EVALUATION OF FARM MACHINERY MANAGEMENT SYSTEM:

THE CASE OF OROMIA SEED ENTERPRISE

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SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

A thesis submitted in partial fulfillment of the requirements for the Award of the degree of Master of Science in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

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ADVISOR APPROVAL SHEETS

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Subject: Thesis submission

This is to certify that the thesis entitled "**Evaluation of farm machinery management system: The case of Oromia Seed Enterprise**" submitted in partial fulfillment of the requirement for the degree of the Masters in Agricultural Machinery Engineering, the Graduate Program of the Department of Mechanical System and Vehicle Engineering, and has been carried out by Mr. Alemayehu Teshome Gemmechu pgr/18413/11, under my supervision.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
ASAE	American Society of Agricultural Engineering
ASABE	American Society of Agricultural and Biological Engineering
DBHP	Drawbar Horse Power
ECRA	Ethiopian Custom and Revenue Authority
FDRE	Ethiopia Federal Democratic Republics of Ethiopia
EIAR	Ethiopia Institute of Agricultural Research
GDP	Growth Development Plan
Ha	Hectare
Hr	Hour
LSD	Least Significant Different
METEC	Metals and Engineering Corporation
OSE	Oromia Seed Enterprise
PT	Primary Tillage
PTO	Power-Take Off
RM	Repair and Maintenance
ST	Secondary Tillage

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ABSTRACT

Agricultural mechanization deals with design, utilization and management of technical systems and processes of engineering for production, storage, treatment, and processing of agricultural goods. In Ethiopia, agricultural mechanization is being encouraged to boost agricultural production. But, different types of machines dropped and many of them became scrap. Some of the machineries are failing frequently. Based on these problems the study aimed to investigate farm machinery management systems in Oromia Seed Enterprise. In order to achieve the objective of this study, different methods were used. A total of 18 respondents who were randomly selected from the maintenance department of Oromia Seed Enterprise to fill the questionnaire on the status of the maintenance management system of the farm states using structured questionnaire sheets. In addition, data of farm machinery during the seasons 2010/11 and 2011/12 in terms of individual farm machinery costs, farm operations costs, rates of work, and power requirements were collected. On the spot, the assessment showed that machinery has about 48% is in bad working condition. The comparison was made between the actual records of the enterprise and the standard management calculations carried out for the different farm machinery parameters. It was observed that there were highly significant differences between the actual and calculated costs for the individual farm machinery made in the season and between the two studied seasons. The calculated fuel costs were greater than the actual fuel costs by 53.39% and the calculated oil costs were greater than the actual oil costs by 66.94% in the two seasons for tractors. Also, the calculated fuel costs were greater than the actual fuel costs by 51.04% and the calculated oil costs were greater than the actual oil costs by 87.75% in the two seasons for combine harvesters. The calculated repair and maintenance costs were greater than the actual repair and maintenance costs by 61.46% in the two seasons for tractors. Also, the calculated repair and maintenance costs were greater than the actual repair and maintenance costs by 39.84% in the two seasons for combine harvesters. The calculated operating costs were greater than the actual operating costs by 32.60 % in the two seasons for tractors. Also, the calculated operating costs were greater than the actual operating costs by 49.66 % in the two seasons for combine harvesters. The actual rates of work were greater than the calculated ones by 17.77%. This variation revealed no significant difference between them. The average actual power used in the scheme was greater from the calculated power requirement by 14%. The study concluded farm machinery cost management was poor. The enterprise dealt with improper methods for cost items determinations, especially for the more important items like depreciation and repair and maintenance. Therefore, it's important to improve the farm machinery management system by a proper recording of information's, and a better selection of farm machinery.

Keywords: farm machinery, state farm, maintenance, machinery cost, management and evaluation.

CHAPTER ONE

1. INTRODUCTION

1.1. Background and justification

Agricultural mechanization deals with design, utilization and management of technical systems and processes of engineering for production, storage, treatment, and processing of agricultural goods. Agricultural mechanization aims to increasing land and labor use, working to increase the cultivated area, saving resources (seed, fertilizer, water), and improving energy products and quality protecting the environment; through proper use of inputs, saving sustainability of agricultural production, creating attractive jobs for men and women, to prevent rural exodus, improving farm management and multi farm use, and increasing farm income (Ali, 2005).

As agricultural production in the less developed countries depends mostly on short-duration rainfall and irrigation in limited areas, as such, this type of production is a risky business and requires careful decisions about the level of mechanization to be developed and the selection of the proper machines to be used to maximize the utilization of the short growing season. Moreover, these countries are frequently facing acute problems concerning financing agricultural production operations. This necessitates making the correct decision, especially when high sums of money are to be directed for buying machines and implements to expand existing agricultural areas or to replace old equipment and machines. On the other hand, choosing of the wrong type of machine or the wrong side of the power unit may lead to either over or under-utilization of these valuable and expensive inputs, and may ultimately lead to a huge pileup of unused scrap metal, and back-breaking financial debt (Nagat, 2004).

Farm machinery plays an important role in agricultural production. It contributes a major capital input cost in most agricultural business. Farm machinery offers several potential improvements for farming system such as increased land and labor productivity, reduction of risk, increase of food quality and save of time (Mohammed, 2015).

Machinery management deals with determining the costs for performing a particular operation, selecting the best size and type of equipment for each application, matching machinery component in a complete system, establishing an effective maintenance program determining the optimum age for replacing a particular machine and scheduling farm operation for the best use of the machine (Osman 2011).

One of the important influencing profits in farm business is the cost of owning and operating farm machinery. Farm machinery cost is one of the few costs that good management can minimize and learning how to accurately estimate machinery costs will aid in cutting costs. Accurate costs estimate play an important role in every machinery management decision when to trade, which size to buy and how much to buy.

Machinery management has increased in importance in today farming operations because of its direct relation to the success of management in mixing land, labour and capital to return a satisfactory profit. The importance of farm machinery in the total farming system is indicated by its costs concerning the total costs of crop production. The application of machines to agricultural production has been one of the outstanding developments in agriculture; hence machinery management is the study of selection, operation and replacements. This necessitates making the correct decision about the level of mechanization to be adopted and the selection of the proper and required machines to be used. Machinery contributes a major capital input cost in most farm businesses; many factors are involved in the process of equipping a modern farm for carrying out field operations, and among the most significant factors is economic (Wan, 1998).

The success of many farm-level production systems depends on the wise selection of machinery systems. The main aim of tractor and machinery selection studies is to complete a certain field operation during a specific time and at minimum cost. The number of crops in a rotation, different land sizes for different crops in crop rotation, and the use of the same implement with different machinery (Harsh *et al*., 1982).

Timeliness is an important machinery management concept and it has to be figured in a manner so that the equivalent losses can be determined in term of money per unit time or area. Although timeliness is an important management factor, cash flow is even more important. Therefore, planning machinery system management decision ahead of time will help in maintaining a good financial position. Combining proper management procedures with accurate records will help in achieving proper decisions with confidence (Nagat, 2004).

Machinery management decisions are harder to pin down than most other decisions related to farming because machinery management problems are quite varied, and the decision in each case could mean the difference between the profit and loss (Harsh *et al*., 1982). The selection

of the level of farm mechanization is the most difficult problem in machinery management because it is complicated by the variety of machine types and sizes, capital investment, trained labour requirements, timeliness, farm size and the possibility of using the same equipment with different speeds, width and tractive efficiencies of machines and with different crops. Proper management of farm machinery is very important in mechanized farming due to the high investment involved in the purchase and operating of farm machines.

1.2. Statement of the problem

In Ethiopia, agricultural mechanization is being encouraged to boost agricultural production. Hence, mechanizing agriculture through the adoption and appropriate use of the farm tractor and its related implements is necessary to boost the productivity of land and labour while reducing drudgery and improving the timeliness of agricultural operations (FAO, 2008). There exist some tractors and equipment hiring services in many districts of the country. Also some private farms, institutions, government agencies, cooperative bodies etc. buy and operate tractors and combine harvesters for agricultural and other services. At present, there are many different makes and models of tractors and combine harvesters in the country.

Ethiopia's agricultural mechanization technology has continued to be import oriented. Agricultural machines and equipment were imported into the country to support mechanization policy. The former Nazareth Tractor Factory now called the Adama Agricultural Machinery Industry operating under EFDRE Metals and Engineering Corporation (METEC) is the important enterprise, which imports and assembles tractors like Belarus and other Chinese brands ranging from walking tractors of 8 hp to four-wheel tractors in the 300hp range. Mechanized services of tractors and combine-harvesters have especially been taken up in major wheat-growing areas in the southeast of the country (the zones of Arsi, West Arsi, and Bale, in particular). Oromia seed enterprise, which has cultivation lands about 25,000 hectares in Arsi, West Arsi and Bale zone, is one of the institutions which scaling up mechanization in its enterprise. It deals with different types of machinery e.g. tractors, combine harvester, sprayer and different farming implements. It was accommodated 275 tractors, 38 combine harvester, 181 tillage implement, 100 disking implement, 19 broadcasting planters, 34-row drillers, 45 sprayers and 291 trailer carriages in different state farms of the enterprise (OSE,2019).

The Oromia seed enterprise had different farm machinery which can be used for different agricultural operation. Farm machinery is crucial for the enterprise to perform agricultural fields. But, in this enterprise, different types of machines in the enterprise were dropped and many of them became scrap. Some of the machineries are failing frequently. When machines are failed, the enterprise is enforced to use out-source machines during peak season from the local service provider. Hence, using of out-source machines affected at primarily the enterprise, because of spent unnecessary expenditure and reducing the profit of enterprise. Secondly, local farmers were affected when the enterprise uses out-source machines, by increasing hiring cost and shortage of machines during peak season. Therefore, these problems need big attention.

1.3. Objectives

1.3.1. General objective

The general objective of this study is to investigate the farm machinery management systems in Oromia Seed Enterprise.

1.3.2. Specific objective

- To evaluate the status of farm machinery in the enterprise
- To assess the maintenance management system in the enterprise
- To evaluate selection and management systems of farm machinery

1.4. Significance of the study

Today, in the race of generating more earnings and to remain competitive among rival, the decision making was important and should be optimized. The productivity of industries is highly dependent on their machinery and equipment. Machinery and equipment productivity can be improved by managing the farm machinery in optimum process condition, proper selection, good maintenance, reducing idle time and making more effective use of available machinery and its capacity. Proper management for agricultural machinery is very important due to the high investment involved in the purchase and operating cost of the machinery. Identify causes of the mechanical problems and thoroughly analyze failures in farm machinery management system that lowers productivity. As a result of effective and efficient farm machinery management, it was possible to prolong the physical, technical and economic service time of agricultural machinery/equipment. The main significance of the study was to bring and

implement effective machinery management systems to ensure that the machinery was in good condition, serviceable and safe to be operated in producing quality products. If the machinery could not be properly handled and maintained OSE couldn't produce enough seed production and shortage seed supply will be occurred and the problem will expand to the country level.

1.5. Scope of the study

The scope of this research proposal limited to evaluate the farm machinery management systems in Oromia Seed Enterprise of Arsi branch. The evaluation considered different machinery parameters (machinery make, machinery model and machinery specification, age, purchased price and working hour), operators and maintenance staff (their age, service life, skill and educational profile) and landholding capacity of the enterprise. The boundary of problems investigated determined of machinery status, maintenance status, total operating costs, work rate and power requirement.

CHAPTER TWO

2. LITERATURE REVIEWS

2.1. Farm machinery

Farm machinery is an important element and fundamental for agricultural development and crop production in modern agricultural of many countries. The main objectives of the machinery are to reduce the difficulties of farm operations and to maximize production. Farm machinery is any equipment that farmers use to till, plant, cultivate, and harvest, including tractors, ploughs, discs, planters and combines (Omer, 2013).

2.2. Farm Machinery management

Edwards (2001) reported that, putting together an ideal machinery system is not easy, equipment that works best one year, may not work well next because of changes in weather conditions or crop production practices. Improvement in design may make older equipment obsolete. And the number of acres being farmed or the amount of labor available may change, because many of these variables are unpredictable. Although the mechanical side plays its part, the farmer should finally approach machinery management from the economical side. Optimum machinery management will occur when the economic performance of the total machinery system is maximized. This means the successful farm business, composed of several enterprises, will apply to the machinery to produce goods at a profit. Machinery management is very complex. It is firstly a decision involving the timeliness of operations; secondly it is a decision with an outcome that should last for long duration. Therefore the ownership cost as well as operational cost involved. The smaller machinery set, the harder it is going to work, causing repair cost to increase. The bigger the machinery set, the higher the ownership cost will be, resulting in more interest on borrowed funds to be paid.

*ASAE (*2000) reported that, machinery management is an important part of farm management. It also indicated that Farmers must make both short-and long-term machinery management decisions. Therefore effective of machinery management is an important element of cost in any farm management program. Consideration should be given to all options including: purchasing new equipment, upgrading existing equipment, renting or leasing exchange of work, joint ownership, custom or hiring. Each machinery decision will be dictated by the farm's resource needs and capacity.

Machinery management deals with determining the costs for performing a particular operation, selecting the best size and type of equipment for each application, matching machinery component in a complete system, establishing an effective maintenance program, determining the optimum age for replacing a particular machine and scheduling farm operation for the best use of the machine (Osman, 2011).

Farm machinery has improved the efficiency of farming dramatically over the years, the cost of owning and operating machinery can be excessive. Proper management and optimization of mechanized equipment are essential for reducing costs and maximizing profits, (Hunt 2001).

2.3. Machinery use and management

The application of machines to agriculture production has been one of the outstanding developments in agriculture. Machinery management is the study of selection, operation and replacement of farm machines (Bowers, 1987). The effectiveness of the mechanization policy is determined by the management skills in matching the power output and machinery complement to the time available at an acceptable level of fixed and operating costs. The adequacy of machinery management has a major impact on the farm profitability therefore, the economic goal of machinery management is achieved when the overall profitability of the farm business maximized. The optimization of the power and machinery requirements is achieved through a combination of the maximum tractor demand and tractor fleet size for simultaneous operation.

Maximizing returns from machinery operation can be achieved by proper machinery management, and this may be done through: Keeping records of field work done by a various machines and the number of working days available for critical field operations. Also by knowing the average machine capacity, the accurate estimated costs for any machine and to combine these costs to have the total cost, improving the field efficiencies with machines to cut costs and complete more work in the available time. Improving the machine reliability by the elimination of the unnecessary down time, development of short and long range plan for farm operation including the repair, purchase and trade-in of equipment, review the problems from time to time to speed up management decisions (Bowers, 1987).

2.4. Farm machinery selection

Selection of power matching with machines is one of the most important decision parameters of agricultural mechanization planning and machinery management. Many factors are affecting the selection such as agricultural conditions, farming requirements of soil and crops, management scales and economic condition (Depney *et al*., 1983).

2.4.1. Economic selection

Economic development means by which nations seek to increase the efficiency of meeting people's demand through the proper utilization of resources and the importance of production efficiency of these countries (Lazarus, 2009). Therefore, the mechanization will provide one of the outstanding tools for achieving the economical production of crops.

Agricultural production in the less developed countries depends mostly on short-duration rainfall and irrigation in limited areas. As such, this type of production requires a careful decision about the level of production to be adopted and the selection of the proper machines to be used, to maximize the utilization of the short growing season. This necessitates mainly the correct decisions, especially when high sums of money are to be directed for buying machines and equipment to expand existing agricultural areas and replace old equipment and machines. If the decision of selection is based on a few hours per year, a large-sized machine may be needed because the largest machine could use less time to complete the job but requires too much ready cash. So, the balance between machine size and paid money is an important issue for proper and careful selection.

2.4.2. Physical selections

a) Selecting tractor size

Deciding the tractor size is to provide enough power to get all-important field operations completed on time, and to provide sufficient annual use, so costs will be minimized. This can be done by listing all field operations according to energy requirements and to estimate the total time available. Tractive force is usually used to predict the tractor power required to pull a machine. Engine horsepower is not usually used as the output needed to perform the work, because of the power losses (Jones and Bowers, 1977).

b) Selecting machine size

The selection must be based on, selecting proper size machine for the proper unit, getting sufficient capacity to get the needed work to be done within the allotted time, and getting the maximum net profit. When the speed is maximum (controllable), efficiency is a function of time loss (controllable), the width will be the determining factor in the selection of machinery, but must be done economically. This depends on the cost, labour, power, machine capacity and performance, area and working hours and time of operation (Jones and Bowers, 1977).

2.5. Skills for farm machinery management

According to Ahmed (1989), mentioned some factors affecting manager's skill in making a decision: machinery selection criteria, tractor size, scheduling operation, staff requirement, training in machinery operation, repair and maintenance services, availability of spare parts, infrastructure development, agricultural engineering development and the ability to maintain field efficiency.

According to Siemens and Bowers (1999) "among each factor the decision could mean the difference between a profit and a loss**".** According to Culpin (1975) mentioned that the requirements for good management of labour and machinery as the choice of equipment, capital invested in equipment, standards for checking mechanization efficiency, labour requirements, and tractors need. The responsibility of selecting the staff members is in the hand of the project manager who should be a good organizer and know well the operation management and the repair of the farm machinery and also has a good knowledge of agriculture.

2.6. Farm machinery field performance

Performance rates for field machines depend upon achievable field speeds and upon the efficient use of time. Field speeds may be limited by heavy yields, rough ground, and adequacy of operator control. Small or irregularly shaped fields, heavy yields, and high capacity machines may cause a substantial reduction in field efficiency (ASAE STANDARDS, 2000). Siemens and Bowers (1999) reported that a daily inspection program usually put the machine at an optimum performance level. More complicated machines; performing sophisticated multiple tasks generally have low field efficiency. Measures of agricultural machinery performance are the rate and quality at which the operation is accomplished. The choice of power units and their machinery complements for farming operations is very important. To operate farms efficiently, the size and number of tractors and equipment should match the power required by the various

sequences of cropping operations, which must be performed within a specific time during the year.

2.6.1. Farm machinery rate of work

According to Liljedahl *et al*. (1979) cited that, the greatest single factor affecting the hourly cost of machinery operation is the use per year. It is better to use a machine as long as possible, but too much use will negatively affect the performance of the machine. The total cost was reduced with increasing annual hours of use. Low annual use resulted in high costs per hour. High annual hours of use resulted in low fixed costs. Culpin (1975) stated that the average use of main tractors fleet in the region of 700-800 hours. He mentioned the factors affecting operating costs as: size and number of the machine, the number of days worked annually, type of work performance, the care received by the tractor. Dafalla (1990) reported that old tractors have less annual use and high cost when compared with new ones. Increased annual use of machinery resulted in low hourly operation costs. Singh and Tendon (1987) found that the average annual use of 37 tractors was 1222 hours per tractor. Despite the increase in tractor size, the hourly cost of the tractor was decreased with increased annual use.

2.6.2. Farm machinery field capacity

Hanna (2002), defined field capacity as the rate at which a machine performs its primary function. He added measurements or estimates of machine capacities are used to schedule field operations, power units and labour and to estimate machine-operating costs.

The following time fractions to be considered when computing the capacities or costs of the machinery. These are machine preparation time, travel time to and from the field, machine preparation time in the field before and after the operation, theoretical field time, turning time and time to load or unload the machine, machine adjustment time, maintenance repair time, and operation's personnel time. Not all the above time elements are commonly charged against machine operations. The operator's personnel time, machine preparation time are highly variable quantities and are usually unrelated to the operating efficiency of the machine (Hunt, 2001).

2.6.2.1. Theoretical field capacity

The theoretical field capacity of an implement as the rate of field coverage that would be obtained if the machine were performing its function 100% of the time at rated forward speed

and always covered 100% of its rated width. Hana (2016), suggested the following equation for theoretical field capacity calculation:

$$TFC = \frac{S \times W}{C} \quad \ldots\ldots\ldots\

According to Siemens and Bowers (1999), reported that there are several important reasons why a machine may have built into the operation. Some lost time factors are be dominated by good planning and management, and typically factors causing lost time include: unused capacity, filling procedures, turning and field conditions, unclogging machines, making adjustments, reducing breakdowns, servicing machines, rest stops, checking machine performance and unmatched machine capacity. They added, "For maximum field efficiencies there can be no time lost". Also, they suggested the following table for range field efficiencies.

Table 2. 1. Range field efficiencies

Operation	Field efficiency
Tillage	77-90%
Disc harrow, disc plough	75-85%
Landplane	65-80%
Tooth harrow cultivation	65-80%
Row crop	65-80%
Sprayers	55-65%

Source: ASAE, (1996)

2.6.4. Farm machinery power requirement

According to Hunt (1979), mentioned that efficient power performance includes the selection of implements that neither overload nor fail to use adequately the power available from a tractor or self-propelled engine. Field machine power requirements consist of functional requirements and rolling resistance requirements. A major task facing modern farmers is to match power units to the size and type of machines so that all field operations can be carried out on time with a minimum cost.

2.6.4.1. Power requirements estimation

According to Hunt (1979) reviewed that, power requirements can be quoted in many different ways depending on the characteristics of the operation and the machine. Quite often a force instead of a power requirement is reported to remove the variations in forwarding speed. The variation due to different sizes of implements is removed by reporting draft per foot of effective width of implements.

According to Edwards *et al*., (2001), mentioned that the horsepower needed to pull a certain implement depends on the width of the implement, draft requirement, and soil conditions. They suggest the following formula for estimating the required horsepower measured at the brake power. Tractors are often rated by brake power or PTO power rather than drawbar power (Ajit *et al*, 2006). After the drawbar power is calculated, the PTO power and/or net flywheel power can be estimated equation 2.4 as follows:

$$PTO = \frac{\text{Speed} \times \text{width} \times \text{draft} \times \text{soil factor}}{3.6} \quad \text{.....} \quad (2.4)$$

Table 2. 2.Soil factors as quoted from ASEA standards

Type of soil	Soil factor
Firm	1.5
Tilled	1.8
Sandy or soft soil	2.1

Source: ASAE, (2003).

2.6.4.2. Factors affecting power requirement for farm machinery

Siemens and Bowers (1999), reported the factors to be considered when selecting power units: engine type, power rating, soil resistance to the machine, tractor size, matching implement, sizing for critical work, and tractor type. Faidley *et al*., (1975) stated that the power required for field operation depends on the amount of work to be done and the time available.

2.7. Farm machinery cost

One of the important costs of influencing profit in the farming business is the cost of owning and operating farm machines. Machinery cost estimates play an important role in every machinery management decision and are required to be made at the research and development stage to guide the designer. It is made for commercial units to establish the hiring rates and to determine the cost of machinery inputs for effective crop production management. The cost of operation of a farm machine as influenced by the size, quality and physical condition of the machine needs to be estimated at the time of its selection. An effective farm manager must also know the principles of cost and apply them when deciding to buy, lease, rent or share machinery (Schuler and Frank 2006).

Hunt (2001) reported that most of the management decisions for farm machinery involve an accurate knowledge of costs. The determination of field machinery cost of operation is dependent on so many factors that each farm's machinery system must be treated as a special case, significant difference use of machines, price levels, the energy required, fuel costs, and labour costs.

2.7.1. Farm machinery fixed costs estimations

Langemeier and Taylor (1998) stated that fixed costs are independent of machine use, and the annual fixed costs can be calculated based on the relationship between fixed costs items and the new value of a machine. He mentioned the costs items as depreciation, interest, insurance, taxes, and housing.

