determine the influence of repeated tractor tyre passage on soil compaction. The rear tyres were set at four different inflation pressures of 138, 97, 69 and 48kPa with a constant speed of 10.59Km/h at 1500rpm rotation of the engine. A specific path/tract was taken for each pressure and there were six tyre passes for each inflation pressure on their respective selected tracts. The bulk density, shear strength and cone index was taken after the 2nd, the 4th and the 6th passage of the tyre for each inflation pressure. The slippage was also measured for each inflation pressure on the highway and on the field where the experiment was conducted. The reduction in the tyre inflation pressure from 138 to 48kPa and increase in the number of tyre passes shows increase in soil bulk density, cone index, and shear strength and decrease in wheel slip from 3.6111% to 2.5360% and further increase from 97kPa to 138kPa shows increase wheel slip to 4.03226%. Compaction effect was also seen to be most significant at around soil depth 7cm to 10cm.

TABLE OF CONTENT

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Compaction of agricultural soil occurs when soil particles are rearranged in such manner that they are brought closer to each other, thereby reducing the volume. (Anazodo and Onwualu 1984) considers soils to be compacted when the total porosity and particularly the air filled porosity are so low as to restrict aeration as well as the soil is so tight and its pores so small as to impede root penetration and drainage. Compaction can occur naturally or artificially. Textural composition, moisture status, manner in which soil is formed is possible natural factors affecting soil compaction. Rain drops and subsequent drying reduce the total volume of the soil and hence increase compaction. Nature has a way of controlling its effects on the above mentioned types of compaction. However, there is little or no way through which the soil can naturally rectify the compaction caused artificially. Such are those caused by: tramping of livestock, human beings, soil engaging tools and most importantly wheels and tracks of various equipments and machines used in modern crop production. (Arvidsson et al, 1996). These machines apply pressure to the soil. The pressure in turn rearranges the particles in such a way that the volume of a given mass of soil is decreased; thus, bulk increasing density, penetrometer resistance increases, pore volume decreases and pore size distribution shifts towards a large proportion of small pores. Any change in these properties will affect many other soil properties like hydraulic conductivity, aeration, moisture availability, infiltration rate, etc. The result of the complex interaction involved has been shown by many researchers to have decreased crop yield (Flocker et al, 1978) as reported by (Anazodo and Onwualu, 1984).

In Nigeria, mechanization of agricultural (at least for tillage) is increasing. Although the vehicles involved may not be heavy as those used in more developed countries, the low structural stability and the high erosivity of tropical soil may worsen the problem of compaction (Attanda et al, 2006). In the rain forest zone of the country for example, tillage is done when rain starts. This is the period when soil compaction is more pronounced because of high soil moisture content. On the other hand most of the modern farms in the northern part of the country are under irrigation and so soil compaction will also be a big problem. There is the ever pressing need to bring more land under cultivation to supply the yearly increase in demand of agricultural produce which leads to fully mechanize agricultural production. However, this should not be compromised with the need to protect agricultural lands from such effects of land clearing machines as excessive soil compaction. For agricultural production, land clearing involves the removal of such unwanted vegetation as grasses and shrubs, and retention of top soil for crop growth. The land clearing operating in which stumps are not completely removed is better than one in which the top soil is much disturbed. While the former is an unfinished job, the later is a spoilt. (Anazodo and Onwualu, 1984).

Several methods are employed in land clearing operations such as; manual, chemical and mechanical methods, but the common ones are the manual and the mechanical methods. However, the manual method has obvious limitations in terms of output and capacity and attempt to change this result usually leads to the use of mechanized method. This problem has become of great concern the world over and thus scientist, engineers and field practitioners have conducted field investigations; and made some interesting findings. For example; (Raghavan and Mckyes, 1978) as reported by (Anazodo and Onwualu, 1984) is of the view that the degree of soil compaction depends on soil type, moisture content, contact pressure, wheel slip and intensity of traffic. A study of the literature shows that the best way to solve the problem of soil compaction is to reduce its occurrence in the first place. In 1980, two conferences held in Sweden and The Netherlands. (Soane et al, 1981) as reported by (Anazodo and Onwualu, 1984), called for more research into the mechanics and occurrences of soil compaction, as a first step towards solving the problem.

In Nigerian, substantial studies have been made for our local soil conditions. Such studies justify the use of many imported machines we use in the country. It assists in the recommendation as regards field traffic planning, contact pressure of the tyres of agricultural vehicles, weights of the tractors and implements. One of the most important machines commonly in use during cultivation of agricultural land is the wheeled tractor this is why this study will be on the effect of farm tractor tyre inflation pressure on soil environment. The tractor tyre is directly involved in soil compaction and the tyre's inflation pressure also goes a long way in affecting the effect of tyre on soil physical parameters. (Oni et al, 1995)

1.2 Statement of the Problem

Soil physical parameters that support optimum plant growth and the durability of the tyre itself are adversely affected by the usage of inappropriate farm tractor tyre inflation pressure

1.3 Justification

Many research work has been done on the effects of tractor tyre inflation pressure as related to a lot of factors for example, speed of operation, tractive performance, loading capacity, field efficiency, etcetera) but not as related to soil physical parameters, so this calls for this research work to be done in other to have an additional information on how to maximize mechanized agricultural activities especially ones that involve the use of farm tractor by appreciation the advantages of using the right tyre inflation pressure.

Therefore, this research work will provide information that will; help to improve soil condition especially after tillage operations, improve the performance of the tractor by reducing slippage which will consequently increase field efficiency and increase the durability of the tyre by showing it connection with appropriate tyre inflation pressure

1.4 Objectives

The main objectives of this research work are:

1. To investigate the relationship between tyre inflation pressures and soil compaction.
2. To investigate the relationship between tractor traffic and soil compaction
3. To show the relationship between tyre inflation pressure and wheel slip and also
4. To investigate the soil depth at which compaction is significant.

1.5 Scope

Taking the aerodynamic factor to be constant, this study is limited to the environmental condition in the experimental site i.e. temperature range between 32^0C to 41^oC, relative humidity between 45 to 56, vegetative cover, soil type; sandy-loam, soil moisture regime to the depth of 21cm and soil structure of NCAM in Kwara State of Nigeria. The tractor used is a four-wheel drive Tak 90 with rear tyre size; 18.4-30.

CHAPTER TWO

2.0 LITERATURE REVIEW

Changes in physical properties of soil such as bulk density, porosity, shear strength and cone index which in turn influence edaphic factors through changes in hydraulic, thermal, aeration and mechanical behaviour of soil are going to be the observed soil character that will be used in this study. Bulk density, porosity, shear strength and cone index are all function of how compacted soil aggregate are, therefore, the level of soil compaction will be used to analysis these expected changes in the soil physical properties. Most of the approaches in evaluating soil compaction are based on relating changes in certain soil properties to the number of passes of the tractor tyre as well as the tyre contact pressure. A review of such works was done by (Soane et al, 1981) as reported by (Anazodo and Onwualu, 1984).

Bulk density has been used to evaluate and predict soil compaction due to tractor traffic. Researchers, (Pollard and Webster, 1978; Pollard and Elliot, 1978) all as reported by (Anazodo and Onwualu, 1984) used the same principle. In their studies on a sandy loam soil, sever tractor wheeling was simulated. The soil was then studied for six years. The results showed bulk density to increase from 1.51g/cm^3 to 1.66g/cm^3 in 20 – 30cm depth due to compaction. Water holding capacity was also decreased (14.7 to 13.2%) for the same depth. At deeper depth of 30 – 40cm the corresponding values were 1.59 g/cm^3 and 13.9% & 13.7% for un-compacted and compacted soil respectively. These persisted for two years. In a slightly different approach, (Horn, 1994) in their subsequent works used dry density instead of bulk density to evaluate compaction. This dry density is given as bulk density divided by one plus moisture content of the soil in decimal. Statistical models were developed in subsequent work

(Mohamed et al 2002) relate dry density to position pressure applied (number of passes x contact pressure) and moisture content for different soil types. The soil types were sand, sandy loam, loamy sand and clay. The equations show that dry density of all soil types increases with an increase in contact pressure and decreases with increase in moisture content. Higher densities occurred at the centre line of the tyre and as the distance increases away from the centre the dry density decreases linearly. In similar studies (Gill et al, 1956; Munro et al, 1976; Mckyes et al, 1977) as reported by (Anazodo and Onwualu 1984), dry density measurements were taken at various depth below the tractor tyre and at horizontal distances right and left of the tyre centre line. Lines of contours of equal density change and were than plotted. This was done after machine combination of different weights and tyre contact pressures were used on the soil. The contours obtained were similarly bulb shape as that for pressure distribution. This showed that density changes were more under the tyre centre line and decreased outwards. Models have also been developed to predict penetrometer resistance in term of number of passes and tyre contact pressure, moisture content and depth. This experiment, though done on a clay soil, shows that penetrometer resistance increase with increase in compaction (*number of passes of tractor x contact pressure)* and decreases with moisture content. These relationships were not linear but logarithmic. (Mohamed et al 2002). Another interesting approach was to relate laboratory compaction curves to actual field values. (Weaver and Jamison, 1951), (Raghavan et al, 1976) as reported by (Anazodo and Onwualu, 1984), obtained such curves. They demonstrated that a conventional tractor compaction test could be used to index and predict with reasonable accuracy of compaction behaviour of agricultural soils over a wide range of moisture contents and single or multiple passes of tyre of varying contact pressure. They also concluded that the results are likely to apply to all soil types though they carried out their experiment on soils varying from sand to sandy loam. (Mohamed et al, 2002)

The effect of wheel slip in causing soil compaction has been studied both in the laboratory and in the field. (Poulos, 1981) showed that compaction was increased when shear stress (slip) was superimposed on soil that was originally subjected to axial load. In the field, (Davies, 1973) as reported by (Anazodo and Onwualu, 1984) earlier showed that wheel slip was more effective in causing soil compaction that was additional loads. In a more detailed work by Raghavan it was found that compaction reaches a maximum between 10 and 50% dry density of up to 0.25 d/cm^3, due to wheel slip. The results were confirmed in the laboratory using a modified shear box. Porosity has also been investigated by researchers. (Raghavan et al, 1979) used a term called air filled porosity. This was calculated from bulk density, specific gravity and moisture content. The result shows that porosity decreased with increase in compaction and depicted by number of passes multiply by contact pressure. The porosity values at 0 – 20cm depth were almost double than at 20cm downwards. (Shebi et al, 1983) showed that wheel slippage is a function of tyre inflation pressure, tyre size, tyre shapes, tyre flexibility and soil type. All these studies point to the fact that soil compaction could be checked by a careful choice of farm tractor weight, tyre size, tyre design and number of traffic passes in the farm this is why this study will be checking the effect of tyre inflation pressure on soil compaction to add to the soil compaction factors. However, it should be pointed out that the net effect of soil compaction on crop production is not always disadvantageous. Indeed, (Anazodo et al, 1984), showed from their field investigations that moderated level of soil compaction have beneficial effect in silage corn production under appropriate tillage mechanization system. The total amount of soil deformation can be related to soil compaction which should be minimized in agricultural tractors and machineries. This can be achieved by using wide low-pressure tyres or by reduction of vehicles' mass. The higher the soil deformation the greater the rolling resistance as more traction energy is consumed on soil deformation then fuel consumption increases. It is not practical to use wide-low pressure tyres as their effect on tractive performance is negative for tractors running on hard roads and increases the tear wear of the tyre thereby reducing it durability. (Anazodo et al, 1984)

2.1 Soil Physical Properties

Oxford advanced learners dictionary defined soil as the upper layer of the earth in which plants and trees grow. According to the International Society of Soil Science (ISS), soils are broadly classified into three types depending on their particle size. Soil having particle size less than 0.002mm diameter are clay, those with particle size range between 0.002mm and 0.02 diameter are silt while those with particle size ranges between 0.02mm to 2.00mm are sand. Any soil with particle size greater than 2.00mm diameter cannot be considered as agricultural soil. (Fariran and Areola, 1978)

2.1.1 Soil Strength

Many studies have been carried out in order to determine the best relationships existing between a pneumatic tyre and its off-highway medium which it operates. (Onafeko and Reece, 1997) as reported by (Mohamed et al, 2002) set out to carry out full scale wheel tests to check the validity of the Bekker-Land locomotion laboratory theories. They came up in 1964 with a formula describing shear stress of soil as a function of the soil cohesion, soil pressure, rolling radius of wheel, wheel entry angle, wheel slip and angle of shearing resistance of the soil. Shear strength in reference to soil is a term used to describe the maximum strength of soil at which point significant plastic deformation or yielding occurs due to an applied shear stress. There is no definitive "shear strength" of a soil as it depends on a number of factors affecting the soil at any given time and on the frame of reference, in particular the rate at which the shearing occurs. In very simple terms, the strength of soil is the *maximum shear stress* (τ_f) it can sustain, or the shear stress acting on a shear slip surface along which it is failing. There are three distinct strengths: peak, critical (or ultimate) and residual. Shearing may be simple or direct. (Ziesak, 1999).

Peak strength: The peak strength is the maximum value of the shear stress or the maximum value of the ratio of shear stress to effective mean or normal stress. For drained tests these will occur simultaneously, for undrained tests they may occur at different points and the definition used here is the maximum stress ratio. (Ziesak, 1999).

Critical state strength: At its critical state soil continues to distort at constant effective stress and at constant volume. This applies for turbulent flow of the particles: if the flow becomes laminar, as in clays at large strain, the strength falls to the residual. (Ziesak, 1999).

