Performance Evaluation of Moldboard Plow for Tow Tractors (Casii Maxxum 125 and New Holland T6050)

George Kifle Sima

A Thesis Submitted to the Department of Mechanical Engineering
School of Mechanical, Chemical, and Material Engineering

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

Office of Graduate Studies
Adama Science and Technology University

February 2024
Adama, Ethiopia

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DECLARATION

I hereby declare that this Master thesis entitled "Performance Evaluation of Moldboard Plow for Tow Tractors (Casii Maxxum 125 and New Holland T6050)" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

George Kifle Sima	______________________	___________________
Name of the student	Signature	Date of Submission

RECOMMENDATION OF ADVISOR

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Performance Evaluation of Moldboard Plow for Tow Tractors (Casii Maxxum 125 and New Holland T6050)" prepared under my guidance by George Kifle Sima submitted in partial fulfillment of the requirements for the degree of Masters of Science in Agricultural Machinery Engineering. Therefore, I recommend the submission of a revised version of the thesis to the department following the applicable procedures.

Dr. Amana Wako Koroso (Ph.D.) ____________________ ____________________

Major Advisor Signature Date

APPROVAL PAGE OF M.Sc. THESIS

I, the advisors of the thesis entitled "Performance Evaluation of Moldboard Plow for Tow Tractors (Casii Maxxum 125 and New Holland T6050)" developed by George Kifle Sima, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Amana Wako (Ph.D.) ____________________ __________________

Major Advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by George Kifle Sima have read and evaluated the thesis entitled "Performance Evaluation of Moldboard Plow for Tow Tractors (Casii Maxxum 125 and New Holland T6050)" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

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Internal Examiner Signature Date

Dr Girma Moges (Ph.D.) __________________ March 15, 2024

External Examiner Signature Date

Finally, approval and acceptance of the thesis are contingent upon the submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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Department Head Signature Date

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School Dean Signature Date

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Office of Postgraduate Studies, Dean Signature Date

ACKNOWLEDGMENT

First of all, I would like to thank my almighty God, who gave me the commitment and tolerance to pass various obstacles and come up to the accomplishment of this thesis. Next, I am very grateful for my research advisor, Dr. Amana Wako for his supported, instructed, and advised me with heart and patience throughout the research effort. I am grateful to all of the agricultural experts and office workers in the targeted regions for their good collaboration and help in data collection for this thesis study. My heartfelt thanks also go to Adama Science and Technology University for its assistance in the form of research facilities. Finally, I would like to express my heartfelt appreciation to my parents for their inspiration and financial support throughout my studies.

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ACRONYMS

ASABE	American Society of Agricultural and Biological Engineering
ASAE	American Society of Agriculture Engineers
ASTM	American Society for Testing and Materials
ATC	Agricultural Training Center for Mechanization
DF	Degrees of Freedom
EIAR	Ethiopian Institution of Agricultural Research
EFC	Effective field capacity
FAO	Food and Agricultural Organization of a united nation
ISO	International Organization for Standardization
LSD	Least Significance Difference
m a.s.l	Meter Above Sea level
M.B	Moldboard
MoA	Ministry of Agriculture
MS	Mean Squares
OEE	Overall Energy Efficiency
PSD	Particle Size Distribution
PTO	Power takeoff
PUR	Power Utilization Ratio
RCBD	Randomized Complete Block Design
SPSS	Statistical Package for the Social Sciences
SSAP	Supporting Sustainable Agricultural Productivity in Ethiopia
TFC	Theoretical field capacity
USDA	United States Department of Agriculture

ABSTRACT

In modern agriculture, the demand for highly sophisticated machinery and implements is essential for better agricultural production efficiency. Effective management of agricultural machinery is essential for efficient use, requiring, proper selection and tractor implement matching . However, in Ethiopia, the absence of a scientific approach in estimating drawbar pull requirements for tillage implements presents challenges in tractor-implement matching systems The study aimed to evaluate a proper matching of tractor and implement for land preparation by determining drawbar pull and drawbar power. . Field tests were conducted using Casei Maxxum 125 and New Holland T 6050 tractors with four bottom moldboards at Lasalle Agro Processing PLC. The field tests were conducted with four bottom moldboard with varying operating depth (20 cm, 25 cm, and 30 cm), operating width (1.2 m and 1.8 m), and engine speeds (2000 rpm, and 2200 rpm). Parameters such as travel reduction (wheel slippage), drawbar pull, drawbar power, PTO power requirement, Power Utilization Ratio, and field capacity during plowing operations were evaluated. The soil physical properties were also measured. The experimental plots were laid side by side in a randomized complete block design (RCBD). results indicated that the highest drawbar pull, drawbar power, and power utilization ratio was shown by the T6050 tractor model, with values of 41.04 kN, 52.44 kW, and 78.86 %, respectively. The results revealed that the combination recommended at the first place were New Holland T6050 Tractor model paired with mold board implement operating at 2200 rpm and 1.8 m working width for all operating depths. In the second place New Holland T6050 tractor combined with the mold board implement operated at a 2000 rpm 1.8 m working width for 20 and 25 cm operating depth was recommended. Lastly, Caseii Maxxum 125 operated at 2200 rpm and 1.8 m working width at 20 and 25 cm operating depth was recommended at third place among the various tractor implement combinations from the standpoint of operational capacity and economy.

Keywords: Drawbar Pull, Drawbar Power, Tractor-Implement Matching, Tractor, Tractor Performance and Working Width.

CHAPTER ONE

1. INTRODUCTION

Agriculture, as the backbone of numerous economies worldwide, heavily relies on efficient farm machinery utilization to bolster productivity, alleviate labor intensity and ensure sustainable farming methods (Welteji & Zerihun, 2018). Tractors, in particular, stand out as indispensable assets in providing the necessary power for various field operations. However, understanding the intricate dynamics of tractor performance and fuel consumption is paramount for fostering sustainable and economically viable farming practices (Pandey et al., 2023).

Ethiopia, with its rich agricultural heritage and growing population, recognizes the importance of mechanization in boosting agricultural production and ensuring food security. The selection and proper utilization of farm machinery, such as tractors and implements, play a significant role in determining the success and profitability of farming operations in the country. Understanding the performance characteristics of specific implements like the moldboard plow when used with tow tractors is essential for maximizing efficiency and minimizing costs in agricultural practices (Nigate, 2023).

Various agricultural operations, such as plowing, seeding, cultivating, and spraying, necessitate specialized equipment such as moldboard, disc, chisel, rotary, and Subsoiler plows (Ibrahim kareem & Sven, 2019). These implements are essential for tillage operations, which are key in creating optimal soil conditions necessary for proper seed emergence and crop production, constituting a significant portion of energy utilization in crop production (Jyoti et al., 2019).

Mechanization technology in agriculture plays a pivotal role in augmenting production and productivity. Particularly in emerging and less developed countries, mechanization development is crucial for ensuring national welfare and food security. Soil tillage, as a fundamental aspect of crop production, involves the mechanical manipulation of soil to facilitate optimal conditions for seeding, germination, and crop growth (Oduma et al., 2018). According to (Komissarov & Klik, 2020).Tillage methods can be broadly classified into conventional and conservation practices, each serving distinct purposes. While conventional tillage involves multiple operations to prepare the seedbed and control weeds and pests, conservation tillage, including minimum tillage and no-till practices, aims to minimize soil disturbance and preserve moisture.

Efforts to enhance overall energy efficiency in tractors and implements and proper matching between them can significantly reduce fuel consumption. Performance data from diverse tractors and implements are invaluable for farm machinery management and manufacturers alike, enabling informed decisions on machinery selection and system evaluation (Almaliki et al., 2016).

Tractor performance evaluation becomes imperative in the context of increasing global population and the consequent need to boost agricultural production. Efficient farm tractor operation entails proper selection and deployment of matching tractors and implements, considering factors such as fuel consumption and operational costs (Bilal Ahmad, Usman Ali, Fazal Ahmad Jamal, 2021). In Ethiopia, where the economy heavily relies on agricultural but faces financial challenges due to high machinery costs, efficient tractor operation is curial for sustainable farming practices. Proper selection and deployment of tractors and implements considering factors like fuel consumption and operational costs are necessary for successful farming economics (Gebrekidan, 2022).

Fuel consumption, being the largest variable cost during tractor field operations, exerts a significant influence on the vehicle's profitability, particularly in developing countries. Mechanization in countries like Ethiopia plays a crucial role in the agricultural economy but poses financial challenges due to high machinery investment and operating costs. Therefore, efficient tractor operation becomes imperative for sustainable farming economics (Ayele, 2022).

Machinery selection in farming operations is a complex decision-making process, influenced by factors such as available working time, machine capacities, and application costs. The success of production systems often hinges on the judicious selection of machinery systems, emphasizing the importance of timeliness and cost-effectiveness (Naim, 2016). Proper matching between tractors and implements is pivotal for optimizing operations and farm profitability. Parameters such as drawbar pull and power requirements play crucial roles in determining suitable matches, ensuring efficient resource utilization , and cost minimization (Sornpoon & Jayasuriya, 2013).In practice, estimating drawbar pull and power requirements enables informed decisions on tractors and implement selection, contributing to improved productivity and profitability. Failure to match tractors and implements adequately can result in increased production costs, reduced profitability, and operational inefficiencies (Fathollahzadeh et al., 2010).

In conclusion, tractor performance evaluation and selection are essential components of modern agriculture, aiming to enhance efficiency, minimize costs, and ensure sustainable farming practices. Analyzing parameters such as fuel consumption, drawbar pull, and power requirement facilitates informed decision-making, ultimately contributing to the success and profitability of agricultural operations.

1.2. Statement of Problem

The proper matching of tractors with implements is crucial for optimizing agricultural operations. This process relies on the determination of key parameters such as drawbar pull and drawbar power requirement, which vary depending on factors such as soil type and implement characteristics (Sornpoon & Jayasuriya, 2013).

While performance data from different tractors and implements is essential for effective farm machinery management, the current reliance on farmers' experience and trial-and-error methods for selecting equipment often leads to suboptimal outcomes (Almaliki et al., 2016).Consequently, the accurate prediction of drawbar pull requirement becomes imperative for tractor selection and implement matching, as it serves as the primary input for correct matching and enhanced productivity (Fathollahzadeh et al., 2010).

Moreover, addressing machinery management problems requires an accurate estimation of total working time, effective field capacities, and matching power units with machinery capacities (Naim, 2016). Efficient farm tractor operation hinges upon the proper selection and deployment of matching tractors and implements (Ayele, 2022). However, the lack of availability of field performance data for both tractors and implements poses a significant challenge to the proper selection of equipment tailored to specific farming situations (Gebrekidan, 2022). Therefore, the overarching problem lies in the absence of readily accessible and comprehensive data on the performance parameters of tractors and implements, hindering farmers' ability to make informed decisions and optimize agricultural operations effectively.

1.3. Objectives

1.3.1. General Objective

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

1.3.2. Specific Objectives

- To determine the drawbar pull and drawbar power requirement of the Mould Board plow.
- To compare the drawbar power requirement of the mould board plow with the drawbar power output of the Caseii Maxxum 125 and New Holland tractor T6050.

1.4. Significances of the Study

This study introduces the effect of operating depth, working width, and engine speed on the drawbar pull, drawbar power requirement, Power utilization ratio, field capacity of machinery, and fuel consumption of the 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 implementing drawbar power and pull is required. The contribution of this study is fundamental and beneficial for farmers, both in commercial and private settings , as well as decision-makers to make appropriate decisions on the selection of machinery. And since this research was done analytically it can serve as a valuable reference for assessing tractor-implement compatibility and can be utilized in future research involving different equipment. It offers a basis for comparative analysis and validation of analytical estimations against established standards.

1.5. Scope of the Study

The scope of this research was limited to examining the effect of drawbar pull and drawbar power requirement of implement on the tractor operating condition under three different operating depths and two different working widths (120 and 180 cm) for Caseii Maxxum 125 and New Holland tractor T6050 tractors analytically and experimentally to achieve a 120 cm working width by removing one point linkage of moldboard. Then detect whether it is operating overloading or under loading conditions and recommend which tractor implements a combination at which working depth and width is better for the tractor to work in optimal condition.

CHAPTER TWO

2. 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 (Amare & Endalew, 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 (Berhane 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 are critically important to achieving the strategic goal of increasing the production and productivity of strategic and high-value crop and livestock commodities (Sims et al., 2016).Agricultural mechanization can significantly increase crop yields, and 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 is 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 toward other high-value-adding activities and sectors (NGUYEN, 2017).

Agricultural mechanization is not new to Ethiopia. While agricultural mechanization is a valuable instrument for 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 remains oxen power the most common implements utilized in Ethiopian agriculture are still animal-drawn implements, such as plows (Amare & Endalew, 2016).

The overall benefits of increasing agricultural mechanization are immense and wide-ranging, both in agricultural productivity, as well as overall livelihood development. According to (MoA, 2014) this range from direct benefits to smallholder agriculture to indirect economic benefits, including a 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 several distinct challenges. These have constrained both the widespread availability of implements and ultimately, the use of implements in agricultural production, especially in the smallholder context (Berhane 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 are limiting to an increase in agricultural productivity through increased mechanization. The third key constraint is a lack of physical machinery available; both from domestic and 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 (Ranjbarian et al., 2017).

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, human is also a major source of farm power (Srivastava, 2020).

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 to human power. Power is needed on the farm for operating different tools, and implements and during various farm operations. While mobile power is used for doing different field jobs, 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 humans, draught animals, power tillers, and tractors; whereas the stationary power is obtained from oil engines (diesel, petrol, and kerosene) and electric motors (Sims et al., 2016).

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 the intensity of cropping the time is drastically reduced and it is not possible to harvest and thresh the standing crop, on the one hand, and prepare the seedbed and do timely sowing operations of the subsequent crops, on the other hand, on 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 the availability of farm power is more have, in general, higher productivity as compared to others. The variations in the trend of productivity in a few states are because of the variations in crops grown and the rainfall pattern in those states (Amare & Endalew, 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 their 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. 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 (Mehta et al., 2011).

Table 2. 1 Source 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(Sims & Kenzle, 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 a 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 (Mandal et al., 2015).In Ethiopia, further disaggregation by region shows that using mechanical sources of power is most common in Oromia than in other regions. Using machines to plow land, harvesting, and threshing are more common in Oromia (Berhane et al., 2016).

Table 2. 2 Households using agricultural machinery, in percent in Ethiopia

Region	Farmers No.	For any operation	For plowing	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: (Berhane et al., 2016).

According to the north Africa and Latin American have 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. 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 (Sims & Kenzle, 2006).

By introducing the modern practices 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 a 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 removing drudgery from farm operations so that rural educated youth do not run to urban areas in pursuit of jobs that are already in short supply. Agricultural mechanization aims for 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 the proper use of animate and inanimate energy and improved implements (Boydaş & Turgut, 2007).

2.4. 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. 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. 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 (Rashidi et al., 2013).

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 tilt obtained depends primarily on soil moisture content at time of tillage (Kumar et al., 2012).

2.5. 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 but these methods have had low adaptability by Ethiopian farmers (Roy et al., 2017).

2.5.1. Tillage Implements' Activity Determination by Soil Condition

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. 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. It is used to prepare the soil bed for growing crops in the least possible time by accomplishing maximum field capacity of tillage implements (Duiker & Beegle, 2006).

The moldboard plow works best in moist soil where the moisture level is near field capacity (Morris et al., 2010). If the soil was excessively dry or excessively wet, the operation takes more power and the results are poor. 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. 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., 2020).

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 30 cm/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. 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 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 (Morris et al., 2010).

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. They can be used also as primary implements for orchards 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 (Jantalia et al., 2007). 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 gangs throw the soil back toward the center as next operation. Thus, tilling the soil twice and leaving the field more nearly leveled (Serrano et al., 2007).

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 (Angela, 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 un braked 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 (Ranjbarian & Askari, 2017).