2.7.1.1. Depreciation

Depreciation is often the largest cost of farm machinery, it measures the amount by which the value of a machine decreases with time, whether the machine used or not. Culpin (1975) reported "the machinery depreciates from the moment it comes on the farm. The rate of depreciation varies according to the kind of equipment, the amount of work that it does, and the care that is taken in servicing and storing it". Siemens and Bowers (1999) added the value of a machine declines because of wear, age, the expense of operating a machine in optimum reliability, obsolescence, the change of enterprise size. Kastens (1997) stated that the list price of the used machines does not represent an accurate estimation for current machinery evaluation. He added that the best way is to use the current list price. The today dealer records could be a suitable method, but the development of the models and maybe the manufacturing discontinued making it an inappropriate method. Hunt (1979), Siemens and Bowers (1999) mentioned the following methods of depreciation estimation.

a) Straight-line method

This is the simplest and more common method; an equal reduction of value is used for each year the machine is owned (Hunt, 2001). It could be calculated by the following formula:

$$D = \frac{P - S}{L} \quad \ldots\ldots\ldots\

S- The salvage value, Birr

L- Years owned.

b) Sum of the year digits

This method is more accurate but more complicated, it depreciates the machine to zero at the end of economic life (Hunt, 2001). The amount of depreciation can be calculated through:

$$D = \frac{L - n}{YD}(P-S) \quad \text{(2.6)}$$

Where: D- Depreciation

L- Economic life

P- Purchase price

S- Salvage value.

YD- the sum of year's digit method (1+2+3+…+L)

n- The age of the machine at the beginning of the year in question.

c) Declining Balance

It's the simplest methods, in which a constant percentage is applied each year to the remaining value of the machine at the beginning of the year (Hunt, 2001). It was calculated by equation 2.7 as follows:

$$RV = C \times \left[1 - \frac{r}{l}\right]^{y} \quad \text{(2.7)}$$

Where: RV- The remaining value of the machinery

C- Initial cost of the machinery.

r- Rate of depreciation, r is between 1 and 2. r=2 for new machinery and if requires double-declining balance and under accelerated depreciation. r=1.5 for used machinery

L- Machinery use full life

Y- Age of the machine in which depreciation is determined.

$\frac{r}{l}$- Decimal rate of depreciation

$$D = RV_n - RV_{n-1} \quad \text{(2.8)}$$

Where: D- Depreciation, Birr.

RVn - Remaining value at year n, Birr.

RVn_{-1}- Remaining value at year after the year n.

2.7.1.2. Interest

Interest charges are usually computed when operating costs are being determined and may be calculated so that the result will be constant or equal yearly charges throughout the life of the machine. The interest rate can be varying but usually in the range of six to twelve (6 to 12%).

The interest of agricultural machinery can be determined as indicated in equation 2.9 as follow (William, 2009):

$$I = \frac{(P+S+D)}{2} \times IR \quad \text{..... (2.9)}$$

Where: I- Interest (birr)

P- Purchased price (birr)

S- Salvage value (birr)

D- Depreciation (birr)

IR- Interest rate (%)

According to Bowers (1992), interest is a large expense item for agricultural machinery. It is a direct expense item on borrowed capital. Even if cash is paid for purchased machinery, money is 30% tied up that might be available for use elsewhere in the business. The interest rate varies but usually will be in the range of 8 to 10%.

2.7.1.3. Tax

Tax differs from country to country, according to Goense (1995). Tractors and self-propelled machines may have yearly cost for registration plate in some countries. Vat and sale taxes are to be included in the purchase price. Bowers (1994), describes the tax, a paid on farm machinery for a place that does have property as for other properties. The cost estimated equal to one to two (1-2%) of the purchased price of the machine at the beginning of the year often used. Tax can be determined by equation here below (Hunt, 2001):

$$T = \left[\frac{P}{2}\right] \times 0.55 \times TR \quad \text{..... (2.10)}$$

Where: T & TR- tax (Birr) and tax rate respectively

P- Purchased price (Birr)

S- Salvage value (Birr)

2.7.1.4. Insurance

Insurance policies are usually carried on more expensive machines while the risk is usually assumed on the simpler, less expensive machines. The annual charge for insurance or risk is assumed to be from 0.25 to 0.5 percent of the remaining value (Bowers, 1994). According to Goense (1995), insurance is required for tractors and self-propelled machines to cover third party liability when driving on public roads. This is most cases 1% of purchased price.

For other equipment, a cover against fire and accident is required which is about 0.25 percent of purchased price. If machinery is not insured the owner will have to take the risk of accident himself, which on the average will near the insurance cost. Another alternative is used as equation 2.11 if the real insurance rate is known (William, 2009):

$$In=\left[\frac{P+S+D}{2}\right]\times IR \quad \ldots\ldots\ldots\

2.7.2. Estimating farm machinery variable costs

Edwards *et al*., (2001) defined variable costs of farm machinery as costs vary directly with the amount of machine use, and include repair and maintenance costs, fuel and lubricants cost, and labour cost.

2.7.2.1. Repair and maintenance costs

Annual repair costs for a given machine normally increase as use increases. However, accurate predictions of machinery repair costs are difficult to obtain. Spare parts required by the machinery are influenced by the type and size of the operation and the service facilities available (Johnson, 1979). Even the repair costs required for identical machines used the same number of hours vary with different types of work or working conditions. For example, a tractor used for heavy work on rough terrain likely will require more repair than one used for light work on smooth terrain. Also, the amount and effectiveness of preventive maintenance can influence repair costs. Despite the sizeable problems encountered in specifying repair costs, researchers have estimated accumulated repair and maintenance costs at various stages in the life of most farm machinery. The direct cost of repair and maintenance are presented in two different ways:

- The total life of repair and maintenance costs as a percentage of the machines list price
- Accumulated repairs and maintenance costs as a power function of accumulated machine use.

When only total lives of repair and maintenance costs are used it is assumed that they accumulate linearly with accumulated life. The variable repair and maintenance costs per hour are following this approach depends on the intensity of machines use (Goense, 1995)

$$RCH = PP \times (\frac{1}{100}) \times (\frac{TR}{TH}) \quad \text{(2.12)}$$

Where: RCH- repair and maintenance cost per hour

PP - purchase price

TR- total life repair cost as a percentage of PP (total accumulated repair cost)

TH- total technical life (total accumulated hours).

$$ARM_n = RF1 \times CLP_n \times \left[\frac{AH_n}{1000}\right]^{RF2} \quad \text{(2.13)}$$

Where: ARM- accumulated repair and maintenance cost for n year

CLP - current list price

AH- accumulated hours

RF- repair factor

n- Number of years (age of the machine) in which RM cost is determined.

It should be emphasized that these repair costs be viewed only as estimates of average repair and maintenance expenditures, even though they are widely used. If available, good machinery repair records will provide a superior basis for predicting repair costs (William, 2009)

2.7.2.2. Fuel and lubrication cost

Fuel and lubrication costs for farm machinery vary, based on the number of hours the engine was operated (Siemens and Bower, 1999). Fuel expenditures also depend on the fuel consumption rate per hour and the fuel price. In turn, the rate of fuel consumption varies according to the size of the engine, kind of work performed (i.e., the engine load factor), and type of fuel, among other things. Annual average fuel requirements for tractors may be used to calculate overall machinery costs. However, you should base the cost of each particular operation, such as disking or ploughing, on actual fuel costs for the power required. According to Siemens and Bower, (1999) the fuel price varies from time to time to deviation the coefficient of fuel requirements required as in the table.

Table 2. 3. Multipliers or coefficient of fuel requirements

Engine fuel type	Average fuel consumption (gallons per hour per rated PTO hp)	Typical Lb/gal
Gasoline	0.068	6.1
Diesel	0.043	6-9
L. P. Gas	0.080	4.25-4.5

Source: Siemens and Bower, (1999).

a) Fuel cost

Fuel cost (Willimam, 2005) is calculated by multiplying the fuel consumption by the price of fuel.

Average fuel consumption in gallon per hour (Qav).

Qavg = 0.060 × maximum PTO hp (For gasoline engine)…….. (2.14)

Qavd = 0.044 × maximum PTO hp. (For diesel engine)……..……..... (2.15)

Annual fuel cost = F×Qav (gal /hr) × Fuel price x Hours used annually……..... (2.16)

Where: F= fuel multiplier and

Qav = Average fuel consumption in gallon per hour.

b) Lubricants cost

Lubrication costs for all machinery are estimated to be 15 percent of the fuel expenditures, so annual fuel costs are multiplied by 0.15 to determine lubrication and fuel costs (Norm, 2008).

2.7.2.3. Labour cost

According to Edwards, et al., (2001), stated that actual hours of labour usually exceed field machine time by 10% to 20% because of travel time and time required to lubricate and service the machine, and consequently, labour cost can be calculated by the following formula:

Average labour cost = Labor wage × 1.2……...…….. (2.17)

2.7.3. Total farm machinery cost per hour

According to Culpin (1975), it's impossible to state with any accuracy the annual or hourly cost of running any particular kind of tractor, without first defining the work done by the tractor. According Hunt (1979), mentioned that the reports of Fenton, Barger, Fairbanks, Larson and others (Kansas State University), which pointed the possibility of combining the fixed costs into a single percentage of the purchase price, add it to the summation of variable costs. The total cost of machinery is the summation of total fixed costs and total variable costs.

2.8. Downtime and availability

In agricultural production availability of the machinery or getting ready for the job to be assigned is very important. In the enterprise, if the machinery is not available unlike that of service bus (transportation bus) the loss of income is not manifested. Rather the availability of machinery results in the loss of production of agricultural products (Amana *et al*., 2014).

Effective working hours: The hours taken on effective work of machinery and it is expressed as Effective working hours: The hours have taken on effective work of machinery and it is expressed as:

Effective working hours = total planned working hours - downtime in hours ……. (2.18)

Utilization capacity: This is expressed in percentage and symbolized as X, Y and Z.

$$X = \frac{\text{Effective working hours}}{\text{Total working hours}} \times 100 \ldots\ldots\ldots\

$$Y = \frac{\text{Operational down hours}}{\text{Total working hours}} \times 100 \ldots\ldots\ldots\

Organizations that take a proactive approach to reliability place a high value in knowing the condition of their assets. The need for parts was much more predictable. There are fewer "surprises"; more parts can be purchased on a just-in-time basis. Since the volume of inventory required is based to a large degree on usage, the fewer parts we use, the fewer we need to keep on hand (Anthony, 2006)).

2.10. Machinery replacement strategy

According to *Edwards (2005)* reported that a complete line of machinery is one of the largest investments that a farm business can make. Yet, unlike land or business, machinery must be constantly monitored, maintained, and eventually replaced. How and when equipment is replaced can mean a difference of thousands of money in annual production costs. Replacing farm machinery is an important and complex decision. Each farming operation must identify its most important reasons for replacing machinery, and then establish a consistent pattern. Reliability, long-run costs, the pride of ownership, obsolescence, need for capacity, and tax savings should all be considered before making a final decision. He also stated that the replacement policy must be regularly as changing factors such as interest rates, expected repair or maintenance costs and tax rates. There are several strategies that a farmer can follow for replacing machinery namely:

• Replacing it frequently replaces something every year.
• Replace when cash is available or lastly keep it forever.

On the other hand, machinery also generates income and a decision to buy a new machine influence a farmer's cash flow over a couple of years. A wrong decision can have drastic effects on the future of the farm business. The replacement cost reflects the present value of a stream of cost and income over different life spans of a machine. The optimum replacement age of a machine is a year where the replacement cost is the lowest. The decision to replace farm machinery can be made for several reasons:

Cost minimization: the standard rule for minimizing the long-run cost of equipment is to make a change when the annualized total cost of owning and operating machine begins to increase. Being able to anticipate when large repair costs will be needed is a key consideration in deciding when to replace a machine.

Reliability*:* besides the standard machinery costs, most operators also consider timeliness costs in their replacement decisions. Timeliness costs occur when crops are not planted or harvested at the optimal time. They can be attributed to losses in yield.

New technology**:** in some cases machinery may be in perfectly good working order, but the introduction of new technology has made it obsolete. Newer models may do a better job of harvesting or planting, or operate more efficiently. Care should be taken to distinguish new technology that can increase profits changes that simply provide more convenience and comfort.

Need for capacity**:** when the number of acres of the crop being produced increases, operators may need to replace machinery with models that have a higher capacity to complete planting and harvesting without serious timeliness losses. Likewise, when farm size is reduced it may be possible to cut costs by downsizing the machinery set.

2.11. Description of Oromia Seed Enterprise

Oromia Seed Enterprise is an established initiative by regulation No. 108/2008 to play a significant role in seed production, processing and marketing. The end goal of this initiative is to ensure seed utilization and change in the productivity of farmland of smaller holders in the region. Even though OSE was established with a small capital at the initial, it has been expanding in all face since the establishment. At present, its capital is more than 1.6 billion birrs. It does have more than 1500 experienced staff in agriculture. OSE is growing different varieties crop on more than 25,000 hectares at different areas (OSE, 2019).

The availability and increased use of seeds of improved varieties are underlined as a pivotal instrument to attain fast and sustainable agricultural development in the country. The Ethiopian government thus has identified improving the efficiency of the seed systems as the most effective means of meeting the Growth and Transformation Plan (GTP). Different studies undertaken by different responsible bodies were indicated the wide gap that exists between seed demand and supply nearly for every crop varieties.

As a public enterprise, Oromia Seed Enterprise has double responsibilities. It has a mission to fulfil the government obligation of seed demands of the regional state and as well as operate, competing, and sustaining as a commercial business entity. The government needs the enterprise to produce large quantity of low-profitable (non-profitable) self-pollinating crops for the

strategic purpose to support the extension and food-security programs. As a business entity, it has also expected to increase production and productivity of improved seed technologies and markets (sales) to achieve marginal profits to sustain within the country's seed industry.

Therefore, a viable strategy is required to produce and disseminate the required quantity of the strategic crops (self-pollinate, low-margin crops) besides achieving higher profits to sustain the enterprise in the seed business.

It has about twelve farms with three branch offices located in Bale, Arsi and West. The branches are thought to manage the farms under their respective operation areas. Arsi and Bale branches were previously administrated under the federal government and included under OSE administration in 2006 E.C.

2.11.1. Geographical information about OSE land

Table 2. 4. Information about OSE Land

Farm center	Located area		Total land holds (ha.)	Distance (km)		Annual rainfall in (ml)	Elevation in (m)
	zones	districts		From branch office	From the main office (Addis Ababa)		
Bale branch	Bale	Robe town	12,081	-	412	-	-
Herero	W/Arsi	Dodola	3,440	103	315	510	2365
Hunte	W/Arsi	Adaba	2,194	85	349	757	2380
Sinana	Bale	Sinana	3,888	42	454	488	2470
Robe	Bale	Sinana	2,559	14	426	632	2470
Siraro	W/Arsi	Bilito S	3,548				
Arsi branch	Arsi	Asela town	11,824		174		
Lole	Arsi	Munesa	2,414	40	214	702.2	2400-2450
E/gojolo	E/shoa		7		170		
Garedela	W/Arsi	G/asasa	2,818	132	306	573.4	2400-2500
Tamela	W/Arsi	G/asasa	3,224	116	290	590.8	2400-2450
Adele	Arsi	Amigna	2,761	138	312	858.9	2400-2450
A/gugu	Arsi	A/gugu	600	320	494	1494	1490-1800
West branch	E/walega	Nekemte town		116	290	590.8	2400-2450
Ukke	E/walega	Gidami gidda	727	138	312	858.9	2400-2450
Loko	E/walega	Gidami gidda	448	51	382		

Source: OSE, 2019

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Study area descriptions

The study was conducted in Oromia seed enterprise which administrated under Arsi branch in four farm states. These are Adele, Geredela, Lole and Temela farm states.

3.1.1. Description of Adele farm location

Adele farm is one of the twelfth farms under OSE. It is located in Arsi zone Amigna district, Oromia regional state, Ethiopia. It covers an area of 2,761 hectares (2,503.5 ha cultivated and 257.5 ha non-cultivated). Mean annual rainfall and temperature is 858.9mm/year and 14.5^0C respectively. Its altitude and slope 2400-2450 m above mean sea-level and 0-3% respectively. The main crops being cultivated in the farm are wheat, faba bean, and linseed. It is a semi-mechanized farming area and human labour is used for some agronomic activities like weeding and loading-unloading of the grains. The average yield of crop per hectare is 26 quintal, 15 quintals, and 12 quintals for wheat, faba bean, and linseed respectively. The main soil type of the farm is vertisol with soil PH-value of 5.5-6.0.

3.1.2. Description of Geredela farm location

Geredela farm is one of the twelfth farms under OSE. It is located in West Arsi zone Gedeb-Asia district, Oromia regional state, Ethiopia. It covers an area of 2,750.5 hectares (2,615.5 ha cultivated and 135 ha non-cultivated). Mean annual rainfall and temperature is 348.2mm/year and 20^0C respectively. Its altitude and slope 2400-2450 m above mean sea-level and 0-3.6% respectively. The main crops being cultivated in the farm are wheat, barley, faba bean, and rapeseed. It is a semi-mechanized farming and human labour is used for some agronomic activities like weeding and loading-unloading of the grains. The average yield of crop per hectare is 27 quintal, 22 quintals, and 8 quintals for wheat, barley, and rapeseed respectively. The main soil type of the farm is sandy soil, loam soil, and clay soil with soil PH-value of 6.3-7.0.

3.1.3. Description of Lole farm location

Lole farm is one of the twelfth farms under OSE. It is located in Arsi zone within three districts of Tiyo, Digelu Tijo and Munesa, Oromia regional state, Ethiopia.it covers an area of 2,414 hectares (2,301.39 ha cultivated and 112.61 ha non-cultivated). Mean annual rainfall and

temperature is 585.2mm/year and 19^0C respectively. Its altitude and slope 2400-2450 m above mean sea-level and 0-3% respectively. The main crops being cultivated in the farm are wheat, faba bean, and linseed. Moreover, the farm has the potential to cultivate barley, potato, sunflower and linseed. It is a semi-mechanized farming and human labour is used for some agronomic activities like weeding and loading-unloading of the grains. The average yield of crop per hectare is 43 quintal, 24 quintals, and 23 quintals for wheat, faba bean, and linseed respectively. The main soil type of the farm is sandy clay loam soils with soil PH-value of 5.8-6.6.

3.1.4. Description of Tamela farm location

Tamela farm is one of the twelfth farms under OSE. It is located in West Arsi zone Gedeb-Asasa district, Oromia regional state, Ethiopia.it covers an area of 3,224 hectares (2,953.5 ha cultivated and 270.5 ha non-cultivated). Mean annual rainfall and temperature is 475mm/year and 20^0C respectively. Its altitude and slope 2400-2450 m above mean sea-level and 0-2% respectively. The main crops being cultivated in the farm are wheat, barley, and rapeseed. Moreover, the farm has the potential to cultivate safflower, teff and linseed. It is mechanized farming where human labour is used for some agronomic activities like weeding and loading-unloading of the grains. The average yield of crop per hectare is 36 quintals and 12 quintals for wheat and rapeseed respectively. The main soil type of the farm is sandy clay loam with soil PH-value of 5.9-6.3.

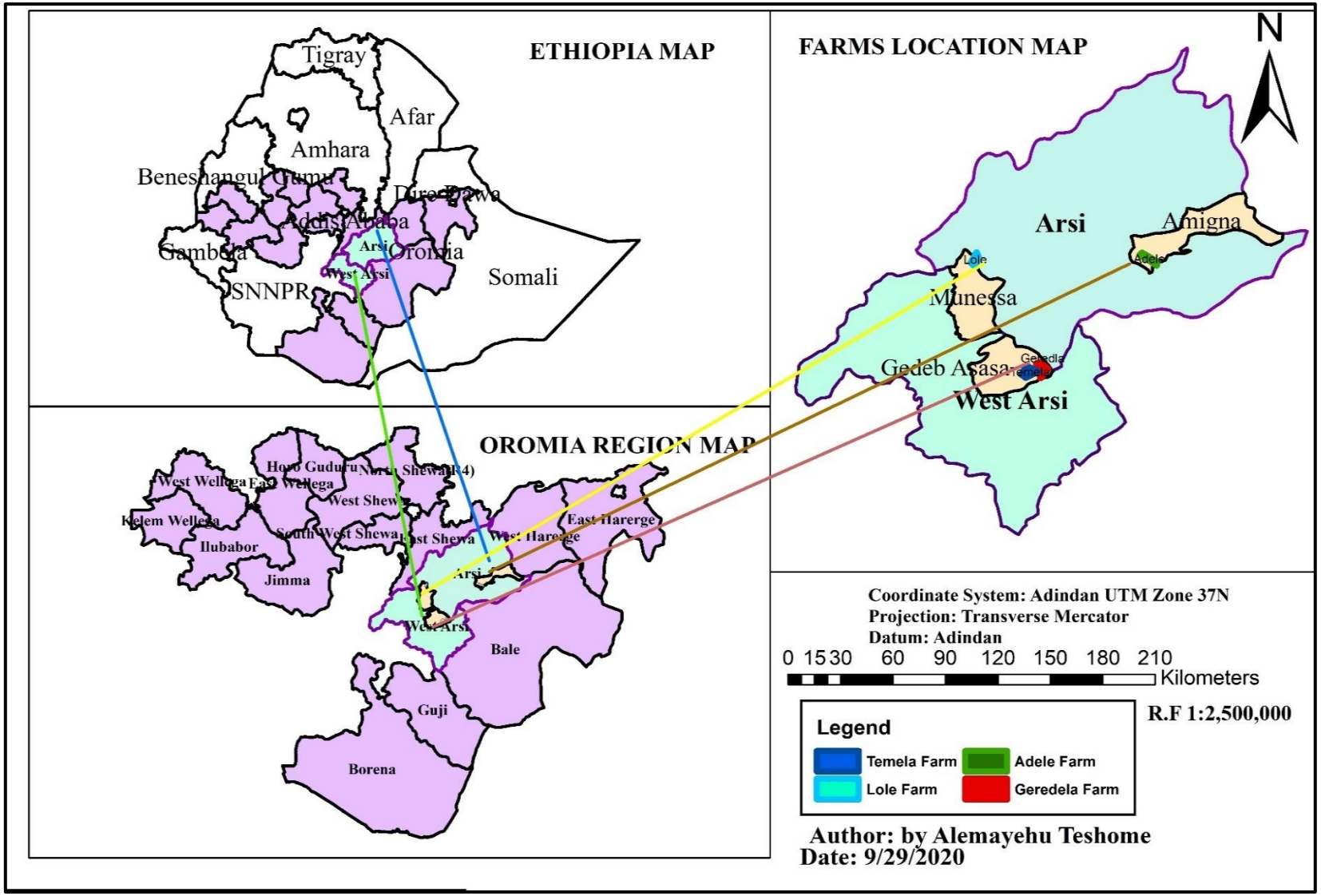


Figure 3. 1. Study area descriptions map

3.2. Materials

Types of farm machinery in the study area are shown in table 3.2, 3.3, 3.4 and 3.5.