When soil is at its critical state there is a unique relationship between shear stress, effective normal stress and water content (or specific volume or void ratio). Critical states are unique and do not depend on initial state or stress path. Critical shear stress (critical state strength) increases with increasing effective normal stress and with decreasing water content. The critical state line can be represented as a graph in 3 dimensions. For isotropic compression, shear stresses are zero and the isotropic normal compression line can also be represented. (Poulos, 1971)

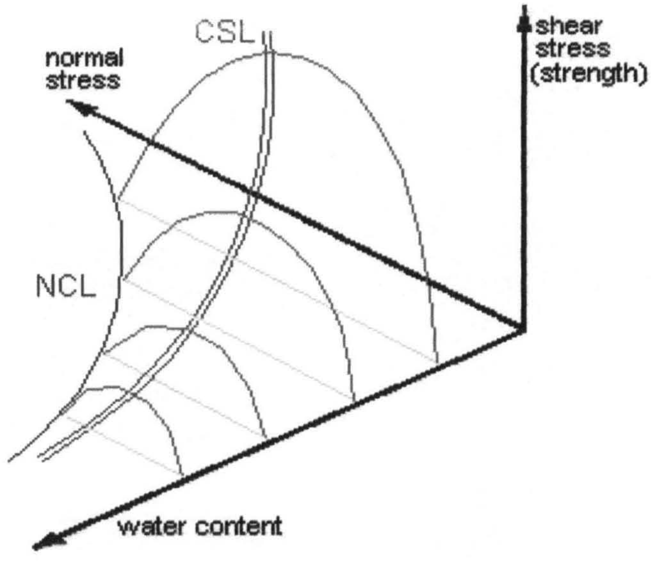


Fig 2.1: Isotopic Compression (three dimensional representations)

Residual strength: This is the very lowest strength which occurs after very large displacements. For sands the residual strength is the same as the critical state strength. For clays the residual is about ½ the critical state strength. For clays the flat clay particles become aligned parallel to the direction of shear. (Ziesak, 1999)

2.1.1.1 Factors Controlling Shear Strength of Soils

(Poulos, 1981) as reported by Wikipedia, the stress-strain relationship of soils, and therefore the shearing strength, is affected by:

1. Soil composition (basic soil material): mineralogy, grain, size and grain size distribution, shape of particles, pore fluid type and content, ions on grain and in pore fluid.
2. State (initial): Defined by the initial void ratio, effective normal stress and shear stress (stress history). State can be described by terms such as: loose, dense, over consolidated, normally consolidated, stiff, soft, contractive, dilative, etc.

3. Structure: Refers to the arrangement of particles within the soil mass; the manner the particles are packed or distributed. Features such as layers, joints, fissures, slickenside, voids, pockets, cementation, etc, are part of the structure. Structure of soils is described by terms such as: undisturbed, disturbed, remoulded, compacted, cemented, flocculent, single-grained; flocculated, deflocculated; stratified, layered, laminated; isotopic and anisotropic.
4. Loading conditions: Effective stress path, i.e., drained, and un-drained; and type of loading, i.e., magnitude, rate (static, dynamic), and time history (monotonic, cyclic). (Poulos, 1981).

Cone penetrometer is use to measure soil strength in traction studies. (ASAE, 1884) defined cone Index as the force per unit area required to push the penetrometer through a specified very small increment of soil. The effect of shear strength of the soil on slippage and tractive efficiency at wheel numeric (C_n) of 30, tractive efficiency was 0.72 and slip was 0.16 while at C_n of 50, tractive efficiency was 0.63 and slip was 0.18. It was also deduced that maximum tractive efficiency occurs at lower slip values for the large C_n values that are associated with higher soil strengths or lower wheel loading. (Wismer and Luth, 1974) as reported by (Ahmed, 2001)

2.1.2 Soil Bulk Density

Soil compaction is an increase in bulk density and a decrease in pore space of the soil that is often caused by applying pressure to the soil with tractors and other heavy equipment such as trucks, combines and grain carts. Compaction can cause a physical barrier to normal healthy root growth, causing symptoms of water stress and nutrient stress. The effects of reduced pore space are reduced water infiltration, water holding capacity, and air exchange. In years when moisture is either in short supply or excessive, the pore space in a well-structured soil acts as a reservoir and conduit system for water, buffering the effects of moisture extremes. An ideal soil is composed of about 50 percent pore space allocated equally to air and water. Pore space also allows roots to displace soil as they grow. But heavy wheel traffic, especially under wet soil conditions, damages soil structure and packs soil particles closely together, reducing pore space. Tightly packed soil is a serious condition for plants. Roots encounter a physical barrier to growth because there is nowhere to move the soil, and the reservoir and conduit system for air and water is shut down. (Ahmed, 2001)

(Oni et al (1995) defined soil bulk density as a property of the soil which describes how tightly the soil particles are pressed together. He went further to say that this property increases with moisture content as well as depth. This was further corroborated by (Sherrudin et al, 1998), (Thorne and Thorne, 1979) as reported by (Ahmed, 2001) gave an equation relating bulk density of the soil with available soil moisture as:

$$\Phi a = (dB \times Is \times \Phi s)/dw \qquad (2.1)$$

Where; Φa = available soil moisture (g/cm)

dB = bulk density of soil (g/cm^3)

dw = density of water (g/cm^3)

Is = depth of soil (cm)

Φs = percentage of soil moisture (g water/100g dry soil)

(Ahmed, (2001).

Bulk density is the ratio of mass of the soil to its total volume. Thus the bulk density according to (Oni et al, 1995) is given as

$$dB = M/V = (Ms + Mw + Ma)/V \tag{2.2}$$

Where;	dB	=	bulk density (g/cm^3)
	M	=	total mass of soil (g)
	Ms	=	mass of mineral soil (g)
	Mw	=	mass of water in the soil (g)
	Ma	=	mass of air, assumed negligible (g)
	V	=	total volume of soil (cm^3)

The higher the bulk density, the more compacted the soil particles and the lower the pore space (porosity). (Oni et al, 1995)

2.1.3 Soil Permeability

Permeability of soil is its capacity to transmit water and air through it self. Good soil aeration id essential to plant growth. Soil aeration is dependent on size range and quantity of soil macro-spaces through which gasses can move and diffuse freely within the soil and by which soil air can be constantly replenished from atmosphere. Air movement in soils is influenced by many environmental factors such as temperature, barometric pressure and soil moisture content occupying pore space, and action of wind. (Ankidawa et al, 2007). (Grover, 1995) gave the definition of soil moisture content as the amount of liquid, usually water, which is present in the soil. It is expressed as a percentage of mass of water in the soil to the mass of dried soil (for dry weight classification), or mass of water to the mass of wet soil (for wet weight classification).

(Yusuf, 2001) reported in his study of the performance of rigid tines in relation to soil parameter the moisture content affects the type of failure caused by an implement as well as the failure strength of the soil. (Oni et al, 1995) supported this view by stating that when moisture in high, the soil becomes very difficult to work owing to its increased failure strength and when the moisture becomes too high the difficulty on working on the soil no longer due to hardness but due to too much softness of the soil which makes wheel slip excessive. An increase in soil moisture content had a tendency to reduce the specific draught requirements of a disc plough in clay soil. (Yusuf, 2001)

2.2 Slippage

The primary purpose of the tractor tyre or track is to support the weight of the tractor while moving with the minimum amount of resistance over a field surface. To do this, the wheel or track must rearrange soil particles so as to give the soil enough strength to support the weight as well as generate forward propulsion. When a tyre passes over an agricultural soil it deforms the soil vertically and leaves a wheel track. The tractor tyre may be thought of as permanently travelling up a hill or climbing out of its own track. The effect of this is a retarding force or Rolling Resistance. Rolling resistance increases in direct proportion to an increase in weight on the tire. (Ahmed, 2001). Just as the soil deforms vertically in response to the tractors weight it must deform horizontally to generate traction. The amount the soil deforms horizontally is referred to as wheel slip. At zero level of wheel slip, no soil deformation is occurring and in consequence no power. At 100% wheel slip, considerable thrust is being generated but since no forward motion is occurring, no power is being produced. (Akker van den, 1988).

Tractive efficiency measures how well a tractor uses the power available at the axle to pull an implement through the soil. Improving tractive efficiency reduces costs through improved fuel efficiency and increases the productivity of the tractor. Improving tractive efficiency doesn't usually require an investment in new equipment. The time spent in improving tractive efficiency provides immediate fuel savings and improved performance. Lightly ballasted tractors and tire inflation pressures maintained at optimum levels for safe operation and satisfactory tire life also protect the soil. Overinflated tractor tires are a common cause of poor tractive efficiency and compaction. Large forces from overinflated tires and over-ballasted tractors compact the soil, squeezing soil particles closely together and reducing pore space. Crops grown in soils damaged by compaction are less likely to survive moisture extremes such as heavy rain and droughts. Appropriate inflation pressures and properly ballasted tractors minimize the forces applied to the soil surface, which minimizes compaction and improves long-term productivity of the soil. Carefully managed tire inflation pressure and ballast can maximize tractive efficiency by checking slippage, minimize compaction, and increase tractor drive train life and also increase profitability. (Dipankar De, 1982)

2.2.1 Types of Tractive Efforts

When a figure for tractive effort is quoted in technical documentation it is either for the starting tractive effort (at a dead start with the wheels not turning) or as the continuous tractive effort which will be quoted at a particular speed.

The maximum tractive effort: is the maximum pulling force a vehicle or machine can exert under any (non-damaging) conditions. In general the maximum tractive effort will be obtained at a standstill and/or low speeds. A variety of factors limit the maximum value:

- The maximum tractive effort cannot exceed the 'Tractive mass (m)' x 'the coefficient of friction' (μ) If a vehicle attempts to supply more force ($F_{tractive} >$ μm) this will cause Wheel spin.
- The gear ratios of drive components.
- The maximum power capable of being supplied to the drive systems.
- The safe working torques of the drive system components.

The continuous tractive effort: is the tractive effort which is supplied at a given velocity. It may refer to the tractive effort required to keep a vehicle rolling without acceleration or the maximum force that can be produced at given speed. Because of the relationship between Power (P), velocity (v) and force (F) of:

$$P = vF \text{ or } P/v = F \qquad (2.3)$$

(Mohamed et al, 2002)

The continuous tractive effort is inversely proportional to the velocity for constant power. In vehicles, which have a power, source (diesel engine, etc), which is limited in terms of maximum total power the maximum continuous tractive effort at a given speed, is limited by the engine's power. Continuous tractive effort is quoted as a force at a given speed. (Bower, 1993) as reported by (Mohamed et al 2002)

Note: As with any physical formula, consistent units of measurement are required: pressure in psi and lengths in inches give tractive effort in lbs, while pressure in Pa and lengths in metres give tractive effort in N.

Force is applied to the tire in two ways:

Force is applied to the tire in two ways:

- Longitudinally - Longitudinal force comes from the torque applied to the tire by the engine or by the brakes. It tends to either accelerate or decelerate the car.
- Laterally - Lateral force is created when the tractor drives around a curve. It takes force to make a tractor change direction -- ultimately, the tires and the ground provide lateral force.

For a wheel based machine the important factors, which vary the energy impact to the soil, are the load per wheel, the dimension of the wheel, the type of wheel and the inflation pressure of the tyre. In order to understand the interaction of a vehicle with the soil the contact points of a machine with the ground are important: the wheel and its tyre. Here we have static and dynamic forces, which lead to soil-interaction.

Static forces: The static forces are influenced by the following parameters:

- Total weight of the machine
- Weight distribution
- Number of wheels and
- Type of tyre used.

The pressure under the tyre depends not only from the forces, but also from the size of the contact area. (Ziesak. 1999)

$$Pressure = force/area\ [Pa = N/m^2] \tag{2.4}$$

2.3 Tyres

Tyre, a covering mounted on the rim of a wheel that serves as a cushion and surface for traction. Tyres are used on road vehicles, tractors, aircraft and spacecraft landing gear, factory and warehouse machinery, and on a variety of other vehicles, including shopping carts and baby carriages. Tyres are made of chemically treated rubber and fabric. Those for indoor use are generally solid rubber with a smooth surface, while those used outdoors are pneumatic, or hollow and filled with pressurized air, and have a traction pattern cut into the surface. (Redmond, 2007). Tyres are quite a complicated piece of technology, most people think that they are simply a rubber ring that is there to grip the road and help stop the road bumps being transferred to the vehicle. However 'gripping' the road is not as simple as it sounds given the various extreme conditions that our everyday tyres have to put up with, extremes of temperature, extremes of dry and wet conditions, extremes of cornering forces, acceleration forces and braking forces. (Redmond, 2007)

A tyre has to deform slightly at the point of contact with the road for instance in, order to achieve any change of direction or speed and it has to do this in a progressive and predictable way in all the extremes of conditions that driving on the road throws at it. It has to do this also without excessive wear, damage or permanent deformation. This study is on the effect inflation pressure of a tractor tyre has on the path it treads. The tractor tyre is an example of a pneumatic tyre. (Redmond, 2007)

2.3.1 Pneumatic Tyres

Pneumatic tyres are tyres that are filled with pressurized air inside it. The main parts of the pneumatic tyre are the tread, the body, and the beads. The tread is a thick pad of rubber into which grooves are cut to form cleats or ridges. The tread provides traction to move and stop a vehicle and to prevent skidding and sliding while a vehicle is in motion. Tractor tyres have especially deep grooves that enable the tire to move through soft earth. The body gives the tyre its strength and form. It consists of layers of fabric permeated with rubber. Each fabric layer is called a ply, and the number of plies in its body sometimes describes the strength of a tyre. The beads of a tyre are the two bands that hold the tyre to its wheel. They are located along the tyre's inner edges and are made up of strands of wire surrounded by rubber and covered. In conventional bias-ply construction, the threads, or cords, of the fabric ply lie at an angle to the tread line of the tire. In radial tyres, the cords run straight across. Radial tyres also have fibreglass or steel belts between the plies and the tread. A bias-belted tire combines these features and has both angled cords and a belt. This arrangement strengthens the sidewalls and increases the tyre's load-carrying capacity. (Redmond, 2007)

2.3.2 Tyre Size and Rating

Load capacity of a tyre is determined by its size and inflation pressure. Larger tyres, allowing higher inflation pressure provide more load capacity while smaller tyres allowing lower inflation pressure provides less load capacity. Pneumatic tyres are made in a variety of sizes. Manufacturers of agricultural tractor tyres are moving to metric sizing and a new load rating system. This is an example of a metric tyre rating; 520/85R42 157 A8 R1. How to interpret the information in the size listing is shown below: www.drivertechnology.co.uk/tyre-size-coding

(Metric Size Rating) 520/85 / R42 / 157 / A8 / R1

A B C D E

A. Tire section width - Width of the tyre in mm, divided by 25.4 to convert to inches, for example; 520mm/25.4 = 20.5 inches.

