Tillage Implements Performance Evaluation for Agricultural Tractors

A Case Study of Kulumsa Agricultural Research Center

Endeg Andargie Nigate

A Thesis Submitted to the Department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

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Declaration

I hereby declare that this Master Thesis entitled " Tillage Implements Performance Evaluation for Agricultural Tractors: A Case Study of Kulumsa Agricultural Research Center" is my own work, that is, it has not been submitted for the award of any academic degree, diploma, or certificate by any other university. All sources of materials that were used for this thesis have been duly acknowledged through citation.

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Name of student	Signature	Date

Recommendation of Advisors

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Tillage Implements Performance Evaluation for Agricultural Tractors: A Case Study at Kulumsa Agricultural Research Center**"** prepared under my guidance by Endeg Andargie Nigate and submitted in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Machinery Engineering. Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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Approval Page

I the advisor of the thesis entitled "Tillage Implements Performance Evaluation for Agricultural: A Case Study of Kulumsa Agricultural Research Center" and developed by Endeg Andargie Nigate, hereby certify that the recommendation and suggestions made by the board of examiners were appropriately incorporated into the final version of the thesis.

Dr. Amana Wako Koroso (PhD)	______________	______________
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We, the undersigned, members of the Board of Reviewers of the thesis open defense by Endeg Andargie Nigate have read and evaluated the thesis entitled "Tillage Implements Performance Evaluation for Agricultural Tractors A Case Study of Kulumsa Agricultural Research Center" and examined the candidate during the open defense. This was, therefore, to certify that the thesis was accepted for partial fulfillment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ASAE	American Society of Agricultural Engineers
ASABE	American Society of Agricultural and Biological Engineers
BD	Bulk density
D	Depth of Soil
FAO	Food and Agriculture Organization of the United Nations
FC	Fuel Consumption
ha/hr	Hectare per Hour
hr	Hour
KW	Kilowatt
KN	Kilonewton
KNW	Kilo Newton Watt
L	Litter
L/ha	Litter per Hectare
L/hr	Litter per hour
M	Meter
M/S	Meter per Second
MC	Moisture Content
Pdb	Drawbar Power
PTO	Power Take-Off
S	Wheel Slippage
RDBD	Randomized Complete Block Design
T	Time
USA	United States of America

ABSTRACT

A field experiment was conducted at Kulumsa Agricultural Research Center to evaluate performance data for different tillage implements under different soil and working conditions through field performance evaluation evaluate the performance of three tillage implements on two different soil types (sandy clay loam and clay loam soil) in terms of their effects on soil bulk density, soil moisture content, draft force, fuel consumption, wheel slippage and field efficiency. The implements were moldboard plow, disc plow (primary tillage implement), and disk harrow (secondary tillage implement) under three different operating speeds (16.5 (S1), 17.5 (S2), and 18.5 (S3) km hr-1. The speed of the tractor was determined based on tractor horsepower, implement weight, and depth of tillage for this work. Results showed that the efficiency of the disc plough was highest on clay loam soil with an efficiency of 91.82% and the least was on sandy clay loam soil. Disc plow-tractor attachment was less fuel consumed than dis harrow and moldboard plow. Comparison between implements, disc plow efficiency was higher than disc harrow or moldboard plow reduction in the bulk density of the soil enhances the field performance of the implements. The ranges in implement draft, fuel consumption and other parameters indicated that substantial energy savings can be readily obtained. The ranges in implement draft, fuel consumption and other mentioned parameters indicated that substantial energy savings can be readily obtained by selecting energy-efficient tillage implements and by proper matching of the tractor size and operating parameters to the tillage implement. So, disc plow-tractor attachment was less fuel consumed than dis harrow and moldboard plow.

Keywords: Moldboard Plow, Disc plow, and Disc harrow, Tillage Implement Performance, Wheel Slippage

CHAPTER ONE

1. INTRODUCTION

1.1. Background and Justification

Soil tillage may be defined as the mechanical manipulation of soil with tools and implements for obtaining conditions ideal for seeding, germination, seedling establishment and growth of crops. Tillage is the mechanical backdown of soil in order to improve soil conditions for seed preparation and crop production. It represents the most costly single operation to farmers and the most tasking to the tractors. (Ibrahim kareem & Sven, 2019). The objectives of tillage include preparation of a suitable soil condition, control of soil moisture content, minimization of weeds and pests, and burying of organic material to add humus to the soil. Method of tillage can be broadly classified into two categories: conventional tillage and conservation tillage. Conventional tillage method involves plowing followed by harrowing and tertiary operations in the preparation of a seed bed and further cultivation after emergence of plants. Conservation tillage includes among other operations; minimum tillage, no-till or direct seeding and strip till. Conservation tillage are mainly practiced in order to minimize soil loss and preserve soil moisture (Komissarov & Klik, 2020). Minimum tillage reduces the number of tillage operations done on the field during seedbed preparation and cultivation. In direct seeding planting is done in a limited (commonly 15 cm or lesser) seedbed or slot produced by clutters, row cleaners, disk outset, in-row chisels, or roto-tillers. A press- wheel follows to provide firm soil-seed union. Strip tilling is when a farmer only cultivates thin strips in their field where seeds will be planted. The strips are located where the rows of crops are located. Each year, the strips will shift roughly fifteen centimeters in one direction. Based on purpose, the wheeled tractor is divided firstly into general purpose tractor which is used for broad farm operations; such as plowing, harrowing, sowing, harvesting, and transporting work. Such tractors have low ground clearance, increased engine power, good adhesion, and wide tires. Secondly, the row crop tractor used for yield cultivation is provided with changeable driving wheels of different tread widths. It has high ground clearance to save damage to crops. A broad wheel track can be adjusted to suit inter-row distance. Finally, the special purpose tractor is used for limited jobs like cotton fields, marshy land, highlands, garden, etc. Special designs are a tractor-implement connection having an overall energy efficiency below 10% indicates dirt poor load matching or/and low tractive efficiency, while a value above 20% indicates a good load match or/and high tractive efficiency (Turker et al.,2012). Many researchers believed that the increase of overall energy efficiency for tractors and implements and correct matching of tractors and agricultural machinery can be effective in decreasing fuel consumption (Almaliki et al., 2016). Performance data from different tractors and implements are very important for farm machinery management and manufacturers alike. Proper selection of tractors and implements for a particular farm situation can be determined from these performance parameters. These data can also be used to evaluate various farm machinery systems to determine the relative advantages of each system. As field machines commit a major portion of the total cost of crop production systems, appropriate selection and matching of farm machinery are essential to significantly minimize the cost of ownership and operation of farm machinery. Also, the efficient operation of tractors and implements is the main concern for farmers because of the rising cost of fuel and other operating costs. The agriculture tractor revolution comes out from the quality analysis of effort to increase the efficiency of energy use in agricultural production (Carolan, 2018). So, it is necessary to evaluate tractor performance with different implements. Furthermore, studying the relationship between different parameters is necessary for quality analysis. It is essential to coordinate the components of mobile energetic devices to create conditions for their optimum work. It can be argued that the tractor is one of the main contributors to total agricultural fuel consumption. Fuel consumption is the single largest variable cost during the field operation of tractors and is also one of the most influential parameters controlling the salability of the vehicle, particularly in developing countries. Fuel consumption is the highest operating cost than any other operating costs and fuel consumption is controlled by other operating parameters (R. D. Grisso et al., 2004).

There are several tillage implements, classified as primary or secondary implements, which follow each other in the tillage operation to achieve the tillage objectives. Researchers are essentially aimed to improve the soil physical properties, in which their performance can be affected by soil types and the surrounding conditions. Therefore, the selection of suitable tillage implements to match certain soil types and conditions is an essential factor in reducing the cost of operation and energy loss. As a consequence, optimizing the field performance of tractor, and conserving the soil fertility as well as reducing the adverse effects on soil structure such as compaction will be achieved.

Tillage implement power requirements and performance data in different soil types and conditions are an important factor in matching tractors with implements. Tillage implements drawbar power requirements and performance data is not well documented for soils thus forcing farmers and managers to use the American Society of Agricultural Engineers (ASAE) Standards data which are based on USA and European soil types and conditions (Okoko et al., 2018). This study will help generate this important data which would go a long way in reducing the cost of production to the farmers and hence increase productivity leading to improved livelihoods and poverty, it will also aid in guiding the farmers, managers and decision makers on the size implement of and tractor to buy for their field conditions. Tillage or soil surface control to prepare the desired seedbed is a large input in agricultural production. It is a labor-intensive activity in limited-resource agriculture on smallholder farms, and a capital and energy-intensive activity in large-scale mechanized farming. properly used, tillage can be a powerful tool to alleviate some soil-related constraints to crop production e.g., compaction, crusting, low infiltration, poor drainage, unfavorable soil moisture, and temperature regimes, disposal of undesirable biomass, and pest management. Improper tillage can lead to deterioration of soil structure, minimized infiltration, accelerated runoff and erosion, and consequential degradation of soil and the environment (Gedamu, 2020). Tillage controls the extent to which soil and water can be conserved by its effect (at the time of seedbed preparation) on resulting surface roughness, mulch retained on the surface, aggregate size, and stability. Conservation of moisture is of utmost importance in semi-arid and arid areas as a means of ensuring crop production and controlling erosion by rain and wind.

1.2. Statement of the Problems

The controversy over using different tillage systems has diverted the research focus from determining the economic efficiency of tillage implements that may minimize the cost of production (Leghari et al., 2016). Furthermore, implements are paired to tractors without considering the tractor power output and the power demand of implements based on speed, depth, and width of tillage and soil conditions, resulting in overloading or underloading of the tractor. Overloading and underloading lead to breakages of implement and tractor parts, resulting in costly maintenance and repair costs, poor performance of the implements, unnecessary wastage of power and increasing downtime (Micone & De Waele, 2015). Recently, there is significant dynamics in the use of mechanization in Ethiopia, with a fast increase in the number of tractors in the country. However, the importation is not based on energy demand adapted to soil and field conditions.

Implement performance under different soil types and working conditions, and the availability of performance data, are critical for efficient farm equipment selection and management. One way of achieving this goal is through evaluation studies aimed at obtaining important performance for different tillage implements under different soils and working conditions (Antonucci et al., 2019). This study was aimed at generating performance data for disc plough, moldboard plough, and disc harrow power requirements for different soil types and working conditions. In this study problems of implement tractor combination become tested and identifies which tractor implement attachment was required more fuel and good in field efficiency

1.3. Objectives

1.3.1. General Objective

The main objective of this thesis is

- To generate performance data for different tillage implements under different soil and working conditions through field performance evaluation

1.3.2. Specific Objective

The specific objectives of this thesis project are:

- To investigate the performance of tillage implements performance under different soil types.
- To determine the effects of tillage depth, forward speed on draft, fuel consumption, wheel slippage and filed efficiency for matching of tractors and implements.
- To assess the effect of soils on the performances of implement's and set recommendations for the end users.

1.4. Scope and Limitation of the Study

The research investigated the effect of soil types, tillage depth and tractor forward speed on fuel consumption, draft force and drawbar power requirement for a five bottom disc plough with a total width of 150 cm, a four bottom reversible moldboard plough with a width of 160 cm and a twenty-four bottom disc harrow a width of 300 cm. The depths were 20cm, 22cm and 25cm and the speeds were 16.5 km/h, 17.5km/h and 18.5km/h. Although other sizes and types of plows are available for use within the country, they were not considered in the study. The research only focused on three cites on two types of soils. The result could be different if it was assessed and tested on a wide range of soil types.

1.5. Significance of the Study

Mechanized tillage can help farmers in saving time and money. So, understanding the performance of tillage implements will help to match with the power source, which ultimately make the operation more efficient both in terms of time and cost. Therefore, it is important to select the suitable machine or machines to carry out the specific operation with a minimum cost of energy and in the shortest possible time is essential for all mechanization sectors.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Effect of implement on Soil Tillage

The draught of a tillage tool is affected by the soil properties, tool design and operational parameters (Ghali, 2019). Soil properties include bulk density, soil strength (compaction), water content, soil texture and structure. Tool design parameters consist of tillage tool rake angle, shape and curvature, aspect ratio, attachments and soil-metal sliding friction. Tillage depth, travel speed and width of cut of implement are the operational parameters. (Rashidi et al., 2013), stated that depth of tillage and speed of operation have the greatest influence on the draught force requirement with most common tillage tools. Soil compaction is a major factor affecting the draught of most tillage implements hence increasing the cost of tillage operations (Anpat & Raheman, 2017). Soil tilth is defined as the physical condition of soil as related to its ease of tillage, fitness as a seedbed, and its promotion of seedling emergence and root penetration (Samarajeewa et al., 2006). In relation to tillage is the structure of freshly tilled soil defined by the size and shape distribution, spatial arrangement, and internal structure of soil fragments produced by tillage. For a given soil and tillage implement, the tilth obtained depends primarily on soil moisture content at time of tillage (Kumar et al., 2012).

2.2. Effect of Tillage Implements and Operation on Soil Disturbance

Tillage can be classified broadly as; primary and secondary tillage. The former is the initial operation intended to reduce soil strength, cover crop residues and rearrange soil aggregates while the latter is intended to create refined soil conditions (Jantalia et al., 2007). Most farmers use disc and moldboard plows and disc harrows for the two tillage methods. Immediately after harvest of previous crops, a farmer can choose to use either a disc plough or disc harrow depending on the condition of the field or availability of the implement. Due to changes in soil properties and the climate conditions there has been adoption of other systems of tillage like conventional and conservation tillage systems. According to (Samarajeewa et al., 2006) conservation tillage is practiced in order to reduce soil loss and preserve soil moisture. The need for sustainable farming methods and increasing fuel prices compel farmers to change the farming methods and find alternative economic tillage methods. Minimum tillage and direct seed drilling are some of the methods that farmers apply recently for a long-term erosion free farming at lower fuel cost (Roy et al., 2017), but these methods have had low adaptability by Ethiopian farmers.

2.2.1 Tillage Implements' Activity Determination by Soil Condition

(Al-Hamed et al., 2014) developed a computer program for the purpose of matching tractors and tillage implements with the aim of reducing chances of overloading or under loading of tractors. The program was majorly based on (ASABE) standard equations for predicting drought power requirement. The spreadsheet was based on the Brixius model and American Society of Agricultural Engineers (ASAE) standards D497.5 to predict tractor performance and implement drought respectively. (AL-JANOBI et al., 2010) also developed an excel spreadsheet to estimate performance parameters for chisel plough-tractor combination during tillage process based on artificial neural network. Moldboard plow is considered one of the important tillage implements in soil (Mohammad Askari & Khalifahamzehghasem, 2013). It is the oldest primary tillage implements and remains the only tillage operation with the advantage of total soil inversion, leaving a trash free surface and the burial of any weed seeds (Morris et al., 2010). It is used to prepare the soil bed for growing crops in the least possible time by accomplishing maximum field capacity of tillage implements (Siddabattula et al., 2019). The moldboard plow works best in moist soil where the moisture level is near field capacity (Muñoz et al., 2007). If the soil was excessively dry or excessively wet, the operation takes more power and the results are poor. (Ranjbarian et al., 2017) moldboard plow was particularly used in arid, semi-arid soils, where penetration by moldboards would be difficult and where hidden rocks or stumps might cause serious damage to moldboard. Harrows are designed as secondary tillage implements.

Nevertheless, the advantage of the offset disc harrow has been and still is, for primary tillage (Javadi & Hahiahmad, 2006). The offload disc harrow performed the function of a plow and a cultivator under conditions neither of these implements would perform satisfactorily(Serrano et al., 2007). Subsoiler or chisel plows are usually used to break up impervious soil layers below the normal tillage depth. (Rashidi et al., 2013) chisel plows normally run eight to ten inches deep (20 to 25 cm) and the subsoiler can penetrate to 16-22 inches (40-55 cm). The effectiveness of deep tillage varies from soil to soil, from area to area, and from time to time, but the need for deep tillage has, however, been questionable for greater than 50 years (Orzolek, 2018). The difficulty of choosing the most efficient implements for a particular circumstance is evident from the wide variation in the number of cultivation operations carried out by different growers under basically the similar conditions (Leghari et al., 2016).

A. Disc plow implement: The common disk plow consists of a series of blades mounted individually on a frame. The disk blades are set at an angle, called the disk angle, from the full-face line of travel, and also at a tilt angle from the vertical, (plate). Standard disk plows commonly have three to six blades, spaced to cut 18 to 30cm/disk. The disk angles vary from 42 to 45 and the tilt angles vary from 15 to 25. The disk diameters are commonly between 60 and 70 cm (Morris et al., 2010). Disc plow is used for cutting and mixing stubble, or covering crops with soil. Blades in the disk on the plow are concave, usually representing a section of a hollow sphere. The action of a concave, disc blade is seen to be similar to the action of a moldboard plow button in a way that the soil is lifted, pulverized and partially inverted, and displaced to one side. Disc plow moves all the soil towards the same side. Disc plows can cut through crop residues and roll over roots and other obstructions. Disc plow is directly mounted to the tractor.

- The plow is hydraulically operated.
- Basic implementation for the preparation of land.
- It is available in basic 2 furrows 3 furrow versions for converting it to 3 furrows or 4 furrow plows.

The disc plow is especially useful in hard and dry trashy, stumpy land conditions and in soils where scouring is a major problem. Heavy-duty pipe frame has high trash clearance allowing the plow to operate under heavy crop residual. Being fully mounted and comparatively lighter in weight results in a lighter draft as compared to an equivalent trailed plow where more power is required to operate and consequently higher operating costs.

B. Disc Harrow implement: The disc harrows are used as secondary implements to crush the clods, cutting up and mixing stubble, level the ground and controlling weeds (Jantalia et al., 2007). They can be used also as primary implements for orchards (Serrano et al., 2007). (Sufficiency, 2019) enumerated factors within the harrow itself that affect the depth to which it penetrates the soil such as; the angle of the disc gang, the weight of the harrow, the sharpness of the discs, the size of the discs, the concavity of the discs, and the angle of hitch. Other factors include soil type and conditions also influence the penetration of the disc harrow. Disc harrows are divided into three types; single acting, which has two opposite gangs of disc blades, both throwing soil outward from the center of the tilled strip. The second type is the tandem disc harrow, in which two traditional gangas throw the soil back toward the center as next operation. Thus, tilling the soil twice and leaving the field more nearly leveled.

C. Moldboard Plow implement: Moldboard plows are the most widespread used tillage equipment in the world as well as the biggest consumer of power in tillage. During tillage moldboard plows leave almost no untilled land and result in better pulverization. For this purpose, most researchers have endeavored to carry out numerous studies to optimize the performance of the moldboard plough either through trial-and-error method or through semi- theoretical approaches (Hiuhu, 2015). The parts of moldboard plough are frog or body, moldboard or wing, share, landside, connecting rod, bracket and handle. This type of plow leaves no unbraked land as the furrow slices are cut out clean and pulverized to one side resulting in better pulverization. The animal drawn moldboard plow is small, ploughs to a depth of 15 cm, while two moldboard plows which are bigger in size are attached to the tractor and plowed to a depth of 25 to 30 cm. Moldboard plows are used where soil inversion is necessary. Victory plough is an animal drawn moldboard plow with a short shaft. Moldboard plow is one of primary tillage implements used by farmers in south regions of Iran. The literature contains a considerable number of published works dealing with modeling of the draft parameters of moldboard plow implement during tillage activities even though the effect of forward speed and plowing depth treatments on the draft parameters was not completely modeled (Mohammad Askari et al., 2017).

2.2.2. Tillage Operation

Soil tillage may be explained as the mechanical breakdown of soil in order to modify soil conditions for crop production. It represents the most costly single operation to famers and the most tasking to the tractors (Zentner et al., 2002). The objectives of tillage include; production of a suitable soil tilth, control of soil moisture, destruction of weeds and pests, and burying of organic material to adding humus to the soil. Methods of tillage can broadly be classified as conventional and conservation tillage. Methods of tillage can broadly be classified as conventional and conservation tillage. Conventional tillage method involves plowing abide by harrowing and tertiary operations in the preparation of a seed bed and further cultivation after emergence of plants.

Conservation tillage includes among other operations; minimum tillage, no-till or direct seeding and strip till. These are majorly practiced in order to break soil loss and preserve soil moisture (Obalum et al., 2011).

Minimum tillage reduces the number of tillage operations done on the field during seedbed preparation and cultivation. A press-wheel follows to provide firm soil-seed contact. Strip tilling is when a farmer only cultivates thin strips in their field where seeds will be planted. The strips are located where the rows of crops are located. Each year, the strips will shift roughly fifteen centimeters in one direction. Conservation tillage systems often require some other changes to be made both on the method and equipment. For example, planter changes are needed to provide for cutting through the plant residue left on the surface, for it to be able to place the seeds. This is usually accomplished by adding fluted or serrated/notched disc clutters ahead of the furrow openers. But even with such modifications done on tillage implements and methods, there is need to properly select and match the implements to available power units based on field and operating conditions. To efficiently handle demand in agricultural food production, soil physical properties must be managed adequately. The main concern of soil physics for plant productivity is to preserve a comfortable proportion between solid, liquid, and gaseous phase. Soil's physical properties (Blagodatsky & Smith, 2012) are extremely vital to plant growth. The influence of tillage implements on soil physical properties is significant (Boydaş & Turgut, 2007).

2.2.3. Importance of Tillage Operation

Tillage is one of the major important activities in the crop production systems that optimizes the condition of soil bed environment for seed establishment and crop growth. Since primitive societies learned to manipulate soil by simple tools, cultivation has been an important component of farming(Sornpoon & Jayasuriya, 2013). The selection relating to tillage methods are strongly affected by the other part of the cropping system. Thus, the selection of tillage method is very important for cultivation (Sornpoon & Jayasuriya, 2013). A proper tillage can alleviate soil related constraints while improper tillage may lead to a range of degradation processes, e.g., deterioration in soil structure, accelerated erosion, depletion of soil organic matter and fertility and disruption in cycles of water, organic carbon and plant nutrient.

