Evaluation of Compatibility of Tractor and Implement. A case of Kulumsa Agricultural Research Center.

By:

Marta Tesfaye Mekonnen

Thesis submitted to

Department of Mechanical System and Vehicle Engineering

School of Mechanical Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirements for the Degree of Master in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

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APPROVAL SHEET OF BOARD OF EXAMINERS

I, the undersigned, members of the Board of Examiners of the final open defense by *Marta Tesfaye* have read and evaluated her thesis entitled "*Evaluation of Compatibility of Tractor and Implement. A case of Kulumsa Agricultural Research Center*" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master's in *Agricultural Machinery Engineering.*

______________________	________________	________________
Advisor	Signature	Date
______________________	________________	________________
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______________________	________________	________________
Internal Examiner	Signature	Date
______________________	________________	________________
External Examiner	Signature	Date

DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name**:** ***Marta Tesfaye Mekonnen***

Signature: ________________

This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Name: ***Dr.Ing. Simie Tola***

Signature: _____________________

Date of submission …………………

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DEDICATION

To the Almighty of God,
To those who light for me candles of love and support,
To my beloved family
To my fiance Alemayehu Mengistu
And every one who contributed to the success of this effort,
I dedicate this work.

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ACRONYMS

ANOVA	Analysis of variance
ASABE	American Society of Agricultural and Biological Engineering
ATC	Agricultural Training Center for Mechanization
EIAR	Ethiopian Institution of Agricultural Research
EFC	Effective field capacity
FAO	Food and Agricultural Organization of united nation
GIZ	German Development Cooperation
KARC	Kulumsa Agricultural Research Center
kmph	kilometer per hour
MoA	Ministry of Agriculture
MF	Massey Fergusson
NH	New Holland
OEE	Overall Energy Efficiency
PSD	Particle Size Distribution
PTO	Power takeoff
PUR	Power Utilization Ratio
RCBD	Randomized Complete Block Design
SIDA	Swedish International Development Agency
SSAP	Supporting Sustainable Agricultural Productivity in Ethiopia
TFC	Theoretical field capacity

ABSTRACT

Nowadays the requirements of highly sophisticated machinery and implements are highly needed for better agricultural production. Machinery needs effective management system which is the main parameter for efficient use. To achieve these, proper selection and tractor-implement matching is required. In our country there is a problem in proper tractor implement matching systems because there is a problem using the scientific approach to estimate data on drawbar pull requirement of tillage implements. The study aims to evaluate a proper matching of tractor and implement used in land preparation by determining drawbar pull and drawbar power. The materials used are Massey Ferguson MF 6480 and New Holland TT 6080 tractors and Reversible slatted Mould board plough model LEMKEN Jewel 8 implement. Field test were conducted with Reversible slatted Mould board plough model LEMKEN Jewel 8 under 20cm, 30cm, 35cm operating depth, 1.6m and 2.4m working width, 2000 rpm and 2200 rpm engine speed using Massey Ferguson MF 6480 and New Holland TT 6080 tractors at Kulumsa Agricultural Research Center, Kulumsa, under identical operating conditions. The parameters evaluated were travel reduction (wheel slippage), drawbar pull, drawbar power, fuel consumption, and field capacity during ploughing and harrowing operations. The soil physical properties were also measured. The experimental plots were laid side by side in a randomized complete block design (RCBD). Results indicate that the highest drawbar pull, drawbar power, and power utilization ratio was shown by the TT6080 tractor model which is 63.8kN, 81.56kW, and 98.56 % respectively. From the results revealed the combination recommended at the first place were TT6080 Tractor model combined with mould board implement operates with 2200 rpm and 2.4 working width for all operating depth. At the second place tractor model combined with mould board implement operates with 2000 rpm 2.4m working width with 20 and 30 cm operating depth was recommended. MF6480 operated with 2200 rpm and 2.4 m working width with 30 and 35cm operating depth was therefore recommended at the third place among the other tractor implement combination from the standpoint of operational capacity and economy.

Keyword: *matching, Tractor, drawbar pull, drawbar power, working width and depth.*

CHAPTER ONE

INTRODUCTION

1.1. Background and Justification

Ethiopia has a long history with agriculture. It is the basic support of the Ethiopian economy and the people. It provides raw materials for agro-processing industries, income support and food security to a large proportion of the rural households, a market for industrial products and an earner of foreign exchange (MoA, 2014).

While agricultural productivity in Ethiopia is improving, there are still major gaps in productivity when compared with the rest of Africa in some crop areas, and almost universally, when compared with global output levels because in other countries there have been significant correlations between increased use of agricultural mechanization and increased productivity.

Agricultural mechanization can be defined as the economic application of engineering technology to enhance the effectiveness and productivity of human labor (Dagninet *et al.*, 2016). The use of agricultural mechanization technology, like other inputs, can play an important role in increasing production and productivity. Agricultural mechanization solves the problems of insufficient human and animal labor at critical points in the production cycle of commodities.

With increasing of the global population, the contribution of mechanization towards boosting agricultural production is enormous. Particularly, in some emerging and less developed countries mechanization development and its use is a backbone to the extent that it is responsible for the nations’ welfare and feeding the vast majority of their population.

In Ethiopia mechanization plays an important role in agriculture and overall economy of the country. But machinery need high financial investment to purchase and high operating cost which cause high costs of production. As a result, current farming economics reinforce the importance of efficient farm tractor operation. Efficient farm tractor operation, on the other hand, requires proper selection and deployment of matching tractors and implements.

Machinery selection has increased in importance in today farming operations because of its direct relation to the success of management in mixing land, labor and capital to return satisfactory profit.

Machinery selection decisions are harder to pin down than most other decision related to farming. Most machinery management problems may be solved through accurately estimating the total working time that is available for major field operations, proper determination of machines effective field capacities, matching of power units with machines capacities, and accurately predicting of any machine application costs.

The success of many farm-level production systems depends on wise selection of machinery systems. The main aim of tractor and machinery selection is to complete a certain field operation during at specific time and minimum cost.

In machinery management timeliness is an important concept and it has to be figured in a manner so that the equivalent losses can be determined in terms of money per unit time or area. Although, timeliness is an important management factor, cash flow is even more important.

Correct matching of tractors and implements can increase efficiency of operation and farm profitability. This in turn results reduced power loss, improved operating efficiency, reduced operating costs and optimum use of capital. To establish proper matching between tractor and implement there is a need for determination of some parameters. The first parameter is determination of drawbar pull which varies with the type of soil and implement. The second parameter is drawbar power requirement of the implement which shows the power required by the tractor to pull the implement. The other parameter to be determined is the drawbar power of the tractor which gives information about the amount of power available at the tractor drawbar.

In agriculture, land preparation requires high energy through intensive tillage; so proper selection and matching of tractor with the implement based on the type of operation to be followed was crucial. This in turn requires estimation of drawbar pull of implement. Drawbar pull is the major component of forces acting on an implement being drawn by a tractor. It is an important consideration in selecting implements, and tractor sizes that are compatible with the operations. In addition to the required tractor size, implement draft could also be used to estimate the fuel required for an operation.

Drawbar power is achieved through the drive wheel to move the tractor and or implements through the soil. Drawbar power can be expressed as the product of pull and travel speed. Therefore, the ideal tractor converts all the energy from the fuel into useful work at the drawbar. In practice, most of the potential energy is lost in the conversion of chemical energy to mechanical energy, along with losses from the engine through the drive train and finally through the tractive device so estimating the availability of power at the drawbar of the tractor is also an important factor to be considered.

Tractor and implement matching is an important factor for machinery management. Well matched tractor and implement allow efficient use of resources, reduce production cost and profitability. The financial consequences of using unmatched tractor and implement combination on both fixed and variable cost are large.

Matching tractor and implement size is a major factor in land preparation cost. Properly matched tractor and implements make a good use of the available resources. This in turn results higher productivity and profit. On the contrary, improperly matched tractor implement results increased cost of production, reduced profitability, poor field performance, poor work quality, and frequent breakdowns.

The availability of drawbar pull and power requirement data of tillage implements is an important factor in selecting suitable tillage implements for a particular farming situation. But farmers are mostly depending on past experience for selecting tractors and implements for various farming operations with trial and error method. Therefore, prediction of drawbar pull requirement is important for tractor selection and implements matching. Drawbar pull data is the main input for correct matching and for better productivity.

Finally, the research was aimed to determine the drawbar pull, drawbar power, wheel slip, field capacity, and power utilization ratio analytically and experimentally showing the way how it can be reduce the operation cost by comparing the drawbar power requirement of tillage implement with the drawbar power output of the tractor. The evaluation was conducted in an experimental land in Kulumsa Agricultural Research Center with the help of Ethio-German Agricultural Training Center for Mechanization (ATC).

1.2. Statement of Problem

Selection of suitable machine and implement is a difficult problem in machinery management because it is complicated by the variety of machine types and sizes, capital investment, trained labour requirements, timeliness, farm size and possibility of using the same equipment with different speeds, width and tractive efficiencies of machines and with different crops.

Estimated data were not available which is updated in parallel with existing soil type, working depth and width. Most often farming sites depend on their experience to match tractors and implements and this may likely make the tractor to operate at less than optimum efficiency or more than what it is needed to operate.

The implement drawbar pull and power requirement is an important factor to determine tractor and machinery selection in machinery management. In our country context, commercial farming sites and farmers have no idea of these parameters; they just use trial and error method to match the tractor with the implement. This makes different types of machines became useless without completing its life span. These means there is no systematic investigation carried out to know that the implement is compatible with the tractor which leads to a poor management.

1.3. Objectives

1.3.1. General Objective

The main objective of this study was to evaluate a proper matching of tractor and implement used for land preparation.

1.3.2. Specific Objectives

- To determine the drawbar pull of Mould Board plough.
- To determine the drawbar power requirement of Mould Board plough.
- To compare the drawbar power requirement of Mould Board plough with the drawbar power output of the Massey Fergusson and New Holland tractor

1.4. Significances of the Study

This study introduces the total effect of operating depth, working width, engine speed on the drawbar pull, drawbar power requirement, power utilization ratio, field capacity of machinery and fuel consumption of tractor which in turn affects the tractor implement matching.

The drawbar power requirement of the implement in turn decides the working condition of the tractor. Thus, to make the operation of the agricultural equipment effective and efficient providing data on implement drawbar power and pull is required.

So the contribution of this study is fundamental and supportive for the farmers, commercial and private farming sites, and decision makers to take appropriate decisions on the selection of the machinery.

And since this research was done analytically it can be useful for other researches. It can be used as reference for the analytical estimation of the compatibility of tractor and implement for comparing the future researches which is going to be done using some equipment. This means it can be used to compare and prove or disprove the analytical estimation which is done using in an already developed standard.

1.5. Scope of the Study

The scope of this research was limited to examine the effect of drawbar pull and drawbar power requirement of implement on the tractor operating condition under three different operating depths and two different widths for New Holland and Massy Ferguson tractors analytically and experimentally. Then detect whether it is operating overloading or under loading condition and recommend which tractor implement combination at which working depth and width is better for the tractor work in optimal condition.

CHAPTER TWO

LITERATURE REVIEW

2.1. Mechanization

Agricultural mechanization can be defined as the economic application of engineering technology to enhance the effectiveness and productivity of human labor (Dagninet *et al.*, 2016). This includes land preparation to planting, harvesting, on-farm processing, storage, and marketing of products. The use of agricultural mechanization technology, like other inputs, can play an important role in increasing production and productivity.

It solves the problems of insufficient human and animal labor at critical points in the production cycle of commodities. It can also significantly reduce post-harvest loss and increase the availability of more food without increasing production, which is critical for agricultural transformation. Moreover, mechanization is an indispensable pillar for making farm operations efficient and productive, while also contributing to the efficiency and productivity of all the other inputs used in crop production, such as seeds, fertilizer, water, labor and time (Guush *et al., 2016*).

Creating a sustainable mechanization supply chain and developing and implementing business models for effective mechanization service provision that takes into account the needs of smallholder farmers, including women, and the different geographical area clusters is critically important to achieve the strategic goal of increasing the production and productivity of strategic and high value crop and livestock commodities (Brain *et al., 2016).*

Agricultural mechanization has the ability to significantly increase crop yields, reduce the labor needed across multiple crops and in multiple components of the mechanization value chain. Much of these practices are currently performed by draught animal power, which are not only inefficient but also give s a very less productivity. When introducing mechanized technologies, the reliance on draught animal power can be reduced, agricultural productivity can be increased, and labor can be channeled towards to other high-value adding activities and sectors (Xinshen *et al*., 2016).

Agricultural mechanization is not new to Ethiopia. While agricultural mechanization is a valuable instrument to the growth and development of agriculture, its progress in Ethiopia has been slow. According to MoA, 2014 currently there is approximately only 0.3877 kW per hectare. The farm power is calculated from current power available from oxen at 13 million head (87%), and 12,500 tractors (13%). While this index is used to show mechanization, the primary contributing factor still remains oxen power the most common implements utilized in Ethiopian agriculture are still animal-drawn implements, such as ploughs (Dagninet *et al.*, 2016).