Aspect ratio - This number provides the height of the tyre relative to the tyre width. In this, 85 is the aspect ratio; this means the tyre section height is 85% of the tyre width, 20.5 in. x 85% = 17.4 in.

B. Tire construction - The R after the aspect ratio indicates the tyre has Radial Construction.

Nominal rim diameter - Located after the tyre construction. In this example, 42 indicate a 42 in. rim.

C. Load index (LI) - This is a uniform way to report the load-carrying capacity of a tyre. For example, a 157 LI means that the tire has a maximum load carrying capacity of 9,100 lb. at the speed specified by the speed symbol when the tire is inflated to its rated inflation pressure. When a tire is used in single application, there would be 18,200 lb. load carrying capacity for the axle (9,100 x 2 tires).

D. Speed symbol - top speed that a tire is designed to travel; A8 is rated for 25 mph (40kph).

E. Tread depth - R1 Standard tread, R1W Wet Traction tread, R2 Cane and Rice tread.

From this the rolling circumference can be worked out.

$$Diameter, d = (2 \times B) + C, \qquad (2.5)$$

$$therefore, d = (2 \times 111 = 222) + (15" \times 25.4 = 381) = 603mm$$

$$Circumference, C = pi \times d \qquad (2.6)$$

$$therfore\ C = 3.142 \times 603 = 1895mm$$

CHAPTER THREE

3.0 METHODOLOGY

3.1 Experimental Site

This research work was conducted at the National Centre for Agricultural Mechanization Idofian, Kwara State which is in the Northern Guinea Savannah Zone of Nigeria. The particle size analysis of the site was early conducted by the centre and it shows that the soil type is Sandy-loam. Measured Temperature range of the day is between 33°c to 40°c and Relative Humidity range between 46- 58. The moisture content and the bulk density of undisturbed soil in the area at three depths are given in table 3.1 below

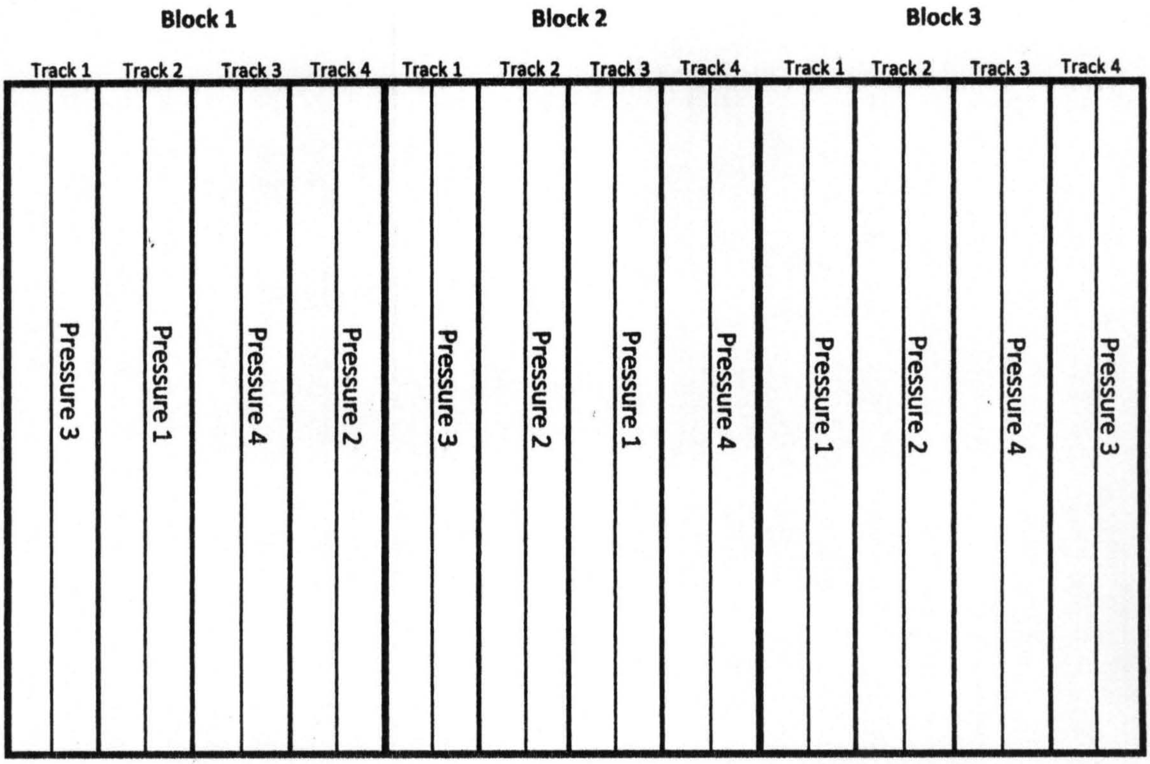
Table 3.1 Sites' soil parameters before the experiment

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear Strength (kPa)	Cone Index
0-7	7.86	1.4334	16	20
7-14	9.55	1.4672	40	95
14-21	11.75	1.4854	72	160

3.2 Experimental Layout and Design

A randomized block statistical design with a total of four treatment combinations was planned with each in three replicates i.e. the experimental area was divided into three blocks with each block having a track for the each selected tractor tyre inflation pressure. The treatment (tyre inflation pressure) was randomly selected for the four tracks in each block so as to minimise variation in measurement due to bias error. The experiment factors considered are of two types; the Quantitative factors: Temperature, Tyre size & Relative humidity and the Qualitative factors: Soil Condition & type and Tractor type. The Variables are the Bulk density, Cone Index, Shear Strength and The Wheel slip.

Figure 3.1 Randomized Complete Design Block (3x4)



3.3 Experimental Tractor and Equipment

1. Tractor: The following are the specifications of the tractor used for this experiment: Tractor model: Tak 90 (4WD); Rear Tyre size: 18.4R30; Front Tyre size: 12.4 R24; Tyre maker: Good Year.
2. Equipments Used to Estimate Soil Compaction: the equipment used includes; the bulk density apparatus, cone penetrometer, shear vane, electronic sensitive weighing balance and oven.
3. Equipments Used to Adjust the Tyre Inflation Pressure: The equipments used for adjustment of the tractor tyre inflation pressure are; Air Compressor and the pressure gauge

3.4 Experimental Procedure

Soil surface preparation was carried out in the experimental field one week before the main experimental day; the land was ploughed using disk plough with three disks. The large soil clods formed by disk ploughing were further reduced using an off-set disk harrow with seven disks per gang.

3.4.1 Soil Cone Index Measurement

The cone penetrometer was used in the measurement of cone index. Measurements at three soil depth (0-7cm, 7-14cm, 14-21cm) were taken after the second, fourth and six passage of the tractor tyre for each selected inflation pressure with each pressure having it own tract within the block. The procedure was repeated for block2 and block3. The data collected were recorded and the average values were calculated.

3.4.2 Shear Strength Measurement

The Shear Vane was used to measure shear strength. Measurements at three soil depth (0-7cm, 7-14cm, 14-21cm) were taken after the second, fourth and six passage of the tractor tyre for each selected inflation pressure with each pressure having it own tract within the block. The procedure was repeated for block2 and block3. The data collected were recorded and the average values were calculated.

3.4.3 Soil Bulk Density Measurement

The bulk density apparatus, electric oven and the electronic weighing balance were used in the measurement of bulk density. The bulk density apparatus was used to take soil sample at three soil depth (0-7cm, 7-14cm, 14-21cm) after second, fourth and six passage of the tractor for each selected tyre inflation pressure with each pressure have it tract within the block. The soil samples collected for each inflation pressure at the three different soil depth were carefully packaged and labelled. This procedure was carried out again for block2 and block3. All the samples were then weighed using the sensitive electronic weighing balance to get the wet weight and records were carefully made. The samples were then put into the electric oven for 30hours at a temperature of $105^{o}c$ to dry it. The dry weight was then measured using the weighing balance and record was also made. The average wet weight, dry weight moisture and moisture content was then calculated. Bulk density for each inflation pressure after the second, fourth and sixth tractor passage at the three different soil depth was calculated using the average values of dry weight using the formula;

$$dB = dry\ weight\ at\ 105°C/166.31\ (g/cm^3) \qquad (3.1)$$

Where, db = bulk density and 166.31 is the volume of the bulk density apparatus' cylinder. The percentage moisture content was also calculated using the formula;

$$\%MC = \frac{A-B}{B} \times 100 \qquad (3.2)$$

(Mohamed et al 2002)

Where; A = Wet Weight

B = Dry weight at $105^{0}C$

3.4.4 Slippage Measurement

The slippage at different tractor tyre inflation pressure was measured using the distance covered by ten revolution of the tractor's rear tyre with a constant speed of 10.6km/k at 1500rmp. The tractor speed was ensured to be constant by running it a few meters to attain and maintain it at 10.6km/h before the start of the counting of the tyres' revolution. A mark is made on the ground at the start of the counting of the tyre's revolution and after the tenth revolution another mark was made. The distance between the two marks was then measured. This was done for each selected inflation pressures on the highway and on the experimental site and percentage slippage was calculated using the formula

$$Slippage = (Dt - Df)/Dt \times \frac{100}{1} \tag{3.3}$$

(Mohamed et al 2002)

Where; *Dt* = distance covered on the highway by ten rear tyre revolution

Df = distance covered on the field by ten rear tyre revolution

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Average Values of Soil physical Parameters at Different Inflation Pressure

At Inflation Pressure of 138kPa (20 psi), the average values of moisture content, bulk density, shear strength and cone index measured after the second, fourth and sixth tyre passage are given in table 4.1,4.2 and 4.3 respectively.

Table 4.1: Soil physical parameters at tyre inflation pressure of 138kpa after 2 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	8.91	1.7358	58	95
14	9.99	1.7195	86	185
21	10.40	1.6289	128	200

Table 4.2: Soil physical parameters at tyre inflation pressure of 138kpa after 4 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	5.88	1.8555	68	135
14	8.91	1.7986	101	200
21	7.39	1.7164	136	215

Table 4.3: Soil physical parameters at tyre inflation pressure of 138kpa after 6 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	7.71	1.9871	85	147
14	10.51	1.8419	109	207
21	11.00	1.7419	141	228

At Inflation Pressure of 97kPa (14psi), the average values of moisture content, bulk density, shear strength and cone index measured after the second, fourth and sixth tyre passage are given in table 4.4,4.5 and 4.6 respectively.

Table 4.4: Soil physical parameters at tyre inflation pressure of 97kpa after 2 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	9.01	1.6271	50	72
14	10.66	1.6419	80	167
21	11.51	1.6042	113	194

Table 4.5: Soil physical parameters at tyre inflation pressure of 97kpa after 4 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	7.67	1.7078	62	88
14	8.54	1.7457	97	160
21	10.46	1.6911	124	197

Table 4.6: Soil physical parameters at tyre inflation pressure of 97kpa after 6 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	7.69	1.7311	72	104
14	8.77	1.7714	103	171
21	10.86	1.7153	132	203

At Inflation Pressure of 69kPa (10 psi), the average values of moisture content, bulk density, shear strength and cone index measured after the second, fourth and sixth tyre passage are given in table 4.7,4.8 and 4.9 respectively.

Table 4.7: Soil physical parameters at tyre inflation pressure of 69kpa after 2 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	7.67	1.6014	51	64
14	8.90	1.6248	83	147
21	9.21	1.5872	110	180

Table 4.8: Soil physical parameters at tyre inflation pressure of 69kpa after 4 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	7.00	1.6888	58	97
14	8.22	1.7049	96	171
21	9.92	1.6735	125	212

Table 4.9: Soil physical parameters at tyre inflation pressure of 69kpa after 6 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	7.40	1.7481	78	118
14	10.04	1.7526	101	180
21	11.89	1.7093	125	214

At Inflation Pressure of 48kPa (7 psi), the average values of moisture content, bulk density, shear strength and cone index measured after the second, fourth and sixth tyre passage are given in table 4.10,4.11and 4.12 respectively.

Table 4.10: Soil physical parameters at tyre inflation pressure of 48kpa after 2 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	8.22	1.5313	46	49
14	9.11	1.5642	81	120
21	10.80	1.5479	109	177

Table 4.11: Soil physical parameters at tyre inflation pressure of 48kpa after 4 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	8.03	1.6805	58	70
14	8.53	1.6991	94	149
21	9.73	1.6313	121	188

Table 4.12: Soil physical parameters at tyre inflation pressure of 48kpa after 6 tyre passes

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Shear strength(kPa)	Cone Index
7	8.11	1.7011	68	95
14	8.81	1.7283	100	161
21	9.18	1.6544	119	197

4.1.2 Calculating Slippage at Different Inflation Pressure

$$Slippage = \frac{Dt - Df}{Dt} \times \frac{100}{1} \qquad (4.1)$$

(Mohamed et al 2002)

Where: Dt = distance covered by ten revolution of the tractor's rear tyre on the high way measured in meters.

Df = distance covered by ten revolution of the tractor's rear tyre on the field measured in meters.

→ Slippage for 138kPa (20psi) tyre inflation pressure, having Dt = 38.7m and Df = 7.2m

$$Slippage = (38.7 - 37.2)/38.7\ x\ 100/1 \quad = 4.0323\%$$

→ Slippage of 97kPa (14psi) tyre inflation pressure, having Dt =37.45m and Df = 36.5m

$$Slippage = (37.45 - 36.5)/37.45\ x\ 100/1 = 2.5367\%$$

→ Slippage at 69kPa (10psi) tyre inflation pressure, having Dt = 37.2m and Df = 36.2m

$$Slippage = (37.2 - 36.2)/37.2\ x\ 100/1 \quad = 2.7624\%$$

→ Slippage at 48kPa (7psi) tyre inflation pressure, having Dt = 36.0m and Df = 34.7m

$$Slippage = (36 - 34.7)/36\ x\ 100/1 \quad = 3.6111\%$$

4.2 Discussion of Results

4.2.1 Effect of Farm Tractor Tyre Inflation Pressure on Slippage

Travel reduction, according to (Douglas et al, 1980) refers to the reduction in forward speed that occurs due to the increase in slippage of the traction member when a wheel or a track propels a tractor with or without an attached load over the medium. The term slip is often use interchangeably with travel reduction. Higher inflation pressure reduces rolling resistance slightly and typically provides a slight improvement in steering response and cornering stability. Increasing tyre inflation pressure fr 48kPa to 97kPa shows decrease in wheel slip from 3.6111% to 2.5360% and further increase from 97 to 138kPa shows increase wheel slip. Achieving maximum tractor performance requires optimizing tyre inflation pressure. Overinflated tyre has smaller footprints and produces less traction. However, underinflated tyres have decreased durability and life. Although both cases are detrimental, the majority of tractors have tyres overinflated. Over inflating tyres will significantly reduce tractive performance. The tyre must have optimum ground contact to transfer power effectively. Over-inflated and under-inflated tyre especially the rear tyres increase wheel slip which result in more operating time, more fuel consumption and off cause high operating cost, but if the tyre inflation pressure is moderate there will be reduction in wheel slip which means an increase in field capacity. In other words, the operator will now finish tillage operations quicker. When the field capacity is increased, labour and operating cost are reduced. The primary concern about lowering inflation pressure in tyres is the tyre life but as long as the inflation pressure is set for then weight that the tyre is supporting, tyre durability should not be a problem.