Table 3. 1. Type of machinery in study areas

Tractors	Combine harvesters	Implements
John Deere 6615	New Holland TC55	Disc plough
John Deere 6165	Tucano Class	Moldboard plough one way
Agro track 150	New Holland TC 5060	Moldboard plough two way
New Holland 8030		Disc harrow 32 disc
New Holland100-90		Disc harrow 36 disc
Massey Ferguson399		Cultivator
Massey Ferguson 465		Seed broadcaster
Landin		Seed driller
ZT 300		Fertilizer
ZT 303		Trailer
		Water tanker sprayer

Source: OSE annual report (2019)

Table 3. 2. Types of tractors in duty

Tractor types	Model	Quantity	Age	HP	Purpose
John Deere 6615	6615J	5	11	120	FOP*
John Deere 6165	6165J	4	6	165	FOP*
Agro track 150	Agro-150	6	4	150	FOP*
Massey Ferguson399	MF-399	5	24	100	FOP*
Landin	Landin7-215	2	3	225	FOP*
Total		22	-	760	

FOP*-indicates field operation and shunting

Table 3. 3. Types of the combine harvester in duty

Combine harvester types	Model	Quantity	Age	HP
New Holland	TC-55	5	19	120
Claas Tucano 320	Tucano 320	3	3	220
New Holland	TC -5060	2	9	170
Total		10	-	510

Table 3. 4. Types of implements in duty

Implements types	Quantity	Number of bottoms	Width (m)	Service years
Nardi-Disc plow	6	4	1.00	37
Gherard-Disc plow	4	6	1.50	12

Mold board plow	2	4	1.00	41
Reverse mold board plow	2	5	2.00	41
Gherard-mold board plow	2	5	2.50	3
Disc harrow	3	28	3.10	33
Disc harrow	6	32	3.57	33
Disc harrow	4	36	4.00	33
Cultivator	2	9	3.00	38
Seed broad caster	8	1	10.00	39
Sprayer	6	1	18.00	22
Total	45	-	-	-

3.3. Methods

3.3.1. Types of data collected

The data required for the investigation was identified and gathered by communicating maintenance department head, chief mechanics, and finance department staff, mechanization and production department of Oromia seed enterprise. Data include types, number and status of machinery, service life, purchased price, the number of maintenance staff and operator's, educational background, age and service life were part of it. Machinery specification data, which include making, model, engine type, power and machinery age. Machinery costs data, which include list price, date of purchase, depreciation, insurance, housing, and taxes. Type of work, annual hours of use, field capacity, annual repair and maintenance expenses, fuel and lubricants consumption, labour wage and expected life. Field data include the size of the field, soil type, climatic condition, and infrastructures. Machinery maintenance policy and strategic planning in the maintenance department. Maintenance information, organization and implementation in the maintenance department.

3.3.2. Research methods

The study used primary and secondary sources of data. The relevant primary sources contain original, raw and unprocessed data. The relevant secondary data were collected from documents, maintenance technical manual, monthly and annual reports of production, mechanization, and finance and maintenance department of each farm estates. Data collection was quantitative and qualitative. Quantitative data was a data which express anything in quantity, in number, in

percentage and can be measured. Qualitative data which express anything in quality like a good, fair, poor, sufficient, insufficient etc.

A survey on the overall farm machinery management system was conducted on four sub-farm states of OSE from September 2019 to June 2020. Primary data were collected through a structured questionnaire on maintenance personnel. A questionnaire was prepared for maintenance staff and operators, containing information about maintenance management systems: regarding mainly maintenance planning and scheduling, implementing maintenance police and stratagem, workshop facility and suitability, training for maintenance staff and operators and spare part availability. The questioner which was distributed to farm machinery maintenance department was attached in Appendix-E. The physical observation was also made on the current existing maintenance activities and records of the maintenance department of the company.

3.3.3. Sampling method

A total of 18 respondents who were randomly selected from the maintenance department of OSE to fill the questionnaire on the statues maintenance management system of the farm states using structured questionnaire sheets. The research questions were conducted on five workshop staff, four workshops which were in farm sites of farms aforementioned and one workshop was located in Asela town and served for all farm state of OSE. From each site, the respondents were randomly selected using stratified sampling techniques. Moreover, the interview was conducted for skilled mechanics and semi-skilled mechanics. The interview was administered on a one-to-one basis with the researcher asking questions and listening to the responses of each maintenance technician.

All existing farm machinery both in work and out of work of farm sites were considered to evaluate the current condition and specifically, machinery in work was purposively selected to analysis machinery performance and utility. Type of machinery existed in the study area were tractors, combine harvesters and implements. For economic analysis purpose, current functional or active tractors and combine harvesters were considered. Based on this, twenty-two tractors (four John Deere 6165, five John Deere 6615, two Landini, six Deutz-Fahr Agrotron 150 and Messay Ferguson 399) and ten combine harvester (three Claas Tucano 320, five New Holland TC-55 and two New Holland TC-5060) were purposely selected.

3.4. Working hours and availability of machinery determination

The working hours for individual machinery was determined from OSE annual report (2019), to be utilizing for both actual and calculated parameters. The average working hours for each model was calculated by dividing total working hours of tractor and combine harvester's models by the total number of model tractors and combines. The average working hours for each make was determined by dividing total working hours of tractor and combine harvester makes by the total number of make tractors and combine harvester.

Effective working hours, operational downtime, non-operational downtime and availability of machinery were determined by using equation 2.18, 2.19, 2.20, 2.21 and 2.22 respectively.

3.5. Farm machinery cost determination

3.5.1. Depreciation cost determination

This study tried to investigate both actual costs of depreciation of enterprise and calculated management cost of depreciation.

1. The actual cost of depreciation of enterprise as a report of 2012 calculated (MoFED, 2007).

$$AAD=\frac{P}{5} \quad \text{.....} \quad (3.1)$$

Where: AAD-Annual average depreciation cost (Birr)

P-Purchase price of the machine, the 5-indicated economic life of machine years

2. Calculated management equation of depreciation was estimated by using equation 2.7.

3.5.2. Repair and maintenance cost determination

This study compiled data from repair and maintenance costs for tractors and combine harvesters in the Enterprise. The study considered tractors (Massey Ferguson-399, Landin, Agro-track 150, John Deere 6615 and John Deere 6165) and combine harvesters (Tucano, New Holland TC-5060 and New Holland TC-55). The capacity of these farm machinery was ranged from 75 kW to 240 kW. Service life and annual use hours of these machines are different. To determine the RMC of each machine, the accumulated lifetime of use was considered based on the annual hour of use.

Repair and maintenance costs calculated in the following sequences:

1. Actual enterprise records (OSE, 2012)

The recorded repair and maintenance costs of each machinery were considered in the study area

2. Management calculating equation (Amana, 2016; ASABE, 2015; Dahab, 2000) computed repair costs as an exponent of the repair factor and percentage of annual working hours and new list price. Maintenance and repair cost were estimated by using equation 2.13.

3.5.3. Fuel cost determination

All the tractors and combine harvesters found in the study area were diesel type. This consumption for tractors and combine harvesters can also be determined by the amount of energy demanded at the drawbar or through the PTO. To relate the energy requirements and the farm machinery fuel consumption, it is important to consider the load on the machine. The machines loads vary from heavy operations like subsoiling and ploughing at the dry field to light and routine tasks. Fuel consumption of individual tractor could vary even for particular operation over the duty cycle because of different factors (Amana, 2016).

The current fuel price determined at a rate equivalent to the current price (Birr/L). Then the fuel cost per hour calculated by the following sequences:

1. Actual Enterprise records (OSE, 2012):

   Annual fuel cost = fuel consumed × current fuel price ……..…… (3.2)

2. Calculated management equation (Grisso et al, 2004, ASABE standard EP496.3, 2006 and ASABE Standards D497.7, 2011) estimated diesel fuel consumption which was calculated from the equation 2.14 – 2.16.

3.5.4. Lubricant cost determination

Depending on the type of fuel used and the amount of time the machines used fuel and lubrication costs usually represent at least 16%-45% of the total cost (Bowers et al., 1999). The study used annual average fuel required for each tractor and combine harvester. However, fuel consumption varied in the operation of the machines. Thus, fuel cost determination was based on the actual power (kW) for the machines. Surveys indicate that total lubrication costs on most farms average about 15 per cent of fuel costs. Therefore, once the fuel cost per hour has been

estimated, it is just needed to multiply it by 0.15 to estimate total lubrication costs (Norm, 2008). The current oil and lubricant cost determined at a rate equivalent to Birr/L. Then the oil cost per hour calculated by the following sequences:

1. Actual enterprise records (OSE, 2012)

   The recorded lubricant consumed by each machinery in the study area was used.

   Annual Lubricant Cost = lubricant consumed × current price ……...…..….. (3.3)

   Lubricant cost per hour = Annual lubricant cost/annual hours use

2. Calculated management equation (Norm, 2008) to determine oil cost by using equation

3.5.5. Labour cost determination

In the study area, there were two labors or operators. Operator level one and level. Operator level one operated tractor and operator level two operated combine harvester and their monthly salary was also different charges**.** Labour charges should be included in machinery cost calculations and should cover the total cost of labour including the average wage rates as well as benefits, taxes, and payroll overhead costs paid to the machine operation. Labour hours per acre are based on field capacity of the machinery. Labour cost per hour calculated using the following sequences:

1. Actual enterprise records (OSE, 2012):

Labour cost per hour equal to Grade 9 wage divided by monthly working hours for tractors operator. Labour cost per hour equal to Grade 10 wage divided monthly working hours for combine harvester operator.

Where: Grade 9&10 were the dominant permanent tractor and combine harvester operator respectively in the study area. Monthly working hours is the operator working hours per day (8hr) times (30) days.

2. Calculated management equation (Edwards *et al*., 2001) calculated labour cost by using equation 2.17.

3.6. Field work rate determination

1. Actual enterprise records (OSE, 2019):

The actual field capacity of each machinery was calculated using equation 3.20 (OSE reports, 2019).

$$EFC = \frac{\text{Area covered}}{\text{Actual annual working hours}} \quad \text{..... (3.4)}$$

2. Calculated management: Hanna (2002) had calculated field capacities and field efficiency by using equation 2.2 and 2.2 respectively.

3.7. Power requirement determination

The calculated horsepower obtained by applying Hanna, (2002) formula, and considering 20% additional power requirement for rolling resistance and obstacles by using equation 2.4.

3.8. Data analysis

The data were analyzed using an analysis tool of a computer package (MS-excel and SPSS). Two or one way ANOVA was used, as the replications permit. Where differences between factors are significant at the level of 0.05, the method of mean separation test will be used for making pair comparison. Collected data were interpreted and analyzed in the form of a table, bar graphs, and regression graphs. Based on the research questions and finding of the study, collected data were interpreted in the descriptive method such as average and percentage values; and statistical methods.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Status of agricultural machinery

Those machineries, which were working and delivering service and relatively low in operation cost, well maintained and recent ones were categorized as good machinery. Under this category those machineries which low frequency of breakdown was included. They were in better performance in terms of operation within dust farm land. Those machinery which were operable with the poor maintenance management system, frequent breakage of the systems which requires high repair and maintenance cost were categorized as fair. These machinery can be maintained and corrected by minimum and low technical complexity. The age of some machinery in this category was not much but requires high operational cost. The main problem was the lack of preventive and condition monitoring. Those machinery which was operable and out of operation which requires major operation cost, some of them were unrepaired. They were out of operation for years. In this category, aged machinery which has been using with high repair cost and those which requires disposal (out of operation for years and subjected to Sevier sun and dust) were categorized as bad. It was uneconomical; these machineries lead the OSE to a loss in production because of high operation cost.

Due to the historical background of the enterprise and traditional recording and reporting system of machinery, it was difficult to conduct a detailed analysis of machinery status. Production and mechanization department of Enterprise had no document that shows clearly the condition and status of machinery. Machinery status can be easily identified if a planned maintenance and condition monitoring was implemented. Different types of machinery with different service life, the different types of machinery in the same farm state and the same machinery with different activities could be at different status. The performance of all of them should be known by performance testing of engine and field efficiency of implements even though a clear record of machinery status does not exist. From the observation, inspection and interview held with farm machinery section head the current status of machinery shown in Table 4.1.

Table 4. 1. Machinery status in percentage

Types of machine	Farm state names	Numbers	Good (%)	Fair (%)	Bad (%)
Tractors	Adele	21	13	21	66
	Geredela	27	11	15	74
	Lole	27	11	30	59
	Temela	39	10	16	74
	Total	114	11	22	67
Combine harvester	Adele	3	75	25	0
	Geredela	6	16	33	50
	Lole	6	33	16	50
	Temela	7	14	71	14
	Total	22	35	36	29

The study showed that about 11% of these tractors were in good working condition while 22% were serviceable and a total of 67% were in bad working position. Some of these tractors had their vital spare parts such as filters, radiator, key starter and alternator removed from them. About 35% of these combine harvesters were in good working condition while 36% were serviceable and a total of 29% were in bad working condition. On the spot, the assessment showed that machinery has about 48% is in bad working condition. Proper categorization of machinery in different status helps to provide cost-effective maintenance work and manage them in a well manner. OSE should identify farm machinery status thoroughly in a regular way. In doing so, OSE enables it to plan and implement a replacement policy system of the machinery. Every machinery does have its own useful life other than physical life. The age of the machinery determines repair and maintenance as well as operation cost. Which consists of the idea of Amana (2014) as the machinery gets older it should be replaced with a new one.

4.2. Machinery replacement

Replacement of machinery in a big enterprise owns several types of machinery is very important to maximize mass production. The purchase of new machinery results from a need to replace them if they are inadequate. When the machinery is adequate the reliability increases and delay of field operation decrease.

In the study area, there was no replacement policy or replacement plan. From the result of Table 4.2, 75.45% of the tractor requires replacement. These tractors, most of them were beyond economic useful life. 17.54 % of the tractors were purchased within 2001-2002 E.C. An average 40% of these were getting ready for replacement.

Table 4. 2. Age of the tractor concerning the type of tractors

Age in range	Tractor type and quantity											
	Agro150	Belarus	Ford	IMT	JD	Landin	MF	NH	NTP	ZT	Total	%
>30	-	-	2	1	-	-	-	-	2	38	43	37.72%
20-30	-	-	-	-	-	-	18	-	-	-	18	15.79%
12-19	-	2	-	-	-	-	14	9	-	-	25	21.94%
5-11	-	-	-	-	12	-	-	8	-	-	20	17.54%
<5year	6	-	-	-	-	2	-	-	-	-	8	7.01%
Total	6	2	2	1	12	2	32	17	2	38	114	100%

From the result of Table 4.3, 72.72% of the combine harvester requires replacement. These combine harvesters are beyond economic useful life and were purchased in 1994 E.C. They are getting ready for replacement. Another farm machinery under the study area was implemented. Almost all of the implement completed their economic life. They were purchased before thirty years.

Table 4. 3. Age of the combine harvester concerning the type of combine harvester

Age in range	Combine harvester makes/ models type and quantity				
	Tucano	TC-5060	TC-55	Total	%
12-19	-	-	16	16	72.72%
5-11	-	3	-	3	13.64%
< 5year	3	-	-	3	13.64%
Total	3	3	16	22	100%

From the result of Table 4.3, 72.72% of the combine harvester requires replacement. These combine harvesters are beyond economic useful life and were purchased in 1994 E.C. They are getting ready for replacement. Another farm machinery under the study area was implemented. Almost all of the implement completed their economic life. They were purchased before thirty years. From the result of Table 4.2 and 4.3, the least percentage of machinery (tractor and combine harvester) should be replaced due to failure of the engine.

The New Holland 8030, which were bought in 2001 and had a service life of 11 years, could not work further in OSE farm because of extremely high operation cost and frequent failure of

the engine which was unaffordable. It was observed that they were idle. Therefore, OSE has to have a replacement plan to sustain reliability and competency of enterprise.

Inflation effects must be considered in making replacement decisions. Annual depreciation charges may be quite low or even negative in times of rapid inflation producing a premature minimum unit accumulated cost. In such instances, replacement is better indicated by comparing the unit accumulated cost of the present machine with the projected costs for a potential successor machine. Optimum replacement time may be delayed beyond that time determined under more stable economic conditions. The replacement plan should also consider new arrivals of latest machinery, which has high quality with high efficiency and low maintainability.

4.3. Downtime and availability of machinery

In agricultural production availability of the machinery or getting ready for the job to be assigned is very important. In OSE if the machinery is not available, the loss of income is not directly known. Rather the availability of machinery results in the loss of production of agricultural products. Hence, the availability of OSE machinery resulted in a loss of yield of the crop and its related products, because of the increase in downtime.

To analyze downtime and availability of machinery (tractors and combine harvesters) the data was taken from mechanization department. Seasonal working hours, effective working hours, down hours (time), utilization capacity and availability of the machinery are thoroughly analyzed in respective of all machinery. For implements information about downtime were not available.

Table 4. 4. Tractors utilization capacity, performance efficiency and availability

Tractors make	Plate Number of Tractors	Total clock hours	Gross hours	Net working hours(X)	Operational down hours(Y)	Non-operational down hours(Z)	Utilization capacity (%)			Performance Efficiency (%)	T.W.D p.s (165)	Availability (%)
							X	Y	Z			
John Deere 6165	5109-02A	1204	890	736	157	315	61.13	13.00	26.12	82.74	86	52
	5109-04T	1016	816	695	121	200	68.40	11.88	19.71	85.20	73	44
	5109-03L	1730	1262	1114	149	467	64.39	8.59	27.02	88.23	124	75
	5109-03G	1627	1105	908	197	527	55.78	12.12	32.41	82.15	116	70
John Deere 6615	5109-01A	1878	1327	1068	259	551	56.88	13.79	29.33	80.48	134	81
	5109-02T	1069	761	610	151	707	57.06	14.09	66.16	80.19	76	46
	5109-03T	1367	1073	907	167	293	66.34	12.20	21.45	84.47	98	59
	5109-01T	180	140	125	15	40	69.53	8.25	22.22	89.39	13	8
	5109-02G	1270	861	675	187	409	53.13	14.70	32.21	78.37	91	55
Agro-track 150	5111-01A	1494	982	789	191	512	52.83	12.76	34.28	80.38	107	65
	5111-02A	1908	1326	1113	213	582	58.33	11.14	30.53	83.96	136	83
	5111-01T	429	316	278	39	113	64.71	9.03	26.26	87.75	31	19
	5109-04L	1291	985	897	88	306	69.50	6.83	23.67	91.05	92	56
	5109-05L	1904	1304	1137	167	599	59.72	8.79	31.48	87.17	136	82
	5111-01G	807	750	590	160	57	73.08	19.82	7.06	78.65	58	35
Landin	5112-01T	308	222	192	30	86	62.25	9.80	27.95	86.40	22	13
	5112-01G	1576	1078	882	185	498	55.94	11.76	31.62	81.81	113	68
Massey Ferguson 399	5104-06T	257	169	141	29	88	54.65	11.08	34.28	83.15	18	11
	5104-07T	276	147	127	20	129	45.90	7.27	46.83	86.32	20	12
	5104-04L	1989	1422	1174	249	927	59.04	12.50	46.59	82.55	142	86
	5104-01L	1259	959	771	189	390	61.23	14.98	30.94	80.34	90	55
	5104-04G	1116	867	682	155	279	61.12	13.85	25.03	78.71	80	48
	5104-07G	234	199	183	17	35	78.21	7.26	14.96	91.96	17	10
Total	23	26189	18961	15792	3131	8111	60.30	11.96	30.97	83.29	1871	--

Note: T.W.D p.s – Total working days per season, A-Adele-Geredela-Lole and T-Temela farm state respectively.

X- Effective working hour, Y- Operational downtime hour and Z- Non-operational downtime hour.

From the above data (Table4.4) downtime of the tractor is very high which reduces effective working hours of the machinery. In another way, the availability of machinery is very low. The statistical analysis showed that the effective working hours and availability days were significantly affected by the tractor's model (Table 4.4). As a result, Agro-track 150 accounted for highest effective working hours and availability days (63.03% and 56.67%), followed by John Deere 6165 (62.43% and 60.25%), John Deere 6615 (60.59% and 49.80%), Messay Ferguson 399 (60% and 37%) and finally Landin (59.1% and 40.5). The highest downtime scored by Landin (40.95%). These may be attributed mainly to high frequent failure and poor management system.

Table 4. 5. Combine harvester's utilization capacity, performance efficiency and availability

Combine harvester makes	Plate Number of Combine harvesters	Total clock hours	Gross hours	Net working hours(X)	Operational down hours(Y)	Non-operational down hours(Z)	Utilization capacity (%)			Performance Efficiency (%)	T.W.D p.s (60)	Availability (%)
							X	Y	Z			
TUCANO	5704-001G	492	321	246	75	171	50.02	15.21	34.77	76.68	41	68
	5706-0001A	396	256	181	75	140	45.69	19.02	35.29	70.61	33	55
	5704-001L	696	425	329	96	271	47.26	13.85	38.89	77.33	58	97
TC-5060	5705-005T	942	612	376	208	330	39.92	22.07	35.06	61.46	79	131
	5703-001A	396	275	185	184	121	46.81	46.43	30.62	67.47	33	55
	5703-001L	522	388	277	95	136	53.00	18.28	26.10	71.35	44	73
TC-55	5705-002G	426	265	199	67	161	46.65	15.63	37.71	74.90	36	59
	5705-004G	336	195	144	51	140	42.76	15.26	41.60	73.70	28	47
	5705-003T	642	402	300	101	240	46.77	15.80	37.45	74.67	54	89
	5705-004T	600	372	291	81	228	48.52	13.47	38.01	78.27	50	83
	5703-0001A	420	279	192	87	141	45.62	20.83	33.55	68.66	35	58
	5705-004L	324	192	169	23	132	52.31	7.06	40.89	88.11	27	45
Total	12	6192	3982	2889	1144	2212	46.65	18.48	35.72	72.54	516	--

Note: T.W.D p.s – Total working days per season, A-Adele-Geredela-Lole and T-Temela farm state respectively.

X- Effective working hour, Y- Operational downtime hour and Z- Non-operational downtime hour.

From the above data (Table 4.5), effective working hours of combine harvesters are very low, which was less than 50% and availability days of Combine harvesters is a high percentage. Why combine harvesters effective working hours was less? Because, as observed in table 4.5, the non-operational downtime is high. These revealed that existing in high availability of machinery alone was not guaranteed for the state if they did not work effectively in a good manner. These should be achieved through good management systems.

Generally speaking, the utilization of equipment is measured in availability performance, it is observed that machinery are existing in lower availability and low effective working hours. Hence, the productivity of machinery is at a lower level. Availability of the machinery can be increased by implementing effective and reliable maintenance since the task of maintenance is to increase the availability of machinery.

The main cause of downtime: The cause of downtime is the frequent failure of machinery. But the cause of failure is due to abuse and misuse of machinery such as:

- Improper driving on the rough road especially between farms.
- Driving with leakage lubricant and coolant as a result of the damaged instrumental panel.
- Driving with worn-out components like brake linings, clutch, joints, bushings etc.
- Improper lubrication about the type of lubricant and frequent lubrication.
- Continuous operation of machinery 24 hours without rest. This is manifested especially on tractors, oil viscosity reduces with time which causes breakage.
- Fast driving on channel and bridge which result to tire inflation and axle breakage.

Lack of spare part: Most of the time spare parts for new machinery are not available in store. The enterprise should assure that the availability of spare part of the new machine in the local market. Hence, machinery stops for a long time waiting for spares. Therefore, OSE should pre-plan better for spare parts. In doing so, OSE optimizes machinery utilization and availability of machinery on the work to be assigned.

4.4. Effect of over utilization of farm machinery on economic life

The results in Table 4.6 showed that machinery types were at maximum hour usage while some of them were at minimum hour usage. According to ASAE standard (1993) agricultural machinery data estimated useful life of tractor and self-propelled combine harvester is 10,000 hours and 3,000 hours respectively.

