DETERMINING SUITABLE AND APPROPRIATE SOIL TILLAGE EQUIPMENT DESIGN REQUIRMENT FOR BOTH UPLAND AND FADAMA FARMING IN MINNA

A dissertation presented in partial fulfilment of the requirement for the Degree of B. Tech (Honours) Agricultural Engineering.

BY

EGBEJIMBA ANTHONIA IFEOMA

Department of Agricultural Engineering
School of Engineering and Engineering Technology
Federal University of Technology
Minna, Niger State.
Nigeria.

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CERTIFICATION

I certify that this work was carried out by Miss Egbejimba Anthonia Ifeoma in the Department of Agric. Engineering, Federal University of Technology, Minna.

14th August 1991

Mr. A.F. Adisa
Supervisor

Date

Mr. G.M. Yisa
Head of Department

Date

Dean, SEET

Date

15/8/91

External Examiner

Date

DEDICATION

This dissertation is dedicated to Almighty God for His generosity to mankind and for making what seem impossible possible and also to my kind and loving mother, Mrs. B. EGBEJIMBA.

ACKNOWLEDGEMENT

I am particularly grateful to my able Supervisor, Mr. F. Adisa, to whom I am greatly indebted for creating time to read through this work critically and making useful suggestions despite his tight schedules.

I am also grateful to Mallam M.G. Yisa our Ag. Head of Department who contributed materially and advisorily to the success of this dissertation.

I would like to express my deep appreciation particularly to Jack G.A. for his moral support, prayers and avowed interest in my progress and also to Dr. and Mrs. Akuchie for their unalloyed assistance and prayers.

Above all, my God deserve glory, honour and thanksgiving for His loving kindness and protection.

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ABSTRACT

Tillage has been defined as those mechanical, soil stirring action carried out for the purpose of nuturing crops creating suitable soil condition for crop growth. The goal of proper tillage is to provide a suitable environment for seed germination, root growth, weed control, soil erosion control and moisture control avoiding moisture excesses and reducing stress of moisture shortage.

Tests were carried out in both upland and fadama and the soil was tested and analysed to determine some soil characteristics which are related to soil tillage operation. The tests carried out were the bulk density, moisture content, shear strength, wheel slippage, soil particle size, the draw bar pull force, and total plow resistance were then calculated for.

The results obtained from both the field and laboratory tests were found to be 1.754kW in fadama and 1.815kW using the spring tine harrow of weight 121kg and 0.716kW in fadama and 1.313 in upland using the ridger of weight 67kg, for the draw bar pull. The total plow resistance for upland is 5.2537kN with spring tine harrow and 14.6552kN with ridger while for fadama, it was 4.0134kN with spring tine harrow and 16.1kN with ridger. The angle of inclination of the implements used were 3.6^{o} for ridger and 23.6^{o} for the spring tine

NOTATION

C	=	Cohesion
T	=	Shear stress
Ø	=	Angle of shearing resistance
H	=	Shear force
A	=	Area
W	=	Normal load
Cx	=	Adhesion
	=	Angle of soil/metal friction
X	=	Rake angle
Y	=	Unit weight
P	=	Force/unit width
Q	=	Surcharge
Z	=	Characteristics lenght dimension
NY) NC) NQ) NX)	=	Pure numbers which depend on the geometry of the failure surface A, Ø and S.

CHAPTER ONE

OBJECTIVES OF THE PROJECT

With the aim of determining suitable and appropriate soil tillage equipment design requirement for both upland and fadama farming in Minna, I intend to:

a. carry out different soil tests to measure the bulk density, moisture content (both on weight and volume basis), particle size analysis, and soil resistance in both fadama and upland region in Minna.

b. carry out some soil tillage tests with different types of tillage tools available in the University to measure some soil tillage operation factors and to determine the power requirement range for soil tillage operations in upland and fadama areas in Minna.

The results obtained in (a) and (b) above are to be made available for the indigenous soil tillage implement design requirements in terms of soil cutting, mixing, disintegration, bursts and movement of the soil instead of relying on the available data from different part of the world whose soil types, condition and tillage operation requirements are different from what obtains in Minna and Nigeria in general.

1.2 Project Justification

In Minna, there is a relatively poor agricultural extension services in providing for the farmers relevant informations for their decision making on choice of agricultural techniques because of unavailable data for tillage equipment selection and designing. Most machinery and implement selection for farm operations has been based on guess work without any concrete data available.

With this project I can be able to recommend suitable tillage equipment design requirement that will enable the designers to design suitable tillage equipments to suit the crops, soil and environmental conditions for both upland and fadama farming and also reduce the operating cost in the use of tillage practices which usually scare willing farmers.

CHAPTER TWO

2.0 INTRODUCTION

Tillage has been defined as the process which mechanically manipulates the soil. Its primary objectives according to Wilkinson et al are to:

a. Prepare a suitable seed bed

b. Improve the physical condition of the soil and

c. Destroy weed.

All for the purpose of nurturing crops.

Tillage is one of the oldest practices ever known to man. History recorded that man used such crude tools as wood to break the soil by harnessing the human and animal powers for the process. This practice subsequently led to the development of farming tools. Such developments were recorded in ancient Egypt, Rome, England and the U.S.A. These advances in Tillage tools led to the classification of the practice into primary and secondary tillage operation.

Primary tillage operation is aimed at reducing soil strength and rearranging soil aggregates. Common tools for this practice include mould board plows, disk plows, subsoilers and disk and rotary tillers.

Secondary tillage operation is subsequent to primary tillage and it is aimed at providing a suitable seedbed for the crops. Common tillage tools for this practice include disk and tined harrows, rotary weeders and cultivators to mention few.

Recent advances in this aspect of agricultural practices led to further classification to <u>conventional</u> and <u>minimum</u> tillage operations. The former combines both the primary and secondary tillage practices while the latter provides for minimum soil manipulation by employing one or more tillage tools.

Man, in his attempt to reduce energy input on the farm aimed at conserving the dwindling energy sources of the world, brought about the concept of reduced and zero tillage. Reduced tillage is a composite operation whereby the primary tillage operation is simultaneously carried out with planting of crops. This is aimed at reducing or eliminating secondary operation. Zero tillage, on the other hand, is a process whereby crop planting is performed on an untilled seed bed.

The primary objective of any cropping program is continued profitable production, so most farmers prefer to follow proven practices with readily available equipment. This offers reasonable assurance of predictable results with least risks. But no tillage operation can be justified merely on basis of tradition or habit. Any tillage practise which doesn´t return more than its cost by increasing yield and improving soil conditions should be eliminated or change. Contrary to previous beliefs, soil needs to be worked only enough to assure optimum crop production and weed control. any tillage activity beyond this is of questionable value.

After knowing what tillage is all about, the discussion in this paper will first of all be based on the characteristics of soil, how these affect implements as regards their different shapes, the power requirements estimation in puling implements and design shapes and requirements for tillage equipments. Practicals and tests were carried out and analysed to determine these.

The knowledge of natural soil, soil engaging tools and soil machines principles have been advanced to the study of soil-tool interactions and are the bases for the design and application of these soil engaging tools. Methods of measuring relevant properties have also been proposed. The method of characterizing soil texture is of utmost importance to tillage researchers. The action of tillage tools operating in the soil has been studied by many researchers aimed at correlating the geometric variation of these tools with soil distruption and the overall influence of these on tillage force required for achieving such work.

CHAPTER THREE

3.0 LITERATURE REVIEW

Vector Algebra and the equilibrium of forces are found applicable to the design and force prediction on under cutting tillage tools respectively. Yet, there are observable differences in predicted and observed forces particularly on model tools. This is often due to the complex nature of agricultural soils. Agricultural soils are non-homogeneous and anisotropic but performance studies of soils and tillage tools are based on the homogeneity of soils. There is also the problem of scaling such soils for research purposes similitude technique attempts to reduce this variability.

3.1 Relevant Soil Tool Parameters (ONI, 1981)

The goal of tillage is the disruption (elastic and plastic deformation) of soils by soil engaging tools. As a tool moves through the soil, it compresses the soil until the soil reaches its maximum shear strength at which point failure occur. This is in agreement with the Mohr-Coulomb equation which consist of 2 parts:

a. Frictional Component ($\sigma \tan \emptyset$) which is a function of the normal load,

b. Cohesive component (C) which is independent of the normal load. These two components are expressed in the equation as $\tau = C + \sigma \tan \emptyset$ where

τ = shear strength of soil

C = apparent cohesion, the shear strength with zero normal load

σ = total pressure normal to the shear plane

Ø = angle of shearing resistance

C and Ø are empirical parameters of the equation whose values hold good only under a given set of soil testing conditions. If a test is conducted under constant pure water pressure the equation is modified to $\tau = Ct + \sigma e \tan Øt$ where Ct = true cohesion; Øt = true angle of shearing resistance $\sigma e = (\sigma - \mu)$ = effective pressure.

μ = pure water pressure.

Fig. 1 illustrate the Mohr-Coulomb failure diagram applicable to soil failure under the influence of a soil engaging tool. The cohesion of top soil (tillage regimes) is much lower than that of subsoils of similar texture, but their frictional components are higher in magnitude. In addition to cohesion and the angle of shearing resistance are the soil-metal friction and adhesion.

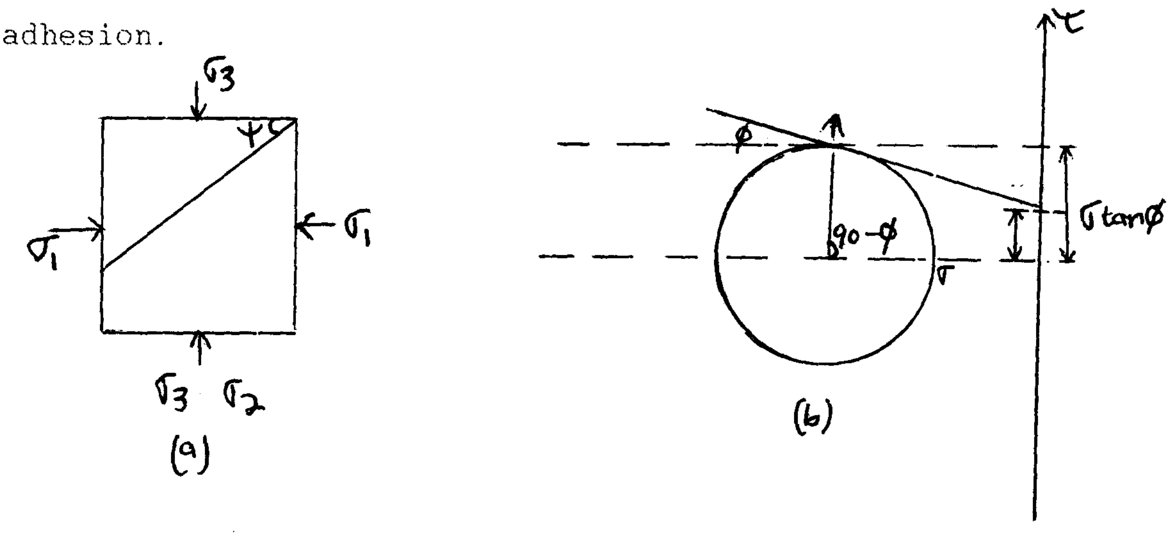


Fig. 1: Mohr-Coulomb Failure diagram

The soil metal friction is influenced by the normal forces, soil type and surface roughness of the soil. Soil metal friction can account for about 40-50 percent of the total plough resistance.

Soil adhesion is the attraction between the soil and soil engaging tool. Adhesion impairs the quality of the work and increases with increase tractive resistance, soil dispersion, contact pressure and soil moisture.

The non-uniformity of soil structure coupled with the rapidly changing of soil moisture makes the soil strength characteristics determination difficult. It is known that the ultimate tensile and compressive strength of soils decrease with an increase in soil moisture.

Another property often used to characterize the soil is soil density. It describes how tightly the soil particles are pressed together. Soil density increases with soil moisture to some limit. An increase in soil bulk density has been found to increase the soil shear strength, soil frictional angles, soil cohesion and soil failure energy. Freshly plowed soil has a density of less than 1.00gm/cm^3 and hence it is too loose for seedy crops. Most crops perform best at a soil density of 1.10 to 1.40gm/cm^3 . Table 1 compares soil density values with the corresponding values for the rate of water movement into the soil. Tillage processes (plowing etc) change density values of soil.

