Optimization of Machine Tractor Outfit: Case of Disc Plough

By

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SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

MECHANICAL SYSTEMS AND VEHICLE ENGINEERING DEPARTMENT

Thesis Submitted to the Mechanical Systems and Vehicle Engineering Department for the Partial Fulfillment of the Requirements for the Award of Master of Science Degree in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

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APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Mengistu Mekonnen have read and evaluated his/her thesis entitled "Optimization of machine tractor outfit: a case of disc plough" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master of science in Agricultural Machinery Engineering.

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DECLARATION

STUDENTS DECLARATION

I hereby declare that the work which is being presented in the thesis entitled ‘‘Optimization of machine tractor outfit: a case of disc plough’’ for the partial fulfillment of the requirement for the award of MSc. Degree in Agricultural Machinery Engineering is an authentic record of my own work carried out from May 2017 to May 2018 under super vision of Dr.Ing. Simie Tolla and Dr.Ing. Fekadu Lemessa from program of Mechanical systems and Vehicles Engineering, Adama Science and Technology University, Ethiopia.

The matter embodied in this thesis has not been submitted by me and other for the award of any other degree or diploma. All relevant resources of information used in this thesis have been dully acknowledged.

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ADVISORS DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of Master of Science Degree in Agricultural Machinery Engineering.

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Co - Advisor Sign Date

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LIST OF ACRONYMS

AAMEI	Adama Agricultural Machinery Engineering Industry
AFC	Actual Field Capacity
AIRIC	Agricultural Implement Research and Improvement Center
BDP	Bottom Disc Plough
CI	Cone Index
DBHP	Draw Bar Horse Power
GDP	Gross Domestic Product
GoE	Government of Ethiopia
ha	hectare
hp	horse power
Li	Liter
MARC	Melkasa Agricultural Research Center
METEC	Metals and Engineering Corporation
MFWD	Mechanical Front-Wheel Drive
MTO	Machine Tractor Outfit
MFWD	Mechanical Front-Wheel Drive
NTAP	Nazareth Tractor Assembly Plant
SFC	Specific Fuel Consumption

ABSTRACT

Agricultural mechanization in Ethiopia is found to be at minimum level mainly depending on draft animals and human drudgery. One of the factors affecting on tractor matching to a proper disc plough in different climate and soil condition. The objective of this study was to optimize machine tractor outfit for some selected agricultural tractor with disc plough. Therefore, three models of disc plough with tractors 80 hp and 50hp on the 2nd and 3rd gears forward speeds of 1.18 m/s, 2.01m/s,0.89 m/s, and 1.18m/s respectively was tested and ploughed in vertisol and sandy clay loam soil type. The results obtained during ploughing operation in vertisol soil type 80 hp with 4 bottom disc plough 66 cm disc diameter the field capacity, average pull force and average fuel consumption was 0.35 ha/hr 17000N and 28 lit/ha respectively and 80 hp with 3 bottom disc plough 66 cm disc diameter the field capacity, average pull force and average fuel consumption was 0.52 ha/hr, 13500N and 21.8 lit/ha respectively. Sandy clay loam soil 80 hp with 4 bottom disc plough 66 cm disc diameter the field capacity, average pull force and average fuel consumption was 0.62 ha/hr, 11500N and 20 li/ha respectively and 80 hp with 3 bottom disc plough 66 cm disc diameter the field capacity, average pull force and average fuel consumption was 0.52 ha/hr, 8500N and 23.08 lit/ha respectively. Sandy clay loam soil 50 hp with 3 bottom disc plough 66 cm disc diameter the field capacity, average pull force and average fuel consumption was 0.31 ha/hr 8500N and 19.2 lit/ha respectively and 50 hp with 4 bottom disc plough 50 cm disc diameter the field capacity, average pull force and average fuel consumption was 0.26 ha/hr, 7500N and 15.39 lit/ha respectively. Based on the performance evaluation results in vertisol soil type 80 hp tractor with 3 bottom disc plough 66 cm disc diameter and in sandy clay loam soil type 80 hp tractor with 4 bottom disc plough 66 cm disc diameter, 50 hp tractor with 3 bottom disc plough 66 cm disc diameter was the most appropriate for ploughing as it recorded the highest field capacity, low pull force and fuel consumption.

Key words: Disk angle, Disk plow Draught, Farm Tractors, implements, Optimization, Tillage

CHAPTER ONE

1. INTRODUCTION

1.1. Background and Justification

Agriculture has been the Main economic driving sector in Ethiopia and plays the biggest role in contributing to GDP and for the recorded changes in growth as compared to other economic sectors. Agricultural has created and is creating conducive situations which enable the transformation to industrialization. Agricultural productivity in Ethiopia is improving, there are still major gaps in productivity when compared with the rest of Africa in some crop areas, and almost universally, when compared with the global output level (FAO, 2009).

Crop production is physically demanding and the working conditions are often harsh. It is less strenuous to drive a tractor than to till the soil with a spade all day long. A tractor pulling a plow can cultivate a larger area than a human with a spade in the same amount of time, thereby increasing productivity and timeliness. Timeliness is an important factor in agricultural production. Completing certain farming operations such as soil tillage, planting and harvesting in a timely manner increases yields and improves profitability. Farming operations are seasonal with fluctuating labor demand. More labor is needed during land preparation, planting and harvesting than during other periods of plant growth (Ajit et al, 2006).

A tillage is to modifying the state of the soil in order to provide conditions favorable to crop growth. Three things are involved in soil tillage, which are the power source (tractor or animal), the soil and the implement (Disc plough). It can be defined as any positive action when forces are reasonably applied with the aim of altering the soil conditions for agricultural purposes. Ploughing is a primary tillage operation which is performed to shatter and achieve soil inversion. It is the initial soil working operation and also the deepest tillage operation of about 150 to 300 mm. Ploughing is the most important primary tillage operation for arable farming in preparation for the production of vegetable and cereal growing crops. It creates a suitable soil condition for plant growth which increases crop productivity and boosts the agricultural economy.

Disc Plough is a tillage implement used for primary soil tillage operation. It is used in tropical region where condition is very hard and rough and totally unsuitable for use of the conventional mold board plough. Consequently, disc plough has a tilt adjuster with which the angle of tilt of the blade is adjusted. The width of cut per disc (Disc plough) depends upon the spacing and the angle (adjustable) between the gang axis and the direction of travel. It was observed that disc plough has a higher total and specific draught than other tillage implements, for a given soil type and tractor forward speed.

Draught of tillage implement (Disc plough) however plays a vital role in developing more efficient tillage system by selecting suitable combination of tractor and implements Draught is the horizontal component of pull force, parallel to line of motion, while side draught, is the horizontal component of pull, perpendicular to the line of motion. The force required to overcome the soil resistance and move the tillage implement at the required speed is called the cutting force. The horizontal component of this cutting force is called the draught. Draught is the total horizontal force parallel to the direction of travel required to propel the implement. It is the sum of the soil and crop resistant and the implement rolling resistance (Nkakini.., 2015).

The proper selection of tractor and implement for a particular farm situation requires availability of the field performance data of both tractors and implements. Tractor and implement test are needed in different farm sites under different operating conditions to prevent serious damage. This will enable the proper selection of tractor and implement for a particular requirement.

Now, Adama Agricultural Machinery engineering Industry (AAMEI) is the biggest industry in Ethiopia which works to transform the traditional farming to mechanized farming. The industry assembles different agricultural tractors and Implements (disc ploughs). These research objectives are to investigate the draught force of a disc plough at various tractor forward speeds in different types of soil. To study the relative effect of the parameters involved with the draught of the research conducted in the area of the study and end with providing recommendations on how the uses of farm tractors with implement will be enhanced.

1.2. Statement of the Problem

Many factors have contributed to agricultural mechanization. Reducing human drudgery, increasing productivity, and improving timeliness of agricultural operations such as planting and harvesting, and reducing peak labor demands are among the most compelling. A tractor pulling a plow can cultivate a larger area than a human with a spade in the same amount of time, thereby increasing productivity and timeliness. Timeliness is an important factor in agricultural production.

In Ethiopia there was a factors affecting the use and operation of agricultural tractors and implement optimization scientifically. The factor resulted a gap on how to use and implement agricultural machinery by considering their capacities with farm locations. There for the Ethiopian farmers face a problem on the selection of agricultural machines with implements. These problem results a faliety on their machine. Due to improper selection and management of machines regarding on different types of topography, agro-ecology, lack of skilled operator, improper hitching and optimization of tractors with their implement .So to solve the problems it is better to optimize tractor with disc plough.

1.3. Objective

1.3.1. General Objective

The main objective of the study is to optimize machine tractor outfit on some selected Agricultural tractor with disc plough.

1.3.2. Specific Objective

i. To conduct tractor draught performance based on types of implement and soil condition.
ii. To determine tractor and disc plough capacities in actual utilization of field work.
iii. To evaluate the tractor efficiency based on data from drawbar performance.

1.4. Significance of the Study

Tractor enhances human capacity, leading to escalation and increased productivity as a result of proper seedbed preparation, timely planting by integrating functional processes. Tractor also plays a great role in weed control, harvesting, post-harvest handling and accessibility to market. Realizing this, currently the government is stepping forwarding in provision of improved technologies through various institutes and organizations. Adama Agricultural Machinery Industry is one the organization which is working towards addressing problems pertinent to provision of improved agricultural implements and machineries. One of the factors affecting the uses of tractors and implements is how to uses different types of agricultural tractors and implements in different areas.

In this study, the main objective of the test was to check which plough is suitable for which tractor horse power in the agro technical conditions of the tested area. i.e economically, agriculturally ,technically ,adaptability, performance capacity, efficiency and durability of the disc plough to the prevalent climatic and soil conditions. By Identify tractors horse power, Disc ploughs number of discs and measuring soil properties for the improvement of specific technologies to optimize of agricultural tractors and disc plough.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. The Agricultural Tractor

The agricultural tractor is one of the class of mobile machines that involves the ‘traction’ process. The word 'traction' and name 'tractor' come from the word to 'draw' or 'pull' so a tractor is basically a machine for pulling; other mobile machines such as locomotives are in the same class. Vehicles like road trucks and even motor cars, which are essentially vehicles for carrying loads, also involve the traction process. The tractor is also in the class of machines that involves operation under what are known as 'off-road' conditions. Others in this class include machines used in earth moving, mining and military work, also four-wheel drive motor vehicles for cross - country operation (Macmillan, 2002).

2.1.1. Performance Limitations

A tractor’s performance can be improved by means of the choice of the correct gear and implement size, double tires, ballasting and four-wheel drive. To understand this, let’s first look at the factors that play a role in the performance of a tractor .With the same diameter, a broader tyre has a larger contact surface, which leads to lower soil pressure and therefor lower rolling resistance. With the use of double tyres, the contact surface is doubled and the soil pressure reduced by half. Since the weight that each tyre carries is halved, the tyre pressure can even be reduced by 40% without the tyres distorting and folding too much, which damages the tyres. If only the inner wheels are filled with water, the weight increase as a result of the double wheels will be slight (Andrei, 1976).

Since its main function is to pull (or push), the question arises as to how well and within what limits the tractor succeeds in performing those functions. How we might measure and represent that performance is also of interest. This output is expressed, as in engineering mechanics, in terms of force (engine torque and drawbar pull), speed (rotational and travel), power (engine and drawbar) and non-dimensional numbers (wheel slip, tractive efficiency) (Macmillan, 2002).