Table 4. 6. Estimated useful life hour and accumulated hour usage of machinery

Machinery type	Plate number	HP	Purchased year	EUL hour	Accumulated hour usage	Variation %
John Deere 6165	5109-02A	165	2006	10,000	9750	+3
	5109-04T	165	2006	10,000	10419	-4
	5109-03L	165	2006	10,000	8000	+20
	5109-03G	165	2006	10,000	9656	+3
John Deere 6615	5109-01A	120	2001	10,000	13500	-26
	5109-02G	120	2001	10,000	14273	-30
	5109-02T	120	2001	10,000	10578	-5
	5109-03T	120	2001	10,000	13000	-23
	5109-01T	120	2001	10,000	13250	-25
Deutz-Fahr Agrotron 150	5111-01A	150	2008	10,000	6660	+33
	5111-02A	150	2008	10,000	5900	+41
	5111-01T	150	2008	10,000	4000	+60
	5111-01G	150	2008	10,000	7923	+21
	5109-04L	150	2008	10,000	6900	+31
	5109-05L	150	2008	10,000	7200	+28
Landin 7-215	5112-01G	215	2009	10,000	4500	+55
	5112-01T	215	2009	10,000	4109	+59
Claas Tucano 320	5706-01A	245	2009	3,000	1550	+48
	5704-01L	245	2009	3,000	1500	+50
	5704-01G	245	2009	3,000	1400	+53
New Holland TC5060	5703-01A	170	2003	3,000	4850	-38
	5703-01L	170	2003	3,000	4600	-35
	5705-05T	170	2003	3,000	4560	-34
New Holland TC55	5703-01A	120	1993	3,000	5550	-46
	5705-04L	120	1993	3,000	5400	-44
	5705-02G	120	1993	3,000	5500	-45
	5705-04G	120	1993	3,000	4600	-35
	5705-03T	120	1993	3,000	4200	-29
	5705-04T	120	1993	3,000	4048	-26

From the above table, a positive sign indicates the machinery was below estimated useful life hour and a negative sign indicates the machinery was above estimated useful life hour. It was observed from the result in Table 4.5 that John Deere 6615 tractors were above estimated useful life by 21.8% variation. This indicated that John Deere 6615 tractors were over-utilized through annual working. Also for John Deere 6165 tractors, only about 7.5% of hour usage was left to reach to estimated useful life. When we see two tractors, John Deere 6615 and 6165, John Deere 6165 was younger than John Deere 6615 in service. But it has high accumulated hour usage. This indicated that the tractor is stressful. Landin 7-215 and Deutz-Fahr Agrotron 150 were around the middle of useful life. New Holland TC5060 and New Holland TC55 combine

harvesters were above estimated useful life by 35.7% and 37.5% respectively. Claas Tucano 320 combine harvester was in the middle of a useful life. Messay Ferguson 399 does not have hour meter and data which shows accumulated hour usage due to long service years and poor data recorded culture.

Table 4. 7. Effect of annual working hours on the machinery service life

Machinery type	Plate number	HP	Current age	Useful life years		Annual working hour (hr/year)
				ASAE	OSE	
John Deere 6165	5109-02A	165	6	12	5	890
	5109-04T	165	6	12	5	816
	5109-03L	165	6	12	5	1262
	5109-03G	165	6	12	5	1105
John Deere 6615	5109-01A	120	11	12	5	1327
	5109-02G	120	11	12	5	861
	5109-02T	120	11	12	5	761
	5109-03T	120	11	12	5	1073
	5109-01T	120	11	12	5	140
Deutz-Fahr Agrotron 150	5111-01A	150	4	12	5	982
	5111-02A	150	4	12	5	1326
	5111-01T	150	4	12	5	316
	5111-01G	150	4	12	5	807
	5109-04L	150	4	12	5	985
	5109-05L	150	4	12	5	1304
Landin 7-215	5112-01G	215	3	12	5	1078
	5112-01T	215	3	12	5	222
Messay Ferguson 399	5104-06T	100	24	12	5	169
	5104-07T	100	24	12	5	147
	5104-04L	100	24	12	5	1422
	5104-01L	100	24	12	5	959
	5104-04G	100	24	12	5	867
	5104-07G	100	24	12	5	199
Claas Tucano 320	5706-01A	245	3	12	5	256
	5704-01L	245	3	12	5	425
	5704-01G	245	3	12	5	321
New Holland TC5060	5703-01A	170	9	12	5	275
	5703-01L	170	9	12	5	388
	5705-05T	170	9	12	5	612
New Holland TC55	5703-01A	120	19	12	5	279
	5705-04L	120	19	12	5	192
	5705-02G	120	19	12	5	265
	5705-04G	120	19	12	5	195
	5705-03T	120	19	12	5	402
	5705-04T	120	19	12	5	372

In an economic analysis, machinery depreciation is the one which depends on age and time of the machinery. In the analysis behind, it is considered fundamentally depreciation as a separate function of age and hours of use. That is ageing tractors without putting hours on it will cause it to depreciate at a certain rate and putting more hour on tractors without making it any older will cause it to depreciate at a different rate (Amana, 2016).

The result in Table 4.7 showed that average working hours of John Deere 6165 (plate number 5109-04T), John Deere 6615 (plate number 5109-01T and 5109-02T), Deutz-Fahr Agrotron 150 (plate number 5111-01T and 5111-01G), Landin 7-215 (plate number 5112-01T) and Messay Ferguson 399 (plate number 5104-06T, 5104-07T and 5104-07G) tractors in the study area were below estimated hours of use (833 hours/year) which was estimated from 10,000 hours for 12 years. But the rest of the tractors were showed higher actual hours use than average yearly estimated hours of use. For combine harvester there was no available literature shows annual estimated hours of use.

However, these machines were idle when there was no demand and off- operation for many months. But during the peak season both tractors and combine harvesters were working for a long time including night time when the field was clear to be seen under the moon besides headlight. This scenario made the useful life of both tractors and combine harvesters shorter than predetermined hours.

For instance, Deutz-Fahr Agrotron 150 tractors are reached to complete their economic lives but the service life is early four years served. Over utilization of farm machines in enterprise perhaps due to shortage of farm machinery. However, over utilization has a negative technical implication where there is no proper machinery handling which resulted in a negative economical implication.

4.5. Agricultural machinery maintenance management system

4.5.1. Manpower and employee characteristic

Based on recent machinery /equipment and the technology employed on their construction machinery system is complex and there is some variation in operation, maintenance and safety improvement from time to time. The determination of requirements for manpower involves identifying how many people were required and what skills they should possess. To use and manage/handle/ the newly purchased machinery properly, to understand machinery equipment

function and mechanism, to have the power to find out the cause of system trouble, to have the ability to find and improve machinery's minor and major defect sources, it is very important to plan to upgrade and update the maintenance crew (technicians), operators knowledge and skill from time to time. Building capacity of maintenance staff with the proper knowledge will ensure proper and effective maintenance and increase the performance of maintenance personnel and operators. In the study area, the assessment was made on the educational background of maintenance staff. The current educational status (background) of maintenance manpower is shown in Figure 4.1.

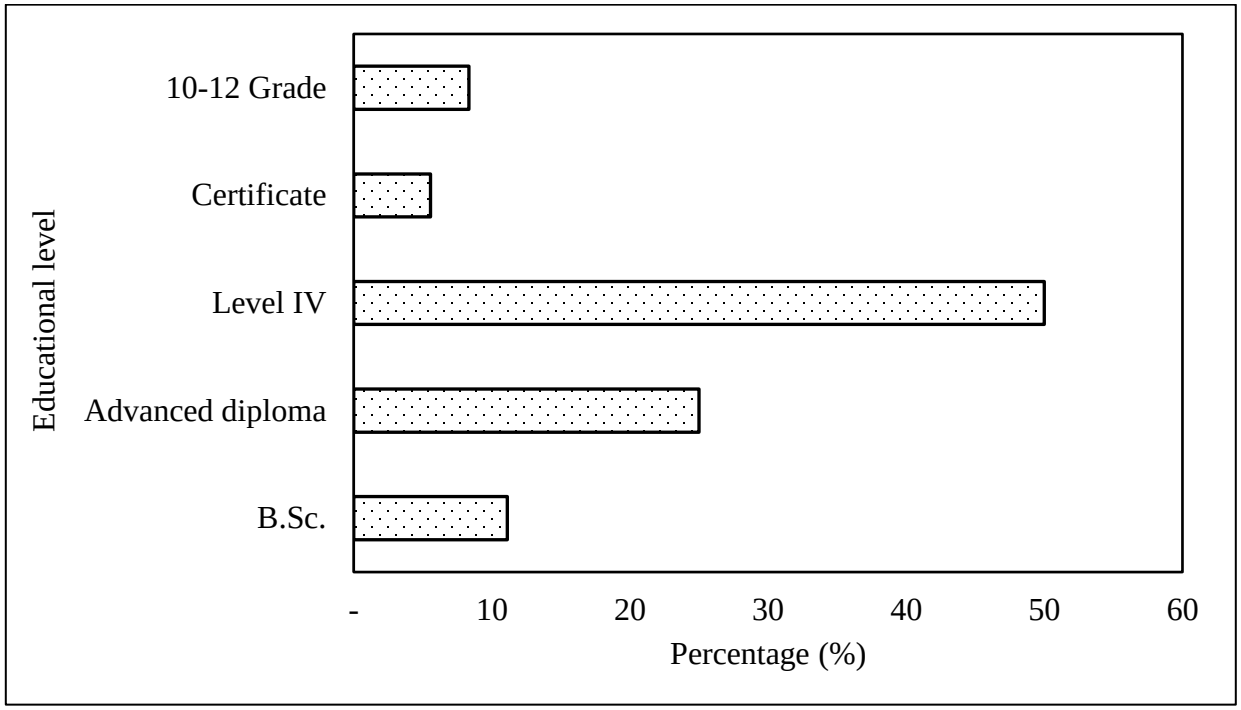


Figure 4. 1. Educational profile and quantity in percentage

Figure 4.1 showed that, the educational background of the maintenance staff at farm states. Those who have Level IV education constitute 50% of the maintenance staff. About 25% of staffs have an Advanced Diploma and about 11.11% of Bachelor's degree in staffs. Education is a necessity if one is to operate and maintain a machine effectively since it will enable the machinery maintainer to read the services' manual and understand how the machinery is used. Majority of these operators having no formal education implies they cannot read and understand the services' manual which impairs their effectiveness in undertaking recommended operation and maintenance practices putting themselves and the machinery at risk.

To achieve the objective of maintenance and the desired quality of maintenance, the right man at the right place and the right job should be put. Having these many people which are unqualified it is challenging to be effective in maintenance. Furthermore, these people couldn.t follow scientific procedures during maintaining, repairing machinery. It is difficult to understand the system of machinery. Rather they follow the traditional way of maintenance and develop try and error method which results in frequent breakage and failure of machinery systems.

In addition to the educational background, the assessment was made on experience of maintenance staff. The result is as shown in figure 4.2 below.

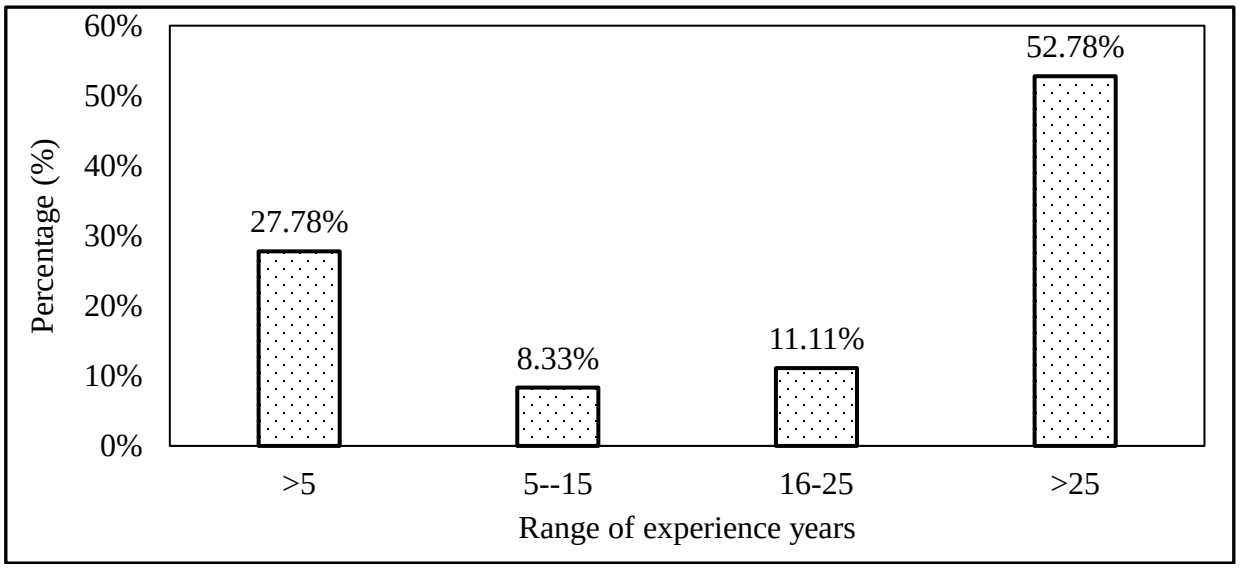


Figure 4. 2. Experience years and quantity in percentage

From the above figure, about 52.78% of the maintenance staff have more than 25 years' experience without adequate educational background. These technicians were familiar with the old machine model and to maintain new machinery may be difficult for them if they did not have an appropriate educational background. About 27.78% of maintenance staff are working for less than five years.

The experience was very important because it takes repair crew to perfection but due to lack of appropriate knowledge basis of the repair crew yet the OSE machinery maintenance system is poor. Most of the technicians could not follow repair manual /service manual. To achieve quality maintenance as activities that are to set equipment condition that precludes quality defects,

based on the basic concept of maintenance perfect machinery to maintain perfect quality of machinery. Therefore, OSE should have to have repair crews that have experience with appropriate educational background.

Table 4. 8. Age of maintenance staff

Range	25-30	31-35	36-40	>40	Total
Number	10	2	4	20	36
%	27.77%	5.56%	11.11%	55.56%	100%

Responses to the questionnaire indicated that all maintenance staff in OSE are males. As shown in Table 4.8, 27.77% of the maintenance staff were between 25 and 30 years of age. 5.56% of them were between 31 and 35 years, 11.11% were between 36 and 40 years and 55.56% were 41 years and above. In OSE most of the maintenance staff are not young enough, 55.56% of them are above 40 years old and they are getting ready to retired. As one gets older body flexibility reduced. Therefore, they couldn.t take machinery components to the desired position like a youngster. About 44.44% of maintenance staffs are less than 40 years. Maintenance department should design to develop a staff of the youngster to optimize effectively, maintenance and things of that older staff and have a plan to replace those aged staff with young, educated and well-trained ones.

Table 4. 9. Current educational background of operators

Machine type	Educational level				Total
	Diploma	12^{th} and10^{th} complete	5-9 grade	<5 grade	
Tractor	26	-	-	23	49
Combiner	-	5	5	-	10
Total	26	5	5	23	59
%	44.07%	8.47%	8.47%	38.99%	100

Table 4.9 showed that the educational background of tractor and combiner operators at OSE. Those who have no formal education constitute and less than grade five attained 38.99% of the operators. About 44.07% of the operators have a diploma and about 16.94% attained school from grade five to twelve. Education is a necessity if one is to operate and maintain tractor and combiner effectively since it will enable tractor and combiner operator to read the operators' manual and understand how the machine is used. Majority of these operators having no formal education implies they cannot read and understand the operators' manual which impairs their

effectiveness in undertaking recommended operation and maintenance practices putting themselves and the machine at risk. Therefore, OSE should pay attention to it. Almost all of the operators should have at least Auto mechanic or Agro mechanic diploma with adequate training on machinery operations and handling.

4.5.2. Maintenance workshop condition of OSE

In the study area, there is five workshop center. From these, one is located near to Asela town and the rest are located near to farm state. From the study maintenance workshop area located and maintenance tools/equipment quality and quantity has a higher negative impact on the maintenance service department. The maintenance workshop area location should be comfortable for rebuilding, assembling, disassembling and overhauling of machine components. Preventive or breakdown maintenance works need a well-organized workshop to perform the mechanical job. The existing workshop is not organized and contaminated. The existing equipment is very old working beyond its useful age. This affects quality and effective maintenance. Engine diagnosing and performance testing equipment which used to identify the status of machinery did not exist. So it is better to purchase new equipment to optimize predictive maintenance. In addition to these special tools and testing instruments in OSE were not existing. In this condition, machinery are not properly monitored and resulted in a high frequency of breakdowns.

No matter how the skilled technicians are there, without proper tools and equipment it is impossible to avoid frequent breakdown maintenance. Some failed machinery were taken to Asela workshop. This workshop is not different from those located nearest to farm states by equipped workshop facility. Rather it increases downtime of machinery bringing from far apart distance. It is a very old workshop and not well established and equipped with modern tools. Some engine components which required rebuilding, resurfacing and grinding were taken to Addis Ababa. Duration of time it takes to bring back was a minimum of four months which increase downtime. It was observed that the equipment and machinery are frequently failed these affect the performance of machinery therefore, the maintenance management should give attention.

The following comments and recommendations were made. Poor maintenance workshop facility influences the quality of maintenance and efficiency of technical personnel. Therefore,

it was recommended that purchasing new and precise equipment's and hand tools within the budget year deserve priority. Due to the absence of special tools and testing instruments in the maintenance department, conditions of machines were not properly monitored. As a result higher frequency of breakdown maintenance was occurring. Therefore, OSE should establish maintenance management systems.

4.5.3. Maintenance organization in the training program

In the study area, different types of machinery were available to be maintained. To have quality maintenance process, the department should be organized with good maintenance tools in quality and quantity, availability of maintenance planner and continuous training was essential to come up with the dynamic advancement of technology and to compete with the market change.

The maintenance and service department did not have a policy on training. However, the importance of training becomes mandatory if new vehicles or equipment imported whereas the machinery becoming advanced. Unskilled maintenance workers were one of the problems of the maintenance department. Therefore, providing training to maintenance workers should be the basic and the primary aim for the farm state to achieve quality and quantity of agricultural operations. Figure 4.3.show the questionnaire assessment on manpower training

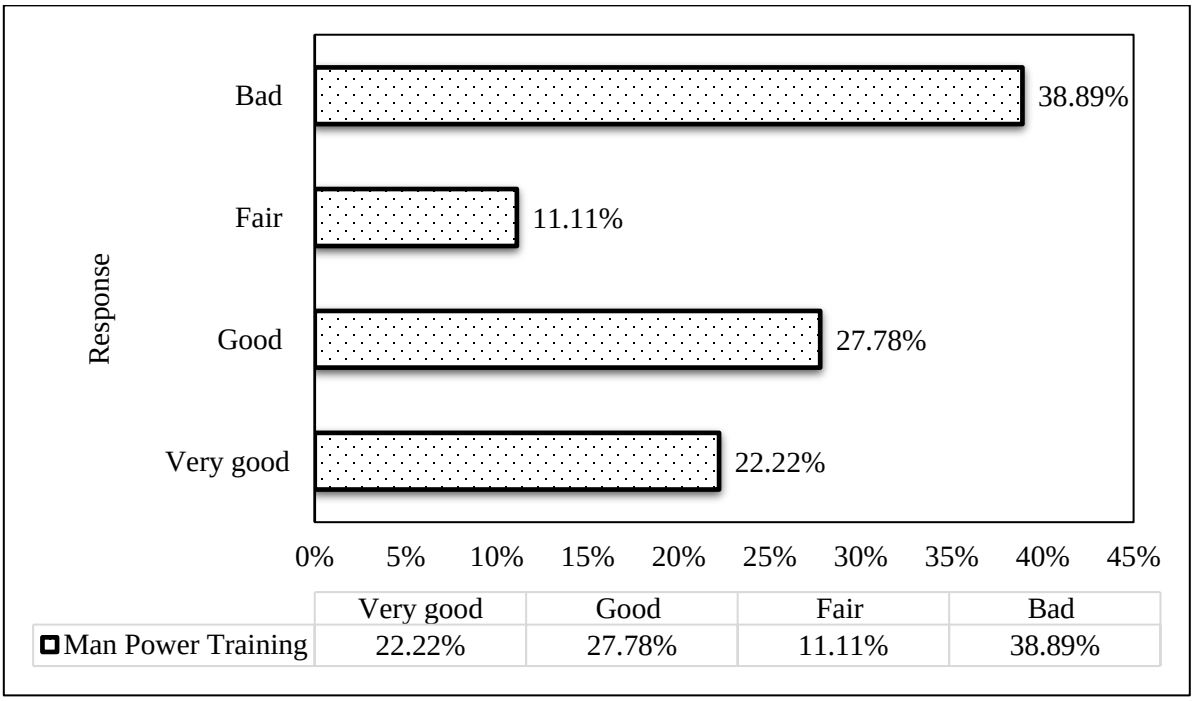
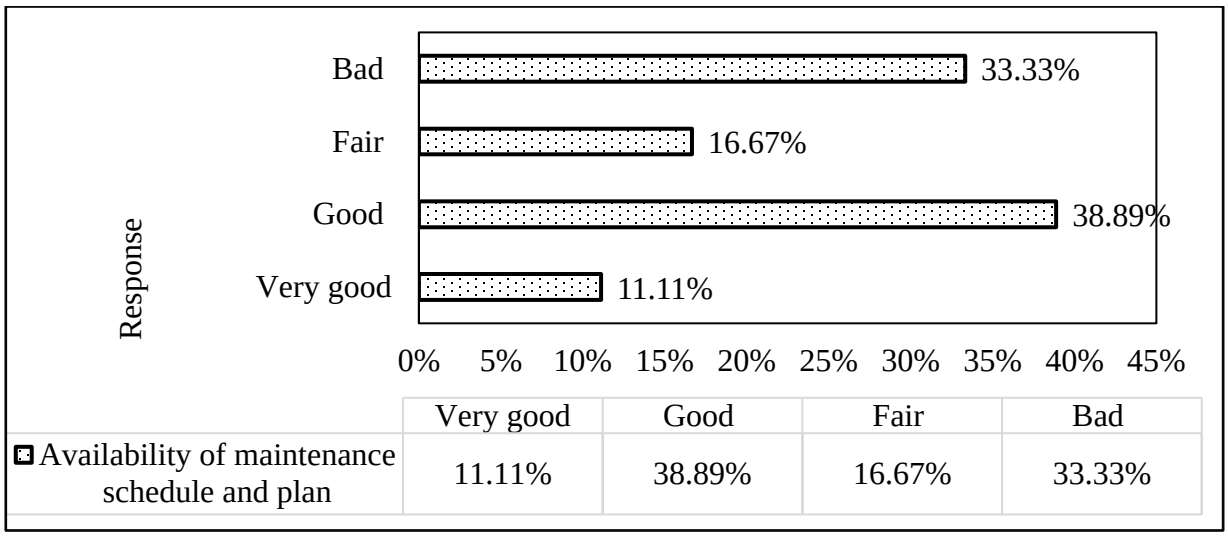


Figure 4. 3. Response Assessment on Manpower Training

From the assessment, the frequency of maintenance training, the quality and skill level of maintenance personnel have a higher negative impact on maintenance work quality. It can be seen from Figure 4.3 that 22.22% of the maintenance interviewed have had some form of training in machinery maintenance. However, about 38.89% did not have any form of training in tractor maintenance. Maintenance training enables the machine operator to effectively maintain his machine which in turn increases the lifespan of the machine. Training develops confidence in maintenance personnel and fills the skill gap. Therefore, training for maintenance personnel was very essential to improve the skills of the labour force.

The planning and scheduling assessment includes annual work plan implementation rate, preventive maintenance program completed within the planned time, the commitment of maintenance management on schedule monitoring and planning effectiveness when comparing the actual and estimated time. From the study with selected major variables on maintenance planning and scheduling implementation, 33.33 % was a bad response in the OSE as indicated in figure 4.4.



	Very good	Good	Fair	Bad
Availability of maintenance schedule and plan	11.11%	38.89%	16.67%	33.33%

Figure 4. 4. Availability of maintenance planning

The other important to be considered were maintenance checklists which have a higher negative impact on maintenance planning and scheduling accomplishment. Especially, it was known that lubrication checklists were major parts of any successful maintenance planning program. It requires application of the right lubricant at the right time, in the right quantity using the right method within the planned and scheduled time. In which it ensures long life and safe working of the equipment.