2.5.2. 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. The objectives of tillage include; production of a suitable soil tilt, 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 (Zentner et al., 2002).

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. 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 (Obalum et al., 2011).

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 (Javadi & Hahiahmad, 2006).

2.5.3. 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. 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. 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 (Sornpoon & Jayasuriya, 2013).

2.6. Effect of Soil Properties on Draught and Performance

2.6.1. 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 150 mm respectively and speed at 1.0 m/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. Observed that decreased moisture content contributed to increased soil disruption above the ground surface (M. M. Ahmed, 2004).

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

Bulk density is the weight of soil to volume. 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.(Moeenifar et al., 2014), 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. Also found a 15 to 35% increases in drought when the soil bulk density of a fine sandy loam was changed from 1680 kg/m^3 to 1830 kg/m^3. 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. 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 labor 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 (Rashidi et al., 2013).

2.6.3. 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 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 (Boydaş & Turgut, 2007).

2.7. 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 (Ranjbarian 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).

2.8. 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. Increased depth of tillage resulted in decreased trench widths which were contrary to popular belief that increased plowing 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 plowing depth was increased. More research is recommended in different soil types and conditions (Ibrahim kareem & Sven, 2019).

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. 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 (Oduma et al., 2018).

2.9. 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. 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 (Osunbitan et al., 2005).

2.10. 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 (Stamp et al., 1970). From a physical side of view, tillage is exerting a pressure on soil profile, which differs in magnitude and direction. 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 (Oduma et al., 2017).

2.11. Performance Parameters of Agricultural Implement

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

2.11.1. 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. 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 (M. M. Ahmed, 2004).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).

2.11.2. Fuel Consumption

Fuel consumption is usually expressed as specific consumption (L/h) or (L/ha).(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. concluded these factors: machine use, size and kind of implement attached (load), operating speed, and soil conditions (Seifu et al., 2023).

2.11.3. Implement Draft

The draft is the total force parallel to the direction of travel, required to propel the implement (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. Hence, availability of draft force data for a specific tillage implement in particular farm situation is vital in this realm (Shafaei et al., 2018).

2.11.4. 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(B. M. 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. 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. 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 (Damanauskas et al., 2015).

2.12. 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 (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.(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.

2.13. 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. 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 tilt. This data can assist you in selecting appropriate tillage systems for a certain soil (R. Grisso et al., 2006).

2.14. Machinery Matching with Power Sources

Selecting machine size involves fitting the properly sized equipment to the amount of work for a given period. Lowering the field efficiency would decrease the effective capacity, on the other hand increasing capacities means a direct cost saving, so, always be thinking of ways to improve field efficiency. The wrong decision in acquiring machinery can have a huge negative effect on both fixed and variable expenses (Adamchuk et al., 2016). 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 out 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 crop production to reduce losses (Srivastava, 2020).

In the past, misunderstood concepts and the 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 (Awulu et al., 2016). In 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 the market, environment, and other regulatory constraints. Under more complicated economic conditions available tractors, machinery, and equipment, their purchase price, crops to be grown, and marketing factors create some questions for decision-making. How much power, number of tractors, and tools are required; for these reasons and others, technical understanding is needed for bringing quick solutions (Naim, 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. 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. To make the right choice of tillage machinery it is necessary to have enough information about drawbar pulls for certain types of soil (Mandal et al., 2015).

Correct matching of machinery should result in increased efficiency of operations, less operation costs, and optimum use of capital on fixed costs. 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 sizes for different crops, and the use of the same implement with different speeds, depths, and tractive efficiencies complicate as well the selection of machinery (Mehta et al., 2011).

To determine how large a machine is needed it is necessary to determine the 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 a tractor and an implement, consideration must be given to various factors like the area to be covered (ha), working speed (mph), working hours, estimated field efficiency (percentage), the width of machine (working width, m), power requirements for implement to be used (kW).On the other hand, when selecting the power required there are some factors to be considered like engine type, power rating, 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 a combination process this rating power can be in the form of drawbar pull, horizontal power for PTO relative power. Proper matching of implements with tractors and the performance evaluation of the combination is very much important to minimize the expenditure in farming operations (Awulu et al., 2016). 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 the engine and hence poor efficiency and higher operating costs. Implements that are too large for the horsepower available can cause overload, excessive tire slippage, an increase in fuel consumption, and unsatisfactory performance in general. Implements that are too small result in inefficient operations, low production, and increased cost (Mandal et al., 2015).

2.15. Drawbar Pull

Drawbar pull refers to the force required to pull an implement in the horizontal direction of travel(Naji Al-Dosary et al., 2023). Drawbar pull is the force required to propel an implement in the direction of travel. 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 the draft of moldboard plow is following ASABE Standard D497.6 (ASABE, 2009)(R. D. Grisso et al., 2008).

$D = F_{1}\,[A + B(S) + C(S)^2]W \times T$ ………………………………………………………………………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 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 the field. The availability of data on the drawbar pull requirement of tillage implements is also an important factor when 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 (Tayel et al., 2015).

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. Drawbar pull affects the energy requirement of tillage implements. It reflects the soil's physical conditions and the degree of compaction of agricultural soils. For unique soil type, plowing speed and implement the design, drawbar pull varies with soil bulk density, soil moisture content, and plowing 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. Drawbar pull and power requirements are important parameters evaluating the performance of tillage implements and are therefore considered as essential data when attempting to correctly match tillage implements to a tractor. Machine selection and sizing require an estimation of the power requirements of the implement the lack of information about implement performance forces the farmer to rely on experience for the 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 speed (R. D. Grisso et al., 2008).

2.16. Drawbar Power

The primary purpose of agricultural tractors, especially those in the middle to high power ranges, is to perform drawbar work. Since drawbar is the most commonly used power outlet of a tractor, the ability to provide a 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.The value of a tractor is measured by the amount of work accomplished relative to the cost incurred in getting the work done (Naderloo et al., 2009).

The ideal tractor converts all the energy from the fuel into useful work at the drawbar. Drawbar power is the power that is actually available at the tractor drawbar which is ready to transmit to the implement. It is required to pull a tillage implement as a function of travel speed and drawbar pull of the implement. However, due to power losses, not all fuel energy is converted into useful work. 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 (Bulgakov et al., 2019). This is the power that the tractor should be able to provide at the drawbar. 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 (Naim, 2016)[i].

According to ASABE Standard D497.6 the drawbar power requirement of the implement can be calculated as the equation below (Reichenbach et al., 2019).

$$P_{db} = (\frac{D \times S}{3.5}) \quad \text{..........} 2.2$$

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 (Reichenbach et al., 2019):

a) Effect of soil type and condition

The power requirements machine depends on soil and crop conditions, which are highly variable. In addition to soil type, the tillage draft of plows 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	The 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 the 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. Concluded that an increase in forward velocity results in the increase in implement draft, wheel slippage, drawbar power, and overall energy efficiency but results in the decrease in traction efficiency (B. M. Ahmed, 2015).

c) Effect of plowing depth

Variations in plowing depth depend on unevenness of the ground surface, soil strength variations, plowing speed variations, presence of stones, and strong roots in the soil. Concluded that the draft requirement of an implement increased with the operational depth of the implement is increased (Ibrahmi et al., 2015).

2.17. Wheel Slip

Wheel slippage in tractors has always been one of the main efficiency factors affecting the fuel consumption of tractors. A tractor working at its highest level of efficiency 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. Tractor performance is influenced by traction elements, soil conditions, implement type, and tractor configuration (Cutini et al., 2022).

The soil moisture content, bulk density, soil texture, and shear strength contribute to tillage energy requirement. It is known that the resistance of plows and energy requirement for plowing depend on the plow body parameters and soil properties such as hardness, density, friction, and adhesion. 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. By decreasing soil moisture content, the net traction of the tractor decreased and resulted in reduced rolling resistance. The rolling resistance of the wheel can increase by the reduction of some key soil parameters (Tayel et al., 2015).

Furthermore, increasing the plowing depth also increases the friction between the tire and soil interface which, changes the slicing forms of soil that, in turn, causes a percentage increase in rolling resistance, wheel slip, and fuel consumption. 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 for secondary tillage operations due to the depth of the two different tillage implements (Taiwo & Owusku-Sekyere, 2015).

According to (ASABE, 2003)(Taiwo & Owusku-Sekyere, 2015) slip was calculated.

$$S = \left(\frac{A_n - A_1}{A_n}\right) \times 100 \qquad \text{.......} 2.3$$

Where: S = slip, percent;

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

A1 = the advance distance under actual load conditions per revolution, m.

2.18. Capacity

2.18.1. Machine Capacity

The capacity of a machine is its rate of performance, and is 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 hour. One method for measuring machine capacity is field capacity. It is measured in area per time or tons per time. The field capacity is determined by three factors: speed, width, and efficiency (Jithender et al., 2017).

2.18.1.1. 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 on time. 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 (Taiwo & Owusku-Sekyere, 2015).

2.18.1.2. Theoretical Field Capacity

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

$$TFC = \frac{W \times S}{10} \quad \text{..........} 2.4$$

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 (Taiwo & Owusku-Sekyere, 2015).

2.18.1.3. Effective Field Capacity

The effective field capacity is the measure of the ability of a machine 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. The effective field capacity (EFC) is a more usable measure because it brings in the factor of efficiency. According to the EFC can be calculated by dividing the area covered with theoretical field capacity or by multiplying the theoretical field capacity with field efficiency (Mandal et al., 2015).

$$EFC = \frac{W \times S}{10} \times \eta \quad \text{..........} 2.5$$

Where: EFC = theoretical field capacity ha/h;

W = width of machine/implement m;

S = speed of operation km/h;

η= Field efficiency

2.19. Fuel Consumption

The 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 (R. D. Grisso et al., 2004).Fuel consumption is measured by the amount of fuel used during a specific period. The primary tillage operations require 75% of the total energy spent before the seed-time. There are many sources of energy, fuel energy represents on an essential role in power production which is needed for agricultural production. The speed of operation, width of cut, depth of cut, type of soil, and skill of the 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. 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 (Kim & Kim, 2010).

According to ASABE EP 496.2, (2003) (Khater, 2017) The average gasoline fuel consumption can be calculated;

$$Q_{avg} = 0.305 \times P_{pto} \quad \text{.......} 2.6$$

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

$$Q_{avg} = (0.305 \times P_{pto}) \quad \text{.......} 2.7$$

Where: Qavg = average gasoline consumption, L/h;

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

PTO power required by the implement was estimated from the drawbar power required multiplied by the tractive condition of the soil of a specific tractor type from.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the Study Area

This study was conducted at Lasalle Agro Processing PLC. It is located in the Abono Gebriel Kebele Dugda Wereda East Shewa Zone of the Oromia Region, It has a latitude and longitude of 8°10′N 38º43′E with an elevation of 1636 meters above sea level.

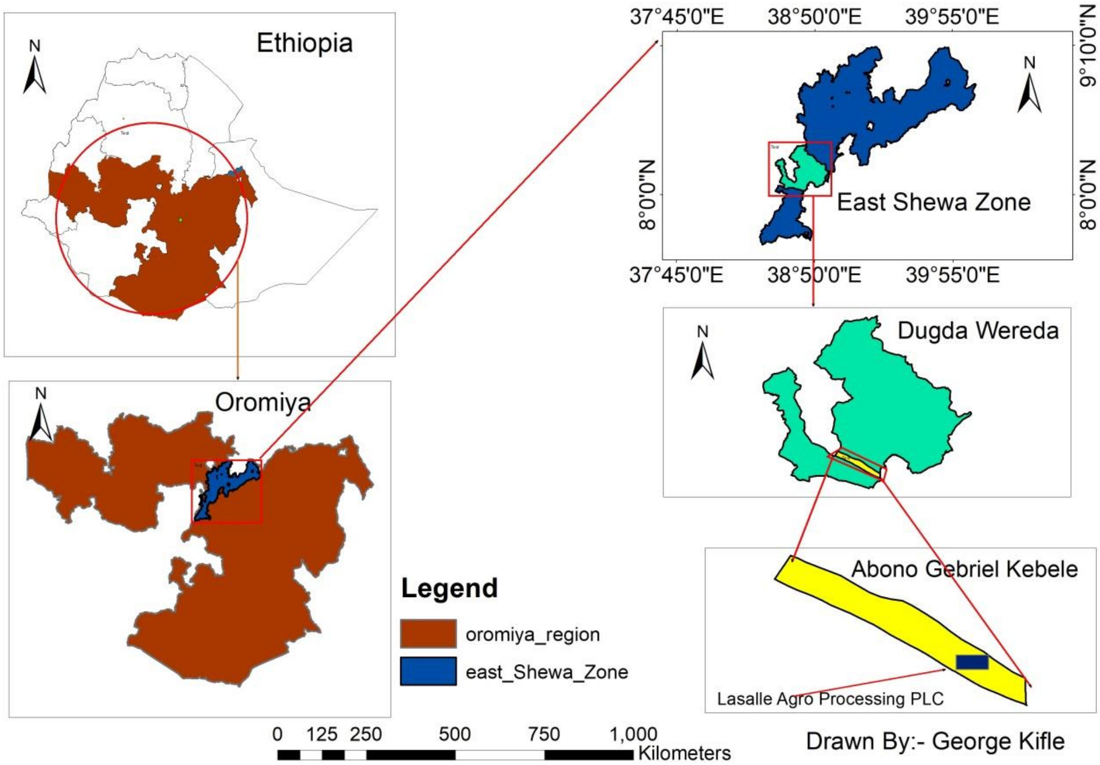


Figure 3. 1 Location map of the study area

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 an undisturbed soil sample
Trimmer	For trimming the soil sample edge.
Balance	For measuring the weight
Oven	For particle size distribution
Sieve	For particle size distribution

Tractor	Caseii Maxxum 125, New Holland T6050
Implements	Four bottom Moldboard plow
Timer	For counting the running time of the tractor
Tape measure	For measuring the running distance and width of cut
Ruler	For measuring the depth of cut
Weight balance	To measure the weight of wet and dry soil for the determination of moisture content and bulk density of the soil.
Electric Oven	For drying the soil samples
Sample Boxes	Used for keeping the soil samples in the oven.

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 Lasalle Agro Processing PLC. The field has a dimension of (100×50) m^2. The assumed run given for the tractor is 50 m and 25 m was given for calibration of the tractors. To operate with one tractor the area given is (50x50) 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	
		Case IH Maxxum 125	T6050
1	Manufacturer	Case IH Maxxum	New Holland
Engine			
1	Rated Power - ISO 14396/EC R120 (kW/hp(cv)	125	93/127
2	Rated speed	2200	2200
3	(Std/Engine Pwr		555@1250

	Management (Nm))		
4	Cylinders/displacement, cu. Cm	FPT 4 Cylinder/4.5 L (273 cu in.)	6/6728
5	Torque Rise % (maximum)		38
6	Aspiration	Turbocharged	Turbocharged
3	Intercooling	Air-to-air intercooler	air-to-air intercooler
HYDRAULICS			
1	Steering and services pump flow, L/min	12.4 gpm (47 L/min)	40 (47 with 16x16)
2	Total tractor hydraulic flow, L/min.	CVT model - 45.4 gpm (172 L/min)/multi-controller models - 42.4 gpm (160 L/min)	103 (110 with 16x16)
3	3-point hitch category	Cat II standard/Cat II-IIIN optional	Cat II MDC, Cat II/IIIN EDC
4	3-point hitch lift capacity—std./opt., kg at ball ends	6,700 lbs. (3030 kg) /7,950 lbs. (3606 kg)	4170/6985
CAPACITIES			
1	Fuel tank, L	197.5	250
2	Engine oil, L	15	15
3	Hydraulic fluid, L	75	65 (62 16x16)

Source: Manufacturers manual (2012)(*New Holland T6000 Series Tractors 100 to 155 Hp C Lass-Leading Performance and Reliability Flexible T6000 Tractors Satisfy the Demands*, n.d.)(*Maxxum ® 115 – 150 Tier 4 B / Final Tractor Specifications Maxxum 115 - 150 Tier 4 B / Final Tractor Specifications*, N.D.).