Table 1: Influence of soil density on the infiltration rate of water

Soil type	Soil density, gm/cm^3	Water Infiltration rate cm/hr
Soil Clay	1.36	13.72
	1.41	7.37
	1.44	4.90
Silky loam	1.31	44.70
	1.36	17.44

(Oni, 1981)

3.2 Design of Soil Engaging Implement

Soil engaging implements form a large and important section of the equipment used in agriculture today. These implements change the soil state and the change produced depends on the nature of the soil and of the soil/implement interface. A well designed soil engaging implement is one which performs the manipulation required in the most efficient way, usually with a minimum effort.

This chapter presents information, extracted from theory and experimental practice which should be of use in the design of implement shapes for particular soil failure, since this is very well done in research publications and references to these are only given.

3.3 General Principles of soil failure

Nature of soil failure (BAVER, 1963) Soil is extremely weak in tension, very strong in compression and in practice fails mainly in shear. When soil is strained the shear stress builds up to a peak value, which, in certain loose dry soils, remains constant with increasing strain, (Fig 1.1), and in other soils, falls off before levelling out to a smaller constant value, the residual stress (Fig. 1.11). The magnitude of the shear stress developed are frequently a function of the compressing stress normal to the place of shear failure (Fig. 2). If the peak of the residual stresses are plotted against the corresponding normal stresses an approximate straight line relationship is obtained (Fig. 3). The relationship can be expressed in form of the Coulomb equations:

$$\tau = C + \sigma \tan \emptyset \quad \ldots\ldots\ldots \quad (1)$$

The Coulomb equation expressed in terms of force is:

$$H = CA + w \tan \emptyset \quad \ldots\ldots \quad (2)$$

Line A (Fig 3) represents the situation in a loose dry soil, cohesion being zero, line B a wet plastic clay which exhibits no friction (angle of shearing resistance zero) and line C a soil with both frictional and cohesive properties.

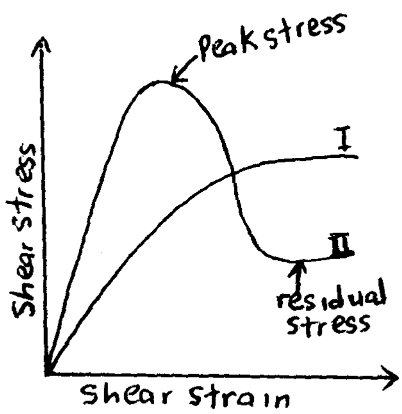


Fig. I.

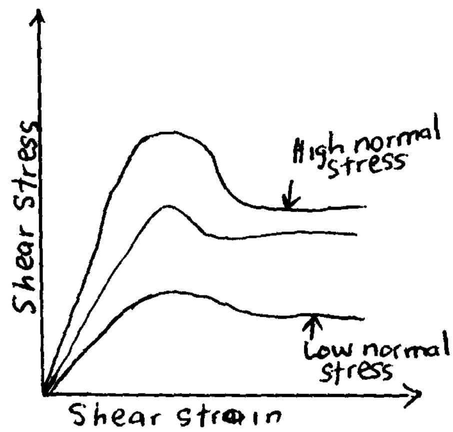


Fig. 2

These stress/strain and stress/stress relationship exist for a soil sheared in bulk, the strength being termed the bulk shear strength. They also exist for the shear of individual clod or aggregate clod shear strength. For the disintergration of clod in the soil mass by shear, the bulk shear strength must exceed the clod shear strength. The magnitude of the bulk and clod shear strengths vary for a given soil with soil moisture content (Fig. 4). Common values for the cohesion and angle of shearing resistance of many loam soils when being cultivated in the friable state, are cohesion 1.0 - 1.4KN/M^2 and angle of shearing resistance 30^o.

Cohesion is a function mainly of the soil moisture and can take two forms:

a. Molecular Cohesion - At low soil moisture content there is strong bounding between the clay particles. This is the main factor influencing the clod strength.

b. Film cohesion - At higher soil moisture content there is a bounding between the clods themselves due to surface tension forces. Organic matter and plant roots also contribute to the total cohesive force during soil shear.

The angle of shearing resistance is a function of the roughness of the shearing surfaces and the degree of interlocking of the soil particles and/or aggregates.

Failure at a soil/metal interface (Payne, 1956, __ __)

The resistance to sliding at a soil/metal interface like soil/soil shear, is frequently a function of the normal stress between the surfaces (fig. 5).

$$Y^{1} = C_{2} + \sigma \tan \phi \quad .... (3)$$

$$H^{1} = C_{2} A + W \tan \phi \quad .... (4)$$

The adhesion compared is usually very small, except under certain plastic soil condition when a non-scouring condition frequently develops. The tangential resistance varies with soil moisture content in the following way. Under friable soil condition, adhesion is normally zero and the angle of the soil/metal friction for a reasonably polished implement is 15.

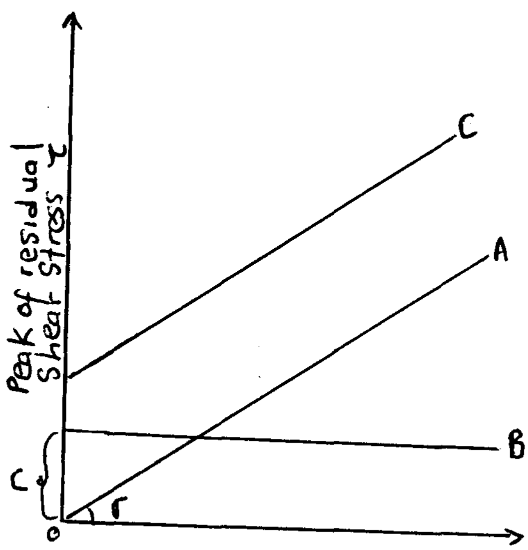


Fig. 3

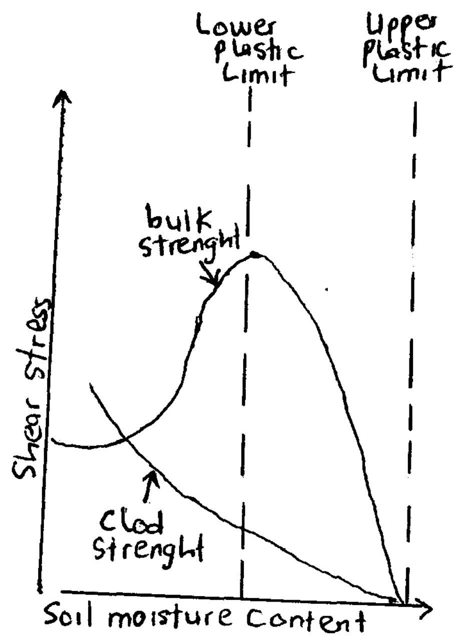


Fig 4.

3.4 How Soil disturbances is affected by Implement factors

Rupture Distance - (Recce A.R. et al, 1965)

The Rupture distance increases with the depth of working and a more acute rake angles. This distance can be determined for rake angle of between (45 - Ø/2) and (180 - Ø/2) from available graphs.

Width of disturbed area (Tanner, D.W. et al, 1960)

The width of disturbed area remains fairly constant with change in rake angle, although there is a slight increase in width as the rake angle decreases. With increasing depth of working, the width of the disturbed area increases but at a decreasing rate, until a point is reached where no further increase occurs .

Total disturbed volume

Due to the effect of changing rake angle on the rupture distance and the width of the disturbed area, the total disturbed volume at a particular depth of work increases with decreasing rake angles.

Changes in soil unit weight (Payne, P.C.J., 1956)

Changes in soil unit weight depend largely upon the direction of the resultant time force acting on the soil. In most agricultural situations, the tine force has an upward vertical component at rake angles less than 45^{o}, this tends to lift the soil upwards producing a loosening effect. With backward (obtuse) rake angles loosening effect. With backward (obtuse) rake angles there is a large vertical downward component with tends to produce compaction. This downward force, also increases the normal loading between the soil particles. Although the same downward force acts upon the soil particles within the clod or aggregate, it does not increase the clod shear strength appreciably, since clod shear strength is mainly a function of cohesion and the cohesive force is independent of the normal load (see equation 2). Therefore the application of a downward force will increase the bulk shear strength more than the clod shear strength, thus increasing the chances of clod disintegration.

3.5 How Implement performance is affected by soil factors

Draught

Draught is influenced by four main groups of factors:

a. Soil/soil parameters

b. Soil/metal parameters

c. Implement shape

d. Forward speed

Soil/Soil Parameters (Kolbuszewski, 1964)

Little can be done to change the apparent cohesion and angle of shearing resistance of a given soil, although any compaction on the failure surface will increase ϕ. From equation (2) however, it is apparent that minimizing the normal load in frictional soils and the strength, and hence the draught force. Vibrations to a very limited extent can reduce the apparent normal load in frictional soil's, but the important factor is to ensure no unnecessary surcharging load is applied to the soil.

Soil/metal parameters (Crowther E.M., et. al, 1924)

The polish on an implement surface is usually more important than the material in influencing the value of the angle of soil metal friction. A large reduction in δ can be achieved by removing the rust from a tine, but the worthwhile returns obtained from very high degrees of polish are very small in most soil. Minimizing the normal load or the interface and the interface area will minimize the frictional and adhesive components respectively when they are present.

The normal load can be reduced by eliminating all unnecessary surcharge and by attempting to lift the soil away from the interface, e.g. by providing an air cushion using compressed air or by vibrating. By choosing a suitable path of oscillation, it is possible to throw or attempt to throw the soil away from the interface, and if motion can then occur whilst the normal load is reduced, a reduction in the sliding force will be achieved.

The soil moisture content at the interface plays a very large part in determining the sliding resistance

since the area of the

soil/implements failure surface is usually fairly small (at least when compared with the soil/soil failure surface), there is the possibility of changing the soil moisture content around the tine to advantage. The moisture contents can also be increased by adding water directly at interface.

One further way of reducing the interface resistance is to eliminate sliding completely by using such things as moving belts and rollers.

CHAPTER FOUR

4.0 METHODOLOGY

4.1 Parameters for designing of soil engaging Implements

Many soil operations in agriculture are extremely complex, therefore for clarity, it is proposed here to break the operation down into single basic units. The units have been chosen after considering plant, mechanization and soil and water conservation requirement and when these units are used either individually or in combination they should satisfy the majority of these requirements. The basic operations are defined as follow;

a. Bursting

b. Compaction

c. Disintergration

d. Cutting

e. Inversion

f. Mixing

g. Movement

h. Smoothing

i. An Chorage

Whilst it must be realised that many current soil engaging implements perform two or more of these operation at the same time, with varying degrees of success, it is proposed to consider the design of tools for each basic operations individually based upon the principles outlined earlier.

Due to lack of equipment to carry out some of the practicals needed, my design analysis will be based on number a;c;d;f and g.

4.1.2 Bursting

The object of this operation is to burst open the soil. So increasing the porosity and breaking through any pans, bursting will be most effective with a low bulk share strength and therefore an upwards force should be applied to the soil and all surcharging effects avoided. Tines with rake angles of 45^{o} or less exert an upward force on the soil and minimum draught can be achieved with rake angles between 15^{o} - 20^{o}. Therefore a 20^{o} rake angle narrow tine would provide the maximum upward force with minimum draught. Although this design may be feasible at shallow depth length, strength, stiffness and bending problems become acute at greater depth, (Fig. 1). It is therefore necessary to compromise on the rake angle of the tine since draught increases are only slight with increasing rake angle would appear to be the most satisfactory. Numerous bursting tine shapes are possible, but their efficiency varies with working depth.

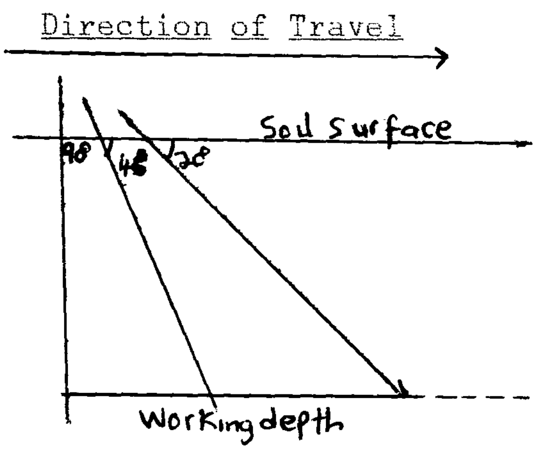


Fig I.