Tractor testing with appropriate instrumentation has been a very important procedure in tractor development. Tractor designers need the instrumentation to help them improve the performance of the tractor as indicated by drawbar pull, power and fuel efficiency. Researchers use instrumented tractors for evaluation in both field and laboratory. Instruments can also assist farmers in operating their tractors more efficiently. As the tractor is a field machine, it should be tested in the field to obtain actual operating data. Until about 10 years ago, most tractor testing was confined to the laboratory, since field test procedures were often very complicated and cumbersome because of the limited capabilities of the instrumentation systems (Chung, 1983).

The fuel consumption of the traxctor Elashry (2002) was used a separated apparatus for fuel consumption. It was installed and connected to tractor fuel tank through hoses and two 2-way valves. The secondary tank was first filled with fuel to the mark on the tope of the tab. During the actual run, the tractor was first let go on its fuel from the main tank. To measure the fuel consumption during a specific field operation, the secondary tank was utilized through the valve (1) and (2).at the end of the run, the valves were refilled off. The secondary tank was refilled to the mark on the tube from a graduated cylinder and amount of refuel was taken as fuel consumption during the specific operation duration.

2.1.2. Hitching

Tractors frequently serve as the power source for field machines. A hitch connects the implement to the tractor. The tractor provides the tractive force to move the implement through the field. Most agricultural operations involve hitching some type of implement to a tractor. The forces transmitted through a hitch can affect the performance of both the tractor and the implement. Modern hitches include feedback for automatic control of pull and/or depth of tillage implements. The three-point hitch has now become standard equipment on most tractors Quick-attaching couplers have been developed to allow faster attachment of three-point hitches to implements (St. Joseph, 2012).

Hitching affects both vertical and horizontal force relations between tractor and implement.
Vertical effects on the tractor are of special interest because of their effect on the tractive performance of the tractor. The force imposed on the tractor by the implement could be transmitted through a drawbar or through a semi mounted or fully mounted hitch (St. Joseph, 2012).

You learned about the tractor's center of gravity and stability baseline. Tractor hitches are designed so the downward and rearward force during a pull are below the center of gravity. To maintain tractor stability, the "angle of pull" should be kept as low as possible by hitching to the drawbar only. Pulling a load with the downward and rearward force above the tractor's center of gravity will result in a rear overturn. You must hitch only to the drawbar to prevent the tractor from rearing up and turning over (Hosta ,2004).

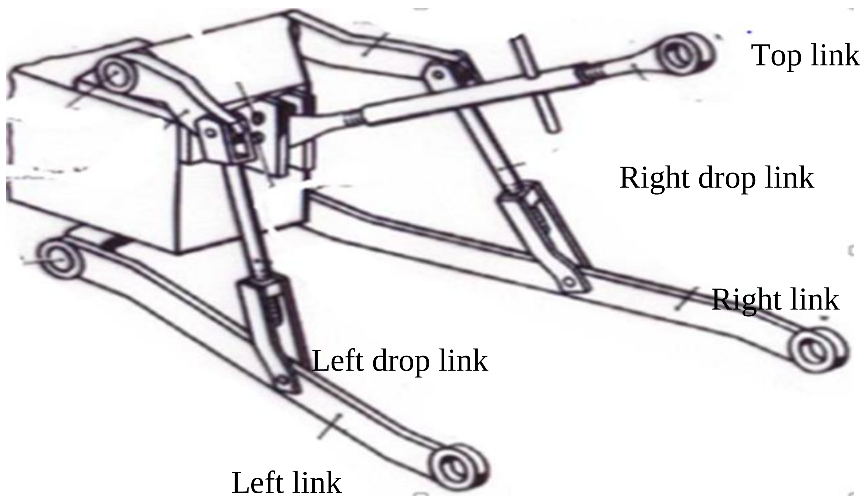


Fig. 2.1. Tractor three-point hitch system.

When the tractor is uses together with heavy turn-over ploughs attach ballast weights on the front bar (which can carry 200-kg weight at a time) with the plough set in the working position the turn buckled if the lower links should be of such a length as to permit a horizontal sway of the link rear hinged up to 120 mm to either side (Belarus, 1984).

2.1.3. Tractor Size

Tractors are generally grouped in to four categories as dictated by size, weight, horsepower and suitability for purpose. The main tractor groups are low and garden up to 25 hp, compact, 25 to 45 hp, utility 45-85 hp and farm tractor 85 up to 450 hp. Towing capacity is determined by many factors including wheelbase, vehicle width, engine size, transmission, differential gear ratio, and the vehicle weight (Cherry, 2008).

The proper selection of tractor and implement for a particular farm situation requires availability of the field performance data of both tractors and implements. Tractor and implement test are needed in different farm sites under different operating conditions to prevent serious damage. This will enable the proper selection of tractor and implement for a particular requirement (Samir et al, 2010).

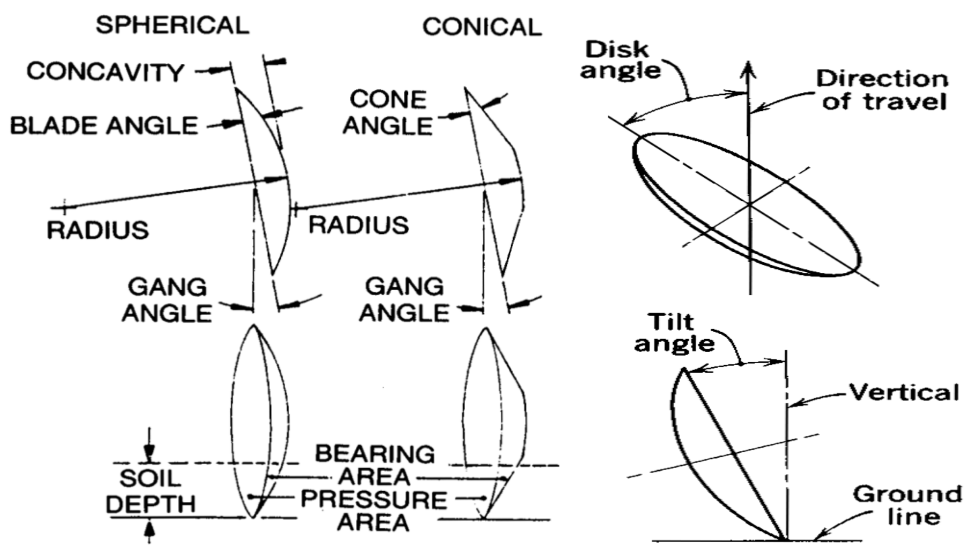
2.1.4. Tractor Power

The tractor will be realized that a tractor cannot in practice be operated on full engine power, and that after various losses, particularly wheel slip, only about half of the nominal horse power is available for useful work. A very common misconception is to assume that having a big tractor is synonymous with better timeliness. Timeliness is not related to individual tractor size as such, rather to the total tractor power available. The estimated output of tractors under the circumstances on that farm. This is, therefore, a choice that relates to the individual farm and its own peculiar set of enterprises and conditions. Larger tractors cost more to buy and to run. Therefore, the size of tractor must be related to the scale of operation so that costs can be spread. To put it another way, appetite has to be satisfied to keep cost per hectare or cost per unit production within economic limits (Bill, 1984).

2.2. Disc Plows

The common disk plow consists of a series of disk blades mounted individually on a frame. The disk blades are set at an angle, called the disk angle, from the forward line of travel, and also at a tilt angle from the vertical. Standard disk plows usually have three to six blades, spaced to cut 18 to 30 cm/disk. The disk diameters are commonly between 60 and 70 cm. The disks used in the disk implements are either conical. Both blades have a spherical radius associated with the concavity of the blades. Disk plows are used for primary tillage and are available in integral, semi-integral, and drawn hitching configurations. They are most suitable for conditions under which moldboard plows do not work satisfactorily, such as in hard, dry soils, and in sticky soils where a moldboard plow will not scour. Scrapers, furnished as standard equipment on most disk plows, assist in covering plant residue and inverting the soil and prevent soil buildup in sticky soils. A disc plough range for ploughing at a depth of 10 to 30 cm (St. Joseph, 2012).

Consequently, disk plows are built with heavy frames and wheels (total masses of 180 to 540 kg/disk blade), and even then additional mass must sometimes be added to obtain a desired depth. The soil penetration ability of a disk plow depends upon disk diameter, tilt angle, and disk angle. Whereas the moldboard plow absorbs side forces mainly through the landsides, a disk plow must depend upon its wheels for this purpose. A standard disk plow does not have special attachments to protect its disk blades from damage due to impact with rocks buried in the soil usually, the disk plow is able to withstand impact forces because of its heavy frame and its lower operating speed (Michigan, 2012)..



(a) Disk blade geometry **(b)** disk and tilt angles

Fig. 2.2. Disk blade geometry, disk and tilt angles

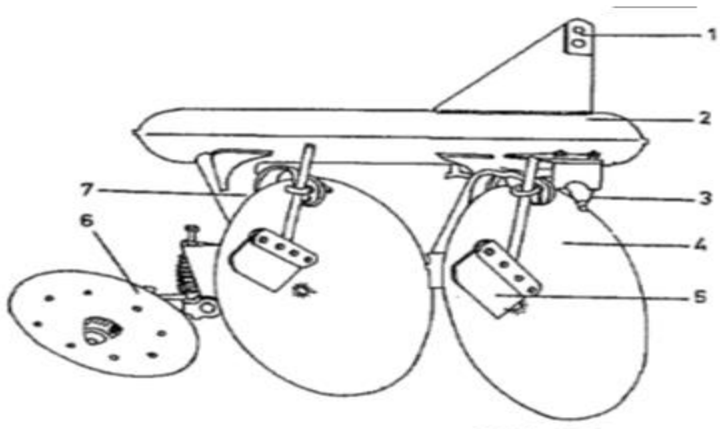
Disc ploughs are most suitable for conditions under which moldboard ploughs do not work satisfactorily, such as:

1. Sticky, waxy, gumbo, no scouring soils and soils having a hardpan or plow sole,
2. Dry, hard ground that cannot be penetrated with a moldboard plow,
3. Rough, stony, and rooty ground where the disc will ride over the rocks,
4. Peaty and leaf-mold soils where the moldboard plough will not turn the slice,
5. Deep ploughing
6. Clay and sandy loams.

The horizontal disc angle and the vertical tilt angle must be set for a better plough performance in various soils (Harries, 1937).

2.2.1. Components and Angels of Disc Plough

The disc plough consists of a series of individually mounted inclined disc blades on a frame which may be supported by wheels. The plough consists of common main frame disc beam assembly rockshaft (category-I or II) a heavy spring loaded furrow wheel and a gauge wheel in models disc plough is designed to operate as(2,3 or 4) bottom by adding or removing the sub beam assembly according to requirement the disc angle ranges from (40^0 to 45^0).



1. Top hitch 2. Frame 3. Side hitch 4. Disc bottom 5. Scraper

6. Rear furrow wheel 7. Standard

Fig. 2.3. Component of tractor drown two bottom disc plough

The draft decreases and penetration increases until 45^0 angle is reached. To obtain the desired width of cut and the tilt angle ranges from (15^0 to 25^0). The non-adjustable plough disc blades are set at on 18^0 to 20^0 tilt angle for penetration the discs of the plough are of high carbon or alloy steel and the edges are hardened and sharpened the discs are mounted on tapered roller bearings scrapers prevent soil build up on the disc in sticky soils. The furrow slice rides along the curvature and is pulverized to some extent before being thrown (Sharma, 2010).