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

Specifications	Unit	MAP164 16095
Number of Bodies	Pcs	4
Total Length (L)	Mm	3400
Total Width(W)	Mm	1740-2300
Total Height(H)	Mm	1450

Height(H)	Mm	750
Working Depth(max)	Mm	40
Working Width	Mm	1240-180
Space Between Bodies	Mm	950
Body Size	Inch	16
Chassis Size		160×120×8
Required Power	Hp	120-130
Weight	Kg	780

(*PROFILE PLOUGH MECHANIC INCH ADJUSTABLE TYPE*, n.d.).

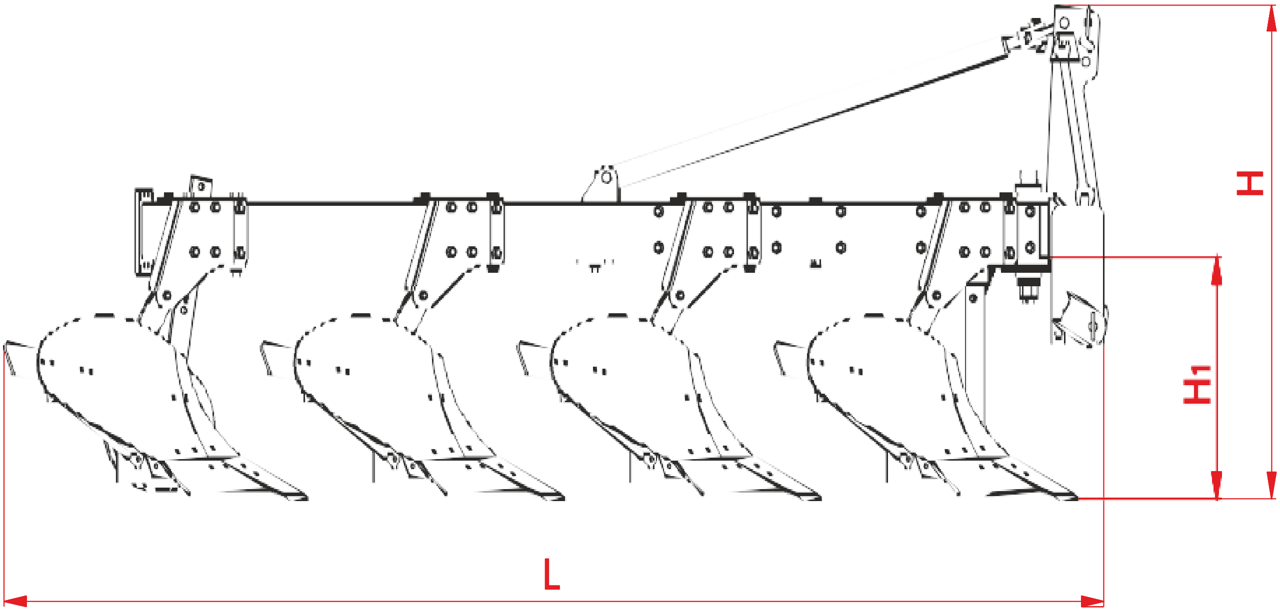


Figure 3. 2 Dimension of four bottom mold board.

3.3. Experimental Design

For the experiment, I used two different types of tractors with four bottom mold board ploughs. It was done using Randomized Complete Block Design. The tractors were operated in combination with the implement at three working depths, speeds and tow working widths (120 and 180 cm) to achieve a 120 cm working width by removing one point linkage from four bottom point linkage moldboard. 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 mold board with a different working depth

	T_1MW_1N1	$T_1MW_1N_2$	$T_1MW_2N_1$	$T_1MW_2N_2$	$T_2MW_1N_1$	$T_2MW_1N_2$	$T_2MW_2N_1$	$T_2MW_2N_2$
D_1	T_1MDW_1N1	$T_1MD_1W_1N_2$	$T_1MD_1W_2N_1$	$T_1MD_1W_2N_2$	$T_2MD_1W_1N_1$	$T_2MD_1W_1N_2$	$T_2MD_1W_2N_1$	$T_2MD_1W_2N_2$
D_2	T_1MDW_1N1	$T_1MD_2W_1N_2$	$T_1MD_2W_2N_1$	$T_1MD_2W_2N_2$	$T_2MD_2W_1N_1$	$T_2MD_2W_1N_2$	$T_2MD_2W_2N_1$	$T_2MD_2W_2N_2$
D_3	T_1MDW_1N1	$T_1MD_3W_1N_2$	$T_1MD_3W_2N_1$	$T_1MD_3W_2N_2$	$T_2MD_3W_1N_1$	$T_2MD_3W_1N_2$	$T_2MD_3W_2N_1$	$T_2MD_3W_2N_2$

Where; T_1= Casei Maxxum 125

T_2= New Holland tractor T6050

M= Mould board plow

N= Engine speed

W= Working width

D_1= 20 cm operating depth

D_2= 25 cm operating depth

D_3= 30 cm operating depth

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 a combined sieve. The percentage of material by weight retained on the various sieves can be computed as follows:

$$Percent\ Retained = \frac{Weight\ in\ grams\ retained\ on\ a\ sieve}{Total\ weight\ in\ grams\ of\ oven\ sample} \times 100 \quad \text{....................(3.1)}$$

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

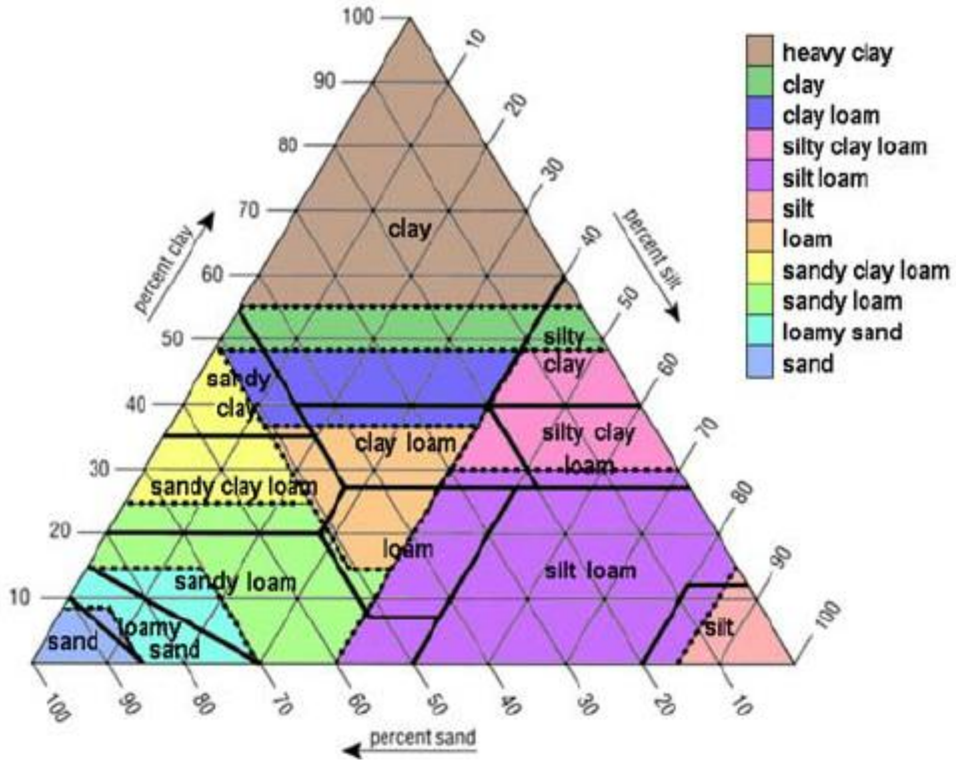


Figure 3. 3 USDA Soil textural triangle

3.4.2. Soil Moisture Content

The moisture content of the soil was evaluated by direct as well as indirect methods (Masi et al., 2021). The direct methods are those that involve driving away water by evaporation, leaching or chemical reaction then determining the amount of water lost. This is accomplished by determining the weight difference of the sample, collection 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;

$$W = \frac{W_W - W_d}{W_d} \times 100 \quad (3.2)$$

Where; W = Moisture content, % d_b

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 & Tugel, 2002). Bulk density is dependent on soil texture and the densities of soil minerals (sand, silt, and clay) and organic matter particles, as well as their packing arrangement. It was determined (Javadi & Hahiahmad, 2006).

$$\rho = \frac{M}{V} \quad \text{.......(3.3)}$$

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 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. 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 (Roul et al., 2009).

3.5.1. Drawbar Pull

The American Society of Agricultural and Biological Engineers (ASABE) issued the standard (ASABE, 2009), for estimating the drawbars pull for different implements at different working conditions. The machine- specific parameters such as A, B, and C were obtained from tables available in the issued standard. Once the implementing type under consideration is known, the values for A, B, and C were directly 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 was referred from corresponding to the implementing type (Roul et al., 2009). And the other parameters like working width and tillage depth were measured and calculated, based on this according to equation (2.1) drawbar pull was calculated as follows;

$$D = F_1 [A + B(S) + C(S)^2] W \times T \quad \text{.......(3.4)}$$

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 for major tools cm;

W = machine working width, m.

3.5.2. Drawbar Power

Once the drawbar pull has been determined, the drawbar power required to pull the implement was determined using the following formula obtained from ASABE Standards EP496.2 (Khater, 2017) by multiplying the drawbar pull by the actual travel speed and dividing it by 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;

$$P_{db} = \left(\frac{D \times S}{3.6}\right) \qquad (3.5)$$

Where: Pdb = drawbar power kW;

D = Drawbar pull kN;

S = travel speed km/ h;

3.6. Wheel 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 the 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 traveling with some specified number of revolutions of the tire and run the tractor loaded and measure the distance it was traveling with the same number of revolutions as the first.

According to (Khater, 2017)noted in equation (2.3) slip was calculated as follows;

$$S = \left(\frac{A_n - A_1}{A_n}\right) \times 100 \qquad (3.6)$$

Where: S = slip, percent;

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

A1 = 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 et al., 2011).

$$TFC = \frac{W \times S}{10} \quad \text{..........(3.7)}$$

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

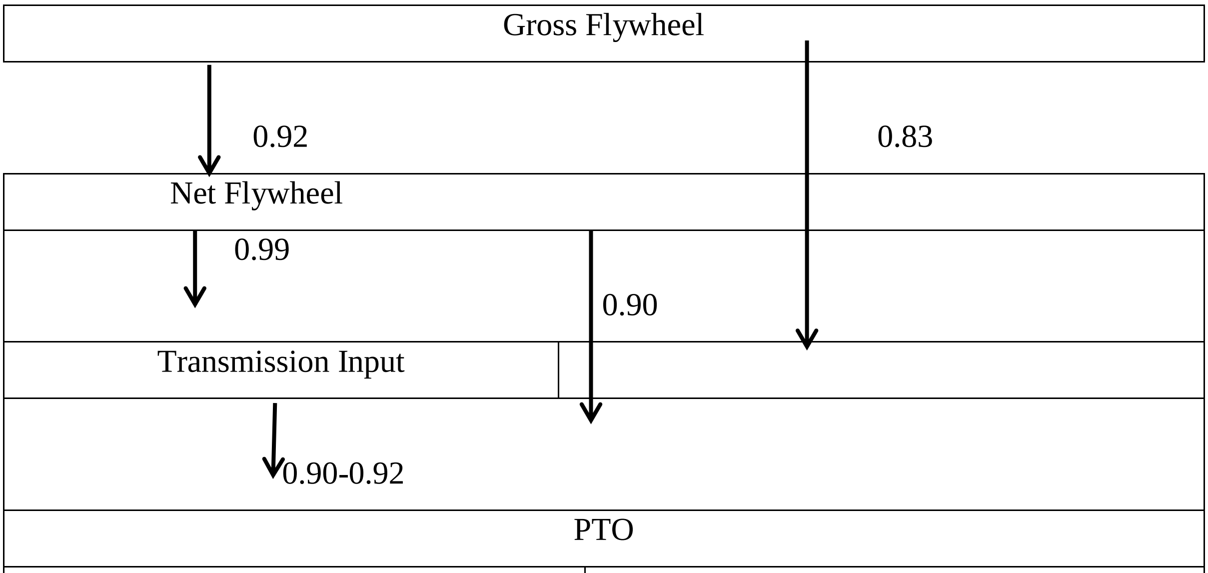
Effective field capacity was calculated following equation (2.5);

$$TFC = \frac{W \times S}{10} \times \eta \quad \text{..........(3.8)}$$

Where: η = field efficiency 75-85% (Khater, 2017).

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 (Randal K. Taylor et al., 2013) 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 the Figure below. After comparing the calculated drawbar requirement of the implement with the available usable tractor power the status of the current working condition of a tractor can be known. If the tractor's 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 costs because the tractor is subjected to frequent breakage.



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

Drawbar

(Gosaye et al., 2015)..

Figure 3.4 Power performance expected from agricultural tractors

3.9. Power Utilization Ratio

The power utilization ratio is the ratio between the equivalent power required by the implement and the maximum available power from the tractor (Randal K. Taylor et al., 2013).

$$\text{Power Utilazation Ratio} = \frac{\text{Equivalent PTO Power required by the implement}}{\text{Maximmum available PTO power from the tractor}} \quad \text{.........................(3.9)}$$

3.10. Data Analysis

Analysis of the drawbar pull, drawbar power, wheel slip, field capacity, power utilization ratio, and fuel consumption under different operating depths, working widths and engine speeds 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 SPSS software package for statistical analysis.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

This study was conducted to evaluate the effect of operating depth and working width on the drawbar pull and drawbar power of the implement. Several performance measurements and computations were made; including computation of drawbar pull, drawbar power, Wheel slip, effective PTO power requirement, power utilization ratio, and effective field capacity. The results are presented in tables and graph, discussed, and the relevant interpretations are given in the following sub-sections.

4.1. Soil Physical Properties

To determine soil type of the study area, soil samples were taken from 0-30 cm and 30-60 cm depth. The soil textural class of the field was determined based on the particle -size distribution using the USDA Soil Textural Triangle method. The results in table 3 (Annex) indicated that there is minimal variation in soil texture distribution in the study area. Sandy soil was the dominant soil type, with %Clay = 12.8, % Silt = 18.2, and % Sand = 69.0. The bulk density of the soil at the field was found to be 1.25 g/cm^3 and a moisture content of 30%.

4.2. Drawbar Pull and Drawbar Power Requirement

4.2.1. Drawbar Pull

Drawbar pull is the force exerted in the horizontal direction by the tractor's to overcome resistance and move the implement forward. According to ASABE Standard D497.6 (ASABE, 2009)(R. D. Grisso et al., 2008) drawbar pull was calculated based on the equation given in methodology (2.1).

The results from the computation of the drawbar pull for the two tractors are presented in Table 4.1. In both tractor models, the highest drawbar pull was observed when the tractors were operating at depth of 30 cm and a working width of 180 cm. The New Holland T6050 exhibited a higher drawbar pull of 41.04 kN for moldboard plow compared to the Caseii Maxxum 125 tractor. The lowest draft was recorded with Caseii Maxxum operating at a depth of 20 cm and a working width of 120 cm at 2000 rpm engine speed which was 17.49 kN.