4.2.2 Effect of Farm Tractor Tyre Inflation Pressure on Soil Bulk Density

The soil bulk density was observed to increase as the tyre inflation pressure increases as shown in fig 4.1. This is as result of the reduction in tyre-ground contact area thereby increasing the pressure on the treaded path. The increase in tyre inflation pressure causes the side wall of the tyres not to bend. This makes the tyre-ground contact area to be smaller as the inflation pressures go higher form 48 to 138kPa. The increase in pressure caused by the rut depth of the reduced tyre-ground contact area result in a compacting effect on the soil, bringing the soil particles closer to each other thereby increasing the bulk density of the soil and reducing the pore space.

4.2.3 Effect of Inflation Pressure on Cone Index

The increase in tyre inflation pressure has been seen from its effect on bulk density to increase soil compaction. A compacted soil generally has poor aeration, low nutrient and water availability to crop root and limit root system development. Cone index was observed to increase as the tyre inflation pressure increases as show in figure 4.2; this means an increase in the level of soil compaction. The soil resistance to cone penetrometer pressure measured after the each test was found to be higher that that obtained before the test was conducted. This could be due to tractor's weight compressing the soil. This weight of compression being impacted on the ground through the tyre, the tyre-ground contact area was seen to play an important role in the distribution of this pressure. Higher tyre inflation reduces the tyre-ground contact thereby concentrating the weight on a smaller area and since pressure is force per area, the pressure per area in contact will be more. This explains while there is a significant increase in the value of cone index as the tyre inflation pressure goes higher. At soil depth (0-7cm), the cone index increase from 49 to 95 when the tyre inflation pressure was increased from 48 to 138kPa and also at soil depth(7-14cm), a significant increase was seen with cone index increasing from 120 to 185 as the tyre inflation pressure increase from 48 to 138kPa. At soil depth (14 – 21cm) the effect of tyre pressure was seen to be minimal as the increase in cone index value before the experiment and after the second passage was not as much as that of the previous soil depth. At soil depth (14 – 21cm) the cone index before the experiment as shown in Table 3.1 was 160 while after the second tyre passage at inflation pressure of 48kPa it was 177, also the increase in the value of cone index as the inflation pressure increases from 48 to 138kPa was not as significant as that of the previous soil depth with increase from 177 to 200.

4.2.4 Effect of Farm Tractor Tyre Inflation Pressure on Soil Shear Strength

According to (Dipankar De et al, 1982), reduced inflation pressure has greater contact area as the tyre deforms (deflects) more intensively and therefore results in decrease of soil deformation in both vertical and longitudinal directions. For higher inflation pressure Moreover, contact pressure becomes smaller and the soil surface is loaded more with higher force per contact area. According to Akker van den J. (1988) this is easily predictable with the Bekker's equation:

$$P = (kc/b + k\varphi)zn \qquad (4.2)$$

Where:

P – Contact pressure, kPa; kc,

kφ – coefficients,

n – Soil state exponent,

b – Wheel width.

From fig 4.3, it can be seen that at each soil depth especially from 0-7cm the shear strength of the soil was increasing as the tyre inflation pressure increases, this is due to increasing soil compaction as the inflation pressure increases. This effect on soil shear strength confirms the behaviour of tyre inflation pressure on soil compaction as it as been seen on both soil bulk density and cone index. Heavy vehicles running on soft, moist soils cause huge deflections of soil surface, which are irreversible and immediate in the first pass of a vehicle. The total amount of soil deformation can be related to soil compaction, which should be minimized in case of agricultural tractors and machinery. That can be achieved by means of using wide low-pressure tyres, parallel wheels or by reduction of vehicles' mass. The higher the soil deformity, the greater the rolling resistance is, as more traction energy is consumed on soil deformation. Then, fuel consumption increases. It is not practical to use wide low-pressure tyres as their effect on tractive performance is negative for vehicles running on hard roads.

4.2.5 Effect of Farm Tractor Traffic on Soil Compactive State.

Fig 4.4, 4.5 and 4.6 illustrate the influence of repeated passes of agricultural tractor on soil Compactive state. It was observed that soil bulk density and cone index increased with increase in tractor passes, attaining maximum values at the sixth pass. The two tractor passes gave the least variation in soil bulk density as the depth increases but was consistently higher in value then the zero tractor pass at each soil depth.

4.2.6 Soil Depth at which Farm Tractor Tyre Inflation Pressure and Traffic r: More Compaction Effect

Soil compaction according to this study is indicated by increase in soil bulk density and soil resistance to cone penetrometer and is caused by two factors; the increased tyre inflation pressure and tractor traffic. Some studies have shown that when soil is compacted, bulk density increases, pore volume decreases, size distribution shift towards smaller pore size and pore space continuity decreases. A compacted soil generally has poor aeration, low nutrient and water availability to crop root and can limit root system development. (Yusuf, 2001). It was established above that increasing tyre inflation pressure increases soil compaction and thus increases soil bulk density but from in fig4.4, significant increase in soil bulk density was observed at soil depth of 7cm and 14cm. Comparing Fig 4.4, 4.5 and 4.6, as the tyre inflation pressure increases (from 48kPa to 138kPa), the corresponding increase in the values of soil bulk density at the three selected soil depth (7, 14 and 21cm soil depth) was most significant at soil depth of 7cm, then followed by soil depth of 14cm and lest significant at soil depth of 21cm. This can be confirm by subtraction the value of bulk density before any tractor traffic in for each soil depth in Fig 3.1 from the value of bulk density of tyre inflation pressure of 138kPa after the selected number of tyre passes (2,4 and 6).

For two tyre passes -	Soil depth, 7cm:	$1.7358 - 1.4334 = \mathbf{0.3024}$
	14cm:	$1.7095 - 1.4672 = 0.2423$
	21cm:	$1.6239 - 1.4854 = 0.1385$
For four tyre passes –	Soil depth, 7cm:	$1.8555 - 1.4334 = \mathbf{0.4221}$
	14cm:	$1.7986 - 1.4672 = 0.3314$
	21cm:	$1.7164 - 1.4854 = 0.2317$
For Six tyre passes –	Soil depth, 7cm:	$1.9871 - 1.4334 = \mathbf{0.5537}$
	14cm:	$1.8419 - 1.4672 = 0.3747$
	21cm:	$1.7419 - 1.4854 = 0.2565$

Maximum increase in bulk density for each selected tyre passes was found at soil depth of 7cm followed by 14cm and least at 21cm. Another important factor that made the above conclusion possible is the increasing tyre inflation pressure that causes huge corresponding compaction effect which is most significant at soil depth of about 7cm.

4.3 Advantages of Correct Tyre Inflation Pressure

Correct tyre inflation pressure is balancing between over-inflation and under-inflation which both has negative effects. Maintaining correct tyre inflation pressure helps to reduce excessive soil compaction thereby making the adverse effect of mechanization on soil physical environment to reduce hence improve seed germination and increase total crop production output. This can be achieved by avoiding over-inflation. Maintaining correct tyre inflation pressure also helps optimize tyre inflation pressure and fuel economy. Correct tyre inflation pressure allows drivers to experience tire comfort, durability and performance designed to match the needs of the vehicle. Tyre deflection (the tread and sidewall flexing where the tread comes in contact with the ground) will remain as originally designed and excessive sidewall flexing and tread squirm will be avoided. Heat build-up will be managed and rolling resistance will be appropriate. Proper tyre inflation pressure also stabilizes the tyre's structure, blending the tyre responsiveness, traction and handling. These can be achieved by avoiding under inflation

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the result obtained, the following conclusions can be made; (i) increasing tyre inflation pressure causes increase in the soil bulk density, cone index and soil shear strength, (ii) increasing tyre inflation pressure from 48kPa to 97kPa shows decrease in wheel slip from 3.6111% to 2.5360% and further increase from 97kPa to 138kPa shows increase wheel slip to 4.03226% and (iii) compaction effect was also seen to be more at around soil depth 7cm to 10cm.

5.2 Recommendations

1. It is recommended that the tractor operator take note of the weight of the tractor and the implement to be lifted by the tractor and check the owner's manual or tyre information placard to known the recommended inflation pressure to be use.

2. The tyre pressure should be set first thing in the morning to get the cold tyre inflation pressure.

3. When checking and adjusting the tyre inflation pressure, the "right" inflation pressure is those provided by the vehicle manufacturer, not the "maximum" inflation pressure branded on the tyre's side wall.

4. It is also recommended that similar experiment be carried out under different conditions (both the qualitative and quantitative condition) i.e. different soil type, tyre size, geographical zone, soil condition, tractor type and even tyre inflation pressure.

REFERENCES

Ahmed M. A. 2001. *Effect of Tyre Inflation Pressure and Speed of Operation on Tractor Tractive Performance.* Thesis. Agricultural Engineering. University of Ilorin pp 16-19

Akker van den J. 1988. *Model computation of subsoil stress distribution and compaction due to field traffic.* Institute for Land and Water Management Research, Report No. 23.

Anazodo U. G. N. and Onwualu A. P. 1984. *Evaluation of Soil Compaction due to Farm Tractor Traffic.* Proceeding of the Nigerian Society of Agricultural Engineers Symposium on Soil & Water Management, Nov 26-28th. pp. 137-145

Ankidawa B. A., Ohu J. O and Tanko J. A. 2007. *The Effects of Soil Aggregate and Moisture content on Air Permeability of a New Vertisols Marte, Borno State, Nigeria.* Proceedings of the 8th International Conference and 29th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (A Division of the Nigerian society if Engineers). Vol. 27, pp 269-271

Arvidsson J. and Ristic S. 1996. Soil stress and compaction effects for four tractor types. *Journal of Terramechanics,* Vol.33 (5), pp. 223-232.

Attanda M. L., Yusuf D. D. And Ndirika V. I. O. 2006. *Effect of Soil Compaction in Different Tillage Practices on Seed emergence.* Proceedings of the 7th International Conference and 28th Annual General Meeting of the Nigerian Institution of Agricultural Engineers. (A Division of the Nigerian Society of Engineers)

Atkinson J. 2000. *Shear strength.* Geotechnical Reference Package, University of West England, Bristol.

Dipankar De,, Chaudhuri D. And Pandey K. P. Autumn, 1982. Tractive Power Losses on Tracks of a Tractor. *Journal of Agricultural Mechanization in Asia, Africa and Latin America (AMA),* Vol. XIII, No. 4. pp. 79-80

Douglas E., Mickey E., Taylor F., Negi S. and Raghavan G. S. (1980). Unsaturated Hydraulic Conductivity of Tilled Clay Soil. *Canadian Journal of Agricultural Engineering.,* 22: pp153-161

Fariran A. And Areola P. (1978) *Essentials of soil study.* Heinemann Educational Books, Ibadan.

Grover, B. L. (1995). Simplified Air Permeameters for Soils in Place. *Soil Society of America Proceedings.* Pp 414 - 418

Horn R. and Lebert M. 1994. *Soil Compactability and Compressibility.* In: B.D. Soane and C. Van Ouwerkerk (Eds.): Soil Compaction in Crop Production, Elsevier Science., pp. 41-96.

Mohamed H. D. And Mutawalli D. M. (Winter, 2002). Tractor Tractive Performance as Affected by Soil Moisture Content, Tyre Inflation Pressure and Implement Type. *Journal of Agricultural Mechanization in Asia, Africa and Latin America, Journal of Agricultural Mechanization in Asia, Africa and Latin America(AMA),* Vol. 33, No. 1. pp. 29-31

Oni K. C. And Adeoti J. S. (Autumn, 1995). Mechanized Land Clearing and Tractor Traffic Effects on Agricultural Soil and Crop Growth. *Journal of Agricultural Mechanization in Asia, Africa and Latin America (AMA),* Vol.26, No.4. pp. 25-28

Poulos, S. J. (1971), *"The Stress-Strain Curve of Soils",* GEI Internal Report, <http://www.soilmechanics.us/StressStrain.

Poulos, S. J. (1981), "The Steady State of Deformation", *Journal of Geotechnical Engineering* **107** (GT5), <http//:www.wikipedia.com/Soil Shear Strength.

Redmond, W. A. 2007. "*Tire.*" Microsoft® Student 2008 [DVD]. Microsoft ® Encarta ® 2008. © 1993-2007 Microsoft Corporation.

Shebi J. C., Oni K. C. and Braide F. G. 1983. *Tractive Performance of Three Agricultural Tractors.* Proceedings of the First National Tillage Symposium held at National Centre for Agricultural Mechanization Kwara State. pp. 177-180.

William W. C. 1997. University of Missouri, Department of Agricultural Engineering. *"Publication G1235"*. <http//:www.extension.missouri.edu/publications.

Yusuf D. D. 2001. Influence of Soil Loosening by Rotary Tiller in soil Physical Properties. *Journal of Agricultural Engineers and Technicians.* Vol.9, pp. 13-15.

Ziesak M. (1999). Avoiding soil damages, caused by forest machines. Dipl.-Forstwirt, Lehrstuhl für Forstliche Arbeitswissenschaft und Angewandte Informatik der TU-München, Germany

APPENDICES

Appendix A: Glossary of Terms

Inflation Pressure- It is the pressure of air inside a tyre that applies a tensile stress to the tire cords permitting them to carry the vehicle's load.