2.2.2. Disc Adjustment

Width of cut adjustment there are usually two adjustments

1. An adjustment so that the front disc blades will cut its full share, but not too much,
2. An adjustment affecting the cutting width of the entire plow. The width of individual disks can be reduced by moving the standard forward on the main frame or altering the angle of the frame relative to the direction of travel. For hard and dry soils, decrease the width of cut;

- By decreasing the width of cut of an individual disk,
- By decreasing the number of disks and decrease the spacing between the disks.

Depth of cut adjustment the depth of cut depends on the diameter of the blade; about one-third the blades diameter is the limit for depth. Typical ranges of cutting depth are 4 to 14 in. The depth of cut for disc plow can be controlled by either the gage wheel or by the hydraulic system of the tractor.

The performance of disk implements is measured in terms of draft, specific draft, power requirements, and depth. Unlike moldboard plows, the depth of penetration of disk implements is determined by the implement weight and soil condition. Thus, the ability to maintain a uniform desired depth becomes an important performance criterion (St. Joseph, 2012).

2.2.3. Draft of Plows

Tillage energy represents a considerable portion of the energy utilized in crop production. The availability of draft requirement data for tillage implements is an important factor in selecting suitable tillage implement for a particular farming situation (Askari et al, 2011).

Practically all draft tests on plows have been made with the moldboard type. The few made with the disk plow seem to indicate that it is slightly lighter in draft than the mold Board, when plowing under similar conditions and turning the same volume of soil. The type of scraper used to clean the disk will also affect the draft. Adjustments of disc plow various adjustments that are done on disk ploughs are aimed at controlling the depth or width of ploughing or to increase the pulverization. These objectives can be achieved as follows:

1. Increasing the tilt angle, penetration is improved,
2. Increasing the disk angle, penetration is reduced but the width of cut is improved,
3. Adding weights to the plough, penetration can be increased,
4. the rear furrow wheel on the disk plough should run with the front of the wheel angled slightly towards the ground to help in taking some of the side draught;
5. the disk of the plough should be well polished and sharp;
6. the plough wheels should be properly adjusted to keep the plough running level;
7. The width of the cut by the plough may be adjusted by adjusting the angle between the frame and the land wheel axle.

Alteration of the vertical angle of the disc will affect penetration. The more vertical the disc, the greater will be the penetration. If penetration is not difficult, the use of a larger tilt angle will result in better inversion of the furrow slice. A large tilt angle is best for sticky soils (Harries, 1937).

2.2.4. Towing Capacity

When you are hauling horses, you should plan to haul about 25% less than the maximum load rating. It's better to have more truck and not need it than to need more truck and not have it. In general, and especially for interstate driving, the weight of a loaded towing vehicle should be at least 75 percent of the weight of the loaded trailer. Towing capacity is determined by many factors including wheelbase, vehicle width, engine size, transmission, differential gear ratio, and the vehicle weight (Cherry, 2008).

Lower tire pressures are helpful from a compaction standpoint, as ground pressure is roughly equal to tire pressure. In addition, lower pressures help control power hop as they allow a wider range of tire pressure adjustments to be made. Larger tires can operate at lower pressures for the same weight. Correctly inflated radial-ply tires provide a 5% to 7% efficiency improvement over bias-ply tires (Frank, 2003).

Cupera, et al. (2011) measurements of forces existing in the three-point linkage of a tractor and the projection of measured force effects into its center of gravity. Tractive efficiency is a measure of the ability of the tractor to transfer power from the axle to the drawbar through the tire and soil interface. This implies that tractive efficiency depends on wheel slip, soil and tire conditions as well as drive configurations. The measured and calculated parameters were rolling resistance, wheel slip and tractive efficiency.

2.2.5. Field Performance

Gohlich, (1984**)** rolling resistance and wheel slip are sources of power losses, as well as producing unfavorable soil effects. There is a loss of efficiency, particularly when operating with powerful heavy tractors on soft freshly-tilled soil using implements which require only low traction.

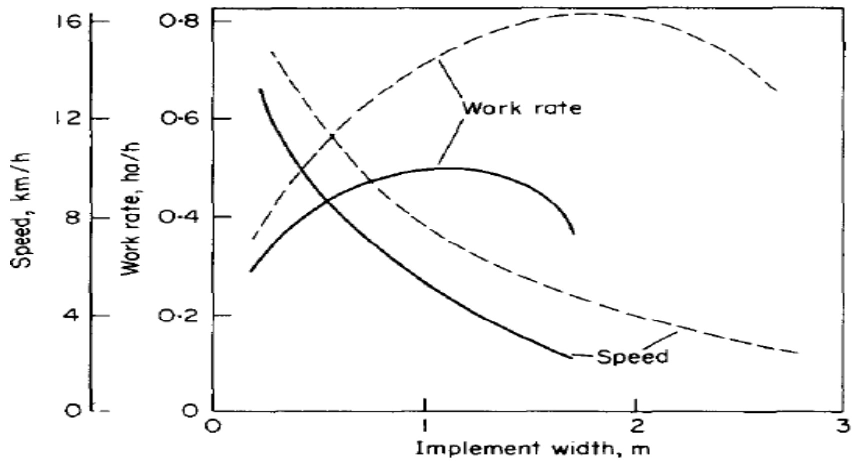


Fig. 2.4. Work rate and ground speeds vs implement width

. ——~~L~~oamy clay: ------ -, sandy loam

An optimization of the relationship between the field work performed, as expressed in hectare per hour, and the fuel cost is the wish of every farmer. For some farmers, field work performed will take the first priority, while other farmers will consider the reduction of fuel cost to be more important. Today, the relationship between the work done and the fuel used is solely dependent upon the experience and capability of the driver. *Fig. 2.4 gives* an example of the dependence of the work rate and the ground speed on working implement widths for different soils.

The fuel consumption of soil tillage operations varies widely and can be reduced through proper matching of tractor size, operating parameters, tillage implement. Of the average fuel consumption for ploughing (25 L ha-1), only 5 L ha-1 of the fuel energy is used for the drawing of the plough, while the remaining fuel consumption is due to efficiency losses in the engine, transmission, and wheel/soil interface. The term "fuel" is used here exclusively to denote diesel fuel. Additional, soil related, parameters, such as soil texture and organic matter content, influence fuel consumption in soil tillage (Tayel et al, 2015).

Draught of tillage implement (Disc plough) however plays a vital role in developing more efficient tillage system by selecting suitable combination of tractor and implements. Farmers employ draught requirement data from tillage implement (Disc plough) in specific soil type to determine the matching size of tractor for operation. Draught is the horizontal component of pull force, parallel to line of motion, while side draught, is the horizontal component of pull, perpendicular to the line of motion. The force required to overcome the soil resistance and move the tillage implement at the required speed is called the cutting force. The horizontal component of this cutting force is called the draught. Draught is the total horizontal force parallel to the direction of travel required to propel the implement. It is the sum of the soil and crop resistant and the implement rolling resistance (Nkakini, 2015).

2.3. Soil

Steve, (1971) a soil is a mass of discrete particles that are the products of decomposition and disintegration of rocks and organic matter by natural processes. A soil assumed to be completely described by: (1) the composition of its solids, (2) the composition of the liquids, gases, and sometimes solids (including dissolved and suspended materials) in its pores, and (3) the distributions of size, shape, and angularity of its grains.

Nkakini, (2015) soil type and condition are the most implement factors that contribute to the draught force of agricultural implement. The draught required to pull a tillage implement (Disc plough) is basically a function of soil properties, implement width, operating speed and depth of cut at which it is pulled, moisture content and bulk density. According to some research findings, the increase in soil bulk density increased the draught forces of tillage implement (Disc plough).

2.3.2. Soil Texture

One aspect of the physical properties of soil, its *texture*, is described by the percent of particles in various size classes. The sides of the triangle are axes, each representing the percentages of sand, silt, and clay that constitute the soil. Special names are assigned to various combinations as designated by the areas within the triangle. Thus, if a soil is composed of 40% sand, 35% silt, and 25% clay, it is called a loam. This is noted by the in the figure. Note that because of the importance of the surface area-to-volume ratio, soils with as little as 20% clay still are called clay soils. There are various laboratory methods of measuring the relative amounts of sand, silt, and clay (Ajit et al, 2006).

But, most soils are composed of a combination of the different types. How they mix will determine the texture of the soil, or, in other words, how the soil looks and feels. One type of soil is sand. Sand within soil is actually small particles of weathered rock. Sand is fairly coarse and loose so water is able to drain through it easily. Silt is another type of soil.

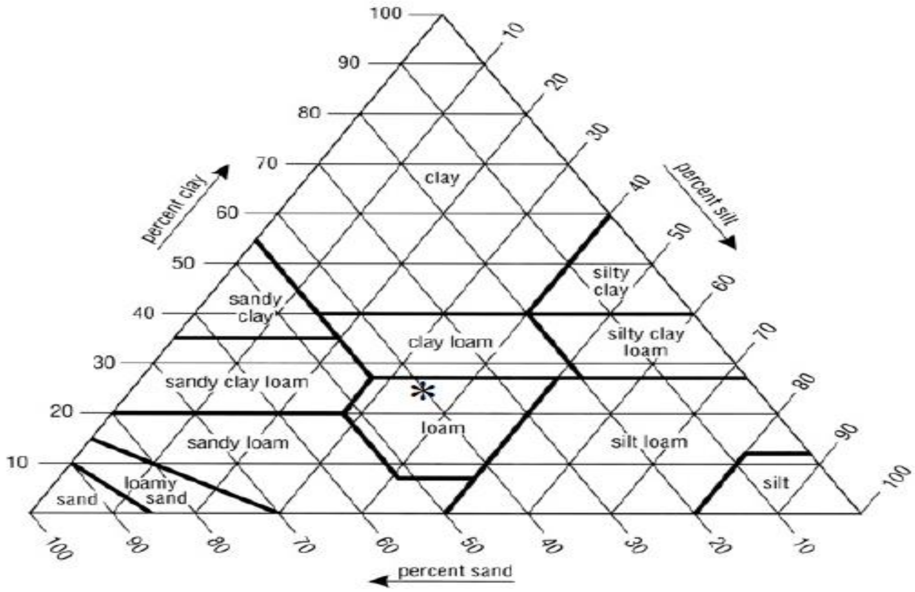


Figure 2.5 USDA soil texture triangle showing the percentages of sand, silt, and clay. Note that these percentages are after sieving out particles > 2.0 mm (gravel and stones) and removing the organic matter.

Silt can be thought of as fine sand, and it will hold water better than sand. Clay is very fine-grained soil. Its particles are even smaller than silt, therefore, clay does not drain well or provide space for plant roots to flourish now, and we can consider loam as our fourth type of soil, even though it is really a combination of sand, silt and clay. This types of soil you want because it holds moisture, but also allows for good drainage (Steve, 1971).

Soil strain transducers were used beneath a mechanical front-wheel drive (MFWD) tractor equipped with single and dual rear tires and beneath a steel track tractor in a silty clay loam, with no drawbar load applied to the tractors. Engineering strain in the vertical direction was greater beneath a rear tire of the MFWD tractor equipped with single rear tires than for front tires of the MFWD tractor, rear tires of the MFWD tractor equipped with dual rear tires, or a track of the track-type tractor (Terra, 2005).

2.3.4. Cone Penetrometer

The Cone penetrometer are used to determine the resistance to penetration of a soil. The resistance of penetration (kN/cm^2) of the soil now can be determined by dividing the reading value by the surface of the cone. The soil parameter for empirical prediction of tractive performance is based on the force (kN) to push a circular cone base area 322 mm^2 shown in

Figure 2.6 (a) into the soil at a constant speed 30 mm/sec (Frank, 2003).