Proper lubrication converts solid friction into fluid friction and thus reduces wear and tear of moving parts and cuts down power consumption. It also keeps bearings within allowable temperature ranges and protects them from rust, dust and corrosion. Therefore, lubrication was a major part of preventive programs guarantees a long life of the equipment and its components without failures.

The key to implementing effective organizational change is the wise management of the process. In OSE farm machinery maintenance management, as one can see from a past brief explanation regarding machinery status, OSE faces a problem of maintenance systematization. Many numbers of machinery are not in good status. In agriculture even single machinery not working has meaningfulness. Many types of machinery are also beyond their useful ages. This resulted in high operating cost, spare part cost and downtime cost. Therefore, they reduce profit and continuous loss that attribute to lack of proper maintenance management system.

The OSE applied two maintenance systems. The first one is breakdown maintenance systems. Breakdown maintenance is corrective maintenance system in which machinery is run until breakdown occurs. This is the most commonly practiced in the OSE.

The main causes of practicing breakdown maintenance system in the enterprise are lack of; proper maintenance management of machinery, commitment, proper training, upgrading of maintenance crew, proper skill and knowledge of machinery, convenient workplace, proper repair and maintenance tool and shortage of knowledge and skill of operators.

The second one is the Preventive maintenance system, which is referring to those critical systems which have to reduce the likely hood of failures of the obsolete minimum. Preventive maintenance includes minor lubrication maintenance program which interns include tasks of changing of engine oil, oil filter, oil bath type air cleaner, final drive oil, front differential oil, gearbox oil, oil of steering(power steering), hydraulic oil, brake oil (brake fluid), coolant and greasing of components. To prevent breakdown, preventive servicing is carried out with the specific objective of detecting or locating wear areas and ensuring perfect functioning.

4.5.4. Spare part status

It is true that most of the managers spend their time on equipment problems and directing people rather than on matters about spare parts and maintenance consumables. However, the need for

spare parts was much more predictable. Since the volume of inventory required is based to a large degree on usage, the fewer parts we use, the fewer we need to keep on hand. The challenge was to determine what a correct inventory should be and how to manage it. From the study as shown in figure 4.5, the situation of the spare parts during the study is poor therefore, most the machinery maintain through cannibalization.

In the OSE, there was no effective and efficient way of spare parts planning and control system. As clearly shown in the figure 4.5, the situation of the spare parts during the study 38.89% is poor. Spare parts of some machinery are not available in the market, especially the new model and very old model machinery were exposed to this problem.

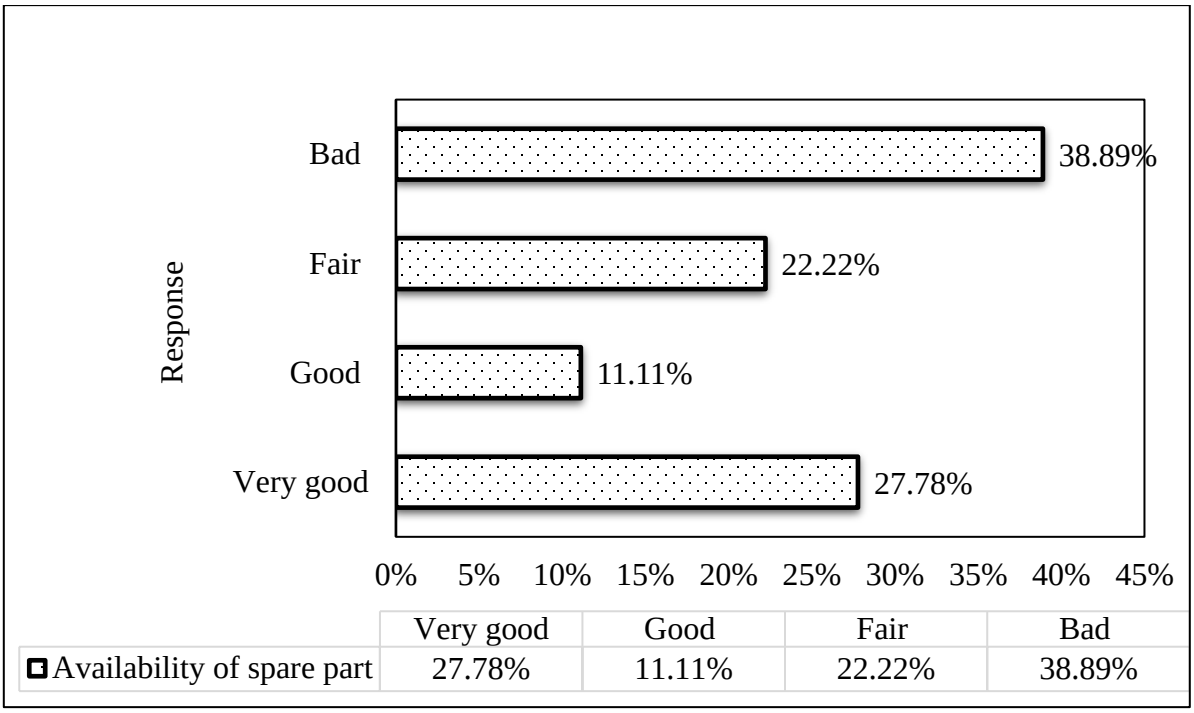


Figure 4. 5. The situation of the spare parts during the study

The availability of the important spare parts during the season have a great effect on the performance of the machinery. However, usual machine or equipment stoppage for many days during the season was common, due to mainly un-availability of a given spare part. Bearing in mind the effect of timeliness in rain-fed agriculture, such a delay may cause great losses due to delayed farm operations. Moreover, the use of the spare part that was locally manufactured or rehabilitated might solve temporary the problem and to varying degrees, but ultimately this type of spare parts need to be replaced by genuine ones. Genuine spare parts are of dependability and

reliability and sporadically found in scattered workshops, here and there, but with no definite locations. The other limitation is the purchase of non-genuine spare parts, and some non-genuine spare parts with substitute materials were working in the factory which, cause a higher frequency of breakdown. This was attributed to the absence of reliable and regular suppliers were available. The main cause of this problem was improper materials requirement planning. On the other hand, most of the machines' downtime in OSE was caused by a shortage of spare parts. This showed an absence of coordination between supply and maintenance departments.

4.6. Farm machinery cost management

4.6.1. Depreciation cost

The actual and calculated depreciation cost of the different machinery used in the OSE were evaluated. To determine the depreciation value of agricultural machinery it requires commonly purchased price and economic life (useful life) of the machines. In OSE depreciation cost has been inhabited with a straight-line method which was calculated as purchased cost divided by five years of the economic life of machinery. And the researchers used the declining balance method up to five age of machinery to compare with actual values of enterprise only for this study purpose. For this particular case data of machinery were taken from Appendix A.

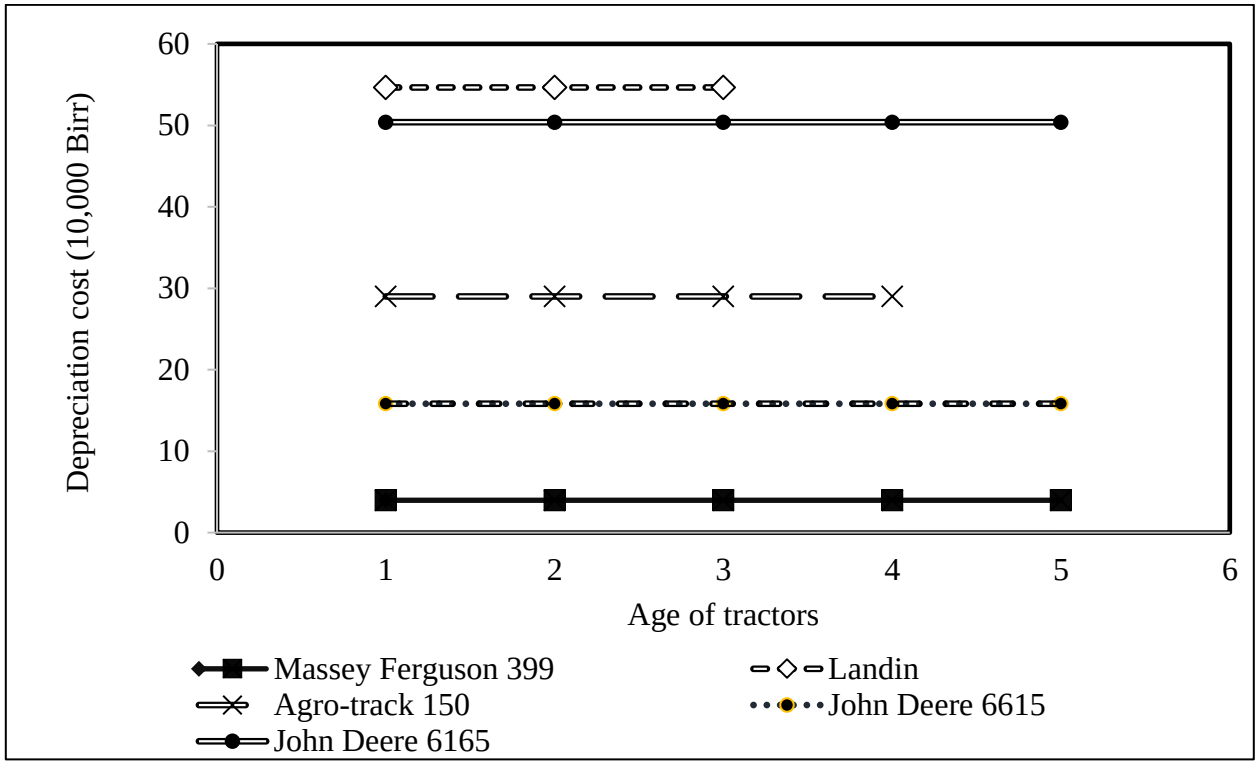


Figure 4. 6. Actual depreciation cost (Birr) of tractors.

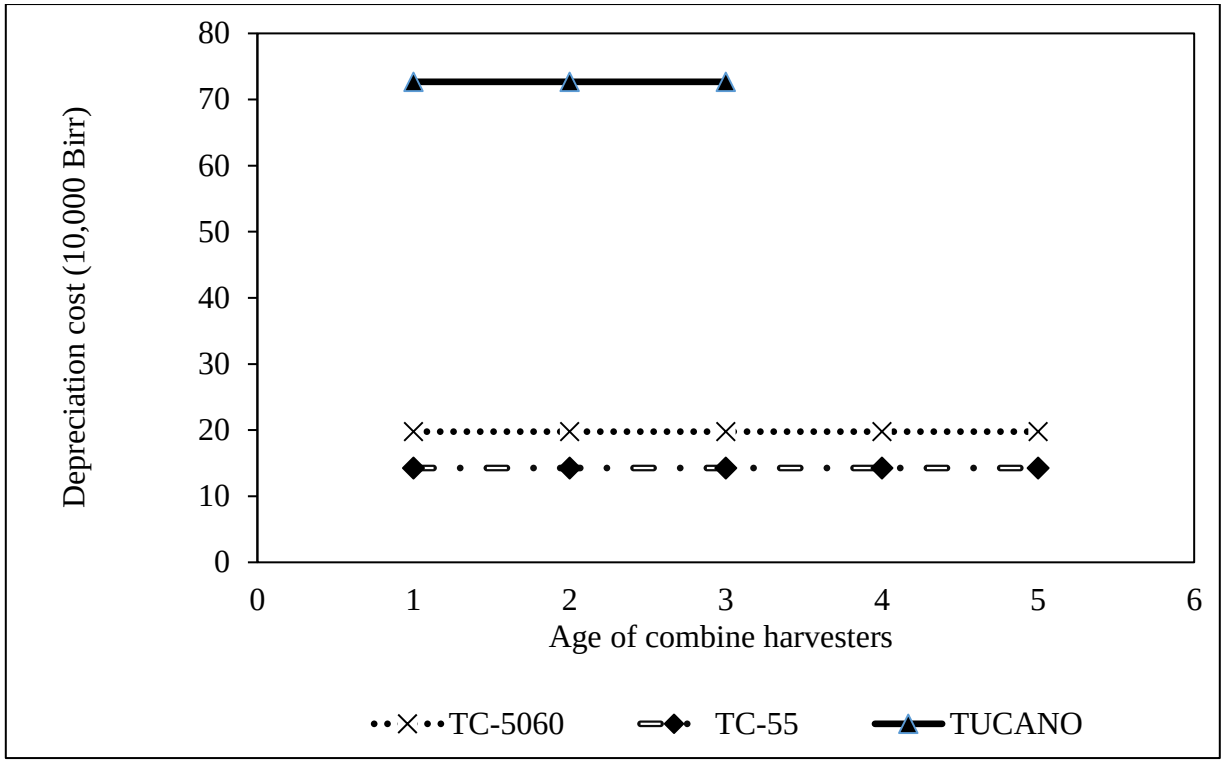


Figure 4. 7. Actual depreciation cost (Birr) of combine harvesters

From above Figure 4.6, showed that except Landin and Agro-track 150, others were completed their depreciation cost at early five years. These means, machinery complete their economic values and no resale values after all. This result is inconsistent with Amana W. (2016) findings, the purchase price related to machines bought either new or second hand and the resale value after a long period of ownership may become the scrap value. During the early life of the machine, therefore, both the resale value and the period of ownership must be assumed.

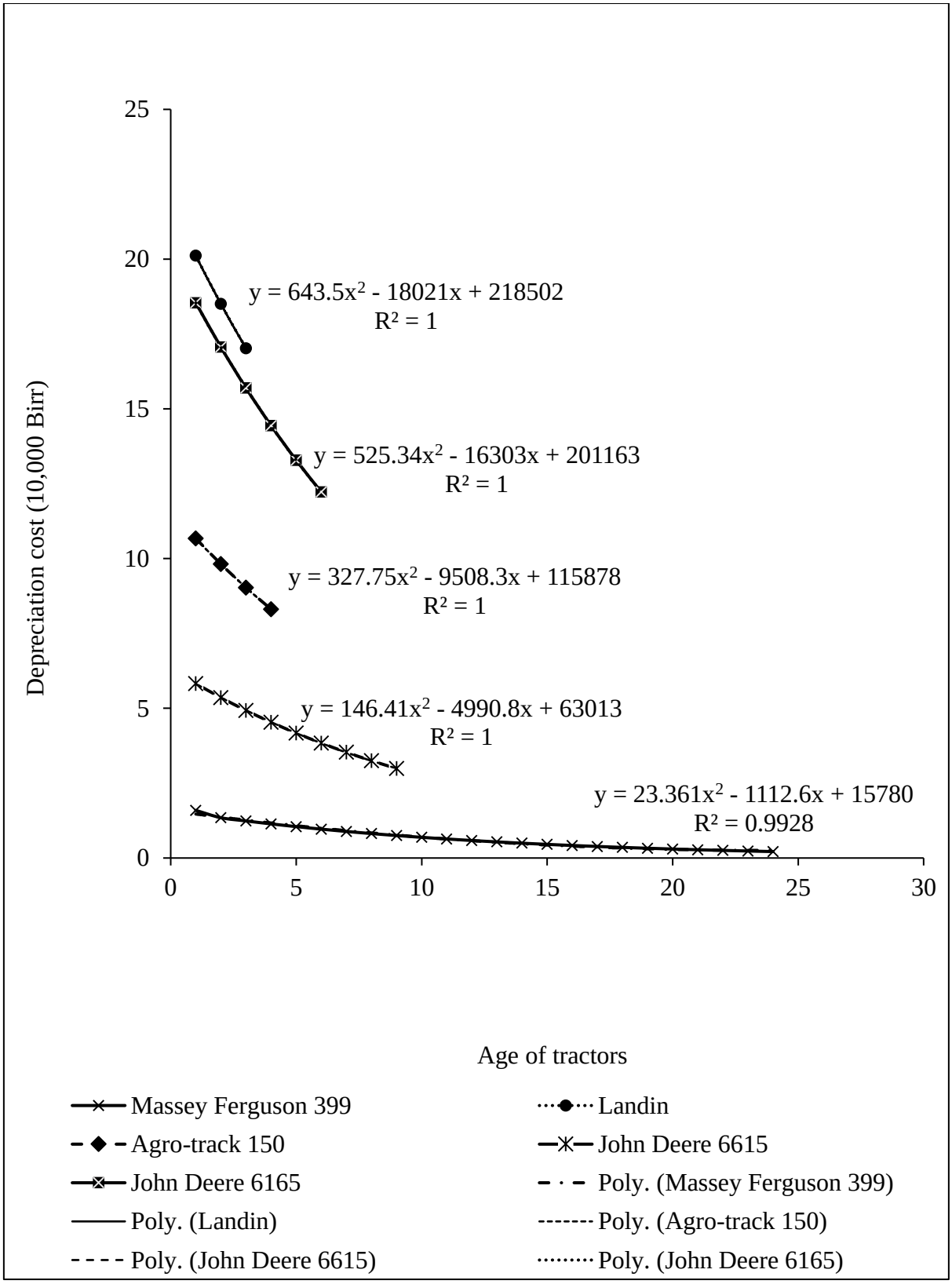


Figure 4. 8. Calculated depreciation cost (Birr) of tractors

In order to determine depreciation cost as a function of service life of machines, least square regression method was used. Second order polynomial function was used to determine the relationship. Regression curve for depreciation costs of Messay Ferguson 399, John Deere 6615, Agro-track 150, John Deere 6165 and Landin tractors were found as $y = 23.361x^2 - 1112.6x + 15780$, $y = 146.41x^2 - 4990.8x + 63013$, $y = 327.75x^2 - 9508.3x + 115878$, $y = 525.34x^2 - 16303x + 201163$ and $y = 643.5x^2 - 18021x + 218502$ respectively.

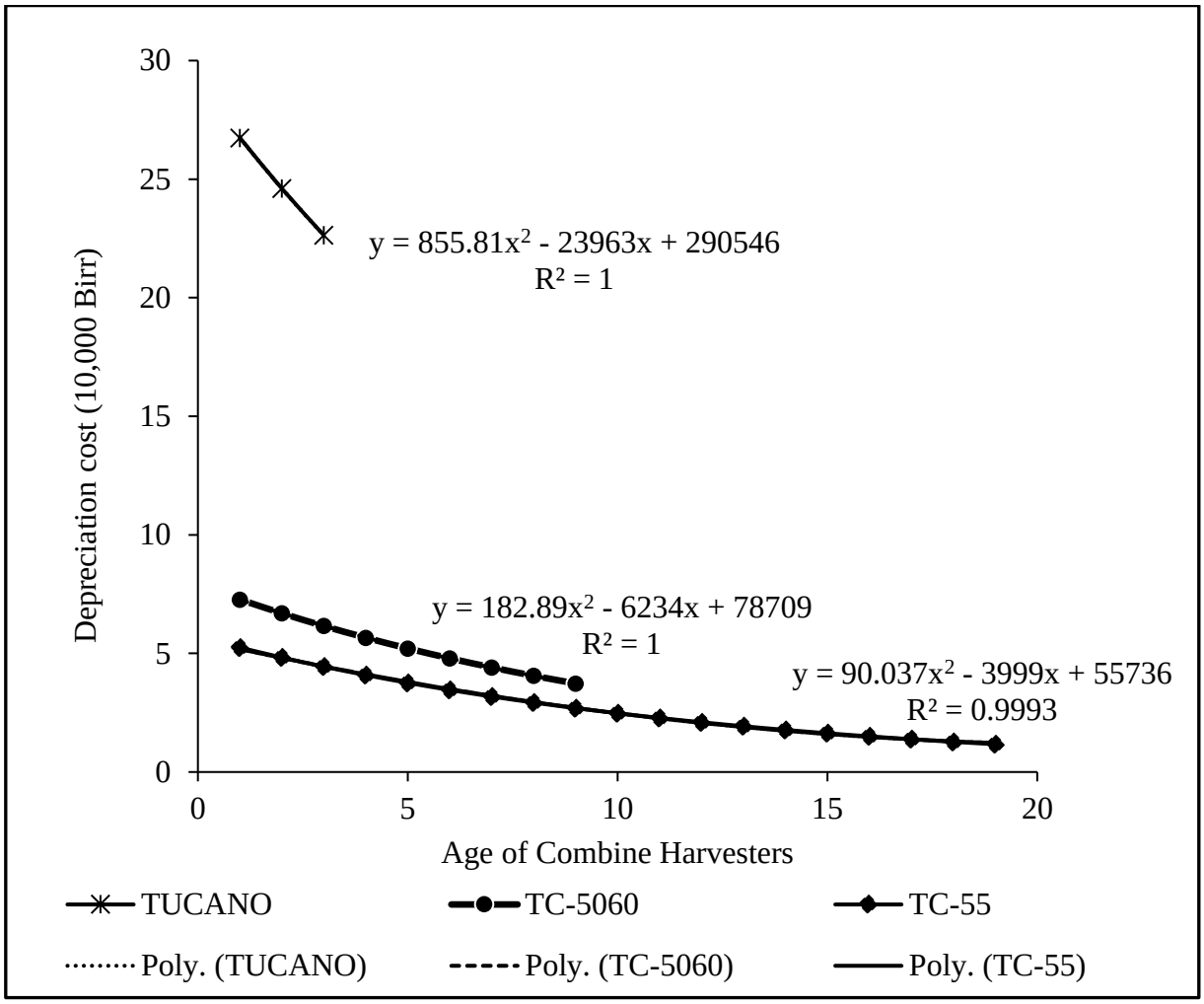


Figure 4. 9. Calculated depreciation cost of combine harvesters

Regression curve for depreciation costs of Tucano, TC-5060 and TC-55 were found as $y = 855.81x^2 - 23963x + 290546$, $y = 182.89x^2 - 6234x + 78709$ and $y = 90.037x^2 - 3999x + 55736$.

From above Figure 4.8, showed that tractors value were gradually depreciated in the form of curve line. From this result, Landin tractor has high depreciation values and followed by John Deere 6165, Agro-track, John Deere 6615 and Messay Ferguson 399 respectively. From above

Figure 4.9, also showed that combiner value was gradually depreciated in the form of curve line. From this result, Tucano combiner has high depreciation values and followed by TC-5060 and TC-55 respectively. These may be attributed that the purchased price of tractors and combines differences.

Generally speaking, actual depreciation costs of all aforementioned tractors and combine harvesters were higher than calculated depreciation cost by 66% when considered the age of tractors and combine harvesters up to five years. This may be attributed to the poor management system on machinery costs.

Depreciation or capital consumption measures the rate at which the value of the existing capital stock declines with time as a result of wear and tear or obsolescence. Depreciation is often the largest cost of farm machinery, it measures the amount by which the value of a machine decreases with the passage of time, whether the machine used or not. Culpin (1975), reported "the machinery depreciates from the moment it comes on the farm. The rate of depreciation varies according to the kind of equipment, the amount of work that it does, and the care that is taken in servicing and storing it".