2.3. Effect of Soil Properties on Draught and Performance

2.3.1. Effect of Soil Moisture Content on Draught and Performance

(Olatunji, 2011) conducted investigations to study the factor of moisture content and cone index, to implement draught force and soil disturbance of some tillage tools including tillage tines. They concluded that draught force increased at a decreasing rate as soil moisture content increased from 11% to 22.5%. In the first case, the rake angle and depth were held constant at 450 and 150mm respectively and speed at 1.0m/s. In the second case, rake angle depth and speed were held constant at 900, 150 mm and 1.0 m/s respectively and the cone index was held constant at a mean of 400 kPa. The moisture content varied from 6.0 to 17.5%, the range of moisture content of soil being in the moist or friable soil consistency typical of when tillage operations in loamy soils are undertaken. (Raper & Sharma, 2004) observed that decreased moisture content contributed to increased soil disruption above the ground surface.

2.3.2. Effect of Bulk Density on Draught and Performance of Tillage Tool

Bulk density is the weight of soil to volume. (Dahab & Mohamed, 2002) soils with a bulk density higher than 1.6 g/cm3 tend to inhibit root growth and are rapid with compaction and tend increase with depth. (Rashidi et al., 2013), reported increase in power requirements with increase in soil bulk density using disc plough which shows higher forces to be overcome in plowing 15 as the bulk density increase. (Manuwa & Ademosun, 2007), also found a 15 to 35% increases in drought when the soil bulk density of a fine sandy loam was changed from 1680 kg/m3 to 1830 kg/m3. Numerous gains made in mechanizing tillage activities during the twentieth century were improved in the closing decades of the century. Structural adjustment left gaps in support for the smallholder sector, with the minimization or withdrawal of agricultural input subsidies and credit, share-out of produce markets, closure of government tractor hires services, and weakened veterinary services. At the same instant, the stock of draught animals was decimated in many communities by disease, drought, turn on sales and theft. FAO estimated that, in the late 1990s, 65 percent of the cultivated area in sub–Saharan Africa was prepared by hand, 25 percent by draught animals, and 10 percent by tractor (Bishop-sambrook, 2005). In the next 30 years, FAO projects that, in the absence of change, many of the region will continue to be tilled by hand or draught animals. However, there will be some movement away from humans as the principal source of farm power. Loss of labour has been compounded by the effects of improved access to primary education and persistent urban migration, drawing children and young adults away from farming. In an era of come-down markets for many cash crops, increasing accesses on households' Meagre financial resources, and the removal of support for purchasing farm inputs, many rural livelihoods are under severe strain. An understanding of the interaction between farm power and livelihood outcomes is central to enhancing smallholder livelihoods.

2.3.3. Effect of Soil Compaction on Draught and Performance of Tillage

Compaction of soil is explaining the compression of soil particles into a smaller volume, which reduces the size of pore space accessible for air and water). human-induced compaction of agricultural soil can be the result of using tillage tools during soil tillage or result from the hard weight of field equipment. It is usually measured by use of a cone penetrometer which utilizes a 600 right circular cone attached to a smaller shaft (Raper, 2007). Soil resistance to penetration is measured by an optically indicating dynamometer (Probing ring) as the instrument is pressed into the soil and the resistance is expressed in units of stress (kPa) (NGUYEN, 2017). This corresponds with the findings of (Manuwa & Ademosun, 2007) which showed that drought increased at an increasing rate as the cone index increased from about 200 to 850 kPa. This is because the soil strength (cohesion) increased with increased cone index.

2.4. Effect of tillage tool speed on draught

Tool speed and tillage depth had advance effects on the draught of the model tools at different levels of face and slide angles, and cutting-edge height. Although there were steady increases in draught with increase in the levels of tool speed and tillage depth, nose and slide angles, and cutting-edge height, tool speed and tillage depth had more influence on the draught of the model tools than the tool design parameters. This could be seen from the coefficients of the model equation obtained for determining the draught of the model tools. Trend line equations for all data points in all treatments gave polynomial equations of the second degree. There were no optimum values of tools speed or tillage depth for which the draught of the model tools was minimum (Mohammad Askari et al., 2017). The selection of model tool will therefore depend on soil failure distribution and size and quality of furrow created (Mamman & Oni, 2005).

2.5. Effect of tillage implements speed and depth on performance

Tillage implement speed affects the performance in that it tends to produce more pulverized soil (small soil aggregates) at higher speeds than at lower speeds. Higher speeds also increase tillage tool draught (Ibrahim Kareem & Sven, 2019). Increased depth of tillage resulted in decreased trench widths which were contrary to popular belief that increased ploughing depth results in wider trench widths. The soil used for this experiment could be partially responsible for this finding with severe compaction near the surface resulting in narrower trench widths when ploughing depth was increased. More research is recommended in different soil types and

conditions. Many factors affect draft of implements such as type and condition of soil and tractor implements characteristics. Tillage depth, texture and moisture content of soil are essential parameters that have effect on draft. In clay soils, implements have higher draft in relative to the loam and sandy soils (O Oduma et al., 2018). In specific range of content, implements have lowest draft and out of this range, they may have higher draft. Tillage depth, working width, geometry and stability categorization of implements and forward speed are parameters that may have effect on draft. In most tillage implement, increasing forward speed increases in the value of draft depend on type and design of implements and soil conditions.

2.6. Influence of Tillage on Soil Bulk Density

The degree of loosening is closely related to soil texture, soil moisture content, and the kind of tillage operation. Some of soil physical properties influenced by loosening are bulk density, soil , strength, infiltration, water redistribution within the soil profile and the moisture retention (Osunbitan et al., 2005). Tillage treatments affect crop growth and yield by altering bulk density, compaction and hydraulic properties of the soils. Desired plant growth depends on rooting ability, nutrient status and accessibility of roots to nutrients, soil aeration, and water availability. Availability of water is restricted severe soil compaction. Plants spend higher energy to extract water from soil due to decreased pore size or lack of pore continuity caused by compaction.

2.7. Adverse Effect of Tillage Practices on Soil

Several studies have indicated that machinery traffic and adaptation of different tillage activities greatly affected several soil properties under different plant growth systems (Academy & Sciences, 2003). From a physical side of view, tillage is exerting a pressure on soil profile, which differs in magnitude and direction (O Oduma et al., 2017). The degree of compaction relative to the soil compressibility, its moisture content, axle load and how often equipment is driven on the soil Heavy equipment, especially when operated under moderately wet soils, also tends to decrease soil air content and to increase the physical resistance to penetration of the soil by roots.

The effects of soil compaction include restriction of root development, nutrient and water movement, and oxygen availability which often results in decreased yields of both agronomic and horticultural crops.

2.8. Performance Parameters of Agricultural Implement

Measures of agricultural machine performance are the rate and quality at which the operations are accomplished (Author, 2017). There are a lot of factors reflecting the machine performance such as field capacities and efficiencies, fuel consumption, slippage, draft, and drawbar power.

2.8.1. Implements Field Capacities and Efficiencies

Field efficiency is the proportion of effective field capacity to theoretical field capacity, explained as percent. It includes the effects of time lost in the field and failure to utilize the full width of the machine (Mohamed & Widaat, 2004). It changes with the size and shape of the field, pattern of field operation, crop yield, moisture, and crop conditions. Theoretical field capacity of an implement is the rating of field coverage that would be obtained if the machine is performing its 100 percent of time at the rated forward speed and always covering 100 percent of the rated width (Santhosh & Kumar, 2019). Effective field capacity is the actual rate of performance of land or crop processed in a given time based upon total field time (Zheng et al., 2014).

2.8.2. Fuel Consumption

Fuel consumption is usually expressed as specific consumption (L/h) or (L/ha) (Gerhard Moitzi et al., 2013). (Brose & Wade, 2002) reported that 45-60% of consumed fuel required for the tractor to propel itself. Many factors affect fuel consumption of a machine. (Elfaki & Elamin, 2007) concluded these factors: machine use, size and kind of implement attached (load), operating speed, and soil conditions.

2.8.3. Implement Draft

The draft is the total force parallel to the direction of travel, required to propel the implement (M. Askari et al., 2011), it's also defined as the horizontal component of pull parallel to the line of the motion (Chethan et al., 2018). The draft requirement of tillage implement has great concern for designing tillage implement and deciding suitable tractor size. Horizontal component of force generated by tractor to pull tillage implement within soil is known as draft force. Draft force of implement is a major factor in matching of tractor with implement in different tillage operations. Determination of proper size and power of tractor required to perform tillage operations with specific implement is obtained based on draft force data(Shafaei et al., 2018). Hence, availability of draft force data for a specific tillage implement in particular farm situation is vital in this realm.

2.8.4. Wheel Slippage

Slip is the relative motion in the movement of the mutual contact surface of the tractor or transport device and surface. Which supports it, it's also known as a power loss (Ahmed, 2015). Slippage of tractor's wheels always wastes power and fuel. With pneumatic tires, this wastage may be serious, even if the wheels do not spin. There are different factors affecting slippages such as draft, load, speed (Damanauskas et al., 2015). Wheel slip is the reduction in distance traveled per revolution of the wheel in work compared with the distance traveled by the same wheel developing zero thrusts on the same operating surface. A driven wheel always has some wheel slip, albeit small, just to provide the necessary horizontal force for propelling itself forward, equally, a towed wheel always has some skid-negative wheel slip- to overcome the frictional resistance of the wheel rotating on the axle. To be strictly correct, therefore, the distance traveled by a wheel developing zero thrusts is the mean of the distances traveled both a self-propelled wheel (developing no drawbar pull) and a towed wheel (overcoming no braking force) on the same operating surface and during the same number of wheel revolutions (Abdalla & Mahgoub, 2002). The soil reaction force comprises two components, a vertical component which must be equal and opposite to the vertical load on the wheel, and a horizontal component, which must be equal and opposite to the net effect of any tractive thrust and rolling resistance. This horizontal force is given by the drawbar pull for a driven wheel and by the towing force for a towed wheel.

2.9. Effect of Soil Types and Conditions on the Tillage Implement Performance

Measures of agricultural machine performance are the rate and quality at which the operations are accomplished (O Oduma et al., 2018). Tillage operations are soil-related procedure; soil type and condition

are cardinal factors affecting the field performance of the tractor through their effect on the powered implement and tractor traction (Okechukwu Oduma et al., 2020). (Okeke et al., 2016) stated that the performance of plough varies considerably according to the type of soil, its moisture content, weed growth, crop residues and shape of the field. when the soil compaction increased , the bulk density increased and consequently the soil penetration resistance became high , accordingly , the implements in the firm soils require a greater draft force to overcome a considerable amount of soil resistance , thus the draft force required to pull the implement in firm soil condition was greater than that of loose condition high bulk density , higher slippage and increased fuel consumption , and decreased operating speed should be achieved in the firm soil . Simple correlation analysis showed that the draft accounted for 77.3% of the availability of the slippage and 63% of the availability of fuel consumption.

2.10. Importance of Tillage Implements Selection

Tillage is the most costly operation in the budget of the farmer (Meyer-Aurich et al., 2006). Thirty percent of total power used through agricultural production is extended in the mechanical manipulation of the soil. Therefore, efforts must be exercised in the selection and use of tillage implements (R. Grisso et al., 2006). Selecting a tillage system is one of a crop producer's most important management decisions, especially from an economic side of view. Improper and justified use of tillage implements destroy the root zone in the soil and ultimately stagnates crop yield, and the unwise use of tillage implements wasted fuel and human energy with minimum benefits in terms of yield. Selecting the best tillage system for a particular soil and cropping situation requires matching the operation to the crop sequence, topography, and soil type, and knowing the immediate effect of the operation on the soil properties, and how this operation optimizes short term change in soil organic matter and productivity. To work on matching tillage systems to different soil types, the type of limitation of various tillage systems based on wetness and soil temperature, water erosion, wind erosion, flooding frequency, topsoil thickness and soil tilth. This data can assist you in selecting appropriate tillage systems for a certain soil.

2.11. Research Gaps

According to the review of literature of the present study the researcher has established the following research gaps:

- Very few researches have been conducted on farmers ‟ attitude towards mechanized agriculture on tillage implement-tractor selection and assembling mechanisms. No specific research has so far been studied combinedly on farmers‟ knowledge, attitude and practice towards tillage implements relation to selecting tractor-implement attachments based on tractor horsepower, implement weight, soil type and conditions and farm size.

- Thus, the research worker carried out the present study to determine farmers‟ knowledge, attitude and practice towards implements selection for agricultural mechanization.
- Farmers‟ level of problem faced in agricultural machinery has been identified in very few research. The researcher carried out to cross check the level of problem faced by the farmers in using agricultural machinery.
- Very little research has been conducted on farmers‟ practice towards agricultural mechanization. So, the researcher carried out the study to find the relationship between each of the selected characteristics of the farmers with their practice of agricultural mechanization.

There are different types of tillage systems such as different alliance of plows as primary and harrows as secondary implements. Draft and energy data for many of these implements are sparse or non-existent. Energy input data for a range of conventional primary tillage implements under local conditions are essential for choosing the most energy-efficient systems. On the other hand, past global researches showed that the draft requirement of chisel plow was about half of the draft requirement of the moldboard plow in equal width and depth operation (Sahu & Raheman, 2006). Recently, extensive activities for replacing moldboard plow by chisel plow in dry farming have been done in all over the world (Al-Kaisi & Yin, 2005). One of the main indexes of energy consumption in tillage operation is overall energy efficiency of tractor. The overall energy efficiency transferred energy from tractor (for implement launch) per energy equivalent of fuel consumption in different operations (Far et al., 2015). This index is more important comparing draft efficiency and specific fuel consumption in survey of tractor performance(Reicosky et al., 2015). A tractor-implement combination having an overall energy efficiency below 10% indicates poor load matching or/and low tractive efficiency, while a value above 20% indicates a good load match or/and high tractive efficiency. Many researchers believed the increasing of overall energy efficiency for tractor and implements and correct matching of tractor and agricultural machinery can be effective in decreasing fuel consumption (Almaliki et al., 2016). The effectiveness of deep tillage varies from soil to soil, from place to place, and from year to year, but the need for deep tillage has, however, been questionable for more than 50 years (Heninger et al., 2002).The difficulty of selecting the most effective implements for a particular circumstance is evident from the wide variation in the number of cultivation operations carried out by different growers under basically the same conditions(Tsiropoulos et al., 2015). Tillage operation is one of the most important aspects of crop production system and its energy requirement represents the major portion of energy utilized for crop development(Alluvione et al., 2011). The gap is differentiated as mentioned in the above articles so; I want to evaluate the effect of semi-arid soils by three tillage implements under a single tractor with the same horsepower in three different soil types.

The literature contains a considerable number of published works dealing with modeling of the draft parameters of moldboard plow implement during tillage activities even though the effect of forward speed and plowing depth treatments on the draft parameters was not completely modeled. Soils with a bulk density higher than 1.6 g/cm3 tend to inhibit root growth and it is rapid with compaction and tend to increase with depth. Tillage implement speed affects the performance in that it tends to produce more pulverized soil (small soil aggregates) at higher speeds than at lower speeds. Many factors affect the draft of implements such as type and condition of soil and tractor implements characteristics. Tillage depth, working width, geometry and stability categorization of implements and forward speed are parameters that may have effect on draft. In most tillage implementations, increasing forward speed increases in the value of draft depending on type and design of implements and soil conditions. Factors during machine use, size and kind of implement attached (load), operating speed, and soil conditions. Draft force of implement is a major factor in matching of tractor with implement in different tillage operations. Determination of proper size and power of the tractor required to perform tillage operations with specific implement is obtained based on draft force data. Tillage operations are soil-related procedures; soil type and condition are cardinal factors affecting the field performance of the tractor through their effect on the powered implement and tractor traction.

CHAPTER THREE

3. METHODS AND MATERIALS

3.1 Methods

3.1.1 Study Area Descriptions

The study area carried out in Kulumsa Agricultural Research Center was established in 1966 by the government of Ethiopia and the Swedish International Development Agency (SIDA). The research Center is mandated to wheat, malt barley and highland pulse crops research nationally and serves as Wheat Center of Excellence for East Africa and located at the distance from Addis Ababa 167 km. The type of soil that is sufficient for my chosen research work and also the supply of plows and tractors are easily available as well as most of the Arsi farmers are also mechanization users, so in order to bring better production outputs and reduce production costs for them, this and such information and advice services have made me do my research in this place.

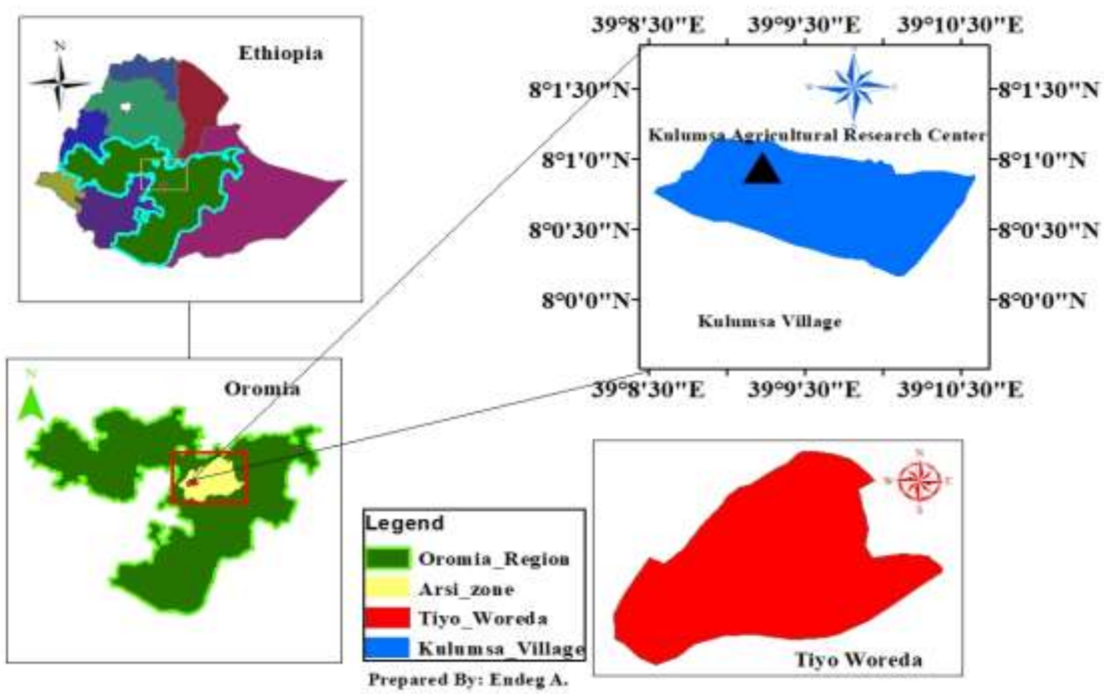

Figure 3.1. Map of Study Area

3.1.2. Method of Data Collection

The data about the performance of implements were collected through observation, measured data and recorded documents, direct contact with managers; agricultural engineers; mechanics; operators; maintenance service department. Different factors would be considered in the investigation of information and data. Laboratory experiments were helped in differentiating soil conditions. Whereas soil samples were collected by taking soil samples at the selected study areas of sites where performance evaluation could be undertaken. The field investigation and experiment would try to study the comparative performance of 4WD tractors drawn with different implement tillage systems in relation to minimize cost of operation. Evaluate the performance of a four-wheel tractor with three implements (disc plow, disc harrow, and moldboard plow and trailer implement considerably according to given parameters. All data which was collected could be used to know the primary and secondary data machinery parameters on the performance of tractors and implements (Takeshima et al., 2013).

3.1.3. Data Collection and Analysis

Data were collected from the various parameters which was tested which include, soil physical properties, operation time, machine working width, operation speed, and machine performances; under different soil conditions, types and the factor of soil characteristics on the performances of the implements. This data was analyzed using tables with ANOVA from which the effect of soil physical properties on the field performances of the given types of implements was adjusted and recorded the output results. the main objective to demonstrate a systematic and organized guidelines with on how data collection and analysis should be studied with detail explanation for efficient use of implements mounted on the tractor to monitor ground speed, implement working depth, fuel consumption, engine speed (Saleh A Alsuhaibani et al., 2013).

3.1.4. Sample Size

Field tests, laboratory experiments, and consultation were investigated and evaluated to determine the performance of selected equipment on farms where this task was successfully performed. The sample size should include testing of soil samples, field testing of tractors with instruments, and assessment of conditions while performing required tasks. Soil samples were taken from each plot of nine soil samples for both soil moisture content and bulk density at three depths. Since 3 depths were taken in the plot and 3 soil samples were taken from each depth, 9 soil samples were taken from the plot, 9 draft data for each implement from each plot, and 3 cultivators and Wheel slip with speed was also recorded.