Cold Inflation Pressure- is the inflation pressure of the tyre before the vehicle is driven and the tyre warmed up

Traction- Is the maximum amount of force the tire can apply against the ground (or that the ground can apply against the tire -- they're the same thing).

Wheel slip- it occurs when the force applied to a tire exceeds the traction available to that tire.

There are two kinds of contact that tires can make with the surface it tread: static and dynamic.

- Static contact - The tire and the road (or ground) are not slipping relative to each other. The coefficient of friction for static contact is higher than for dynamic contact, so static contact provides better traction.
- Dynamic contact - The tire is slipping relative to the ground. The coefficient of friction for dynamic contact is lower, so you have less traction.

Soil Compaction- It is the compression processes that occur in soil, causing it to lose pore space.

Radial-Ply Tyre- This is the tyre which as the cords of it body plies run radially/straight accross from bead to bead

Bias-Ply Tyre- This is the tyre which has the cords of it body plies run diagonally/at an angle from bead to bead

Cone Index- It is the force per unit base area required to push the soil penetrometer through a specified very small increment of soil

Base Area- It is the cross-sectional area at the base of the cone penetrometer expressed in mm^2 (in^2)

Cone Penetrometer- It is a 30^0 circular stainless steel cone with driving shaft use to provide a standard uniform method of characterising the penetration resistance of soils

Bulk Density- Bulk density is a measure of the weight of the soil per unit volume (g/cm^3), usually given on an oven-dry (110° C) basis

Soil Moisture Content- It is the amount of liquid, usually water, which is present in the soil.

Soil Shear Strength- Shear strength in reference to soil is a term used to describe the maximum strength of soil at which point significant plastic deformation or yielding occurs due to an applied shear stress.

Appendix B: Tire and Inflation Pressure Management

Tires should be selected and managed to provide maximum contact area with the soil surface. Contact area depends on the size, type and number of tires as well as tire inflation pressure. Properly inflated radial tires provide a larger and flatter footprint than bias-ply tires. Large, dual, radial tires maintained at minimum tire inflation pressures transmit power to the soil through the largest area. Increasing the contact area of tires reduces the pressure exerted by the tire on the ground. The pressure exerted by a tire on the soil surface near the lugs is roughly 2 pounds per square inch greater than the tire inflation pressure. When dual tires are used in place of single tires, each tire carries a smaller portion of the weight of the tractor; hence, tire inflation pressures can be reduced. Whenever tire pressures are reduced, the tire flexes over a larger area and further reduces the pressure applied to the soil surface.

Determining optimum ballast and tire pressure configurations

The optimum ballast and tire pressure configuration for a tractor depends on: the type and size of the tractor; the type, size and number of tires; soil type and soil condition and draft, which depends on the type, width and operating depth of the tillage tool or other implement. Variables such as tire size and implement type can be controlled, but soil characteristics can vary considerably within a field. Hence, an optimum configuration must be determined for average conditions. Several optimum configurations may be determined for various types of field operations and soil types. The following procedure is a step-by-step guide to determining an optimum configuration.

Step 1: Select a field operation such as chisel ploughing, field cultivating or planting and equip the tractor according to guidelines in the owner's manual, your experience or other available guidelines.

Step 2: Weigh and record each axle separately. Fill mounted tanks such as fuel tanks and sprayer tanks. If mounted equipment is used, weigh the tractor with the mounted equipment.

Step 3: Determine tire type and size from the tire codes on the sidewall of the tires. Tires may be either radial or bias ply. Radial tires will have a star marking; (*, **, etc.). Bias ply tires will have a ply rating (4-ply, 6-ply, etc.). Tire size codes are based on tire design and rim diameter, for example, 18.4R-38.

Step 4: Check and adjust weight distribution. Refer to the owners manual or to Table 1 and adjust front and rear weights so that the weight of the tractor is properly distributed between the front and rear axles. Record the final weight of each axle.

Step 5: Determine the weight supported by each tire. Divide the axle weight by the number of tires on the axle.

Step 6: Adjust tire inflation pressures. Refer to the tire inflation pressure chart for your tires, which is available from your tire dealer. Locate your tires on the chart by tire size. Determine the minimum tire inflation pressure listed in the chart for the weight supported by each tire, as calculated in Step 5. Adjust tire inflation pressures as necessary. Refer to "Tire Load and Inflation Pressure Guidelines" for more information about tire management. Caution: Do not over inflate tires! Tires with lower ply ratings or lower star markings have lower maximum pressures. For example, the maximum inflation pressure for a one-star radial is lower than the maximum pressure for a two-star radial. Maximum pressures should be used only if necessary to support the load on the tire.

Step 7: Assess tractive efficiency by measuring or observing wheel slip. Refer to "Measuring Wheel Slip by Counting Tire Revolutions" to measure slip. Wheel slip can be estimated by observing the appearance of the track. If the track is scrambled so that the lug marks are completely broken, slip is high. If the track is well-defined and the lug marks are unbroken, slip is low.

Step 8: Add or remove ballast to optimize slip. If slip is high or greater than 15 percent, excessive power is being lost to wheel slip. Excessive wheel slip may be caused by: soil that is too wet; a draft force that is too large; tires that provide inadequate contact with the soil surface because they are too small or overinflated or a tractor with inadequate ballast.

Consider equipping the tractor with larger tires, dual tires or radial ply tires. Ballast may also be added to improve traction. Increased ballast will cause greater soil pressures and increase compaction. Consider using dual tires to decrease soil pressure and remember to adjust tire pressures. (William, 1997)

Appendix C: Tire Load and Inflation Pressure Guidelines

Tires should be inflated according to "tire load and inflation pressure tables." The loads listed in the tables are the maximum loads for a given tire design and inflation pressure that will provide safe operation and acceptable tire life at the maximum rated speed. Most tables are based on recommendations published by the Tire and Rim Association and are standardized by tire type and size. Consult the table published by the manufacturer of your tires for specific information. Radial tires can be inflated at pressures as low as 6 pounds per square inch (psi) equivalent to 41.4kPa, depending on the design of the tire and the application. The lowest tire pressures are usually recommended only for tractors with dual tires pulling drawn (as opposed to mounted) equipment on relatively flat surfaces. Tire pressures listed in the tables should be increased by 4 psi for a tractor with single tires operated on sloping surfaces or equipped with mounted equipment to prevent tire damage from side forces. When operating at lower pressures, an additional 4 psi is also recommended if the tire is operated under harsh conditions or under heavy loads where greater torque on the wheel could cause rim slip. Dual tires are highly recommended under those conditions. When dual or triple tires are used, the maximum weight allowed per tire i s smaller, because at any instant in rough terrain, an individual tire may carry more than its share of the load. The loads in the "tire load and inflation pressure tables" are for safe operation at the indicated tire pressures at maximum rated speeds, which are generally 25 miles per hour. Load and inflation tables often include footnotes allowing increases in maximum loads for tires that are always operated below the maximum rated speed. (William, 1997).

Appendix D: Pictures Showing Equipments and Procedures Used for the Experiment

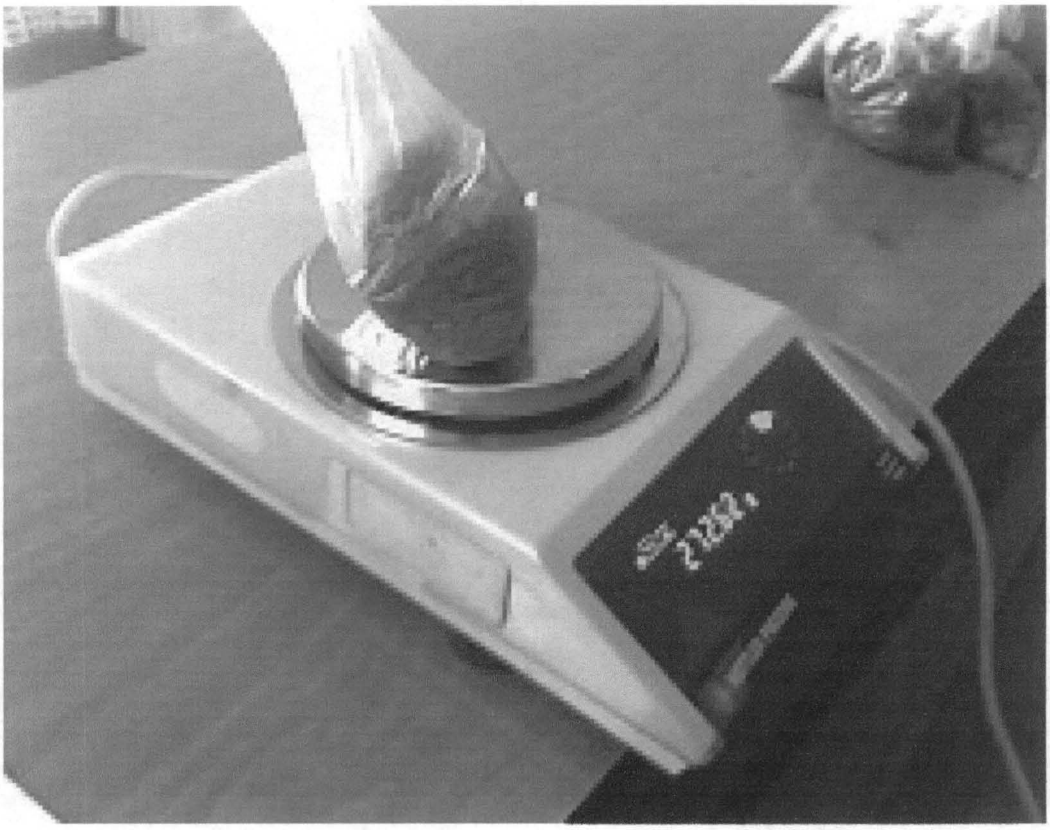


Plate3.1
Picture showing Sensitive Electronic Weighing Balance Used for the Experiment

Plate 3.2:
The Tractor Used for the Experiment

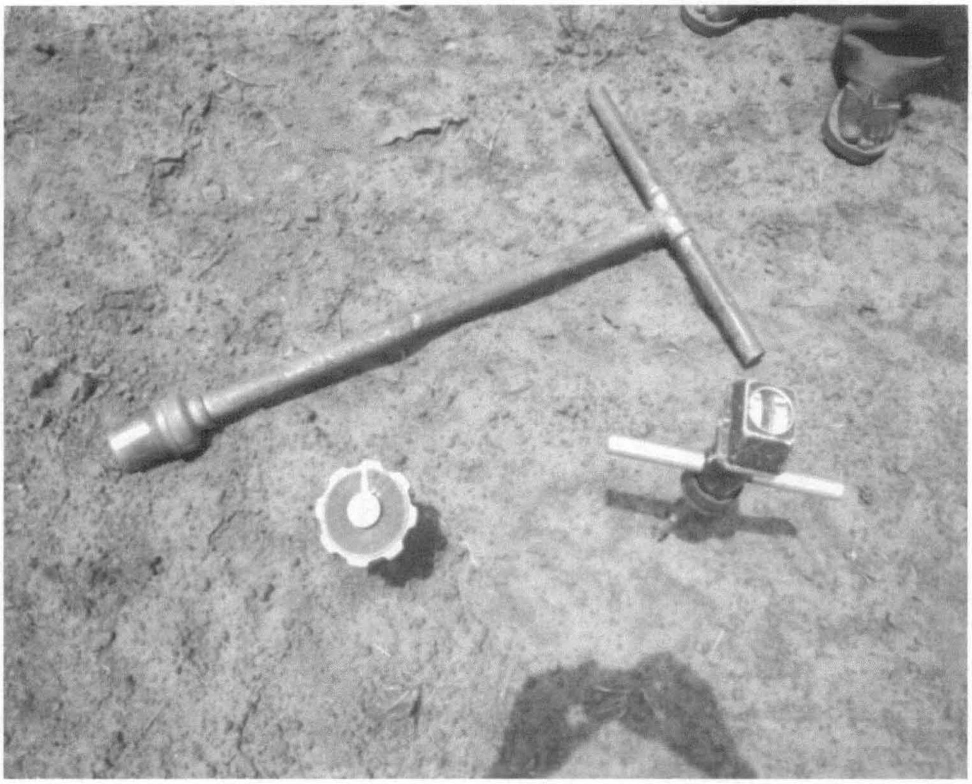


Plate 3.3

Picture showing the bulk density apparatus, the cone penetrometer and the shear vane used for the experiment