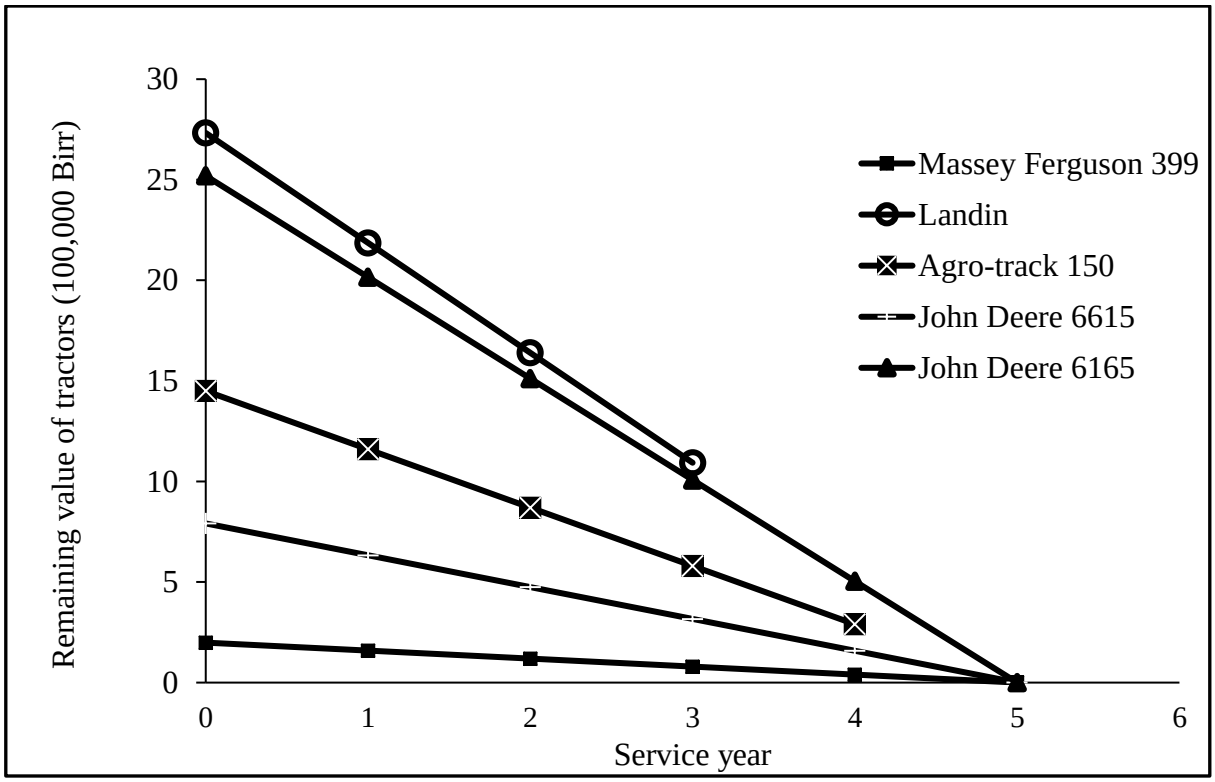


Figure 4. 10. Actual remaining values of tractors

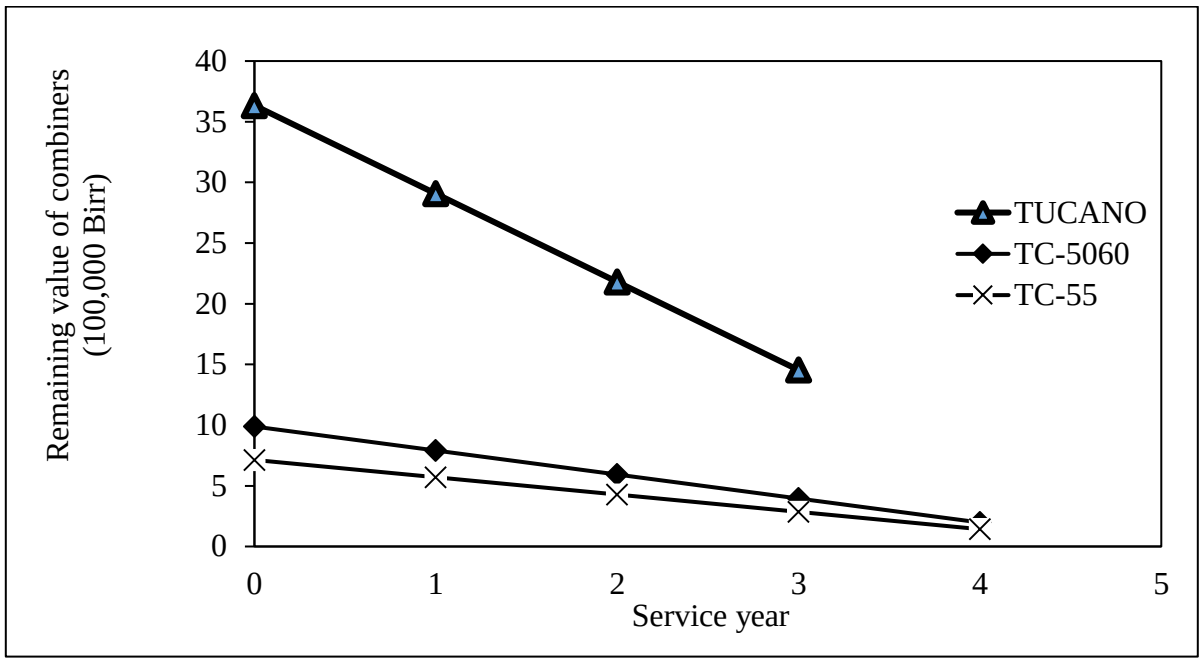


Figure 4. 11. Actual remaining values of combine harvesters

From the above figures (Fig. 4.10 and Fig. 4.11) actual remaining cost of machinery for both tractors and combine harvesters were determined. From above figure 4.10 showed that except Agro-track 150 and Landin the rests were completed their remaining values at age of five. Also from figure 4.11 showed that TC-5060 and TC-55 were completed their values at an early age. As indicated in the appendix- A1 & A2 the straight-line method which the enterprise has been using and has constant asset value depreciation up to five years, while book values of the machinery are reduced with different rate up to five years and they put ten Birr after five years upto service years. These not acceptable in the real world. Because of the machine service beyond their economic life. This attributed that, poor machinery management on cost of machinery in the proper manner of the enterprise.

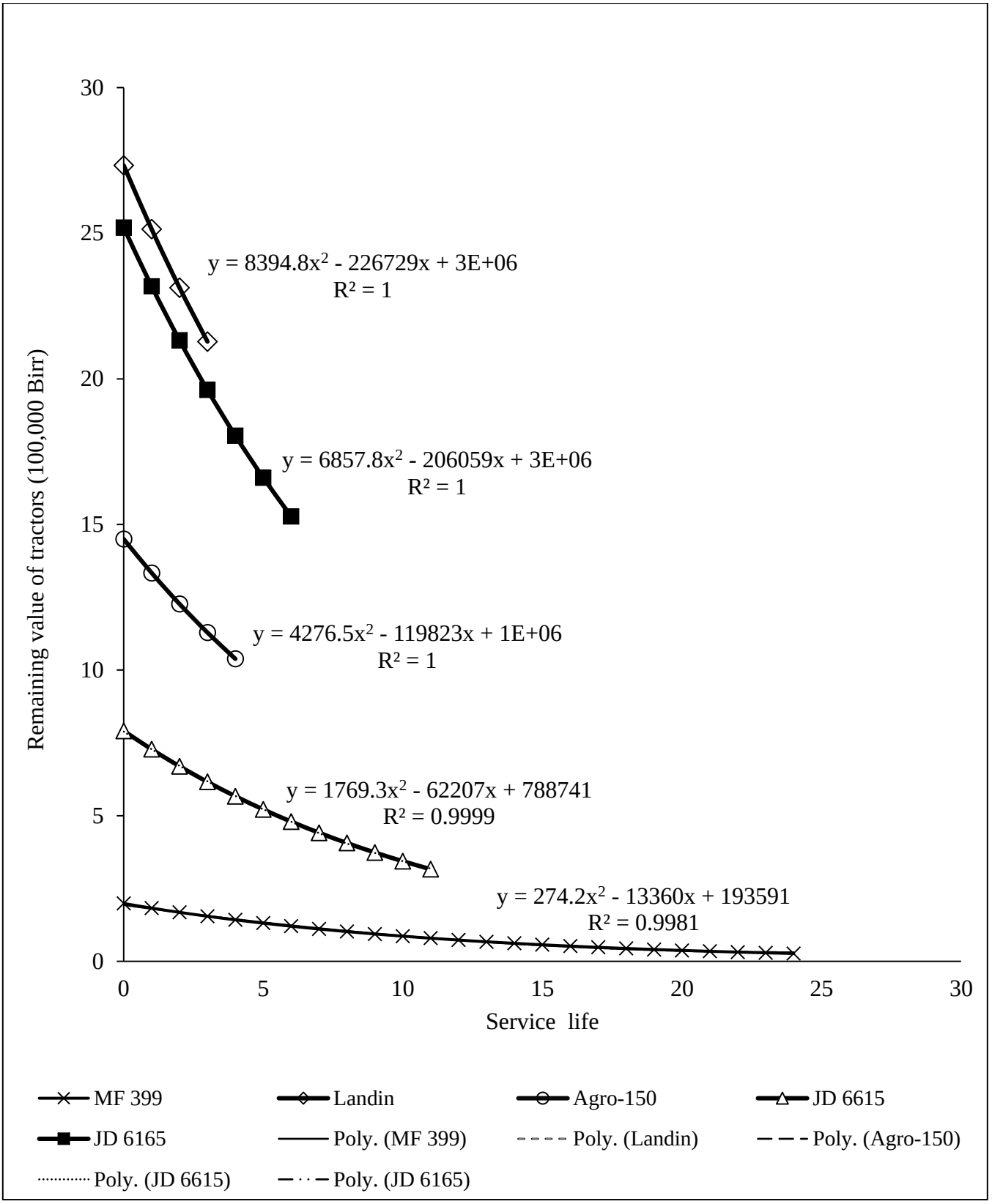


Figure 4. 12. Calculated remaining values of tractors

In order to determine remaining values cost as a function of service life of machines, least square regression method was used. Second order polynomial function was used to determine the relationship. Regression curve for remaining values costs of Landin, John Deere6165, Agro-track 150, John Deere 6615 and Messay Ferguson 399 tractors were found $y = 8394.8x^2 - 226729x + 3E+06$, $y = 6857.8x^2 - 206059x + 3E+06$, $y = 4276.5x^2 - 119823x + 1E+06$, $y = 1769.3x^2 - 62207x + 788741$ and $y = 274.2x^2 - 13360x + 193591$ respectively.

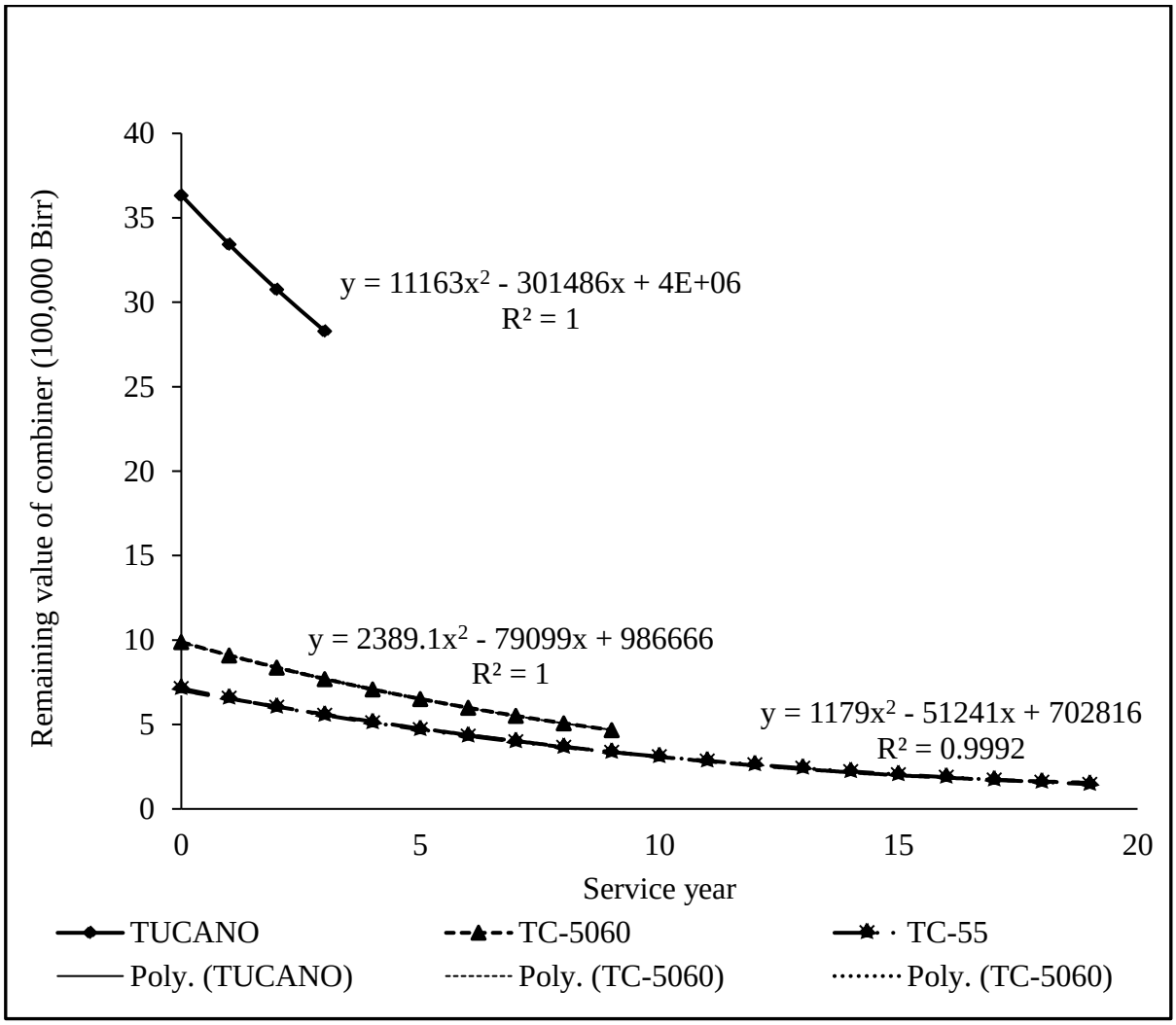


Figure 4. 13. Calculated remaining values of combine harvesters

Regression curve for remaining values costs of Tucano, TC-5060 and TC-55 were found as $y = 11163x^2 - 301486x + 4E+06$, $y = 2389.1x^2 - 79099x + 986666$ and $y = 1179x^2 - 51241x + 702816$ respectively.

4.6.2. Fuel and oil cost

Fuel consumption estimation is based on the average annual fuel consumption. Along with fuel cost, oil costs were also determined for the aforementioned tractors and combine harvesters as 15% of their fuel costs (ASABE standard D497, 2006). In the study area, actual fuel and oil consumption was collected from data recorded for each activity of tractors and combine harvesters. All machinery was consumed diesel fuel. None of the machinery consumed gasoline. The actual and calculated fuel and oil costs of the different tractor and combine harvester makes and models used in the OSE were evaluated during the seasons 2010/11 and 2011/12 as shown in Tables (4.10), (4.11), (4.12), (4.13) and appendix A.

Table 4. 10. One way ANOVA of cost type and season costs of tractor makes

Dependent	Source variance	Sum of Squares	df	Mean Square	F	Sig.
Actual fuel cost per hour	Between Groups	78154.450	4	19538.612	11.350	.000
	Within Groups	29264.946	17	1721.467		
	Total	107419.396	21			
Calculated fuel cost per hour	Between Groups	196229.461	4	49057.365	3.601E+32	.000
	Within Groups	.000	17	.000		
	Total	196229.461	21			
Season of 2010/2011 fuel cost per hour	Between Groups	168710.519	4	42177.630	87.267	.000
	Within Groups	8216.375	17	483.316		
	Total	176926.894	21			
Season of 2011/2012 fuel cost per hour	Between Groups	71778.405	4	17944.601	2.194	.113
	Within Groups	139054.392	17	8179.670		
	Total	210832.797	21			
Actual oil cost per hour	Between Groups	1498.639	4	374.660	8.283	.001
	Within Groups	768.917	17	45.230		
	Total	2267.557	21			
Calculated oil cost per hour	Between Groups	4415.123	4	1103.781	4.642E+32	.000
	Within Groups	.000	17	.000		
	Total	4415.123	21			
Season of 2010/2011 oil cost per hour	Between Groups	1221.170	4	305.292	12.208	.000
	Within Groups	425.130	17	25.008		
	Total	1646.300	21			
Season of 2011/2012 oil cost per hour	Between Groups	2903.789	4	725.947	35.167	.000
	Within Groups	350.928	17	20.643		
	Total	3254.716	21			

Table 4.10 and 4.11 showed that the statistical analysis of the effects of cost type (actual and calculated) and season (2010/11 and 2011/12) for the individual tractor and combine harvester

make. The analysis showed fuel and oil cost per hour per annual. The result in table 4.10 for tractors showed that cost type (actual and calculated) of fuel and oil has highly significant differences (Tables 4.10) and for season 2010/11 fuel cost per hour, 2010/11 of oil cost per hour and 2011/12 of oil cost per hour have a highly significant difference. But for season 2011/12 of fuel cost per hour has no significant difference (Table 4.10).

Table 4. 11. One way ANOVA of cost type and season costs of combine harvester makes

Dependent	Source variance	Sum of Squares	df	Mean Square	F	Sig.
Actual fuel cost per hour	Between Groups	26786.935	2	13393.468	31.272	.000
	Within Groups	2997.992	7	428.285		
	Total	29784.928	9			
Calculated fuel cost per hour	Between Groups	236263.035	2	118131.518	3.068E+33	.000
	Within Groups	.000	7	.000		
	Total	236263.035	9			
Season of 2010/2011 fuel cost per hour	Between Groups	111600.422	2	55800.211	177.678	.000
	Within Groups	2198.364	7	314.052		
	Total	113798.786	9			
Season of 2011/2012 fuel cost per hour	Between Groups	98406.477	2	49203.238	324.235	.000
	Within Groups	1062.262	7	151.752		
	Total	99468.739	9			
Actual oil cost per hour	Between Groups	633.808	2	316.904	.679	.538
	Within Groups	3269.133	7	467.019		
	Total	3902.941	9			
Calculated oil cost per hour	Between Groups	5317.535	2	2658.767	4.419E+33	.000
	Within Groups	.000	7	.000		
	Total	5317.535	9			
Season of 2010/2011 oil cost per hour	Between Groups	255.609	2	127.804	.301	.749
	Within Groups	2969.174	7	424.168		
	Total	3224.782	9			
Season of 2011/2012 oil cost per hour	Between Groups	1303.200	2	651.600	133.974	.000
	Within Groups	34.045	7	4.864		
	Total	1337.246	9			

The result in table 4.11 for combine harvesters showed that cost type (actual and calculated) and season (2010/11 and 2011/12) of fuel cost has highly significant differences (Tables 4.11) and calculated oil cost per hour and season 2011/12 of oil cost per hour have a highly significant difference. But actual oil cost per hour and season 2010/11 of oil cost per hour have no significant difference (Table 4.11).

Table 4. 12. Average Fuel cost per hour from 2010/11-2011/12 season

Machine type	Model type	Average actual cost per hour (Birr/hr)	Average calculated cost per hour (Birr/hr)	Variation (%)
Tractors	JD 6165	204.03	468.45	56.45
	JD 6615	161.66	340.69	52.55
	Agro 150	195.01	425.86	54.21
	Landin	327.99	610.40	46.27
	MF 399	103.82	283.91	63.43
	Total	992.51	2129.30	53.39
Combine harvesters	Tucano	320.02	695.57	53.99
	TC-5060	221.49	482.64	54.11
	TC-55	202.18	340.69	40.65
	Total	743.70	1518.90	51.04

For the same model of tractors, the average actual fuel costs were lower than the average calculated fuel costs by 56.45%, 52.55%, 54.21%, 46.27% and 63.43% for John Deere 6165, John Deere 6615, Deutz-Fahr Agrotron 150, Landini 7-215 and Massy Ferguson 399 respectively(Table 4.12).

Table 4. 13. Average Oil cost per hour from 2010/11-2011/12 season

Machine type	Model type	Average actual cost per hour (Birr/hr)	Average calculated cost per hour (Birr/hr)	Variation (%)
Tractors	JD 6165	18.03	70.27	74.35
	JD 6615	28.66	51.10	43.92
	Agro 150	11.90	63.88	81.37
	Landin	34.77	91.56	62.03
	MF 399	12.23	42.59	71.27
	Total	105.59	319.40	66.94
Combine harvesters	Tucano	6.75	104.34	93.53
	TC-5060	8.65	72.40	88.06
	TC-55	12.52	51.10	75.51
	Total	27.91	227.84	87.75

Also for the same model of tractors, the average actual oil costs were lower than the average calculated oil costs by 74.35%, 43.92%, 81.37%, 62.03% and 71.27% for John Deere 6165, John Deere 6615, Deutz-Fahr Agrotron 150, Landini 7-215 and Massy Ferguson 399 respectively(Table 4.13).

Generally, the calculated fuel costs were greater than the actual fuel costs by 53.39% and the calculated oil costs were greater than the actual oil costs by 66.94% in the two seasons for

tractors. This may be attributed to the bad record of data and poor management followed in the enterprise.

For the same model of combine harvesters, the average actual fuel costs were lower than the average calculated fuel costs by 53.99%, 54.11% and 40.65% for Claas Tucano 320, New Holland TC5060 and New Holland TC55 respectively (Table 4.12). Also for the same model of combine harvesters, the average actual oil costs were lower than the average calculated oil costs by 93.53%, 88.06% and 75.51%, 62.03% and 71.27% for Claas Tucano 320, New Holland TC5060 and New Holland TC55 respectively (Table 4.13).

Generally, the calculated fuel costs were greater than the actual fuel costs by 51.04% and the calculated oil costs were greater than the actual oil costs by 87.75% in the two seasons for combine harvesters. This may be attributed to the bad record of data and poor management followed in the enterprise.

The statistical analysis of the mean costs types with tractors model given in Appendix-A7 & A8 revealed significant differences ($P \leq 0.05$). Accordingly, Landini 7-215 was observed to have the highest average actual and calculated fuel costs (327.99 and 610.40Birr/hr), followed by Deutz-Fahr Agrotron 150 (195.01 and 425.86Birr/hr), John Deere 6615 (161.66 and 340.69 Birr/hr), John Deere 6165 (160.59 and 468.45 Birr/hr), and finally Massy Ferguson 399 (118.22 and 283.91 Birr/hr). Also, Landini 7-215 was observed to have the highest average actual and calculated oil costs (34.77 and 91.56 Birr/hr), followed by John Deere 6165 (32.04 and 70.27 Birr/hr), John Deere 6615 (28.66 and 51.10 Birr/hr), Deutz-Fahr Agrotron 150 (11.90 and 63.88 Birr/hr), and finally Massy Ferguson 399 (7.91 and 42.59 Birr/hr). It was clear from results, that calculated mean cost has affected the power of tractor and the actual mean cost was affected by horse power, working hour and field condition on tractors models fuel and oil costs are highly significant ($P \leq 0.05$). Therefore, Landini 7-215 makes revealed very high fuel and oil cost compared to other tractors makes models Appendix-A7 & A8. This may be due to that they were worked on heavy field operation and have the highest horse power. Massy Ferguson showed the lowest fuel and oil costs, although it was not new. This was attributed to that, they were worked on light field operation and have the lowest horse power. The obtained results amplified by the reviewed Hunt (1979). Within the same model, there were different costs. For the John Deere 6165 tractors, the plate number 5109-03L revealed the highest actual average

fuel costs (269.59 Birr/hr), while plate number 5109-02A showed the highest average actual oil costs (32.04 Birr/hr), but plate number 5109-02A and 5109-03G have the lowest actual average fuel and oil costs (160.59 and 8.94 Birr/hr) respectively. For John Deere 6615, plate numbers 5109-01A and 5109-02G showed the highest average actual fuel and oil costs (202.79 and 41.77 Birr/hr) respectively, while plate number 5109-01T has the lowest average actual fuel and oil costs (60.54 and 22.24 Birr/hr). For Deutz-Fahr Agrotron 150, plate number 5111-01G revealed the highest actual average fuel and oil costs (221.56 and 19.21 Birr/hr), but plate numbers 5111-02A and 5109-05L have the lowest average actual fuel and oil costs (138.14and 5.63 Birr/hr) respectively. For Landini 7-215 tractors the plate number 5112-01G showed the highest actual average fuel and oil costs (352.56 and 38.18 Birr/hr), while plate number 5112-01T revealed the lowest actual average fuel and oil costs (303.41 and 31.35 Birr/hr). For Messay Ferguson 399 tractors the highest actual average fuel and oil costs (136.85 and18.30 Birr/hr) were observed on plate number 5104-04L and 5104-04G respectively, while plate number 5104-01L and 5104-06T showed the lowest actual average fuel and oil costs (75.83 and 7.91 Birr/hr) respectively. Finally, the same model tractors have equal average calculated fuel and oil costs, because of equal horse power of each model.