The parameter, termed the cone index (CI) is given by,

$$CI = \frac{Force\ on\ cone}{Base\ area\ of\ the\ cone} \qquad [\ kPa\ ] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1):$$

Where: CI = Cone Index (kpa)

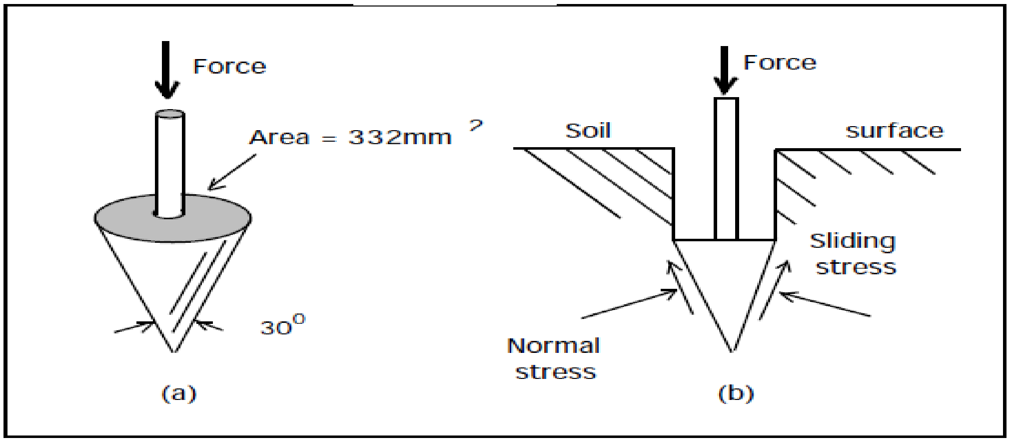


Fig. 2.6 Cone penetrometer for measurement of soil parameter

The passage of the cone into the soil is resisted by the normal and soil - metal resistance forces as suggested in Figure 2.4(b). These in turn will depend on the strength and compressibility of the soil and soil / metal sliding characteristics of the cone surface all of which will depend on the soil texture, moisture content, etc. The cone index does not therefore represent a soil 'property' as such but a complex and ill-defined parameter or measure of soil 'strength' and deformability; it is assumed to be a correlate for tractive force and rolling resistance. Typical values of cone index are given by Dwyer (1976) as shown in Table 2.1.

Table. 2.1 Soil cone index for various surface conditions.

Surface condition	**Cone Index , kPa**
Dry grassland	1500
Dry stubble	1000
Wet Stubble	500
Dry loose soil	400
Wet loose soil	200

The affecting properties and parameters of soil on draft force and required energy include: soil moisture content, bulk density, cone index and soil structure. These parameters as the major influencing parameters on the draft force were analyzed in a sand clay loam soil (43% clay, 29% sand and 28% silt). Penetration tests were conducted at 15 points from 0 to 20 cm deep using a manually operated penetrometer (Askari, 2011).

CHAPTER THREE

3. MATERIAL AND METHOD

3.1. Description of the Study Site

The study site was located at Adama Agricultural Machinery Engineering Industry (AAMEI) of Metals and Engineering Corporation (METEC). The Industry located from the capital city of Ethiopia 99 km east of Addis Ababa. It's found at an elevation of 1712 m above sea level with latitude of 39.27^0 E and longitude of 8.54^0 N at Adama (Oromia Regional State). Soil type in the area is sandy clay loam. The test was conducted at Adama , Asela And Awash melkassa. Melkassa Agricultural Research Center is found at an elevation of 1560 m above sea level with point locations of $8^0$24' N latitude and $39^0$21' E longitude. The dominant soil type in the area is sandy loam.

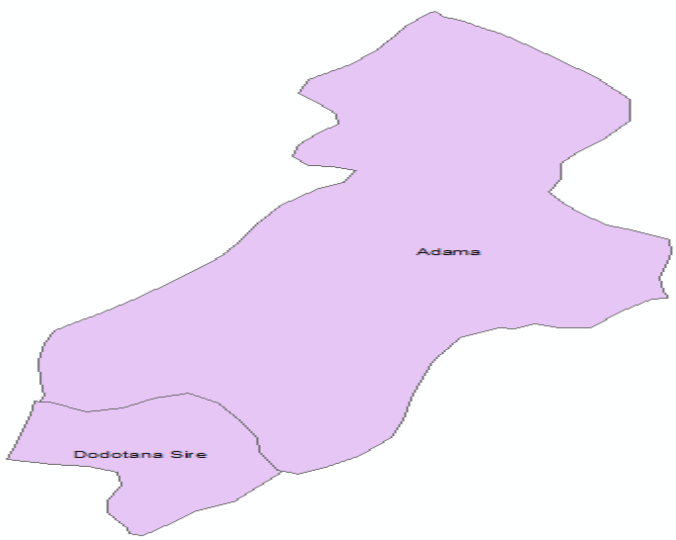


Fig: 3.1. Map of study site

And Asela is also located 76 Km south from Adama. It's found at an elevation of 2450 m above sea level with latitude of 39.07^0 E and longitude of 7.57^0 N. soil type in the area is sandy loam.

3.2. Tractor

The Poland made agricultural tractors were tested for ploughing. Thetractor models are URSUS model 5014A and model 8014A. The tractors were designed to do all kinds of agricultural operation with mounted, semi mounted and trailed machine and implements.

Table. 3.1 Specification of tractor

Dimensions	URSUS 5014A 50 hp	URSUS 8014A 80 hp
Length, mm	3900	4210
Width, mm	1890	2000
Height ,mm	2640	2690
Wheel base, mm	1985	2230
Wheel Front track, mm	1285	1560
Wheel Rear track, mm	1356	1560
Ground clearance ,mm	305	380
Turning radius of with inside wheel brakes, mm	3200	4470
Weight ,kg	2652	3003
Rear wheel ballast weight ,kg	140	210
Front wheel ballast weight, kg	100	260

3.3. Disc Plough

The China made agricultural disc plough were tested for ploughing. The model of disc ploughs are 1LY 320, 1LY 325 and 1LY 425. The purposes are: 1. To identify disc plough model and number of disc. 2. To check the diameter of discs by measuring instrument (tap) or to calculate diameter of the disc (Dd) as stated by (Sharma 2010). To determine the parameters of the disc plow the following calculation is used.

$$D_d = \frac{k.d_p}{\cos\beta} \text{ (cm)} \qquad (3.1)$$

Where k = a coefficient which varies from 2.5-3 for deep tillage

d_p = depth of ploughing cm

β = tilt angle of disc which is 15^0-25^0-with vertical

D_d = diameter of the disc mm (cm)

Table. 3.2 Implements and their parameters

Model	No. disc	Disc diameter ,mm	Working depth, mm	Working width, cm	Weight, kg
1 LY 320	4	510	200	60	180
1 LY 325	3	660	250	78	390
1 LY 425	4	660	250	105	480

The plough 1LY 320, 1LY 325, and 1LY 425 were tested at Melkasa Agricultural Research Center and Asela. The depth of cut depends on the diameter of the blade; about one-third the blades diameter is the limit for depth and range for ploughing at a depth of 10 to 30 cm olso suggested by (St.Joseph,2012)

3.4. Field Description and Parameters

The condition of field was affect ploughing operation. Therefore, field condition is important for ploughing operation test. The following parameters were determined before ploughing.

i. Experimental Site and Design:
ii. Soil physical properties Determination
iii. Soil moisture and resistance
iv. Adjustment and attachment of plough
v. Skill (Method of ploughing)
vi. Depth of ploughing
vii. Size of plot

3.4.1. Experimental Site and Design:

The Experiments were conducted in the field URSUS model 8014,80 hp and URSUS model 5014,50 hp tractor with model 1LY 425, 325, 320 disc plough in ploughing operation forming four treatments with using Randomized Complete Block Design (RCBD). RCBD is one of the most widely used experimental designs in agricultural research. The design is especially suited for field experiments. The primary distinguishing features of the RCBD is the presence of blocks of equal size, each of which contains all the tests. Therefore, the experimental area for each testing site was 15 m by 100 m and was designed with four different strips 100 m by 3 m wide with a space of 1 m between each strip. The data was analyzed in result and discussion section.

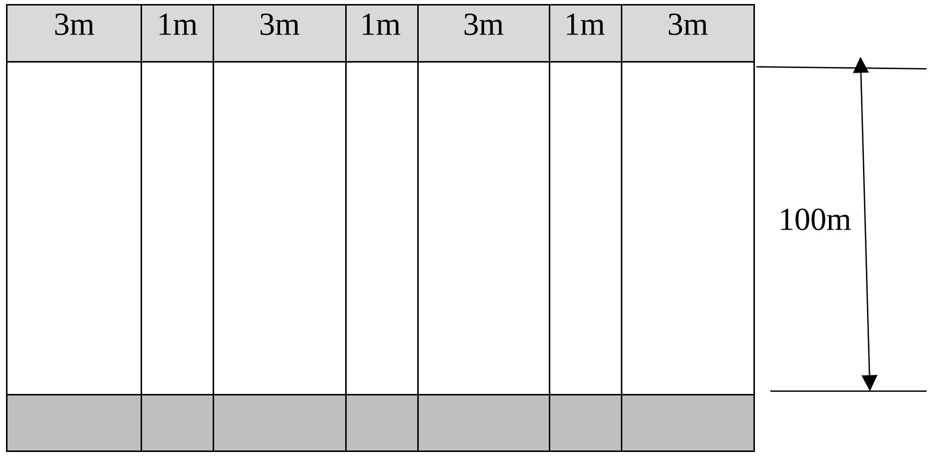


Figure: 3.2. RCBD plot size sample representation

Fig: 3.3 Teste field

3.4.2. Determination of Soil Moisture Content:

The samples were collected at a depth of soil surface before operations for determination of moisture content. The soil moisture was determined by oven dry method. Three samples were collected randomly from the test plots. The samples were kept in oven for 24 hours at temperature of 105°C. The samples were weighed before and after drying. The moisture content (Dry basis) was determined by the following formula (Rangapara, 2014).

Moisture content (%)$= \frac{Ww-Wd}{Ww}\ x\ 100$……………………..................……(3.2)

Where, W_w= Weight of wet soil sample, and

W_d = Weight of dry soil sample

3.4.3. Measuring Soil Resistance

The samples were collected from 10, 20 and 30 cm depth of soil surface for measuring of soil resistance. The soil resistance was measured by Cone penetrometer from 10, 20 and 30 cm depth of soil surface. Thirty samples were measured randomly from the test plots.

Cone penetrometer testing involves pushing a cone into the soil at a certain rate and recording the resisting force exerted by the soil on the penetrometer. The force required divided by the area of the base of the cone.

Fig. 3.4. Measuring soil resistance by cone penetrometer

According to (Frank, 2003). Fig.2.4 the parameter, termed the cone index (CI) is given by,

$$CI = \frac{Force\ on\ cone}{Base\ area\ of\ the\ cone} \quad \text{……….……………………..………. (3.3)}$$

Where: CI = Cone index (kpa)

The spring type dynamometer was measured the tractor drawbar pull. The dynamometer system for the test and evaluation were transferred to the field.

Fig. 3.5. A dynamometer to measure the drawbar force

The stop watch was used to measure the time for the test ploughing operation. The outfit was let to work on the plot. The time was recorded using hand watch.