The overall benefits of increasing agricultural mechanization are immense and wide-ranging, both on agricultural productivity, as well as overall livelihood development. According to (MoA, 2014) this range from direct benefits on smallholder agriculture to the indirect economic benefits, including: reduction in labor units and manual labor; utilizing machines can save farmers a significant amount of effort and time (time that can be invested in performing other economically and socially productive activities); mechanized devices reduce the use of inputs like seed and chemicals; using of mechanized devices was gave an enhanced quality of agricultural output by reducing postharvest loss; supporting rural employment and increasing skill diversification; supporting overall industrialization.

The advancement of agricultural mechanization in Ethiopia has faced a number of distinct challenges. These have constrained both the widespread availability of implements, and ultimately, the use of implement in agricultural production, especially in the smallholder context (Guush *et al., 2016*).

The first significant constraint has been a lack of inclusive agricultural mechanization policy and strategy and institutional capacity. The second constraint is that the land size and topography in Ethiopia is limiting to increase in agricultural productivity through increased mechanization (Nahum, 2017). The third key constraint is a lack of physical machinery available; both from domestic or international sources. This means that there are limited channels to bring agricultural machinery into the country and it has to compete against many other types of infrastructure and construction equipment. The last major constraint is farmer behavior and perception/lack of awareness of agricultural machinery (MoA, 2014).

2.2. Farm Power in Agriculture

The availability of power is a pre-requisite for any agricultural activity whether the source is human, animal or motorized. In developed countries agriculture, the general availability of virtually unlimited amounts of farm power in its different forms is almost taken for granted and comes almost exclusively from internal combustion engines or electric motors. The human is just the “brain” and control of the system.

However, in most developing countries, the human is also a major source of farm power. In developing countries there is a great variation in the proportional use of the three primary sources of farm power. In some countries there is a dynamic situation in which human and animal power is being replaced by mechanical power, but in others, farmers have to give up mechanical and animal power and revert back to human power (Clarke *et al.*, 2002).

Power is needed on the farm for operating different tools, implements and during various farm operations. While mobile power is used for doing different field jobs, the stationary power is used for lifting water and operating irrigation equipment; operating threshers, shellers/decorticators, cleaners, graders and for other post- harvest operations.

The mobile farm power comes from human, draught animals, power tillers, tractors; whereas the stationary power is obtained from oil engines (diesel, petrol, and kerosene) and electric motors (Srivastava, 2003). Availability of adequate farm power is very crucial for timely farm operations for increasing production and productivity and handling the crop produce to reduce losses. With the increase in intensity of cropping the time is drastically reduced and it is not possible to harvest and thresh the standing crop, on one hand, and prepare seedbed and do timely sowing operations of subsequent crop, on the other hand, in the limited time available, unless adequate farm power is available.

Similarly for precision farming, increasing area under irrigation, conservation tillage, straw management and diversification in agriculture, more power is required for water lifting and precision placement/application of agricultural inputs seed, fertilizer, irrigation water, plant protection chemicals etc and meeting the requirements of diversified agriculture. There has been close nexus between farm power availability and increased productivity. Those states where availability of farm power is more have, in general, higher productivity as compared to others. The variations in the trend of productivity in few states are because of the variations in crops grown and the rainfall pattern in those states (Dagninet *et al.*, 2016).

2.3. Sources of Farm Power

The different sources of power available on the farm for doing various mobile and stationary operations are Human (men, women, children), Draught animals (bullocks, buffaloes, camels, horses and ponies, mules and donkeys). The power available from draught animals is related to its body weight. The maximum draft available from different animals, in sustained working, on whole day basis (in two shifts) using local yokes/harnesses have been found as under: Bullocks: 10-12% of body weight in summer and 12-14% in winter , Buffaloes: 12% of body weight in all seasons, Camels: 18% of body weight up to 7 h, 26% up to 6 h following 2 h work + 2 h rest schedule, Donkeys: 32% of body weight up to 6 h and 36% up to 4 h in two shifts (Singh, 2003). Mechanized sources like tractors, power tillers, and self-propelled machines like combines, dozers, reapers, and sprayers are under mobile power. Diesel/oil engines, Electric motors under stationary power.

Table 2.1. Sources of power for land preparation (% of total)

	Human power	Draft animal power	Mechanical power
Sub-Saharan Africa	65	25	10
East Africa	40	40	20
South Asia	30	30	40
Latin America	25	25	50

Source: FAO, 2006.

2.3.1. Mechanical Power

It is available through tractors, power tillers and oil engines. The oil engine is a highly efficient device for converting fuel into useful work. The efficiency of diesel engine varies between 32 and 38%, whereas that of the carburetor engine (Petrol engine) is in the range of 25 and 32%.In recent years, diesel engines, tractors and power tillers have gained considerable popularity in agricultural operations (Nelson, 2015). In Ethiopia further disaggregation by region shows that using mechanical source of power is most common in Oromia than other regions. Using machines to plough land, harvesting and threshing are more common in Oromia (Guush *et al., 2016*).

Table 2.2. Households using agricultural machinery, in percent

Region	Farmers No.	For any operation	For ploughing	For harvesting	For threshing
Tigray	603	9.1	8.3	0.5	0.7
Amhara	1656	7.4	5.7	1.6	0.1
Oromia	2111	11.5	4.1	7.1	5.6
SNNP	1599	7.7	6.2	1.6	0.0
Full sample	5969	9.1	5.5	3.4	2.1

Source: Guush *et al., 2016*

According to the figure below in the north Africa and Latin American have a better utilization of tractors on the other hand sub-Saharan Africans and East Asian uses human or hand source of power to cultivate their land (Clarke *et al.*, 2002).

The improvement in agricultural production is the prerequisite for the overall development of our country which depends not only on the availability of improved seeds and fertilizers but also on the timeliness of the completion of crucial agricultural operations, workability and quality of operation.

By introducing modern practice of rational farming and improved implements, which best suit the needs of farmers, the whole farming operation can be placed in a better position to meet the local food and fiber requirements with significant surplus for foreign exchange and agro-industries. In this regard, the introduction of mechanical power sources can play a significant role in increasing agricultural production and to remove drudgery from farm operations so that rural educated youth do not run to urban areas in pursuit of jobs which are already in short supply.

Agricultural mechanization aims to sustainable agricultural production by bringing lands under cultivation, saving energy and other resources, protecting the environment and increasing the overall economic welfare of farmers. Thus developing appropriate mechanization technology improve production and productivity, reduce the huge production losses and it has a great contribution to food security. Moreover mechanization can conduct agricultural production through proper use of animate and inanimate energy and improved implements.

2.4. Machinery Matching with Power Sources

Selecting machine size involves fitting the proper sized equipment to the amount of work for a given period of time. Lowering the field efficiency would decrease the effective capacity, on the other hand increasing capacities means a direct cost saving, so, always to be thinking of ways to improve field efficiency (Nagat, 2004).

Wrong decision in acquiring machinery can have huge negative effect on both fixed and variable expenses (Mirko *et al., 2014*). Machine and equipment are major inputs to agriculture, the effective use and application of these inputs to farm production is one of the management tools to maximize farm production and profit. Farm power is important in agriculture for timely field operations carried by operating different types of dynamic farm equipment and for stationary jobs. Availability of adequate farm power is very crucial for timely farm operations for increasing production and productivity and handling the crop production to reduce losses (Srivastava, 2004).

In the past, misunderstood concepts and inappropriate selection and use of certain mechanization inputs mainly tractors and heavy machinery in many parts of the world, lead to heavy financial losses and lower agricultural production as well as environmental degradation (Tajudeen *et al., 2010*). At recent years, the agricultural sector has increasingly focused on the ability of the farmers to make their available resources as productive as possible with in market, environment and other regulatory constraints (Omer *et al., 2016*).

Under more complicated economic conditions available tractors, machinery and equipment, its purchase price, crops to be grown and marketing factors create some questions for decision-making. How much power, number of tractors, and tools required; for these reasons and others, technical understandings needed for bringing quick solutions (Omer *et al., 2016*). A careful approach to matching implements and tractors can increase efficiency and cut costs for farmers. Implement matching involves an attempt to balance the characteristics of a load application unit and a power unit, which is usually a tractor (Subrata *et al.,* 2015). The matching process is something, farmers often do sub-consciously but this method can be improved. Any improvements that can be made substantially affect farm performance. In order to make the right choice of tillage machinery it is necessary to have enough information about drawbar pulls for certain types of soil (Alimardari *et al.,* 2008). Correct matching of machinery should result in increased efficiency of operations, less operation costs and optimum use of capital on fixed costs (Powell, 2000).

Choosing the right machinery complement is complicated by many factors: changing weather conditions, non-uniform farm soils and the frequent need to reconsider farm policies and cropping patterns. Further complications come from the wide range of machinery types and sizes increasingly made available to the farmer. On the other hand, the number of crops in a rotation, different tillage systems, different land size for different crops and the use of the same implement with different speeds, depths and tractive efficiencies complicate as well the selection of machinery (Omer *et al.,* 2005).

To determine how large a machine is needed it is necessary to determine capacity to complete the specific operation within the period available, and to estimate the correct working hours during that period. However, keeping an accurate record of days and hours of work help to provide an average figure for planning operations. A tractor properly matched to an implement provides a “system” that performs at maximum efficiency. When determining an appropriate balance (match) between tractor and an implement, consideration must be given to various factors like area to be covered (ha), working speed (kmph), working hours, estimated field efficiency (percentage), width of machine (working width, m), power requirements for implement to be used (kW) (Hoggart, 2001).

On the other hand when selecting power required there are some factors to be considered like engine type, power rating, and soil resistance to machines, tractor size, and sizing for critical work. The rating power source is obtained from the conversion of the energy contained in the fuel by combination process this rating power can be in form of drawbar pull, horizontal power for PTO relative power (Summer *et al.*, 2007).

Proper matching of implements with tractor and the performance evaluation of the combination is very much important to minimize the expenditure in farming operations. To obtain a suitable implement according to tractor horsepower, implement size plays an important role. An improper matching of tractor-implement combination results in under loading of engine and hence poor efficiency and higher operating costs. Implements that are too large for the horsepower available can cause overload, excessive tire slippage, increase in fuel consumption and unsatisfactory performance in general. Implements that are too small results in inefficient operations, low production and increased cost (Subrata *et al.,* 2015).

2.5. Drawbar Pull

Drawbar pull refers to the force required to pull an implement in the horizontal direction of travel (Tajudeen *et al.,* 2010*)*. Drawbar pull is the force required to propel an implement in the direction of travel (ASABE, 2006). It is primarily a function of the implement width and the speed at which is pulled. The most commonly used equation for validation of the values obtained for draft of moldboard plough is in accordance with ASABE Standard D497.6 (ASABE, 2009).

$$D = F_i \left[A + B(S) + C(S)^2 \right] WT \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2.1]$$

Where: D = drawbar pull, N;

F = a dimensionless soil texture adjustment parameter;

i = soil factor and it is = 1 for fine, 2 for medium and 3 for coarse texture soils;

A, B & C = machine – specific parameters referred from ASABE table appendix table 1;

S = forward speed, km/h;

T = tillage depth, cm;

W = machine working width, m

Measuring of drawbar pull for specific soil conditions is important for the assessment of an agricultural machine. Measuring of drawbar pull of different implements provides useful information on power requirements for different tillage and different management systems in field (Naderloo *et al.,* 2009). The availability of data on the drawbar pull requirement of tillage implements is also an important factor while selecting suitable tillage implements for a particular farm situation. Data available on drawbar pull during tillage in different soil conditions can help farmers make rational choices about tractors and tillage machines and their efficient exploitation (Alimardani *et al.,* 2008; Kheiralla *et al.,* 2003). Farm managers and consultants use draught and power requirement data of tillage implements in specific soil types to determine the size of tractor required and to calculate the cost and energy requirement of different tillage implements (Sahu *et al.,* 2006).

Drawbar pull affects the energy requirement of tillage implements. It reflects the soil physical conditions and the degree of compaction of agricultural soils. For unique soil type, ploughing speed and implement design, drawbar pull varies with soil bulk density, soil moisture content and ploughing depth. These influencing factors are the main axis of interest of previous research, adapting field experiments to understand how these factors affect the drawbar pull of tillage implements (Mouazen *et al.*, 2002*)*.

Drawbar pull and power requirements are important parameters evaluating performance of tillage implements and are therefore considered as essential data when attempting to correctly matching tillage implements to a tractor (Naderloo *et al.*, 2009). Machine selection and sizing require an estimation of power requirements of the implement the lack of information about implement performance forces the farmer to rely on past experience for selection of tractors and implements. For tillage tools operated at deeper depths, drawbar pull depends on soil texture, tillage depth, and geometry of the tool in addition to implement width and the speed.

2.6. Drawbar Power

The primary purpose of agricultural tractors, especially those in the middle to high power ranges, is to perform drawbar work (Ahaneku *et. al.*, 2011). Since drawbar is the most commonly used power outlet of a tractor, the ability to provide draft to pull various types of implements is a primary measure of the effectiveness of a tractor. Drawbar work is achieved through the drive wheel to move the tractor and its implements through the soil (Mirko *et al.*, 2014).