3.1.5. Experimental treatments and design

The treatments was 3×3×3 include three types of tillage implements (disc plow, disc harrow and moldboard plow) and three forward speeds(16.5, 17.5 and 18.5km/hr) by three plots with three replications in order to get good results from the assessments expanded experiments in field tests and replicated three times in each location, and which the soils which was testes in the fields, by complete block design (Hinkelmann, 2012)

Table 3.1. Field Layout of the Experiment

I1D1SP1	I1D2SP1	I1D3SP1	I1D1SP1	I1D2SP1	I1D3SP1	I1D1SP1	I1D2SP1	I1D3SP1
I1D1SP2	I1D2SP2	I1D3SP2	I1D1SP2	I1D2SP2	I1D3SP2	I1D1SP2	I1D2SP2	I1D3SP2
I1D1SP3	I1D2SP3	I1D3SP3	I1D1SP3	I1D2SP3	I1D3SP3	I1D1SP3	I1D2SP3	I1D3SP3
I2D1SP1	I2D2SP1	I2D3SP1	I2D1SP1	I2D2SP1	I2D3SP1	I2D1SP1	I2D2SP1	I2D3SP1
I2D1SP2	I2D2SP2	I2D3SP2	I2D1SP2	I2D2SP2	I2D3SP2	I2D1SP2	I2D2SP2	I2D3SP2
I2D1SP3	I2D2SP3	I2D3SP3	I2D1SP3	I2D2SP3	I2D3SP3	I2D1SP3	I2D2SP3	I2D3SP3
I3D1SP1	I3D2SP1	I3D3SP1	I3D1SP1	I3D2SP1	I3D3SP1	I3D1SP1	I3D2SP1	I3D3SP1

3.2. Materials

3.2.1. Tractors and Implements

The tools I used to apply during the study were mainly a 120-horsepower tractor and three field tools, two primary tillage implements (moldboard plow and disc harrow) and a secondary tillage implement (disc harrow), 1LY-5 series disc plough is connected with tractor three-point suspension, the plough rotates during operation, and the soil is ploughed, especially suitable for the ploughing operation of complex farmland with weeds, upright stems, large soil resistance, and brick and stone fragments in the soil The disc harrow, HARROOW 24 model series agricultural machinery heavy-duty offset disc harrow are mainly used for cleaning away stubble of plants before tillage, or crushing clods after tillage on uncultivated land and in stickily heavy clay soil fields, they can also be used as a plough for primary tillage in dry cultivated fields. Moldboard plow c model has multiple working position correction and safety systems to handle the combined tasks of soil aeration, crop residue burial and incorporation. Doing away with welded joints between the frame and plough bodies in favour of bolting ensures strength, reliability and stability even under considerable stress.

Table 3.2. Tractor Specifications

Engine		**Mechanical**	
Perkins 1106D turbocharged diesel 6-cylinder liquid-cooled		Chassis:	4x2 2WD 4x4 MFWD 4WD
		Differential lock:	electro-hydraulic front and rear
		Steering:	Power
Displacement	402 ci 6.6 L	Brakes:	hydraulic wet disc
Bore/Stroke	4.13x5.00 inches 105 x 127 mm	Trailer brakes:	hydraulic*
Emission	Tier III	Cab:	Cab standard with air-conditioning.
Power (gross):	120 hp 108.1 Kw	Differential lock:	electro-hydraulic front and rear
Air cleaner:	Dry		
Compression	16.2:1		
Rated RPM	2200		
Starter:	Electric		
Starter volts:	12		

Tractor hitch		**Power Take-off (PTO)**		**Dimensions & Tires**	
Rear Type	II	Rear PTO	independent	Wheelbase	282cm
Control	lower-link draft sensing	Rear RPM	540/1000	Weight:	12800 to 13710 pounds
Rear lift (at 24"/610mm	9391 lbs. 4259 kg	Front PTO	independent*****	Front tire	10.00x16
Front Hitch	Optional)	Front RPM	1000 (1.375)	Rear tire	18.4R38 (2WD)
Front lift	3991 kg (8,800 lbs.)				

Table 3. 3. Implement Specifications

Implement	Disc Plow	Disc Harrow	Moldboard Plow
Model	1LY-5	HARROW 24	C
Working width (mm)	1500	2400-3500	1200-2000
Working depth (mm)	250~300	250-500	300-500
Number of discs (pc)	5	24	4
Total weight (kg)	560	2,540 –5,100	907
Tractor power (hp)	120	90-250	80-150

3.3. Methods and Measurement of Parameters

3.3.1. Soil Physical Properties Measurement

Experiments were conducted at Kulumsa Agricultural research Center and experimental farm. Physical properties of the soil were determined, ware taken soil samples for three sites randomly selected from the field and for three tillage depths was taken three samples with determined in the experiment were three depths by 20cm intervals, because this interval was taken to get more bulk density effects and the study was intended for normal tillage depths by the hydraulic device for a tractor according to the method use taken of the soil samples for different depths. The soil at the experimental site was sandy clay loam and clay loam soil. Soil from the field was classified by mechanical analysis. Soil samples were collected during the tillage experiments to determine the average moisture contents, bulk density of soil parameters to determine soil conditions under which the experiments were conducted. The samples were weighed using a balance and the weight of each sample was recorded. Then the samples were placed in an oven maintained at 110˚C for 48 hours. The dried soil samples were reweighed and the weight was again recorded.

3.3.2. Soil Bulk Density Measurement

Experiment area soil samples from the three-level of moisture content were taken from 0-20, 20-40, and 40-60 cm by an auger. For measuring bulk density, three soil samples from three plots of the land be collected using the triangle method (Mujdeci et al., 2017). The collecting samples were immediately put in plastic bags to conserve moisture during transferring to the laboratory and weighed, then dried at 105 ˚C for 48 hr. Mass of dried soils would be weighted, Soil bulk density will be determined by:

$$BD(g/cm^3) = \frac{weight\ of\ dry\ soil(gm)}{the\ volume\ of\ dry\ soil(cm3)} \quad \text{…………………………………………………}3.1$$

3.3.3. Soil Moisture Content Measurement

Core samples should be taken at a 5-cm interval up to the plow depth. Five core samples tractor-drawn plows, at evenly distributed places in the test plot, should be taken for moisture content determination. In the laboratory each sample should be taken out of the core sample and be thoroughly mixed. From the mixed sample, a smaller sample of 30g should be taken from the total sample that was taken from the field for determining soil moisture content by standard oven-drying method (i.e., drying the soil at 110°C for 48hrs). This temperature is optimum for soil sample drying in the oven dry. Soil moisture content on a dry weight basis is calculated using the following formula.

$$\%\mathrm{MC} = \frac{\text{weight of wet soil} - \text{weight of dry soil(gm)}}{\text{weight of dry soil(gm)}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

3.3.4. Implement Draft Measurement

Measurement of implement draft and developing draft prediction equations has received most of the attention in tractor measurement systems. Fuel consumption is the single largest variable cost during the field operation of tractors and is also one of the most influential parameters controlling the salability of the machine, particularly in developing countries. Many of the results of the research have been summarized in ASABE Standard D497.6. This standard uses a simplified draft prediction equation proposed by (Kichler et al., 2011)

Draft will calculate

$$D = Fi\,[A + B \times S + C \times S^2]\, W \times T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

Were

- D- is the implement draft;
- Fi- is a dimensionless soil texture adjustment parameter, 1 for fine, 2 for medium, and 3 for coarse-textured soils and also case of this work was applicable.
- A, B, and C are machine-specific parameters (ASAE 497.7, 2011),
- S is field velocity;
- W is implemented width; and
- T is tillage depth is given from tables.

The objective of the Standard is to provide a draft prediction equation that applies to a wide range of soil conditions. There are many types of tillage systems such as different combinations of plows as primary and harrows as secondary implements. Draft and energy data for many of these implements are sparse or non-existent. Energy input data for a range of conventional primary tillage implements under local conditions are essential for selecting the most energy-efficient systems.

3.3.5. Fuel Consumption Measurement

1. The tractor was started working the plot with a full auxiliary tank capacity
2. After finishing the plot, the auxiliary tank was refilled, using the one-litter measuring cylinder to determine fuel consumed(Taiwo, 2015). The fuel consumption rates were calculated in liter/ha as follows:

$$FC(L/ha) = \frac{fuel\ used\ per\ plot(L)}{area\ of\ plot(ha)} \quad \ldots\ldots\ldots 3.4$$

$$FC(L/hr) = \frac{fuel\ used\ per\ plot(L)}{time\ needed\ to\ cover\ the\ plot(hr)} \quad \ldots\ldots\ldots 3.5$$

3.3.6. Wheel Slippage Measurement

Slip is defined as the proportional measure by which the actual travel speed (or distance) of a wheel falls short or exceeds the 'ideal' or 'zero' slip speed (or distance). The magnitude of slip is thus dependent on how the `zero´ slip is defined and measured(G. Moitzi et al., 2014).The correct zero condition would be under conditions where the travel speed equal to linear speed of the surface of the wheel equal to rotational speed x rolling radius. However, since the rolling radius is impossible, or at least difficult, to measure, a more convenient zero condition and method of measuring it are used. Wheel Slippage Measured by the practical and theoretical speed.

Practical speed: After tillage depth determination in the experiment the plow hacked in the soil with practical speed 17.5km .hr-1, within treatment length (210 m) for both soil moisture and tillage depth in three replications. The Eq (3.6) was used for calculation of the practical speed.

$$VP = \frac{3.6D}{Tp} \quad \ldots\ldots\ldots 3.6$$

Where: Vp, practical speed Km.hr-1, Tp, practical time (hr) and D, Travel distance in the plot.

Theoretical speed: Without plowing the soil, only the implement touches the soil, with speed 17.5km/hr within the three plots for each implement in the plot length of 210m. The Eq (3.7) was used for calculation of theoretical speed

$$VT = \frac{3.6D}{Tt} \quad \ldots\ldots\ldots 3.7$$

The Eq (3.8) was used for calculation of the slippage percentage using two speeds of the practical and theoretical.

$$\text{Slippage} = \frac{VT \times VP}{VT} \times 100 \quad \ldots\ldots 3.8$$

3.3.7. Field Efficiency Measurement

The theoretical, effective field capacities (TFC, EFC) and field efficiency (FE) were calculated as follows.

Determination Field Efficiency: - The field efficiency was determined from the expression suggested by (Anjum et al., 2014).

$$\text{FE} = \frac{100Te}{Tt} \quad \ldots\ldots 3.9$$

where, FE= field efficiency, %; *Te* = actual working(productive) time, hr; *Tt* = total working time = (*Te* +*Td*), hr; *Td* = delay or idle time

Determination of the Effective Field Capacity: - The effective field capacity was determined from the expression suggested by (Okechukwu Oduma et al., 2019).

$$\text{EFC} = \frac{S \times w \times FE}{C} \quad \ldots\ldots 3.10$$

Where, EFC = effective field capacity, ha/hr; *S* = speed, km/hr; *w* = width of implement (cm); *FE* = field efficiency as a decimal; *c* = constant, 10.

Determination of Theoretical Field Capacity: - The theoretical field capacity was determined by rearranging the expression suggested by (Okechukwu Oduma et al., 2019), for field efficiency and obtained a new relationship for theoretical field capacity as follows:

$$\text{FE} = \frac{TFC}{EFC} \quad \ldots\ldots 3.11$$

Where, *TFC* = theoretical field capacity, ha hr^{-1}; *EFC* = effective field capacity, ha hr^{-1}; *FE* = field efficiency decimal.

$$\text{Dpb} = \frac{\text{D} \times \text{va}}{3.6} \quad \ldots\ldots 3.12$$

Were

- DPb – Drawbar Power (kW).
- D – Draft (KN).
- Va – Real velocity of the tractor in the farm (m/s).

CHAPTER FOUR

4. RESULT AND DISCUSSION

Analysis of Variance (ANOVA) was made to investigate the relationship and interactions between implements draft with different parameters including soil properties, soil tillage depth, forward speed, wheel slippage, drawbar power, fuel consumption, field capacity and efficiency. The results of research are presented in consecutive sections.

4.1. Soil Analysis

The result of the soil analysis test, which was carried out in the laboratory for soil moisture content and soil bulk density is presented in table 4.1 below.

Table 4.1. Soil moisture content and bulk density analysis

D(cm)	Plot 1	Plot.2 %MC	Plot.3	Plot.1 BD (gm/cm3)	Plot.2	Plot.3
I	11	13	15	1.03	1.43	1.3
II	12	14.67	17.34	1.05	1.72	1.55
III	12.5	14.93	17.36	1.34	1.63	1.71
I	11.6	13.87	12.48	1.08	1.52	1.41
II	12.2	14.67	13.27	1.15	1.63	1.42
III	13	15.06	16.33	1.24	1.65	1.58
I	13.2	12.45	12.6	1.13	1.62	1.71
II	13.4	13	14.21	1.18	1.62	1.81
III	14.2	14.55	15.8	1.33	1.64	1.84

Where, %MC1= Moisture content1, %MC2= Moisture content2, %MC3= Moisture content3

4.2. Effect of Soil Type on Implement Performance

The result of the effect of soil type on implement performance is presented from Table 4.2, 4.3, and 4.4. The highest average performance efficiency with overall average efficiency was 83.65%, 82.04% and 74.73% for disc plow, moldboard, and disc harrow, respectively. This is in agreement with the observations that soil type and condition are specific indicators that affect the field performance of the implement through their effect on the hitched implement and tractor

Table 4.2. Performance evaluation of Moldboard plow

Particulates	Plot 1	Plot 2	Plot 3	Average
Plot size, m2	3024	3024	3024	3024
Average Width, m	1.6	1.6	1.6	1.6
Average speed, m/s(km/hr)	17.5	17.5	17.5	17.5
Draft, KN	36	55.44	79.23	56.89
Draft per unit width of cut, KNM-1	22.5	34.66	49.52	35.56
Power, Kw	173.79	270.43	348.92	264.44
Total field time, s(hr)	48:32.04(0.81)	58:55.68(0.93)	1:00:14.31(1)	54:39.46(0.91)
Productive Time, s(hr)	35:38.82(0.59)	45:37:72(0.76)	47:47.3(0.79)	41:34.57(0.69)
Delay Time, s(hr)	13:39.79(0.23)	13:18.38(0.16)	11:08.35(0.19)	13:02.13(0.22)
Effective Field Capacity, ha/hr	0.2394	0.2288	0.221	0.2297
Theoretical Field Capacity, ha/hr	0.28	0.28	0.28	0.28
Field Efficiency, %	72.84	81.72	79	82.04
Fuel Consumption, L/ha	29.76	32.24	38.86	27.28
Fuel Consumption, L/hr	11.84	10.48	11.75	11.36

Table 4.3. Performance Evolution of Disc plow from the Three Plots

Particulates	Plot 1	Plot 2	Plot 3	Average
Plot size, m2	2835	2835	2835	2835
Average Width, m	1.5	1.5	1.5	1.5
Average speed, m/s (km/hr)	17.5	17.5	17.5	17.5
Draft, KN	3.55	3.56	7.92	5.01
Draft per unit width of cut, KNM^{-1}	2.37	2.373	5.28	3.34
Power, Kw	17.3	26.93	38.47	27.57
Total field time, s(hr)	40:50.23(0.69)	44:14.68(0.73)	51:25.07(0.86)	54:39.46(0.91)
Productive Time, s(hr)	32:38.42(0.54)	35:34:72(0.59)	47:47.3(0.79)	41:34.57(0.69)
Delay Time, s(hr)	18:39.79(0.31)	9:18.38(0.15)	11:08.35(0.18)	13:02.13(0.23)
Effective Field Capacity, ha/hr	0.2054	0.212	0.2412	0.2195
Theoretical Field Capacity, ha/hr	0.2625	0.262	0.263	0.2625

Field Efficiency, %	78.26	80.82	91.86	83.65
Fuel Consumption, L/ha	22.93	26.46	37.03	28.81
Fuel Consumption, L/hr	9.56	10.27	12.35	10.68

traction (O Oduma et al., 2018). It is also in agreement with the findings of (Okechukwu Oduma et al., 2021)who stated that the performance of plough varies considerably according to the type of soil who stated that the performance of plough varies considerably according to the type of soil. (Okoko et al., 2018) had a similar observation and reported that clay soil has a higher break up energy requirement than clay loam soil. Furthermore, the result of this research is also consistent with the observation that disc plough has increased field efficiency at increased rate when working on a coarser textured soil. The ANOVA test on the effect of soil type on implement performance showed that the average bulk density of the soil was 1.17, 1.62, and 1.59 gcm^{-3} in plots 1,2 and 3, respectively. The reduction or lower bulk density recorded in soil 1 than bulk densities in soil 2, and 3. The statistical analysis of the effect of bulk density on implement performances showed that a significant difference between the values of bulk density densities for different implements at 5% probability level.

Table 4.4. Performance Evaluation of Disc Harrow from the Three Plots

Particulates	Plot 1	Plot 2	Plot 3	Average
Plot size, m2	5670	5670	5670	5670
Average Width, m	3	3	3	3
Average speed, m/s(km/hr)	17.5	17.5	17.5	17.5
Draft, KN	17..3	26.93	38.47	27.57
Draft per unit width of cut, KNM-1	5.77	8.98	12.82	9.19
Power, Kw	71.2	110.69	158..12	113.34
Total field time, s(hr)	42:52.04(0.71)	48:35.98(0. 81)	53:25.19(0.88)	49:00 (0.82)
Productive Time, s(hr)	30:38.82(0.51)	35:34:72(0.59)	42:18.3(0.7)	37:30(0.63)
Delay Time, s(hr)	12:39.79(0.21)	13:01.26(0.22)	11:07.35(0.18)	12:47.13(0.21)
Effective Field Capacity, ha/hr	0.377	0.3824	0.417	0.392
Theoretical Field Capacity, ha/hr	0.524	0.524	0.524	0.524
Field Efficiency, %	71.83	72.84	79.54	74.73
Fuel Consumption, L/ha	29.76	32.24	38.86	27.28
Fuel Consumption, L/hr	11.84	10.48	11.75	11.36

4.3. Effect of Speed on Draft at Different Levels of Depth in Plot 1

Table 4.5, 4.10, 4.13 and Figure 4.1, 4.4, 4.5, and 4.6 illustrates the effect of tractor forward speed on implement draft at different levels of tillage depth for 5- bottom disc plough, moldboard and offset disc harrow operating on plot 1 plot 2 and pot 3. From the above listed figures, it was observed that draft increased with an increase in forward speed. For all levels of speed, draft increased with an increase in tillage depth. For a 5-bottom disc plow, at a tillage depth 20cm, draft increased from 3.1 to 3.3 KN when tractor speed increased from 16.5 to 18.5km/hr. At the tillage depth of 22cm, the draft increased from 3.4 to 3.6 KN when the tractor speed increased from 16.5 to 18.5 km/hr while at tillage depth of 25cm, draft increased from 3.9 to 4.1 KN when the tractor speed increased from 16.5 to 18.5km/hr. For a reversible 4-bottom moldboard plow, in plot1, at a tillage depth of 20cm, the draft increased from 29 to 35 KN when tractor speed was increased from 16.5 to 18.5 km/hr. The draft obtained at tractor speed of 16.5 to 18.5 km/hr, the draft increased from 32 to 38 KN tillage depth of 22cm, while at a tillage depth of 25cm, draft increased from 37 to 43 KN increased at tractor speed of 16.5 to 18.5 km/hr respectively with average draft of 36 KN. For a 24-bottom disc harrow with tillage depth of 20 cm, draft increased from 12.7 to 13.5 KN at implement speeds of 16.5to 18.5 km/hr respectively. at a tillage depth of 22 cm, draft increased from 14 to 14.8 KN at a tractor speed of 16.5 to 18.5km/hr respectively. The draft obtained at a tractor speed of 16.5 to 18.5km/hr draft increased from 15.9 to 16.8 KN while at speed of 16.5 to 18.5 km/hr with average draft of 14.62 KN. This is because of both increased depth and speed in all plots.

4.4. Effect of Speed on Power Requirements at Different Levels of Depth in Plot 1

Table 4.5, 4.10, and 4.13 and Figure 4.13, 4.14, and 4.15 illustrates the effect of tractor forward speed on power requirement at different levels of tillage depth for a 5-bottom disc plough, at a tillage depth of 20 cm, power requirement increased from 14.2 to 16.8 KW at tractor speed of 16.5 to 18.5 km/hr respectively. The power requirement obtained at a speed 16.5 to 18.5km/hr power increased from 15.6 to 18.5 KW with a tillage depth of 22cm, while at a tillage depth of 25cm, power requirement increased from 17.8 to 21 KW with a tractor speed of 16.5 to 18.5km/hr respectively with average drawbar power of 17.3 KN. For a reversible moldboard plow, 5 – bottom disc plough, and offset disc harrow. For a reversable moldboard plough, at a tillage depth of 20cm, power requirement increased from 135 to 177 KW at implement speed of 16.5 to 18.5 km/hr respectively. The power requirement obtained at an implement speed 16.5 to 18.5km/hr power increased from 148 to 195 KW with a tillage depth of 22cm. while at a tillage depth of 25cm, power requirement increased from 168 to 222 KW with a tractor speed of 16.5 to 18.5 km/hr respectively and drawbar power of 36 KW. For a 24 Bottom disc harrow tillage depth of 20 cm, power requirement increased from 58.4 to 69.1 KW at implement speeds of 16.5 to 18.5, respectively, at a tillage depth 22 cm, power requirement increased from 64.2 to 76 KW to at tractor speeds of 16.5 to 18.5km/hr, respectively. while at tillage depth of 25cm, power requirement increased from 73 to 86.4 KW. with a tractor speed of 16.5 to 18.5 km/hr respectively and average drawbar power of 71.2 KW.

4.5. One-Way ANOV of the Parameters in each Blocks of the Plot

4.5.1. Analysis of the Parameters of the Implements in plot 1

An ANOVA was performed using minitab V7 as shown in following tables, whereas fuel consumption, depth, and slippage of the parameters found significant difference. Variance analysis shows the effect is also at three tillage speed, and depths on the draft force, in this analysis was corroborated the significant effect that produces the depth of tillage on draft including fuel consumption.