Fuel apparatus a separate apparatus was used to measure fuel consumption. It consisted of a secondary tank of 5 liters capacity attached to the primary fuel filter of the tractor. The fuel consumption was measured as per the standard method by observing the fuel required for traveling 100 m long distance. The volume of fuel used was taken into account as fuel consumed for a particular time period. Fuel consumption during the test was measured by topping the 5 liter container at start of each run there topping at the end of specific run using measuring can. The similar measurements reported by Elashry (2002).

Fuel consumption rate: The fuel consumption rate are determine as follow (Ahmed et al, 2017).

$$FCR = \frac{CR}{A} \qquad \text{...3.4}$$

Where: FCR = fuel consumption rate (L / ha)

CR = reading of cylinder (L)

A = plot area (ha)

The steel rule and meter was used to measure the depth of cut and the width of cut. The depths of cut were measured with a steel tape, from the bottom of the furrow to the surface level of the soil at randomly selected points.

Fig. 3.6. Measuring depth of cut

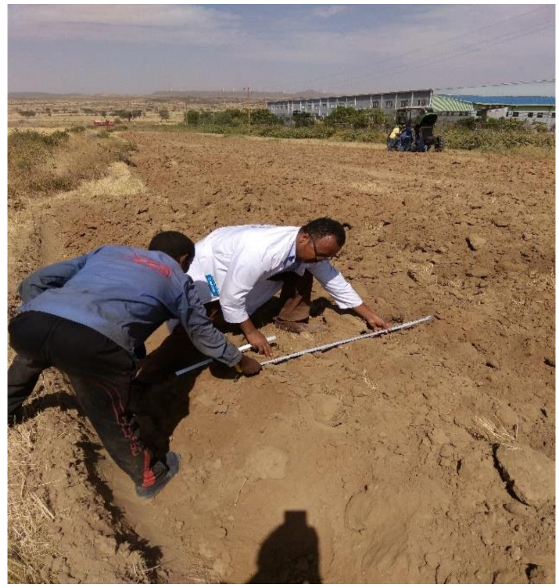


Fig. 3.7.Measuring width of cut

3.4.4. URSUS 5014A and URSUS 8014A Models Tractor Drawbar Pull and Speed

From URSUS operational manual, the drawbar force of tractor URSUS 5014A and URSUS 8014A tractors are listed below.

Table. 3.3. Draw bar force and speed on URSUS 5014A, 50hp

Gears	Draw bar force k.gf	Speed km/h
I	870	2.5
II	870	3.2
III	870	4.26
IV	870	7.24
V	560	8.9
VI	420	15.23
VII	300	17.95
VIII	300	30
Revers I		3.98
Revers II		8.97

Table. 3.4 Draw bar force and speed on URSUS 8014A, 80hp

Gears	Draw bar force k.gf	Speed km/h
I	1400	2.50
II	1400	4.26
III	1400	7.24
IV	1400	8.90
V	1150	10.54
VI	950	15.15
VII	750	17.95
VIII	600	30.0
Revers I		5.26
Revers II		8.97

The output speed of 5.5 km/hr in the URSUS 80 hp tractor manufacturer manual is the productivity at this speed was 0.49 ha/hr of operational time and URSUS 50 hp was 0.30 ha/hr. Source: - URSUS 2014 Manual.

3.4.5. Adjustment of Plough

Adjustment of all the plough bottoms for depth of cut is effected by means of the top link and right hand drop link of the hitch. The horizontal position of the plough frame is an indication of the proper travel of the plough. If the front plough bottom cuts deeper than the rear one increase the length of the top link if the rear plough bottom is set deeper shorten the top link. The depth of working is adjusted by changing the height of the position of the plough ground engaging wheel. Fix the top link at the top hole in the shackle to enable operation of the sensor in a wide range of the depth of cut. If the top hole setting fails to give the required (great) depth of cut, fix top link at the middle hole or, if necessary at the lower one. The width if the plough cut is adjusted by changing the position of the plough hanger axle.

3.4.6. Draught Force

The drawbar pull (draught force) was determined using trace-tractor techniques. Dynamometer was attached to the front of the tractor mounted with implement. Another auxiliary tractor was used to pull the implement mounted tractor through the dynamometer both in their transportation positions and tillage operating positions for ploughing.

The average drawbar-pull (Draught to pull the implement) is the difference between the towing force, while in neutral gear without implement in tillage operation and the towing force while the implement is in tillage operation respectively as shown in fig 3.8 &3.9.

In order to determine drought force equation 3.5 was uses

$$P = P_2 - P_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.5$$

By Nkakini, (2015) Equation 3.5 is used in determining the draught force. Where, P = draught force, P_1 = the force required to pull the implement in transportation position, P_2 = the force required to pull the Implement during tillage operation.

Fig. 3.8 Tractors–dynamometer, implement mounted position during transportation

Fig; 3.9 Tractors–dynamometer, implement mounted in tillage operation.

$$P = P2 – P1$$

Where: P = drought force

P_1 = force required to pull the implement in transportation position,

P_2 = force required to pull the Implement during tillage operation.

Calculation of drawbar horse power (DBHP) is stated by (Sharma, 2010).

$$\text{DBHP} = 60\% \text{ of BHP (Brake horse power)} \quad \ldots\ldots\ldots\ldots 3.6$$

$$\text{DBHP} = \frac{\text{draft(kg)} \times \text{speed(m/min)}}{4500} \quad \ldots\ldots\ldots\ldots 3.7$$

Draft of plough= n $W_c.d_p.k.f$ [kg]…………………………………………………….… …3.8

Where n = number of bottoms or disc in plough

W_c = width of cut in cm

D_P = depth of ploughing in cm

k = a constant for heavy soils k=0.75-0.85 kg/cm^2

f = factor of safety (FOS) = 1.5

DBHP = Draw bar horse power $\left(\frac{kg.m}{min}\right)$

3.4.7. Measurement of Field Performance

i- Theoretical field capacity

Theoretical field capacity is the rate of work when the implement uses its full width and time and it was calculated as follow (Ahmed et al, 2017).

$$TFC = \frac{S \times W}{C} \quad \text{..} 3.9$$

Where: TFC = Theoretical field capacity (ha/h)

S = Working speed (km/h)

W = cutting width of implement (m)

C = Conversion factor = (10)

ii- Effective field capacity Effective field capacity is the actual rate of work and it was calculated as follow: -

$$EFC = \frac{A}{T} = \quad \text{..} 3.10$$

Where:

EFC = effective field capacity (ha/h).

A = hectare.

T = hour.

iii- Field efficiency Field efficiency was calculated as follow:

$$FE = \frac{EFC}{TFC} x 100\ \% \quad \text{..} 3.11$$

iv- Rear wheel slippage The rear wheel slippage was determined as follows:

$$S = \frac{D_U - D_I}{D_U} \; x \; 100 \; \% \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.12$$

Where:

S = rear wheel slippage (%)

Du = distance travelled by unloaded tractor

Dl = distance travelled by loaded tractor

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Soil Resistance and Moisture Content of Soil

During carrying out the experiments, the soil conditions of the experimental field were studied and different parameters were calculated (Tables). The soil of the field was vertisol and sandy clay loam soil. Moisture content on dry basis of soil was measured by oven dry method. Five soil samples were taken randomly at 5 different locations in the plot using core sampler of 8.0 cm diameter and 12 cm height.

Table. 4.1. Soil moisture content in the field test (Adama.

Observation	Weight	Weight of soil after oven dried(gm)	Moisture content %Wb
1	525	425	19.04
2	510	413	19.01
3	512	415	18.94
4	502	399	20.52
5	563	455	19.18
Average	522.4	421.4	**19.33**

According to table 4.1, moisture content on dry basis of soil was measured by oven dry method. Soil type sandy clay loam moisture content at 5 different places was found to be 19.04 %, 19.01%, 18.94 %, 20.52 % and 19.18 % on wet basis respectively. The average moisture content of the experimental field was 19.33%.

Table. 4.2. Soil moisture content in the field test Melkasa

Observation	Weight of a soil (gm)	Weight of soil after oven dried(gm)	Moisture content %Wb
1	507	410	19.13
2	512	415	18.94
3	522	420	19.54
4	525	425	19.04
5	520	422	18.84
Average	517.2	418.4	19.07

Table 4.2, presented the data obtained at Melkasa, the type of soil in the test fields is clay sandy loam soil. The fields for test in this area were almost the same to Adama. According to table 4.2, moisture content at 5 different places was found to be 19.00 %, 18.94 %, 19.54%, 19.04 % and 18.79% on wet basis respectively. The average moisture content of the experimental field was 19.07 %.

Table 4.3, presented the data obtained at Asela, the test field was vertisol (black soil). According to table 4.3, in the tests period of the soil moisture content at 5 different places was found to be 33.13%, 32.24%, 33.33%, 31.44% and 343.71% on wet basis respectively. The average moisture content of the experimental field was 32.77%.

Table. 4.3. Soil moisture content in the field test Asela

Observation	Weight of a soil (gm)	Weight of soil after oven dried(gm)	Moisture content %Wb
1	160	107	33.13
2	183	124	32.24
3	162	108	33.33
4	194	133	31.44
5	178	118	33.71
Average	175.4	118.20	32.77

According to table 4.4 and 4.5, Soil resistance from field test at Melkasa the average cone index of the soil which is found at around Adama and Melkasa were 0.37kN/cm$^{2.}$ ·This index value indicate that the soil property in the respective site become wet loose soil. Dwyer, (1979) stated that the value of cone index of wet loose soil was in the range of 0.2 to 0.4 kN/cm^2.Therefore, Adama and Melkasa soil type lies in stated range.

Table. 4.4. Data obtain Soil resistance from field test at Adama

Soil resistance				
Cone penetrometer measurement in Adama				
Average penetrometer reading kN/cm^2				
Depth cm				
Day	10	20	30	Average
1	0.38	0.42	0.48	0.43
2	0.42	0.35	0.42	0.36
3	0.34	0.46	0.45	0.42
4	0.25	0.31	0.29	0.28
5	0.24	0.26	0.39	0.3
6	0.25	0.38	0.39	0.35
7	0.32	0.29	0.35	0.32
8	0.28	0.35	0.48	0.43
9	0.36	0.4	0.45	0.4
10	0.32	0.41	0.49	0.46
	0.316	0.363	0.419	0.366

Table. 4.5. Data obtain Soil resistance from field test at Melkasa

Soil resistance				
Cone penetrometer measurement in Melkasa				
Average penetrometer reading kN/cm^2				
Depth cm				
Day	10	20	30	Average
1	0.28	0.35	0.48	0.37
2	0.32	0.35	0.42	0.36
3	0.34	0.41	0.45	0.4
4	0.27	0.31	0.29	0.29
5	0.24	0.39	0.26	0.3
6	0.25	0.38	0.41	0.35
7	0.32	0.29	0.36	0.32
8	0.38	0.42	0.48	0.43
9	0.39	0.42	0.48	0.43
10	0.42	0.46	0.49	0.46
	0.321	0.378	0.412	**0.37**

According to table 4.6, Soil resistance from field test at Asela the average cone index of the soil which is found at around Assela was 0.89 kN/cm$^{2.}$The daily measurement was given in appendix C. This index value indicate that the soil property in the respective site become dry stubble soil. Dwyer (1979) stated that the value of cone index of dry stubble soil was in the range of 0.5 to 1 kN/cm^2.therefore Asela soil type lies in stated range.