The value of a tractor is measured by the amount of work accomplished relative to the cost incurred in getting the work done. The ideal tractor converts all the energy from the fuel into useful work at the drawbar. Drawbar power is the power that actually available at the tractor drawbar which is ready to transmit to the implement (Faleye *et al.*, 2014). It is required to pull a tillage implement as a function of travel speed and drawbar pull of implement.

However, due to power losses, not all fuel energy is converted into useful work (Grisso *et al.*, 2010). In practice, most of the potential energy is lost in the conversion of chemical energy to mechanical energy, along with losses from the engine through the drive train and finally through the tractive device (Zoz *et al.*, 2003). This is the power that the tractor should be able to provide at the drawbar (Mehta *et al.*, 2010). Drawbar horse power is the power available for moving a load through the field the flywheel power is reduced by losses as the power is transmitted through the transmission, differential and final drive gears. There are further drawbar losses caused by slippage over ballasting and operating on inclined fields (Cherinet, 2011). According to ASABE Standard D497.6 (ASABE Standards, 2009) the drawbar power requirement of the implement can be calculated as the equation below,

$$P_{db} = \left(\frac{D \times S}{3.6}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2.2]$$

Where: P_{db} = drawbar power (kW)
D = Drawbar pull (kN)
S = travel speed (km/ h)

Power requirements

Efficient machinery performance includes the selection of implements that neither over loaded nor failed to use adequately the power available from a tractor. A power requirement for any operation is affected by some factors, and these are:

a) Effect of soil type and condition

The power requirements machine depends on soil and crop condition, which are highly variable. In addition to soil type, tillage draft of ploughs is increased if the soil is either too wet or too dry and if the soil is tilled, firm or soft.

Table 2.3. Effect of soil condition on machine performance

Condition of soil	Usable DB hp as % of maximum PTO hp	Ratio of maximum PTO hp to usable DB hp
Firm	67%	1.5
Tilled	56%	1.8
Soft or sandy	48%	2.1

Source: Nagat (2004)

b) Effect of forward speed

Forward speed causes significant variations in plough draft. The forward speed can be determined by dividing the distance travel it’s time taken to travel the distance. Quite often a force instead of a power requirement is reported to remove the effect of variations in forward speed. The variations due to different sizes of implements are removed by reporting draft per unit of effective width. Both speed and size variations are eliminated when terminal work or energy requirements are quoted. Saed *et al.,* (2015) concluded that increase of forward velocity results in increase of implement draft, wheel slippage, drawbar power and overall energy efficiency but results in decrease of traction efficiency.

c) Effect of ploughing depth

Variations in ploughing depth depend on: unevenness of the ground surface, soil strength variations, ploughing speed variations, presence of stones and strong roots in the soil. (Al-Suhaibani, 2010) Concluded that draft requirement of an implement increased with operational depth of the implement is increased.

2.7. Slip

Wheel slippage in tractors has always been one of the main efficiency factors affecting fuel consumption of tractors. A tractor working at its highest level of efficiency does not only cut down fuel cost but, generally, also makes maximum use of time and money. Agricultural tillage involves soil cutting, soil turning, and soil pulverization which thus, demands high energy, not just due to the large amount of soil mass that must be moved, but also due to inefficient methods of energy transfer to the soil (Ahaneku *et al*., 2011).

Tractor performance is influenced by traction elements, soil conditions, implement type, and tractor configuration (Zoz *et al.,* 2003). The soil moisture content, bulk density, soil texture and shear strength contribute to tillage energy requirement (Olatunji *et al.,* 2009). It is known that the resistance of ploughs and energy requirement for ploughing depend on the plough body parameters and soil properties such as hardness, density, friction and adhesion (Aday, 2011, Vilde., 2004).

Operations that involve machinery traffic and soil engaging tools, such as tillage and planting, on agricultural soil are considered tractable. If it can develop adequate shear resistance to minimize wheel slip and soil damage (Ani *et al.,* 2004). By decreasing soil moisture content, net traction of tractor decreased and resulted in reduced rolling resistance. The rolling resistance of wheel can increase by reduction of some key soil parameters (Fenyvesi *et al.*, 2002). Furthermore, increasing the ploughing depth also increases the friction between the tire and soil interface which, changes the slicing forms of soil that, in turn, causes the percentage increase in rolling resistance, wheel slip and fuel consumption (Zoz *et al.*, 2003 *and* Soltani *et al.*, 2007).

Tractive efficiency is a measure of the ability of the tractor to transfer power from the axle to the drawbar through the tire and soil interface. This implies that tractive efficiency depends on wheel slip, soil and tire conditions as well as drive configurations. Wheel slip might be considered higher for primary tillage than in secondary tillage operations due to the depth of the two different tillage implements (Inchebron *et al.*, 2012).

According to (ASABE, 2003) slip was calculated

$$S = \left(\frac{A_n - A_1}{A_n}\right)100 \qquad [2.3]$$

Where: S = slip, percent;

A_n = the advance distance under no load conditions per revolution, m;

A_1 = the advance distance under actual load conditions per revolution, m.

2.8. Capacity

2.8.1. Machine Capacity

The capacity of a machine is its rate of performance, and usually measured in terms of quantity per time, area per time or quantity per area. Differences in crop yields and crop conditions can mean that one machine may have a low area per hour capacity but a high mass per hour capacity when compared with an identical machine in a different field. In this case, a valid comparative capacity would be mass per hours.

One method for measuring machine capacity is the field capacity. It is measured in area per time or tons per time. The field capacity is determined by three factors: speed, width, efficiency.

2.8.2. Field Capacity

Calculating field capacities is just part of the overall concept of farm machinery management. Successful farm machinery management does not guarantee a profit, but machinery costs are a major expense and they must be monitored and managed. Therefore, the efficient use of farm machinery starts with determining working capacity in conjunction with the amount of work to be accomplished in a timely manner (Mark Hanna, 2016).

The term capacity means the amount of work that can be performed. The measures of capacity for agricultural machines are theoretical field capacity, effective field capacity and material capacity. Field capacity is measured in hector per hour. The effective field capacities should be used to size your machinery, given the amount of time or good field days available to accomplish the specific task.

2.7.2.1. Theoretical Field Capacity

Theoretical field capacity (TFC) is a simple calculation involving speed and width with efficiency set at 100% (Cherinet, 2011). It is impossible to maintain the theoretical field capacity of a machine over long periods of time. Interruptions such as turning, filling seed hoppers and breakdowns cause severe reductions in theoretical field capacity.

$$\mathrm{TFC} = \frac{\mathrm{W} \times \mathrm{S}}{10} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2.4]$$

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

W = width of machine/implement (m)

S = speed of operation (km/h)

The theoretical field capacity can be used as a benchmark for evaluating the performance of a machine or operator because it is the maximum capacity attainable at a given speed. The machine cannot operate at its theoretical capacity at all times while it is in the field due to the following factors: Turning and idle travel, operating at less than full width, cleaning clogged equipment, machine adjustment, lubrication and refueling during the day, waiting for other machines, waiting for repairs to be made.(Hancock *et al.*, 1991)

2.7.1.2. Effective Field Capacity

The effective field capacity is the measure of a machines ability to do a job under actual field conditions. It is the actual output achieved by a machine. It is a function of the proportion of the machine width utilized, the travel speed and the amount of time lost in the field during the operation. Time is lost to implement blockages, working areas such as headlands more than once, adjustments, checking and minor repairs and excludes daily servicing requirements such as lubrication but would include the time taken to change points (Subrata *et al.,* 2015).

The effective field capacity (EFC) is a more usable measure because it brings in the factor of efficiency. According to (Mehta, 2010) the EFC can be calculated by dividing the area covered with theoretical field capacity or by multiplying the theoretical field capacity with field efficiency.

$$\mathrm{EFC} = \frac{\mathrm{W} \times \mathrm{S}}{10} \times \eta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.5]$$

Where: EFC = theoretical field capacity (ha/h)

W = width of machine/implement (m)

S = speed of operation (km/h)

η = Field efficiency

2.9. Fuel Consumption

Ability to predict tractor fuel consumption is very useful for budgeting and management. Depending on the type of fuel and the amount of time a tractor or machine is used, fuel and lubricant costs usually represent at least 16 percent to over 45 percent of the total machine costs. Thus, fuel consumption plays a significant role in the selection and management of tractors and equipment used in agriculture (Robert *et al.*, 2014).

Fuel consumption is measured by the amount of fuel used during a specific time period. The primary tillage operations require 75% of the total energy spent before the seed-time (Tarig *et al., 2008*). There are many sources for energy, fuel energy represents on essential role in power production which is needed for agricultural production (Grisso *et al.*, 2006).

The speed of operation, width of cut, depth of cut, type of soil, and skill of operator affects fuel consumption. The normal range for the overall energy efficiency (OEE) is 10% to 20% and this can be used as a quick check of the validity of fuel consumption measurements, where energy is the specific implement energy and fuel is the fuel consumption under load (Mahmood *et al*, 2014).

According to ASABE Standards (2006, 2009) are widely used for estimating fuel consumption for budget preparations. The most widely used relationship for estimating diesel fuel consumption in gallons per hour (gal/h) is by multiplying rated PTO power with 0.305 and it can be calculated using the power utilization ratio.

According to ASABE EP 496.2, (2003) the average gasoline fuel consumption can be calculated;

$$Q_{avg} = 0.305 \times P_{pto} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2.6]$$

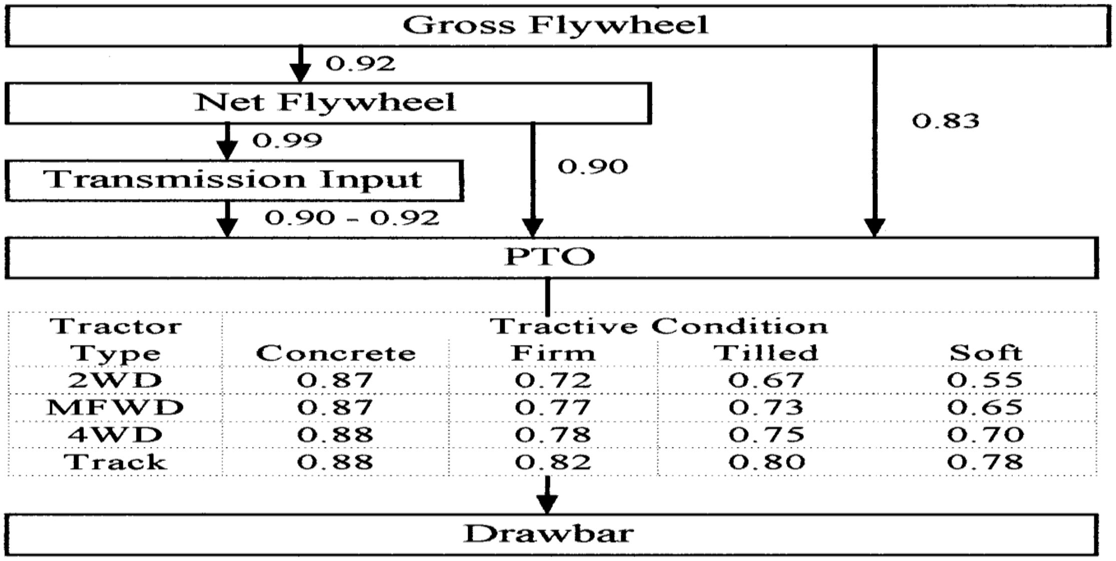
It is also stated that a diesel tractor will use approximately 73% as much fuel as a gasoline tractor, so Q_{avg} for diesel tractor was calculated as;

$$Q_{avg} = \left(0.305 \times P_{pto}\right) \times 0.73 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2.7]$$

Where: $Q_{avg} =$ average gasoline consumption, L/h;

Ppto is maximum PTO power required by the implement, kW;

PTO power required by the implement was estimated from the drawbar power required multiplied by tractive condition of the soil with for specific tractor type from Figure below.



Tractor Type	Tractive Condition Concrete	Firm	Tilled	Soft
2WD	0.87	0.72	0.67	0.55
MFWD	0.87	0.77	0.73	0.65
4WD	0.88	0.78	0.75	0.70
Track	0.88	0.82	0.80	0.78

Figure 2.1. Maximum mechanical power performance expected from agricultural tractors (Source: ASABE, 2000, 2003, 2006).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Description of the Study Area

This study was conducted at Ethiopia Institution of Agricultural Research, Kulumsa Agricultural Research Center (EIARKARC). It is located at 167km away from Addis Ababa with an elevation of 2200 m above mean sea level (a.m.s.l) with latitude of 8^{o}2' N and longitude of 39^{o}10' E. Kulumsa Agricultural Research Center was established in 1966 by 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. The total area of land is 442.7 hectare with agro-ecological zones which range between cool highlands to semi-arid. The minimum Average Annual temperature is 10ºC and maximum Average Annual temperature 22ºC with average annual Rainfall of 840mm.