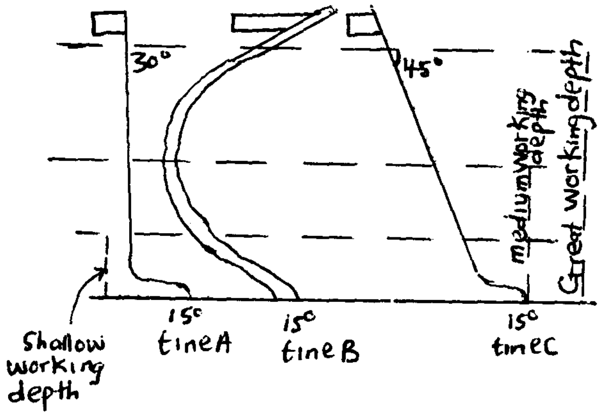


Fig. II

4.1.3 Disintegration (Payne 1959)

Disintegration is a common seedbed operation which reduces the size of clods in cemented and friable soils. To crush clods the bulk shear stength must exceed the clod shear strength and therefore a downward force is required and additional surcharge is an advantage. This can be achieved using a surchaging backward raked tool, either in the form of a wide or narrow tine or a large diameter cylinder or disc. The use of vibrations in a plane normal to the soil surface to increase the surcharging load will increase disintegration. Under friable soil conditions where the clod shear strength is relatively low a continuous large diameter cylinder or cambridge roll would disintegrate the maximum number of surface clods. Due to penetration difficulties with all backward raked tools, disintegration in the deeper soil layers is difficult and it is frequently more convenient and efficient to bring the deep clods to the surface for crushing, using narrow tines with a small rake angle. In the cemented soil condition with very strong clods the loading exerted by the continuous wide tool may be insufficient for disintegration. A greater loading can be obtained under these conditions using narrow tools such as narrow tines or large diameter discs. Disintegration can also be achieved by throwing the clods against a resistant barrier or striking them rapidly whilst on the ground or in the air, so that they break on impact. This can be done using rotating tools but very large peripheral speeds (50 - 60 miles per/hour) may be required to disintegrate very resistant clods when the soil is in a cemented condition and this will increase the torgue requirement and wear. The cutting blade must be designed so that the back of the cutting edge does not rub against the uncut soil. This involves the choice of a clearance angle related to the peripheral speed of the rotor and the forward speed of the machine, fig below

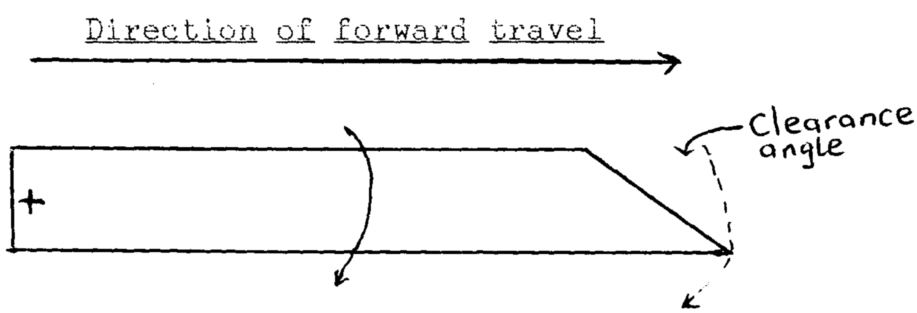


fig.5

4.1.4 Cutting (Fountain, 1954)

Cutting operations are carried out on soil for:

A. Weed control and stubble mulch farming

B. Soil Separation

C. Sowing

a. Weed Control

The cutting requirements for weed control depend upon the nature of the weeds. These can be classified as shallow, deep rooted and perennial rhizomatous types. The control of shallow weeds can best be achieved by cutting below them and lifting them on to the surface, and for this a wide tine or blade type of tool would seem to be the most appropriate. The blade rake angle must be such that it disturbs the weeds sufficiently to bring them to the surface without buldozing them along, so mixing them in with the soil. Rake angles around 16° would appear to be satisfactory.

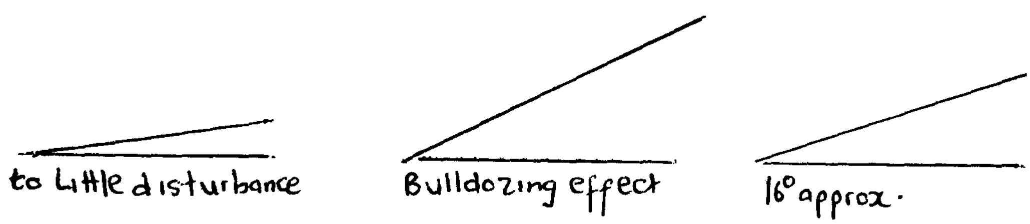


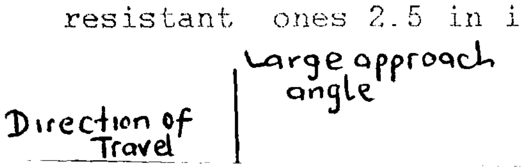
Fig. 9

Where the weeds cannot be brought entirely to the surface, it is important that they be cut cleanly and do not wrap around the blade. In theory, a blade approach angle of 90° to the direction of travel (fig. 10a) should ensure positive cutting of all weeds but at shallow depths penetration is difficult and since there is little resistance to cutting at shallow depths, the weeds actually tend to wrap around the blade. At low approach angles, penetration is good but the weeds readily slide around the side of the blade without being cut (Fig. 10b).

Therefore in choosing the optimal angle of approach, weed cutting, blade blocking and penetration must be considered. As a guide, approach angles between 25° - 50° can be used, the larger angles being most appropriate in areas with few weeds and where penetration is easy, and the small angles under heavy weed and trash conditions and where penetration is difficult.

If penetration is poor and the blade cannot hold its working depth, it is no good just tipping the blade on its nose since the weeds will slip by without being cut (fig. 11).

This penetration problem can only be overcome satisfactorily only by reducing the angle of approach. The overlap between blades (Fig. 12) depends upon the strength of the weeds. With shallow weak weeds an overlap of about 1.5 is adequate but with more resistant ones 2.5 in is more satisfactory (fig. 12).



Wherever weeds and trash are being cut there is a tendency for trash to collect around the leg holding the blade. Whilst this should be avoided, if possible, the leg design should allow any trash which does collect to move away from the blade (fig. 13).

With deep rooted weeds which are firmly anchored in the soil cutting at depth of 10 ins or more can be carried out using continuous blades with an approach angle of 90° and a small rake angle. The cutting of rhizomes into short lengths for the control of perenial rhizomalous weed can be achieved with a rotating tool operating at high peripheral speed and low forward speed.

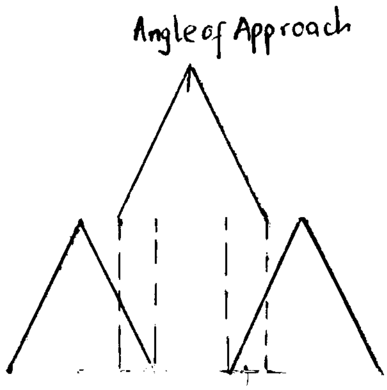


fig. 12: PlanView

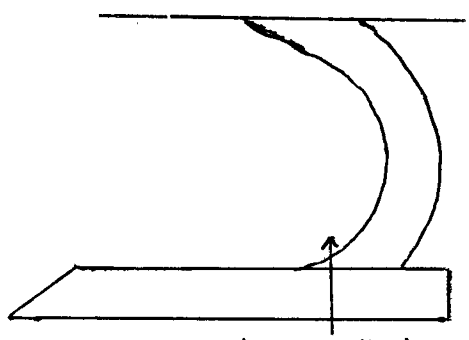


fig. 13

Soil Separation

Clean vertical slots can best be made using backward raked tools although penetration problems may arise in compacted soil. Horizontal cuts are most efficiently made using small rake angle (15°) blades. The reduction of clod size under plastic soil conditions can only be achieved by soil cutting, rather than disintegration and a backward raked narrow tool in the form of a tine or disc is most satisfactory.

Sowing

Sowing operations are performed in bare soil in compact soils with a vegetative cover or in soils covered with loose trash. Slot cutting or opening requirements differ in each case. Under loose, bare conditions, almost any tool will operate satisfactorily providing it can be controlled to work at the correct depth. In compact bare soil, however, penetrating is a problem and forward rake tools are more satisfactory. Very large vertical forces must be appled to backward raked openers such as dics - under these condition.

The presence of a well anchored open vegetative cover does not introduce severe blockage problems and forward raked cutting devices will perform satisfactorily. The use of of a forward raked tine in a continuous sod will cause tearing, thus if a clean slot is required this can only be achieved by first making a vertical slit with a backward raked tool. This introduces penetration problems which can be overcome by using rotary tools rotating in the direction of travel, penetration being achieved through the resulting impacts.

Cutting and seeding directly through a loose trash cover can be exceedingly difficult and often impossible where large quantities of trash are involved. Forward raked tools black radily and backward raked tools will not cut or penetrate the most positive solution would therefore appear to be first exposed bare soil using the tools described earlier. A concave mould board type tool will achieve this.

4.1.5 Mixing

Mixing tools are required for the following purposes.

a. Mixing clods and aggregates, uniformly or otherwise over a particular soil.

b. Mixing in additives to soil e.g. fertilizers, cement for soil stabilisation.

c. Bringing up lower layers for mixing with top soil.

d. Partial burial of trash and plant residues.

A. It is extremely difficult to find a tool which will mix a soil of variable clod size evenly over a given depth. The most satisfactory tools for the purpose is a very rating tool. Vertical and forward raked narrow tines bring the larger clods and particles to the surface leaving the smaller ones below.

B. Mixing Additives: Rotating tools operated with a high peripheral speed and low forward speed, mix in additives broadcast on the surface fairly evenly over a given depth. A multi, concave disc tool, angled to the direction of travel, will mix the sirface layers by throwing the soil and additive backwards and forwards between the discs.

C. Soil Layers: From the analysis of narrow tine failure, a soil wedge moves up the tine to the surface and is replenished with soil from the bottom of the tine. A forward raked narrow tine of rake angle 45 or less will therefore bring lower soil layers to the surface with minimum draught force. If a tine gradually narrows from the bottom to the top and there are friable soil conditions at its working depth, there is the possibility that part of the outside of the soil wedge will be broken away before it reaches the surface and become mixed with the lower soil layers.

D. Partial burial of tash

Although a badly set mould board tool will give partial burial, a more efficient device is the angled concave disc. The greater the quantity of trash to be handled, the larger the diameter of disc required and the greater the disc concavity the greater the amount of burial. As the angle of approach (fig 14) increases, the concave disc becomes more of a forward raked tool and penetration becomes easier.

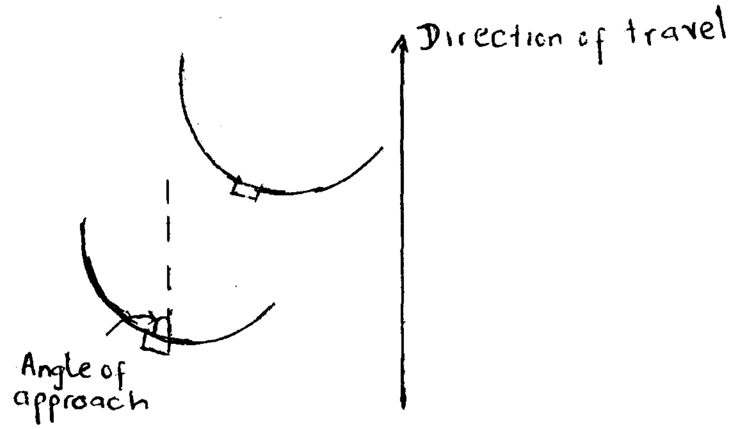


Fig 14

4.1.6 Movement

Soil can be moved by sliding or rolling, either over itself or another material by throwing, carrying or placing. The most effecient method of movement will depend upon the relative values of all the soil/soil and soil metal parameters. In general, rolling forces are usually less.

4.2 MATERIALS AND METHODS

The former discussions were considered individually for clarity and it is necessary to compromise between them in an actual design. However two general rules can be applied as all advantage in all situations and these are firstly, avoiding all unnecessary surcharging effects on the soil and secondly try to solve the problem in a direct rather than indirect way.

Since soil moisture content has such a big influence upon soil shear strength and the resistance to sliding at an interface, it is important to consider what the prevailing soil moisture conditions are likely to be before starting the design. To illustrate this, consider the process of reducing clod size in the preparation of a seedbed. With the soil in a friable condition, clod size can be reduced by loading the clod until it fails by shear along its weakest planes. If the soil is plastic however, this loading will simply squash the clod, changing its shape without reducing its size. In the plastic condition, clod size can only be reduced by cutting and this requires a completely different implement to that required in the friable condition. 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, namely in order of increasing moisture content - the cemented, friable, plastic and liquid states.

4.2.1 Bulk density determination (core method)

Using the manually powered double cylinder core sampler, bulk density (Db) uncorrected for coarse fragments.