Table 4.1. Drawbar pulls of Caseii 125 and T6050 operating with mold board

T_1		T_2	
N_1	N_2	N_1	N_2

	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
	17.49	27.36	18.12	27.03	19	28.63	25.52	28.89
D_1	17.86	26.12	18	26.65	17.76	26.37	25.29	28.06
	18.19	26.5	17.8	26.56	18.76	27.7	24.78	27.88
	22.62	33.7	22.52	33.58	23.56	34.63	31.1	34.85
D_2	21.34	31.6	22.26	33.39	21.85	32.62	30.9	34.45
	22.26	33.39	21.99	32.83	22.66	33.74	30.88	34.39
	25.27	38.6	26.12	39.4	27.7	41.04	36.7	41.04
D_3	25.41	37.4	25.96	39	25.85	38.78	36.25	40.78
	26	39	25.92	38.68	26.79	39.93	35.82	40.32

Table 4.2. shows the result from the analysis of variance (ANOVA) for the effects of Tractor type , operating depth , engine speed and working width on the drawbar pull. The ANOVA results indicated that the model is significant (F= 2134.725, P < .000). The main effect of Tractor type (F=55.936, P<.000), engine speed (F=34.783, P < .000) and working width (F= 505.080, P<.000) were all artistically significant at a 5% level. The interaction effects of Tractor Type with Engine Speed (F= 26.194, P<.000) and Tractor Type with Working Width (F=18.408, P<.000) are also significant. However , the interaction effect of Tractor Type with Operating Depth (F= .674, P<.513) is not statistically significant. The model accounts for a high proportion of the variance (R Square = .997, Adjusted Squared= .997).

Table 4. 2. ANOVA Table of drawbar pull for two Tractors.

Tests of Between-Subjects Effects

Dependent Variable: Drawbar Pull

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	63380.885[a]	10	6338.088	2134.725	.000
Tractor Type (T)	166.075	1	166.075	55.936	.000
Operating Depth (D)	1317.841	2	658.920	221.930	.000
Engine Speed (V)	103.272	1	103.272	34.783	.000
Working Width (W)	1499.603	1	1499.603	505.080	.000
Tractor Type × Operating Depth (T × D)	4.005	2	2.002	.674	.513

Tractor Type × Engine Speed (T × V)	77.771	1	77.771	26.194	.000
Tractor Type × Working Width (T × W)	54.654	1	54.654	18.408	.000
Error	184.081	62	2.969		
Total	63564.965	72			

a. R Squared = .997 (Adjusted R Squared = .997)

The effect of operating depth on drawbar pull by Tractor type for the working width of 120 cm shown in Fig. 4.1. It was observed that if the operating depth increases, the drawbar pull also increases for both Tractor types. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 tractor.

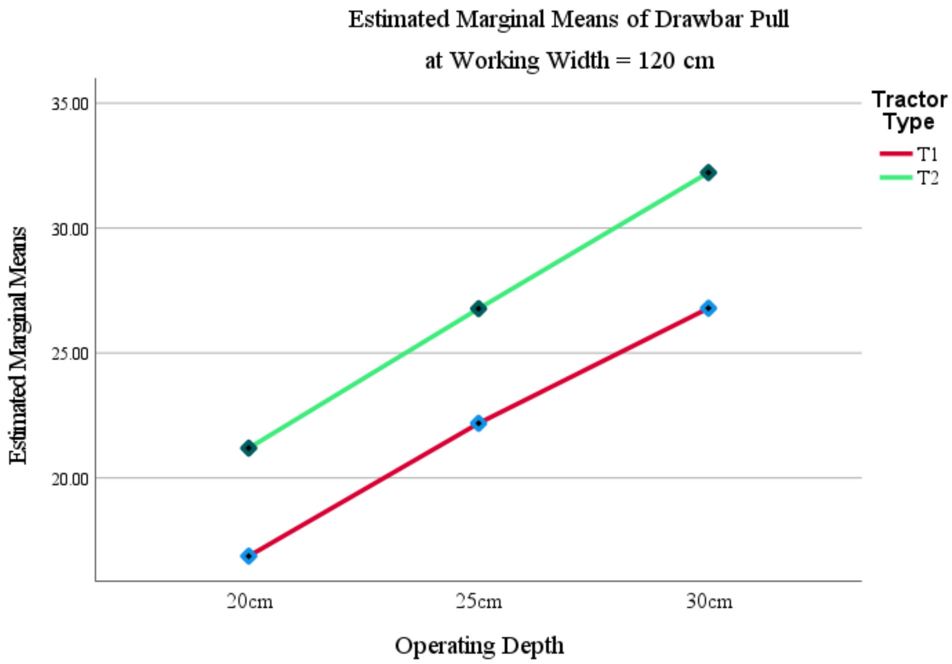


Figure 4.1. Effect of working depth on Drawbar Pull at working of 120 cm.

The effect of operating depth Tractor type on drawbar pull at working width 180 cm on shown in Fig. 4.2. It can be noticed that if the operating depth increases, the drawbar pull also increases for both Tractors. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 tractor.

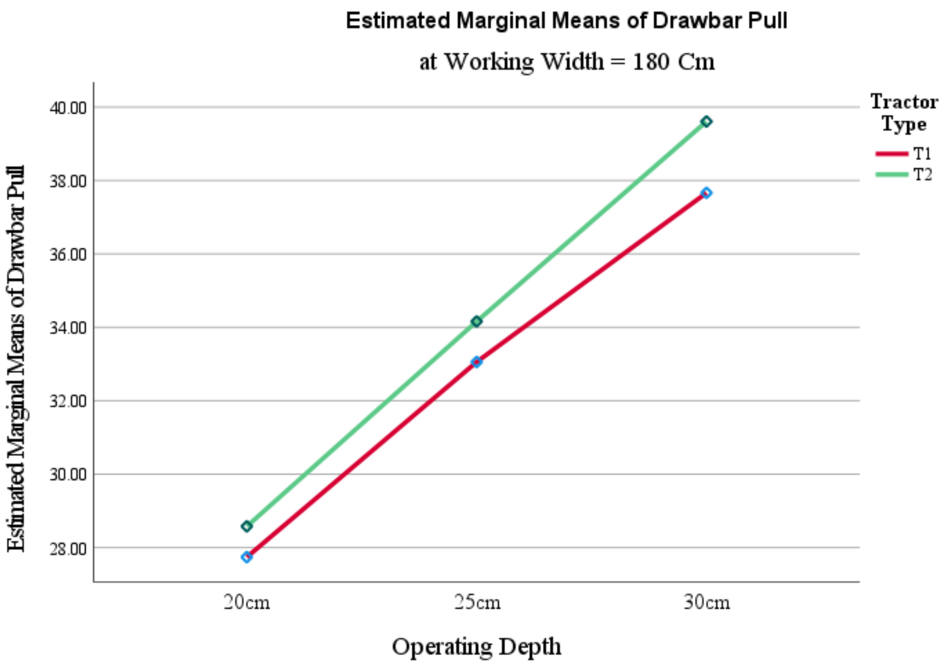


Figure 4.2. Effect of working depth on drawbar pull at working width of 180 cm

The effect of operating depth, Tractor type, engine speed and at working width 120 and 180 cm on drawbar pull is shown in Fig. 4.3. It can be noticed that if the operating depth, engine speed and working width increases, the drawbar also increases in both Tractors.

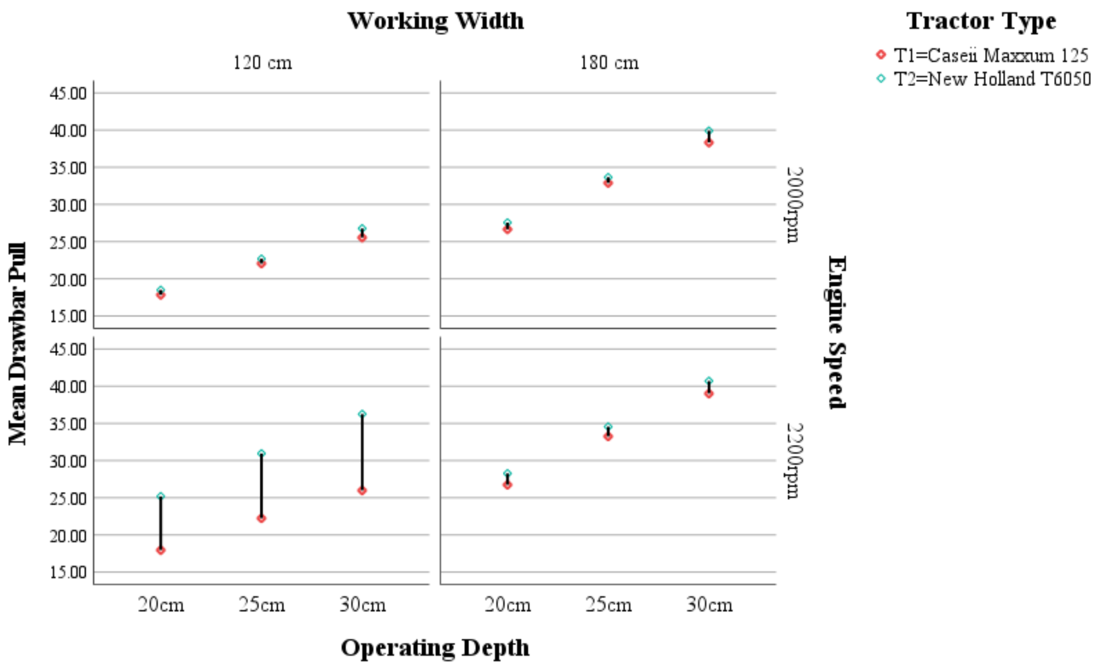


Figure 4.3. Mean Drawbar Pull for the Combine Main Factor

Increasing the drawbar pull of a tractor has several positive impacts on its performance.

Increased Capability**:** By increasing the drawbar pull, the tractor gains the ability to exert greater force and traction. This enhanced capability allows the tractor to handle heavier loads, pull larger implements, and overcome resistance more effectively. The increased drawbar pull enables the tractor to perform tasks that require higher levels of force, such as plowing through tough soil or towing heavy trailers (Rashidi et al., 2013).

Improved Productivity: With higher drawbar pull the tractor can complete tasks more efficiently, leading to improved productivity. The increased force and traction allow the tractor to maintain better speed and performance even when handling demanding workloads. This can result in faster completion of tasks, reduced operating time, and increased overall efficiency (Adamchuk et al., 2016).

Enhanced Versatility: A tractor with increased drawbar pull becomes more versatile and adaptable to various applications. It can handle a wider range of implements, work in different terrains, and tackle more challenging tasks. The enhanced performance allows the tractor to be utilized in a broader range of agricultural, construction, or industrial operations (Leghari et al., 2016).

Improved Traction and Control: Higher drawbar pull result in improved traction between the tractor's wheels or tracks and the ground. This enhanced traction enhances the tractor's ability to maintain control and grip, especially in challenging terrain or when pulling heavy loads. It reduces the chances of slippage or loss of control, contributing to safer and more efficient operation (Almaliki et al., 2016).

Generally, the results indicated in the Fig. 4.1.,4.2. and 4.3. that the drawbar pull increase with increased operating depth, engine speed and working width. Increased drawbar pull positively impacts tractor performance by enhancing capability, improving productivity, increasing versatility, and enhancing traction and control.

4.2.2. Drawbar Power

Drawbar power is the power that is actually available at the tractor drawbar which is ready to transmit to the implement. It is required to pull a tillage implement as a function of travel speed and drawbar pull of the implement (Bulgakov et al., 2019).According to ASABE Standard D497.6 (Reichenbach et al., 2019) drawbar power was calculated based on the equation given in methodology (3.5).

The results from the computation of the drawbar power for the two tractors are presented in Table 4.3. In both Tractor models, highest drawbar power was observed when the tractors were operating at depth of 30 cm and a working width of 180 cm. New Holland

T6050 exhibited a higher drawbar power of 52.44 kW for mold-board plow compared to the Caseii Maxxum 125 Tractor. The lowest draft was recorded with Caseii Maxxum operating at a depth of 20 cm and a working width of 120 cm at 2000 rpm engine speed which was 18.85 KW.

Table 4. 3 Drawbar power of Caseii 125 and T6050 operating with mould board.

	T1				T2			
	N_1		N_2		N_1		N_2	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
	18.85	34.96	22.65	33.04	27.66	42.15	37.85	43.58
	21.08	27.57	21.9	30.8	20.47	29.08	36.6	38.97
D_1	23.04	29.89	20.77	30.25	26.26	36.93	33.73	37.95
	28.09	40.81	27.52	40.11	31.74	46.17	42.85	47.43
	20.24	27.56	25.97	38.96	23.49	34.25	41.72	45.17
D_2	25.97	38.96	24.34	35.57	28.23	41.05	41.6	44.8
	21.97	37.64	27.57	42.68	36.93	52.44	47.91	52.44
	22.94	29.3	26.54	40.19	25.85	38.78	45.31	50.98
D_3	26.79	40.08	26.28	38.14	31.63	45.62	42.79	48.27

Table 4.4. shows the result from the analysis of variance (ANOVA) for the effects of Tractor type , operating depth , engine speed and working width on the drawbar power. The ANOVA results indicated that the model is significant ($F= 603.797$, $P < .000$). The main effect of tractor type ($F=101.989$, $P<.000$), operating depth ($F= 21.923$, $P < .000$), engine speed ($F=37.075$, $P < .000$) and working width ($F= 119.902$, $P< .000$) were all artistically significant at a 5% level. The interaction effects of Tractor Type with Engine Speed ($F= 14.356$, $P<.000$) is also significant. However , the interaction effect of Tractor Type with Operating Depth ($F= 1.772$, $P< .179$) and Tractor Type with Working Width ($F=2.399$, $P< .127$) are not significant. The model accounts for a high proportion of the variance (R Square = .990, Adjusted Squared= .988).

Table 4.4 ANOVA Table of drawbar power for two Tractors.

Tests of Between-Subjects Effects

Dependent Variable: Drawbar Power

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	89358.849[a]	10	8935.885	603.797	.000
Tractor Type (T)	1509.385	1	1509.385	101.989	.000
Operating Depth (D)	648.893	2	324.446	21.923	.000
Engine Speed (V)	548.688	1	548.688	37.075	.000
Working Width (W)	1774.491	1	1774.491	119.902	.000
Tractor Type × Operating Depth (T × D)	52.443	2	26.222	1.772	.179
Tractor Type × Engine Speed (T × V)	212.455	1	212.455	14.356	.000
Tractor Type × Working Width (T × W)	35.504	1	35.504	2.399	.127
Error	917.569	62	14.799		
Total	90276.418	72			

a. R Squared = .990 (Adjusted R Squared = .988)

The effect of operating depth on drawbar pull by Tractor type for the working width of 120 cm shown in Fig. 4.4. It was observed that if the operating depth increases, the drawbar power also increases for both Tractor types. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 tractor.

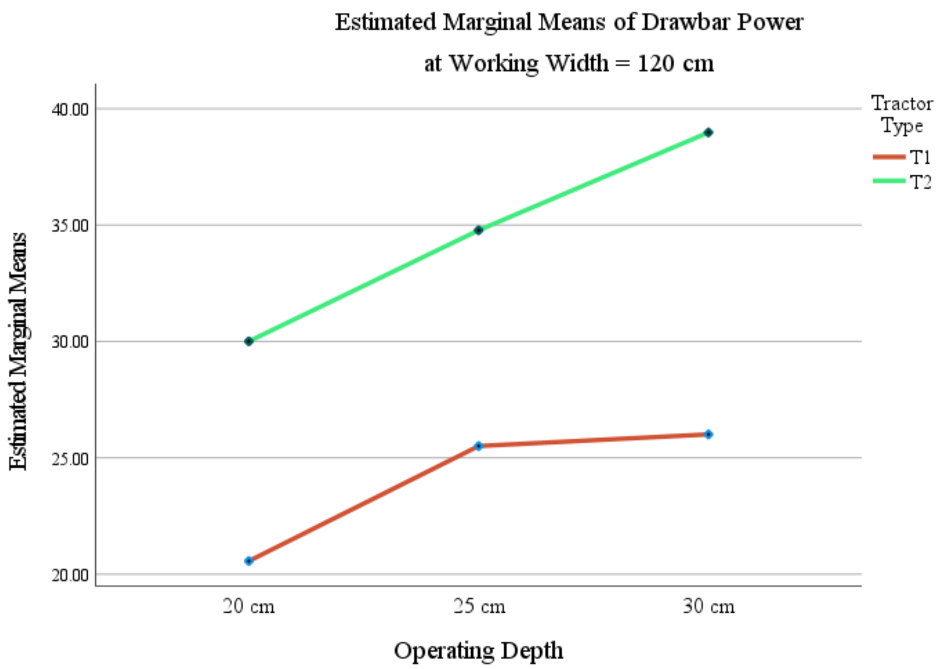


Figure 4.4. Effect of working depth on Drawbar Power at working of 120 cm.