The statistical analysis of the mean costs types with combine harvester's model given in Appendix- A15 & A16, revealed significant differences ($P \leq 0.05$). Accordingly, Claas Tucano 320 was observed to have the highest average actual and calculated fuel costs (320.02 and 695.57 Birr/hr), followed by New Holland TC5060 (221.49 and 482.64 Birr/hr) and New Holland TC55 (202.80 and 340.69 Birr/hr). Also, New Holland TC55 was observed to have the highest average actual oil costs (23.37 Birr/hr), followed by New Holland TC5060 (8.65 Birr/hr) and Claas Tucano 320 (6.75 Birr/hr), while Claas Tucano 320 was observed to have the highest average calculated oil costs (104.34 Birr/hr), followed by New Holland TC5060 (72.40 Birr/hr) and finally New Holland TC55 (51.10 Birr/hr). It was clear from results, that calculated mean cost was affected by the power of combine harvesters and the actual mean cost was affected by horse power, working hour and working condition on combine harvester's models' fuel and oil costs are highly significant ($P \leq 0.05$). Therefore, Claas Tucano 320 makes revealed very high fuel and oil cost compared to other tractors makes models Appendix- A15 & A16. This may be due to that they were worked overworking hour and have the highest horse power. New Holland TC55 showed the lowest fuel and oil costs, although it was not new. This was attributed that,

they have the lowest horse power. The obtained results amplified by the reviewed Hunt (1979). Within the same model, there were different costs. For the Claas Tucano 320 combine harvesters, plate number 5704-001L and 5704-001G revealed the highest actual average fuel and oil costs (330.97 and 7.48 Birr/hr) respectively, but plate number 5706-001A has the lowest actual average fuel and oil costs (301.00 and 6.18 Birr/hr). For New Holland TC5060, plate numbers 5703-001A showed high average actual fuel and oil costs (249.37 and 9.83 Birr/hr), while plate number 5705-005T has low average actual fuel and oil costs (193.62 and 7.46Birr/hr). For New Holland TC55, plate number 5705-003T and 5703-001A revealed the highest actual average fuel and oil costs (228.16 and 74.06 Birr/hr), but plate numbers 5705-004T has the lowest average actual fuel and oil costs (191.13 and 5.68 Birr/hr) respectively. Finally, the same model combine harvesters have equal average calculated fuel and oil costs, because of equal horse power of each model.

4.6.3. Repair and maintenance cost

Repair and maintenance costs (RMC) are crucial in the cost of owning and operation. Newly purchased farm tractors and combine harvesters start deterioration from the use of machines. Particularly in the study area, the environment was so harsh. Since the operation starts during early spring when the weather is so dry, a lot of dust makes the engine and its associated component to wear. On the farm, frequent failures of machine systems and implement mechanisms had been experienced. Minor lubrication and daily service were required. Failures of the machines and its mechanism during peak season increase cost of downtime and decrease income (hiring service cost) for the machine owners. To minimize the cost of downtime during peak season, effective repair and maintenance activities are necessary.

The actual and calculated repair and maintenance of the different tractor and combine harvester makes and models used in the OSE were evaluated during the seasons 2010/11 and 2011/12 as shown in Tables (4.14), (4.15), (4.16) and appendix A.

Table 4. 14. One way ANOVA of cost type and season costs of tractor makes

Dependent	Source variance	Sum of Squares	df	Mean Square	F	Sig.
Actual RM cost per hour	Between Groups	68984.600	4	17246.150	.802	.540
	Within Groups	365461.686	17	21497.746		
	Total	434446.286	21			
	Between Groups	6377.593	4	1594.398	10.149	.000

Calculated RM cost per hour	Within Groups	2670.807	17	157.106		
	Total	9048.400	21			
Season of 2010/2011 RM cost per hour	Between Groups	17043.255	4	4260.814	.452	.770
	Within Groups	160286.541	17	9428.620		
	Total	177329.795	21			
Season of 2011/2012 RM cost per hour	Between Groups	15645.787	4	3911.447	.751	.571
	Within Groups	88484.826	17	5204.990		
	Total	104130.613	21			

Table 4.14 and 4.15 showed that the statistical analysis of the effects of cost type (actual and calculated) and season (2010/11 and 2011/12) for the individual tractor and combine harvester make. The analysis showed a repair and maintenance cost per hour per annual. The result in table 4.14 for tractors showed that calculated cost type of RM has highly significant differences and for actual cost type, season 2010/11 and 2011/12 of RM per hour have no significant difference.

Table 4. 15. One way ANOVA of cost type and season costs of combine harvester makes

Dependent	Source variance	Sum of Squares	df	Mean Square	F	Sig.
Actual RM cost per hour	Between Groups	73324.479	2	36662.239	2.193	.182
	Within Groups	117037.033	7	16719.576		
	Total	190361.511	9			
Calculated RM cost per hour	Between Groups	34771.572	2	17385.786	212.680	.000
	Within Groups	572.223	7	81.746		
	Total	35343.795	9			
Season of 2010/2011 RM cost per hour	Between Groups	4584.551	2	2292.275	.299	.751
	Within Groups	53664.189	7	7666.313		
	Total	58248.740	9			
Season of 2011/2012 RM cost per hour	Between Groups	3061.476	2	1530.738	.216	.811
	Within Groups	49522.902	7	7074.700		
	Total	52584.378	9			

The result in table 4.15 for combine harvesters showed that calculated RM cost type has highly significant differences and actual cost type, season 2010/11 and season 2011/12 of RM cost per hour have no significant difference (Table 4.15).

Table 4. 16. Average repair and maintenance cost per hour from 2010/11-2011/12 season

Machine type	Model type	Average actual cost per hour (Birr/hr)	Average calculated cost per hour (Birr/hr)	Variation (%)
Tractors	JD 6165	49.52	84.65	41.50
	JD 6615	184.91	54.12	70.73
	Agro 150	119.16	47.06	60.51
	Landin	156.27	58.55	62.53
	MF 399	208.71	32.54	84.41
	Total	718.57	276.91	61.46
Combine harvesters	Tucano	103.35	302.76	65.86
	TC-5060	111.16	264.76	58.02
	TC-55	241.85	191.04	21.01
	Total	456.36	758.56	39.84

For the same model of tractors, the average actual RM costs were lower than the average calculated RM costs by 70.73%, 60.51%, 62.53%, and 84.41% for John Deere 6615, Deutz-Fahr Agrotron 150, Landini 7-215 and Massy Ferguson 399 respectively. The average actual RM costs were lower than the average calculated RM costs by 41.5% for John Deere 6165 (Table 4.16).

Generally, the calculated RM costs were greater than the actual RM costs by 61.46% in the two seasons for tractors. This may be attributed to the bad record of data and poor management followed in the enterprise.

For the same model of combine harvesters, the average actual RM costs were lower than the average calculated RM costs by 65.86%, and 58.02 %, for Claas Tucano 320 and New Holland TC5060 and the average actual RM costs was higher than the average calculated RM costs by 21.01% for New Holland TC55 (Table 4.16).

Generally, the calculated RM costs were greater than the actual RM costs by 39.84% in the two seasons for combine harvesters. This may be attributed to the bad record of data and poor management followed in the enterprise.

The statistical analysis of the mean costs types with tractors model given in Appendix-A7 & A8 revealed significant differences ($P \leq 0.05$). Accordingly, Massy Ferguson 399 was observed to have the highest average actual RM costs (208.71 Birr/hr), followed by John Deere 6615 (184.91 Birr/hr), Landini 7-215 (156.27 Birr/hr), Deutz-Fahr Agrotron 150 (119.16 Birr/hr) and finally, John Deere 6165 (49.52 Birr/hr). The highest calculated average RM cost was observed on John

Deere 6165 (84.65 Birr/hr), followed by Landini 7-215 (58.55 Birr/hr), Deutz-Fahr Agrotron 150 (47.06 Birr/hr) and finally Massy Ferguson 399 (32.54 Birr/hr).

It was clear from results, that calculated mean cost was affected by purchased price, repair factor and accumulated hour of tractors and the actual mean cost were affected by operator skill, maintenance systems, working hour and working condition of tractors models and their RM costs are highly significant ($P \leq 0.05$). Therefore, Massy Ferguson 399 model revealed very high actual RM cost compared to other tractors makes models Appendix-A7 & A8. This may be due to that they were worked beyond their economic life. John Deere 6165 showed the lowest RM costs, although it was at middle age. This may be attributed to the bad record of data and poor management followed in the enterprise. The obtained results amplified by the reviewed Hunt (1979).

Within the same model, there were different costs. For the John Deere 6165 tractors, the plate number 5109-04T revealed the highest actual average RM costs (78.73 Birr/hr), while plate number 5109-03L showed the lowest average actual RM costs (16.86 Birr/hr). For John Deere 6615, plate numbers 5109-01T showed the highest average actual RM costs (646.32 Birr/hr), while plate number 5109-01A has the lowest average actual RM costs (45.19 Birr/hr). For Deutz-Fahr Agrotron 150, plate number 5111-01T revealed the highest actual average RM costs (161.34Birr/hr), but plate numbers 5109-05L have the lowest average actual RM costs (81.10 Birr/hr). For Landini 7-215 tractors the plate number 5112-01T showed high actual average RM costs (175.64 Birr/hr), while plate number 5112-01G revealed low actual average RM costs (136.89 Birr/hr). For Messay Ferguson 399 tractors the highest actual average RM costs (376.07 Birr/hr) were observed on plate number 5104-07T, while plate number 5104-04L showed the lowest actual average RM costs (62.58 Birr/hr).

For John Deere 6165 tractors, the highest calculated mean RM cost (97.13 Birr/hr) was observed on plate number 5109-02A, while plate number 5109-03L revealed low calculated average RM costs (62.14 Birr/hr). For John Deere 6615, plate numbers 5109-01T and 5109-02G showed the highest average calculated RM costs (56.97Birr/hr), while plate number 5109-02T has the lowest average calculated RM costs (46.32 Birr/hr). For Deutz-Fahr Agrotron 150, plate number 5111-01G revealed the highest calculated average RM costs (60.27 Birr/hr), but plate numbers 5111-01T have the lowest average calculated RM costs (31.80 Birr/hr). For Landini 7-215

tractors the plate number 5112-01T showed high calculated average RM costs (60.30 Birr/hr), while plate number 5112-01G revealed low calculated average RM costs (56.79 Birr/hr). For Messay Ferguson 399 tractors the highest calculated average RM costs (51.86 Birr/hr) were observed on plate number 5104-07T, while plate number 5104-04L showed the lowest calculated average RM costs (11.81 Birr/hr).

The statistical analysis of the mean costs types with combine harvester's model given in Appendix-A15 & A16 revealed significant differences ($P \leq 0.05$). Accordingly, New Holland TC55 was observed to have the highest average actual RM costs (277.65 Birr/hr), followed by New Holland TC5060 (111.16 Birr/hr) and Claas Tucano 320 (103.35 Birr/hr). Claas Tucano 320 was observed to have the highest average calculated RM costs (302.76 Birr/hr), followed by New Holland TC5060 (264.76 Birr/hr) and New Holland TC55 (191.04 Birr/hr).

It was clear from results, that calculated mean cost was affected by purchased price, repair factor and accumulated hour of tractors and the actual mean cost were affected by operator skill, maintenance systems, working hour and working condition of tractors models and their RM costs are highly significant ($P \leq 0.05$). Therefore, New Holland TC55 model revealed very high actual RM cost compared to other tractors makes models, but low calculated RM costs as indicated in Appendix-A15 & A16. This may be due to that they were worked beyond economic life. It was a too old machine. Claas Tucano 320 showed the lowest actual RM costs, while high calculated RM cost per hour. The obtained results amplified by the reviewed Hunt (1979).

Within the same model, there were different costs. For the Claas Tucano 320 combine harvesters, plate number 5704-001L revealed the highest actual average RM costs (170.66 Birr/hr) respectively, but plate number 5706-001A has the lowest actual average RM costs (48.85 Birr/hr). For New Holland TC5060, plate numbers 5705-005T showed high average actual RM costs (198.15 Birr/hr), while plate number 5705-005A has low average actual RM costs (24.17 Birr/hr). For New Holland TC55, plate number 5703-001A revealed the highest actual average RM costs (462.51 Birr/hr), but plate numbers 5705-002G has the lowest average actual RM costs (120.44 Birr/hr). The same model combines harvesters have equal average calculated RM costs, except Claas Tucano 320 models, plate number 5706-001A showed the highest calculated RM cost (319.43 Birr/hr), while plate number 5704-001L revealed the lowest calculated RM cost (285.61 Birr/hr).

4.6.4. Total operating cost

Operating costs of farm machinery as costs vary directly with the amount of machine use and include repair and maintenance costs, fuel and lubricants cost, and labour cost. The actual and calculated operating costs of the different tractor and combine harvester makes and models used in the OSE were evaluated during the seasons 2010/11 and 2011/12 as shown in Tables (4.17), (4.18), (4.19) and appendix A.

Table 4. 17. One way ANOVA of cost type and season costs of tractor makes

Dependent	Source variance	Sum of Squares	df	Mean Square	F	Sig.
Actual Operating cost per hour	Between Groups	90897.287	4	22724.322	1.574	.227
	Within Groups	245464.338	17	14439.079		
	Total	336361.624	21			
Calculated Operating cost per hour	Between Groups	315639.796	4	78909.949	502.214	.000
	Within Groups	2671.112	17	157.124		
	Total	318310.908	21			
Season of 2010/11 Operating cost per hour	Between Groups	140891.190	4	35222.797	5.236	.006
	Within Groups	114351.88 2	17	6726.581		
	Total	255243.071	21			
Season of 2011/12 Operating cost per hour	Between Groups	128493.550	4	32123.388	6.747	.002
	Within Groups	80941.321	17	4761.254		
	Total	209434.871	21			

Table 4.17 and 4.18 showed that the statistical analysis of the effects of cost type (actual and calculated) and season (2010/11 and 2011/12) for the individual tractor and combine harvester make. The analysis showed the operating cost per hour per annual. The result in table 4.17 for tractors showed that actual cost type of operating has no significant differences and for calculated cost type, season 2010/11 and 2011/12 of operating per hour have a highly significant difference.

Table 4. 18. One way ANOVA of cost type and season costs of combine harvester makes

Dependent	Source variance	Sum of Squares	df	Mean Square	F	Sig.
Actual Operating cost per hour	Between Groups	39292.589	2	19646.294	1.041	.402
	Within Groups	132108.013	7	18872.573		
	Total	171400.601	9			
Calculated Operating cost per hour	Between Groups	509494.147	2	254747.074	3114.453	.000
	Within Groups	572.566	7	81.795		
	Total	510066.713	9			

Season of 2010/11 Operating cost per hour	Between Groups	85959.599	2	42979.800	3.628	.083
	Within Groups	82926.664	7	11846.666		
	Total	168886.263	9			
Season of 2011/12 operating cost per hour	Between Groups	108641.243	2	54320.622	7.154	.020
	Within Groups	53153.863	7	7593.409		
	Total	161795.106	9			

The result in table 4.18 for combine harvesters showed that calculated operating cost type has highly significant differences and actual cost type and season 2010/11 have no significant difference and season 2011/12 of operating cost per hour has a slightly significant difference (Table 4.18).

Table 4. 19. Average operation cost per hour from 2010/11-2011/12 season

Machine type	Model type	Average actual cost per hour (Birr/hr)	Average calculated cost per hour (Birr/hr)	Variation (%)
Tractors	JD 6165	292.82	648.85	54.87
	JD 6615	396.48	471.40	15.89
	Agro 150	347.30	562.29	38.23
	Landin	540.26	785.99	31.26
	MF 399	346.00	384.52	10.02
	Total	1922.86	2853.05	32.60
Combine harvesters	Tucano	458.04	1136.17	59.69
	TC-5060	369.22	853.30	56.73
	TC-55	484.47	616.34	21.40
	Total	1311.73	2605.81	49.66

For the same model of tractors, the average actual operating costs were lower than the average calculated operating costs by 54.87%, 15.89%, 38.23%, 31.26% and 10.02% for John Deere 6165, John Deere 6615, Deutz-Fahr Agrotron 150, Landini 7-215 and Massy Ferguson 399 respectively (Table 4.19).

For the same model of combine harvesters, the average actual operating costs were lower than the average calculated operating costs by 59.69%, 56.73% and 21.40% for Claas Tucano 320, New Holland TC5060 and New Holland TC55 respectively (Table 4.19).

Multiple Comparisons

Table 4. 20. Comparisons of cost and season type of operating cost per hour of tractors

Dependent Variable	(I) Tractor models	(J) Tractor models	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Actual Operating cost per hour	John Deere 6165	John Deere 6615	-103.66300	80.60760	.216	-273.7302	66.4042
		Agro-track 150	-54.48833	77.56470	.492	-218.1355	109.1589
		Landin	-247.44500*	104.06397	.029	-467.0008	-27.8892
		Messay Ferguson 399	-53.19100	80.60760	.518	-223.2582	116.8762
	John Deere 6615	John Deere 6165	103.66300	80.60760	.216	-66.4042	273.7302
		Agro-track 150	49.17467	72.76214	.508	-104.3400	202.6894
		Landin	-143.78200	100.53534	.171	-355.8930	68.3290
		Messay Ferguson 399	50.47200	75.99758	.516	-109.8689	210.8129
	Agro-track 150	John Deere 6165	54.48833	77.56470	.492	-109.1589	218.1355
		John Deere 6615	-49.17467	72.76214	.508	-202.6894	104.3400
		Landin	-192.95667	98.11245	.066	-399.9558	14.0425
		Messay Ferguson 399	1.29733	72.76214	.986	-152.2174	154.8120
	Landin	John Deere 6165	247.44500*	104.06397	.029	27.8892	467.0008
		John Deere 6615	143.78200	100.53534	.171	-68.3290	355.8930
		Agro-track 150	192.95667	98.11245	.066	-14.0425	399.9558
		Messay Ferguson 399	194.25400	100.53534	.070	-17.8570	406.3650
	Messay Ferguson 399	John Deere 6165	53.19100	80.60760	.518	-116.8762	223.2582
		John Deere 6615	-50.47200	75.99758	.516	-210.8129	109.8689
		Agro-track 150	-1.29733	72.76214	.986	-154.8120	152.2174
		Landin	-194.25400	100.53534	.070	-406.3650	17.8570
Calculated Operating cost per hour	John Deere 6165	John Deere 6615	69.18700*	8.40857	.000	51.4465	86.9275
		Agro-track 150	50.47667*	8.09115	.000	33.4058	67.5475
		Landin	-16.84000	10.85542	.139	-39.7429	6.0629
		Messay Ferguson 399	107.94300*	8.40857	.000	90.2025	125.6835
	John Deere 6615	John Deere 6165	-69.18700*	8.40857	.000	-86.9275	-51.4465
		Agro-track 150	-18.71033*	7.59018	.025	-34.7242	-2.6965
		Landin	-86.02700*	10.48733	.000	-108.1533	-63.9007
		Messay Ferguson 399	38.75600*	7.92768	.000	22.0301	55.4819
	Agro-track 150	John Deere 6165	-50.47667*	8.09115	.000	-67.5475	-33.4058
		John Deere 6615	18.71033*	7.59018	.025	2.6965	34.7242
		Landin	-67.31667*	10.23459	.000	-88.9098	-45.7236
		Messay Ferguson 399	57.46633*	7.59018	.000	41.4525	73.4802
	Landin	John Deere 6165	16.84000	10.85542	.139	-6.0629	39.7429
		John Deere 6615	86.02700*	10.48733	.000	63.9007	108.1533
		Agro-track 150	67.31667*	10.23459	.000	45.7236	88.9098
		Messay Ferguson 399	124.78300*	10.48733	.000	102.6567	146.9093
	Messay Ferguson 399	John Deere 6165	-107.94300*	8.40857	.000	-125.6835	-90.2025
		John Deere 6615	-38.75600*	7.92768	.000	-55.4819	-22.0301
		Agro-track 150	-57.46633*	7.59018	.000	-73.4802	-41.4525

		Landin	-124.78300*	10.48733	.000	-146.9093	-102.6567
Season of 2010/2011 Operating cost per hour	John Deere 6165	John Deere 6615	-16.04950	55.01680	.774	-132.1248	100.0258
		Agro-track 150	34.25583	52.93994	.526	-77.4377	145.9493
		Landin	-117.40750	71.02639	.117	-267.2601	32.4451
		Messay Ferguson 399	50.61450	55.01680	.370	-65.4608	166.6898
	John Deere 6615	John Deere 6165	16.04950	55.01680	.774	-100.0258	132.1248
		Agro-track 150	50.30533	49.66207	.325	-54.4725	155.0831
		Landin	-101.35800	68.61801	.158	-246.1293	43.4133
		Messay Ferguson 399	66.66400	51.87034	.216	-42.7728	176.1008
	Agro-track 150	John Deere 6165	-34.25583	52.93994	.526	-145.9493	77.4377
		John Deere 6615	-50.30533	49.66207	.325	-155.0831	54.4725
		Landin	-151.66333*	66.96432	.037	-292.9457	-10.3810
		Messay Ferguson 399	16.35867	49.66207	.746	-88.4191	121.1365
	Landin	John Deere 6165	117.40750	71.02639	.117	-32.4451	267.2601
		John Deere 6615	101.35800	68.61801	.158	-43.4133	246.1293
		Agro-track 150	151.66333*	66.96432	.037	10.3810	292.9457
		Messay Ferguson 399	168.02200*	68.61801	.025	23.2507	312.7933
	Messay Ferguson 399	John Deere 6165	-50.61450	55.01680	.370	-166.6898	65.4608
		John Deere 6615	-66.66400	51.87034	.216	-176.1008	42.7728
		Agro-track 150	-16.35867	49.66207	.746	-121.1365	88.4191
		Landin	-168.02200*	68.61801	.025	-312.7933	-23.2507
Season of 2011/2012 Operating cost per hour	John Deere 6165	John Deere 6615	-18.42400	46.28680	.696	-116.0806	79.2326
		Agro-track 150	-38.26167	44.53949	.402	-132.2318	55.7084
		Landin	-146.87500*	59.75600	.025	-272.9491	-20.8009
		Messay Ferguson 399	4.14200	46.28680	.930	-93.5146	101.7986
	John Deere 6615	John Deere 6165	18.42400	46.28680	.696	-79.2326	116.0806
		Agro-track 150	-19.83767	41.78175	.641	-107.9894	68.3141
		Landin	-128.45100*	57.72978	.040	-250.2502	-6.6518
		Messay Ferguson 399	22.56600	43.63961	.612	-69.5055	114.6375
	Agro-track 150	John Deere 6165	38.26167	44.53949	.402	-55.7084	132.2318
		John Deere 6615	19.83767	41.78175	.641	-68.3141	107.9894
		Landin	-108.61333	56.33850	.071	-227.4772	10.2505
		Messay Ferguson 399	42.40367	41.78175	.324	-45.7481	130.5554
	Landin	John Deere 6165	146.87500*	59.75600	.025	20.8009	272.9491
		John Deere 6615	128.45100*	57.72978	.040	6.6518	250.2502
		Agro-track 150	108.61333	56.33850	.071	-10.2505	227.4772
		Messay Ferguson 399	151.01700*	57.72978	.018	29.2178	272.8162
	Messay Ferguson 399	John Deere 6165	-4.14200	46.28680	.930	-101.7986	93.5146
		John Deere 6615	-22.56600	43.63961	.612	-114.6375	69.5055
		Agro-track 150	-42.40367	41.78175	.324	-130.5554	45.7481
		Landin	-151.01700*	57.72978	.018	-272.8162	-29.2178

*. The mean difference is significant at the 0.05 level.