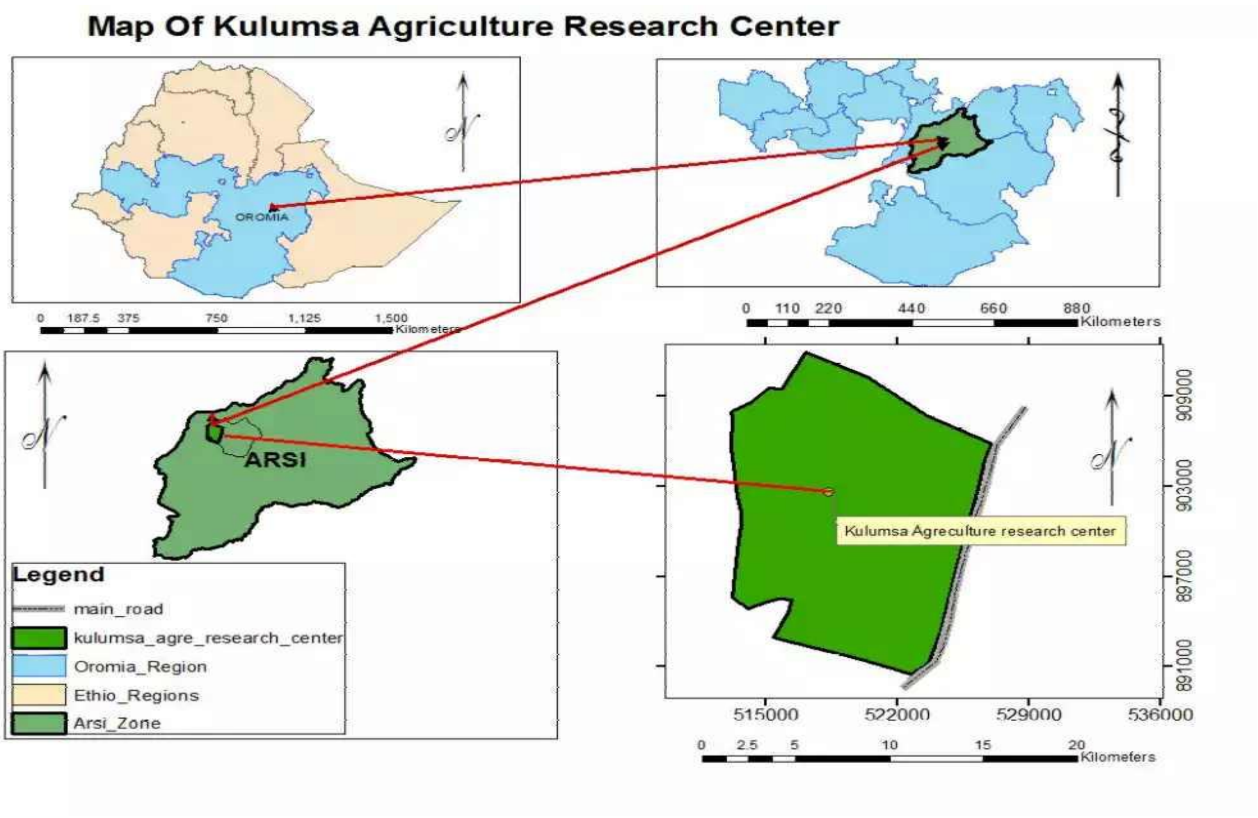


Figure 3.1. Location map of the study area

3.2. Materials

During the time that this research was carried out some resources have been used. The materials used for the study were presented as follows.

Table 3.1. Materials used during the research work.

Material	**Description**
Cylindrical core sampler	For taking undisturbed soil sample
Trimmer	For trimming soil sample edge.
Balance	For measuring the weight
Oven	For drying the soil sample
Sieve	For particle size distribution
Tractor	Massey Ferguson MF6480, New Holland TT6080
Implements	BALDAN MIS 2X.14877 Disc harrow and LEMKEN Jewel 8 slatted Moldboard plough
Timer	For counting running time of the tractor
Tape meter	For measuring running distance

3.2.1. Specification

For this research so many materials have been used. The main material specifications are shown in the table below.

A. Field Specification

The data was collected from Block 60 B GIZ Agricultural Training Center field. The field has a dimension of (210x100) m^2. The assumed run given for the tractor is 60 m and 20 m was given for calibration of the tractors. To operate with one tractor the area given is (40x60) m^2.

B. Tractors Specification

The specification of tractors is listed in the table below as follows.

Table 3.2. Specification of tractors model.

No.	Particulars	Technical details	
		MF 6480	TT6080
1	Manufacturer	Massey Ferguson	New Holland
2	Horse power	147 Hp	158 Hp
3	Overall dimension(L×W×H)	513 × 216 × 287 mm	520 × 220 × 288 mm
4	Rated speed	2200 rev/min	2200 rev/min
5	weight	6218 kg	6615 kg
6	Fuel used	light diesel	light diesel
7	Cooling system	liquid cooled	liquid cooled
8	Fuel tank capacity	265 L	300.2 L
9	Tire size	18.4R38	65R38
11	Wheel base	282 cm	289 cm

Source: Manufacturers manual (2012)

a. New Holland TT 6080 b. Massey Ferguson MF 6480

Figure 3.2. Tractors used in the field experiment

Table 3. 3. Specification of implement used in the field experiment

Implement Type	Reversible slatted mould board
Model	LEMKEN Jewel 8
Number of bottoms	4
Over all dimension (L×W×H)	300×120×83 cm
Working width	120-260 cm
Weight	870 kg

Source: Manufacturer manual (2012)

3.3. Experimental Design

For the experiment I was used two different type of tractor with mould board plough. It was done using Randomized Complete Block Design. The tractors were operated in combination with the implement at different working depth. Data was taken with 3 replication of each combination and the average was taken. The combination of tractor and implement is shown in the table below.

Table 3.4. Combination of tractor and mould board with different working depth

	$T_1MW_1N_1$	$T_1MW_1N_2$	$T_1MW_2N_1$	$T_1MW_2N_2$	$T_2MW_1N_1$	$T_2MW_1N_2$	$T_2MW_2N_1$	$T_2MW_2N_2$
D_1	$T_1MD_1W_1N_1$	$T_1MD_1W_1N_2$	$T_1MD_1W_2N_1$	$T_1MD_1W_2N_2$	$T_1MD_1W_1N_1$	$T_1MD_1W_1N_2$	$T_1MD_1W_2N_1$	$T_1MD_1W_2N_2$
D_2	$T_1MD_2W_1N_1$	$T_1MD_2W_1N_2$	$T_1MD_2W_2N_1$	$T_1MD_2W_2N_2$	$T_1MD_2W_1N_1$	$T_1MD_2W_1N_2$	$T_1MD_2W_2N_1$	$T_1MD_2W_2N_2$
D_3	$T_1MD_3W_1N_1$	$T_1MD_3W_1N_2$	$T_1MD_3W_2N_1$	$T_1MD_3W_2N_2$	$T_1MD_3W_1N_1$	$T_1MD_3W_1N_2$	$T_1MD_3W_2N_1$	$T_1MD_3W_2N_2$

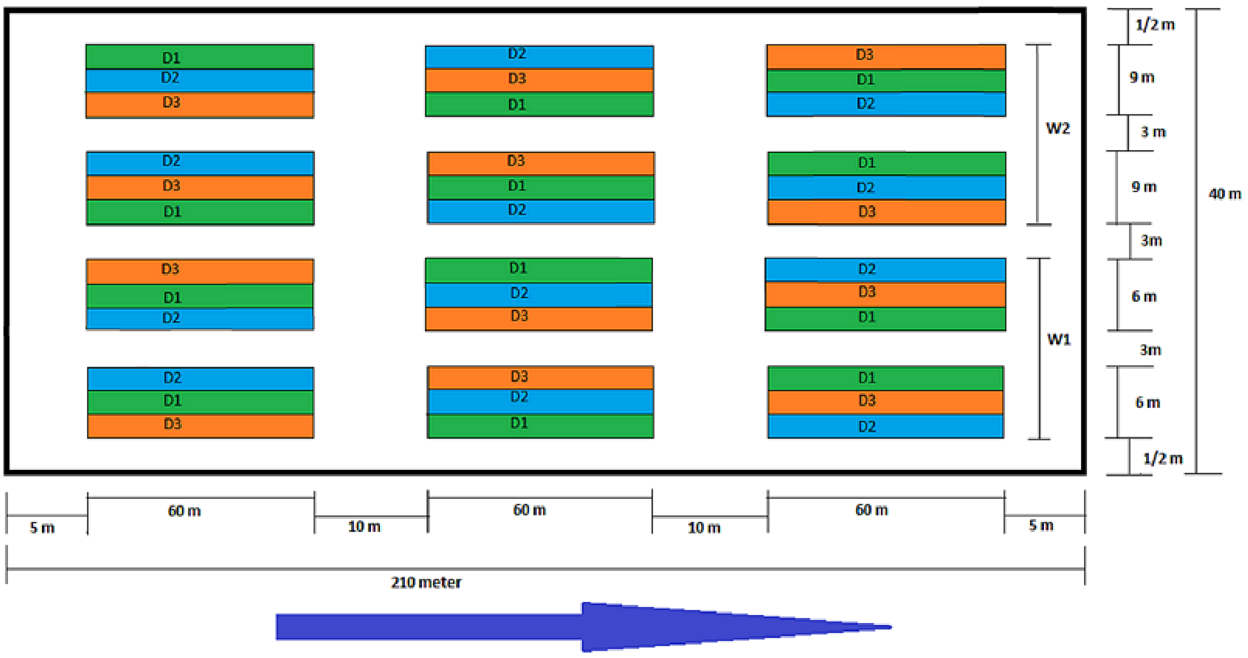


Figure 3.3. Randomized Complete Block Design layout used on the experimental field.

Note that the arrow shows the tractor running direction.

Where; T1= Massey Fergusson MF6480 tractor

T2= New Holland TT6080 tractor

M= Mould board plough

N= Engine speed

W= Working width

D1= 20 cm operating depth

D2= 30 cm operating depth

D3= 35 cm operating depth

Flow chart of the research

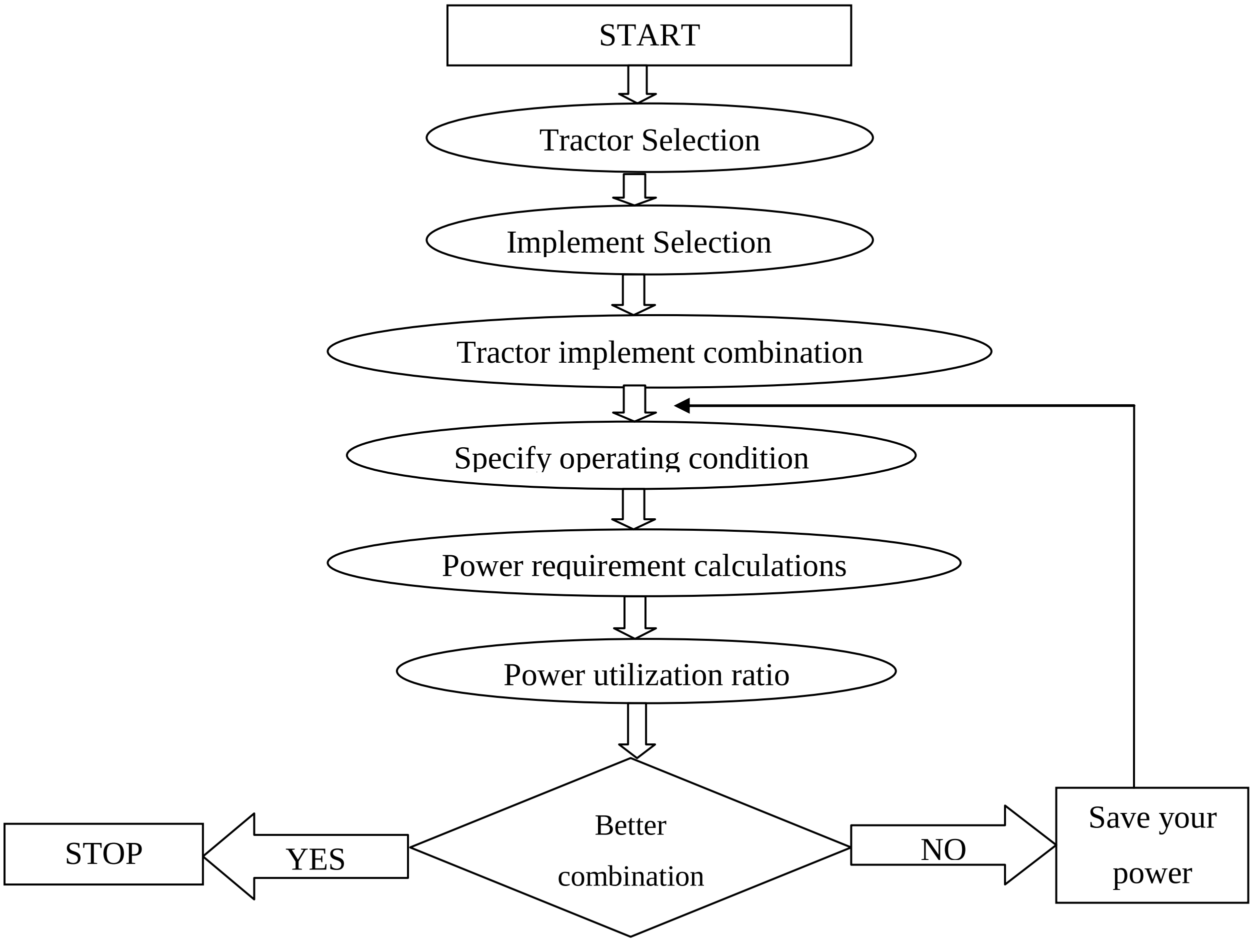


Figure 3.4. Flowchart of the overall operation process in the research

3.4. Soil Parameters Determination

3.4.1. Particle Size Distribution

Particle Size Distribution (PSD) also known as Grain-size analysis is a process in which the proportion of material of each grain size present in a given soil was determined. The grain-size distribution of mixed soils was determined by combined sieve. The percentage of material by weight retained on the various sieves can be computed as follows:

$$\text{Percent Retained} = \frac{\text{Weight in grams retained on a sieve}}{\text{Total weight in grams of oven sample}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3.1]$$

After determining the percentage of clay, silt, and sand the soil type can be determined by the USDA soil textural triangle.