The effect of operating depth Tractor type on drawbar power at working width 180 cm on shown in Fig. 4.5. It can be noticed that if the operating depth increases, the drawbar pull also increases for both Tractors. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 Tractor

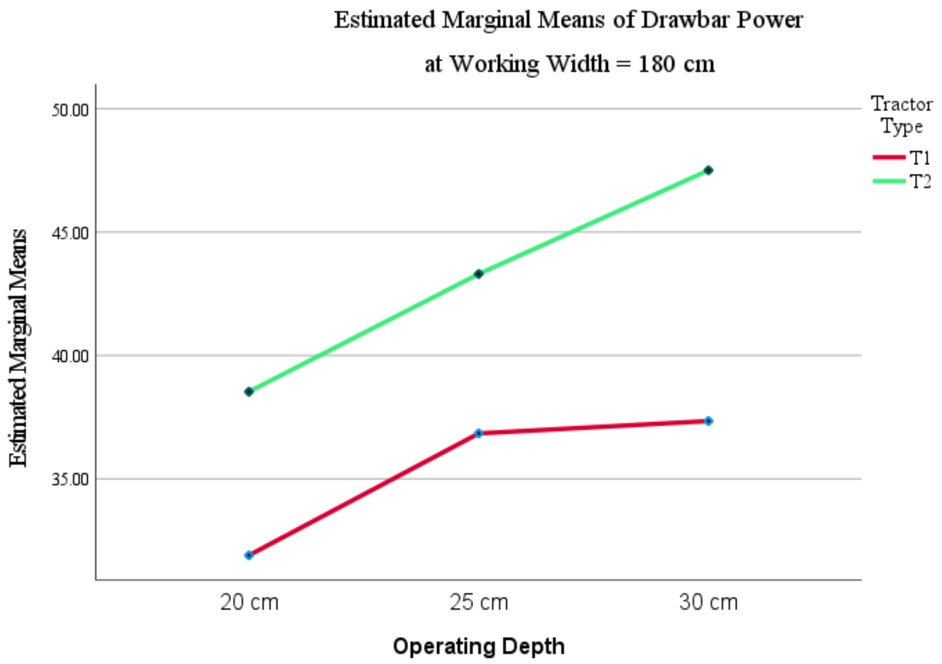


Figure 4.5. . Effect of working depth on Drawbar Power at working width of 180 cm.

The effect of operating depth, Tractor type, engine speed and at working width of 120 cm and 180 cm on drawbar power is shown in figure 4.6. It was observed that if the operating depth, engine speed and working width increases, the drawbar power also increases, the drawbar power also increases for both Tractor types.

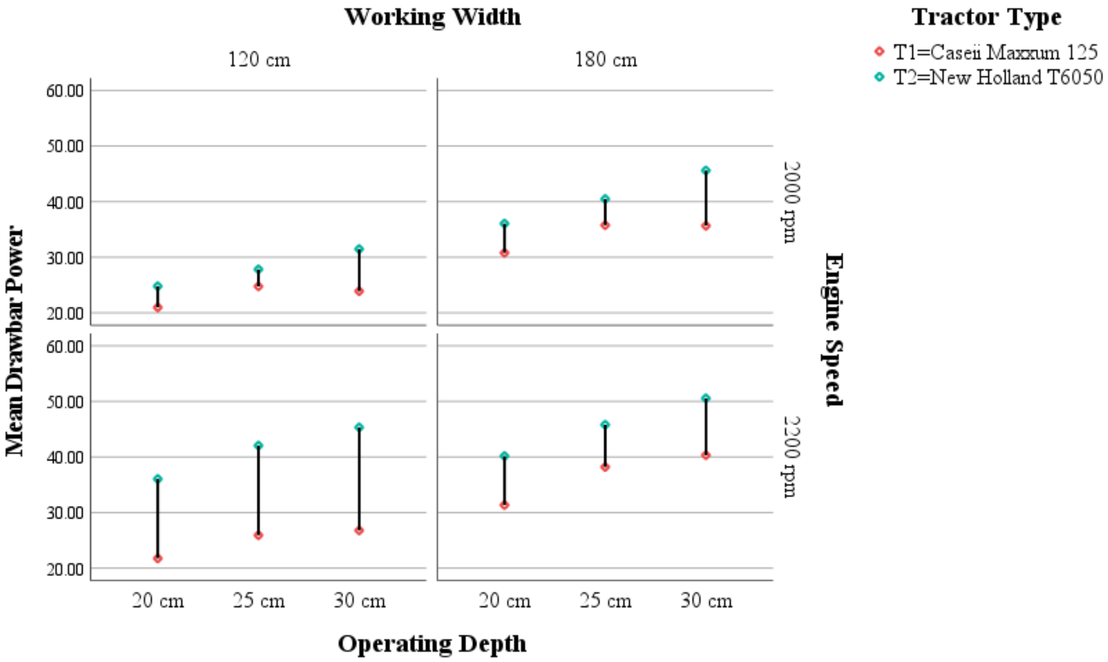


Figure 4.6. Means Drawbar Power for the Combine Main Factors.

The increasing of drawbar power has a positive impact on the performance of a tractor. Here’s why.

Increased Capability**:** By increasing the drawbar power, the tractor gains the ability to exert greater force and traction. This enhanced capability allows the tractor to handle heavier loads, pull larger implements, and overcome resistance more effectively. The increased drawbar power enables the tractor to perform tasks that require higher levels of force, such as plowing through tough soil or towing heavy trailers (Rashidi et al., 2013).

Improved Productivity: With higher drawbar power, the tractor can complete tasks more efficiently, leading to improved productivity. The increased force and traction allow the tractor to maintain better speed and performance even when handling demanding workloads. This can result in faster completion of tasks, reduced operating time, and increased overall efficiency (Chenarbon, 2022).

Enhanced Versatility: A tractor with increased drawbar power becomes more versatile and adaptable to various applications. It can handle a wider range of implements, work in different terrains, and tackle more challenging tasks. The enhanced performance allows the tractor to be utilized in a broader range of agricultural, construction, or industrial operations (Sopegno et al., 2016).

Improved Traction and Control: Higher drawbar power result in improved traction between the tractor's wheels or tracks and the ground. This enhanced traction enhances the tractor's ability to maintain control and grip, especially in challenging terrain or when pulling heavy loads. It reduces the chances of slippage or loss of control, contributing to safer and more efficient operation (Mamkagh, 2019).

Generally, the results indicated in the Fig. 4.4.,4.5. and 4.6. that the drawbar power increase with increased operating depth, engine speed and working width. Increased drawbar power positively impacts tractor performance by enhancing capability, improving productivity, increasing versatility, and enhancing traction and control.

4.3. Wheel Slip

Tire slip occurs when the tires are turning faster than the ground speed of the tractor (Reichenbach et al., 2019).According to (ASABE, 2003)(Taiwo & Owusku-Sekyere, 2015) wheel slip was calculated based on the equation given in methodology (3.6).

The results from the computation of the wheel slip for the two tractors are presented in Table 4.5. In both tractor models, highest wheel slip was observed when the tractors were operating at depth of 30 cm and a working width of 180 cm. New Holland T6050 exhibited a higher wheel slip of 20.8% for moldboard plow compared to the Caseii Maxxum 125 tractor. The lowest wheel slip was recorded with New Holland T6050 operating at a depth of 20 cm and a working width of 120 cm at 2000 rpm engine speed which was 2.08%**.**

Table 4.5 Wheel Slip of Case IH 125 and T6050 operating with moldboard

	T_1				T_2			
	N_1		N_2		N_1		N_2	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
	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
D_1	7.32	14.63	7.9	11.4	14.3	16.67	7.35	12.45
	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
D_2	14.63	14.63	11.1	13.8	16.67	18.75	8.37	11.8
	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
D_3	17.07	17.07	11.58	14.3	18.75	20.8	12.86	13.88

Table 4.6. shows the result from the analysis of variance (ANOVA) for the effects of Tractor type , operating depth , engine speed and working width on the wheel slip. The ANOVA results indicated that the model is significant (F= 39.689, P < .000). The main effect of Tractor type (F=0.417, P<.521), operating depth(F=4.971, P<.010), engine speed (F=0.207, P < .650) and working width (F= 1.458, P<.232) were not all artistically significant at a 5% level. The interaction effects of Tractor Type with operating depth (F= .213, P< .809) Tractor Type with Engine Speed (F= .376, P< .542) and Tractor Type with Working Width (F= .603, P<.441) also were not significant. The model accounts for a high proportion of the variance (R Square = .865, Adjusted Squared= .843).

Table 4. 6 ANOVA Table of Wheel slip for Caseii 125 and New Holland tractor T6050

Tests of Between-Subjects Effects

Dependent Variable: Wheel Slip

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	7379.044[a]	10	737.904	39.689	.000
Tractor Type (T)	7.762	1	7.762	.417	.521
Operating Depth (D)	184.823	2	92.412	4.971	.010
Engine Speed (V)	3.855	1	3.855	.207	.650
Working Width (W)	27.109	1	27.109	1.458	.232
Tractor Type × Operating Depth (T × D)	7.925	2	3.962	.213	.809
Tractor Type × Engine Speed (T × V)	6.994	1	6.994	.376	.542
Tractor Type × Working Width (T ×W)	11.202	1	11.202	.603	.441
Error	1152.704	62	18.592		
Total	8531.748	72			

a. R Squared = .865 (Adjusted R Squared = .843)

The effect of operating depth on Wheel Slip by Tractor type for the working width of 120 cm shown in Fig. 4.7. It was observed that if the operating depth increases, the Wheel slip also increases for both Tractor types. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 tractor.

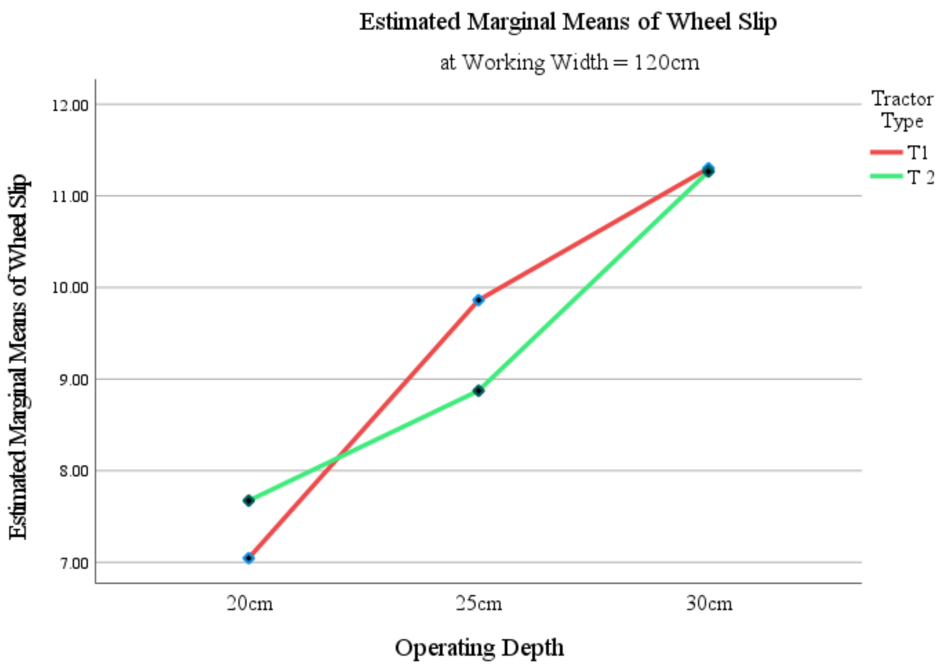


Figure 4.7. Effect of working depth on Wheel Slip at working of 120 cm.

The effect of operating depth Tractor type on Wheel slip at working width 180 cm on shown in Figure. 4.8. It can be noticed that if the operating depth increases, the wheel slip also increases for both Tractors. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 Tractor.

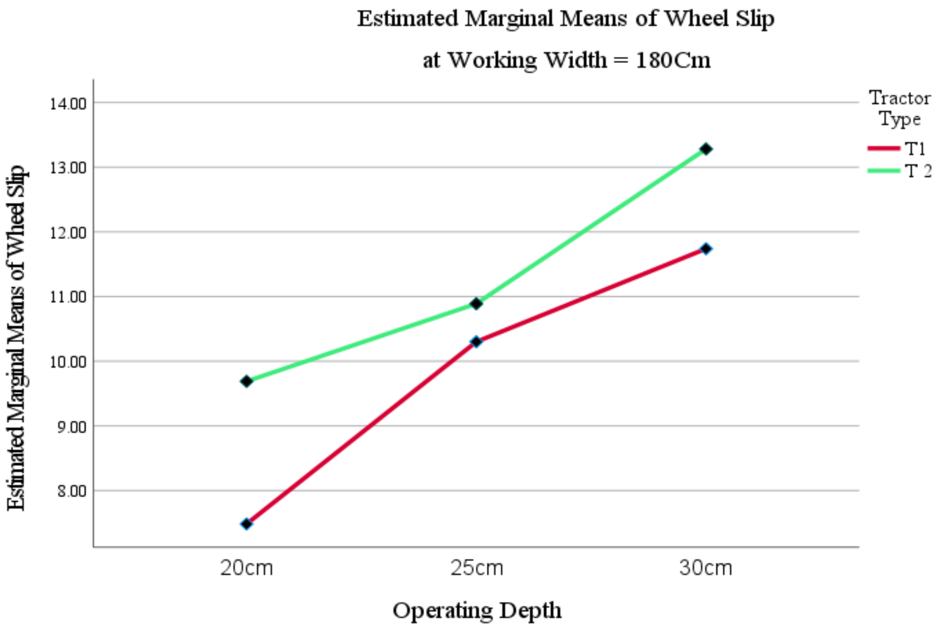


Figure 4.8. Effect of working depth on Wheel Slip at working width of 180 cm

The effect of operating depth, Tractor type, engine speed and at working width of 120 cm and 180 cm on wheel slip is shown in figure 4.9. It was observed that if the operating depth, engine speed and working width increases, the wheel slip also increases, the drawbar power also increases for both Tractor types.