Table 4.5. Result of the Parameters of the Moldboard Plow in Plot 1

D(cm)	Speed(km/hr)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD (g/cm3)	%MC
	16.5	29	135	25.2		1.03	11
	17.5	32	155	12.6	0-20	1.05	13.2
I	18.5	35	177	10.8		1.34	11.56
	16.5	32	148	18.9		1.08	12
	17.5	35	170	12.6	20-40	1.15	12.24
II	18.5	38	195	10.8		1.24	12.45
	16.5	37	168	15.12		1.13	13
	17.5	40	194	9.45	40-60	1.18	13
III	18.5	43	222	8.4		1.33	14.2
Aveg.	17.5	36	174	13.76		1.17	12.51

Table 4.6. Method of Analysis of the given Parameters in each Plots

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

**Equal variances were assumed for the analysis.*

Table 4.7 .Factor Information to individual plots

Factor	Levels Values
Factor	D(cm), Speed(km/hr), Draft (KN), Pdb (KW), BD(g/cm3), %MC, %S

Table 4.8.ANOVA of Moldboard Plow in Plot 1

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	195152	32525.4	294.08	0.000
Error	56	6194	110.6		
Total	62	201346			

- F-Value computed by Adj MS within factor divided by Adj MS within Error
- P<0.000, when the parameters were highly significant
- LSD = tSqrt[2MSE/N] Where t = in. (0.05, DFE), used for all plots
- LSD 9.88

Table 4.9. Model Summary of ANOVA of the Moldboard in plot 1

S	R-sq	R-sq(adj)	R-sq(pred)
10.5167	96.92%	96.59%	96.11%

The factor explains 96.92% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 10.52

Table 4.10 . Result of the Parameters of the Disc Pow in Plot 1

D(cm)	Speed (km/h)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD (g/cm3)	%MC
	16.5	3.1	14.2	18.9		1.03	11
I	17.5	3.2	15.5	18.9		1.05	13.2
	18.5	3.3	16.8	15.12	0-20	1.34	11.56
	16.5	3.4	15.6	15.12		1.08	12
II	17.5	3.5	17.0	25.2		1.15	12.24
	18.5	3.6	18.5	37.8	20-40	1.24	12.45
	16.5	3.9	17.8	25.2		1.13	13
III	17.5	4.0	19.4	25.2		1.18	13
	18.5	4.1	21.0	18.9	40-60	1.33	14.2
Aveg	17.5	3.55	17.3	14.29		1.17	12.51

Table 4.11. ANOVA of the Disc plow in plot1

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	3926.6	654.438	74.55	0.000
Error	56	491.6	8.778		
Total	62	4418.2			

*LSD is 2.784

**P< 0.000 indicates highly significant

Table 4.12. Model Summary of plot 1 ANOVA disc plow

S	R-sq	R-sq(adj)	R-sq(pred)
2.96285	88.87%	87.68%	85.92%

The factor explains 88.87% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 2.96

Table 4. 13. Result of the Parameters of the disc harrow in Plot

D(cm)	Speed(km/hr)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD(g/cm^{3})	%MC
	16.5	12.7	58.4	15.12		1.03	11
I	17.5	13.1	63.7	15.12	0-20	1.05	13.2
	18.5	13.5	69.1	10.8		1.34	11.56
	16.5	14.0	64.2	12.6		1.08	12
II	17.5	14.4	70.0	9.45	20-40	1.15	12.24
	18.5	14.8	76.0	8.4		1.24	12.45
	16.5	15.9	73.0	9.45		1.13	13
III	17.5	16.4	79.6	9.45	40-60	1.18	13
	18.5	16.8	86.4	8.4		1.33	14.2
Aveg	17.5	14.62	71.2	10.98		1.17	12.51

Table 4.14. ANOVA of the Disc Harrow in Plot 1

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	28209.7	4701.62	361.27	0.000
Error	56	728.8	13.01		
Total	62	28938.5			

- LSD 3.389
- P<0.00 indicates highly significant

Table 4.15. Model Summary of the ANOVA of the Disc Harrow in plot 1

S	R-sq	R-sq(adj)	R-sq(pred)
3.60749	97.48%	97.21%	96.81%

The factor explains 97.48% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 3.61

4.5.2. Effect of Speed on Draft at Different Levels of Depth in Plot 2

Table 4.16, 4.19, and 4.22, and Figure 4.2, 4.7, 4.8 and 4.9 illustrates the effect of tractor forward speed on draft implements at different levels of tillage depth for 5- bottom disc plough, moldboard and disc harrow operating on Soil 1, Soil 2 and Soil 3. From these figures, it was observed that draft increased with increase in forward speed. For all levels of speed, draft increased with increase in tillage depth. For a 5-bottom disc plow, at a tillage depth 20cm, draft increased from 4.8 to 5.09 KN, at tractor speeds of 16.5 to 18.5km/hr, at the tillage depth of 22cm, the draft obtained at tractor speed of 16.5 to 18.5km/hr draft increased from 5.30 to 5.60 KN while at speed of 16.5 to 18.5 km/hr, draft increased from 6.03 to 6.36 KN at tillage depth of 25cm with average draft of 3.56KW. For a reversible 4-Bottom moldboard plow at a tillage depth of 20cm, draft increased from 46 to 54 KN at a speed of 16.5 to 18.5 km/hr, respectively. The draft obtained at tractor speed of 16.5 to 18.5 km/hr, the draft increased from 50 to 59 KN tillage depth of 22cm, while at a tillage depth of 25cm, draft increased from 57 to 67 KN increased at tractor speed of 16.5 to 18.5 km/hr respectively and average draft of 54.44 KW. For a 24-bottom disc harrow with tillage depth of 20 cm, draft increased from 19.8 to 20.9 KN at implement speeds of 16.5to 18.5 km/hr respectively. at a tillage depth of 22cm, draft increased from 21.8 to 23KN at a tractor speed of 16.5 to 18.5km/hr respectively. The draft obtained at depth of 28cm and tractor speed of 16.5 to 18.5 km/hr draft increased from 24.8 to 26.2 KN while at speed of 16.5 to 18.5 km/hr and average draft of 22.74 KW.

Table 4.16. Result of the Parameters of the Moldboard plow n Plot 2

D(cm)	Speed (km/hr)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD (g/cm$^{3)}$	%MC
	16.5	46	209	12.6		1.43	12.45
I	17.5	50	241	10.8	0-20	1.72	13
	18.5	54	276	9.45		1.63	13.87
	16.5	50	230	12.6		1.52	13.46
II	17.5	55	265	9.45	20-40	1.63	14.64
	18.5	59	304	9.45		1.65	14.67

	16.5	57	262	8.4		1.62	14.93
III	17.5	62	301	8.13	40-60	1.628	14.55
	18.5	67	345	6.3		1.64	15.06
Aveg	17.5	55.46	270	9.7		1.61	14.07

4.5.2. Analysis of the Parameters of the Implements in plot 2

In this plot the soil type was sandy clay and the design of the experiment had similar procedures with plot 1 and plot 3, so by minitab ANOVA analysis $p < 0.000$ indicates all the parameters and factors affect the tested experiment.

Table 4.17. ANOVA of the Moldboard Plow in Plot 2

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	498745	83124.2	322.03	0.000
Error	56	14455	258.1		
Total	62	513200			

- LSD 15.095
- $P<0.000$ indicates, highly significant

Table 4.18. Model Summary of the ANOVA of the Moldboard Plow in Plot 2

S	R-sq	R-sq(adj)	R-sq(pred)
16.0663	97.18%	96.88%	96.44%

The factor explains 97.18% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 16.07

Table 4.19. Result of the Parameters of the Disc Plow in Plot 2

D(cm)	Speed (km/hr)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD (g/cm^3)	%MC
	16.5	4.82	22.1	18.9		1.43	12.45
I	17.5	4.96	24.1	15.12	0-20	1.72	13
	18.5	5.09	26.2	10.8		1.63	13.87
	16.5	5.30	24.3	18.9		1.52	13.46
II	17.5	5.45	26.5	15.12	20-40	1.63	14.64
	18.5	5.60	28.8	14.54		1.65	14.67
	16.5	6.03	27.6	15.12		1.62	14.93
III	17.5	6.20	30.1	10.8		1.628	14.55
	18.5	6.36	32.7	9.45	40-60	1.64	15.06
Aveg	17.5	3.56	26.93	22.26		1.61	14.07

Table 4.20. ANOVA of the Disc Plow in Plot 2

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	4245.1	707.520	170.76	0.000
Error	56	232.0	4.143		
Total	62	4477.1			

- LSD 1.913
- P< 0.000 indicates, highly significant

Table 4.21. Model Summary of Plot 2 ANOVA Disc Plow

S	R-sq	R-sq(adj)	R-sq(pred)
2.03551	94.82%	94.26%	93.44%

The factor explains 94.82% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 2.04

Table 4.22. Result of the Parameters of the Disc Harrow in Plot 2

D(cm)	Speed (km/hr)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD (g/cm^3)	%MC
	16.5	19.8	90.8	18.9		1.43	12.45
I	17.5	20.4	99.0	15.12	0-20	1.72	13
	18.5	20.9	107.5	12.6		1.63	13.87
	16.5	21.8	99.9	10.8		1.52	13.46
II	17.5	22.4	108.9	9.45	20-40	1.63	14.64
	18.5	23.0	118.3	9.45		1.65	14.67
	16.5	24.8	113.5	8.4		1.62	14.93
III	17.5	25.5	123.8	7.8	40-60	1.628	14.55
	18.5	26.2	134.4	5		1.64	15.06
Aveg	17.5	22.74	110.69	10.84		1.61	14.07

Table 4.23. ANOVA of the Disc Harrow in Plot 2

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	73698	12283.0	405.87	0.000
Error	56	1695	30.3		
Total	62	75393			

- LSD 5.1721
- P< 0.000 indicates highly significant

Table 4.24. Model Summary of ANOVA of The Disc Harrow in Plot 2

S	R-sq	R-sq(adj)	R-sq(pred)
5.50120	97.75%	97.51%	97.16%

The factor explains 97.75% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 5.5.

4.6. Effect of Speed on Power Requirements at Different Levels of Depth in Plot 2

Table 4.16, 4.19, and 4.22 and Figure 4.16, 4.17, and 4.18 illustrates the effect of tractor forward speed on power requirement at different levels of tillage depth for a 5-bottom disc plough, at a tillage depth of 20cm, power requirement increased from 22.1 to 26.2 KW at tractor speed of 16.5 to 18.5 km/hr respectively. The power requirement obtained at an implement speed 16.5 to 18.5km/hr power increased from 24.3 to 28.8 KW with a tillage depth of 22cm. while at a tillage depth of 25cm, power requirement increased from 27.6 to 32.7 KW with a tractor speed of 16.5 to 18.5 km/hr respectively with average drawbar power of 26.93 KW. For a reversible moldboard plow at a tillage depth of 20cm, power requirement increased from 209 to 276 KW at implement speed of 16.5 to 18.5 km/hr respectively. The power requirement obtained at an implement speed 16.5 to 18.5 km/hr power increased from 230 to 304 KW with a tillage depth of 22cm. while at a tillage depth of 25cm, power requirement increased from 262 to 345 KW with a tractor speed of 16.5 to 18.5 km/hr respectively and average drawbar power of 270 KW. For a 24 Bottom disc harrow tillage depth of 20cm, power requirement increased from 90.8 to 107.5 KW at a speed of 16.5 to 18.5 km/hr respectively, at a tillage depth 22cm, power requirement increased from 99.9 to 118.3 KW to at tractor speeds of 16.5 to 18.5 km/hr, respectively. while at tillage depth of 25cm, power requirement increased from 113.5 to 134.4 KW. with a tractor speed of 16.5 to 18.5 km/hr respectively with average drawbar power of 110.69 KW.

4.7. Effect of Speed on Draft at Different Levels of Depth Plot 3

Table 4.25, 4.28 and 4.31 and Figure 4.3, 4.10, 4.11, and 4.12 illustrates the effect of tractor forward speed on draft implements at different levels of tillage depth for 5- bottom disc plough, moldboard and offset disc harrow operating. From these figures, it was observed that draft increased with increase in forward speed. For all levels of speed, draft increased with increase in tillage depth. For a 5-bottom disc plow, at a tillage depth 20cm, draft increased from 6.9 to 7.3 KN, at tractor speeds of 16.5 to 18.5 km/hr, at the tillage depth of 22cm, the draft obtained at tractor speed of 16.5 to 18.5km/hr draft increased from 7.6 to 8 KN while at speed of 16.5 to 18.5 km/hr, draft increased from 8.6 to 9.1 KN at tillage depth of 25cm and average draft of 7.92 KW For a reversible 4-Bottom moldboard plow, in plot 3, Sandy clay soil at a tillage depth of 20 cm, draft increased from 65 to 77 KN at a tractor speed of 16.5 to 18.5 km/hr, respectively. The draft obtained at tractor speed of 16.5 to 18.5 km/hr, the draft increased from 72 to 84 KN tillage depth of 22cm, while at a tillage depth of 25cm, draft increased from 82 to 96 KN increased at tractor speed of 16.5 to 18.5 km/hr respectively and average draft of 79 KW. For a 24-bottom disc harrow with tillage depth of 20cm, draft increased from 28.3 to 29.9 KN at implement speeds of 16.5 to 18.5km/hr respectively. At a tillage depth of 22cm, draft increased from 31.1 to 32.9 KN at a tractor speed of 16.5 to 18.5 km/hr respectively. The draft obtained at tractor speed of 16.5 to 18.5 km/hr draft increased from 35.4 to 37.4 KN while at speed of 16.5 to 18.5 km/hr with average draft of 32.5 KW.

Table 4.25. Result of The Parameters of the Moldboard in Plot 3

D(cm)	Speed (km/hr)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD (g/cm^3)	%MC
	16.5	65	299	10.8		1.3	12.48
I	17.5	71	344	9.4	0-20	1.55	12.6
	18.5	77	394	8.4		1.71	15
	16.5	72	329	7.56		1.41	13.27
II	17.5	78	379	6.87	20-40	1.42	14.21
	18.5	84	434	9.45		1.58	17.34
	16.5	82	374	8.4		1.71	15.8
III	17.5	89	430	7.56	40-60	1.81	16.33
	18.5	96	493	6.3		1.84	17.36
Aveg	17.5	79	386	8.31		1.59	15

4.7.1. Analysis of the Parameters of the Implements in plot 3

In this plot the soil type was sandy clay and the design of the experiment had similar procedures with plot 1 and plot 2, so by minitab ANOVA analysis p <0.000 indicates all the parameters and factors affect the tested experiment.

Table 4.26. ANOVA of the Moldboard Plow in Plot 3

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	1047594	174599	333.10	0.000
Error	56	29353	524		
Total	62	1076947			

- LSD 21.508
- P< 0.000 indicates, highly significant

Table 4.27. Model Summary of ANOVA of the Moldboard Plow of Plot 3

S	R-sq	R-sq(adj)	R-sq(pred)
22.8945	97.27%	96.98%	96.55%

The factor explains 97.27% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 22.89.

Table 4.28. Result of the Parameter of the Disc Plow in Plot 3

Depth(cm)	Speed(km/hr)	Draft (KN)	Pdb(W)	%S	Depth(cm)	BD (g/cm^3)	%MC
	16.5	6.9	31.6	15.12		1.3	12.48
I	17.5	7.1	34.4	12.6	0-20	1.55	12.6
	18.5	7.3	37.4	10.8		1.71	15
	16.5	7.6	34.7	10.8		1.41	13.27
II	17.5	7.8	37.9	9.45	20-40	1.42	14.21
	18.5	8.0	41.1	9.11		1.58	17.34
	16.5	8.6	39.5	9.22		1.71	15.8
III	17.5	8.9	43.0	9.45	40-60	1.81	16.33
	18.5	9.1	46.7	9.22		1.84	17.36
Aveg	17.5	7.92	38.47	10.64		1.59	15

Table 4.29. ANOVA of Disc Plow in Plot 3

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	7650.2	1275.04	248.52	0.000
Error	56	287.3	5.13		
Total	62	7937.5			

- LSD 2.128
- P<0.00, indicates highly significant

Table 4.30. Model Summary of ANOVA the Disc Plow in Plot 3

S	R-sq	R-sq(adj)	R-sq(pred)
2.26506	96.38%	95.99%	95.42%

- The factor explains 96.38% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 2.27

Table 4.31. Result of the Parameters of the Disc Harrow in Plot 3

D(cm)	Speed (km/hr)	Draft (KN)	Pdb (KW)	%S	D(cm)	BD (g/cm^3)	%MC
	16.5	28.3	129.7	12.6		1.3	12.48
I	17.5	29.1	141.5	10.8	0-20	1.55	12.6
	18.5	29.9	153.6	10.8		1.71	15
	16.5	31.1	142.7	12.6		1.41	13.27
II	17.5	32.0	155.6	9.45	20-40	1.42	14.21
	18.5	32.9	169.0	8.4		1.58	17.34
	16.5	35.4	162.2	9.45		1.71	15.8
III	17.5	36.4	176.8	8.4	40-60	1.81	16.33
	18.5	37.4	192.0	8.4		1.84	17.36
Aveg	17.5	32.5	127.98	10.98		1.59	15

Table 4.32. ANOVA of the Disc Harrow in Plot 3

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	6	159750	26625.0	471.44	0.000
Error	56	3163	56.5		
Total	62	162913			

- LSD 7.063
- P< 0.000indicates highly significant

Table 4.33. Model Summary of Anova of the Disc Harrow Plot 3

S	R-sq	R-sq(adj)	R-sq(pred)
7.51508	98.06%	97.85%	97.54%

The factor explains 98.06% of the variation in the response and the Standard deviation between the data points and the fitted values is approximately 7.52.

4.8. Effect of Speed on Power requirements at different levels of Depth in plot 3

Table 4.25, 4.28 and 4.31 and Figure 4.19, 4.20 and 4.21 illustrates the effect of tractor forward speed and depth on power requirement at different levels of tillage depth for a 5-bottom disc plough, at a tillage depth of 20 cm, power requirement increased from 31.6 to 37.4 KW at tractor speed of 16.5 to 18.5 km/hr respectively. The power requirement obtained at an implement speed

16.5 to 18.5km/hr power increased from 34.7 to 41.1 KW with a tillage depth of 22 cm. while at a tillage depth of 25cm, power requirement increased from 39.5 to 46.7 KW with a tractor speed of 16.5 to 18.5 km/hr respectively and average drawbar power of 38.47 KW. For a reversible moldboard plough, at a tillage depth of 20 cm, power requirement increased from 299 to 394 KW at implement speed of 16.5 to 18.5 km/hr respectively. The power requirement obtained at an implement speed 16.5 to 18.5 km/hr power increased from 329 to 434 KW with a tillage depth of 22cm. while at a tillage depth of 25cm, power requirement increased from 374 to 493 KW with a tractor speed of 16.5 to 18.5 km/hr respectively followed by average drawbar power of 386 KW.

For a 24 Bottom disc harrow tillage depth of 20cm, power requirement increased from 129.7 to 153.6 KW at implement speeds of 16.5 to 18.5, respectively, at a tillage depth 22cm, power requirement increased from 142.7 to 169 KW to at tractor speeds of 16.5 to 18.5km/hr, respectively. while at tillage depth of 25cm, power requirement increased from 162.2 to 192 KW. with a tractor speed of 16.5 to 18.5km/hr respectively and average drawbar power of 158.1 KW.

4.9. ANOVA for Speed and Depth on Draft Requirements

The result of (ANOVA) for the test of speed and tillage depth effect on draft for reversible 4-bottom moldboard plow, 5- bottom disc plough, and disc harrow on sandy clay loam and clay loam soil. The result showed that forward speed and tillage depth affected the draft of the tillage implements significantly at 5% level of probability ($p<0.05$), but disc harrow draft-depth, $p<0.05$ in plot 2 and plot 3, draft-speed, $p<0.05$ in plot1 and 2. The other interactions between the two factors were also statistically significant at 5% level of probability.

4.9.1 ANOVA for Speed and Depth on Power Requirements

The result of (ANOVA) for the test of speed and tillage depth on power requirement for 3–bottom disc plough, spring tine cultivator and disc harrow on loamy soil (Okoko et al., 2018). The result indicated that forward speed and tillage depth affected the power requirement of the tillage implements significantly at 5% level of probability ($P<0.05$).

4.9. 2. Effect of forward speeds and depths on Draft

Analysis of Parameters by Tukey simultaneous tests for differences of means of plow type from in all the three plots with speed, depth and draft showed that interactions and effects with each other and also, the changes of implements average draft at draft different tillage depth levels and speed ranges with their interaction effects. (Mohammad Askari et al., 2017) the average draft of each implement has increased with increase of tillage depth level. The average draft of disk plow, disc harrow, and moldboard plow in three depth levels was explained by the comparison of average draft in different tillage depth and forward speed treatments. ANOVA of minitab analysis showed that, the effects of disc plow, depth-speed, speed-draft, and depth-draft were significant at 5% level in all plots. Also, the interaction effect of moldboard plow depth-speed was not significant at5% level, and depth-draft and speed- draft were significant at 5% level. The interaction of disc harrow of depth-draft was significant at5% level in plot1, whereas speed-draft, depth-speed and depth-draft was not significant at 5% level in all plots. The result of this study was in the draft increased as speed and depth of work was increased.

From Figure 4.4-4.15 Showed that average draft of treatments with showed that the moldboard plow at highest forward speed and tillage depth had maximum draft and disc plow in lowest tillage depth and forward speed had minimum draft. (Okoko et al., 2018) Comparison of average draft in different forward speed and plow treatments, that the moldboard plow in highest forward speed had maximum draft and disc plow in lowest forward speed had minimum draft. compared average draft of treatments with minitab test showed that the moldboard plow at highest forward speed and tillage depth had maximum draft and disk plow in lowest tillage depth and forward speed had minimum draft. Comparison of average draft in different forward speed and plow treatments, that the moldboard plow in highest forward speed had maximum draft and chisel plow in lowest forward speed had minimum draft. Comparison of average draft in different tillage depth and plow treatments that the disk plow in lowest forward speed had minimum draft. Just as observed, the moldboard plow required higher draft than disk and disc harrow for the same tillage depth and forward speed ranges due to effects of implement shapes, different geometry. In contrast, 52% of disc plow was followed by moldboard plow with 50.3% of moldboard plow was followed by disc harrow, and finally 52% of disc plow was followed by disc harrow in plot 1. While 48% of moldboard plow was followed by disc plow with 52% of moldboard plow was followed by disc harrow, and 47.6% of disc plow was followed by disc harrow in plot 2. Finally, 55% of disc plow was followed by moldboard plow with 51% of disc harrow was followed by moldboard plow, and 58% of disc plow was followed by disc harrow.