Table. 4.6. Data obtain Soil resistance from field test in Asela

Soil resistance				
Cone penetrometer measurement in Asela				
Average penetrometer reading kN/cm^2				
	Depth cm			
Day	10	20	30	Average
1	0.45	0.54	0.65	0.55
2	0.35	0.48	0.54	0.46
3	0.31	0.48	0.51	0.43
4	0.41	0.54	0.72	0.56
5	0.47	0.39	1.65	0.84
6	0.38	0.45	0.62	0.48
7	0.64	0.87	1.72	1.08
8	1.32	1.49	1.49	1.43
9	1.42	0.9	1.42	1.25
10	1.43	1.67	2.47	1.86
	0.718	0.781	1.179	**0.894**

4.2. Power Test and Field Test of URSUS 8014A Tractor at Asela

URSUS 8014A model tractor with 260kg front weight and 210kg rear weight

Table. 4.7. Power test data collected at Asela URSUS 8014A

Operation	Ploughing			
Plough	1LY 425		1LY325	
Gear combination	2 nd	3rd	2 nd	3rd
Working depth (cm)	25	25	25	25
Working width (cm)	102	102	78	78
Distance covered by 10 rev .of rear wheels during transport (m)	44	44	44	44

Distance covered by 10 rev. of rear wheels during ploughing (m)	33	30	41	39
Ploughing force (dyna. reading) (N)	15000	17000	11500	13500
Slippage %	25	31.8	6.82	11.36

The tractors URSUS model 8014A were tested with various disc ploughs in order to analyze their efficiency in ploughing operation and places having different altitude and soil conditions.

Table. 4.8. Field test data collected at Asela URSUS 8014A

Tractor Used	Model	URSUS 8014A	
	Front weight added	260kg	
Plow used	Model	1LY 425	1LY 325
	Type	Disc	Disc
	No of bottoms	4	3
	Theoretical working width (cm)	1.05	0.78
	Average working depth (cm)	25	25
Results of field test	Soil type	Vertisol	
	Moisture content of soil,%	32.77	
	Soil resistance, kN/cm^2	0.89	
	Run length (m)	100	100
	Time taken (s)	106	55
	Fuel (L)	0.28	0.17
	Working speed (km/hr)	5.5	6.73
	Actual speed km/ hr	3.4	5.07
	Actual Field capacity (ha/hr)	0.35	0.52
	Theoretical field capacity	0.56	0.69
	Efficiency (%)	62.5	73.91
	Specific fuel conception		
	Lit/hr	9.63	14.07
	Li/ha	28	21.8

According to Table 4.7 and 4.8, The test results obtained during ploughing operation in vertisol soil type 80 hp with 4 bottom 66 cm disc diameter disc plough the average performance of the plough output was 0.35 hectares per hour and the fuel consumption is 28 liters per hectare or 9.63 liters/hr and the force required to pull the plough ranges from 15,000N to 17,000N the result was above the pulling capacity of the tractor. The output (productivity) of the plough in 8 hours of operational time is 2.8 hectares and the fuel consumption is 78.4 liters. The fuel consumption per hector was very high and it makes it uneconomical. This output was found when the tractor was going with a speed of 5.5 km/hr. The manufacturer's figure of productivity at this speed is 0.5 ha/hr. of operational time. There for in places of high altitude and vertisol soil type in 80 hp tractor cannot be used for 4 bottom 66 cm disc diameter disc ploughing. The calculation is shown in appendix E and F.

Ploughing operation in vertisol soil type 80 hp with 3 bottom 66 cm disc diameter disc plough**,** the output was 0.52 ha/hr. i.e. 4.16 hectares in 8 hours of operational time and the fuel consumption was 14.07 liters/ hr or 21.8 liters per hectare and the force required to pull the plough ranges from 11500N to 13500N which is within the pulling capacity of the tractor. The performance output was 0.52 ha/hr and this was above the recommended output. So the plough model 1LY 325 3 bottom disc plow has a good efficiency.

4.3. Power Test and Field Test URSUS 8014A Tractor at Melkasa Site

URSUS 8014A model tractor with 260kg front weight and 210kg rear weight

Table. 4.9. Power test data collected at Melkasa site URSUS 8014A

Operation	Ploughing			
Plough	1LY 425		1LY325	
Gear combination	2 nd	3rd	2 nd	3rd
Working depth (cm)	25	25	25	25
Working width (cm)	105	105	78	78
Distance covered by 10 rev .of rear wheels during transport (m)	44	44	44	44
Distance covered by 10 rev. of rear wheels during ploughing (m)	42	41	43	42
Ploughing force (dyna. reading) (N)	8500	11500	6000	8500
Slippage %	4.6	6.8	2.3	4.6

The tractors URSUS model 8014A were tested with model 1LY425 and model 1LY 325 disc ploughs in order to analyze their efficiency in ploughing operation in places of Melkasa.

Table. 4.10 Field test data collected at Melkasa site URSUS 8014A

Tractor Used	Model	URSUS 8014A	
	Front weight added	260kg	
Plow used	Model	1LY 425	1LY 325
	Type	Disc	Disc
	No of bottoms	4	3
	Theoretical working width (cm)	105	78
	Average working depth (cm)	23	23
Results of field test	Soil type	Clay sandy loam	
	Moisture content of soil,%	19.07	
	Soil resistance, kN/cm^2	0.37	
	Run length (m)	100	100
	Time taken (s)	60	55
	Fuel (L)	0.21	0.18
	Working speed (km/hr)	6.82	5.72
	Theoretical speed (km/hr)	7	9.3
	Field capacity (ha/hr)	0.62	0.52
	Theoretical field capacity	0.74	0.73
	Efficiency (%)	83.78	71.23
	Specific fuel consumption		
	Lit/hr	14	10
	Li/ha	20	23.08

According to Table 4.9 and 4.10, the test results obtained during ploughing operation in clay sandy loam soil type 80 hp with 4 bottom 66 cm disc diameter disc plough the average performance of the plough in net operational time was 0.62 hectares per hour and the fuel consumption was 20 liters per hectare or 14 liters/hr. The output (productivity) of the plough in 8 hours of operational time is 4.96 hectares and the fuel consumption was 99.2 liters and the force required to pull the plough ranges from 11,500N to 14,000N which is within the recommended pulling capacity of the tractor. This output was found when the tractor was going with a speed of 6.73 km/hr. The manufacturer's figure of productivity at this speed was 0.60 ha/hr. of operational time. It can be seen that the actual value is greater by 3% than the manufacturer's recommendation. The fuel consumption per hectare was balanced and it makes it economical.

The test results obtained during ploughing operation in clay sandy loam soil type 80 hp with 3 bottom 66 cm disc diameter disc plough the output was 0.52 ha/hr. i.e.4.16 hectares in 8 hours of operational time and the fuel consumption was 10 liters/ hr or 23.8 liters per hectare. Which is given as 0.54 ha/hr and the force required to pull the plough ranges from 5500N to 7500N which is within the recommended pulling capacity of the tractor. The operational time in the manufacturer's figure of productivity is 0.60 ha/hr this was above the recommended output and the fuel consumption per hectare is balanced and it makes it economical.

The plough model 1LY 425 and 1LY 325 in Melkasa both are above the acceptable efficiency. The fuel consumption in the plowing operation listed above was obtained in the recommended range. When it is calculated on the bases of one hector it can be seen from the above data that to pull the plow of the tractor has a good efficiency and above the recommended output.

4.4. Power Test and Field Test URSUS 5014A Tractor at Melkasa Site

Tractor; URSUS 5014A

Table. 4.11. Power test data collected at Melkasa site URSUS 5014A

Operation	Ploughing			
Plough	1LY 325		1LY320	
Gear combination	2 nd	3rd	2 nd	3rd
Working depth (cm)	20	20	17	17
Working width (cm)	78	78	60	60
Distance covered by 10 rev .of rear wheels during transport (m)	39	39	39	39
Distance covered by 10 rev. of rear wheels during ploughing (m)	34	32	35	34
Ploughing force (dyna. reading) (N)	7250	8500	5500	7500
Slippage %	12.82	17.95	10.26	12.82

The tractors URSUS model 5014A were tested with model 1LY325 and model 1LY 320 disc ploughs in order to analyze their efficiency in ploughing operation in places of Melkasa

Table. 4.12. Field test data collected at Melkasa site URSUS 5014A

Tractor Used	Model	URSUS 5014A	
	Front weight added	260kg	
Plow used	Model	1LY 325	1LY 320
	Type	Disc	Disc
	No of bottoms	3	4
	Theoretical working width (cm)	78	60
	Average working depth (cm)	20	17
Results of field test	Soil type	Clay sandy loam	
	Moisture content of soil,%	19.07	
	Soil resistance, kN/cm^2	0.37	
	Run length (m)	100	100
	Time taken (s)	90	80
	Fuel (L)	0.15	0.12
	Working speed (km/hr)	4.26	4.26
	Field capacity (ha/hr)	0.29	0.26
	Theoretical field capacity	0.33	0.31
	Efficiency (%)	87.87	83..87
	Specific fuel conception(SFC) in:-		
	SFC (Lit/hr)	5.92	10.2
	SFC (Li/ha)	19.2	20

According to Table 4.11 and 4.12, the test results obtained during ploughing operation in clay sandy loam soil type 50 hp with 3 bottom 66 cm disc diameter disc plough the average performance of the plough in net operational time is 0.29 hectares per hour and the fuel consumption is 19.2 liters per hectare or 5.92 liters/hr. The output (productivity) of the plough in 8 hours of operational time is 2.48 hectares and the fuel consumption is 47.62 liters and the force required to pull the plough ranges from 7250N to 8500N which is within the recommended pulling capacity of the tractor. This output was found when the tractor was going with a speed of 4.26 km/hr. The manufacturer's figure of productivity at this speed is 0.30 ha/hr. of operational time. It can be seen that the actual value was almost near to the manufacturer's recommendation and the fuel consumption per hectare is balanced and it makes it economical.

The test results obtained during ploughing operation in clay sandy loam soil type 80 hp with 4 bottom 50 cm disc diameter disc plough the average performance of the plough the output was 0.26 ha/hr i.e. 2.08 hectares in 8 hours of operational time and the fuel consumption was 4.20 liters/ hr or 15.39 liters per hectare and the force required to pull the plough ranges from 7200N to 8500N which is within the recommended pulling capacity of the tractor. Which is given as 0.26 ha/hr of operational time. It can be seen that the actual value was near to the manufacturer's recommendation. The fuel consumption per hectare was balanced and it makes it economical.

The plough model 1LY 325 and 1LY 320 in Melkassa both are above the acceptable efficiency. The fuel consumption in the plowing operation listed above was lied in the acceptable range. When it is calculated on the bases of one hector it can be seen from the above data that to pull the plow of the tractor has a good efficiency and the fuel consumption per hectare was balanced and it makes it economical.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

This research focused on the optimization of three models of disc plough with tractors 80 hp and 50hp ploughing operation on clay sandy loam soil at Melkasa and vertisol soil at Asela for disc ploughing with 3 disc bottom and 4 disc bottom of 66 cm disc diameter and 4 disc bottom of 50 cm disc diameter disc plough and tractors of 50 and 80 hp. Were tested with two different driving gear of 2^{nd} and 3^{rd} on an experimental plot of soil moisture on vertisol soil at Asela 32.77 % ,Soil resistance 0.894 kN/cm^2 and the soil so having sticking nature it needs more power for ploughing. On clay sandy loam soil at Melkasa 19.07 %, Soil resistance 0.37 kN/cm^2 which does not have sticking nature and where the soil resistance is less. The plowing operation insures easy at different tractor forward speeds were conducted using dynamo meter. The plough have been tested for their adaptability, performance, capacity and places having different altitude, climates and soil condition. All required observation on operation and consumption of fuel were taken in both test sites.