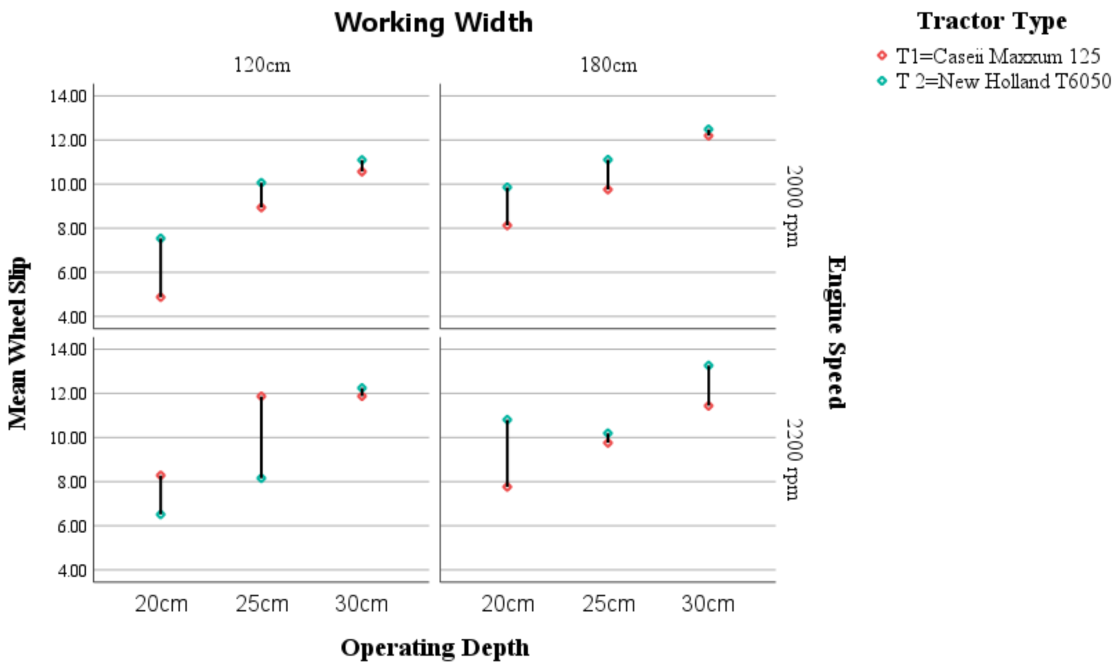


Figure 4.9. Mean Wheel Slip for Combine Main Factor

Here's why increased wheel slip can negatively impact tractor performance. Reduced Traction: Wheel slip indicates a decrease in the traction between the tractor's wheels and the ground. As a result, the tractor loses grip, making it more difficult to maintain control and effectively transmit power to the ground. Reduced traction can lead to inefficient power transfer and decreased drawbar pull, limiting the tractor's ability to perform tasks efficiently (Ghali, 2019).

Decreased Efficiency: When wheel slip occurs, power is wasted as it is not effectively transferred to the ground. The spinning wheels consume energy without contributing to propelling the tractor forward, resulting in lower overall efficiency. This inefficiency can lead to increased fuel consumption and reduced productivity, as the tractor is not effectively utilizing its power to perform tasks (Jithender et al., 2017).

Impaired Performance in Challenging Conditions: Increased wheel slip can significantly impact the tractor's performance in challenging terrain or adverse weather conditions. For example, in muddy or slippery fields, excessive wheel slip can hinder the tractor's ability to maintain traction, leading to reduced drawbar pull and potential difficulty in maneuvering. This can result in slower progress, decreased productivity, and potential damage to the field or implements (Bilal Ahmad, Usman Ali, Fazal Ahmad Jamal, 2021).

Soil Compaction and Surface Damage: Excessive wheel slip can contribute to soil compaction and damage to the ground surface. When the wheels spin and slip, they can dig into the soil, causing rutting and compaction. This can have negative long-term effects on soil health, crop growth, and overall field productivity. Safety Concerns: Increased wheel slip poses safety risks, especially when operating on slopes or uneven terrain. The loss of traction can result in reduced control and stability, increasing the chances of accidents or tip-overs. It is important to maintain adequate traction to ensure the tractor's stability and operator safety during operations (Chenarbon, 2022)..

Generally, the results indicated in the Fig. 4.7.,4.8. and 4.9. that the Wheel slip increase with increased operating depth, engine speed and working width. Increased Wheel slip negatively impacts tractor performance. Wheel slip, a condition where a tractor's drive wheels lose traction and spin faster than the ground speed, can negatively impact a tractor's performance. This results in reduced traction, inefficient power transfer, decreased drawbar pull, and reduced efficiency. It also leads to impaired performance in challenging conditions, such as muddy or slippery fields, and soil compaction and surface damage.

Safety concerns arise, especially when operating on slopes or uneven terrain, as the loss of traction can result in reduced control and stability, increasing the chances of accidents or tip-overs. Therefore, it is crucial to maintain adequate traction to ensure tractor stability and operator safety.

4.4. . Effective Field Capacity

The effective field capacity is the measure of the ability of a machine to do a job under actual field conditions. According to (Mandal et al., 2015) the effective field capacity was calculated based on the equation given in methodology (3.7).

The results from the computation of the drawbar pull for the two tractors are presented in Table 4.7. In both tractor models, highest drawbar pull was observed when the Tractors were operating at depth of 20 cm and a working width of 180 cm. New Holland T6050 exhibited a higher field capacity of 0.83 for mold-board plow compared to the Caseii Maxxum 125 tractor. The lowest field capacity was recorded with Caseii Maxxum operating at a depth of 30 cm and a working width of 120 cm at 2000 rpm engine speed which was 0.32.

Table 4.7. Field capacity of Caseii 125 and T6050 operating with moldboard

	T				T			
	N_1		N_2		N_1		N_2	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
	0.4	0.7	0.46	0.67	0.53	0.81	0.54	0.83
D_1	0.43	0.58	0.45	0.64	0.42	0.61	0.53	0.77
	0.47	0.62	0.43	0.63	0.51	0.73	0.5	0.75
	0.46	0.67	0.45	0.66	0.49	0.73	0.5	0.75
D_2	0.35	0.48	0.43	0.64	0.39	0.58	0.5	0.72
	0.43	0.64	0.41	0.6	0.46	0.67	0.49	0.72
	0.32	0.54	0.39	0.6	0.49	0.7	0.48	0.7
D_3	0.33	0.43	0.38	0.57	0.37	0.55	0.46	0.69
	0.38	0.57	0.37	0.54	0.43	0.63	0.44	0.66

Table 4.8. shows the result from the analysis of variance (ANOVA) for the effects of Tractor type , operating depth , engine speed and working width on the field capacity. The ANOVA results indicated that the model is significant ($F= 1054.798$, $P < .000$). The main

effect of tractor Type (F=59.175, P<.000), operating depth (F= 19.673, P< .000), engine speed (F= 13.732, P < .000) and working width (F= 368.372, P<.000) were all artistically significant at a 5% level. However , the interaction effects of Tractor Type with Operating Depth (F= .816, P<..447), Tractor Type with Engine Speed (F=1.098, P<.299) and Tractor Type with Working Width (F=2.592, P<.112) are not significant. The model accounts for a high proportion of the variance (R Square = .994, Adjusted Squared= .993).

Table 4.8. ANOVA Table of Field Capacity for Caseii 125 and New Holland tractor

Tests of Between-Subjects Effects

Dependent Variable: Field Capacity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	22.430[a]	10	2.243	1054.798	.000
Tractor Type (T)	.126	1	.126	59.175	.000
Operating Depth (D)	.084	2	.042	19.673	.000
Engine Speed (V)	.029	1	.029	13.732	.000
Working Width (W)	.783	1	.783	368.372	.000
Tractor Type * Operating Depth (T × D)	.003	2	.002	.816	.447
Tractor Type * Engine Speed (T × V)	.002	1	.002	1.098	.299
Tractor Type * Working Width (T × W)	.006	1	.006	2.592	.112
Error	.132	62	.002		
Total	22.562	72			

a. R Squared = .994 (Adjusted R Squared = .993)

The effect of operating depth on field capacity by Tractor type for the working width of 120 cm shown in Figure 4.10. It was observed that if the operating depth increases, but the field capacity decreases for both Tractor types. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 tractor.

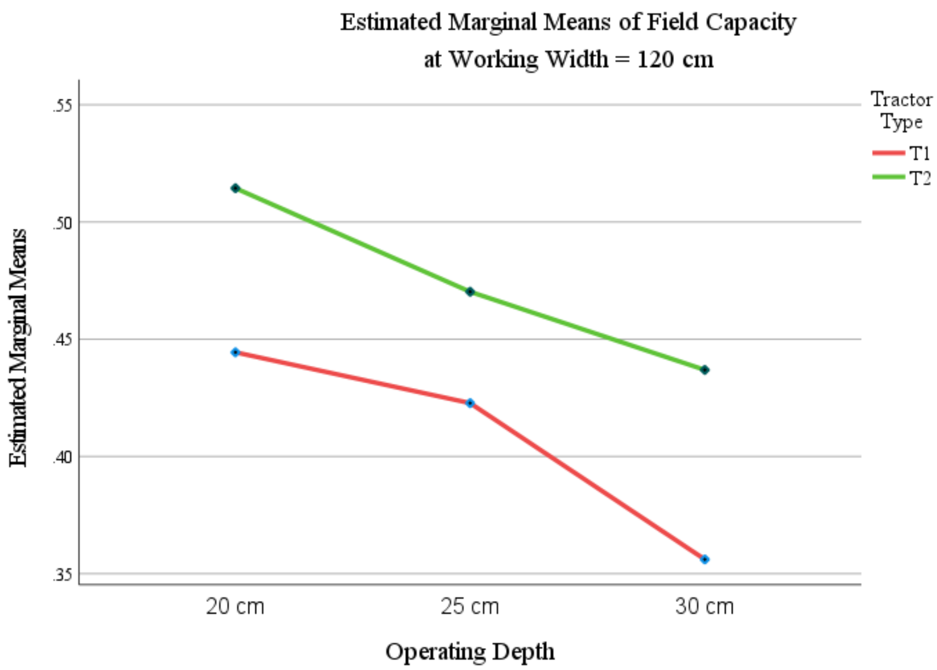


Figure 4.10. Effect of working depth on Field Capacity at working width of 120 cm.

The effect of operating depth Tractor type on field capacity at working width 180 cm on shown in Fig. 4.11. It can be noticed that if the operating depth increases, but the field capacity decreases for both Tractors. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 Tractor.

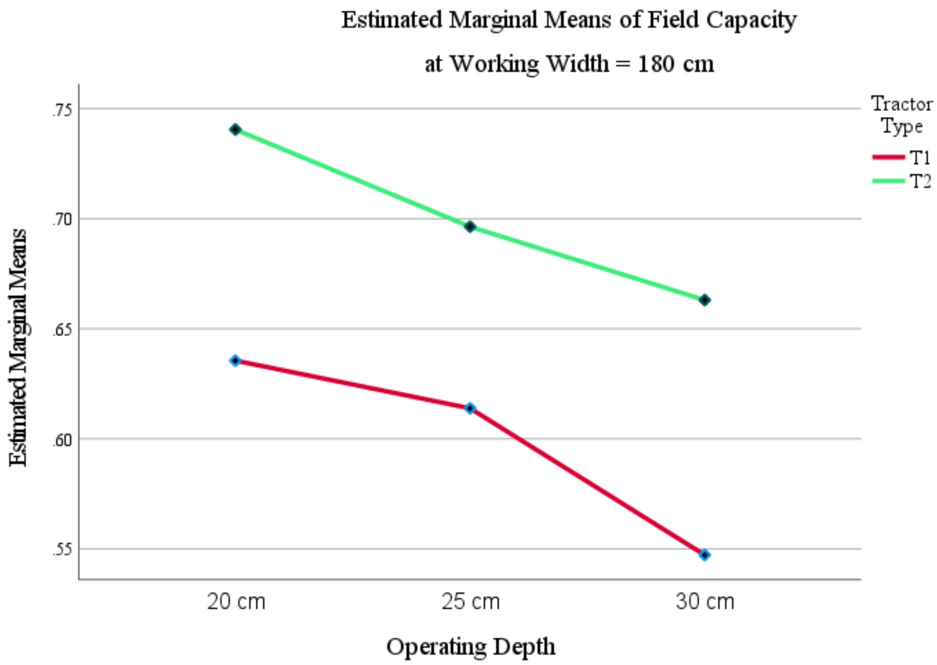


Figure 4.11. Effect of working depth on Field Capacity at working width of 180 cm.

The effect of operating depth, Tractor type, engine speed and at working width of 120 cm and 180 cm on field capacity is shown in figure 4.12. It was observed that if the operating depth, engine speed and working width increases but the field capacity decreases, for both Tractor types.

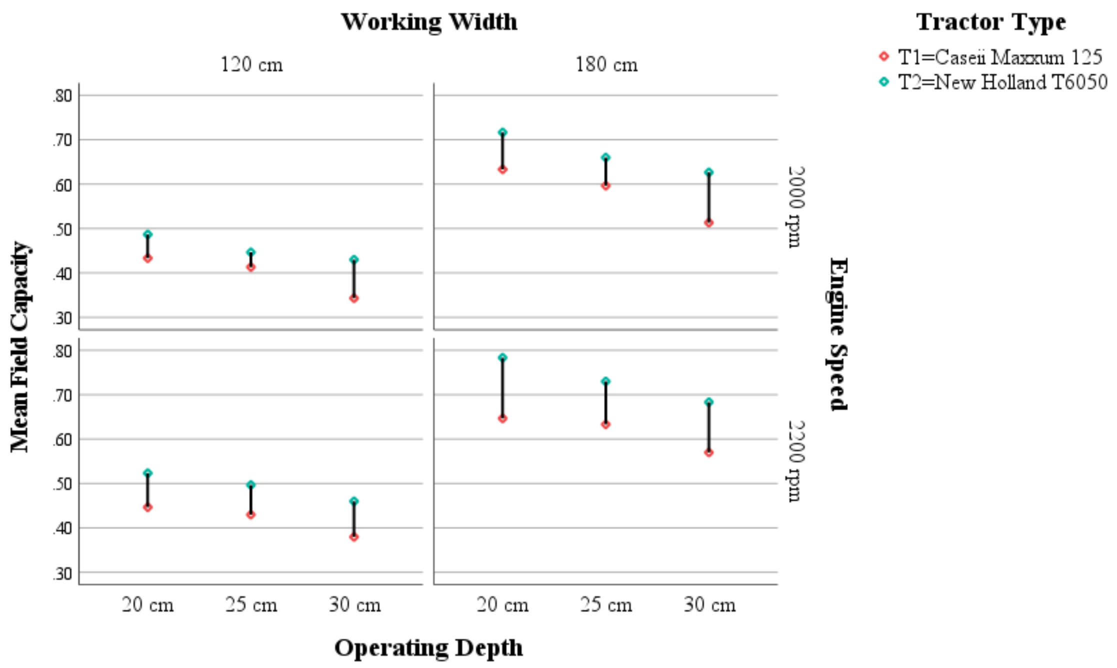


Figure 4.12. Mean Field Capacity for the Combine Main Factor

Here's why a decrease in field capacity can be detrimental to tractor performance.

Reduced Productivity: When the field capacity decreases, it means the tractor can cover fewer acres or hectares in a given time. This leads to reduced productivity as the same amount of work takes longer to complete. Decreased field capacity can be a result of various factors, such as slower operating speeds, reduced efficiency in implements or attachments, or limitations in tractor power. Lower productivity can negatively impact overall efficiency and may result in delayed or incomplete tasks (Ibrahim kareem & Sven, 2019).

Increased Operating Costs: With decreased field capacity, more time and resources are required to complete the same amount of work. This can lead to increased operating costs, including labor expenses, fuel consumption, and maintenance costs. The longer operating hours and increased resource utilization can put additional strain on the tractor and its components, potentially leading to higher maintenance and repair requirements (Leghari et al., 2020).

Limited Time for Critical Operations: In agricultural operations, timing is crucial for tasks like planting, harvesting, or applying fertilizers and pesticides. A decrease in field capacity means less work can be completed within a specific timeframe, reducing the available time for critical operations. This can result in missed windows of opportunity and compromised crop yield or quality (Sopegno et al., 2016).

Increased Fatigue and Operator Stress: Operating at lower field capacity often requires longer hours of work and increased time pressure. The extended operating periods can lead to operator fatigue and increased stress levels. Fatigue can negatively affect the operator's alertness, decision-making capabilities, and overall safety during operation (Adamchuk et al., 2016).

Inefficiency in Resource Utilization: When field capacity decreases, the tractor's capabilities are underutilized. The available power, fuel consumption, and labor resources may not be effectively utilized, resulting in inefficiencies. This can lead to suboptimal use of resources and reduced returns on investment (Gebrekidan, 2022).

Generally, the results indicated in the Fig. 4.10.,4.11. and 4.12. that the Field Capacity decrease with increased operating depth, engine speed and working width. Decrease Field Capacity negatively impacts on tractor performance by By leading to reduced productivity, increased operating costs, limited time for critical operations, increased fatigue and operator stress, and inefficiency in resource utilization.