Apparatus - Core sampler - hand operated core samplers such as the Urland sampler (7.5cm diameter cores) have been used commonly, plastic bag, nylon cloth, rubber band, one-pint cylinderical waxed-paper carton.

Procedure

1. A smooth, "undisturbed" vertical or horizonal soil surface was prepared at the depth to be sampled in moist soil (good core samples were rarely obtained in dry or wet soils by this method.
2. The sampler was pressed in far enough to fill the inner metal cylinder but not so far as to compress the soil.
3. Then I carefully removed the sampler so as to preserve the sample intact and separated the two cylinders, retaining the "undisturbed" soil in the

inner cylinder.

4. I examine the sample in the inner cylinder. If there has been obvious disturbance; e.g. compression due to driving in too far; shattering of coherent material, hole left by a root or a stone that was displace. I discarded the sample. If no or only slight disturbance was evident, the soil sample flush was trimmed at each end of the inner cylinder.

5. Since only bulk density and water content were to be determined, the sample was pushed out of the cylinder into a plastic bag.

6. The sample was weighed at field water content.

7. And the bulk density calculated as follows

   a. Measured diameter and hence radius (r) in cm of made of cutting edge of smapler (with some samplers. This was slightly smaller than the inside diameter of the inner cylinder).

   b. Measured height (h) of cylinder in cm

   c. Volume (cm^3) of sample (v) $= \pi r^2 h$

   d. Determined over-dry weight of sample (w) in grams; dried to constant weight at 105 ^oC (this was done after the core has been used to make several other kinds of measurements).

   e. Calculated bulk density at field water content D.b.m and the water content of the sample as follows:

$$Dbm = \frac{W}{V} \ g/cm^3$$

PW= wt of oven-dry sample (g); $V = \pi r^2 h$

water content (weight basis) = Pw

$$= \frac{\text{weight of moist soil sample - oven -dry weight sample})\times 100}{\text{oven-dry weight of sample}}$$

water content (volume basis) PV = PwxDbm

4.2.2 Particle Size Analysis (Mechanical Analysis)

The soil was crushed and sieved with 2mm sieve. 50gm of the air-dried soil was weighed and carefully transferred to a `milkshake' mix up. 50mls of 5% sodium hexematephosphate was added and also 100mls of distilled water. Sample was mixed with stirring rod and then allowed to set for 30 minutes. The soil suspension was then stirred for 15 minutes in the multimix machine.

The suspension was transferred from the cup to the sedimentation cylinder and the volume of the cylinder was made up to the 1000 ml mark with distilled water.

The cylinder was covered with hand and inverted several times until all soil was in suspension. The cylinder was placed on a flat surface and the time noted. Soil hydrometer was immediately placed into the suspension until the hydrometer was floating, the first reading on the hydrometer was taken at 40 seconds, the hydrometer was then removed and the temperature of the suspension was recorded with a thermometer.

After the first hydrometer reading, the suspension was allowed to stand for 2 hours and the second reading was taken again and the temperature of the suspension noted. The first reading measured the percentage silt and clay in suspension, while the second reading indicated the percentage of clay in suspension.

A blank was prepared by mains 50mls of the 5% sodium hexametaphosphate (calgon) solution up to 1000 mls in a sedimentation cylinder. The blank hydrometer reading was recorded and also the temperature of the blank.

After the last hydrometer reading, the suspension was poured through a 0.2mm sieve and the sand grains retained on the sieve was washed with tap water and then was transferred by washing into a weighed moisture can. The excess was poured away and the moisture can and sand was placed in an oven at 105^{o} C overnight. Finally, the moisture can and oven dry sand was weighed and the result gave the coarse sand fraction.

4.2.3 Wheel Slipage determination

For a quick measurement of wheel slippage in the field, a spot was marked on the ground and a chalk mark on one rear tractor tyre. Then the tractor was driven under load with the implement in its normal operating mode, and 10 complete rotations of the rear tyre as counted and another mark was placed on the ground. The trip was repeated without the two marks. The traction of the last rotation was estimated as nearly as possible. The number of rotations counted on the second trip, and the chart from Appendix B was used to determine on the second percentage of rear-wheel slippage.

4.2.4 Measuring soil resistance (shear strength) using the Field Inspection Vane Tester

Procedure - The vane was pushed into the ground to the required depth. The handles was turned clockwise as slowly as possible with constant speed until the lower part follows the upper part around or even falls back, failure and maximum shear strength was obtained in the clay at the vane.

It was allowed to return to zero position and the readng together with the position of hole and depth were taken and recorded. The graduated scale was then turn anticlockwise back to zero position and the whole sequence repeated using a different depth.

4.2.5 Determination of depth, width of cut and speed used

The harrow was used in harrowing both in the upland and fadama and the depth, width of cut and speed covered were all measured.

Also I used the ridger in both upland and fadama and the different depths, width of cut and speed covered were also measured and recorded.

CHAPTER FIVE

5.0 RESULTS / CALCULATION

5.1.1 Results: from bulk density and moisture content analysi

Sample	wt of can (g) (g)	wt of can + wet soil (g)	Dia of care (cm)	Height of care (cm)	Oven dry wt of soil + (g)	wt of wet soil (g)	wt of dry soil (g)
For Fadama							
Sample A	48.55	105.10	3.20	3.80	92.97	105.10 -48.55 56.55	92.97 -48.55 44.42
Sample B	49.91	109.33	3.20	3.80	99.61	109.33 -49.91 59.42	99.61 -49.91 49.7
For Upland:							
Sample A	49.71	103.86	3.20	3.80	100.23	103.86 -49.71 54.15	100.23 -49.71 50.52
Sample B	49.41	98.99	3.20	3.80	96.01	98.99 -49.41 49.58	96.01 -49.41 46.6

Results from bulk density and moisture content analysis

Sample	wt of can (g)	wt of can + wet soil (g)	Dia of care (cm)	Height of care (cm)	Oven dry wt of soil + (g)	wt of wet soil (g)	wt of dry soil (g)
For Fadama							
Sample C	48.55	105.80	3.20	3.80	93.99	105.80	93.99
						−48.55	−48.55
						57.25	45.44
Sample D	49.01	107.00	3.20	3.80	93.01	107.00	93.01
						−49.01	−49.01
						57.99	44
Upland							
Sample C	49.41	99.56	3.20	3.80	96.08	99.56	96.08
						−49.41	−49.41
						50.15	46.67
Sample D	49.41	101.01	3.20	3.80	98.75	101.01	98.67
						−49.41	−49.41
			r = 1.6			51.6	49.34

Fadama

Sample C: $Dbm_{cf} = \frac{W}{V} = \frac{45.44}{\pi r^2 h} = \frac{45.44}{30.56} = 1.4869 g/cm^3$
(Depth 15cm)

Water content on wt bases $= \frac{57.25 - 45.44}{45.44} = 0.2599\%$
PW_{cf}

Water content on vol. basis $= PV_{cf} = PWxDbm = 0.38645\%$

Sample D $Dbm_{DF} = \frac{W}{V} = \frac{44}{\pi r^2 h} = \frac{44}{30.56} = 1.43979 g/cm^3$
(Depth 25cm)

Water content on wt basis $= PW_{DF} = \frac{57.99 - 44}{44} = 0.31795\%$

Water content on vol. basis $= PV_{DF} = PWxDbm = 0.457787\%$

Upland

Sample C: $Dbm_{CU} = \frac{W}{V} = \frac{46.67}{\pi r^2 h} \quad \frac{46.67}{30.56} = 1.527 g/cm^3$
(Depth 25cm)

Water content on wt basis $= PW_{CU} = \frac{50.15 - 46.67}{46.67} = 0.074566\%$

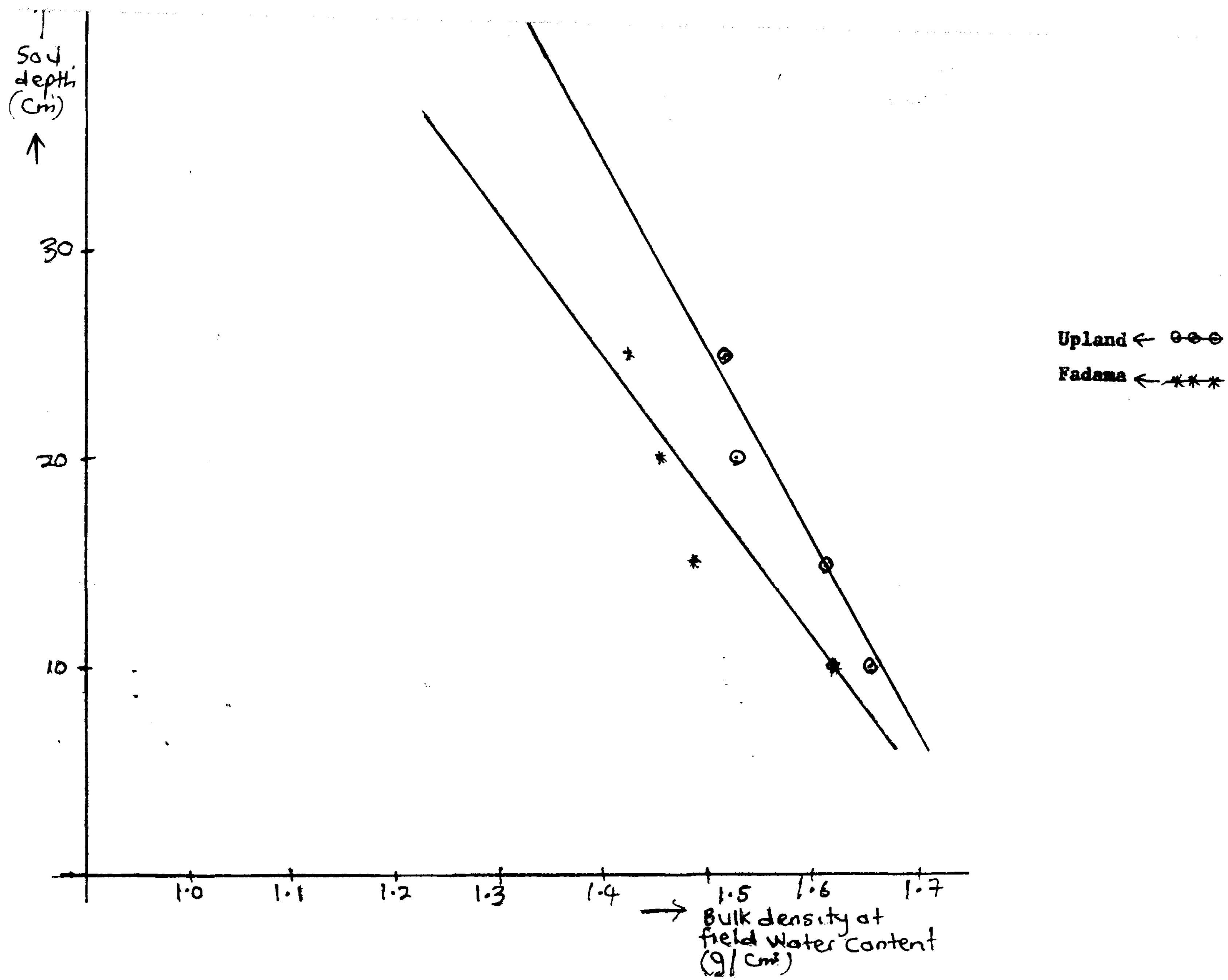
Water content on vol. basis $= PV_{CU} = PWxDbm = 0.11386\%$

Sample D:

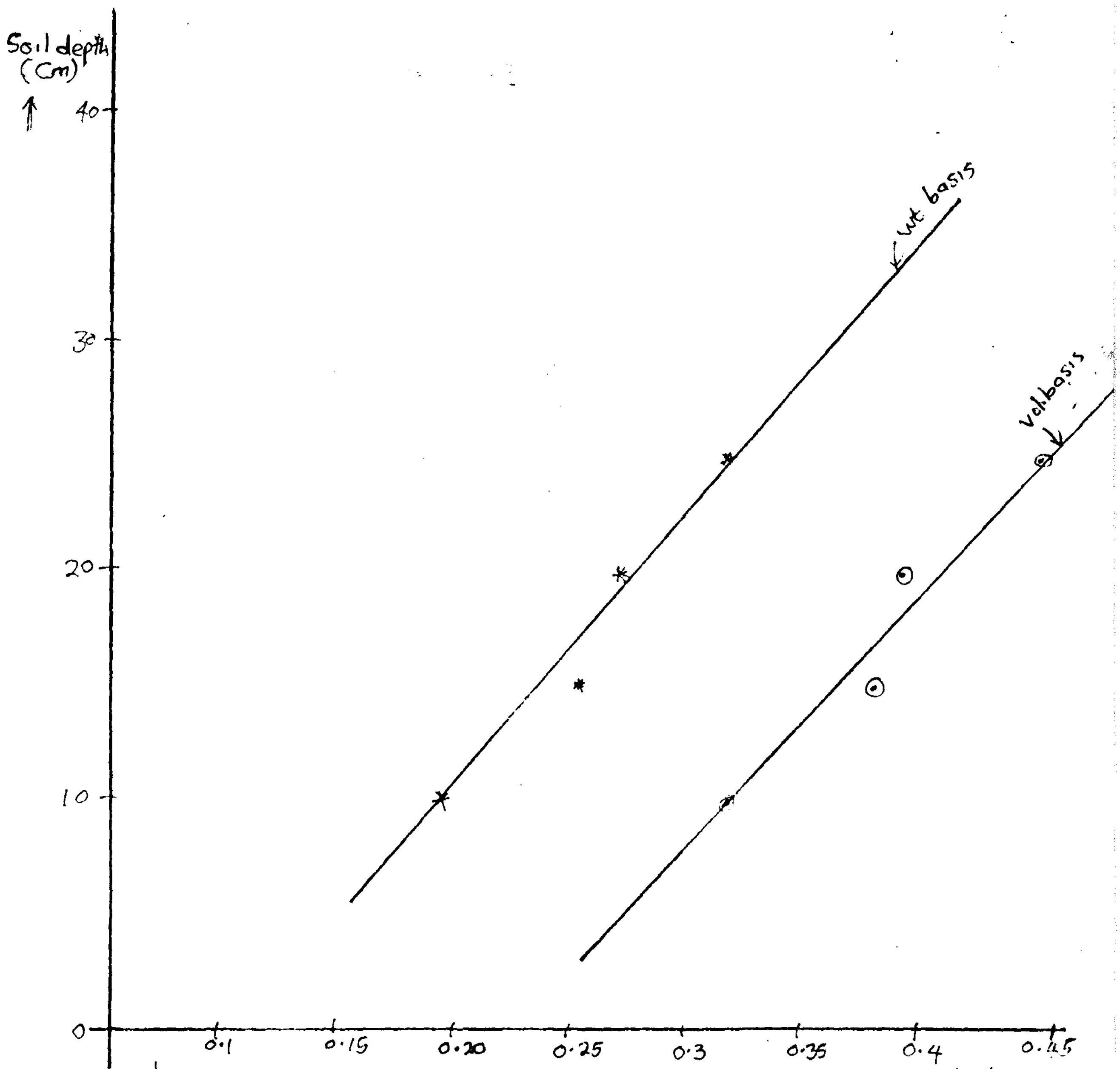
(Depth 15cm) $Dbm_{DU} = \frac{W}{V} = \frac{49.34}{\pi r^2 h} \quad \frac{49.34}{30.56} = 1.6145 g/cm^3$

Water content on wt basis $= PW_{DU} = \frac{51.6 - 49.34}{49.34} = 0.0458\%$

Water content on vol. basis $= PV_{DU} = PWxDbm = 0.0739\%$



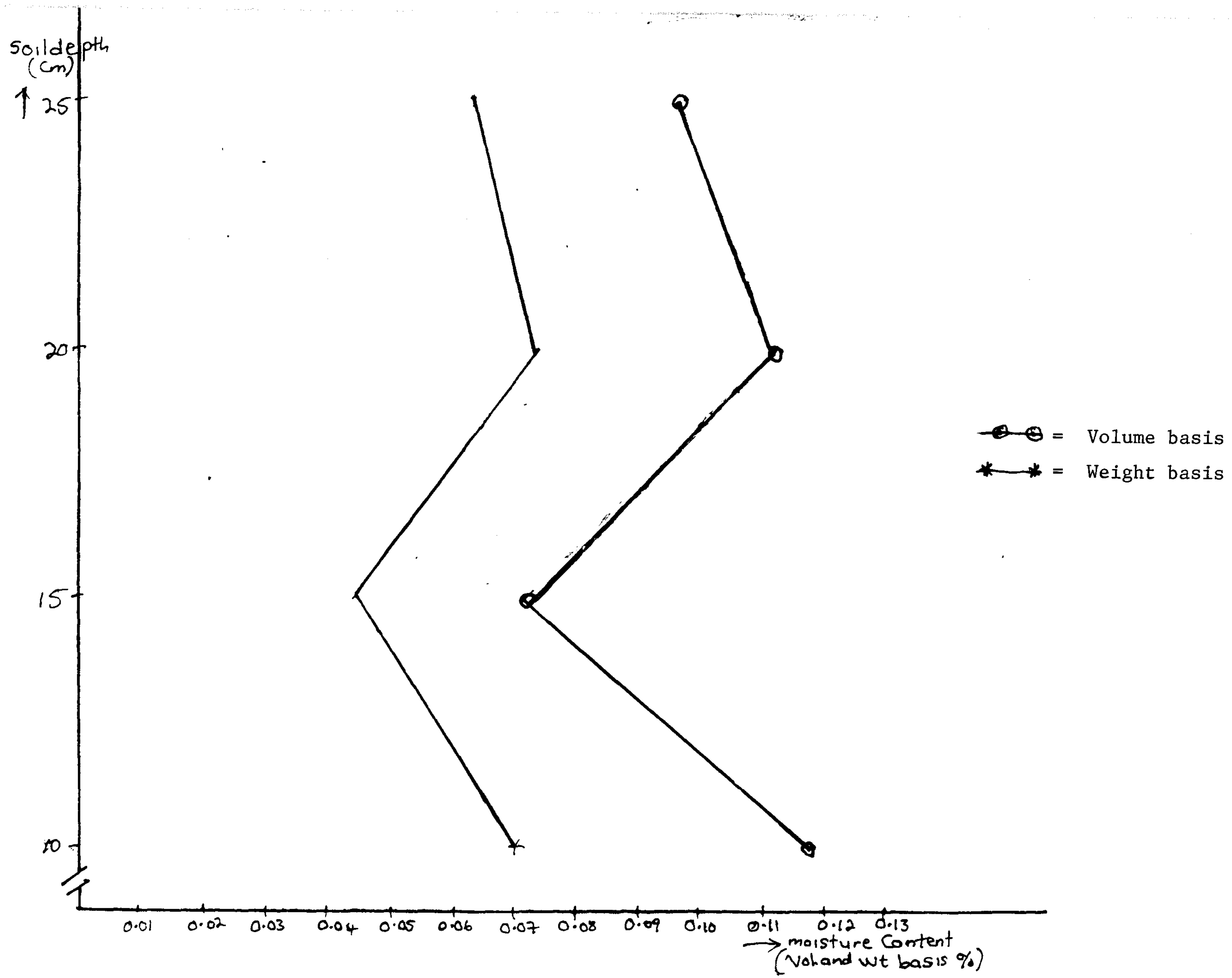
Soil depth (Cm)
30
20
10
1·0
1·1
1·2
1·3
1·4
1·5
1·6
1·7
Bulk density at field Water Content (g/Cm³)
Upland
Fadama

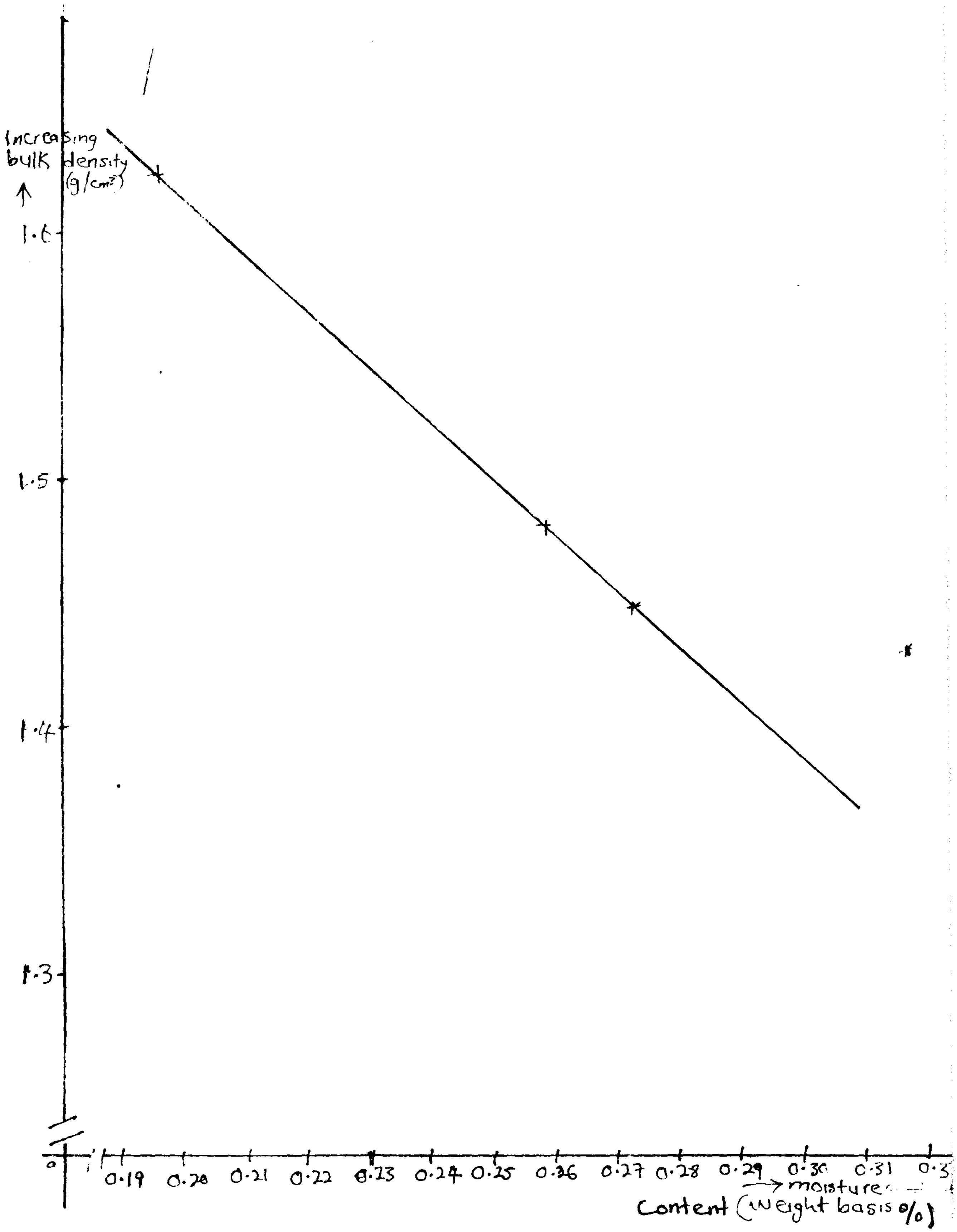


Soil depth (Cm)
40
30
20
10
0
0·1
0·15
0·20
0·25
0·3
0·35
0·4
0·45
wt basis
vol basis
moisture Content (Vol and Weight basis %)