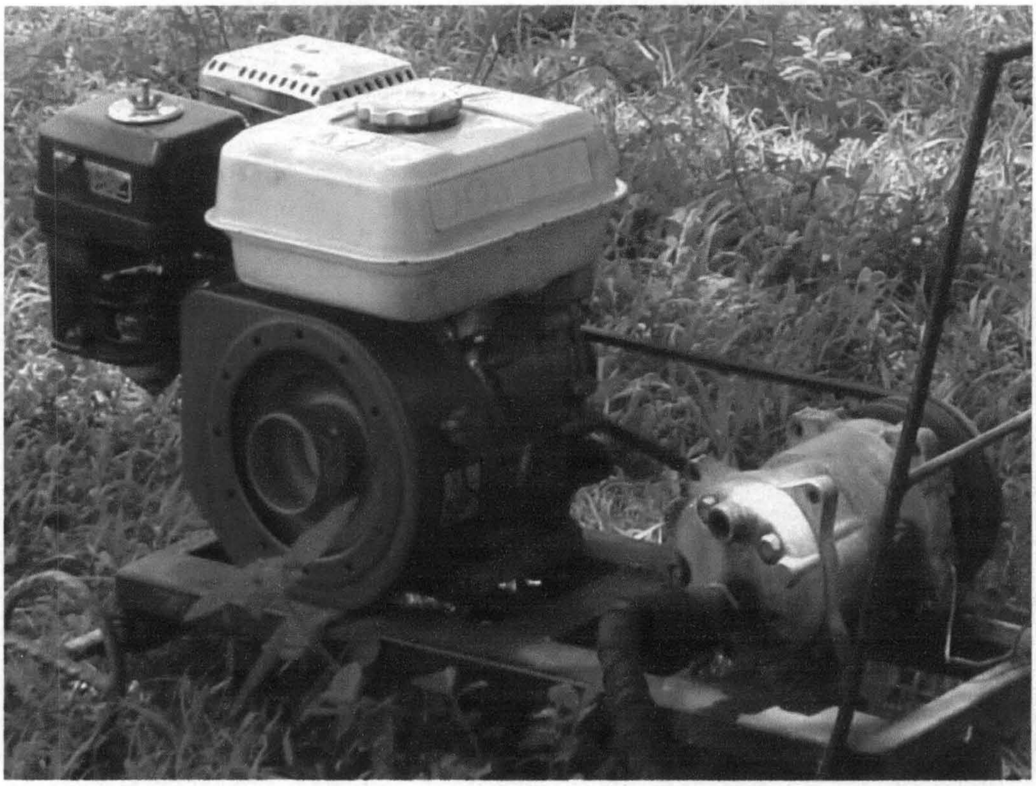


Plate 3.4
Picture Showing the Air Compressor Used for the Experiment

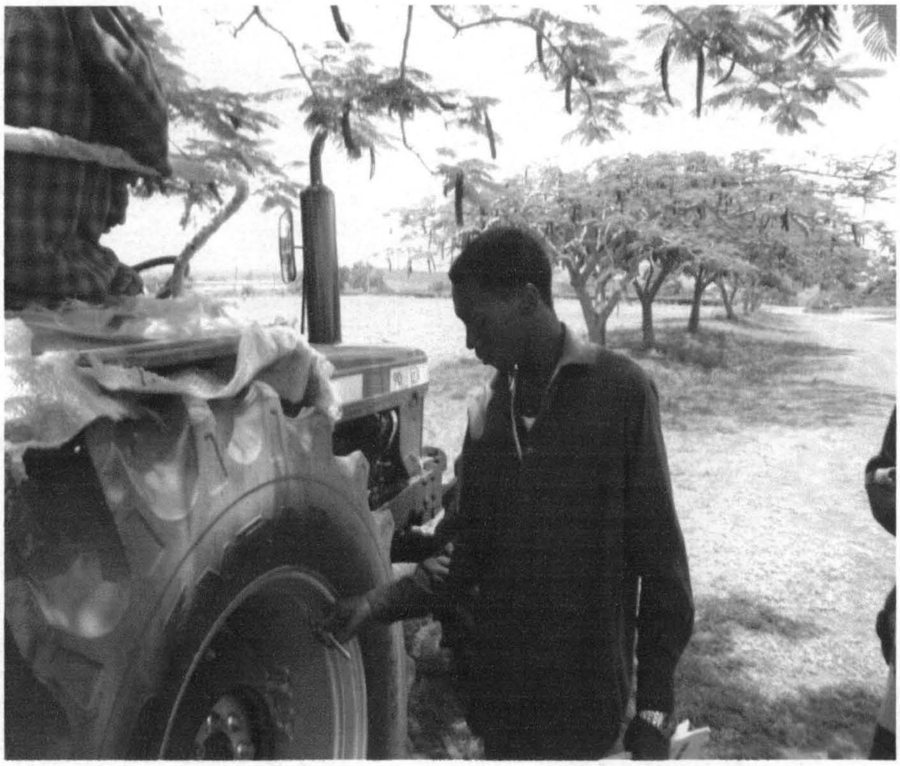


Plate 3.5
Picture Showing Adjustment of Tyre Inflation Pressure Using Pressure Gauge

Plate 3.6
Picture Showing the Measurement of Cone Index Using the Cone Penetrometer

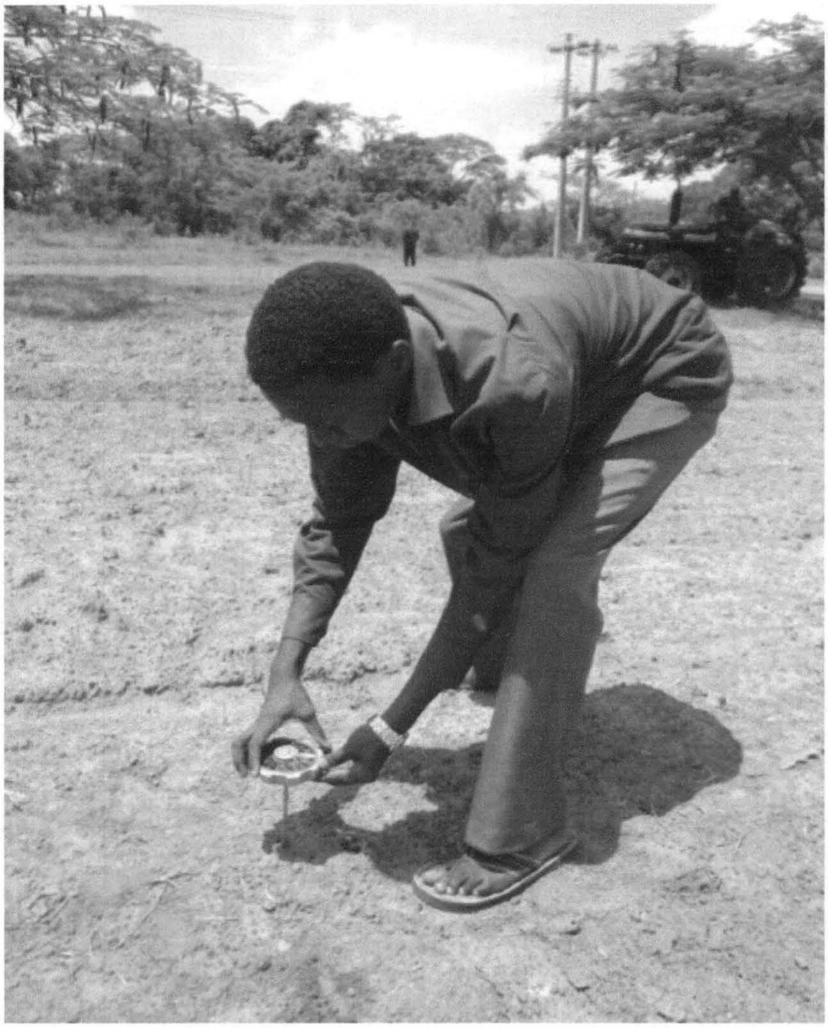


Plate 3.7

Picture Showing the Measurement of Share Strength Using the Share Vane

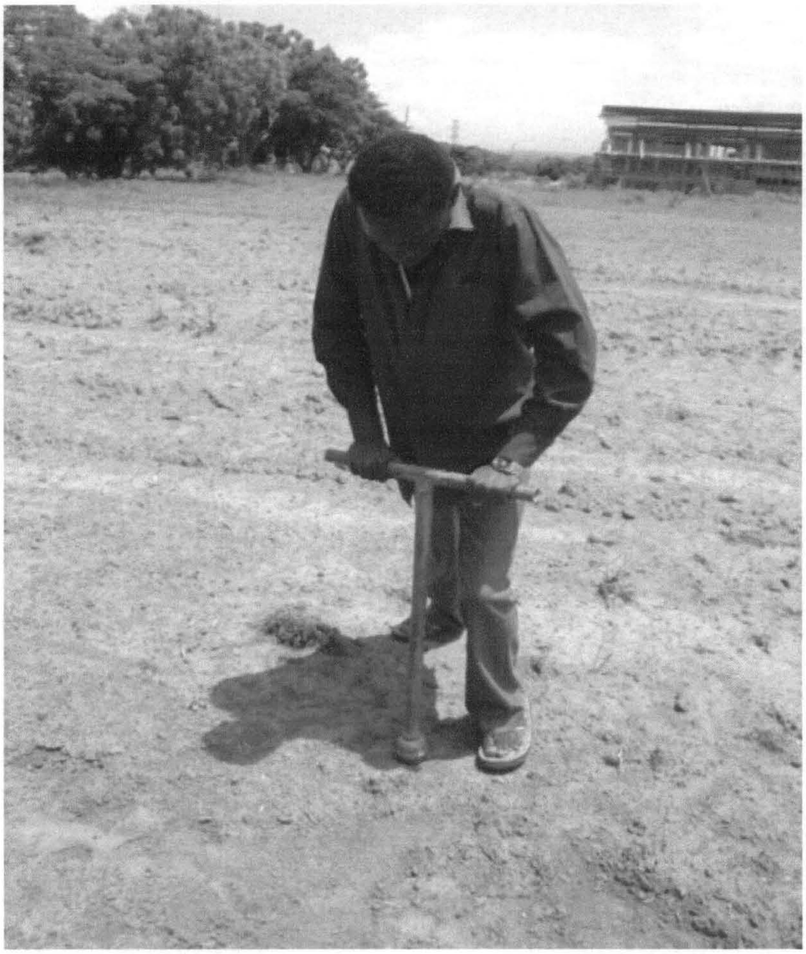


Plate 3.8
Picture Showing the Collection of Soil Sample Using the Bulk Density Apparatus

Appendix E: Graphs Showing Variation Soil Physical Properties with Different Tyre Inflation Pressure After the Second Tyre Passage

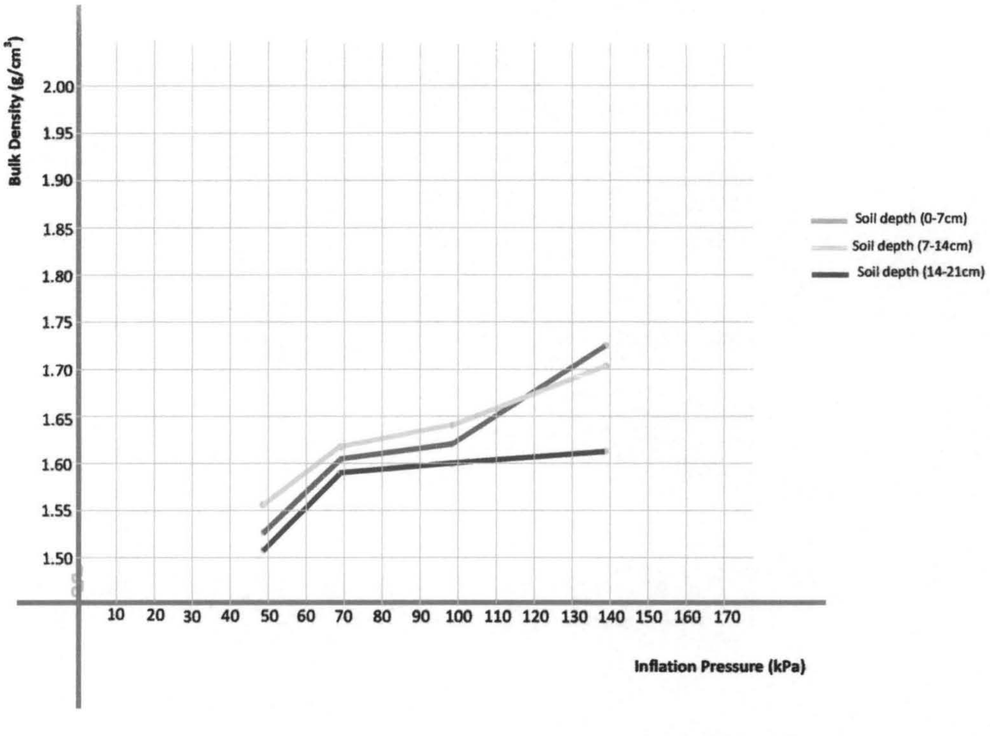


Fig 4.1: Graph showing soil bulk density variation with tyre inflation pressure at different soil depth after the second tyre passage

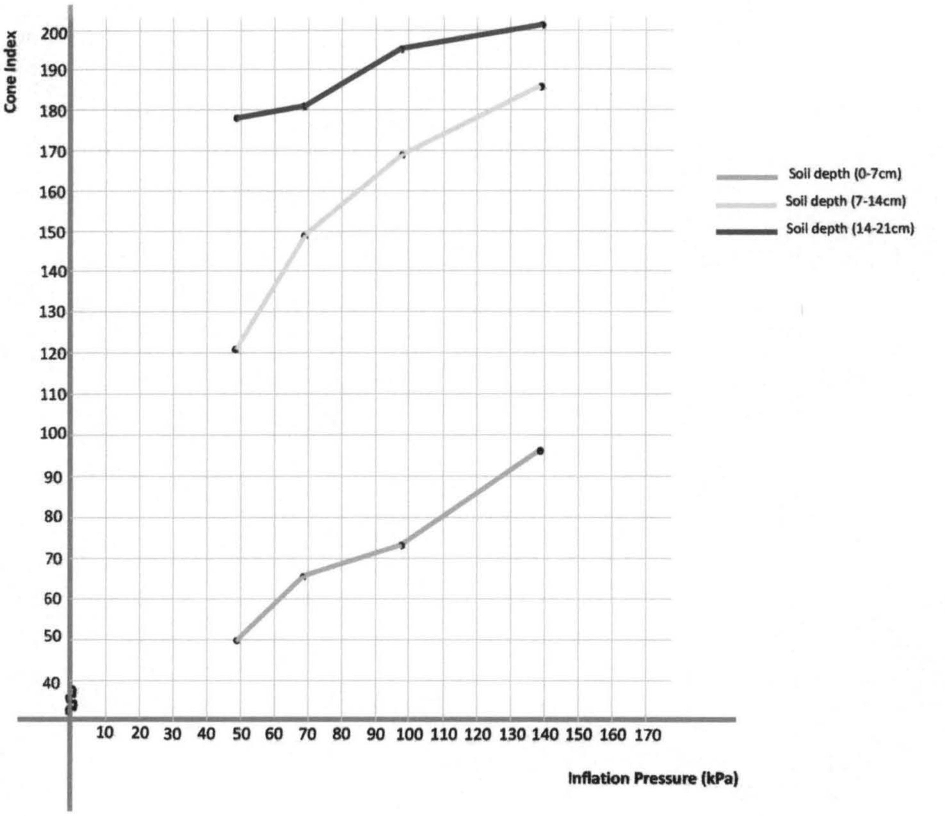


Fig 4.2: Graph showing Cone Index variation with tyre inflation pressure at different soil depth after the second tyre passage