4.5. PTO Power

4.5.1. Tractor Available Power

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 (Karparvarfard & Rahmanian-Koushkaki, 2015). 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 (Randal K. Taylor et al., 2013).According to (Reichenbach et al., 2019) based on the ASABE 2006. .Tractor available power was estimated from net flywheel power by multiplying the net flywheel power by 0.90. From specification of tractors we have 125 hp for Caseii Maxxum 125 and 127 hp for New Holland Tractors T6050.

So tractor available power for Caseii Maxxum 125= 125 hp × 0.9= 112.5 hp. To convert in Kw we multiply by 0.746 Kw/hp. 112.5 hp × 0.746 Kw/hp = 83.93 Kw. Tractor available power for New Holland T6050= 127 hp × 0.9 = 114.3 hp. To convert in Kw we multiply by 0.746 Kw/hp. 114.3 hp × 0.746 Kw/hp = 85.27 Kw.

4.5.2. Equivalent PTO Power requirement of the implement

Correct matching of tractors and implements can increase the efficiency of operations and farm profitability. This in turn results in 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 a determination of drawbar pull which varies with the type of soil and implement. The second parameter is the drawbar power requirement of the implement which shows the power required by the tractor to pull the implement (Sornpoon & Jayasuriya, 2013).

According (Reichenbach et al., 2019) Equivalent PTO Power requirement of the implement was estimated from Drawbar power. By dividing the drawbar power by 0.78 based on the ASABE 2006. So we used the drawbar Power result from (Table 4.3.) and divide by 0.78. The results of Equivalent PTO Power requirement of the implement on the two tractors are shown in (Table 4.9.) The highest Equivalent PTO Power requirement of the implement on New Holland T6050 tractor when the tractors operate at 30 cm and working width 180 cm which is the value of Equivalent PTO Power requirement of the implement 67.23 Kw. And also the Equivalent PTO Power requirement of the implement occur on Caseii 125 when the tractors operate at 20 cm and working width 120 cm which is the value of Drawbar power requirement 24.17 Kw.

Table 4.9. Equivalent PTO Power requirement of the implement.

	T				T			
	N_1		N_2		N_1		N_2	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
	24.17	44.82	29.04	42.36	35.46	54.04	48.53	55.87
D_1	27.03	35.35	28.08	39.49	26.24	37.28	46.92	49.96

	29.53	38.32	26.63	38.78	33.67	47.35	43.92	48.65
	36.01	52.32	35.28	51.42	40.69	59.19	54.94	60.81
D_2	25.95	35.33	33.29	49.95	30.12	43.91	53.49	57.91
	33.3	49.95	31.21	45.6	36.19	52.63	53.33	57.44
	28.17	48.26	35.35	54.72	47.35	67.23	61.42	67.23
D_3	29.41	37.56	34.03	51.53	33.14	49.72	58.09	65.36
	34.35	51.38	33.69	48.9	40.55	58.49	54.86	61.88

Table 4.10. shows the result from the analysis of variance (ANOVA) for the effects of Tractor type , operating depth , engine speed and working width on the drawbar pull. The ANOVA results indicated that the model is significant (F= 604.352, P < .000). The main effect of tractor type (F=102.358, P<.000),operating depth (F=21.792, P< .0000) and engine speed (F=37.291, P < .000) and working width (F= 119.598, P<.000) were all artistically significant at a 5% level. The interaction effects of Tractor Type with Engine Speed (F= 14.482, P<.000) is also significant. However , the interaction effect of Tractor Type with Operating Depth (F= 1.752, P<.182) and Tractor Type with Working Width (F= 2.449, P< .123) is not significant. The model accounts for a high proportion of the variance (R Square = .990, Adjusted Squared= .988).

Table 4.10 ANOVA Table of Equivalent PTO Power requirement of the implement

Tests of Between-Subjects Effects

Dependent Variable: Equivalent PTO Power Requirement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	146936.754[a]	10	14693.675	604.352	.000
Tractor Type (T)	2488.651	1	2488.651	102.358	.000
Operating Depth (D)	1059.671	2	529.836	21.792	.000
Engine Speed (V)	906.670	1	906.670	37.291	.000
Working Width (W)	2907.794	1	2907.794	119.598	.000
Tractor Type × Operating Depth (T × D)	85.182	2	42.591	1.752	.182
Tractor Type × Engine Speed (T × V)	352.097	1	352.097	14.482	.000

Tractor Type × Working Width (T × W)	59.550	1	59.550	2.449	.123
Error	1507.413	62	24.313		
Total	148444.167	72			

a. R Squared = .990 (Adjusted R Squared = .988)

The effect of operating depth on drawbar pull by Tractor type for the working width of 120 cm shown in Figure 4.13. It was observed that if the operating depth increases, the effective PTO Power requirement also increases for both Tractor types. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 tractor.

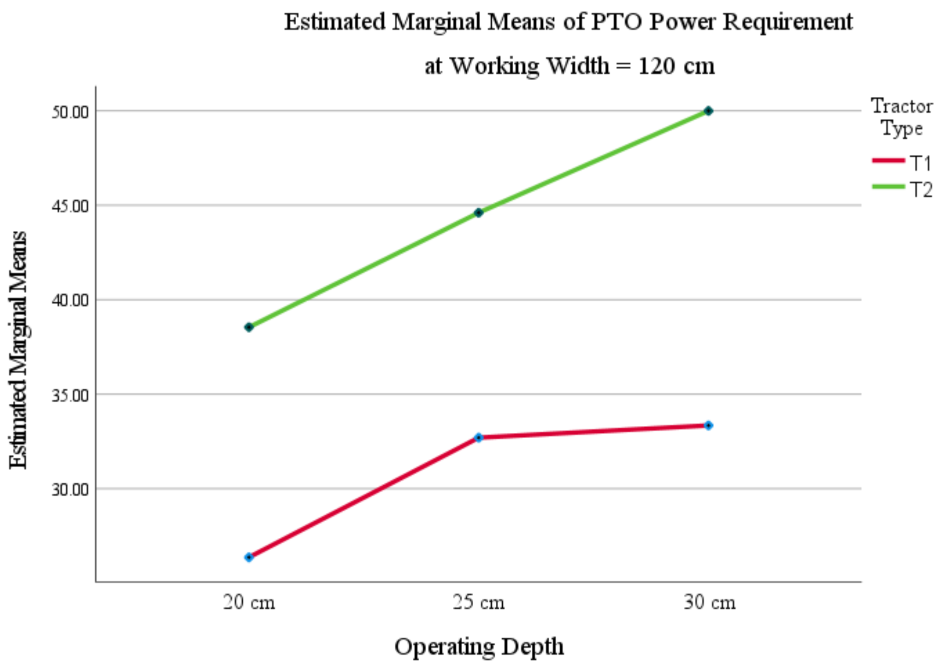


Figure 4.13. Effect of working depth on Effective PTO Power Requirement at working width of 120 cm

The effect of operating depth Tractor type on effective PTO Power at working width 180 cm on shown in Fig. 4.14. It can be noticed that if the operating depth increases, the effective PTO power requirement also increases for both Tractors. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 Tractor.

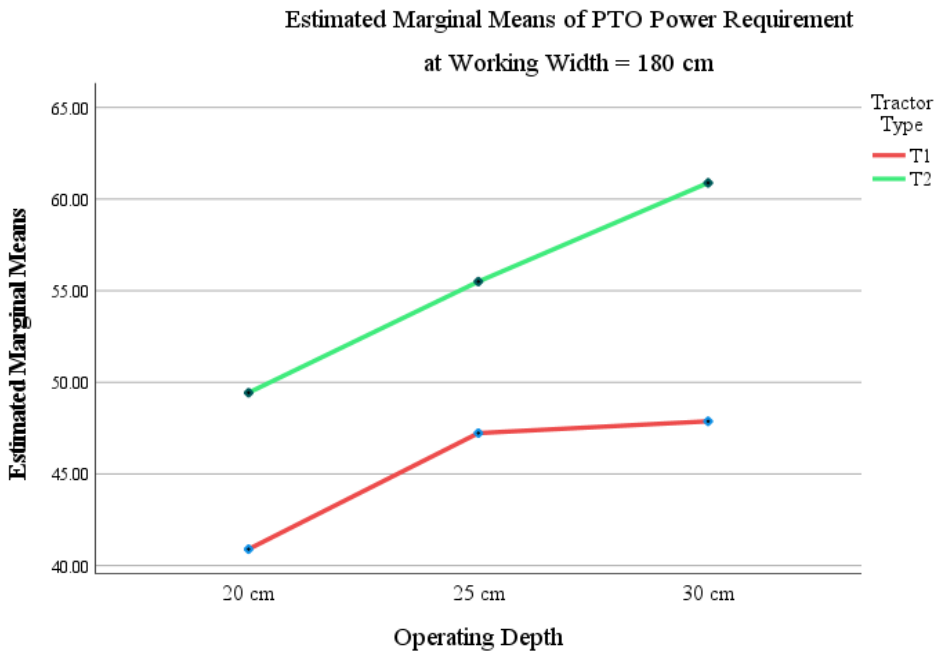


Figure 4.14. Effect of working depth on Effective PTO power requirement at working width of 180 cm

The effect of operating depth, Tractor type, engine speed and at working width of 120 cm and 180 cm on effective PTO power requirement is shown in figure 4.15. It was observed that if the operating depth, engine speed and working width increases, the effective PTO power requirement also increases, the effective PTO power requirement also increases for both Tractor types.

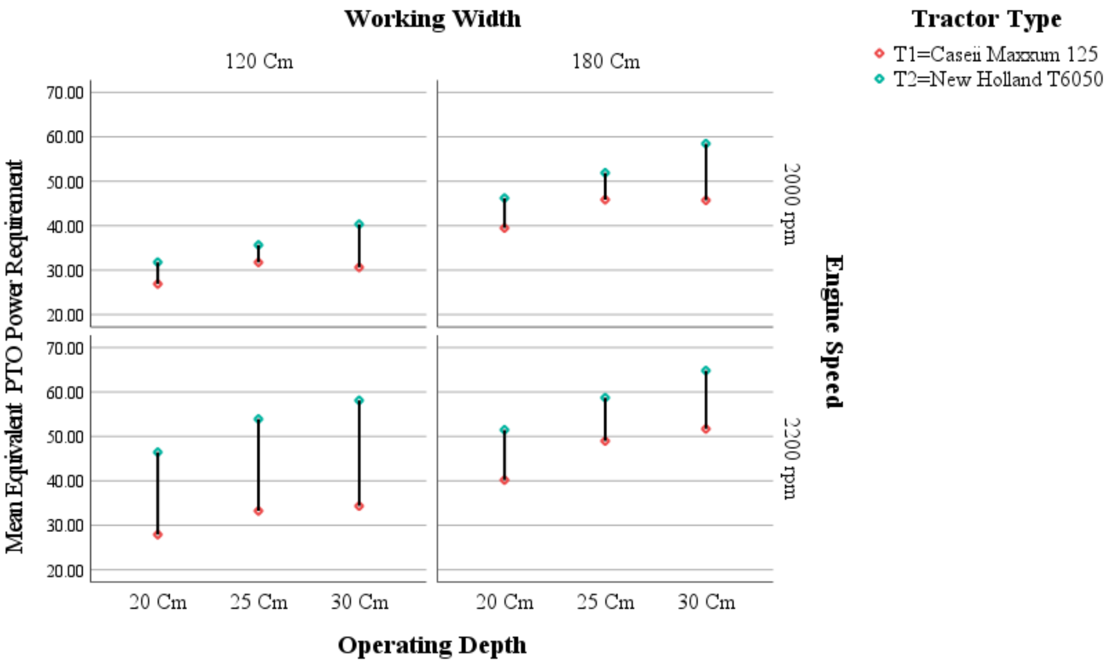


Figure 4.15 Mean Effective PTO power requirement for the Combine Main Factor

Here's why a decrease in Effective PTO power requirement can be detrimental to tractor performance.

Reduced Available Power: The Effective PTO power requirement represents the amount of power needed to operate PTO-driven implements, such as mowers, balers, or pumps. When the PTO power requirement increases, it places a higher demand on the tractor's engine, reducing the available power for other operations. This can limit the tractor's ability to perform tasks that require significant power, such as pulling heavy loads or operating in challenging terrain (Ranjbarian et al., 2017).

Decreased Performance in Other Functions: As the Effective PTO power requirement increases, the tractor's engine may need to work harder to meet the power demands. This can result in reduced performance in other tractor functions, such as decreased drawbar power or reduced travel speed. The overall efficiency and productivity of the tractor can be compromised if the engine is unable to provide sufficient power for both PTO-driven implements and other essential tasks (Sopegno et al., 2016).

Increased Fuel Consumption: Meeting higher effective PTO power requirements often necessitates running the tractor's engine at higher RPMs or under heavier loads. This can lead to increased fuel consumption, as the engine works harder to generate the required power. Higher fuel consumption not only increases operating costs but can also reduce the tractor's operating time between refueling, resulting in decreased efficiency and productivity (Almaliki et al., 2016).

Potential Strain on Tractor Components: Operating the tractor at high effective effective PTO power requirements for extended periods can put additional strain on various components, such as the engine, transmission, and PTO driveline. This increased stress can accelerate wear and tear, potentially leading to higher maintenance and repair costs. It is important to operate the tractor within its recommended power limits to ensure the longevity and reliability of its components (Ghali, 2019).

Generally, the results indicated in the Fig. 4.13., 4.14. and 4.15. that the Effective PTO power requirement increase with increased operating depth, engine speed and working width. Increased PTO power requirement. The increasing effective PTO power requirement negatively impacts a tractor's performance By reducing available power, affecting performance in other functions, increasing fuel consumption, and straining tractor components.

4.6. Power Utilization Ratio

The power utilization ratio is the ratio between the equivalent power required by the implement and the maximum available power from the tractor (Randal K. Taylor et al., 2013)

So we have the results of Equivalent PTO Power required by the implement in (Table 7.9.) and also Field efficiency (η)=0.85 by using the value we can calculate the effective field capacity. The results of Power Utilization Ratio on the two tractors are shown in (Table 4.11.) In both tractor models, highest Power Utilization Ratio(PUR) on New Holland T6050 Tractor when the tractors operate at 30 cm and working width 180 cm which is the value of Power Utilization Ratio (PUR) 0.79. And also the lowest Power Utilization Ratio (PUR) occur on Caseii 125 when the tractors operate at 20 cm and working width 120 cm which is the value of Power Utilization Ratio (PUR) 0.28.

Table 4.11 Power utilization ratio of Tractors operating with mold board

	T				T			
	N_1		N_2		N_1		N_2	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
	0.28	0.53	0.35	0.51	0.42	0.63	0.57	0.66
D_1	0.32	0.42	0.33	0.47	0.31	0.44	0.55	0.59

	0.35	0.46	0.32	0.46	0.4	0.56	0.51	0.57
	0.42	0.62	0.42	0.62	0.48	0.69	0.64	0.71
D_2	0.31	0.42	0.4	0.6	0.35	0.52	0.63	0.68
	0.4	0.6	0.37	0.54	0.42	0.62	0.63	0.68
	0.34	0.58	0.42	0.65	0.56	0.79	0.72	0.79
D_3	0.35	0.45	0.41	0.61	0.39	0.58	0.68	0.77
	0.41	0.61	0.4	0.58	0.48	0.69	0.64	0.73

Table 4.12. shows the result from the analysis of variance (ANOVA) for the effects of Tractor type , operating depth , engine speed and working width on the Power utilization ratio. The ANOVA results indicated that the model is significant (F= 497.407, P < .000). The main effect of tractor type (F=85.406, P<.000), Operating Depth (F= 14.473, P< .000), engine speed (F=29.641, P < .000) and working width (F= 88.876, P<.000) were all artistically significant at a 5% level. The interaction effects of Tractor Type with Engine Speed (F= 15.085, P<.000) is also significant. However , the interaction effect of Tractor Type with Operating Depth (F= 1.965, P<.149) and Tractor Type with Working Width (F=1.972, P< .165) are not significant. The model accounts for a high proportion of the variance (R Square = .988, Adjusted Squared= .986).