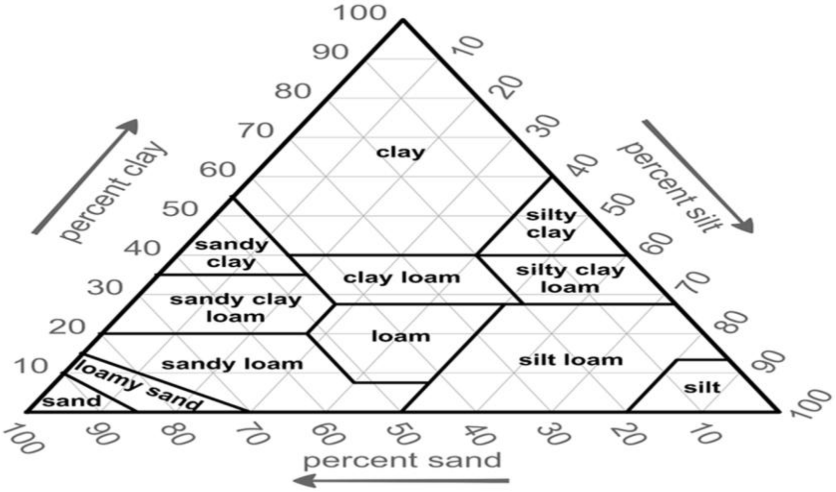


Figure 3.5. USDA soil textural triangle

3.4.2. Soil Moisture Content

The moisture content of soil was evaluated by direct as well as indirect methods (Fan and Su, 2008). The direct methods are those that involve driving away water by evaporation, leaching or chemical reaction then determine the amount of water lost.

This is accomplished by determining the weight difference of the sample, collection of the distillate or measuring the reaction products displaced from the sample. So in either case separation of water from the soil to quantify the amount present was involved. To calculate the moisture content of the soil as a percentage of the dry soil weight;

$$W = \frac{W_w - W_d}{W_d} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3.2]$$

Where; W = Moisture content, % db

W_w = Wet mass of soil, g

W_d = Dry mass of soil, g

3.4.3. Bulk Density of Soil

Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles (Ditzler and Tugel, 2002).

Bulk density is dependent on soil texture and the densities of soil mineral (sand, silt, and clay) and organic matter particles, as well as their packing arrangement. It was determined as (Javadi and Hajiahamad, 2006).

$$\rho = \frac{M}{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3.3]$$

Where; ρ = Bulk density, g/cm^3

M = Mass of the soil, g

V = Volume of the soil, cm^3

3.5. Drawbar Pull and Drawbar Power Requirement

There are two methods of determining drawbar pull and power experimental and analytical. In Experimental methods, the drawbar pull is measured using appropriate equipment's such as Drawbar pull dynamometers. In analytical methods, the drawbar pull is determined analytically by making use of already developed standard procedures as described in the ASABE (2003) and ASABE (2009). Using the ASABE Standard equations and procedures for estimation drawbar pull involves considering soil texture parameters, tillage depth, and machine – specific parameters such as traction type, implement type, and implement size.

3.5.1. Drawbar Pull

The American Society of Agricultural and Biological Engineers (ASABE) issued the standard (ASABE, 2009), for estimating the drawbar pull for different implements at different working condition. The machine- specific parameters such as A, B, and C was obtained from tables available in the issued standard. Once the implement type under consideration is known, the values for A, B and C was directly be read from the standard.

The other parameter like the soil factor “i” was determined based on laboratory analysis of the soil type on which the experiment is being carried out. After the soil textural class was determined based on laboratory analysis, the value of i = 1 for fine, 2 for medium and 3 for coarse texture soils.

Once the value of ‘i’ was determined, a dimensionless soil texture adjustment parameter F_i was referred from ASABE (2009) corresponding to the implement type. And the other parameters like working width and tillage depth was measured and calculated, based on this according to equation (2.1) drawbar pull was calculated as follows;

$$D = F_i \left[A + B(S) + C(S)^2 \right] WT$$

Where: D = drawbar pull, N;

F = a dimensionless soil texture adjustment parameter;

i = soil factor and it is = 1 for fine, 2 for medium and 3 for coarse texture soils;

A, B & C = machine – specific parameters referred from ASABE table appendix table 1;

S = forward speed, km/h;

T = tillage depth (cm) for major tools;

W = machine working width, m.

3.5.2. Drawbar Power

Once the drawbar pull have been determined, drawbar power required to pull the implement was determined using the following formula obtained from ASABE Standards EP496.2 (ASABE, 2003) by multiplying the drawbar pull by the actual travel speed and divide it with 3.6. Travel speed was taken as conventionally practiced in the site for the specific operation under consideration.

According to equation (2.2) drawbar power was calculated using the following equation;

$$P_{db} = \left(\frac{D \times S}{3.6} \right)$$

Where: P_{db} = drawbar power (kW)

D = Drawbar pull (kN)

S = travel speed (km/ h)

3.6. Slip

Tire slip occurs when the tires are turning faster than the ground speed of the tractor. Less slippage can results in the expenditure of too much fuel energy to move the wheels, whereas too much slippage can result in excessive tire spin and energy loss through the tire, which is nonproductive. Procedures that were followed to determine percent wheel slip:

- Place a mark on the tires.
- Flag or mark off a distance of some meter part way into the field
- run the tractor unloaded and measure the distance it was travel with some specified number of revolution of the tire and
- Run the tractor loaded and measure the distance it was travel with the same number of revolution as the first.

According to (ASABE, 2003) noted in equation (2.3) slip was calculated as follows;

$$S = \left(\frac{A_n - A_1}{A_n} \right) 100$$

Where: S = slip, percent;

A_n = the advance distance under no load conditions per revolution, m;

A_1 = the advance distance under actual load conditions per revolution, m.

3.7. Field Capacity

3.7.1. Theoretical Field Capacity

Theoretical field capacity consider 100% efficient tractor and according to equation (2.4) it was calculated as follows (Mehta, 2010);

$$TFC = \frac{W * S}{10}$$

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

W = width of machine/implement (m)

S = speed of operation (Km/h)

3.7.2. Effective Field Capacity

Effective field capacity was calculated in accordance with equation (2.5);

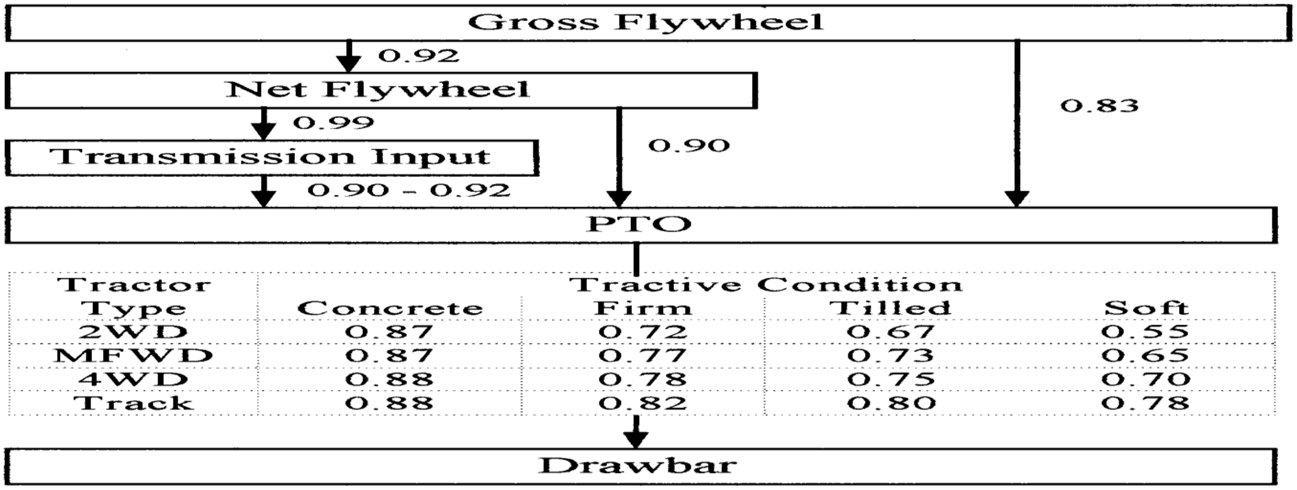
$$EFC = \frac{W \times S}{10} \times \eta$$

Where: η = field efficiency 75-85% ASABE (2003)

3.8. Tractor Available Power

Engine power is not utilized totally due to some power losses. Engine gross power output represents a particular engine’s maximum output under ideal conditions. Net flywheel power is the engine power measured at the flywheel, not counting drive train losses. Drive train loss occurs when the power is transmitted from the fly wheel to the wheel. Then there is power loss due to slip, and rolling resistance.

Then by reducing the total power loss from the total power of the tractor was obtained the drawbar power of the tractor. According to ASABE 2000 throughout the drive train, power at a given location can be used to estimate power at another location. For example, PTO power was estimated from net flywheel power by multiplying the net flywheel power by 0.90. If drawbar power is desired, choose the tractor type and tractive condition to determine the ratio from Figure below.



Tractor Type	Tractive Condition			
	Concrete	Firm	Tilled	Soft
2WD	0.87	0.72	0.67	0.55
MFWD	0.87	0.77	0.73	0.65
4WD	0.88	0.78	0.75	0.70
Track	0.88	0.82	0.80	0.78

Figure 3.6. Maximum mechanical power performance expected from agricultural tractors (Source: ASABE, 2000, 2003, 2006).

After comparing the calculated drawbar requirement of implement with the available usable tractor power the status of the current working condition of tractor can be known. If the tractor available power is much greater than the power requirement of the implement it means the tractor is working under its performance it is consuming time to finish a specific task and also consuming more fuel. If the drawbar requirement of the implement is greater than the available usable power of the tractor it means the tractor is working over its performance due to overloading and this results in high operational cost and maintenance cost because the tractor is subjected for frequent breakage.

3.9. Power Utilization Ratio

Power utilization ratio designated by X and it is the ratio between the equivalent power required by the implement and the maximum available power from the tractor. (ASABE, 2000).

$$X = \frac{\text{Equivalent PTO power required by the implement}}{\text{Maximmum available PTO power from the tractor}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3.4]$$

3.10. Data Analysis

Analysis of the drawbar pull, drawbar power, wheel slip, field capacity, power utilization ratio and fuel consumption under different operating depth, working width and engine speed were determined by the equation mentioned earlier and statistical analysis.

Data collected during field studies and parameters calculated were subjected to analysis of variance using the Microsoft excel (ANOVA) software package for statistical analysis.

CHAPTER FOUR

RESULTS AND DISCUSSION

Study was conducted to evaluate the effect of operating depth and working width on the drawbar pull and drawbar power of the implement. A number of performance measurements have been made; these included computation of drawbar pull, drawbar power, slip, power utilization ratio, and effective field capacity. The summarized results obtained are presented in table and graph, discussed and the relevant interpretations given in the following sub sections.

4.1. Soil Physical Properties

For the soil type test the soil samples were taken from 0-30cm and 30-60 cm depth. The soil textural class of the field was determined based on the particle size distribution through using USDA Soil Textural Triangle method. As indicated in annex table 3 the soil texture distribution doesn't show much variation at the study area. Clay soil was the dominant soil type found on the field which is %Clay = 53.5, %Silt = 29.8, %Sand = 19.3. The bulk density of the soil at the field was found to be 1.25g/cm^3 the moisture content is 30%.

4.2. Drawbar Pull and Drawbar Power Requirement

4.2.1. Drawbar Pull of Implement

The results of the performance tests on the two tractors are shown in Table 4.1. In both tractor models highest drawbar pull occurs when the tractors operating in 35 cm depth in 2200 RPM. New Holland TT6080 exhibited higher drawbar pull which is 63.833kN for mould board. When compared with Massey Ferguson MF6480 and it was operating engine speed 2200 and working width of 2.4m and operating depth of 35 cm. The lowest draft was recorded with Massey Ferguson MF 6480 operating with 20cm depth and 1.6 working width at 2000 RPM engine speed which is 23.32kN.