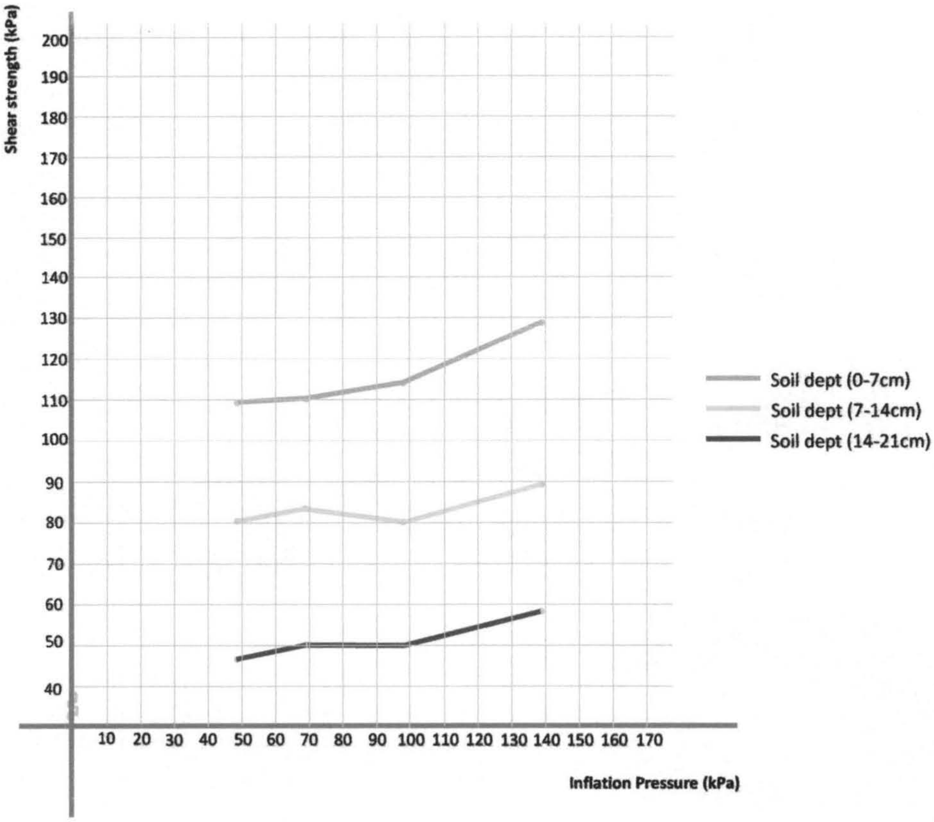


Fig 4.3: Graph showing Soil Shear Strength variation with tyre inflation pressure at different soil depth after the second tyre passage

Appendix F: Graphs Showing Variation of Bulk Density with Tyre Inflation Pressure and Traffic at Different Soil Depth

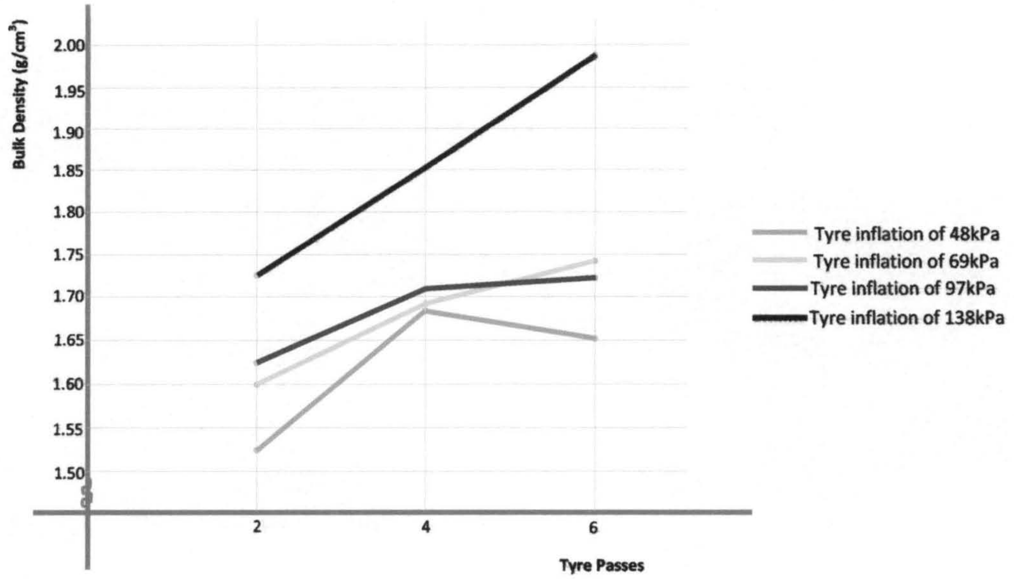


Fig 4.4: Graph showing the relationship between Farm tractor tyre inflation pressure, traffic and soil bulk density at soil depth of 7cm

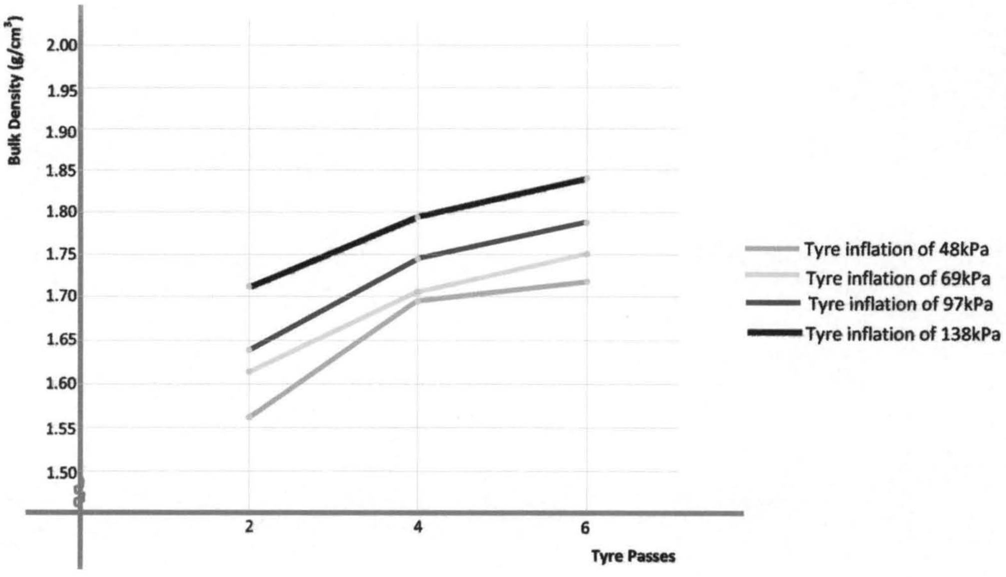


Fig 4.5: Graph showing the relationship between Farm tractor tyre inflation pressure, traffic and soil bulk density at soil depth of 14cm

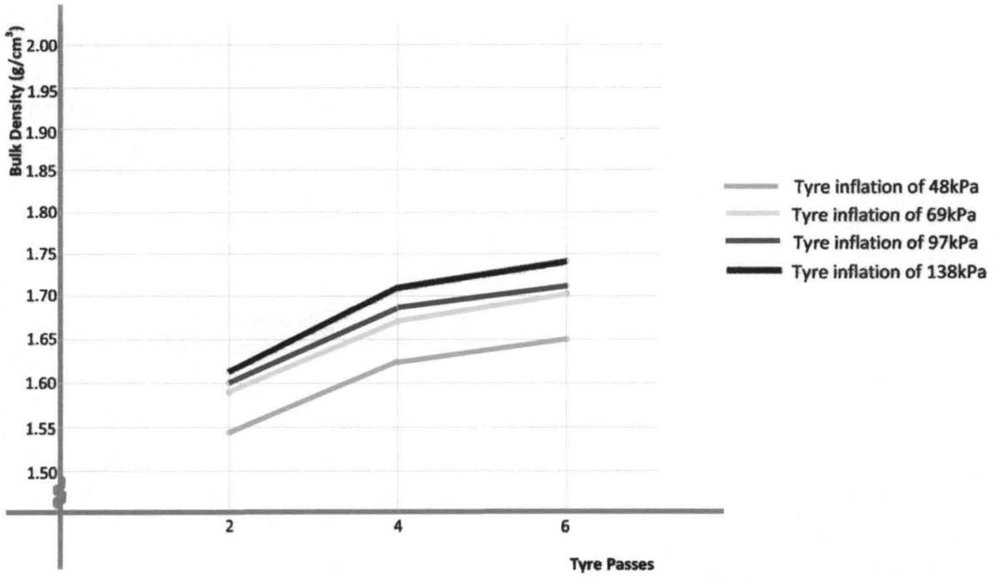


Fig 4.6: Graph showing the relationship between Farm tractor tyre inflation pressure, traffic and soil bulk density at soil depth of 21cm

Appendix G: Graph Showing the Soil Depth at which Compaction Effect is most

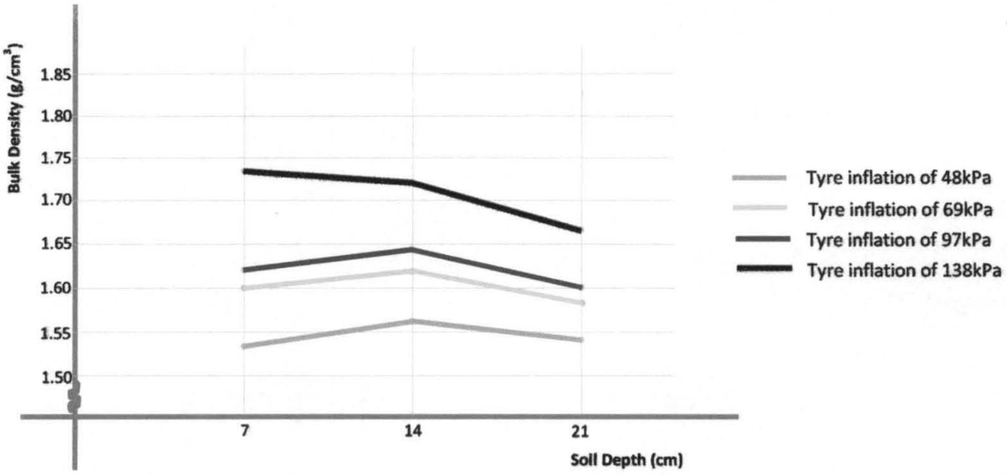


Fig 4.7: Graph showing the depth of soil at which compaction is most at various farm tractor tyre inflation pressures after two tyre passes.

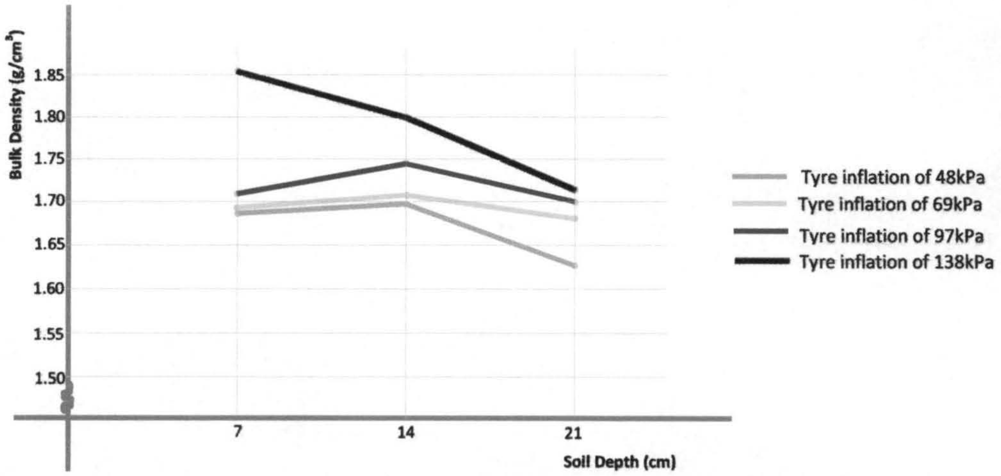


Fig 4.8: Graph showing the depth of soil at which compaction is most at various farm tractor tyre inflation pressures after four tyre passes.

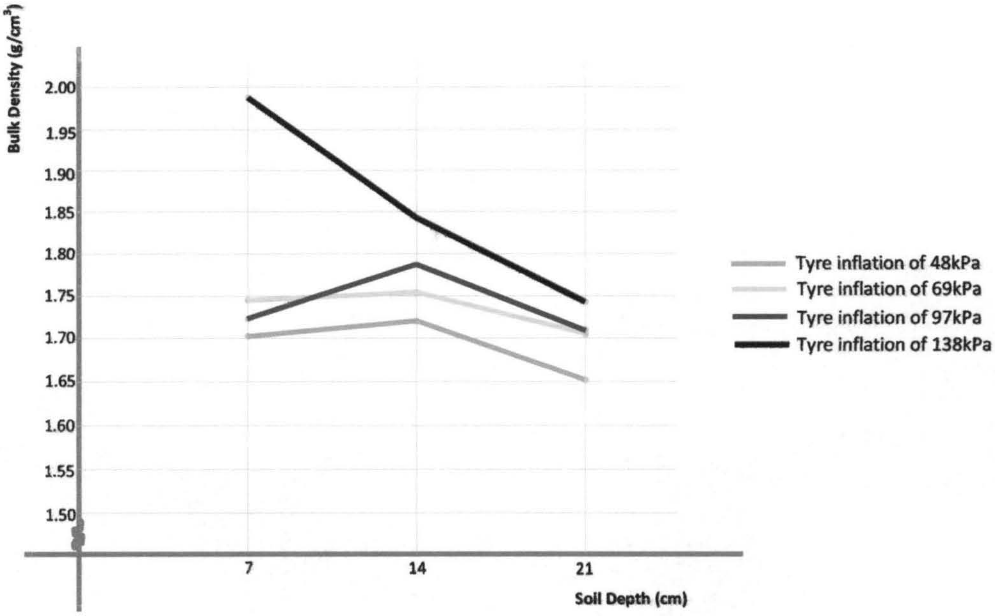


Fig 4.9: Graph showing the depth of soil at which compaction is most at various farm tractor tyre inflation pressures after six tyre passes.