Table 4. 12 ANOVA Table of Power Utilization Ratio for two tractor

Tests of Between-Subjects Effects

Dependent Variable: Power Utilization Ratio

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	20.457[a]	10	2.046	497.407	.000
Tractor Type (T)	.351	1	.351	85.406	.000
Operating Depth (D)	.119	2	.060	14.473	.000
Engine Speed (V)	.122	1	.122	29.641	.000
Working Width (W)	.366	1	.366	88.876	.000
Tractor Type × Operating Depth (T × D)	.016	2	.008	1.965	.149
Tractor Type × Engine Speed (T × V)	.062	1	.062	15.085	.000

Tractor Type × Working Width (T × W)	.008	1	.008	1.972	.165
Error	.255	62	.004		
Total	20.712	72			

a. R Squared = .988 (Adjusted R Squared = .986)

The effect of operating depth on power utilization ratio by Tractor type for the working width of 120 cm shown in Figure 4.16. It was observed that if the operating depth increases, the power utilization ratio also increases for both Tractor types. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 tractor.

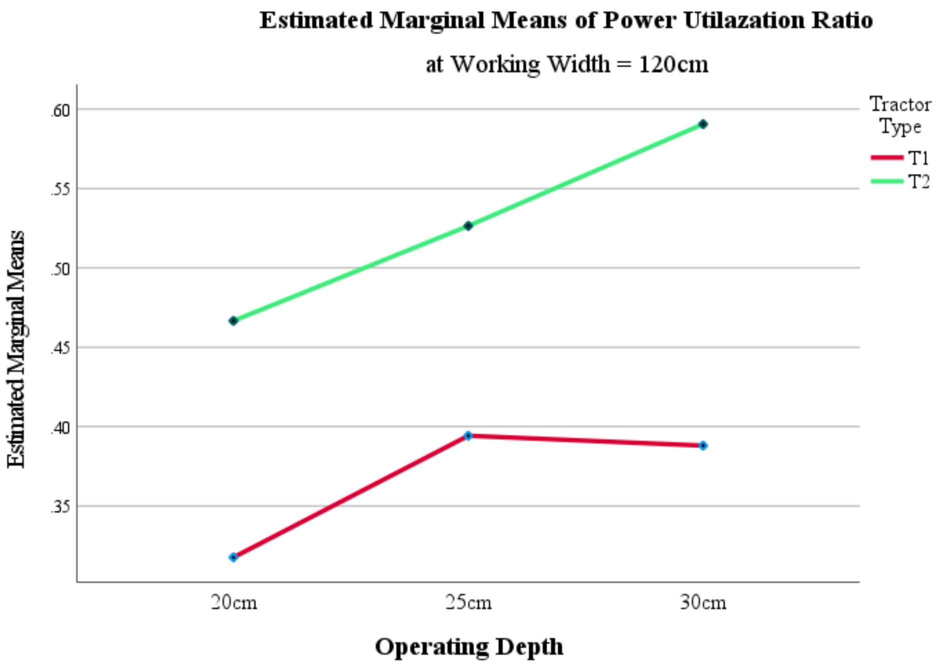


Figure 4.16. Effect of working depth on power utilization ratio at working width of 120 cm.

The effect of operating depth Tractor type on drawbar pull at working width 180 cm on shown in Fig. 4.17. It can be noticed that if the operating depth increases, the power utilization ratio also increases for both Tractors. The letters symbol indicates T_1= Caseii Maxxum 125 tractor, T_2= New Holland T6050 Tractor.

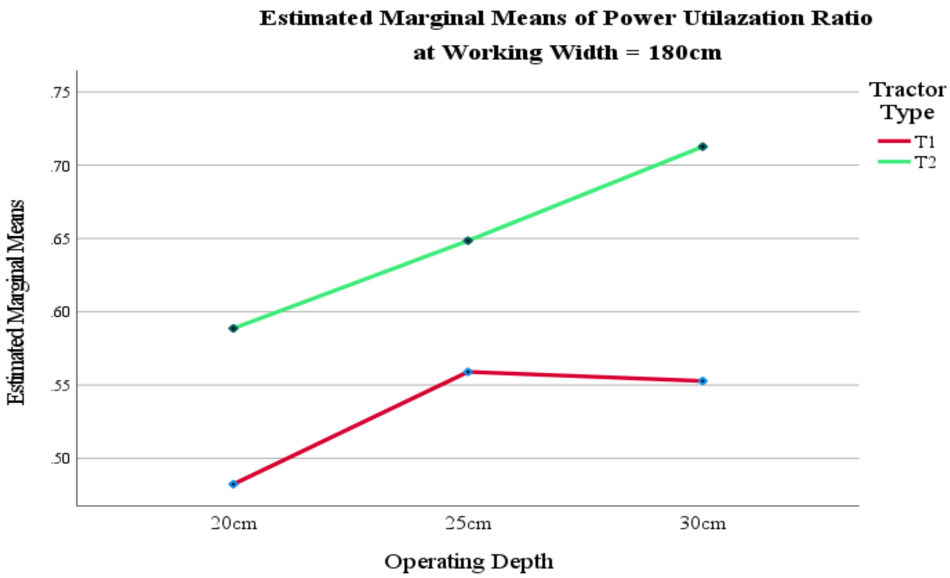


Figure 4.17. Effect of working depth on power utilization ratio at working width of 180 cm.

The effect of operating depth, Tractor type, engine speed and at working width of 120 cm and 180 cm on power utilization ratio is shown in figure 4.18. It was observed that if the operating depth, engine speed and working width increases, the power utilization ratio also increases, the power utilization ratio also increases for both Tractor types.

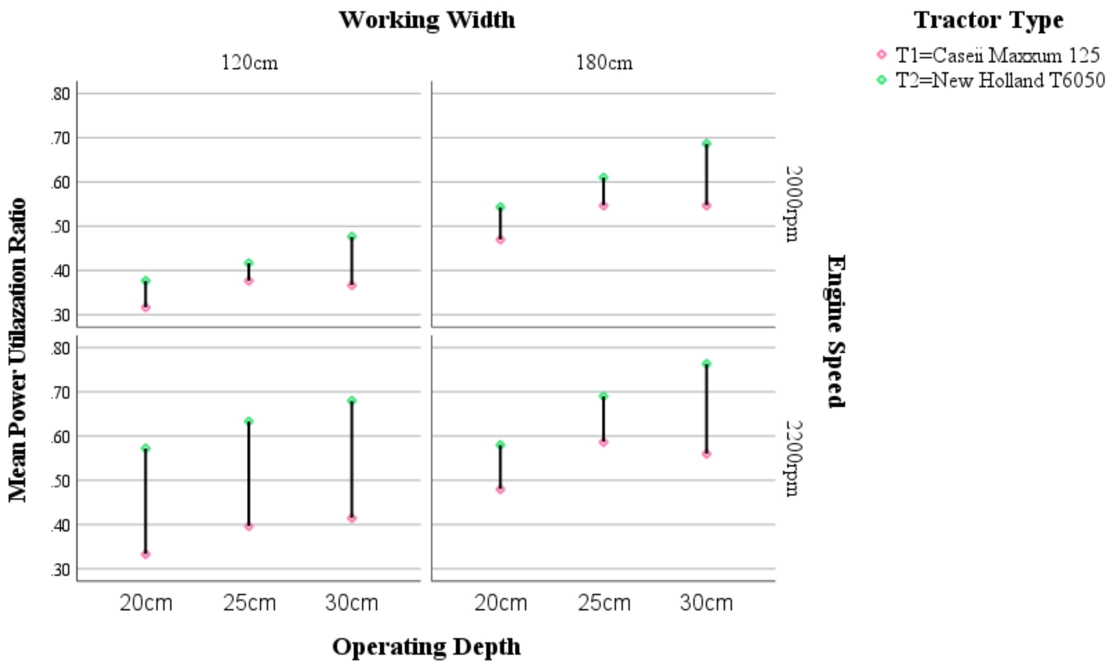


Figure 4.18. Mean Power Utilization Ratio for the Combine Main Factor

The increasing of PTO power Utilization has a positive impact on the performance of a tractor. Here's why Here's why an increased power utilization ratio can be beneficial:

Improved Efficiency: A higher power utilization ratio indicates that the tractor is effectively utilizing a larger portion of its available power. This translates to improved efficiency in converting the engine power to useful work output. With a higher power utilization ratio, the tractor can more effectively perform tasks, such as pulling implements or operating attachments, with better power utilization and reduced energy wastage (Srivastava, 2020).

Enhanced Productivity: When the power utilization ratio increases, the tractor can deliver more power to perform tasks efficiently. This can result in improved productivity as the tractor can complete work faster or handle larger workloads within a given time frame. Increased power utilization enables the tractor to exert more force, maintain higher speeds, or handle heavier loads, contributing to enhanced productivity (Leghari et al., 2020).

Better Performance in Challenging Conditions: Operating in challenging conditions, such as rough terrain or heavy soil, often requires higher power demands. A tractor with an increased power utilization ratio can effectively apply power to overcome resistance and maintain performance in such conditions. It helps the tractor maintain action, control, and stability, enabling it to handle demanding tasks with greater ease (Bilal Ahmad, Usman Ali, Fazal Ahmad Jamal, 2021).

Optimal Resource Utilization: Increasing the power utilization ratio ensures that the tractor is making the most efficient use of available resources, such as fuel and engine power. By maximizing power output and minimizing energy wastage, the tractor can optimize resource utilization, leading to reduced fuel consumption and lower operating costs. This is especially important in agricultural operations where fuel expenses can make up a significant portion of the overall costs (Alele et al., 2018).

Extended Component Life: When the power utilization ratio is high, the tractor operates within its optimal power range. This can lead to reduced stress on the engine, transmission, and other components, potentially extending their lifespan. Operating the tractor at a higher power utilization ratio allows for a smoother and more balanced power delivery, reducing the risk of excessive wear and tear on critical components (Damanauskas et al., 2015).

Generally, the results indicated in the Fig. 4.16.,4.17. and 4.18. that the Power Utilization Ratio increase with increased operating depth, engine speed and working width. Increased Power Utilization Ratio positively impacts tractor performance by enhancing capability, improving productivity, increasing versatility, and enhancing traction and control. An increased power utilization ratio in a tractor can improve efficiency, productivity, and performance in challenging conditions. It indicates that the tractor is effectively utilizing its available power, converting engine power into useful work output. This leads to faster completion of tasks and reduced energy wastage.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The study conducted to evaluate the effect of operating depth and working width on drawbar pull and drawbar power of the implement has provided valuable insights into the performance of tractors in agricultural operations. The evaluation of this research, conducted with Caseii 125 and New Holland T6050 tractors, aimed to determine the best tractor implement combination for optimal properpopp[matching in agricultural operations. The selection of these tractors was based on their availability in the study area, Lasalle Agro Processing study involved testing various parameters, including three different depths, two working widths, and two engine speeds, in sandy loam soil for primary tillage with a four bottom moldboard plow. The data collected from the field were travel speed, operation depth, soil types, and working width. The calculation was made based on already developed standards and formulas. The parameters evaluated were drawbar pull, drawbar power, wheel slippage, field capacity, effective PTO power requirement, and power utilization ratio.

The results showed that increasing operating depth, engine speed, and working width led to higher drawbar pull and drawbar power, positively impacting the tractor's capability, productivity, versatility, and traction. The results indicated that the New Holland T6050 tractor operating at 2200 RPM with a 180 cm working width showed the highest drawbar pull, drawbar power, field capacity, PTO power, and power utilization ratio. In contrast, the Caseii 125 tractor operating at 2000 RPM with 120 cm working width showed the lowest drawbar pull, drawbar power, Wheel Slip, field capacity, PTO power, and Power Utilization ratio.. The analysis also showed that tractor types , operating depth, engine speed, and working width had a significant effect on drawbar pull, drawbar power, PTO power, and Power utilization ratio for both Caseii 125 and New Holland T6050 tractors.

In general, the findings of this study can be instrumental in guiding farmers and tractor manufacturers in optimizing tractor performance for various agricultural tasks. By understanding the factors that influence drawbar pull and drawbar power, farmers can make informed decisions to enhance efficiency, productivity, and overall performance in agricultural operations.

5.2. Recommendation

Based on the results it was observed that Caseii Maxxum 125 was also operated in under loading condition in most of the plowing operations in all operating depths, working width, and engine speeds that were considered during the field test except when it was operated with 2200 rpm, 1.8 working width, and 25 and 30 cm operating depth. New Holland T6050 was operating in a better condition when it was operating with an engine speed of 2000 RPM with 1.8 m working width in 20 and 30 cm operating depth and 2200 RPM in all operating depths in 180 cm working width.

From all combinations, the first highly recommended combination is the New Holland tractor and moldboard plow operating with 2200 RPM engine speed, 180 cm working width, and 30, 25, and 20 cm operating depth. In second place, a New Holland tractor and moldboard plow operating with 2000 RPM engine speed, 1.8 m working width, and 20 and 25 cm operating depth was recommended. The third place Caseii Maxxum 125, and moldboard operating with 2200 rpm engine speed and 1.8 working width operating with the depth of 25 cm and 30 cm was recommended. At last, since this research was done analytically it was very useful feed for the agricultural sectors but it has its weak side in giving the exact situational values so for that reason it is better to use some experimental and on-field equipment to get exact values concerning the soil and machine exact condition.

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APPENDIX

7.1. Appendix Table

Implements		SI Units				Width units						
	Width units	Machine Parameters			Width units	Machine Parameters			Soil parameters			Range
		A	B	C		A	B	C	F_1	F_2	F_3	
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	13.3	0	Ft	48	3.7	0	1	0.85	0.65	35
Disk Harrow, Tandem												
primary tillage	m	309	16	0	ft	53	4.6	0	1	0.88	0.78	50
primary tillage	m	216	11.2	0	ft	37	3.2	0	1	0.88	0.78	30
Disk Harrow, Offset												
primary tillage	m	364	18.8	0	ft	62	5.4	0	1	0.88	0.78	50
secondary tillage	m	254	13.2	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
Colters												
smooth or ripple	tools	55	2.7	0	tools	31	2.5	0	1	0.88	0.78	25
bubble or flute	tools	66	3.3	0	tools	37	3.0	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	11.9	0	1	0.85	0.65	15
No-till	rows	435	21.8	0	rows	248	19.9	0	1	0.85	0.65	20
Rod Weeder	m	210	10.7	0	ft	37	3.0	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												
1fluted colter/row	rows	1820	0	0	rows	410	0	0	1	0.96	0.92	25
Row Crop Planter, zone till												
seed, fertilizer, herbicides												
3fluted colters/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	0	1	1	1	25
Grain Drill, no-till												
1fluted colter/row	rows	720	0	0	rows	160	0	0	1	0.92	0.79	35
Hoe Dril												
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 7. 2: Travel speed of the tractors during field operations.

	T_1				T_2			
	N_1		N_2		N_1		N_2	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
D_1	3.8	4.6	4.5	4.4	5.24	5.3	5.34	5.43
	4.25	3.8	3.8	4.38	4.16	4.15	3.97	5.21
	4.56	4.06	4.2	4.1	5.04	4.8	4.9	4.9
D_2	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
	4.2	4.2	3.985	3.9	4.5	4.38	4.85	4.69
D_3	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
	3.71	3.7	3.65	3.55	4.25	4.14	4.3	4.31

Annex Table 7.3. 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

APPENDIX-

Pictures showing performance evaluation of tractors mold board implements.

Annex Figure 1. Preparation of the tractors implements for the experiment.

Annex Figure 3. Measuring of operation