Based on the performance evaluation results in vertisol soil type 80 hp tractor with 3 bottom disc plough 66 cm disc diameter, in sandy loam soil type testing site 80 hp tractor with 4 bottom disc plough 66 cm disc diameter and 50 hp tractor with 3 bottom disc plough 66 cm disc diameter was the most appropriate for ploughing with the disc plough as it recorded the highest field capacity, low pull force and fuel consumption.

5.2. RECOMMENDATIONS

Making the test period shorter it was not possible to cover the expected hectare of output from each plough. Climatic factors also hindered the test from using this short period effectively. However, in spite of these difficulties the main objectives of the test were realized during this short period. For future work it is possible to identify a lot of problems in relation to the different tractors and implement deployed in the study areas. In this research it was able to identify 80 and 50 hp tractors with 3 and 4 bottom disc plows, but it research address only very small portion of the problems existing on different areas. This research can be extended based on different types of soil and tractor horse power in tractor-implement optimize

REFERENCE

Ahmed M. El Naimon.on (2017): Tractor performance as affected by tilt angle of disc plough under clay soil):.https://www.researchgate.net/publication/315667463.

Andrei Visagie (1976): with minor revisions, by J Fuls, (2004) Reproduced from a publication Tractor Performance

Ajit K. Srivastava, Carroll E. Goering, Roger P. Rohrbach, and Dennis R. Buckmaster (2006): Soil Tillage. Chapter 8 in Engineering Principles of Agricultural Machines, 2nd ed., 169-229.:St. Joseph, Michigan ASABE, Copyright American Society of Agricultural and Biological Engineers.

Askari M., Komarizade M.H., Nikbakht A.M., Nobakht N., Teimourlou R.F (2011): A novel three-point hitch dynamometer to measure the draft requirement of mounted implements Res. Agr. Eng., *57*: 128–136.

Belarus 80/82 tractor service manual (1984): v/o tractor export USSR Mosco

Bill Butterworth (1984): Farm tractors the case guide to tractor selection operation (economics and servicing) first published.

Tayel M.Y., S. M. Shaaban and H.A. Mansour (2015): Effect of Plowing Conditions on the Tractor Wheel Slippage and Fuel Consumption in Sandy Soil Chem Tech Research, (2015): International Journal CODEN (USA)

Cherry Hill (2008): Equipping Your Horse Farm

Chung Young Gun (1983): An instrumentation system for measuring tractor field performance *Iowa State University* University Microfilms I ntBrHâtions! 300 N. zeeb Road, Ann Arbor, Ml 48106

Claude culpin (1992): twelve edition Farm machinery oxford black London Edinburgh Boston.

Čupera J., Bauer F., Severa L., Tatíček M (2011): Analysis of force effects measured in the tractor three-point linkage Res. Agr. Eng., *57*: 79–87.

Dwyer, M.J., Evernden, D.W. and McAllister, M (1976): Handbook of Agricultural Tyre Performance; National Institute of Agricultural Engineering, Report No 18.

Elashry, E. R. (2002): Tractive performance for 4-WD tractors under different tire-ballast combinations. Misr J. of Agric. Eng.19 (2):313- 326.

Frank M (2003): Zoz Retired John Deere Product Engineering Center Waterloo, Iowa, USA Robert D.Grisso Professor Virginia Tech Blacksburg, Virginia, USA Traction and Tractor Performance by the American Society of Agricultural Engineers (ASAE).

FAO (2009): Food and Agriculture Organization of the United Nations. How to feed the world in 2050.(www.fao.org/fileadmin/templates/wsfs/docs/expertpaper/ How) to feed the World.

Gohlich.H (1984): The Development of Tractors and Other Agricultural Vehicles Paper presented at AC ENG 84, Cambridge. U.K. l-5 April the British Society for Research in Agricultural Engineering J. *agric. Engng Res.*

Harries Pearson smith (1929, 1937*):* Farm machinery "and equipment, a.e.second edition seventh impression, by the mcghaw – hill.

Hosta task sheet (2004): Connecting implements to the tractor © The Pennsylvania State University.

J.c turner (1994): Farm machinery operation and care printed in Great Britain by Ebenezer Bayles &son ltd.

Macmillan (2002):The Mechanics of Tractor - Implement Performance R. H. Senior Academic Associate, Agricultural Engineering International Development Technologies Centre University of Melbourne,

Nkakini. S.O (2015): International Journal of Advanced Research in Engineering and Technology (IJARET).July Volume 6, Draught force requirements of a Disc plough

R.a kepner roy bainer e lbarger (1987): Principle of farm machinery third edition Reprint 2000 &2003 copyright 1978 avl publishing company inc USA.

Rangapara Dineshkumar J (2014): Development of mini tractor operated picking type pneumatic plante.r Anand agricultural university, Godhra,

Samir M. Younis, EL. Said R. Elashry, Ahmed. F. Bahnasy, Islam. M., Elsybaee (2010): Development a local system for measuring tractors performance

Sharma (2010): Farm machinery design principle and problems

Slimařik Dušan, Dostal Petr, Polcar Adam (2015): Static Testing of Dra_ Sensor for Three Point Hitch Dynamometer Utilization. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 63(3): 835–839.

Smith Wilkes (1976): Farm machinery and equipment.

St. Joseph, Michigan (2012): Agricultural Machines, 2nd ed., 139-166., American Society of Agricultural and Biological Engineers (ASABE).

Steve j. Poulos January (1971): The stress-strain curves kof soils

Terra mechanics (2005): Journal of 35–46 Available online.

The Agricultural Transformation Agency (2016**):** Caring for Ethiopian Soils

URSUS tractor manual (2014): ul. Frezerów 7, 20-209, Lublin, Poland

V, rodichev, g rodicheva (1984): Tractor and automobiles,

APPENDICES

Appendix A

Specification of disc plough

Model	No of disc	Diameter of disc (mm)	Working Width (mm)	Weight of plough (kg)	Required HP
1LY – 320	4	500	600	180	50
1LY – 325	3	660	750	430	50
1LY – 425	4	660	1050	530	80

Specification of tractors

	Tractor model	
	URSUS 5014A	URSUS 8014A
Engine make	IMR DM33T	MWM International MAXXFORCE4.1A
Power out put (kw/hp) at rpm	34.5/47 at2250	62 / 83/ 2200
Maximum torque ,Nm at rpm	162 at1350	285/1400
Maximum speed ,km/h	30	30
Clutch	Two –disc dry type	Two –disc dry type
Gear box	12 x12 with mech. shuttle	12 x 12 with syn.shuttle
Rear axel	w/mechanical diff. lock	w/mechanical diff. lock
Transmit ion	4WD	4WD
Front axel	w/planetary hub	w/planetary hub
Lifting capacity, kg	1500	2600
Front /Rear wheels	8.3-20/ 12.4-28	11.2-24/16.9-38
Length, mm	3900	4210
Width. Mm	1890	2000
Height, mm	2640	2690
Wheel base, mm	1980	2330
Ground clearance, mm	315	380
Weight without ballast,kg	2652	3003
Front weight (options) ,kg	100	440

Appendix B

Measuring width of cut

Appendix C

8. The parameter, termed the cone index (CI) is given by,

$$CI = \frac{Force\ on\ cone}{Base\ area\ of\ the\ con} \qquad [\text{ kPa }]$$

$$= \frac{0.91}{3.32cm\ 2} = 0.2826\ \text{N/cm}^2$$

Soil resistance								
Cone penetrometer measurement in Melkasa								
Day 1								
Depth								
10			**20**			**30**		
N	cm^2	N/cm^2	N	cm^2	N/cm^2	N	cm^2	N/cm^2
0.91	3.22	0.282609	0.91	3.22	0.282609	1.46	3.22	0.453416
0.85	3.22	0.263975	1.2	3.22	0.372671	1.6	3.22	0.496894
0.97	3.22	0.301242	0.97	3.22	0.301242	1.29	3.22	0.400621
0.84	3.22	0.26087	1.1	3.22	0.341615	1.7	3.22	0.52795
0.89	3.22	0.276398	0.95	3.22	0.295031	1.47	3.22	0.456522
0.95	3.22	0.295031	1.1	3.22	0.341615	1.4	3.22	0.434783
0.85	3.22	0.263975	1.5	3.22	0.465839	1.5	3.22	0.465839
0.87	3.22	0.270186	0.87	3.22	0.270186	1.54	3.22	0.478261
0.82	3.22	0.254658	1.2	3.22	0.372671	1.7	3.22	0.52795
0.92	3.22	0.285714	1.4	3.22	0.434783	1.8	3.22	0.559006
		2.754658			3.478261			4.801242
		0.275466	0	0	0.347826	0	0	0.480124
Day 2								
0.91	3.22	0.282609	1.1	3.22	0.341615	1.3	3.22	0.403727
1.1	3.22	0.341615	0.96	3.22	0.298137	1.1	3.22	0.341615
0.97	3.22	0.301242	0.97	3.22	0.301242	1.29	3.22	0.400621
0.82	3.22	0.254658	1.1	3.22	0.341615	1.2	3.22	0.372671
0.95	3.22	0.295031	0.95	3.22	0.295031	1.47	3.22	0.456522
1.1	3.22	0.341615	1.1	3.22	0.341615	1.4	3.22	0.434783
1.2	3.22	0.372671	1.5	3.22	0.465839	1.5	3.22	0.465839
0.87	3.22	0.270186	0.87	3.22	0.270186	1.1	3.22	0.341615
1.2	3.22	0.372671	1.2	3.22	0.372671	1.7	3.22	0.52795
1.1	3.22	0.341615	1.4	3.22	0.434783	1.4	3.22	0.434783
		3.173913			3.462733			4.180124
		0.317391	0	0	0.346273	0	0	0.418012
Day 3								
0.91	3.22	0.282609	1.1	3.22	0.341615	1.46	3.22	0.453416
1.2	3.22	0.372671	0.94	3.22	0.291925	1.6	3.22	0.496894
0.97	3.22	0.301242	0.92	3.22	0.285714	1.29	3.22	0.400621
1.1	3.22	0.341615	1.3	3.22	0.403727	1.3	3.22	0.403727
0.95	3.22	0.295031	1.3	3.22	0.403727	1.47	3.22	0.456522
1.1	3.22	0.341615	1.4	3.22	0.434783	1.4	3.22	0.434783
1.1	3.22	0.341615	1.1	3.22	0.341615	1.5	3.22	0.465839
1.2	3.22	0.372671	1.6	3.22	0.496894	1.1	3.22	0.341615
1.2	3.22	0.372671	1.7	3.22	0.52795	1.7	3.22	0.52795
1.1	3.22	0.341615	1.8	3.22	0.559006	1.8	3.22	0.559006
		3.363354			4.086957			4.540373
		0.336335	0	0	0.408696	0	0	0.454037