Appendix H: Cone Index Variation with Soil Depth

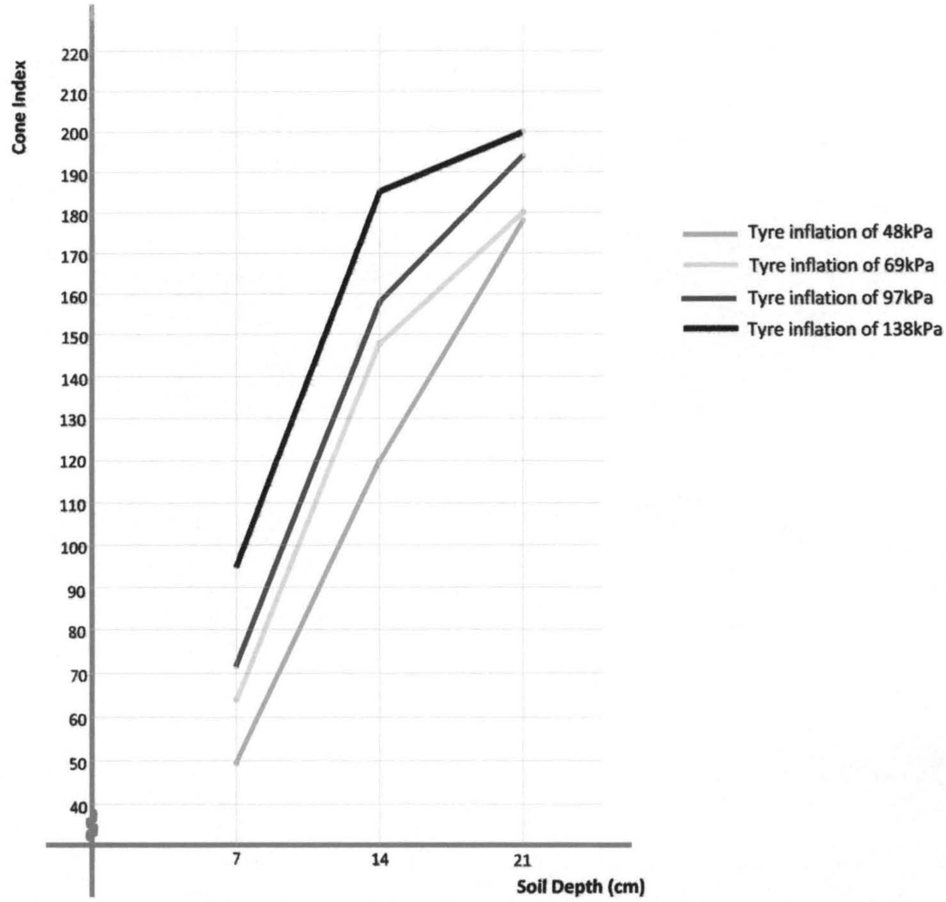


Fig 4.10: Graph showing the relationship between farm tractor tyre inflation pressures and soil cone index at various soil depths after the second tyre passes.

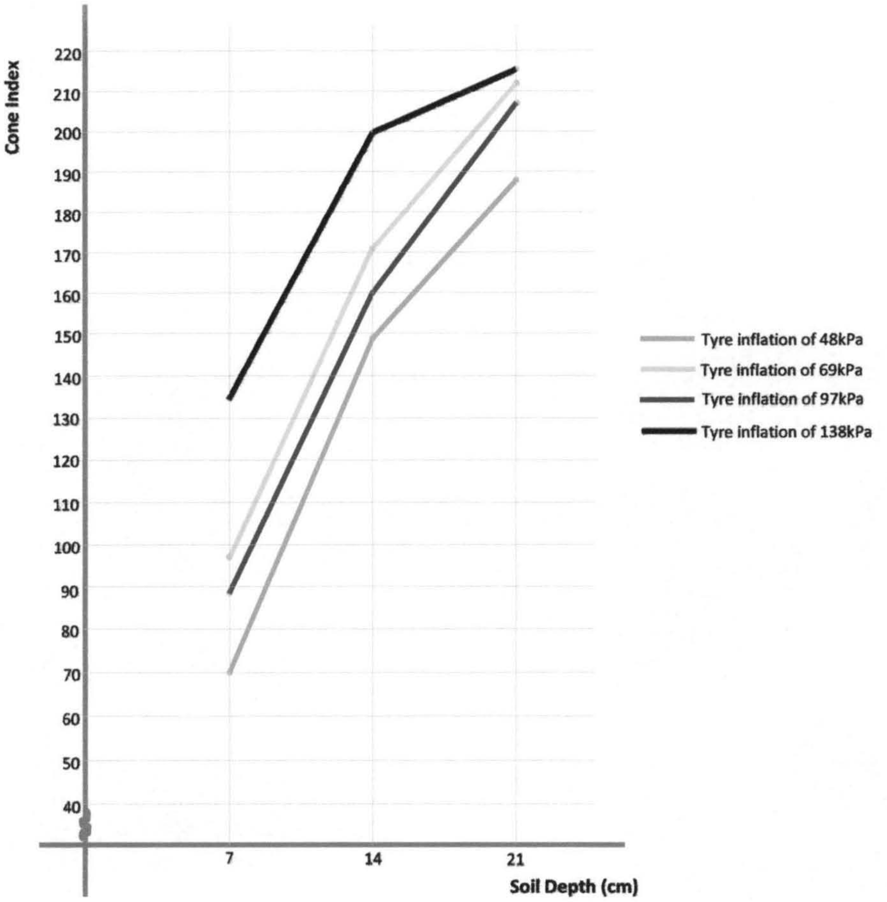


Fig 4.11: Graph showing the relationship between farm tractors tyre inflation pressures and soil cone index at various soil depths after the four tyre passes.

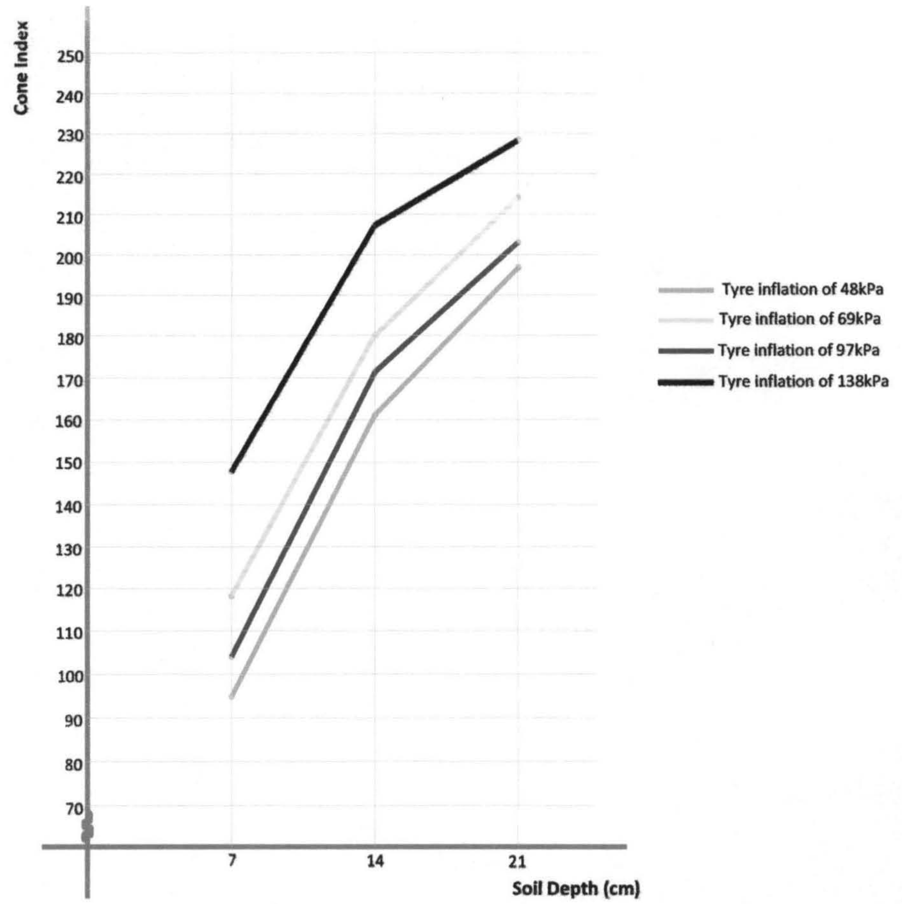


Fig 4.12: Graph showing the relationship between farm tractors tyre inflation pressures and soil cone index at various soil depths after the six tyre passes.

Appendix I: Shear Strength Variation with Soil Depth

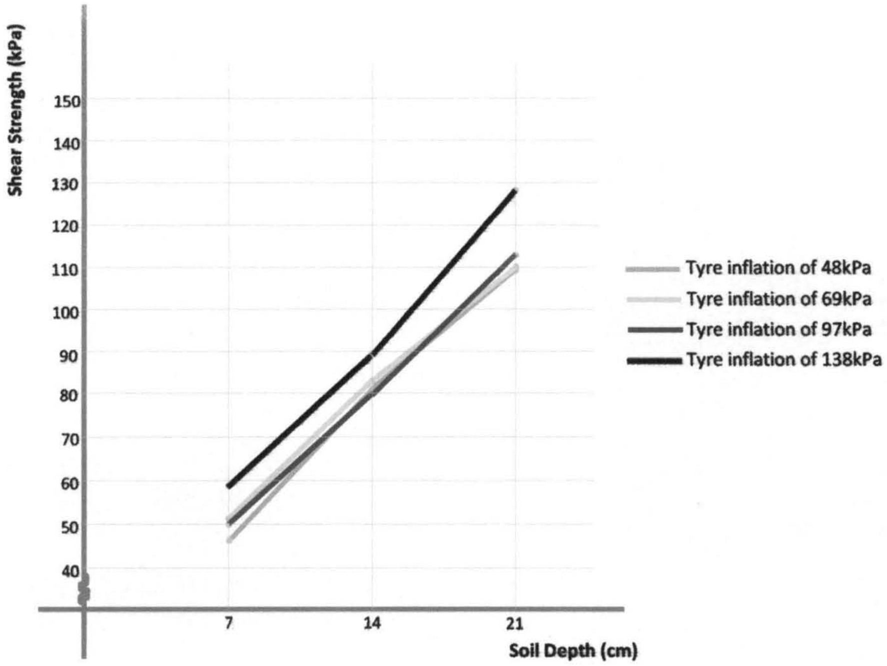


Fig 4.13: Graph showing the relationship between farm tractors tyre inflation pressures and soil shear strength at various soil depths after two tyre passes.

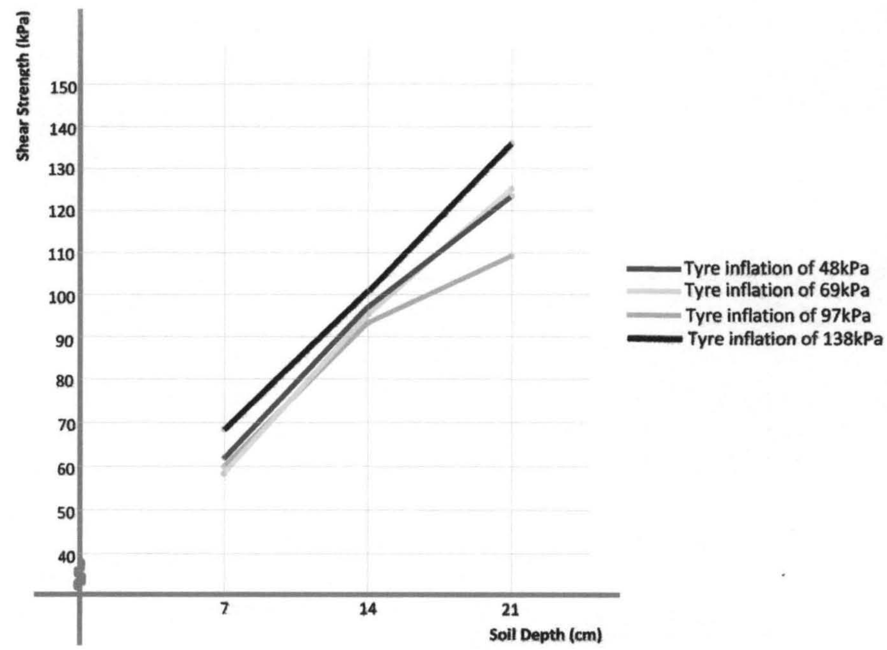


Fig 4.14: Graph showing the relationship between farm tractors tyre inflation pressures and soil shear strength at various soil depths after the four tyre passes.

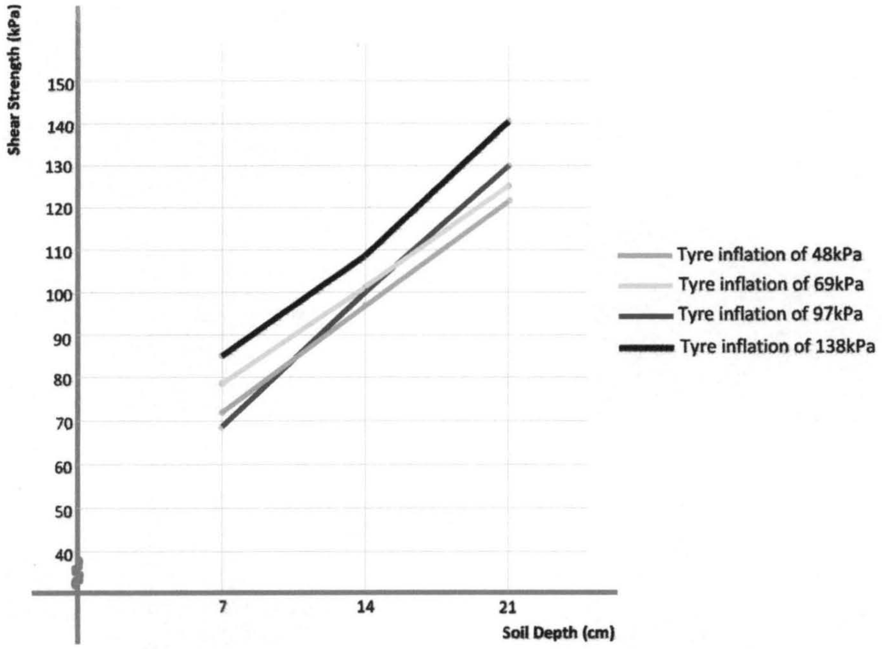


Fig 4.15: Graph showing the relationship between farm tractors tyre inflation pressures and soil shear strength at various soil depths after the six tyre passes.