Table 4.1. Drawbar pulls of MF6480 and TT6080 operating with mould board

	T1				T2			
	N1		N2		N1		N2	
	W1	W2	W1	W2	W1	W2	W1	W2
D1	23.32	36.5	24.169	36.035	25.34	38.17	25.52	38.514
	23.81	34.8	23.995	35.532	23.67	35.15	25.3	37.416
	24.26	35.4	23.743	35.411	25	36.94	24.8	37.174
D2	36.2	53.9	36.035	53.733	37	55.4	37.32	55.76
	34.15	51.21	35.614	53.421	34.96	52.19	37.08	55.124
	35.6	53.4	35.183	52.529	36.25	54	37.05	55.02
D3	39.31	60	40.636	**61.284**	43.1	**63.8**	42.8	**63.833**
	39.53	58.1	40.38	60.664	40.21	60.32	42.3	63.443
	40.44	60.6	40.317	60.167	41.7	62.11	41.8	62.726

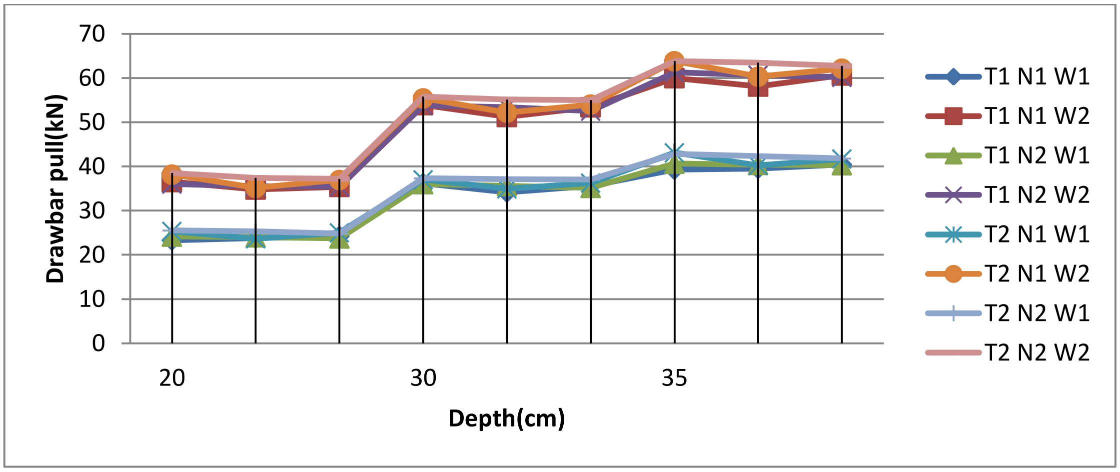


Figure 4.1.Relationship between drawbar pull and working depth mouldboard plough.

4.2.2. Drawbar Power of Implement

Drawbar power is a function of draft and speed. The results of the performance tests on the two tractors are shown in Table 4.2. Since a large pull and high speed results in a large drawbar power, New Holland TT6080 exhibited higher drawbar power which is 81.52 and 81.564 kW operating at engine speed 2000 and 2200 RPM respectively and working width of 2.4m and operating depth of 35 cm for mould board plough. In the same vein the lowest drawbar power was recorded with Massey Fergusson MF 6480 operating at 2000 RPM engine speed which is 25.13 for mould board.

Table 4.2. Drawbar power of MF6480 and TT6080 operating with mould board

	T1				T2			
	N1		N2		N1		N2	
	W1	W2	W1	W2	W1	W2	W1	W2
D1	25.13	46.64	30.21	44.043	37	56.19	37.86	58.09
	28.11	44.1	29.19	41.06	27.3	38.76	36.6	51.967
	30.73	39.9	27.7	40.33	35	49.25	33.76	50.598
D2	44.95	65.3	44.04	64.18	50	73.87	51.42	76.895
	32.4	48.5	41.55	62.32	37.6	54.8	50	72.27
	41.5	62.3	38.94	56.91	45.31	65.7	49.92	71.678
D3	34.2	58.5	42.9	66.39	57.47	**81.52**	55.9	**81.564**
	35.69	45.5	41.28	62.52	40.21	60.32	52.87	79.303
	41.68	62.3	40.54	59.33	58.32	71.42	49.9	75.097

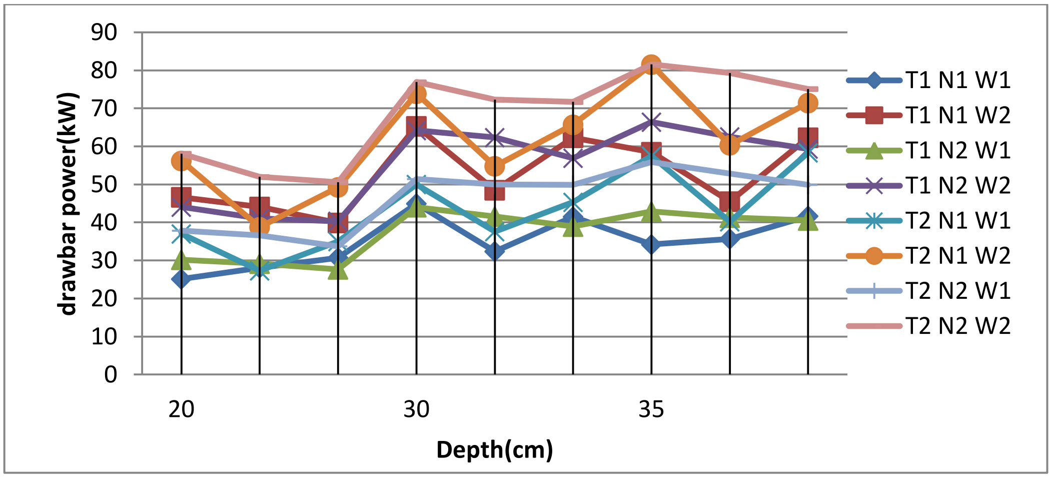


Figure 4.2. Relationship between drawbar power and working depth in mould board plough.

4.3. Slip

Travel reduction affects the traction efficiency of any tractive device. Table 4.3 presents the results of the travel reduction emanating from the field test of the two tractor models. Then the results shows that New Holland Tractor model TT6080 consistently gave the highest values of travel reduction or wheel slip of 20.8% at 35 cm depth and 2.4 m widths at 2000 RPM and lowest slip also occurs with the same tractor while operating with 2000 RPM engine speed and 20 and 30 cm depth with working width 1.6 m and 2.4 m respectively.

Table 4.3. Wheel Slip of MF6480 and TT6080 operating with mould board

	T1				T2			
	N1		N2		N1		N2	
	W1	W2	W1	W2	W1	W2	W1	W2
D1	2.44	2.44	8.62	4.76	2.08	2.5	5.5	8.57
	4.88	7.32	8.33	7.14	6.25	10.4	6.7	11.42
	7.32	14.63	7.9	11.4	14.3	16.67	7.35	12.45
D2	2.44	4.88	12.6	7.14	3.12	2.08	7.75	8.98
	9.76	9.76	11.9	8.34	10.4	12.5	8.36	9.8
	14.63	14.63	11.1	13.8	16.67	**18.75**	8.37	11.8
D3	4.88	7.32	12.25	9.52	2.04	4.16	11.84	12.86
	9.76	12.2	11.8	10.5	12.5	12.5	12.04	13.06
	17.07	17.07	11.58	14.3	**18.75**	**20.8**	12.86	13.88

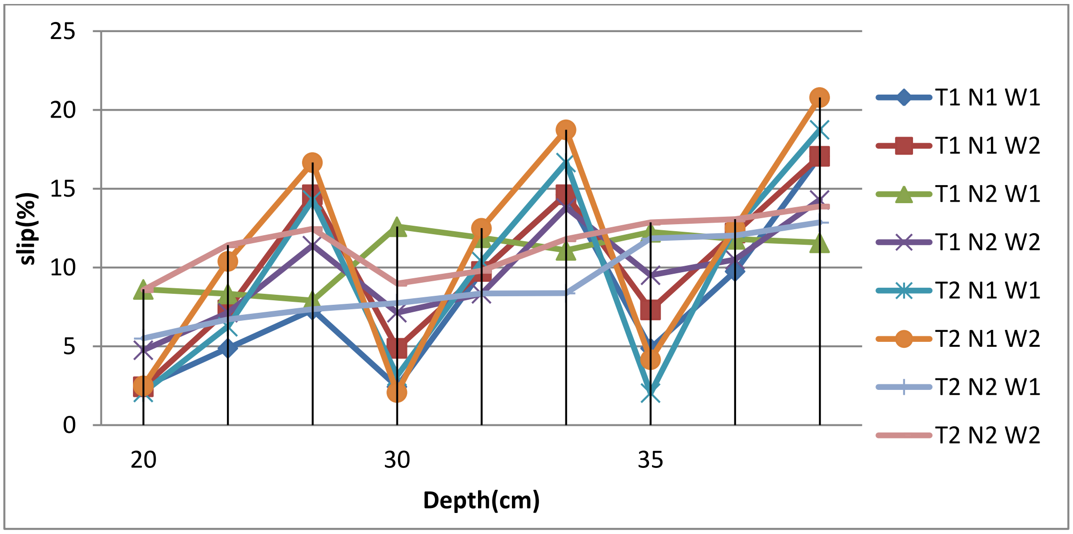


Figure 4.3. Relationship between wheel slip and working depth of mould board plough.

4.4. Field Capacity

The field capacity of a machine is a function of its width, speed and efficiency of operation. The data regarding these parameters is presented in Table 4.4. Both Massey Ferguson tractor model MF 6480 and New Holland model TT6080 shows a better field capacity when operating at 2.4 meter working width in all 20 and 30 cm operating depth with both 2000 and 2200 RPM engine speed. New Holland tractor model TT6080 shows highest field capacity at when it was operating with 2200 RPM and 2.4 meter working width in all depths when it is compared with the MF 6480.

Table 4.4. Field capacity of MF6480 and TT6080 operating with mould board

	T1				T2			
	N1		N2		N1		N2	
	W1	W2	W1	W2	W1	W2	W1	W2
D1	0.53	0.94	0.612	0.9	0.71	**1.08**	0.73	**1.1**
	0.58	0.77	0.595	0.85	0.56	0.79	0.71	1.02
	0.62	0.83	0.57	0.84	0.68	0.98	0.67	0.99
D2	0.61	0.89	0.598	0.88	0.66	0.98	0.67	0.99
	0.46	0.69	0.57	0.86	0.53	0.77	0.66	0.963
	0.57	0.86	0.542	0.8	0.61	0.89	0.66	0.96
D3	0.42	0.72	0.517	0.8	0.65	0.94	0.64	0.94
	0.44	0.57	0.5	0.75	0.49	0.73	0.61	0.92
	0.5	0.75	0.49	0.72	0.58	0.84	0.58	0.88

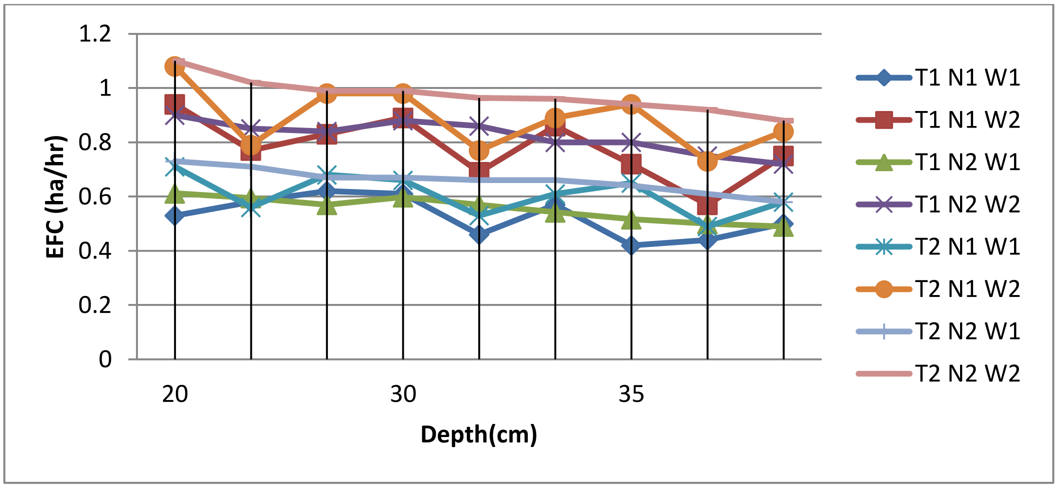


Figure 4.4. Relationship between field capacity and working width of mould board plough.

4.5. PTO Power

4.5.1. Tractor Available Power

Based on the figure provided in the figure 3.4, PTO power was estimated from net flywheel power by multiplying the net flywheel power by 0.90 based on the ASABE 2006. Then Massey Ferguson have a PTO power 132.3 hp or 98.7 kW and New Holland tractor have a PTO power is 142.2hp or 106.1kW

4.5.1. Implement Power Requirement

Based on the figure provided in the figure 3.6, PTO power was estimated from Drawbar power by dividing the drawbar power by 0.78 based on the ASABE 2006. Then the result presented in the table below.