Day 4								
10			20			30		
N	cm^2	N/cm^2	N	cm^2	N/cm^2	N	cm^2	N/cm^2
0.81	3.22	0.251553	0.91	3.22	0.282609	1.1	3.22	0.341615
0.85	3.22	0.263975	0.84	3.22	0.26087	0.92	3.22	0.285714
0.84	3.22	0.26087	0.97	3.22	0.301242	0.92	3.22	0.285714
0.81	3.22	0.251553	1.1	3.22	0.341615	0.91	3.22	0.282609
0.89	3.22	0.276398	0.95	3.22	0.295031	0.92	3.22	0.285714
0.95	3.22	0.295031	1.1	3.22	0.341615	0.82	3.22	0.254658
0.85	3.22	0.263975	0.86	3.22	0.267081	0.93	3.22	0.28882
0.87	3.22	0.270186	1.1	3.22	0.341615	0.95	3.22	0.295031
0.82	3.22	0.254658	1.2	3.22	0.372671	0.82	3.22	0.254658
0.92	3.22	0.285714	0.87	3.22	0.270186	0.94	3.22	0.291925
		2.673913			3.074534			2.86646
		0.267391	0	0	0.307453	0	0	0.286646
Day 5								
N	cm^2	N/cm^2	N	cm^2	N/cm^2	N	cm^2	N/cm^2
0.81	3.22	0.251553	1.2	3.22	0.372671	0.92	3.22	0.285714
0.72	3.22	0.223602	1.5	3.22	0.465839	0.81	3.22	0.251553
0.76	3.22	0.236025	1.4	3.22	0.434783	0.79	3.22	0.245342
0.84	3.22	0.26087	1.3	3.22	0.403727	0.84	3.22	0.26087
0.76	3.22	0.236025	1.2	3.22	0.372671	0.92	3.22	0.285714
0.82	3.22	0.254658	1.2	3.22	0.372671	0.82	3.22	0.254658
0.75	3.22	0.232919	1.2	3.22	0.372671	0.79	3.22	0.245342
0.8	3.22	0.248447	0.92	3.22	0.285714	0.8	3.22	0.248447
0.82	3.22	0.254658	1.2	3.22	0.372671	0.82	3.22	0.254658
0.79	3.22	0.245342	1.4	3.22	0.434783	0.79	3.22	0.245342
		2.444099			3.888199			2.57764
		0.24441	0	0	0.38882	0	0	0.257764
Day 6								
N	cm^2	N/cm^2	N	cm^2	N/cm^2	N	cm^2	N/cm^2
0.92	3.22	0.285714	1.4	3.22	0.434783	1.2	3.22	0.372671
0.81	3.22	0.251553	1.1	3.22	0.341615	1.3	3.22	0.403727
0.72	3.22	0.223602	1.4	3.22	0.434783	1.29	3.22	0.400621
0.73	3.22	0.226708	1.3	3.22	0.403727	1.5	3.22	0.465839
0.76	3.22	0.236025	1.2	3.22	0.372671	1.1	3.22	0.341615
0.82	3.22	0.254658	1.1	3.22	0.341615	1.4	3.22	0.434783
0.75	3.22	0.232919	1.2	3.22	0.372671	1.2	3.22	0.372671
0.8	3.22	0.248447	0.92	3.22	0.285714	1.54	3.22	0.478261
0.82	3.22	0.254658	1.2	3.22	0.372671	1.4	3.22	0.434783
0.79	3.22	0.245342	1.4	3.22	0.434783	1.1	3.22	0.341615
		2.459627			3.795031			4.046584
		0.245963	0	0	0.379503	0	0	0.404658

Day 7								
10			20			30		
N	cm^2	N/cm^2	N	cm^2	N/cm^2	N	cm^2	N/cm^2
0.82	3.22	0.254658	0.91	3.22	0.282609	1.4	3.22	0.434783
0.94	3.22	0.291925	0.85	3.22	0.263975	1.1	3.22	0.341615
0.97	3.22	0.301242	0.97	3.22	0.301242	0.98	3.22	0.304348
1.1	3.22	0.341615	1.1	3.22	0.341615	1.3	3.22	0.403727
0.95	3.22	0.295031	0.95	3.22	0.295031	1.2	3.22	0.372671
1.1	3.22	0.341615	0.89	3.22	0.276398	0.91	3.22	0.282609
1.1	3.22	0.341615	0.86	3.22	0.267081	1.2	3.22	0.372671
0.86	3.22	0.267081	0.87	3.22	0.270186	0.92	3.22	0.285714
1.2	3.22	0.372671	0.92	3.22	0.285714	1.2	3.22	0.372671
1.1	3.22	0.341615	0.86	3.22	0.267081	1.4	3.22	0.434783
		3.149068			2.850932			3.60559
		0.314907	0	0	0.285093	0	0	0.360559
Day 8								
N	cm^2	N/cm^2	N	cm^2	N/cm^2	N	cm^2	N/cm^2
0.97	3.22	0.301242	0.97	3.22	0.301242	1.46	3.22	0.453416
1.2	3.22	0.372671	1.3	3.22	0.403727	1.6	3.22	0.496894
1.3	3.22	0.403727	1.7	3.22	0.52795	1.29	3.22	0.400621
1.4	3.22	0.434783	1.47	3.22	0.456522	1.7	3.22	0.52795
1.2	3.22	0.372671	1.4	3.22	0.434783	1.47	3.22	0.456522
1.1	3.22	0.341615	1.1	3.22	0.341615	1.4	3.22	0.434783
1.2	3.22	0.372671	1.2	3.22	0.372671	1.5	3.22	0.465839
1.3	3.22	0.403727	1.3	3.22	0.403727	1.54	3.22	0.478261
1.2	3.22	0.372671	1.5	3.22	0.465839	1.7	3.22	0.52795
1.4	3.22	0.434783	1.4	3.22	0.434783	1.8	3.22	0.559006
		3.810559			4.142857			4.801242
		0.381056	0	0	0.414286	0	0	0.480124
Day 9								
N	cm^2	N/cm^2	1.4	cm^2	N/cm^2	N	cm^2	N/cm^2
1.3	3.22	0.403727	1.2	3.22	0.372671	1.46	3.22	0.453416
1.2	3.22	0.372671	1.1	3.22	0.341615	1.6	3.22	0.496894
1.3	3.22	0.403727	1.7	3.22	0.52795	1.29	3.22	0.400621
1.4	3.22	0.434783	1.47	3.22	0.456522	1.7	3.22	0.52795
1.2	3.22	0.372671	1.4	3.22	0.434783	1.47	3.22	0.456522
1.1	3.22	0.341615	1.1	3.22	0.341615	1.4	3.22	0.434783
1.2	3.22	0.372671	1.2	3.22	0.372671	1.5	3.22	0.465839
1.3	3.22	0.403727	1.3	3.22	0.403727	1.54	3.22	0.478261
1.2	3.22	0.372671	1.5	3.22	0.465839	1.7	3.22	0.52795
1.4	3.22	0.434783	1.4	3.22	0.434783	1.8	3.22	0.559006
		3.913043			4.152174			4.801242
		0.391304	0	0	0.415217	0	0	0.480124

Day 10								
10			20			30		
N	cm^2	N/cm^2	N	cm^2	N/cm^2	N	cm^2	N/cm^2
1.2	3.22	0.372671	1.4	3.22	0.434783	1.46	3.22	0.453416
1.2	3.22	0.372671	1.4	3.22	0.434783	1.6	3.22	0.496894
1.29	3.22	0.400621	1.29	3.22	0.400621	1.29	3.22	0.400621
1.7	3.22	0.52795	1.7	3.22	0.52795	1.7	3.22	0.52795
1.47	3.22	0.456522	1.47	3.22	0.456522	1.47	3.22	0.456522
1.4	3.22	0.434783	1.7	3.22	0.52795	1.6	3.22	0.496894
1.1	3.22	0.341615	1.6	3.22	0.496894	1.5	3.22	0.465839
1.2	3.22	0.372671	1.5	3.22	0.465839	1.54	3.22	0.478261
1.3	3.22	0.403727	1.2	3.22	0.372671	1.7	3.22	0.52795
1.5	3.22	0.465839	1.5	3.22	0.465839	1.8	3.22	0.559006
		4.149068			4.583851			4.863354
		0.414907	0	0	0.458385	0	0	0.486335

Appendix D

Measuring pulling force by dynamometer

Appendix E

Fuel consumption rate:

$$FCR = \frac{CR}{A} \quad [L/ha]$$

Where: FCR = fuel consumption rate (L / ha) CR = reading of cylinder (L) A = plot area (ha)

Length = 100m , Width = 1.02m

Area = L x W A = 100m x 1.02m = 102 m^2 CR = 0.27.5 L

FCR = $\frac{0.27.5\ L}{102\ m2} =$ 0.00275 L/m^2 $\frac{0.00275\ L\ x\ 10000\ \ m2}{1\ m2}$ = 27.5 L / ha

Fuel consumption URSUS 8014A Asela				
	1LY 425		1LY 325	
	Gear			
Length 100m	2nd	3rd	2nd	3rd
Row 1	0.28	0.33	0.14	0.2
Row 2	0.25	0.27	0.16	0.18
	0.265	0.30	0.15	0.19
Average	0.28		0.17	

Fuel consumption URSUS 8014A Melkasa				
	1LY 425		1LY 325	
	Gear			
Length 100m	2nd	3rd	2nd	3rd
Row 1	0.20	0.24	0.14	0.2
Row 2	0.18	0.22	0.16	0.21
	0.19	0.23	0.15	0.205
Average	0.21		0.18	

Fuel consumption URSUS 5014A Melkasa				
	1LY 425		1LY 325	
	Gear			
Length 100m	2nd	3rd	2nd	3rd
Row 1	0.13	0.18	0.11	0.16
Row 2	0.10	0.20	0.09	0.12
	0.115	0.19	0.10	0.14
Average	0.15		0.12	

Appendix F

i- Theoretical field capacity

$$\text{TFC} = \frac{\text{S x W}}{\text{C}} \quad \text{[ha/hr]}$$

Where:

TFC = Theoretical field capacity (ha/h) S = Working speed (km/h) W = cutting width of implement (m) C =Conversion factor = (10)

S = working speed (5.5 Km/h)

W = cutting width of implement (1.02 m)

C = conversion factor = 10

$$\frac{5.5\frac{\text{km}}{\text{hr}}\text{x } 1.02\text{m}}{10} = \quad 0.56 \text{ ha/hr}$$

ii- Effective field capacity

$$\text{EFC} = \frac{\text{A}}{\text{T}} = \quad \text{[ha/hr]}$$

Where:

EFC = effective field capacity (ha/h).

A = hectare.

T = hour.

$$\text{Effective field capacity (EFC)} = \frac{Area\ (ha)}{Time\ (hr)}$$

$$\text{Area} = \frac{\frac{100\text{m x } 1.02\text{m}}{10000\text{m}^2}\ ha}{\frac{106\ s}{3600\ s}\ hr} = 0.35 \text{ ha/hr}$$

iii- Field efficiency

$$\text{FE} = \frac{EFC}{TFC}\ x\ 100$$

$$\text{Field efficiency (FE)} = \frac{0.35}{0.56} \text{ x } 100 = 62.5\%$$

iv- Rear wheel slippage

$$S = \frac{D_U - D_I}{D_U}\ x\ 100$$

Where:

S = rear wheel slippage (%)

DU = distance travelled by unloaded tractor

Dl = distance travelled by loaded tractor

$$\text{Slippage (S)} = \frac{D_U - D_I}{D_U} \text{ X } 100 = \frac{44-33}{44} \text{ X } 100 = 25\ \%$$

v. Moisture content

$$\text{Moisture content (\%)} = \frac{Ww - Wd}{Ww}\ x\ 100$$

Where, W_w= 517.2

W_d= 418.4

Melkasa Moisture content (% $= \frac{517.2-418.4}{517.2}\ x\ 100 = 19.07\ \%$