Moldboard plow required higher draft and drawbar power in all implements and had lowest field efficiency than disc plow and moldboard plow, but disc plow recorded highest field efficiency than disc harrow and moldboard plow. Therefore, disc plow is recommended for all plots soil on this work as well as disc plow was also used less amount of fuel consumed than moldboard plow.

4.10. Effect of Forward Speeds and Depths on the Slippage

The results of wheel slippage at different forward speeds and depths recorded. The result illustrates that, the mean values of slippage of moldboard plow in plot1 were 11% ,14%, and 16 % at depths I, II and III in plot 2, 7.61, 10.5%, and 10.95%, at depths I, II and III in plot 3, 7.42%, 7.96% and 9.55%, and at depths I, II and III respectively. The mean values of slippage of disc harrow in plot1 were 9.11 %, 10.15 % and 13.68 % and at depths I, II and III and in plot 2, the mean values were 7.07%,9.9% and 15.54 at depths I, II and III, in plot 3, 8.75%,10.15% and 11.4% respectively. The mean values of slippage of Disc Plow in plot 1 were 11.76 % ,14.94%, and 16.66 % at depths I, II and III in plot 2, 7.61, 10.5%, and 10.95%, at depths I, II and III in plot3 7.42%, 7.96% and 9.55%, at depths I, II and III respectively. It is clear that, the disc plow has recorded the highest average wheel slippage as compared to the other three implements at the three speeds and depths. The lowest values of slippage were recorded by the moldboard. Generally, this may be due to the higher draft forces exerted of the implement, the result agrees with the findings of (Leghari ++ et al., 2016). The statistical analysis of slippage at disc plow, disc harrow and disc harrow show that, the effect of speed was highly significant ($P<0.00$), while effect of depth was significant and interaction depth x speed showed that, there was on significant difference. While on disc plow there was no significant difference in depths and interaction depth x slippage and Pdb*speed in plot 1.