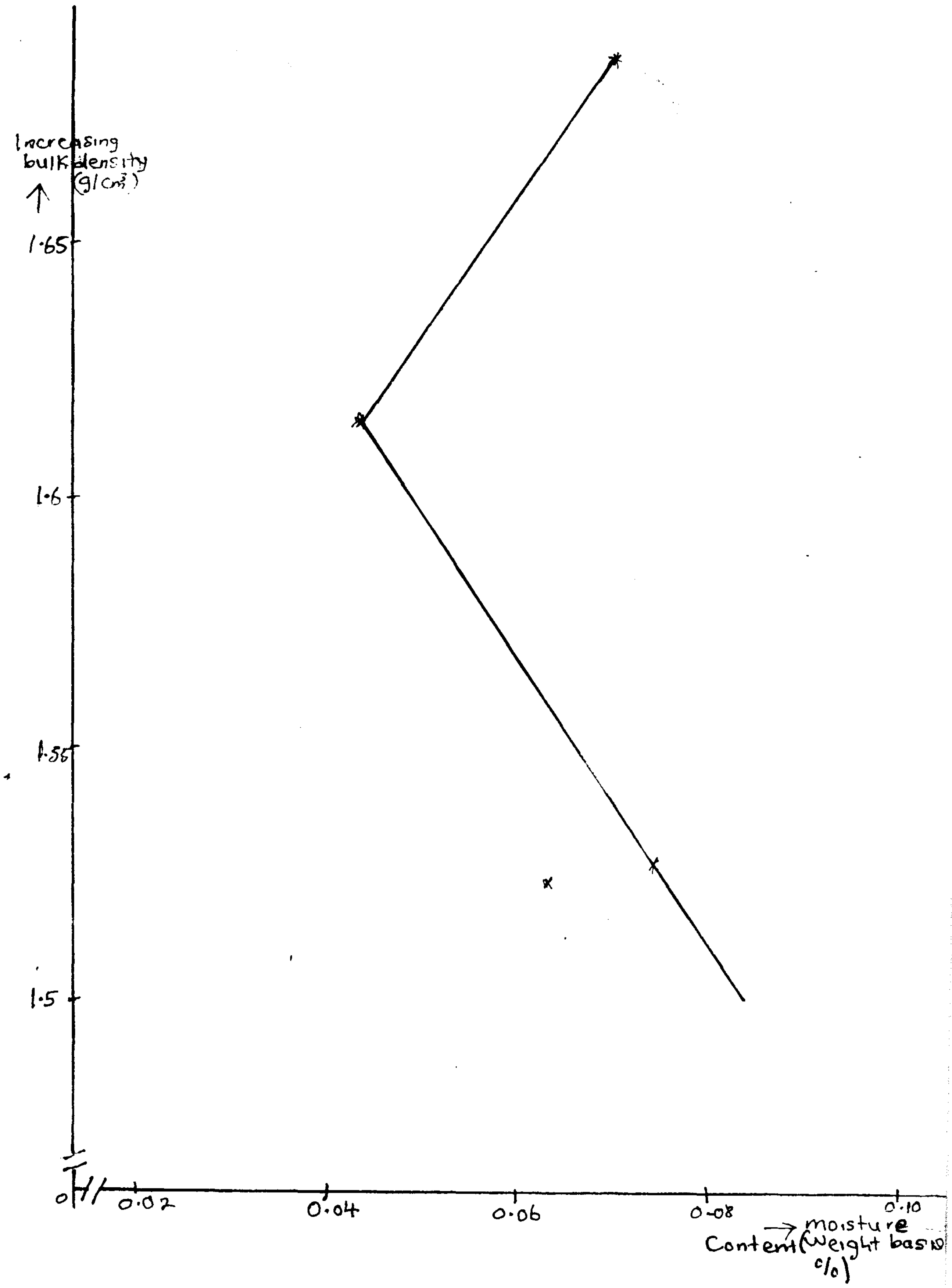
In Fadama

For Upland.


Soildepth (cm)
25
20
15
10
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
moisture Content (Vol and wt basis %)
= Volume basis
= Weight basis


Increasing bulk density (g/cm³)
1.6
1.5
1.4
1.3
0
0.19
0.20
0.21
0.22
0.23
0.24
0.25
0.26
0.27
0.28
0.29
0.30
0.31
→ moisture
Content (Weight basis %)

For Fadama



Increasing bulk density (g/cm³)
1·65
1·6
1·55
1·5
0
0·02
0·04
0·06
0·08
0·10
moisture Content (weight basis %)

For Upland

5.1.2 Calculations for particle size analysis

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

where T = Room temperature minus 20

C = corrected hydrometer reading

R = hydrometer reading of soil suspension

R_L = hydrometer reading of the bulk

Note:

for every degree above 20°C add 0.36g.1

for every degree below 20°C substract 0.36g/1

soil that have high organic matter content may need pre-treatment with hydrogen peroxide prior to the determination.

Conclusion

Location	Sand	Silt%	Clay	Textural Class
Fadama				
Bosso (Minna)	48.4	19.64	31.96	Sandy clay loamy
Upland(Minna)	64.40	4.64	34.96	Sandy day loamy

The textural triangle was used to determine the textural class of the soil samples.

Results from particle size analysis

Sample	Room Temp.	Hydrometer reading of soil susp-ension	hydrometer reading of blank	wt of dry soil + can
For Upland				
	30°C	1st = 7^{s}	0	72.61
	30.5°C	2nd = 4.5	0	can = 50.26
				22.35
Fadama				
	30°C	1st = 15	0	53.64
	30.5°C	2nd = 5	0	can = 49.52
				4.12

C_u = $R - R_L$ + (0.36T)

= 7 − 0 + (0.36 x 30)

= 4.5−0 + (0.36 x 30.5)

C_F = 15 −0 + (0.36 x 30)

= 5− 0 + (0.36 x 30.5)

$C_{Fadama\ 40}$ = 15 − 0 + (0.36 x 30) = 25.8

= $\frac{25.8}{\text{~~50~~g}}$ x 1~~00~~ 2 = 15.98

= $\frac{15.98}{\text{~~50~~g}}$ x 1~~00~~ 2 = 31.96 ——— % clay

.. % silt = 51.6 − 31.96 = 19.64%

thus sand = 100 − 51.6 = 48.4%

C_{Upland} = 7 − 0 + (0.36 x 30) = 17.8

$\frac{17.8}{50}$ x 100 = 35.60% ——— silt + clay

C_{2hrs} = 4.5 − 0 + (0.36 x 30.5) = 15.48

$\frac{15.48}{50}$ x 100 = 30.96% ——— Clay

.. % silt = 35.60 − 30.96 = 4.64%

thus sand = 100 − 35.60 = 64.40%

5.1.3 Result of the Penetrometer (vane tester) shear strength measurement

Location	depth (cm)	Penetrometer readings (Tonnes/m^2) = 10KN/m^2	
		fadama = KN/m^2	Upland = KN/m^2
	5	3.6 = 36	3.5 = 35
	10	6.1 = 61	3.4 = 34
	15	4.45= 44.5	5.9 = 59
	20	2.8 = 28	10.9 = 109
	25	2.7 = 27	14.5 = 145
	30	2.5 = 25	13.2 = 132

5.14 <u>Results for Harrowing in</u>

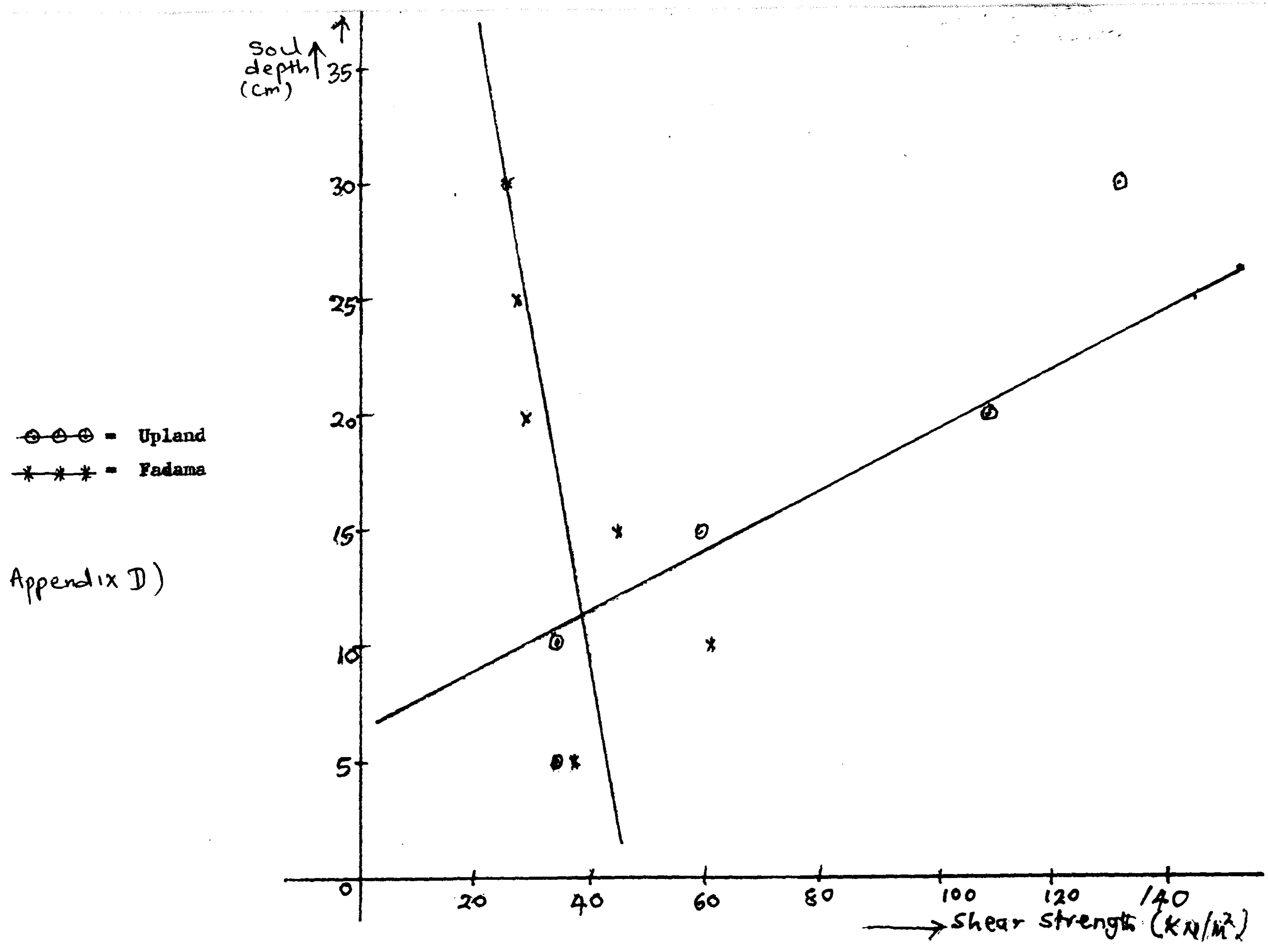
1. <u>Fadama</u> (2) <u>Upland</u>

Speed = 1.4m/sec Speed = 1.5m/sec. $\frac{\text{wt of implement}}{\text{121kg = 1.21KN}}$

<u>Fadama</u>	<u>Width of Cut</u>	<u>Depth of Cut</u>
	1.1	0.1
	1.35	0.01
	1.45	0.08
	1.45	0.06
	1.3	0.05
	1.35	0.08
	1.35	0.05
Average =	1.3357	0.06

2. <u>Upland</u>

	1.30	1.30	0.08
	1.30	1.40	0.07
	1.34	1.40	0.08
	1.25	1.25	0.07
	1.34	1.34	0.10
	1.25	1.23	0.12
			0.12
			0.13
Average =	1.296	1.32	0.09



(See Appendix D)

5.1.5 Ridging Results from Ridging in

1. **Fadama** Speed = 1.07m/sec

(2) **Upland** Speed = 1.96m/sec.

wt of implement on Fadama = 67kg = 0.67KN

Fadama:

	Width of Cut(m)	Dept of Cut(m)
	1.2	0.25
	1.25	0.3
	1.2	0.35
	1.3	0.25
	1.3	0.3
	1.3	0.35
	1.2	0.3
	7	0.25
		0.3
		0.3
Average =	1.25	0.295

Upland

	Width of Cut(m)	Dept of Cut(m)
	1.3	0.3
	1.2	0.25
	1.2	0.28
	1.15	0.25
	1.15	0.28
	1.25	0.2
		0.2
		0.15
		0.28
		0.3
		0.2
Average =	1.208	0.2445

5 Results from slippage, by count wheel rotations

Implement	Rotations	Rear wheel slippage %	wt of implement (kg)	wt of tractor (kg)
Plowing	8 1/6	14%	370	2400
Harrowing (small tractor and implement	8 7/8			
Total:			=	2770kg

5.17: To calculate the draw bar power of the tractor using the different implements will be

pdb = FV

F = draw bar pull in KN = wt of implement x 9.8 —— ma

V = tractor velocity in m^{s-1}

thus for the ridger, pdb will be

1. In Fadama

pdb = FV

= 67 x 10 x 1.07

= 716

= 0.716K

(2) In Upland

pdb = FV

= 67 x 10 x 1.96

= 1313

= 1.313KW

for the Harrowing, pdb will be

1. In Fadama

pdb = FV

= 121 x 10 x 1.45

= 1754

= 1.754KW

(2) In Upland

pdb = FV

= 121 x 10 x 1.5

= 1815

= 1.815KW

Calculation for Plow resistance

Now the formula Px = fG + Koab + Eabv^2(kN)

Px = total plow resistance (kN)

f = resultant of coefficient of frietion of soil

Ko = coefficent of static resistant (Kpa). Ko for loamy soil is between 30 - 50 Kpa. Thus we assume our K_o is 40 Kpa

G = plow wt (KN)