Table 4.5. PTO power requirement MF6480 and TT6080 operating with mould board

	T1				T2			
	N1		N2		N1		N2	
	W1	W2	W1	W2	W1	W2	W1	W2
D1	32.22	59.8	38.73	56.5	47.4	72.04	48.54	74.47
	36.04	56.54	37.42	52.64	35	49.7	46.92	66.624
	39.4	51.15	35.5	51.7	44.9	63.14	43.28	64.87
D2	57.63	83.72	56.5	82.3	64.1	94.7	65.92	98.58
	41.54	62.2	53.27	80	48.2	70.26	64.1	92.654
	53.2	79.9	49.9	73	58.1	85.23	64	91.895
D3	43.85	75	55	85.1	73.1	**104.5**	71.67	**104.57**
	45.76	58.34	53	80.15	51.6	77.34	67.78	101.67
	53.43	79.9	52	76.1	74.8	91.56	63.97	95.28

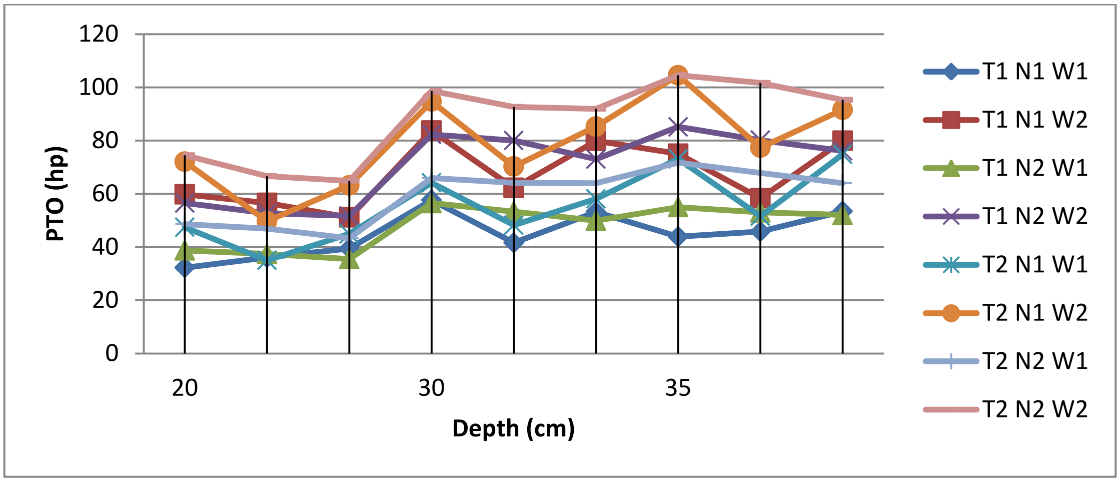


Figure 4.5. Relationship between PTO power requirement and depth of mould board plough

4.6. Power Utilization Ratio

Since the power utilization ratio means the ratio between the PTO power requirement of the implement and the power available in the tractor drawbar the results are presented on the table 4.6 the highest power utilization occur when the New Holland tractor is operating in 2.4 working width and 35 cm operating depth at 2200RPM. The lowest PUR occurs when the Massey Ferguson operates in 1.6 m working width and 20 cm operating depth at 2000 RPM.

Table 4.6. Power utilization ratio of MF6480 and TT6080 operating with mould board

	T1				T2			
	N1		N2		N1		N2	
	W1	W2	W1	W2	W1	W2	W1	W2
D1	32.6	60.6	39.24	57.2	44.7	67.9	45.75	70.2
	36.5	57.3	37.9	53.3	33	46.8	44.2	62.8
	39.9	51.8	36	52.4	42.3	59.5	40.8	61.1
D2	58.4	84.8	57.2	83.4	60.4	89.25	62.1	92.9
	42.09	63.02	54	81	45.4	66.2	60.4	87.3
	53.9	80.95	50.5	74	54.75	80.32	60.3	86.6
D2	44.43	76	55.7	86.2	69	98.5	67.55	**98.56**
	46.4	59.1	53.7	81.2	48.6	73	63.9	95.8
	54.1	80.9	52.7	77.1	70.5	86.3	60.3	89.8

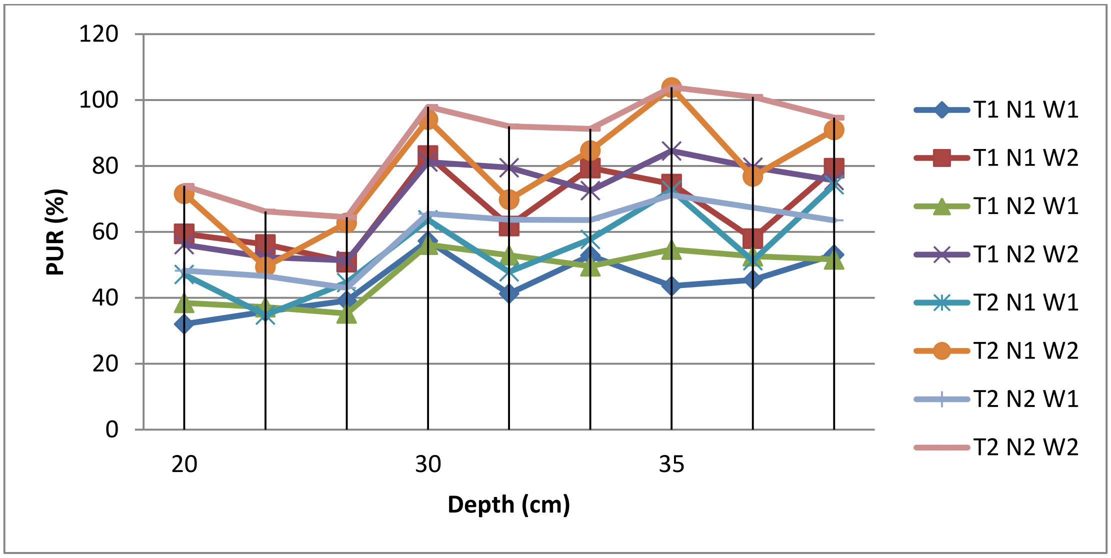


Figure 4.6. Relationship between PUR and operating depth mould board plough

4.7. Statistical Analysis of Parameters

4.7.1. Mouldboard Plough

The analysis of variance (Table 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.17, 4.18) showed that there were no significant interactions between working width*engine speed, operating depth*engine speed, on the drawbar pull, drawbar power, slip, field capacity of machinery, power utilization ratio and fuel consumption of tractor.

The analysis of variance in Table 4.7 and 4.8 showed that working width, operating depth and the interaction between working width and operating depth was significant effect ($p<0.05$)on drawbar pull for both Massey Ferguson 6480 and New Holland TT 6080 respectively. The analysis of variance in Table 4.8 and 4.9 also showed that engine speed, the interaction between engine speed (N) and working width, engine speed and operating depth was no significant (P>0.05) effect on drawbar pull for both Massey Ferguson 6480 and New Holland TT 6080 respectively.

Table 4.7. ANOVA Table of drawbar pull for Massey Ferguson 6480

Source	SS	df	MS	F	P-value
Rep	2.70123	2	1.350615	9.574498	0.109166
D	1319.888	2	659.9442	618.6731	3.93E-13
W	1216.867	1	1216.867	4032.147	1.24E-13
N	0.965391	1	0.965391	1.570453	0.436036
D*W	54.61108	2	27.30554	93.55337	1.33E-05
N*W	0.055468	1	0.055468	0.093931	0.819334
D* N	0.542559	2	0.271279	0.411441	0.673931
Error	14.50699	24	0.604458		
Total	5199.163	35			

Table 4.8. ANOVA Table of drawbar pull for New Holland TT 6080

Source	SS	df	MS	F	P-value
Rep	6.39977	2	3.199885	124.1582	0.129686
D	1416.749	2	708.3744	1722.31	1.08E-11
W	1299.809	1	1299.809	3194.285	4.43E-12
N	3.026647	1	3.026647	2.869971	0.161299
D*W	55.48484	2	515.9171	67.80607	0.000393
N*W	0.172727	1	0.172727	0.148004	0.71405
D* N	0.218712	2	0.109356	0.11852	0.890854
Error	26.50151	24	1.104229		
Total	5579.26	35			

The analysis of variance in Table 4.9 and 4.10 showed that operating depth and working width was significant effect (p<0.05) and the interaction between operating depth and working width was significant (p<0.05)effect on drawbar power for Massey Ferguson 6480 but not for New Holland TT 6080.

The analysis of variance in Table 4.9 and 4.10 showed that engine speed, the interaction between engine speed and working width, engine speed and operating depth, operating depth and working width was no significantly (P>0.05) effect on drawbar power for both Massey Ferguson 6480 and New Holland TT 6080 respectively.

Table 4.9. ANOVA Table of drawbar power for Massey Ferguson 6480

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	80.20681	2	40.1034	8.183144	0.141252
D	832.2597	2	416.1298	43.65257	0.003652
W	1416.803	1	1083.245	97.88044	3.23E-05
N	39.01006	1	31.40805	12.61601	0.483475
D*W	579.7844	2	17.51867	2.300575	0.035394
N*W	156.8044	1	4.150738	0.392263	0.646491
D*N	35.28821	2	17.64411	6.939103	0.56412
Error	550.4563	24	22.93568		
Total	5177.442	35			

Table 4.10. ANOVA Table of drawbar power for New Holland TT 6080

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	236.2272	2	118.1136	78.69095	0.156409
D	1433.025	2	716.5125	450.4995	0.001974
W	1708.506	1	1469.669	144.9929	0.000397
N	91.77805	1	91.77805	32.00236	0.059539
D*W	805.0305	2	556.3692	149.7395	0.461177
N*W	14.52298	1	275.5704	0.290989	0.388848
D*N	226.7469	2	198.2479	0.211686	0.819738
Error	999.6303	24	41.65126		
Total	7890.912	35			

The analysis of variance in Table 4.11 and 4.12 showed that working width, engine speed, the interaction between operating depth and working width, operating depth and engine speed, working width and engine speed was no significant ($P>0.05$) and operating depth have significantly ($P<0.05$) effect on wheel slip of tractor for both Massey Ferguson 6480 and New Holland TT 6080 respectively.

Table 4.11. ANOVA Table of slip for Massey Ferguson 6480

Source	SS	df	MS	F	P-value
Rep	10.43493	1	10.43493	0.743384	0.41017
D	62.49543	2	28.85827	8.00121	0.0175198
W	10.43493	1	10.43493	0.743384	0.41017
N	4.527369	1	4.527369	0.287203	1.7606
D*W	3.639367	2	1.819683	0.169977	0.849195
N*W	6.742881	1	5.479198	0.354116	0.551687
D* N	2.026694	2	11.6425	0.071805	0.933054
Error	395.0409	24	16.46004		
Total	549.2393	35			

Table 4.12. ANOVA Table of slip for New Holland TT 6080

Source	SS	df	MS	F	P-value
Rep	19.14625	1	19.14625	10.57399	0.333481
D	44.38988	2	22.19494	11.69181	0.0390534
W	19.14625	1	20.16248	10.57399	0.352499
N	2.92055	1	2.92055	0.093203	0.814079
D*W	4.865233	2	11.80566	6.387893	0.451315
N*W	1.261006	1	4.290043	0.141809	0.786391
D* N	13.88186	2	6.904956	0.09521	0.910966
Error	708.3055	24	29.51273		
Total	845.3386	35			

The analysis of variance in Table 4.13 and 4.14 showed that working width was significant effect ($p<0.05$)and operating depth was significantly effect on field capacity of machinery both Massey Ferguson 6480 but not for New Holland TT 6080. Engine speed, the interaction between operating depth and working width, engine speed and working width, operating depth and engine speed was no significant effect on field capacity of machinery for both Massey Ferguson 6480 and New Holland TT 6080 respectively(Table 4.13 and 4.14).

Table 4.13. ANOVA Table of field capacity of machinery for Massey Ferguson 6480

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	0.017062	2	0.008531	15.43499	0.102174
D	0.051137	2	0.025568	1.11E+01	0.010347
W	0.30647	1	0.30647	188.7692	9.97E-06
N	0.005012	1	0.005012	1.483269	0.402449
D*W	0.001074	2	0.000872	0.172828	0.843932
N*W	0.000217	1	0.000217	0.0646	0.595873
D*N	0.002878	2	0.000948	0.198149	0.779787
Error	0.087967	24	0.003665		
Total	0.816850	35			

Table 4.14. ANOVA Table of field capacity of machinery for New Holland TT 6080

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	0.031991	2	0.015995	42.33493	0.28572
D	0.031458	2	0.015729	9.06E+00	0.146299
W	0.400744	1	0.400744	229.639	3.51E-05
N	0.014066	1	0.014066	2.79135	0.158066
D*W	0.00090	2	0.00045	59.78072	0.823248
N*W	0.000869	1	0.000869	0.166179	0.699776
D*N	0.000353	2	0.000177	0.048247	0.95388
Error	0.012613	12	0.001051		
Total	0.494501	17			

The analysis of variance in Table 4.15 and 4.16 showed that operating depth and working width was significant effect ($p<0.05$) and the interaction between operating depth and working width, engine speed and working width, engine speed and operating depth and engine speed was no significantly ($P>0.05$) effect on PTO power requirement for both Massey Ferguson 6480 and New Holland TT 6080 respectively.