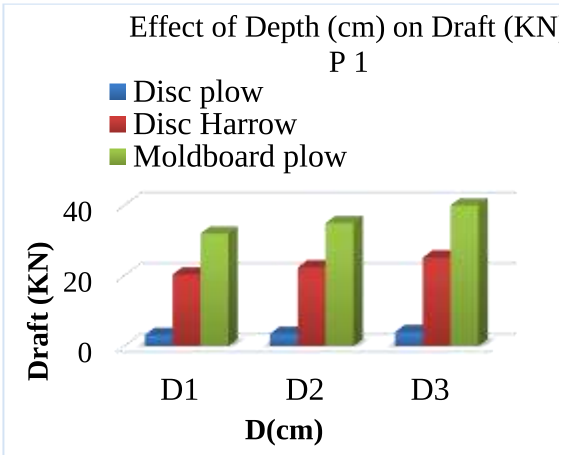

Figure 4.1. Effect of Depth (cm) on Draft in P 1

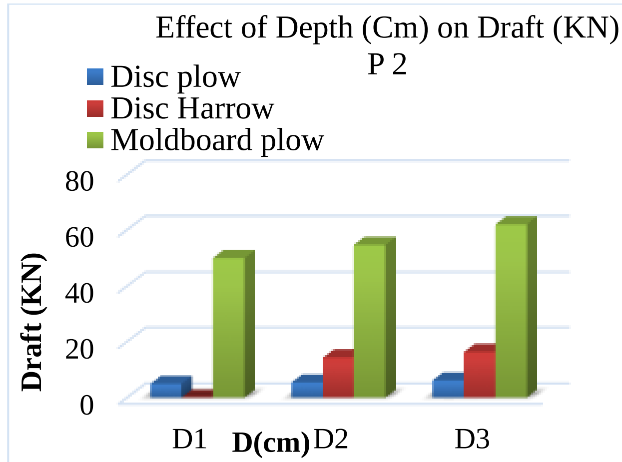

Figure 4.2. Effect of Depth on Draft in P 2

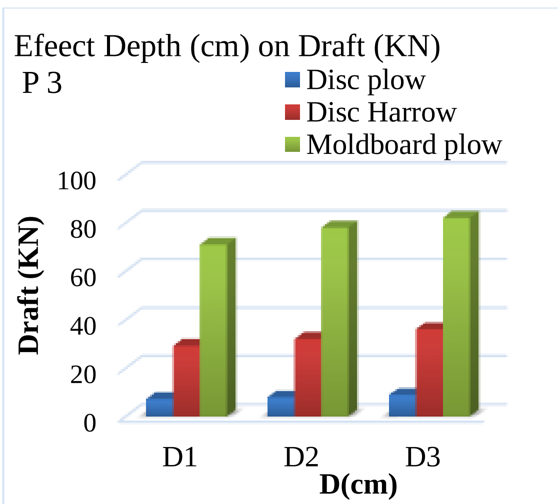

Figure 4.3. Effect of Depth on Draft in P 2

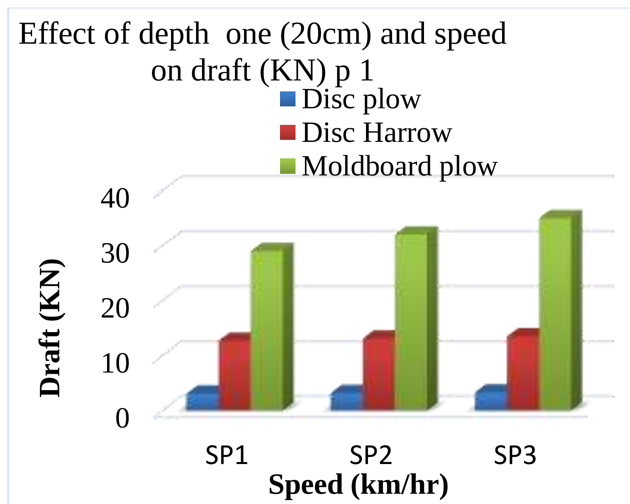

Figure 4.4. Effect of Depth on Draft in P 1

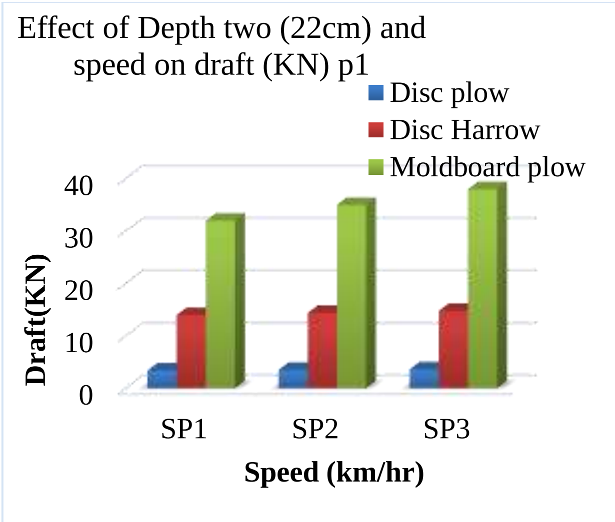

Figure 4.5. Effect of Depth two and Speed on Draft in P 1

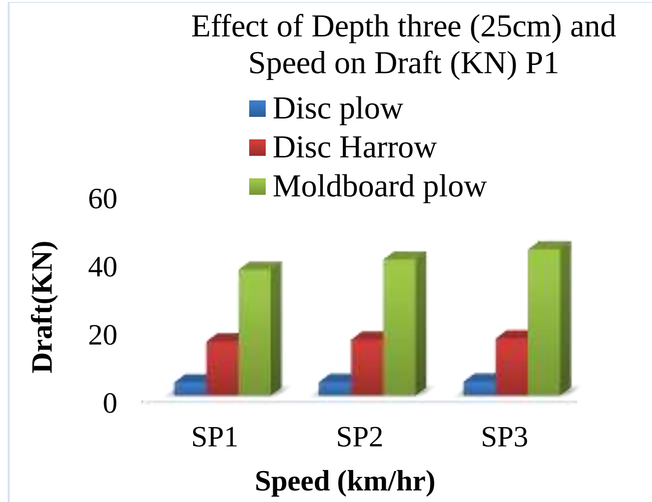

Figure 4.6. Effect of Depth three and Speed on Draft in P 1

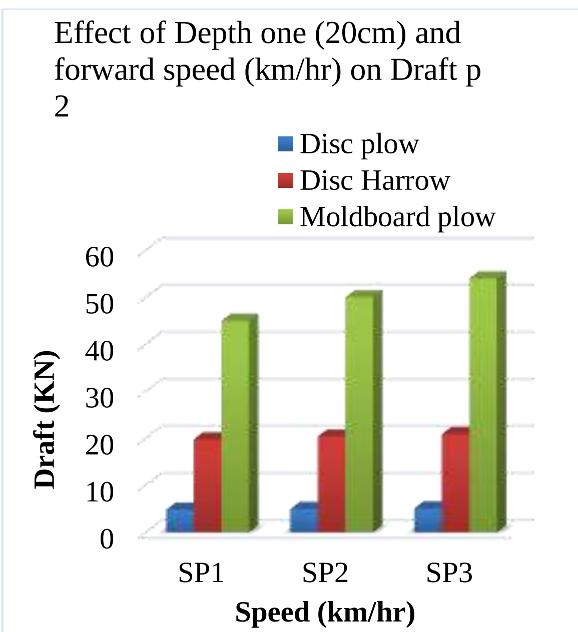

Figure 4.7. Effect of Depth one and Speed on Draft in P 2

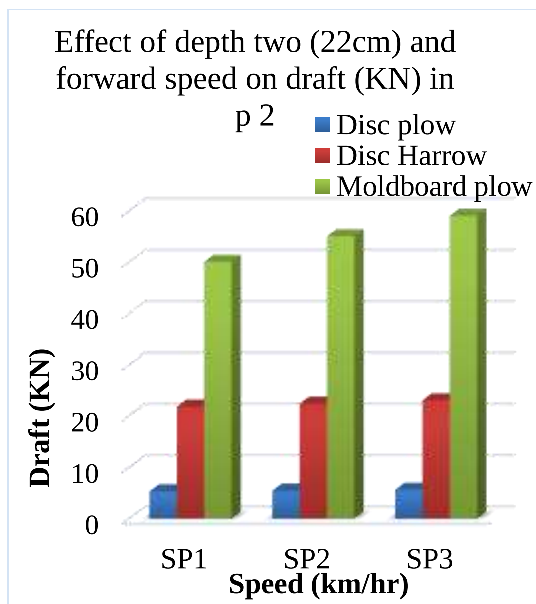

Figure 4.8. Effect of Depth two and speed on draft in p 2

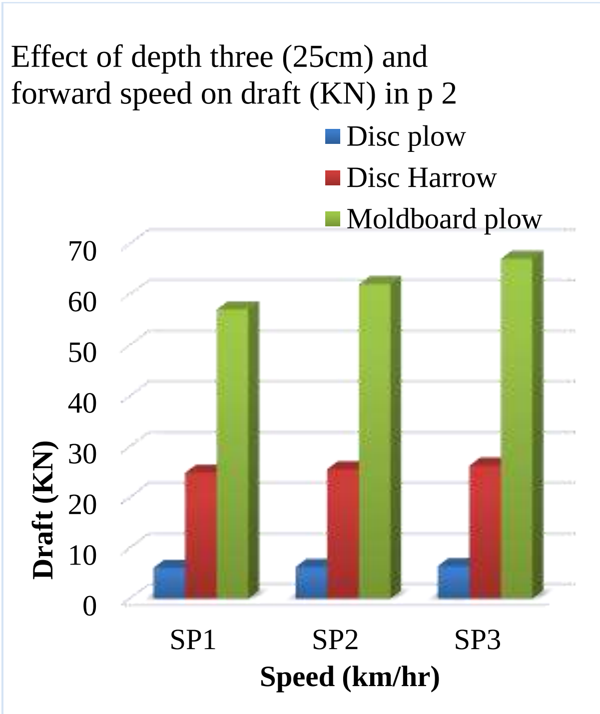

Figure 4.9. Effect of Depth three and speed on draft in p 2

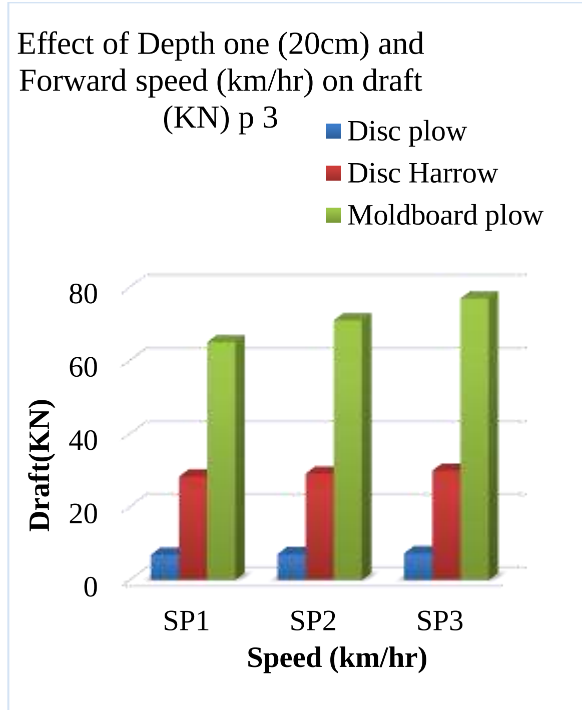

Figure 4.10. Effect of Depth and Speed on Draft in p 3

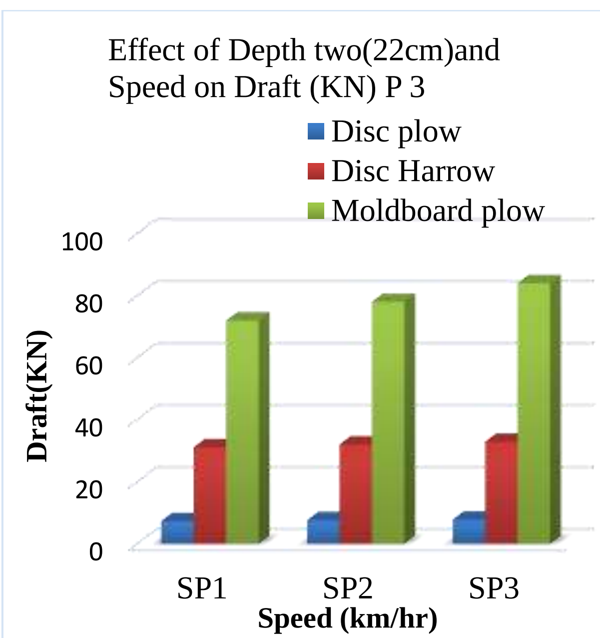

Figure 4.11. Effect of Depth and Speed on Draft in p 3

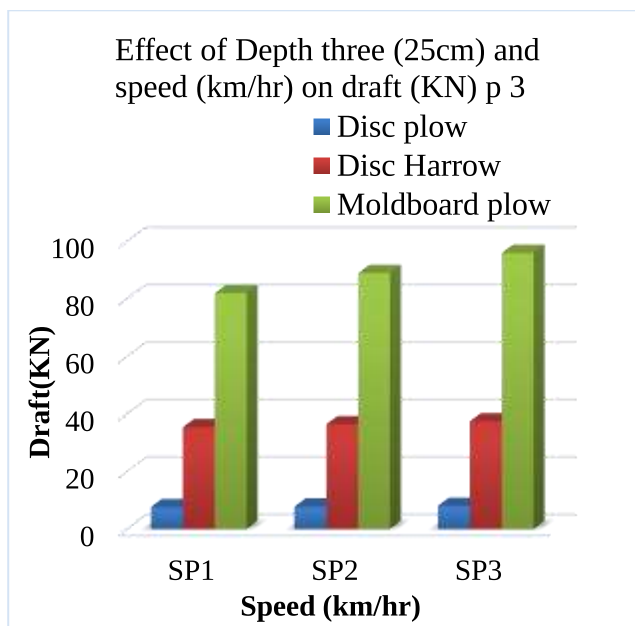

Figure 4.12. Effect of Depth three and Speed on Draft in P 3

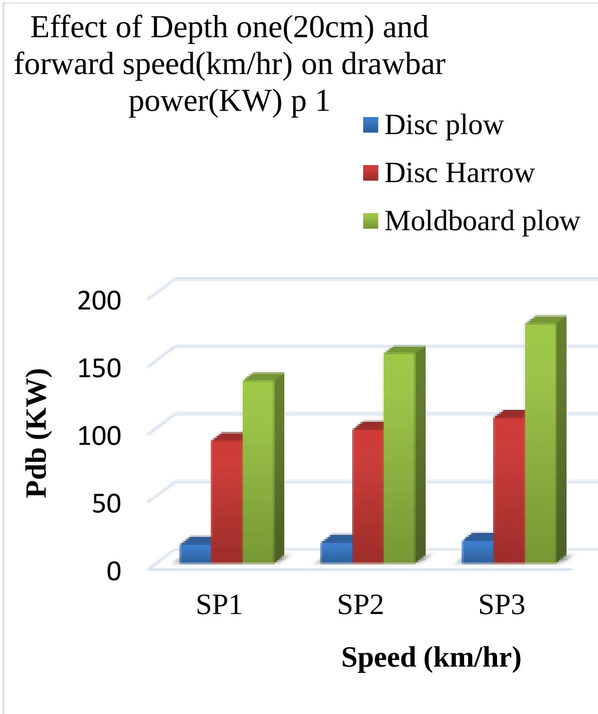

Figure 4.13. Effect of Depth one and speed on drawbar power in p 1

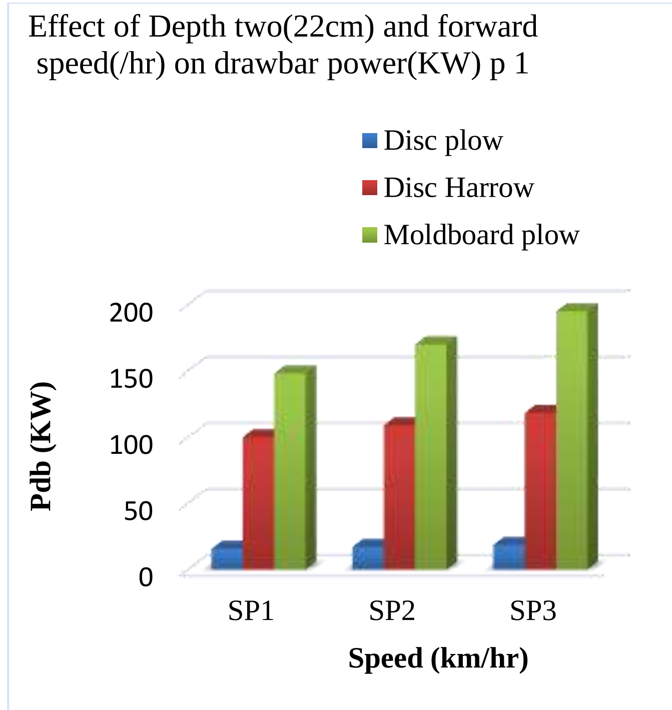

Figure 4.14. Effect of Depth two and speed on drawbar power in p 1

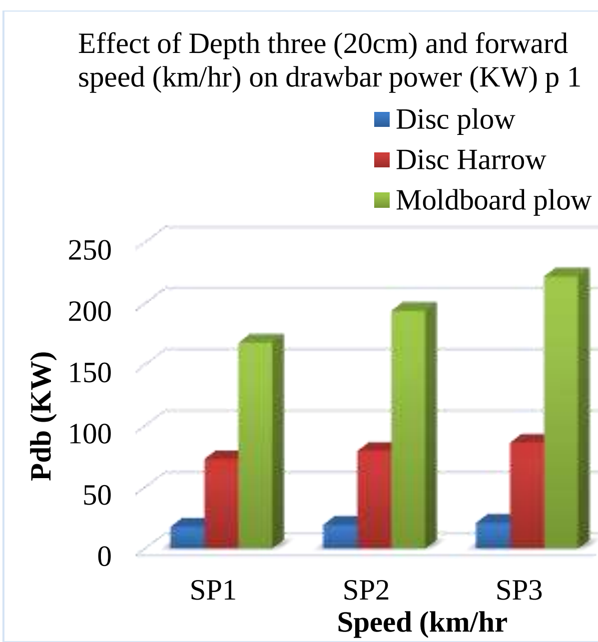

Figure 4.15. Effect of Depth three and speed on drawbar power in p 1

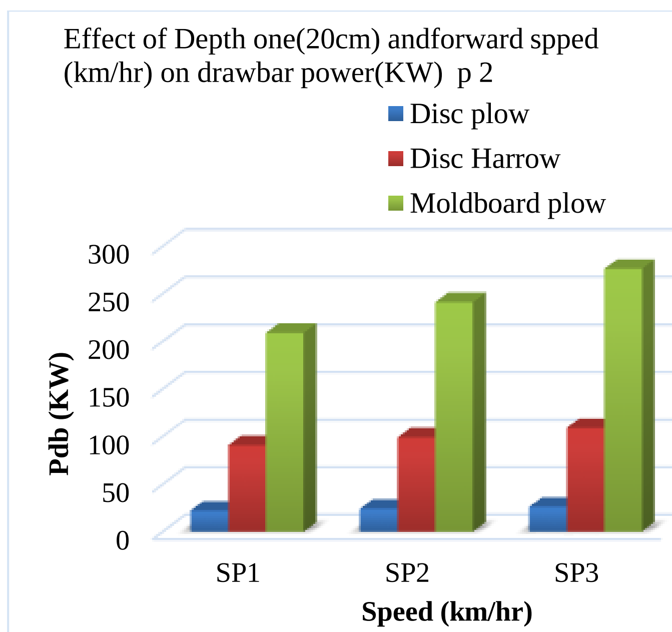

Figure 4.16. Effect of Depth one and speed on drawbar power in p 2

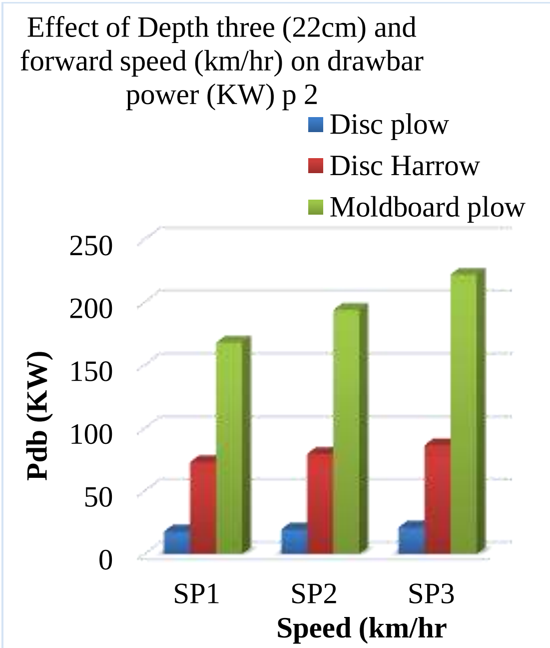

Figure 4.17. Effect of Depth three and speed on drawbar power in p 1

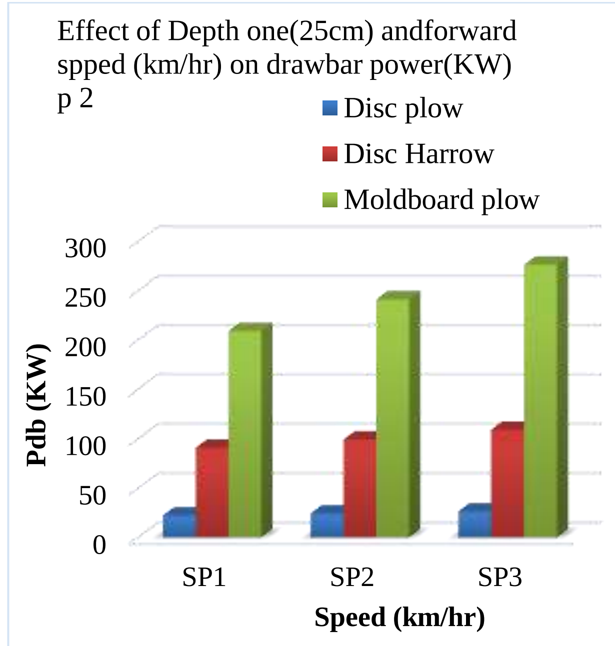

Figure 4.18. Effect of Depth one and speed on drawbar power in p 2

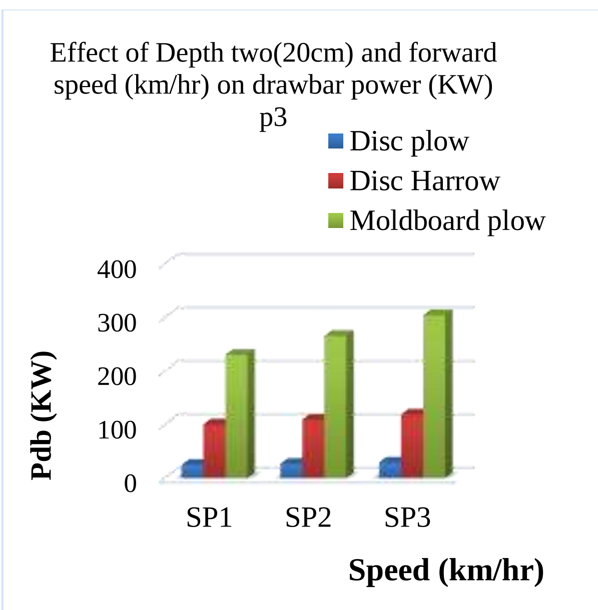

Figure 4.19 Effect of Depth two and speed on drawbar power in p 2

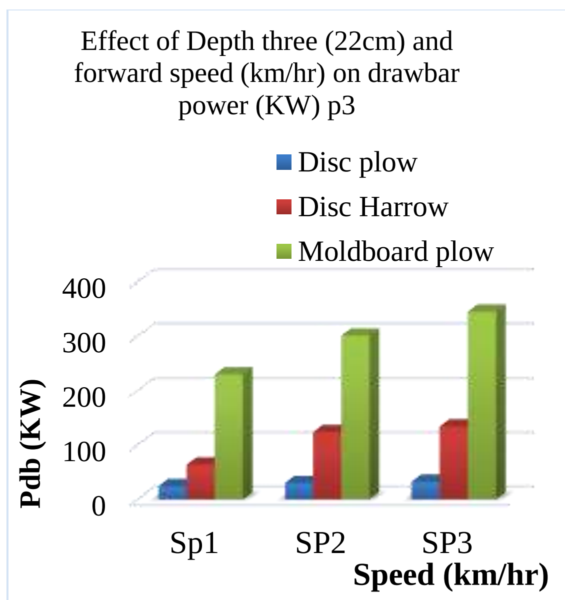

Figure 4.20. Effect of Depth three and speed on drawbar power in p 2

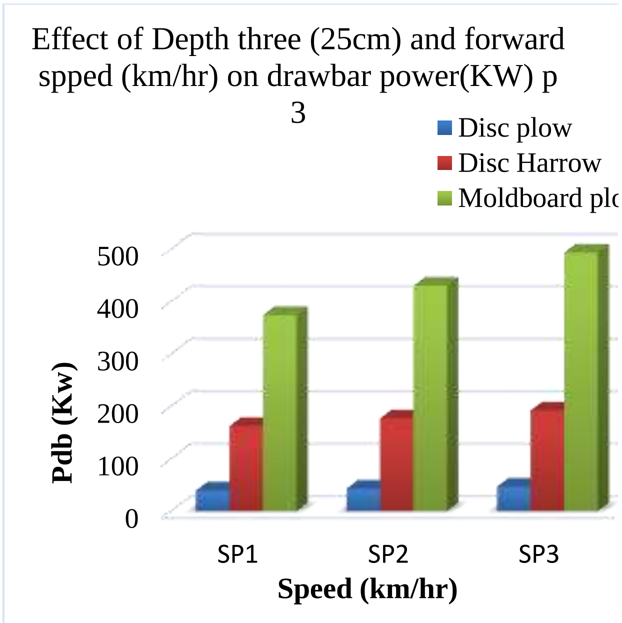

Figure 4.21. Effect of Depth three and speed on drawbar power in p 3

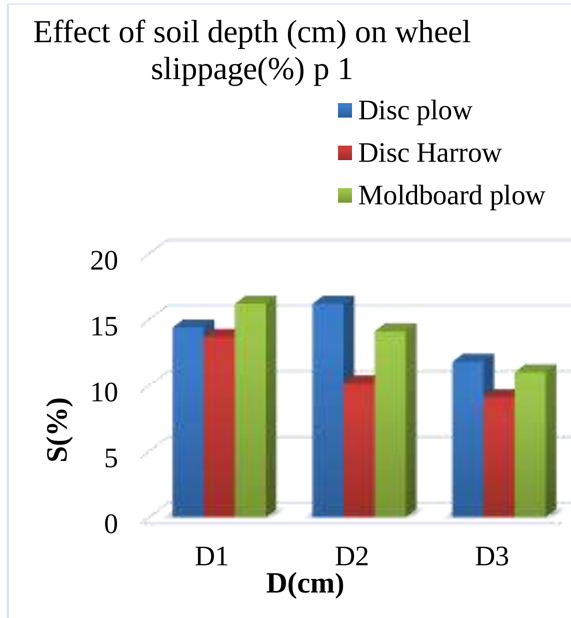

Figure 4.22. Effect of Depth three on wheel slippage in p 1

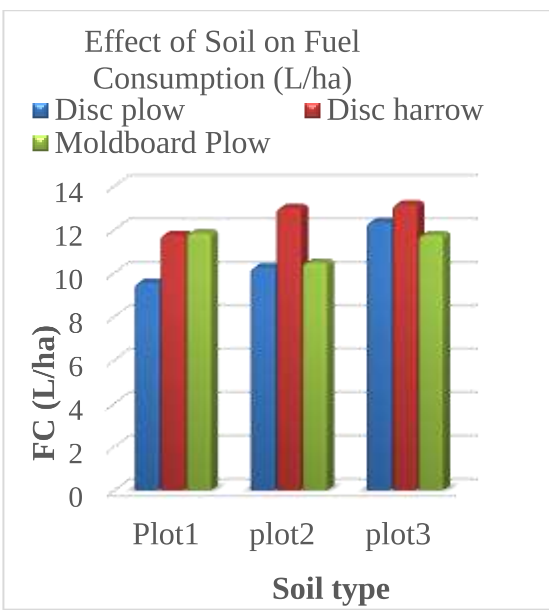

Figure 4.23. Effect of soil on Fuel Consumption (L/Ha)

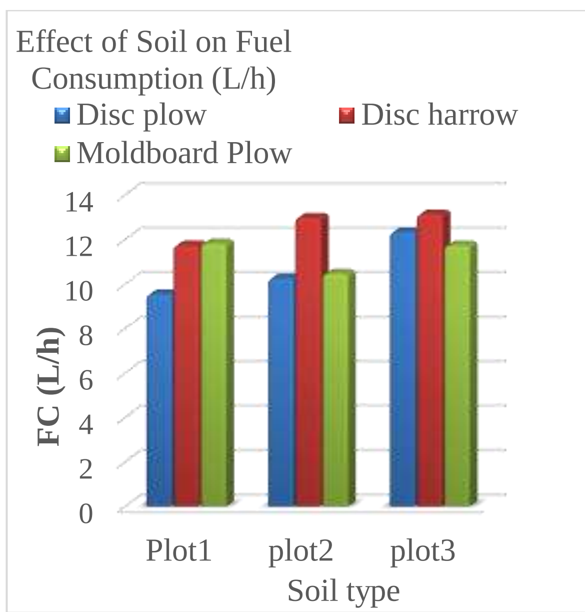

Figure 4.24. Effect of Soil on Fuel Consumption(L/h)

4.11. Implements Performance in the three Locations

The statistical analysis revealed that, there were statically significant and no significant differences ($p<0.05$) due to the implements type on the measured parameters by ANOVA analysis.

4.11.1. Effect of Soil on wheel slippage

The results presented in Table (4.5, 4.10, 4.13, 4.16, 4.19, 4.22, 4.25, 4.28 and 4.31) and Figure 4.23) revealed that the average percentage of wheel slippage for all implements used is below the top limit of wheel slippage. All implements recoded higher wheel slippage in plot 3 than the plot1 and 2, and that may be due to the presence of disc plow in plot 2 which probably created a harsh working condition and made the soil in that location firmer causing a noticeable motion resistance. Higher slippage values in the two locations are 22.26 and 14.29 recorded by the disc plow and moldboard plow respectively. This may be due to increased load transfer to the rear drive wheel of the tractor (G Moitzi et al., 2006). The lowest slippage values were recorded by the moldboard plow (8.34%) and (9.7%) in plot1 and 2 respectively. Generally, fluctuations in plowing depth and speed depend on the field condition and operator skill, and the latter is the key factor that might alter values of slippage by determining the depth and speed of plowing.

Table 4.34. Effect of Soil on Fuel Consumption

Implement		F (L)	Area (ha)	Fc (L/ha)	Time (h)	Fc (L/h)
	Plot 1	6.5	0.28	23.93	0.68	9.56
Disc Plow	Plot 2	7.5	0.28	26.46	0.73	10.27
	Plot 3	10.5	0.28	37.04	0.85	12.35
	Average	8.2	0.28	10.68	0.75	10.72
Disc Harrow	Plot 1	8	0.58	13.86	0.62	11.76
	Plot 2	9.75	0.58	16.90	0.75	13
	Plot 3	10	0.58	17.33	0.76	13.16
	Average	9.25	0.58	14.57	0.71	12.64
	Plot 1	9	0.30	29.76	0.76	11.84
Moldboard Plow	Plot 2	9.75	0.30	32.24	0.93	10.48
	Plot 3	11.75	0.30	38.86	1	11.75
	Average	10.17	0.30	11.36	0.90	11.36

4.11.2. Effect of soil on fuel consumption (L/ha & L/hr)

As shown in Table 4.34 and Figure 4.23 and 4.24 consumption fuel rates in (L/ha)) and (L/h) were numerically higher in plot 3 location of clay loam soil than the sandy clay loam soil location for all implements, and that probably referred to the higher draft requirements for the implements in the third location (Leghari ++ et al., 2016). (Ranjbarian et al., 2017) who reported that, as draft increased, wheel slippage and fuel consumption by the tractor increased. Moldboard, Disc Plow, and Disc harrow recorded the highest rate of fuel consumption (38.86, 37.04, and 17.33 L/ha) in plot 3 respectively. While the Disc Harrow and Disc plow gave the highest fuel consumption rates in the plot 3 location (13.16 L/hr and 12.35 L/hr) and Moldboard plow in plot 1 (11.84 L/hr) respectively. Also, the Disc plow, Disc Harrow and Moldboard plow recorded the lowest rates of fuel consumption at plot 1 location (9.56, 11.76 L/hr) and 10.48 L/hr and in plot 2 respectively.

4.11.3. Effect of Soil on Field Efficiency

The results of field efficiency are shown in Table 4.2, 4.3 and 4.4. In the first location of sandy clay loam soil the disc plow, moldboard plow and disc harrow numerically achieved higher field efficiencies 78.26 %, 72.84%, and 71.83% respectively. In the second location of clay loam soil the moldboard Plow, disc plow, and disc harrow numerically achieved higher field efficiencies 81.72 %, 80.82%, and 79.54% respectively. In the third location of clay loam soil the disc plow, disc harrow and moldboard Plow numerically achieved higher field efficiencies 91.82 %, 79.54%, and 79 % respectively. This result of the mean values of each implement were recorded, the higher field efficiencies 83.63%, 77.85% and 74.73% from disc plow, moldboard plow and disc harrow respectively. operating the implement in the firm soil condition increased the draft and fuel consumption, but gave better efficiency than in loose soil (Okechukwu Oduma et al., 2021). On the contrary, disc plow gave the higher field efficiency in the clay loam soil plot 3 (91.82%) compared to (71.83% and 72.84%) in the plot 1 and plot 2 of sandy clay loam soil and clay loam soil respectively. That probably might be attributed to reduced time losses, and as confirmed field efficiencies, which are assessed on time basis, are generally influenced by operator skill in adjusting his operating pattern.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

Field experiments were conducted with the view to determine the effects of forward speed and tillage depth on the draft of three tillage implements on sandy clay loam and clay loam soil. The results showed that soil conditions were in a good working range for tillage operations. A significant increase in draft was observed for all three tillage implements, with an increase in forward speed and tillage depth. Draft, effective field capacity and fuel consumption increase with an increase in forward speed. Draft, slippage and fuel consumption increase with an increase in tillage depth. The disc harrow recorded the highest average effective field capacity as compared to disc plow and moldboard plow and the highest fuel consumption was recorded in sandy clay loam soil, because motion resistance is higher in fine soils than coarser soils, whereas the highest fuel consumption was recorded in clay loam soil due to the coarser soil that requires more draft. In general, the moldboard plow recorded the highest average draft and slippage as compared to disc plow and disc harrow. Whereas the disc harrow recorded the highest average effective field capacity as compared to disc plow and moldboard plow and the moldboard plow recorded the highest average fuel consumption as compared to disc harrow and disc plow. Draft, effective field capacity and fuel consumption increase with an increase in forward speed draft, slippage and fuel consumption increase with an increase in depth, while slippage decreases with an increase in speed.

5.2. Recommendations

- The results of this research work will help farmers in making the best equipment selections for their agricultural operations by demonstrating how certain soil physical properties affect the performance of various field tools.
- This work is not still enough for end users inorder to select and use appropriate implement-tractor attachments, because other tool sizes and types of plows are available for use within the country, they were not considered in the study.
- The research only focused on three cites on two types of soils and three tillage implements. The result could be different if it will be evaluating and testing on a wide range of soil types and other type of tillage implements. So, the future expectations from Kulumsa Agricultural Research Center and academicians will expect more investigations and studies regarding to more tillage implements that the respective tractor attachment by different type of soils in order to achieving their goals and to serve the communities more beneficial.
- Soil conditions vary among different agricultural or ecological areas; it is therefore recommended that more studies should be conducted in every agricultural zone to provide data on machine/ implement performances based on soil conditions for increased production, minimized production costs, reduced loss/wastage of energy, time and waste of agricultural products.
- As this study did not cover all the agricultural field implements, further research is recommended to make a detailed study in other tillage tools not covered in this work. Finally, reasonable speed and depth should be always put into consideration before any agricultural operation to save fuel consumption.

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APPENDIXES

APPENDIX 1: Treatments and Replications Tale of Draft Forces from each Plots

Impl.	S Km hr	D1				D2				D3			
		Draft (KN)											
		R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
	S1	29	45.7	65.3	46.7	32	50.3	71.8	51.4	37	57.1	81.6	58.6
MBP	S2	32	49.6	70.8	50.8	35	54.5	77.9	55.8	40	62	88.6	63.5
	S3	35	53.7	76.7	55.1	38	59.1	84.4	60.5	43	67.1	95.9	68.7
Mean		32	49.7	71.0	50.9	35	54.6	78.0	55.9	40.0	62.1	88.7	63.6
	S1	3.1	4.82	6.89	4.94	3.4	5.3	7.58	5.43	3.87	6.03	8.61	6.2
DP	S2	3.19	4.96	7.08	5.08	3.5	5.45	7.79	5.58	3.98	6.2	8.85	6.3
	S3	3.27	5.09	7.27	5.21	3.6	5.6	8	5.73	4.09	6.36	9.09	6.5
Mean		3.2	5.0	7.1	5.07	5.7	5.95	5.58	5.74	3.98	6.2	8.85	6.3
	S1	12.7	19.8	28.3	20.3	14	21.8	31.1	22.3	15.9	24.8	35.4	25.4
DH	S2	13.1	20.4	29.1	20.9	14	22.4	32.0	22.9	16.4	25.5	36.4	26.1
	S3	13.5	20.9	29.9	21.4	15	23.0	32.9	23.6	16.8	26.1	37.4	26.8
Mean		13.1	20.4	29.1	20.9	23	24.5	22.9	23.6	23.7	23.4	23.6	23.5

APPENDIX 2: Mean Results of Soil Bulk Density from the three plots

Bulk Density(g/cm3)

	Plot1				Plot2				Plot3			
BD	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
	1.03	1.08	1.13	1.08	1.43	1.56	1.56	1.52	1.3	1.41	1.71	1.47
BD(g/cm3)	1.05	1.15	1.18	1.13	1.52	1.63	1.62	1.59	1.42	1.55	1.81	1.59
	1.34	1.24	1.33	1.30	1.62	1.72	1.63	1.66	1.58	1.71	1.84	1.71
Mean	1.14	1.16	1.21	1.17	1.52	1.64	1.60	1.59	1.43	1.56	1.79	1.59

APPENDIX 3: Treatments and Replications table of Drawbar Power from Each Plot

Implement Type	Speed **Km/h**	Pdb (KN) **D1**				**D2**				**D3**			
		R1	R 2	R 3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
MBP	S1	135	209	299	215	148	230	329	236	168	262	374	268
	S2	155	241	344	247	170	265	379	271	194	301	430	309
	S3	177	276	394	282	195	304	434	311	222	345	493	353
Mean		156	242	346	248	279	291	272	281	281	278	280	280
DP	S1	14	22	32	23	16	24	35	25	18	28	39	28
	S2	15	24	34	25	17	27	38	27	19	30	43	31
	S3	17	26	37	27	19	29	41	29	21	33	47	33
Mean		16	24	34	25	17	27	38	27	19	30	43	31
DH	S1	58	91	130	93	64	100	143	102	73	114	162	116
	S2	64	99	141	101	70	109	156	112	80	124	177	127
	S3	69	108	154	110	76	118	169	121	86	134	192	138
Mean		64	99	142	101	70	109	156	112	80	124	177	127

Where R1, R2, and R3 are replications

APPENDIX 4: Treatments and Replications table of Wheel Slip on Each plot

	Wheel Slip (%)											
	Plot1				Plot2				Plot3			
Implement	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
	25.2	18.9	15.12	19.74	12.6	12.6	8.4	11.2	10.8	7.56	8.4	6.12
Moldboard	25	12.6	9.45	15.68	10.8	9.45	8.13	9.46	9.45	6.87	7.56	7.96
	12.6	10.8	8.4	10.6	9.45	9.45	6.3	8.4	8.4	9.45	6.3	8.03
Mean	16	14	11	13.67	10.95	10.5	7.61	9.69	9.55	7.96	7.42	8.31
	18.9	18.9	15.12	17.64	18.9	15.12	25.2	19.74	15.12	10.8	9.22	11.71
Disc plow	15.12	15.12	10.8	13.68	18.9	25.2	25.2	23.1	12.6	9.45	9.45	10.5
	10.8	14.45	9.45	11.57	15.12	37.8	37.8	30.24	10.8	9.11	9.22	9.71
Mean	14.94	16.16	11.79	14.30	17.64	26.04	23.1	22.26	12.84	9.79	9.30	10.64
	15.12	12.6	9.45	12.39	18.9	10.8	8.4	12.7	12.6	12.6	9.45	11.55
Disc Harrow	15.12	9.45	9.45	11.34	15.12	9.45	7.8	10.79	10.8	9.45	8.4	9.2
	10.8	8.4	8.4	9.2	12.6	9.45	5	9.02	10.8	8.4	8.4	9.2
Mean	13.68	10.15	9.11	10.98	15.54	9.9	7.07	10.84	11.4	10.15	8.75	10.1