E = Coefficient of dynamic resistance $\frac{KN}{m^2} \times V^2$

for V = 1.0 to 2.4 m/s

E = 2.6 kN.S^2/m^4

i.e for fadama, E = 36 x $\frac{1}{(14)}$ 2 = 18.36 KNS/m^4

for upland E = 35 x $\frac{1}{(1.5)}$ 2 = 15.5 KNS^2/m^4

1 and 2 are for the Harrow

thus for the ridger,

for fadama = 36 x $\frac{1}{(1.07\ )}$ 2 = 24.8 KNS^2/m^4

for upland = 35 x $\frac{1}{(1.96)}$ 2 = 9.1 KNS^2/m^4

G = 121kg = $\frac{121 \times 10}{1000}$ = 1.21KN for Harrow

V = velocity of forward travel

a = width of cut (m)

b = depth of cut (m)

f = σ tan ϕ —— ϕ = internal friction

= ϕ for loamy sand soil from Appendix A = 30 and σ = 0.67

∴ F = σ tan 30 = 0.577 x 0.67 = 0.386

1. Thus for the Harrow (see table 5)

Table 5:

Location	Implement	V(m)	A(m)	b(m)
Fadama	Ridger	1.07	1.25	0.295
	Horrow (spring tine)	1.45	1.3	0.06
Upland	Ridger	1.96	1.2	0.24
	Harrow (spring tine)	1.5	1.16	0.09

a. **Fadama:**

$Px = FG + Koab + Eabv^2 (KN)$

$= (0.386)\ (1.21) + (40)\ (1.3)\ (0.06) + (18.36)(1.3)(0.06)$
(1.45^2)

$= 0.467 + 3.12 + 3.01$

$= 6.597$ KN

$= 4.0134$ Kn using given value of E from table

b. **Upland**

$Px = (0.386)(1.21) + (40)\ (1.16)(0.09) + (15.5)(1.16)(0.09)(1.5^2)$

$= 0.467 + 4.176 + 3.64$

$= 8.28$KN

$= 5.2537$ KN using the value of given E from table

2. for Ridger, $G = 67kg = \frac{67 \times 10}{1000} = 0.67$

a. **Fadama:**

$Px = (0.386)(0.67) + (40)(1.25)(0.295) + (24.8)(1.25)(0.295)$
$\times (1.7^2)$

$= 0.25862 + 14.75 + 10.47$

$= 25.47873$ KN

$= 16.1$ KN using given value of E

b. **Upland:**

$Px = (0.386)(0.67) + (40)(1.2)(0.24) + (9,1)(1.2)(0.24)(1.96^2)$

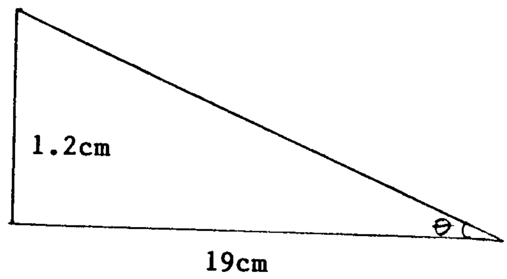
$= 0.25862 + 11.52 + 10$

$= 21.846$KN

$= 14.6552$KN using given value of E

5.19 Angle of Inclinations of

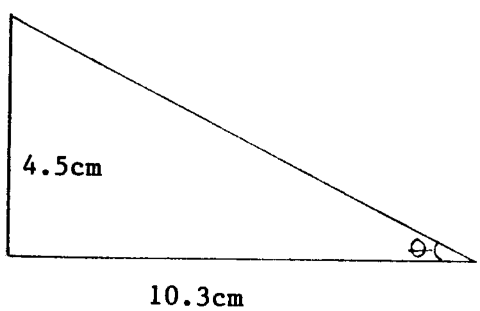
a. Ridger



$$\tan\theta = \frac{1.2}{19} = 0.06316$$

$$= 3.6$$

b. Harrow



$$\tan\theta = \frac{4.5}{10.3} = 0.4369$$

$$\theta = 23.6$$

Results/Discussions

Table 6: showing the rule of thumb draft indicators for diverse tillage tools (A.S.A.E., 1984)

Implement type	Location	Soil	Draft, N force
Spring tine harrow	Fadama	Sandy clay leam	= 480+ = 40.1 x 4 x 10^{-7} = 480.00001
	Upland	"	= 480 + 48.1 x x 4.1 x 10^{-7} 480.00002

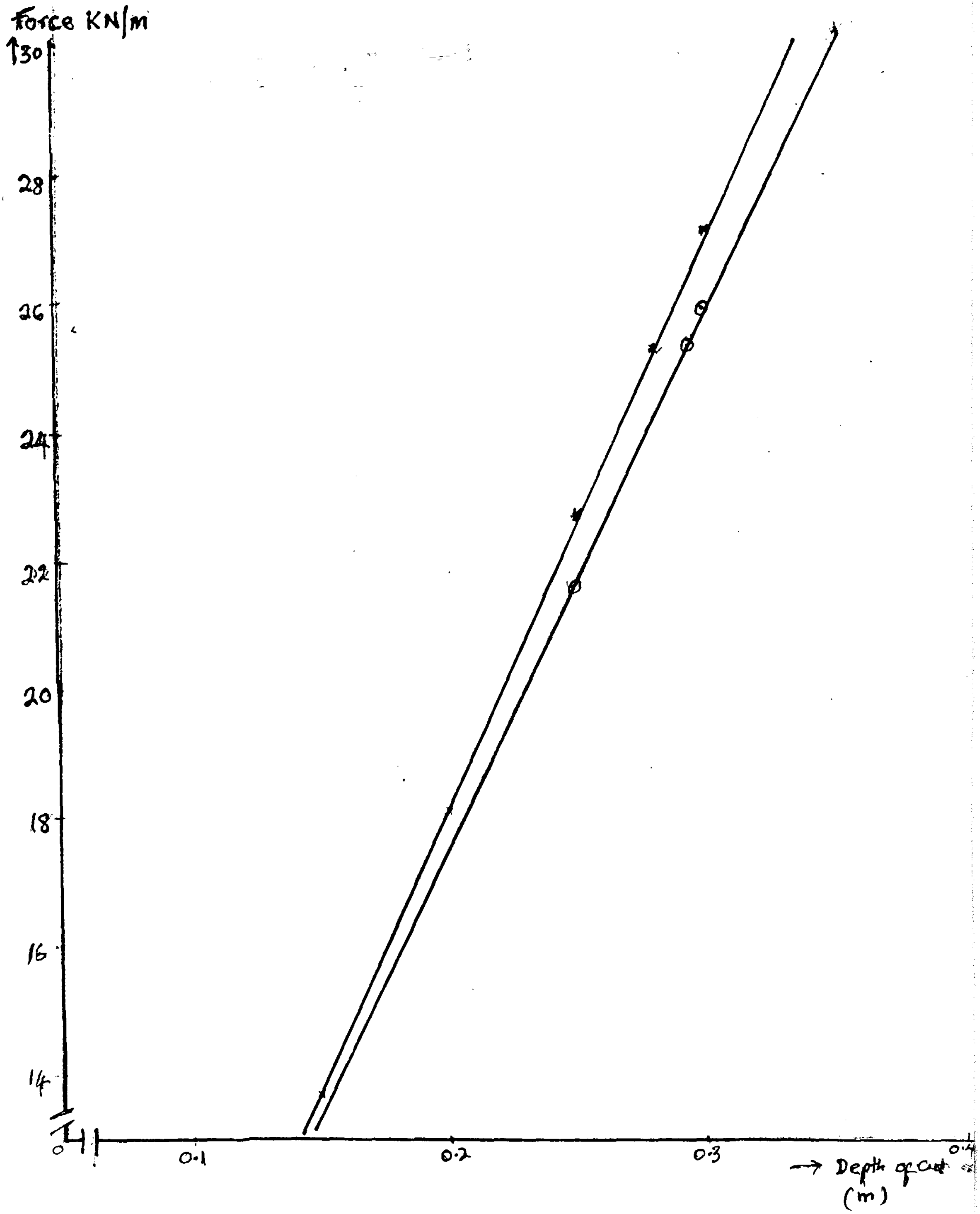
m = implement mass (kg) v = travel speed =

Table 7 : Soil Resistance

Operation	KN of draft/ meter of width	Typical speed km/hr	Draw bar kW/ meter of width	Soil type
Fadama	$\frac{6.597}{1.3}$ = 5.0746	$\frac{1.45}{60x60x1000}$=4x10^{-7}	$\frac{1.754}{1.3}$ = 1.349	Sandy clay leavy
Upland	$\frac{8.28}{1.3}$ = 6.369	$\frac{1.50}{60x60x1000}$=4.1x10^{-7}	$\frac{1.815}{1.16}$ =1.56	"
Ridger				
Fadama	$\frac{25.47}{1.25}$ = 20.376	$\frac{1.07}{60x60x1000}$=2.9x10^{-7}	$\frac{0.716}{1.25}$ = 0.572	"
Upland	$\frac{21.846}{1.2}$ = 18.2	$\frac{1.96}{60x60x1000}$=5.4x10^{-7}	$\frac{1.313}{1.2}$ = 1.094	"

Table 8: Calculation for KN/m

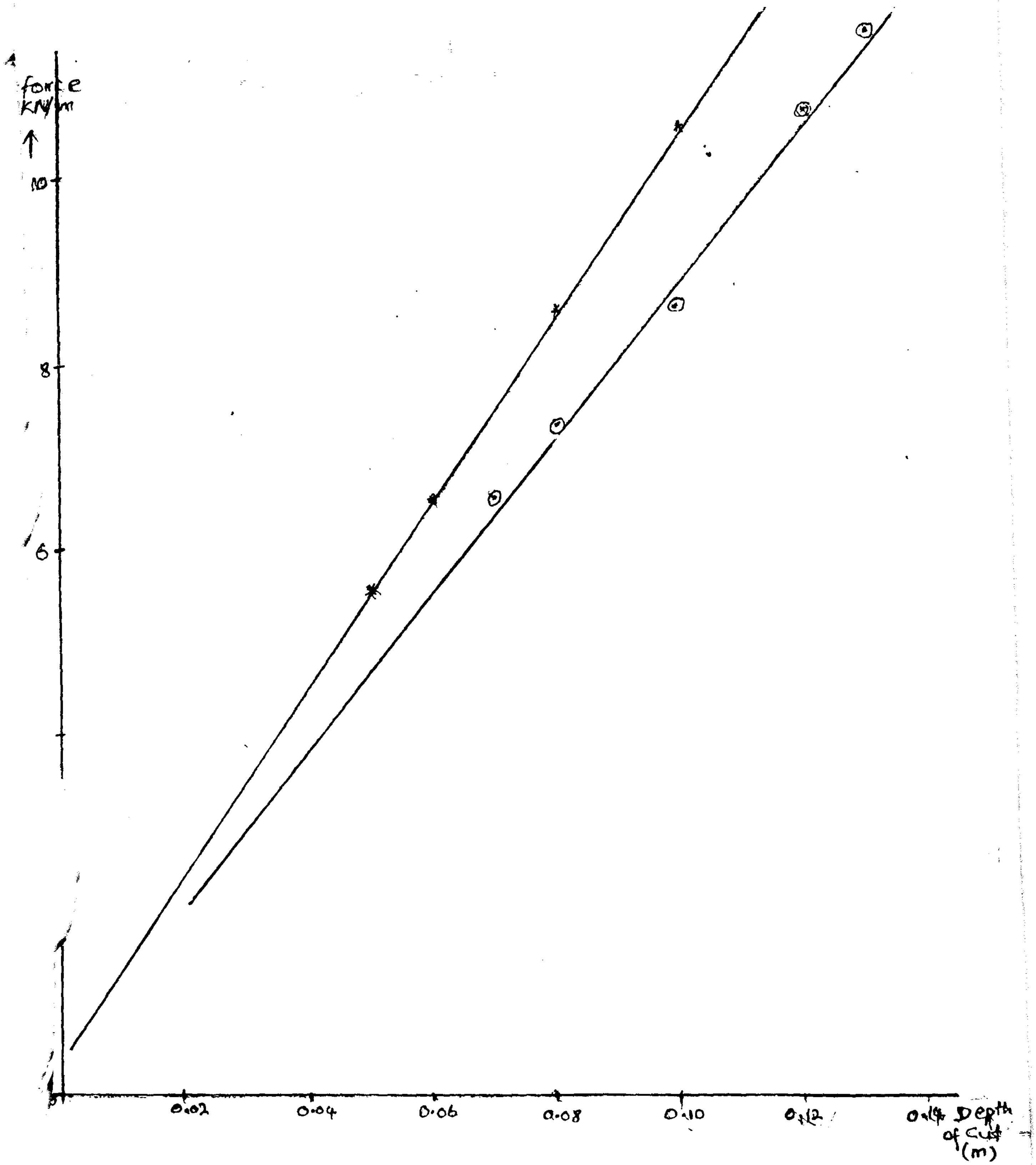
Operation	Location	Depth of cut (m)	Force KN/m	Values got using the given E from table.
Harrowing	Fadama	0.1	10.683	6.3776
(Spring tine)		0.01	1.4886	1.058
		0.08	8.64	5.195
		0.06	6.597	4.0134
		0.05	5.575	3.422
	Upland	0.08	7.414	4.721
		0.07	6.545	4.1896
		0.10	8.688	5.785
		0.12	10.887	6.8486
		0.13	11.756	7.3804
Ridging	Fadama	0.25	21.63	13.72
		0.3	25.9	16.41
		0.35	30.18	19.1
		0.295	25.48	16.1
	Upland	0.3	27.156	18.253
		0.25	22.67	15.255
		0.28	25.36	17.0
		0.2	18.19	12.25578
		0.15	13.7	8.997



→ Ridging in Upland

→ Ridging in Fadama

(See Appendix D)



→ Harrowing in Upland

→ Harrowing in Fadama

(See Appendix D)

5.2 RESULT/DISCUSSION

From the results and calculations, it was seen that the draw bar pull requirement for both the ridger and harrow were higher in the upland region than in the low land region due to, possibly the soil moisture content which is lower in the upland region than in the fadama region. From the graph it could be seen that the deeper the depth, the lower the bulk density and the lower the moisture content and this can possibly be due to the compaction of the soil on the upper surface.