Table 4.15. ANOVA Table of PTO power requirement for Massey Ferguson 6480

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	131.7694	2	65.88468	8.088321	0.141614
D	1370.176	2	685.0878	428.9334	3.64E-03
W	2330.838	1	1782.255	226.3195	3.22E-05
N	64.44303	1	64.44303	1.433821	0.482499
D*W	57.49059	3	28.7453	164.959	0.457132
N*W	6.730125	1	6.730125	0.38675	2.398604
D*N	493.682	2	250.9043	105.4473	0.562419
Error	904.9147	24	37.70478		
Total	8519.242	35			

Table 4.16. ANOVA Table of PTO power requirement for New Holland TT 6080

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	388.4301	2	194.215	71.95439	0.1625269
D	2341.933	2	1170.966	721.9782	1.95E-03
W	2806.036	1	3038.088	136.4708	0.000369
N	146.7581	1	146.7581	2.411855	0.221205
D*W	1319.04	2	1068.287	215.3956	0.464216
N*W	356.4765	1	356.4765	0.259923	0.645801
D*N	22.39616	2	441.1438	0.199704	0.829483
Error	1645.922	24	68.58008		
Total	12941.68	35			

The analysis of variance in Table 4.17 and 4.18 showed that operating depth and working width were significant effect ($p<0.05$) on power utilization ratio. Engine speed, the interaction between operating depth and working width, engine speed and working width, operating depth and engine speed was no significant effect on power utilization ratio for both Massey Ferguson 6480 and New Holland TT 6080 respectively (Table 4.17 and 4.18).

Table 4.17. ANOVA Table of power utilization ratio of Massey Ferguson 6480

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	76.6898722	2	38.34494	7.5163367	0.14028138
D	1406.8579	2	703.42895	44.010800	0.0036153
W	2392.23113	1	2392.23113	125.83604	0.00003204
N	66.105225	1	66.105225	1.438127	0.483518
D*W	59.146072	2	29.5730361	2.3207957	0.4575387
N*W	7.03985833	1	7.03985833	0.396329	0.644028
D*N	58.7865431	2	29.393271	0.645665	0.534651
Error	926.89366	24	38.620569		
Total	8743.19736	35			

Table 4.18. ANOVA Table of power utilization ratio of New Holland TT 6080

Source	*SS*	*df*	*MS*	*F*	*P-value*
Rep	213.5512222	2	106.7756	68.827784	0.153844
D	2082.5961944	2	1041.2980	47.424110	0.001949
W	2698.156444	1	2698.156444	136.1932	0.00037
N	129.96613	1	129.96613	2.4106231	0.222459
D*W	57.06097222	2	28.530486	1.5622610	0.463889
N*W	18.79319	1	18.79319	0.25898	0.646008
D*N	20.6523615	2	10.326180	0.1975388	0.732323
Total	1463.590666	24	60.982944		
Error	11499.83793	35			

Result summary

From the result presented above the highest drawbar pull, drawbar power, field capacity, power utilization ratio was seen with New Holland tractor TT6080 but at the same time the highest slip and fuel consumption was also observed with TT 6080 tractor model. Massey Ferguson MF6480 was also showed a closest value as TT 6080 especially when it was operating with 2200 rpm and 2.4 m working width but with a little lesser slip and fuel consumption. From the statistical analysis of mould board plough we have observed that both depth and width have a significant effect ($p<0.05$) on drawbar pull, drawbar power, pto power requirement, power utilization ratio, and fuel consumption. The operating depth was shown a significant effect ($p<0.05$) on the wheel slip than that of the working width. The working width also showed a significant effect ($p<0.05$) on the field capacity than the operating depth. The interaction between depth and width showed a significant effect ($p<0.05$) on drawbar pull and drawbar power. The engine speed and it's interaction between the depth and width does not show a significant effect ($p>0.05$) in all parameters.

CHAPTER FIVE

CONCLUSION AND RECCOMENDATION

5.1. Conclusion

The evaluation of this research was made with Massey Fergusson 6480 and New Holland TT6080 was conducted with the aim of determining the best tractor implement combination for the proper matching. The parameters were tested with three different depth and two working widths and two engine speeds. The research was done in kulumsa agricultural Research center with cooperation of GIZ SSAP Agricultural Training Center for mechanization. The field tests were carried out with clay soil type for primary with LEMKEN slatted mouldboard. The data collected from the field were travel speed, operation depth, soil types, and working width. The calculation was made based on an already developed standards and formulas. The parameters evaluated were drawbar pull, drawbar power, wheel slippage, field capacity, and power utilization ratio.

Based on the computed values the highest drawbar pull, drawbar power, field capacity, PTO power, Power Utilization ratio, was observed with New Holland tractor operating with 2200 RPM with 2.4m working width. The lowest drawbar pull, drawbar power, Wheel Slip, field capacity, PTO power, Power Utilization ratio, was observed with Massey Ferguson tractor operating with 2000 RPM with 2.4m working width. The

The analysis of the data also showed that both operating depth and working width a significant effect on drawbar pull, drawbar power, PTO power, Power utilization ratio for both Massey Ferguson MF 6480 and New Holland TT6080. At the same time only operating depth shows significant effect on both MF 6480 and TT6080 tractor models. The field capacity result also shows that both operating depth and working width has a significant effect on MF6480 tractor model while only working width shows a significant effect on New Holland TT6080 tractor.

5.2. Recommendation

Based on the results it was observed that Massey Ferguson MF 6480 was also operated in under loading condition in most of ploughing operation in all operating depth, working width, and engine speed that was considered during the field test except when it was operated with 2200 rpm, 2.4 working width, 30 and 35cm operating depth.

New Holland TT 6080 was operating in a better condition when it was operating with an engine speed of 2000 RPM with 2.4m working width in 20 and 30 cm operating depth and 2200 RPM in all operating depth in 2.4m working width.

From all combination the first highly recommended combination is New Holland tractor and mould board plough operating with 2200 RPM engine speed, 2.4 m working width and 35, 30, and 20 cm operating depth (T2N2W2D1 and T2N2W2D2, T2N2W2D3). At the second place New Holland tractor and mould board plough operating with 2000 RPM engine speed, 2.4 m working width and 20 and 30 cm operating depth (T2N1W2D1 and T2N1W2D2) was recommended. At the third place Massey Ferguson 6480 and mould board operating with 2200 rpm engine speed and 2.4 working width operating with depth of 30 and 35 cm (T1N2W2D2 and T1N2W2D3) was recommended.

At last since this research was done analytically it was very useful feed for the agricultural sectors but it has its own weak side on giving the exact situational values so for that reason it is better to use some experimental and on field equipments to get exact value with respect to the soil and machine exact condition.

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7. Appendix

7.1. Appendix Table

Annex Table 1: ASABE table for Draft parameters and an expected range in drafts estimated by the model parameters for tillage and seeding implements

implement		SI Units				English Units						Range
	Width units	Machine Parameters			Width units	Machine Parameters			Soil parameters			
		A	B	C		A	B	C	F1	F2	F3	
MAJOR TILLAGE TOOLS(Subsoiler/Manure Injector)												
narrow point	Tools	226	0	1.8	tools	129	0	2.7	1	0.7	0.45	50
30 cm winged point	Tools	294	0	2.4	tools	167	0	3.5	1	0.7	0.45	50
Moldboard Plough	m	652	0	5.1	ft	113	0	2.3	1	0.7	0.45	40
Chisel Plough												
5 cm straight point	Tools	91	5.4	0	tools	52	4.9	0	1	0.85	0.65	50
7.5 cm shovel/35 cm sweep	Tools	107	6.3	0	tools	61	5.8	0	1	0.85	0.65	50
10 cm twisted shovel	Tools	123	7.3	0	tools	70	6.7	0	1	0.85	0.65	50
Sweep Plough												
primary tillage	m	390	19	0	ft	68	5.2	0	1	0.85	0.65	45
secondary tillage	m	273	13	0	ft	48	3.7	0	1	0.85	0.65	35
Disk Harrow, Tandem												
primary tillage	m	309	16	0	ft				1	0.88	0.78	50
secondary tillage	m	216	11	20	ft	37	3.2	0	1	0.88	0.78	30
Disk Harrow, Offset												
primary tillage	m	364	19	0	ft	62	5.4	0	1	0.88	0.78	50
secondary tillage	m	254	13	0	ft	44	3.8	0	1	0.88	0.78	30
Disk Gang, Single												
primary tillage	m	124	6.4	0	ft	21	1.8	0	1	0.88	0.78	25
secondary tillage	m	86	4.5	0	ft	15	1.3	0	1	0.88	0.78	20
Coulters												
smooth or ripple		55	2.7	0		31	2.5	0	1	0.88	0.78	25
bubble or flute	Tools	66	3.3	0	tools	37	3	0	1	0.88	0.78	25
Field Cultivator												
primary tillage	Tools	46	2.8	0	tools	26	2.5	0	1	0.85	0.65	30
secondary tillage	Tools	32	1.9	0	tools	19	1.8	0	1	0.85	0.65	25
Row Crop Cultivator												
S-tine	Rows	140	7	0	rows	80	6.4	0	1	0.85	0.65	15
C-shank	Rows	260	13	0	rows	148	12	0	1	0.85	0.65	15
No-till	Rows	435	22	0	rows	248	20	0	1	0.85	0.65	20
Rod Weeder	m	210	11	0	ft	37	3	0	1	0.85	0.65	25
Disk-Bedder	Rows	185	9.5	0	rows	106	8.7	0	1	0.88	0.78	40

MINOR TILLAGE TOOLS												
Rotary Hoe	M	600	0	0	ft	41	0	0	1	1	1	30
Coil Tine Harrow	M	250	0	0	ft	17	0	0	1	1	1	20
Spike Tooth Harrow	M	600	0	0	ft	40	0	0	1	1	1	30
Spring Tooth Harrow	M	2000	0	0	ft	135	0	0	1	1	1	35
Roller Packer	M	600	0	0	ft	40	0	0	1	1	1	50
Roller Harrow	M	2600	0	0	ft	180	0	0	1	1	1	50
Land Plane	M	8000	0	0	ft	550	0	0	1	1	1	45
SEEDING IMPLEMENTS												
Row Crop Planter, prepared seedbed												
mounted												
seeding only	Rows	500	0	0	rows	110	0	0	1	1	1	25
drawn												
seeding only	Rows	900	0	0	rows	200	0	0	1	1	1	25
seed, fertilizer, herbicides	Rows	1550	0	0	rows	350	0	0	1	1	1	25
Row Crop Planter, no-till												
seed, fertilizer, herbicides												
1 fluted coulter/row	Rows	1820	0	0	rows	410	0	0	1	0.96	0.92	25
Row Crop Planter, zone-till												
seed, fertilizer, herbicides												
3 fluted coulters/row	Rows	3400	0	0	rows	765	0	0	1	0.94	0.82	35
Grain Drill w/press wheels												
<2.4 m drill width	Rows	400	0	0	rows	90	0	0	1	1	1	25
2.4 to 3.7 m drill width	Rows	300	0	0	rows	67	0	0	1	1	1	25
>3.7 m drill width	Rows	200	0	0	rows	25	0	1	1	1	1	25
Grain Drill, no-till												
1 fluted coulter/row	Rows	720	0	0	rows	160	0	0	1	0.92	0.79	35
Hoe Drill												
primary tillage	M	6100	0	0	ft	420	0	0	1	1	1	50
secondary tillage	M	2900	0	0	ft	200	0	0	1	1	1	50
Pneumatic Drill	M	3700	0	0	ft	250	0	0	1	1	1	50

Annex Table 2: Travel speed of the tractors during field operations.

	T1				T2			
	N1		N2		N1		N2	
	W1	W2	W1	W2	W1	W2	W1	W2
	3.88	4.6	4.5	4.4	5.24	5.3	5.34	5.43
	4.25	3.8	4.38	4.16	4.15	3.97	5.21	5
D1	4.56	4.06	4.2	4.1	5.04	4.8	4.9	4.9
	4.47	4.36	4.4	4.3	4.85	4.8	4.96	4.9
	3.415	3.14	4.2	4.2	3.87	3.78	4.86	4.72
D2	4.2	4.2	3.985	3.9	4.5	4.38	4.85	4.69
	3.13	3.51	3.8	3.9	4.8	4.6	4.7	4.6
	3.25	2.82	3.68	3.71	3.6	3.6	4.5	4.5
D3	3.71	3.7	3.65	3.55	4.25	4.14	4.3	4.31

Annex Table 3. Soil particle size distribution

	Soil depth (cm)	Particle size distribution (%)			Textural class
		Clay	Silt	Sand	
Above edge	0-30	46	35	22	Clay
	30-60	51	40	15	Clay
Middle	0-30	62	23	18	Clay
	30-60	75	20	12	Clay
Lower edge	0-30	39	32	28	Clay loam
	30-60	48	29	21	Clay

7.2. Appendix Picture

Annex Figure 1. Preparation of the tractors.

Annex Figure 2. Marking and field operation of tractor.

Annex Figure 3. Measuring of operation depth.