Appendix 5: Mean Results table of Soil Moisture Contents on Each Plot

	Moisture content (%)											
Plot1					Plot2				Plot3			
MC	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
	11	12	12.45	11.82	13	14.21	14.55	13.92	12.48	13.27	15.8	13.85
MC (%)	11.56	12.24	13	12.27	12.45	14.67	14.93	14.02	12.6	14.21	16.33	14.38
	13.2	13.35	14.2	13.58	13.87	14.67	15.06	14.53	15	17.34	15.8	16.05
Mean	11.92	12.53	13.22	12.56	13.11	14.52	14.85	14.16	13.36	14.94	15.98	14.76

Appendix 6: Table of the Result of Draft and Drawbar power of the Moldboard Plow in Plot1

Pl m	NT	Ap m^2	D cm	S km/hr	W m	Fi	A	B	C	C2	S^²	W* D*FI	c2* S^²+A	DI KN	Pdb kw
210	9	3024	20	16.5	1.6	0.45	652	0	5.1	3.6	272	14.4	2040	29	135
210	9	3024	20	17.5	1.6	0.45	652	0	5.1	3.6	306	14.4	2214	32	155
210	9	3024	20	18.5	1.6	0.45	652	0	5.1	3.6	342	14.4	2397	35	177
210	9	3024	22	16.5	1.6	0.45	652	0	5.1	3.6	272	15.8	2040	32	148
210	9	3024	22	17.5	1.6	0.45	652	0	5.1	3.6	306	15.8	2214	35	170
210	9	3024	22	18.5	1.6	0.45	652	0	5.1	3.6	342	15.8	2397	38	195
210	9	3024	25	16.5	1.6	0.45	652	0	5.1	3.6	272	18	2040	37	168
210	9	3024	25	17.5	1.6	0.45	652	0	5.1	3.6	306	18	2214	40	194
210	9	3024	25	18.5	1.6	0.45	652	0	5.1	3.6	342	18	2397	43	222

Appendix 7: Table of the Result of Draft and Drawbar power of the Moldboard Plow in Plot2

Pl m	NT	PA m^2	D cm	S km/hr	W m	Fi	A	B	C	C2	S^²	W*D *FI	c2* S^²+A	DI KN	Pdb Kw
210	9	3024	20	16.5	1.6	0.7	652	0	5.1	3.6	272	22.4	2040	46	209
210	9	3024	20	17.5	1.6	0.7	652	0	5.1	3.6	306	22.4	2214	50	241
210	9	3024	20	18.5	1.6	0.7	652	0	5.1	3.6	342	22.4	2397	54	276
210	9	3024	22	16.5	1.6	0.7	652	0	5.1	3.6	272	24.6	2040	50	230
210	9	3024	22	17.5	1.6	0.7	652	0	5.1	3.6	306	24.6	2214	55	265
210	9	3024	22	18.5	1.6	0.7	652	0	5.1	3.6	342	24.6	2397	59	304
210	9	3024	25	16.5	1.6	0.7	652	0	5.1	3.6	272	28	2040	57	262
210	9	3024	25	17.5	1.6	0.7	652	0	5.1	3.6	306	28	2214	62	301
210	9	3024	25	18.5	1.6	0.7	652	0	5.1	3.6	342	28	2397	67	345
210	9	3024	22	17.5	1.6	0.7	652	0	5.1	3.6	307	25	2217	56	270

Appendix 8: Table of the Result of Draft and Drawbar power of the Moldboard Plow in Plot3

Pl m	N T	PA m^2	D cm	S km/hr	W m	Fi	A	B	C	C2	S^²	W* D* FI	c2* S^2+ A	DI KN	Pdb kw
210	9	3024	20	16.5	1.6	1	652	0	5.1	3.6	272	32	2040	65	299
210	9	3024	20	17.5	1.6	1	652	0	5.1	3.6	306	32	2214	71	344
210	9	3024	20	18.5	1.6	1	652	0	5.1	3.6	342	32	2397	77	394
210	9	3024	22	16.5	1.6	1	652	0	5.1	3.6	272	35	2040	72	329
210	9	3024	22	17.5	1.6	1	652	0	5.1	3.6	306	35	2214	78	379
210	9	3024	22	18.5	1.6	1	652	0	5.1	3.6	342	35	2397	84	434
210	9	3024	25	16.5	1.6	1	652	0	5.1	3.6	272	40	2040	82	374
210	9	3024	25	17.5	1.6	1	652	0	5.1	3.6	306	40	2214	89	430
210	9	3024	25	18.5	1.6	1	652	0	5.1	3.6	342	40	2397	96	493
210	9	3024	22	17.5	1.6	1	652	0	5.1	3.6	307	36	2217	79	386

Appendix 9: Table of the Result of Draft and Drawbar power of the Disc Plow in Plot One

Pl m	N T	PA m^2	D cm	S km/hr	W M	Fi	A	B	C	C2	W* D*FI	A+ B*S	DI KN	Pdb(kw)
210	9	2835	20	16.5	1.5	0.45	124	6.4	0	3.6	13.5	230	3.1	14.2
210	9	2835	20	17.5	1.5	0.45	124	6.4	0	3.6	13.5	236	3.2	15.5
210	9	2835	20	18.5	1.5	0.45	124	6.4	0	3.6	13.5	242	3.3	16.8
210	9	2835	22	16.5	1.5	0.45	124	6.4	0	3.6	14.9	230	3.4	15.6
210	9	2835	22	17.5	1.5	0.45	124	6.4	0	3.6	14.9	236	3.5	17
210	9	2835	22	18.5	1.5	0.45	124	6.4	0	3.6	14.9	242	3.6	18.5
210	9	2835	25	16.5	1.5	0.45	124	6.4	0	3.6	16.9	230	3.9	17.8
210	9	2835	25	17.5	1.5	0.45	124	6.4	0	3.6	16.9	236	4	19.4
210	9	2835	25	18.5	1.5	0.45	124	6.4	0	3.6	16.9	242	4.1	21
210	9	2835	22.3	17.5	1.5	0.45	124	6.4	0	3.6	15.1	236	3.56	17.3

Appendix 10: Table of the Result of Draft and Drawbar power of the Disc Plow in Plot Two

Pl m	N T	PA m^2	D cm	S km/hr	W m	Fi	A	B	C	C2	W* D*FI	A+ B*S	DI KN	Pdb kw
210	9	2835	20	16.5	1.5	0.7	124	6.4	0	3.6	21	230	4.8	22
210	9	2835	20	17.5	1.5	0.7	124	6.4	0	3.6	21	236	5	24
210	9	2835	20	18.5	1.5	0.7	124	6.4	0	3.6	21	242	5.1	26
210	9	2835	22	16.5	1.5	0.7	124	6.4	0	3.6	23.1	230	5.3	24
210	9	2835	22	17.5	1.5	0.7	124	6.4	0	3.6	23.1	236	5.5	27
210	9	2835	22	18.5	1.5	0.7	124	6.4	0	3.6	23.1	242	5.6	29
210	9	2835	25	16.5	1.5	0.7	124	6.4	0	3.6	26.3	230	6	28
210	9	2835	25	17.5	1.5	0.7	124	6.4	0	3.6	26.3	236	6.2	30
210	9	2835	25	18.5	1.5	0.7	124	6.4	0	3.6	26.3	242	6.4	33
210	9	2835	22.3	17.5	1.5	0.7	124	6.4	0	3.6	23.5	236	5.53	26.9

Appendix 11: Table of the Result of Draft and Drawbar power of the Disc Plow in Plot Three

Pl m	NT	PA m^2	D cm	S km/hr)	W m	Fi	A	B	C	C2	W *D*FI	A+ B*S	DI KN	Pdb Kw
210	9	2835	20	16.5	1.5	1	124	6.4	0	3.6	30	230	6.9	31.6
210	9	2835	20	17.5	1.5	1	124	6.4	0	3.6	30	236	7.1	34.4
210	9	2835	20	18.5	1.5	1	124	6.4	0	3.6	30	242	7.3	37.4
210	9	2835	22	16.5	1.5	1	124	6.4	0	3.6	33	230	7.6	34.7
210	9	2835	22	17.5	1.5	1	124	6.4	0	3.6	33	236	7.8	37.9
210	9	2835	22	18.5	1.5	1	124	6.4	0	3.6	33	242	8	41.1
210	9	2835	25	16.5	1.5	1	124	6.4	0	3.6	37.5	230	8.6	39.5
210	9	2835	25	17.5	1.5	1	124	6.4	0	3.6	37.5	236	8.9	43
210	9	2835	25	18.5	1.5	1	124	6.4	0	3.6	37.5	242	9.1	46.7
210	9	2835	22.3	17.5	1.5	1	124	6.4	0	3.6	33.5	236	7.91	38.5

Appendix 12: Table of the Result of Draft and Drawbar power of the Disc Plow in Plot Three

Pl m	N T	PA m^2	D Cm	S km/hr	W m	Fi	A	B	C	C2	W* D*FI	A+ B*S	DI KN	Pdb Kw
210	9	2835	20	16.5	1.5	1	124	6.4	0	3.6	30	230	6.9	31.6
210	9	2835	20	17.5	1.5	1	124	6.4	0	3.6	30	236	7.1	34.4
210	9	2835	20	18.5	1.5	1	124	6.4	0	3.6	30	242	7.3	37.4
210	9	2835	22	16.5	1.5	1	124	6.4	0	3.6	33	230	7.6	34.7
210	9	2835	22	17.5	1.5	1	124	6.4	0	3.6	33	236	7.8	37.9
210	9	2835	22	18.5	1.5	1	124	6.4	0	3.6	33	242	8	41.1
210	9	2835	25	16.5	1.5	1	124	6.4	0	3.6	37.5	230	8.6	39.5
210	9	2835	25	17.5	1.5	1	124	6.4	0	3.6	37.5	236	8.9	43
210	9	2835	25	18.5	1.5	1	124	6.4	0	3.6	37.5	242	9.1	46.7
210	9	2835	22.3	17.5	1.5	1	124	6.4	0	3.6	33.5	236	7.91	38.5

Appendix 13: Table of the Result of Draft and Drawbar power of the Disc Harrow in Plot One

Pl m	N T	PA m^2	D cm	S km/hr	W M	Fi	A	B	C	C2	W* D*FI	A+ B*S	DI KN	Pdb kw
210	9	5670	20	16.5	3	0.45	254	13.2	0	3.6	27	472	12.7	58.4
210	9	5670	20	17.5	3	0.45	254	13.2	0	3.6	27	485	13.1	63.7
210	9	5670	20	18.5	3	0.45	254	13.2	0	3.6	27	498	13.5	69.1
210	9	5670	22	16.5	3	0.45	254	13.2	0	3.6	29.7	472	14	64.2
210	9	5670	22	17.5	3	0.45	254	13.2	0	3.6	29.7	485	14.4	70
210	9	5670	22	18.5	3	0.45	254	13.2	0	3.6	29.7	498	14.8	76
210	9	5670	25	16.5	3	0.45	254	13.2	0	3.6	33.8	472	15.9	73
210	9	5670	25	17.5	3	0.45	254	13.2	0	3.6	33.8	485	16.4	79.6
210	9	5670	25	18.5	3	0.45	254	13.2	0	3.6	33.8	498	16.8	86.4
210	9	5670	22	17.5	3	0.45	254	13	0	3.6	30.2	485	15	71

Appendix 14: Table of the Result of Draft and Drawbar power of the Disc Harrow in Plot Two

Pl m	N T	PA m^2	D cm	S km/hr	W m	Fi	A	B	C	C2	W* D*FI	A+ B*S	DI KN	Pdb (kw)
210	9	5670	20	16.5	3	0.7	254	13.2	0	3.6	42	472	19.8	90.8
210	9	5670	20	17.5	3	0.7	254	13.2	0	3.6	42	485	20.4	99
210	9	5670	20	18.5	3	0.7	254	13.2	0	3.6	42	498	20.9	108
210	9	5670	22	16.5	3	0.7	254	13.2	0	3.6	46.2	472	21.8	99.9
210	9	5670	22	17.5	3	0.7	254	13.2	0	3.6	46.2	485	22.4	109
210	9	5670	22	18.5	3	0.7	254	13.2	0	3.6	46.2	498	23	118
210	9	5670	25	16.5	3	0.7	254	13.2	0	3.6	52.5	472	24.8	114
210	9	5670	25	17.5	3	0.7	254	13.2	0	3.6	52.5	485	25.5	124
210	9	5670	25	18.5	3	0.7	254	13.2	0	3.6	52.5	498	26.2	134
210	9	5670	22.3	17.5	3	0.7	254	13.2	0	3.6	46.9	485	22.8	111

Appendix 15: Table of the Result of Draft and Drawbar power of the Disc Harrow in Plot Three

Plm	NT	PA m^2	D Cm	S km/hr	W m	Fi	A	B	C	C2	W* D*FI	A+ B*S	DI KN	Pdb kw
210	9	5670	20	16.5	3	1	254	13.2	0	3.6	60	472	28.3	130
210	9	5670	20	17.5	3	1	254	13.2	0	3.6	60	485	29.1	142
210	9	5670	20	18.5	3	1	254	13.2	0	3.6	60	498	29.9	154
210	9	5670	22	16.5	3	1	254	13.2	0	3.6	66	472	31.1	143
210	9	5670	22	17.5	3	1	254	13.2	0	3.6	66	485	32	156
210	9	5670	22	18.5	3	1	254	13.2	0	3.6	66	498	32.9	169
210	9	5670	25	16.5	3	1	254	13.2	0	3.6	75	472	35.4	162
210	9	5670	25	17.5	3	1	254	13.2	0	3.6	75	485	36.4	177
210	9	5670	25	18.5	3	1	254	13.2	0	3.6	75	498	37.4	192
210	9	5670	22.3	17.5	3	1	254	13.2	0	3.6	67	485	32.5	158

Where Pl – plot length; PA-Plot area; NT- Number of turns; DI-Draft of Implements; W-Width of Implement

Appendix 16: ANOVA table of Simple Regression Equation and Results of the Parameters

Simple Regression equation analysis for Moldboard in Plot 1

Regression for DI(KN) vs %MC		Regression for DI(KN) vs BD(g/cm3)		Regression for DI(KN) vs %S	
Y = - 6.89 + 3.399 X		Y = 1.45 + 29.24 X		Y = 45.11 - 0.6873 X	
X	Predicted Y 99% PI	X	Predicted Y 99% PI	X	Predicted Y 99% PI
X	Predicted Y 99% PI	1.02	31.268 (20.577, 41.960)	8	39.615 (30.655, 48.575)
10.8	29.819 (17.005, 42.633)	1.035	31.707 (21.182, 42.231)	8.8	39.065 (30.237, 47.893)
10.95	30.329 (17.803, 42.855)	1.05	32.145 (21.773, 42.518)	9.6	38.515 (29.801, 47.229)
11.1	30.839 (18.580, 43.098)	1.065	32.584 (22.347, 42.821)	10.4	37.965 (29.346, 46.585)
11.25	31.349 (19.335, 43.362)	1.08	33.022 (22.905, 43.140)	11.2	37.416 (28.872, 45.959)
11.4	31.859 (20.067, 43.650)	1.095	33.461 (23.445, 43.477)	12	36.866 (28.378, 45.354)
11.55	32.368 (20.775, 43.962)	1.11	33.900 (23.968, 43.832)	12.8	36.316 (27.863, 44.769)
11.7	32.878 (21.457, 44.300)	1.125	34.338 (24.472, 44.204)	13.6	35.766 (27.328, 44.204)
11.85	33.388 (22.112, 44.664)	1.14	34.777 (24.958, 44.595)	14.4	35.216 (26.772, 43.661)
12	33.898 (22.739, 45.057)	1.155	35.215 (25.425, 45.005)	15.2	34.666 (26.195, 43.138)
12.15	34.408 (23.337, 45.479)	1.17	35.654 (25.873, 45.434)	16	34.117 (25.598, 42.635)
12.3	34.917 (23.905, 45.930)	1.185	36.092 (26.302, 45.882)	16.8	33.567 (24.981, 42.153)
12.45	35.427 (24.444, 46.411)	1.2	36.531 (26.712, 46.350)	17.6	33.017 (24.344, 41.690)
12.6	35.937 (24.952, 46.922)	1.215	36.969 (27.103, 46.835)	18.4	32.467 (23.688, 41.246)
12.75	36.447 (25.429, 47.464)	1.23	37.408 (27.476, 47.340)	19.2	31.917 (23.013, 40.821)
12.9	36.957 (25.877, 48.036)	1.245	37.847 (27.830, 47.863)	20	31.367 (22.321, 40.413)
13.05	37.466 (26.296, 48.637)	1.26	38.285 (28.167, 48.403)	20.8	30.817 (21.612, 40.023)
13.2	37.976 (26.685, 49.267)	1.275	38.724 (28.487, 48.961)	21.6	30.268 (20.888, 39.648)
13.35	38.486 (27.047, 49.925)	39.162	(28.789, 49.535)	22.4	29.718 (20.148, 39.288)
13.5	38.996 (27.382, 50.610)	1.305	39.601 (29.076, 50.125)	23.2	29.168 (19.393, 38.943)
13.65	39.506 (27.691, 51.320)	1.32	40.039 (29.348, 50.731)	24	28.618 (18.626, 38.610)
13.8	40.015 (27.976, 52.055)	1.335	40.478 (29.605, 51.351)	24.8	28.068 (17.846, 38.291)
13.95	40.525 (28.238, 52.813)	1.35	40.916 (29.848, 51.985)	25.6	27.518 (17.054, 37.983)
14.1	41.035 (28.478, 53.592)	1.365	41.355 (30.078, 52.632)	26.4	26.969 (16.252, 37.685)
14.25	41.545 (28.698, 54.392)	1.38	41.793 (30.295, 53.291)	27.2	26.419 (15.439, 37.398)

Simple Regression equation analysis for Moldboard in Plot 2

Regression for DI1 (KN)vs%MC1		Regr for DI1(KN) vs BD1(g/cm3)		Regress. for DI(KN) vs %S1	
Y = - 35.08 + 6.435X		Y = - 11.79 + 41.84 X		Y = 85.08 - 3.058 X	
X	Predicted Y 99% PI	X	Predicted Y 99% PI	X	Predicted Y 99% PI
12.4	44.715 (33.653, 55.778)	1.4	46.778 (21.964, 71.592)	6	66.735 (57.933, 75.538)
12.52	45.488 (34.607, 56.368)	1.415	47.405 (23.312, 71.499)	6.3	65.818 (57.180, 74.457)
12.64	46.260 (35.550, 56.970)	1.43	48.033 (24.626, 71.440)	6.6	64.901 (56.415, 73.386)
12.76	47.032 (36.482, 57.582)	1.445	48.661 (25.903, 71.418)	6.9	63.983 (55.639, 72.328)
12.88	47.804 (37.401, 58.207)	1.46	49.288 (27.139, 71.438)	7.2	63.066 (54.850, 71.281)
13	48.576 (38.309, 58.844)	1.475	49.916 (28.330, 71.501)	7.5	62.148 (54.049, 70.248)
13.12	49.348 (39.203, 59.494)	1.49	50.543 (29.475, 71.612)	7.8	61.231 (53.234, 69.228)
13.24	50.121 (40.085, 60.157)	1.505	51.171 (30.568, 71.774)	8.1	60.314 (52.405, 68.223)
13.36	50.893 (40.952, 60.833)	1.52	51.798 (31.606, 71.991)	8.4	59.396 (51.561, 67.231)
13.48	51.665 (41.806, 61.524)	1.535	52.426 (32.586, 72.266)	8.7	58.479 (50.702, 66.255)
13.6	52.437 (42.644, 62.230)	1.55	53.053 (33.504, 72.603)	9	57.561 (49.829, 65.294)
13.72	53.209 (43.469, 62.950)	1.565	53.681 (34.359, 73.003)	9.3	56.644 (48.939, 64.348)
13.84	53.981 (44.278, 63.685)	1.58	54.309 (35.147, 73.470)	9.6	55.726 (48.034, 63.419)
13.96	54.754 (45.071, 64.436)	1.595	54.936 (35.867, 74.006)	9.9	54.809 (47.114, 62.504)
14.08	55.526 (45.850, 65.202)	1.61	55.564 (36.518, 74.610)	10.2	53.892 (46.177, 61.606)
14.2	56.298 (46.613, 65.983)	1.625	56.191 (37.099, 75.283)	10.5	52.974 (45.225, 60.723)
14.32	57.070 (47.361, 66.779)	1.64	56.819 (37.612, 76.026)	10.8	52.057 (44.257, 59.856)
14.44	57.842 (48.094, 67.591)	1.655	57.446 (38.057, 76.836)	11.1	51.139 (43.275, 59.004)
14.56	58.614 (48.812, 68.417)	1.67	58.074 (38.437, 77.711)	11.4	50.222 (42.277, 58.167)
14.68	59.387 (49.515, 69.259)	1.685	58.702 (38.753, 78.650)	11.7	49.305 (41.266, 57.343)
14.8	60.159 (50.203, 70.114)	1.7	59.329 (39.009, 79.649)	12	48.387 (40.240, 56.534)
14.92	60.931 (50.878, 70.984)	1.715	59.957 (39.208, 80.706)	12.3	47.470 (39.201, 55.738)
15.04	61.703 (51.539, 71.868)	1.73	60.584 (39.353, 81.816)	12.6	46.552 (38.150, 54.955)
15.16	62.475 (52.186, 72.765)	1.745	61.212 (39.448, 82.976)	12.9	45.635 (37.086, 54.184)
15.28	63.247 (52.821, 73.674)	1.76	61.839 (39.496, 84.182)	13.2	44.717 (36.011, 53.424)