Also the total plow resistance was seen to be higher in upland than in fadama using the harrow while using the ridger, it is higher in the fadama than in the lowland and in this latter case, it might be due to the small penetration of the ridger into the soil as a result of the low angle of inclination in the upland region while in the fadama there was accurate penetration and with the presence of the clay and water clogging, it resulted into a higher total plow resistance which is more accurate than that got from the upland.

Again for the shear strength using the penetrometer (vane tester), it was discovered that in the upland, the deeper the depth, the higher the shear strength while in the fadama, the deeper the depth, the lower the shear strength except in the first 10cm depth where it behaves like that in the upland possibly due to the soil surface exposure to sun. Thus in fadama, the top soil has been compacted making it to have a higher shear strength than the sub soil while in the upland, the top soil shear strength has been reduced due to the very low moisture content.

From the graph of force against depth of cut, a uniform line was got from both upland and fadama region showing the increase in force with an increase in depth of cut.

The draw bar pull requirement for an appropriate tillage equipment for a ridger is 0.716KW in fadama and 1.313KW in upland while for a Harrow, it is 1.754KW in fadama and 1.815KW in upland. The angle of inclination of the implements are 3.6^{o} for ridger and 23.6^{o} for harrow. For slippage the normal requirement for proper slippage while working on both fadama and upland region in Minna was that for a Kg weight of both tractor and ballast, the appropriate weight of implement to be pulled should be 0.12kg, that is 0.12kg of implement/kg weight of tractor and ballast.

CHAPTER SIX

6.0 CONCLUSION/RECOMMENDATION

Due to lack of equipments, my research and project work was based on the equipments available and this could not give a satisfactory results as I would have wished for, for a thorough research work. For instance, the angle of inclination for both, especially that of the ridger (3.6^{o}), was so low that the actual depth of cut I would have loved to get was not attained thus making analysis in the upland region base on a shallow depth of 0.24 for ridger and 0.09m for Harrow despite the additional weight of 30kg placed on the implement.

Also due to the lack of dynamometer, I could not measure the power requirements and fuel consumption. Also, due to lack of dynamometer in school, I was made to fabricate an attachment to be used in attaching a spring weight balance in between the implement and tractor so as to use in measuring the force requirement and then the draw bar and draft requirment. But due to the fact that the balance that I was able to acquire could only carry or pull a weight of 50Kg, I could not use the attachment, thus I employed the use of formula to calculate both the drawbar pull and total plow resistance. The specifications and dimensions of the attachment will be explained in the Appendix C.

Thus for the design specifications and for someone that will like to carry out this project from where I stopped, in fabricating the appropriate and suitable tillage equipment for both upland and lowland region in Minna, the person should bear in mind that the draw bar requirement for a Harrow in Fadama is 1.754kw and upland is 1.815kw while the Ridger in fadama is 0.716kw and unland is 1.313kw. Also the total plow resistance for a harrow in fadama is 4.0134kN and upland is 5.253kN while for ridger it is 16.1kN in fadama and 14.6552kN in upland.

It was also observed that penetration into the soil was more difficult in the upland region than in the fadama due to the low moisture content and thus higher soil resistance.

The total plow resistance calculated using my results in getting Eo is slightly different from that got using a given value of Eo. This may possibly be due to the differences in soil structures since there was no specification as to the soil type of the given Eo, and also soil type.

Since tilling in upland has a higher bulk density than in fadama then the power requirement or the total resistance that will result in tilling the soil wil be higher in upland than in fadama. Also due to the higher shear strength in upland which increses with depth than in fadama there will also be higher power requirement in tilling the soil in upland and sinkage in the fadama should also be taken into consideration.

Thus for the total plow resistance, this is higher in upland than fadama with harrow and higher in fadama than in upland using the ridger and this is not very accurate since there is poor penetration of the ridger in upland. Thus all the above conditions should be taken into consideration during the design of tillage equipments in both fadama and upland region in Minna.

Thus for bursting of the soil, a 20^{o} rake angle narrow tine would provide the maximum upward force with minimum draught. Although this design may be feasible at shallow depth, length, strength, stiffness and bending problems become acute at greater depths. For soil cutting, both for weed control and soil separation, the optimal angle of approach should be around 16^{o} though atimes this might depend on the type of weed. For soil mixing, a more efficient device is the angled concave disc with angle of approach of about 50^{o}. And for soil disintegration, this can be achieved using a surcharging backward raked tool, either in the form of a wide or narrow tine or a large diameter cylinder or disc.

Hence, from the project, the tillage equipment designer, using the values I obtained, for the soil/ soil parameters (in knowing the value of Ø and thus the minimum load to be applied) soil/metal parameters (in knowing the ~~the~~ value of δ and knowing the appropriate reduction of the δ to be made), forward speed (in knowing the depth and width of cut achieved with the implements) at various speed, soil/implement factors like the moisture content, bulk density and finally the shear strength and total plow resistance required. The designer can now be able to design suitable and appropriate soil tillage equipments to suit both the fadama and upland region in Minna and also saving costs of operation for the farmers since the farmer will now know the right tillage implements that will suit his farm without spending much on trying different tillage implements.

RECOMMENDATIONS

For someone wishing to make further research or development on this project, the problems or areas left to be investigated which I could not do because of lack of necessary equipments and time available for the project as previously explained, include the following:

1. If suitable field dynamometer is available, then direct draw bar can be measured.
2. With the dynamometer also direct power requirements can be measured.
3. Determine the effect of different shape of some tillage implements on draft, and speed.
4. Determine the effect of different angle of inclination of some tilage implements on draft and speed.
5. Determine the fuel consumption rate of using different implements of different shapes and angle of inclination.

All these should be determined in both upland and fadama taking into consideration the soil characteristics got during my tests to avoid wheel sinkage especialy in the fadama.

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APPENDIX A

Typical values of angle of Internal friction (Ø) for several soils. (JOSEPH 1965)

	Loose	Dense
Gravel	32-36	35-50
Coarse sand	32-38	35-48
Clay sand	28-32	35-40
Silty sand	28-32	32-38
Fine sand	27-32	33-39
Sandy gravel	30-38	36-45
Gravelly sand	30-38	36-50
Silt	20-30	23-32

APPENDIX B

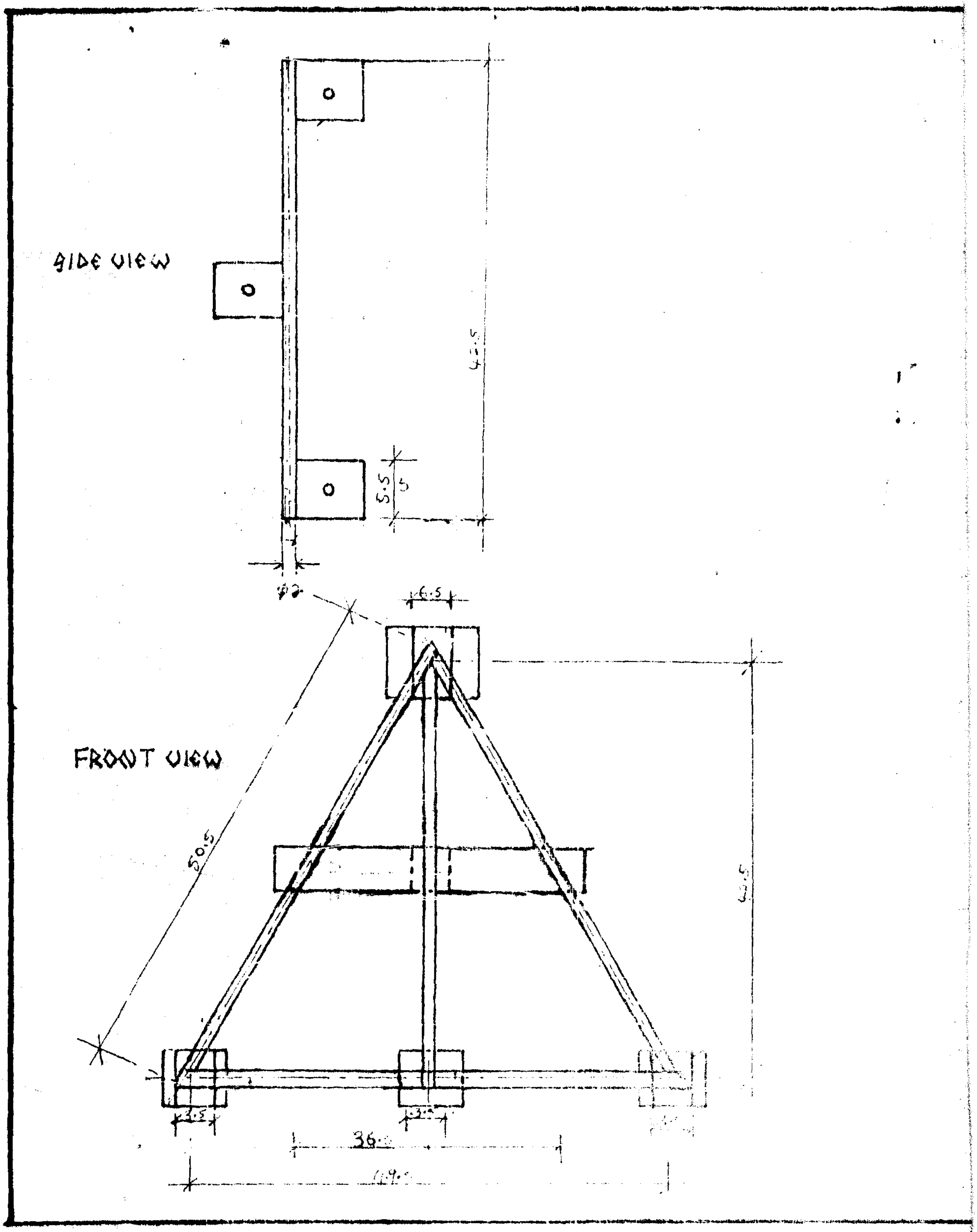
Slippage was got by counting wheel rotations, the tyre tread pattern produced when pulling under load provides an approximate indication

Rotations	Rear wheel slippage %	What to do
10	0	Remove ballast
9 1/2	5	
9	10	Proper ballast
8 1/2	15	
8	20	
7 1/2	25	Add ballast
7	30	

APPENDIX C

Attachment for attaching spring balance between the tractor and implement:

All dimensions are in centimetres. The side view and front view of the attachment is as shown over page and the joints were welded together using an arc welding. A flat bar was used at the middle to get a stronger weld at the joints and to provide a proper attachment for the bar to which the spring balanced will be hooked unto.


SIDE VIEW
FRONT VIEW
5.5
5
6.5
50.5
3.5
36

APPENDIX D

From the graph, the lines were constructed using the Equation of a straight line $Y = a+b\ x$

where a is the intercept of the axis

b is the gradient of the line

Thus for linear correlation - using Regression and Correlation

$$y = an + b\ x \quad \ldots\ldots\ldots\ldots (1)$$

$$(xy) = a\ x + b\ x^2 \quad \ldots\ldots\ldots (2)$$

n is the number of points to be plotted. The equations are least square line, thus from experiment, x, y, xy, x^2 values were got and then the equation (1) and (2) were solved and the values of a and b were got and finally two different values for y were selected and their corresponding x values got to obtain two coordinates used in plotting the straight line graph.