Simple Regression equation analysis for Moldboard in Plot 3

Regres.for DI1(KN) vs %MC		Regres.for DI(KN) vs %BD(g/c3)		Regression for DI(KN) vs %S	
Y = 7.937 + 4.774 X		Y = 11.49 + 42.54 X		Y = 119.5 - 4.848 X	
X	Predicted Y 99% PI	X	Predicted Y 99% PI	X	Predicted Y 99% PI
12	65.231 (53.221, 77.241)	1.25	64.672 (45.393, 83.950)	6.2	89.461 (65.029, 113.89)
12.25	66.424 (54.601, 78.248)	1.275	65.735 (46.783, 84.687)	6.4	88.491 (64.463, 112.52)
12.5	67.618 (55.968, 79.269)	1.3	66.799 (48.154, 85.444)	6.6	87.521 (63.863, 111.18)
12.75	68.812 (57.319, 80.304)	1.325	67.862 (49.504, 86.221)	6.8	86.552 (63.228, 109.88)
13	70.005 (58.656, 81.355)	1.35	68.926 (50.832, 87.020)	7	85.582 (62.554, 108.61)
13.25	71.199 (59.976, 82.422)	1.375	69.989 (52.138, 87.841)	7.2	84.612 (61.842, 107.38)
13.5	72.393 (61.280, 83.505)	1.4	71.053 (53.420, 88.686)	7.4	83.643 (61.090, 106.20)
13.75	73.586 (62.568, 84.605)	1.425	72.117 (54.677, 89.556)	7.6	82.673 (60.296, 105.05)
14	74.780 (63.837, 85.722)	1.45	73.180 (55.910, 90.451)	7.8	81.703 (59.459, 103.95)
14.25	75.973 (65.090, 86.857)	1.475	74.244 (57.116, 91.371)	8	80.734 (58.580, 102.89)
14.5	77.167 (66.324, 88.010)	1.5	75.307 (58.296, 92.319)	8.2	79.764 (57.656, 101.87)
14.75	78.361 (67.540, 89.181)	1.525	76.371 (59.449, 93.293)	8.4	78.794 (56.689, 100.90)
15	79.554 (68.738, 90.371)	1.55	77.434 (60.573, 94.295)	8.6	77.825 (55.677, 99.972)
15.25	80.748 (69.917, 91.578)	1.575	78.498 (61.670, 95.325)	8.8	76.855 (54.622, 99.088)
15.5	81.941 (71.079, 92.804)	1.6	79.562 (62.739, 96.384)	9	75.885 (53.523, 98.247)
15.75	83.135 (72.222, 94.048)	1.625	80.625 (63.780, 97.470)	9.2	74.916 (52.382, 97.449)
16	84.329 (73.347, 95.310)	1.65	81.689 (64.793, 98.584)	9.4	73.946 (51.199, 96.692)
16.25	85.522 (74.455, 96.590)	1.675	82.752 (65.778, 99.727)	9.6	72.976 (49.976, 95.976)
16.5	86.716 (75.546, 97.886)	1.7	83.816 (66.735, 100.90)	9.8	72.007 (48.714, 95.299)
16.75	87.910 (76.620, 99.199)	1.725	84.879 (67.666, 102.09)	10	71.037 (47.414, 94.660)
17	89.103 (77.678, 100.53)	1.75	85.943 (68.570, 103.32)	10.2	70.067 (46.078, 94.057)
17.25	90.297 (78.721, 101.87)	1.775	87.006 (69.449, 104.56)	10.4	69.098 (44.707, 93.488)
17.5	91.490 (79.748, 103.23)	1.8	88.070 (70.303, 105.84)	10.6	68.128 (43.304, 92.952)
17.75	92.684 (80.761, 104.61)	1.825	89.134 (71.134, 107.13)	10.8	67.158 (41.870, 92.447)
18	93.878 (81.761, 105.99)	1.85	90.197 (71.941, 108.45)	11	66.189 (40.406, 91.971)

Simple Regression equation analysis for Disc Plow in Plot 1

Regression for DI1(KN) vs %MC		Regr. for DI(KN) vs BD(g/cm3)		Regression for DI(KN) vs %S	
Y = - 0.3508 + 0.3123 X		. Y = 1.530 + 1.733 X		Y = 4.582 - 0.07164 X	
X	Predicted Y 99% PI	X	Predicted Y 99% PI	X	Predicted Y 99% PI
10.8	3.0217 (2.1677, 3.8756)	1.02	3.2978 (2.1450, 4.4505)	8.2	3.9944 (2.9060, 5.0828)
10.95	3.0685 (2.2319, 3.9050)	1.035	3.3237 (2.1890, 4.4585)	8.7	3.9586 (2.8919, 5.0253)
11.1	3.1153 (2.2949, 3.9358)	1.05	3.3497 (2.2313, 4.4682)	9.2	3.9228 (2.8762, 4.9693)
11.25	3.1622 (2.3565, 3.9678)	1.065	3.3757 (2.2719, 4.4795)	9.7	3.8869 (2.8591, 4.9148)
11.4	3.2090 (2.4167, 4.0013)	1.08	3.4017 (2.3108, 4.4927)	10.2	3.8511 (2.8403, 4.8619)
11.55	3.2558 (2.4754, 4.0363)	1.095	3.4277 (2.3478, 4.5077)	10.7	3.8153 (2.8198, 4.8108)
11.7	3.3027 (2.5326, 4.0728)	1.11	3.4537 (2.3828, 4.5246)	11.2	3.7795 (2.7975, 4.7614)
11.85	3.3495 (2.5881, 4.1110)	1.125	3.4797 (2.4159, 4.5435)	11.7	3.7436 (2.7733, 4.7140)
12	3.3964 (2.6419, 4.1508)	1.14	3.5057 (2.4470, 4.5644)	12.2	3.7078 (2.7472, 4.6684)
12.15	3.4432 (2.6940, 4.1924)	1.155	3.5317 (2.4761, 4.5873)	12.7	3.6720 (2.7191, 4.6249)
12.3	3.4900 (2.7444, 4.2357)	1.17	3.5577 (2.5031, 4.6123)	13.2	3.6362 (2.6889, 4.5834)
12.45	3.5369 (2.7929, 4.2809)	1.185	3.5837 (2.5281, 4.6393)	13.7	3.6004 (2.6567, 4.5440)
12.6	3.5837 (2.8397, 4.3278)	1.2	3.6097 (2.5510, 4.6684)	14.2	3.5645 (2.6223, 4.5068)
12.75	3.6306 (2.8846, 4.3765)	1.215	3.6357 (2.5719, 4.6995)	14.7	3.5287 (2.5859, 4.4716)
12.9	3.6774 (2.9277, 4.4271)	1.23	3.6617 (2.5908, 4.7326)	15.2	3.4929 (2.5473, 4.4385)
13.05	3.7242 (2.9691, 4.4794)	1.245	3.6877 (2.6077, 4.7676)	15.7	3.4571 (2.5066, 4.4076)
13.2	3.7711 (3.0088, 4.5334)	1.26	3.7137 (2.6227, 4.8046)	16.2	3.4213 (2.4638, 4.3787)
13.35	3.8179 (3.0467, 4.5891)	1.275	3.7397 (2.6359, 4.8435)	16.7	3.3854 (2.4191, 4.3518)
13.5	3.8648 (3.0831, 4.6464)	1.29	3.7657 (2.6472, 4.8841)	17.2	3.3496 (2.3723, 4.3269)
13.65	3.9116 (3.1179, 4.7053)	1.305	3.7917 (2.6569, 4.9264)	17.7	3.3138 (2.3237, 4.3039)
13.8	3.9584 (3.1512, 4.7656)	1.32	3.8176 (2.6649, 4.9704)	18.2	3.2780 (2.2732, 4.2827)
13.95	4.0053 (3.1831, 4.8274)	1.335	3.8436 (2.6713, 5.0160)	18.7	3.2422 (2.2210, 4.2633)
14.1	4.0521 (3.2137, 4.8905)	1.35	3.8696 (2.6762, 5.0631)	19.2	3.2063 (2.1672, 4.2455)
14.25	4.0990 (3.2430, 4.9549)	1.365	3.8956 (2.6797, 5.1116)	19.7	3.1705 (2.1117, 4.2293)
14.4	4.1458 (3.2711, 5.0205)	1.38	3.9216 (2.6819, 5.1614)	20.2	3.1347 (2.0548, 4.2146)

Simple Regression equation analysis for Disc Plough in Plot 2

Regression for DI(KN)_1 vs %MC_1 Y = - 35.08 + 6.435 X		Regres. for DI(KN)_1 vs %MC_1 Y = - 11.79 + 41.84 X		Regre for DI(KN)_1 vs %MC_1 Y = 85.08 - 3.058 X	
X	Predicted Y 99% PI	X	Predicted Y 99% PI	X	Predicted Y 99% PI
12.4	4.6156 (3.6098, 5.6214)	1.4	5.0157 (2.7045, 7.3268)	12	5.2204 (3.2792, 7.1617)
12.52	4.6816 (3.6923, 5.6709)	1.415	5.0531 (2.8091, 7.2972)	13.2	5.2571 (3.3550, 7.1593)
12.64	4.7476 (3.7738, 5.7214)	1.43	5.0906 (2.9105, 7.2707)	14.4	5.2938 (3.4266, 7.1611)
12.76	4.8136 (3.8543, 5.7729)	1.445	5.1281 (3.0084, 7.2477)	15.6	5.3305 (3.4937, 7.1673)
12.88	4.8796 (3.9338, 5.8255)	1.46	5.1656 (3.1026, 7.2285)	16.8	5.3672 (3.5563, 7.1782)
13	4.9456 (4.0121, 5.8792)	1.475	5.2030 (3.1926, 7.2135)	18	5.4039 (3.6140, 7.1939)
13.12	5.0117 (4.0892, 5.9341)	1.49	5.2405 (3.2782, 7.2028)	19.2	5.4406 (3.6666, 7.2146)
13.24	5.0777 (4.1651, 5.9902)	1.505	5.2780 (3.3590, 7.1970)	20.4	5.4773 (3.7142, 7.2405)
13.36	5.1437 (4.2398, 6.0475)	1.52	5.3155 (3.4347, 7.1962)	21.6	5.5140 (3.7564, 7.2716)
13.48	5.2097 (4.3132, 6.1061)	1.535	5.3529 (3.5050, 7.2008)	22.8	5.5507 (3.7934, 7.3080)
13.6	5.2757 (4.3853, 6.1661)	1.55	5.3904 (3.5696, 7.2112)	24	5.5874 (3.8250, 7.3498)
13.72	5.3417 (4.4560, 6.2274)	1.565	5.4279 (3.6282, 7.2276)	25.2	5.6241 (3.8514, 7.3968)
13.84	5.4077 (4.5254, 6.2900)	1.58	5.4654 (3.6806, 7.2501)	26.4	5.6608 (3.8727, 7.4489)
13.96	5.4737 (4.5933, 6.3540)	1.595	5.5028 (3.7267, 7.2789)	27.6	5.6975 (3.8889, 7.5061)
14.08	5.5397 (4.6599, 6.4195)	1.61	5.5403 (3.7664, 7.3142)	28.8	5.7342 (3.9002, 7.5682)
14.2	5.6057 (4.7251, 6.4863)	1.625	5.5778 (3.7996, 7.3560)	30	5.7709 (3.9069, 7.6349)
14.32	5.6717 (4.7889, 6.5545)	1.64	5.6153 (3.8264, 7.4042)	31.2	5.8076 (3.9091, 7.7061)
14.44	5.7377 (4.8513, 6.6241)	1.655	5.6527 (3.8468, 7.4586)	32.4	5.8443 (3.9071, 7.7815)
14.56	5.8037 (4.9124, 6.6950)	1.67	5.6902 (3.8612, 7.5192)	33.6	5.8810 (3.9012, 7.8608)
14.68	5.8697 (4.9721, 6.7673)	1.685	5.7277 (3.8697, 7.5857)	34.8	5.9177 (3.8915, 7.9439)
14.8	5.9357 (5.0305, 6.8409)	1.7	5.7652 (3.8725, 7.6578)	36	5.9544 (3.8784, 8.0304)
14.92	6.0017 (5.0876, 6.9158)	1.715	5.8026 (3.8701, 7.7352)	37.2	5.9911 (3.8620, 8.1201)
15.04	6.0677 (5.1435, 6.9920)	1.73	5.8401 (3.8626, 7.8176)	38.4	6.0278 (3.8427, 8.2129)
15.16	6.1338 (5.1982, 7.0693)	1.745	5.8776 (3.8505, 7.9047)	39.6	6.0645 (3.8206, 8.3084)
15.28	6.1998 (5.2517, 7.1478)	1.76	5.9150 (3.8340, 7.9961)	40.8	6.1012 (3.7960, 8.4064)

Simple Regression equation analysis for Disc Harrow in Plot 1

Regression for DI1(KN) vs %MC		Regr. for DI(KN) vs BD1(g/cm3)		Regression for DI(KN) vs %S	
. Y = - 0.3508 + 0.3123 X		Y = 1.530 + 1.733 X		Y = 4.582 - 0.07164 X	
X	Predicted Y 99% PI	X	Predicted Y 99% PI	X	Predicted Y 99% PI
10.8	3.0217 (2.1677, 3.8756)	1.02	3.2978 (2.1450, 4.4505)	8.2	3.9944 (2.9060, 5.0828)
10.95	3.0685 (2.2319, 3.9050)	1.035	3.3237 (2.1890, 4.4585)	8.7	3.9586 (2.8919, 5.0253)
11.1	3.1153 (2.2949, 3.9358)	1.05	3.3497 (2.2313, 4.4682)	9.2	3.9228 (2.8762, 4.9693)
11.25	3.1622 (2.3565, 3.9678)	1.065	3.3757 (2.2719, 4.4795)	9.7	3.8869 (2.8591, 4.9148)
11.4	3.2090 (2.4167, 4.0013)	1.08	3.4017 (2.3108, 4.4927)	10.2	3.8511 (2.8403, 4.8619)
11.55	3.2558 (2.4754, 4.0363)	1.095	3.4277 (2.3478, 4.5077)	10.7	3.8153 (2.8198, 4.8108)
11.7	3.3027 (2.5326, 4.0728)	1.11	3.4537 (2.3828, 4.5246)	11.2	3.7795 (2.7975, 4.7614)
11.85	3.3495 (2.5881, 4.1110)	1.125	3.4797 (2.4159, 4.5435)	11.7	3.7436 (2.7733, 4.7140)
12	3.3964 (2.6419, 4.1508)	1.14	3.5057 (2.4470, 4.5644)	12.2	3.7078 (2.7472, 4.6684)
12.15	3.4432 (2.6940, 4.1924)	1.155	3.5317 (2.4761, 4.5873)	12.7	3.6720 (2.7191, 4.6249)
12.3	3.4900 (2.7444, 4.2357)	1.17	3.5577 (2.5031, 4.6123)	13.2	3.6362 (2.6889, 4.5834)
12.45	3.5369 (2.7929, 4.2809)	1.185	3.5837 (2.5281, 4.6393)	13.7	3.6004 (2.6567, 4.5440)
12.6	3.5837 (2.8397, 4.3278)	1.2	3.6097 (2.5510, 4.6684)	14.2	3.5645 (2.6223, 4.5068)
12.75	3.6306 (2.8846, 4.3765)	1.215	3.6357 (2.5719, 4.6995)	14.7	3.5287 (2.5859, 4.4716)
12.9	3.6774 (2.9277, 4.4271)	1.23	3.6617 (2.5908, 4.7326)	15.2	3.4929 (2.5473, 4.4385)
13.05	3.7242 (2.9691, 4.4794)	1.245	3.6877 (2.6077, 4.7676)	15.7	3.4571 (2.5066, 4.4076)
13.2	3.7711 (3.0088, 4.5334)	1.26	3.7137 (2.6227, 4.8046)	16.2	3.4213 (2.4638, 4.3787)
13.35	3.8179 (3.0467, 4.5891)	1.275	3.7397 (2.6359, 4.8435)	16.7	3.3854 (2.4191, 4.3518)
13.5	3.8648 (3.0831, 4.6464)	1.29	3.7657 (2.6472, 4.8841)	17.2	3.3496 (2.3723, 4.3269)
13.65	3.9116 (3.1179, 4.7053)	1.305	3.7917 (2.6569, 4.9264)	17.7	3.3138 (2.3237, 4.3039)
13.8	3.9584 (3.1512, 4.7656)	1.32	3.8176 (2.6649, 4.9704)	18.2	3.2780 (2.2732, 4.2827)
13.95	4.0053 (3.1831, 4.8274)	1.335	3.8436 (2.6713, 5.0160)	18.7	3.2422 (2.2210, 4.2633)
14.1	4.0521 (3.2137, 4.8905)	1.35	3.8696 (2.6762, 5.0631)	19.2	3.2063 (2.1672, 4.2455)
14.25	4.0990 (3.2430, 4.9549)	1.365	3.8956 (2.6797, 5.1116)	19.7	3.1705 (2.1117, 4.2293)
14.4	4.1458 (3.2711, 5.0205)	1.38	3.9216 (2.6819, 5.1614	20.2	3.1347 (2.0548, 4.2146)

Simple Regression equation analysis for Disc Harrow in Plot 2

Regression for DI1 (KN)vs%MC1		Regression for DI1(KN) vs BD1(g/cm3)		Regression for DI(KN) vs %S1	
Sim. Reg. equ. Y = - 1.446 + 1.284 X		Sim. Reg. equ. Y = 6.279 + 7.132 X		Sim.Reg. equ. Y = 19.82 - 0.4733 X	
X	Predicted Y 99% PI	X	Predicted Y 99% PI	X	Predicted Y 99% PI
10.8	12.419 (8.9093, 15.928)	1.02	13.553 (8.8158, 18.290)	8.1	15.984 (13.020, 18.949)
10.95	12.611 (9.1733, 16.050)	1.035	13.660 (8.9967, 18.323)	8.4	15.842 (12.908, 18.777)
11.1	12.804 (9.4322, 16.176)	1.05	13.767 (9.1709, 18.363)	8.7	15.700 (12.792, 18.609)
11.25	12.997 (9.6855, 16.308)	1.065	13.874 (9.3380, 18.410)	9	15.558 (12.674, 18.443)
11.4	13.189 (9.9330, 16.445)	1.08	13.981 (9.4978, 18.464)	9.3	15.416 (12.552, 18.281)
11.55	13.382 (10.174, 16.589)	1.095	14.088 (9.6499, 18.526)	9.6	15.274 (12.427, 18.122)
11.7	13.574 (10.409, 16.739)	1.11	14.195 (9.7941, 18.596)	9.9	15.132 (12.299, 17.966)
11.85	13.767 (10.638, 16.896)	1.125	14.302 (9.9303, 18.673)	10.2	14.990 (12.167, 17.814)
12	13.959 (10.859, 17.060)	1.14	14.409 (10.058, 18.759)	10.5	14.848 (12.032, 17.665)
12.15	14.152 (11.073, 17.231)	1.155	14.516 (10.178, 18.854)	10.8	14.706 (11.894, 17.519)
12.3	14.345 (11.280, 17.409)	1.17	14.623 (10.289, 18.956)	11.1	14.564 (11.752, 17.377)
12.45	14.537 (11.480, 17.595)	1.185	14.730 (10.392, 19.068)	11.4	14.422 (11.607, 17.238)
12.6	14.730 (11.672, 17.788)	1.2	14.837 (10.486, 19.187)	11.7	14.280 (11.458, 17.102)
12.75	14.922 (11.857, 17.988)	1.215	14.944 (10.572, 19.315)	12	14.138 (11.307, 16.970)
12.9	15.115 (12.034, 18.196)	1.23	15.051 (10.650, 19.451)	12.3	13.996 (11.151, 16.841)
13.05	15.307 (12.204, 18.411)	1.245	15.158 (10.720, 19.596)	12.6	13.854 (10.993, 16.716)
13.2	15.500 (12.367, 18.633)	1.26	15.265 (10.781, 19.748)	12.9	13.712 (10.831, 16.593)
13.35	15.693 (12.523, 18.862)	1.275	15.372 (10.836, 19.907)	13.2	13.570 (10.666, 16.474)
13.5	15.885 (12.673, 19.098)	1.29	15.479 (10.883, 20.075)	13.5	13.428 (10.499, 16.358)
13.65	16.078 (12.816, 19.340)	1.305	15.586 (10.922, 20.249)	13.8	13.286 (10.328, 16.245)
13.8	16.270 (12.953, 19.588)	1.32	15.693 (10.955, 20.430)	14.1	13.144 (10.154, 16.135)
13.95	16.463 (13.084, 19.842)	1.335	15.799 (10.982, 20.617)	14.4	13.002 (9.9772, 16.027)
14.1	16.655 (13.210, 20.101)	1.35	15.906 (11.002, 20.811)	14.7	12.860 (9.7978, 15.923)
14.25	16.848 (13.330, 20.366)	1.365	16.013 (11.017, 21.010)	15	12.718 (9.6158, 15.821)
14.4	17.041 (13.446, 20.635)	1.38	16.120 (11.026, 21.215)	15.3	12.576 (9.4313, 15.721)

Appendix 17: Soil Sample taking Procedure from the Field on each Plots

Appendix 18. Tractor and Tillage Implements used in the operations