The statistical analysis of the mean costs types with tractors model given in Appendix -A7 & A8, revealed significant differences ($P \leq 0.05$). Accordingly, Landini 7-215 was observed to have the highest average actual operating costs (540.26 Birr/hr), followed by John Deere 6615 (396.48 Birr/hr), Deutz-Fahr Agrotron 150 (347.30 Birr/hr), Massy Ferguson 399 (346.00 Birr/hr) and finally, John Deere 6165 (292.82 Birr/hr). The highest calculated average operating cost was observed on Landini 7-215 (785.99 Birr/hr) followed by John Deere 6165 (648.85 Birr/hr), Deutz-Fahr Agrotron 150 (562.29 Birr/hr), John Deere 6615 (471.40 Birr/hr) and finally Massy Ferguson 399 (384.52 Birr/hr).

It was clear from results, that calculated mean cost was affected by purchased price and horse power of tractors and the actual mean cost was affected by operator skill, maintenance systems, working hour and working condition of tractors models and their operating costs are significant ($P \leq 0.05$). Therefore, Landini 7-215 model revealed very high actual operating cost compared to other tractors makes models Appendix-A7 & A8. This may be due to over-utilized. John Deere 6165 showed the lowest actual operating costs, although it was at middle age. This may be attributed to the bad record of data and poor management followed in the enterprise.

Within the same model, there were different costs. For the John Deere 6165 tractors, the plate number 5109-03L revealed the highest actual average operating costs (324.06 Birr/hr), while plate number 5109-02A showed the lowest average actual operating costs (265.74 Birr/hr). For John Deere 6615, plate numbers 5109-01T showed the highest average actual operating costs (750.34 Birr/hr), while plate number 5109-03T showed the lowest average actual operating costs (282.44 Birr/hr). For Deutz-Fahr Agrotron 150, plate number 5111-01T revealed the highest actual average operating costs (415.05 Birr/hr), but plate numbers 5109-05L showed the lowest average actual operating costs (298.94 Birr/hr). For Landini 7-215 tractors the plate number 5112-01G showed high actual average operating costs (548.87 Birr/hr), while plate number 5112-01T revealed low actual average operating costs (531.65 Birr/hr). For Messay Ferguson 399 tractors the highest actual average operating costs (502.12 Birr/hr) were observed on plate number 5104-06T, while plate number 5104-04G showed the lowest actual average operating costs (220.53 Birr/hr). Finally, the same model tractors revealed the calculated operating costs have no significant difference among them.

Multiple Comparisons

Table 4. 21. Comparisons of cost and season type of operating cost per hour of combine harvesters

Dependent Variable	(I) Combine Harvesters	(J) Combine Harvesters	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Actual Operating cost per hour	Tucano	TC-5060	88.82000	125.40791	.502	-207.7226	385.3626
		TC-55	-73.69800	100.32633	.486	-310.9321	163.5361
	TC-5060	Tucano	-88.82000	125.40791	.502	-385.3626	207.7226
		TC-55	-162.51800	114.93825	.200	-434.3038	109.2678
	TC-55	Tucano	73.69800	100.32633	.486	-163.5361	310.9321
		TC-5060	162.51800	114.93825	.200	-109.2678	434.3038
Calculated Operating cost per hour	Tucano	TC-5060	282.87000*	8.25606	.000	263.3475	302.3925
		TC-55	519.83000*	6.60485	.000	504.2120	535.4480
	TC-5060	Tucano	-282.87000*	8.25606	.000	-302.3925	-263.3475
		TC-55	236.96000*	7.56681	.000	219.0673	254.8527
	TC-55	Tucano	-519.83000*	6.60485	.000	-535.4480	-504.2120
		TC-5060	-236.96000*	7.56681	.000	-254.8527	-219.0673
Season of 2010/2011 Operating cost per hour	Tucano	TC-5060	164.63333	99.35906	.141	-70.3135	399.5802
		TC-55	212.05133*	79.48724	.032	24.0939	400.0088
	TC-5060	Tucano	-164.63333	99.35906	.141	-399.5802	70.3135
		TC-55	47.41800	91.06408	.619	-167.9143	262.7503
	TC-55	Tucano	-212.05133*	79.48724	.032	-400.0088	-24.0939
		TC-5060	-47.41800	91.06408	.619	-262.7503	167.9143
Season of 2011/2012 operating cost per hour	Tucano	TC-5060	207.05333*	79.54773	.035	18.9528	395.1538
		TC-55	234.07733*	63.63818	.008	83.5969	384.5577
	TC-5060	Tucano	-207.05333*	79.54773	.035	-395.1538	-18.9528
		TC-55	27.02400	72.90670	.722	-145.3729	199.4209
	TC-55	Tucano	-234.07733*	63.63818	.008	-384.5577	-83.5969
		TC-5060	-27.02400	72.90670	.722	-199.4209	145.3729

*. The mean difference is significant at the 0.05 level.

The statistical analysis of the mean costs types with combine harvester's model given in Appendix-A15 & A16 revealed significant differences ($P \leq 0.05$). Accordingly, New Holland TC55 was observed to have the highest average actual operating costs (531.74 Birr/hr), followed by Claas Tucano 320 (458.04 Birr/hr) and New Holland TC5060 (369.22 Birr/hr) and Claas Tucano 320 was observed to have the highest average calculated operating costs (1136.17 Birr/hr), followed by New Holland TC5060 (853.30 Birr/hr) and New Holland TC55 (616.34 Birr/hr).

It was clear from results, that calculated mean cost was affected by purchased price and horse power of combine harvester's and the actual mean cost was affected by operator skill,

maintenance systems, working hour and working condition of combine harvester's models and their operating costs are significant ($P \leq 0.05$). Therefore, New Holland TC55 model revealed very high actual operating cost compared to other combine harvester's makes models, but low calculated operating costs as indicated in Appendix-A15 & A16. This may be due to that they were worked beyond economic life. It was too old machine. New Holland TC5060 showed the lowest actual operating costs.

Within the same model, there were different costs. For the Claas Tucano 320 combine harvesters, plate number 5704-01L revealed the highest actual average operating costs (536.13 Birr/hr), but plate number 5706-01A has the lowest actual average operating costs (383.95 Birr/hr). For New Holland TC5060, plate numbers 5705-05T showed high average actual operating costs (427.15 Birr/hr), while plate number 5705-005A has low average actual operating costs (311.29 Birr/hr). For New Holland TC55, plate number 5703-01A revealed the highest actual average operating costs (761.19 Birr/hr), but plate numbers 5705-02G has the lowest average actual operating costs (367.83 Birr/hr). Finally, the same model combine harvesters revealed the calculated operating costs have no significant difference among them.

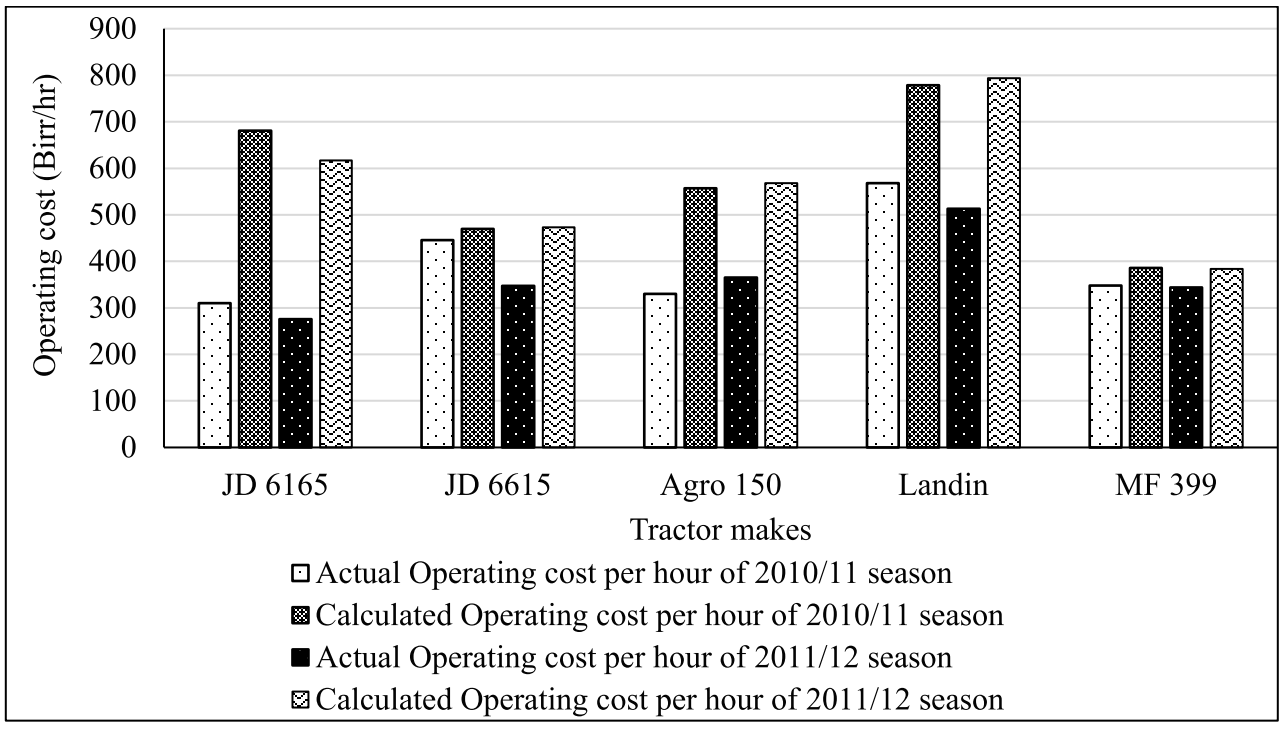


Figure 4. 14. Actual and calculated operating cost per hour of tractor makes

Generally, the calculated operating costs were greater than the actual operating costs by 32.60 % in the two seasons for tractors. This may be attributed to the bad record of data and poor management followed in the enterprise (Fig. 4.14).

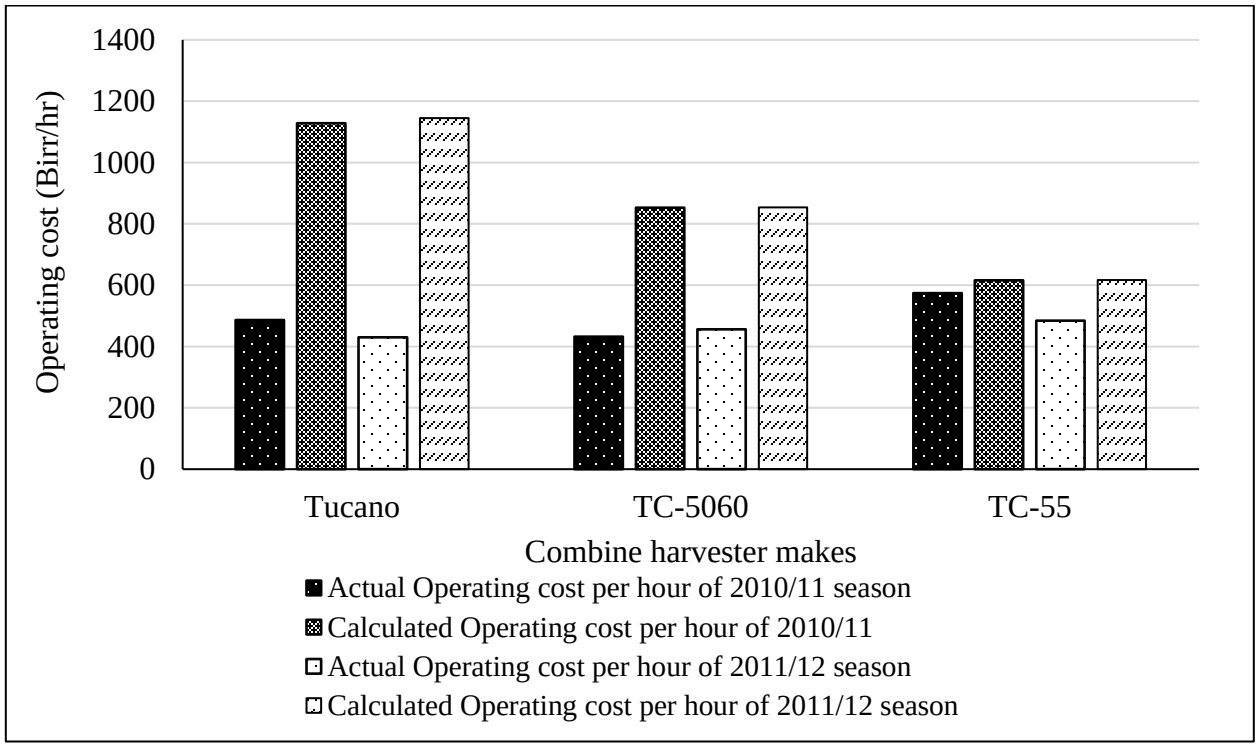


Figure 4.15. Actual and calculated operating cost per hour of combine harvester makes

Generally, the calculated operating costs were greater than the actual operating costs by 49.66 % in the two seasons for combine harvesters. This may be attributed to the bad record of data and poor management followed in the enterprise (Fig.4.15).

4.7. Field work rate

The actual and calculated rates of work for the different field operations performed at the enterprise were evaluated as shown in Table (4.22), (4.23**)** and Appendix-B. The results of each field operation for individual machinery were shown in Appendix-B.

Table 4. 22. One way ANOVA of field operations rates of work

Operation	Source of variance	Sum of Squares	df	Mean Square	F	Sig.
Ploughing	Between Groups	.346	3	.115	.521	.677
	Within Groups	2.438	11	.222		
	Total	2.784	14			

Disking	Between Groups	.997	3	.332	4.763	.023
	Within Groups	.767	11	.070		
	Total	1.764	14			
Sowing	Between Groups	23.307	3	7.769	1.740	.274
	Within Groups	22.323	5	4.465		
	Total	45.630	8			
Fertilizer application	Between Groups	27.123	3	9.041	.685	.583
	Within Groups	118.750	9	13.194		
	Total	145.874	12			
Urea top dressing	Between Groups	24.856	2	12.428	1.886	.458
	Within Groups	6.588	1	6.588		
	Total	31.444	3			
Seed covering	Between Groups	1.593	3	.531	1.654	.253
	Within Groups	2.568	8	.321		
	Total	4.160	11			
Anti-weed chemical spraying	Between Groups	5.191	2	2.595	.218	.816
	Within Groups	35.786	3	11.929		
	Total	40.977	5			
Anti-pest chemical spraying	Between Groups	1.802	2	.901	.134	.879
	Within Groups	26.977	4	6.744		
	Total	28.779	6			
Harvesting	Between Groups	4.121	2	2.060	13.464	.004
	Within Groups	1.071	7	.153		
	Total	5.192	9	2.060		

The statistical analyses of the actual and calculated rates of work for the different machinery rates of work were given in Table (4.22), showed no significant differences between most of the machinery except disking and harvesting operation were have slightly significant different ($P \leq 0.05$).

Table 4. 23. Average Actual and calculated field work rate variation

Field operation	Average actual rates of works	Average calculated rates of works	Variation (%)
Ploughing	0.88	0.89	1.86
Disking	2.36	3.04	22.30
Sowing	11.19	7.70	31.17
Fertilizer application	12.49	7.70	38.36
Urea top dressing	15.96	7.19	54.97
Seed covering	2.66	2.84	6.32
Anti-Weed chemical spraying	10.37	12.29	15.61
Anti-Pest chemical Spraying	9.79	12.29	20.29

Harvesting	1.80	1.57	12.61
Total	67.50	55.50	17.77

Table (4.23) showed the actual and calculated rates of work for the different implement, which were differ, despite that the calculated rates of work used the actual implement widths. Generally, the actual rates of work were greater than the calculated ones by 17.77%, while the highest variation could be observed on Urea top dressing (54.97%), the lowest variation was observed on ploughing field operation (1.86%). It can be observed that the highest rate of work (ha/hr) was for the Urea top dressing (15.96 and 7.19 ha/hr), followed by Fertilizer application (12.49 and 7.70 ha/hr), Sowing (11.19 and 7.70 ha/hr), Anti-Weed chemical spraying (10.37 and 12.29 ha/hr), Anti-Pest chemical Spraying (9.79 and 12.29 ha/hr), Seed covering (2.66 and 2.84 ha/hr), Disking (2.36 and 3.04 ha/hr), Harvesting (1.80 and 1.57 ha/hr), and finally Ploughing (0.88 and 0.89 ha/hr). Power is a determinant factor, so any operation required a suitable power and implement, considering soil conditions. Thus, the rate of work for any operation mainly affected by speed, draft and implement operating width. So either the operation permits usage of high speed, draft and width resulting in a high rate of work, e.g. chemical spraying, or permits usage of the low speed, draft and width resulting in a low rate of work, for example ploughing (Fig. 4.16).

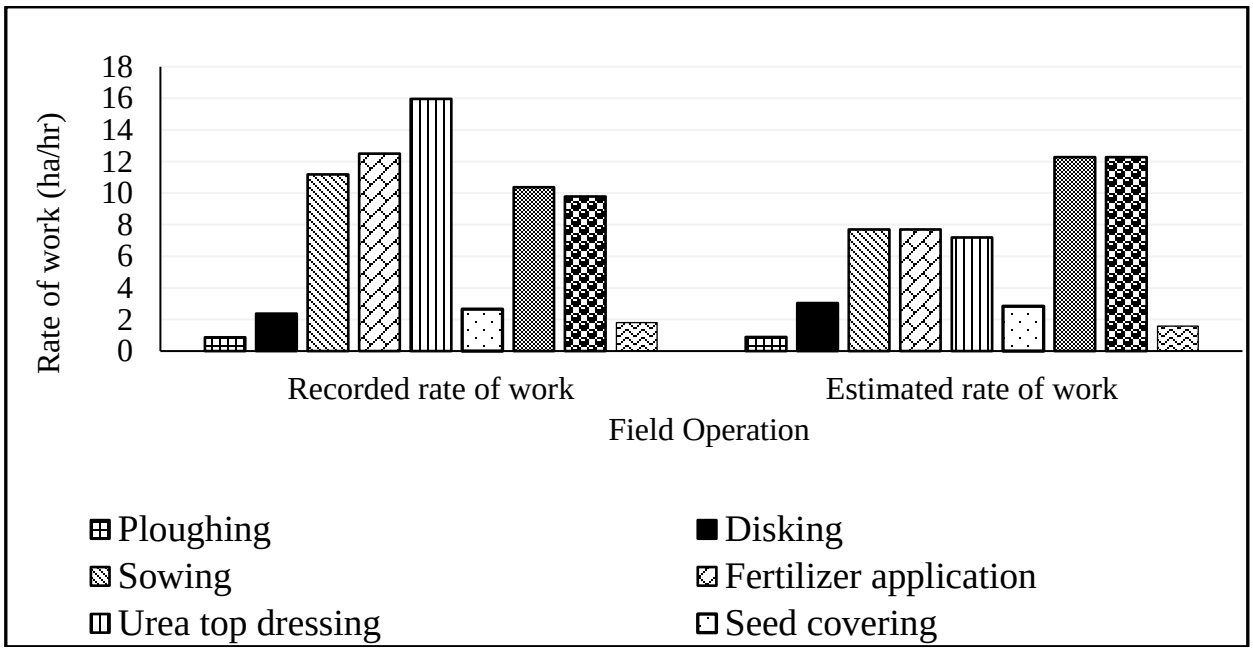


Figure 4.16. Actual and calculated machinery rates of work

4.8.Power requirements

The power required for the field operations at Oromia Seed Enterprise were evaluated as actual and calculated power requirement during the 2010/11 and 2011/12 seasons as shown in Tables (4.24) and (4.25).

Table 4. 24. Actual and calculated power requirement for field operations.

Field operation	Implement	Width (m)	Speed (km/hr)	Draft (KN/m)	PTO power req*	20% PTO power	Calculated power req*
Ploughing	Disc plough	1.50	7.00	17.51	120	24	144
	MB plough	1.00	7.00	17.20	82	16	98
	Disc plough	1.00	7.00	17.51	82	16	98
	RMB plough	2.50	7.00	17.20	201	40	241
Harrowing	Disc harrow	4.00	10.00	7.66	204	41	245
	Disc harrow	3.60	10.00	7.66	184	37	221
	Disc harrow	3.60	10.00	7.66	184	37	221
	Disc harrow	4.00	10.00	7.66	204	41	245

Note: req*- indicates power requirements

Table 4. 25. Actual and calculated power requirement variation

Field operation	Implement	Tractor models	Actual power		Calculated power requirement		Variation (%)
			KW	HP	KW	HP	
Ploughing	Disc plough	JD 6165	124	165	108	144	+12
	MB plough	JD 6615	90	120	74	98	+18
	Disc plough	Agro-track 150	113	150	74	98	+35
	RMB plough	Landini 7-215	161	215	181	241	-11
	Average		122	162.5	109.25	145.25	+11
Harrowing	Disc harrow	JD 6165	124	165	184	245	-33
	Disc harrow	JD 6615	90	120	165	221	-46
	Disc harrow	Agro-track 150	113	150	165	221	-32
	Disc harrow	Landini 7-215	161	215	184	245	-12
	Average		122	162.5	174.5	233	-30
Total			976	1300	1135	1513	+14

Tables (4.24) and (4.25) show the actual and calculated power required for the different field operations. They were varied widely due to variations in field operation speed, draft and operating implement width. It was observed that the actual power requirement was based on enterprise records, while the calculated power requirement was based on mathematical methods. The results showed that the highest actual and calculated horse power was for harrowing with disc harrow-4m (215 and 245 hp), followed by ploughing with reverse mouldboard-2.5m (215

and 241 hp), harrowing with disc harrow-4m (165 and 245 hp), ploughing with disc plough-1.5m (165 and 144 hp), harrowing with disc harrow-3.6m (120&150 and 221 hp), ploughing with disc plough-1m (150 and 98 hp), and finally ploughing with moldboard plough (120 and 98 hp). The high power required by some implements may be due to high implement size and speed as in harrowing or maybe due to high implement draft as in ploughing.

The actual and calculated power variations for the different field operations were given in Table (4.25). The results revealed that the actual power used in the scheme either higher or lesser than what calculated. Generally, for the total power required, the enterprise used more than the power required in some field operations by about 14%. It was also observed that the actual power exceeded the calculated power in ploughing by 11%. While the actual power was less than the calculated in harrowing by 30%. These results revealed that the more power used, may cause over-head costs which adversely affect the profit purposes of the field operations. While less than what required power may cause overload or operation failure.

The economic performance of the enterprise to be maximized, matching of the tractor and implement size with suitable field operation is of great importance. To raise the speed to an extent that permits a good operation quality without engine overloading is also important.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

An investigation into the present status of farm machinery at Oromia Seed Enterprise revealed that their status needs attention especially on handling system rather than parking and throwing here and there in the enterprise. Another need attention was maintenance management system which focused on preventive maintenance rather than corrective maintenance in the maintenance and service department. In OSE most of the machinery has been subjected to repeated maintenance and repair. The following were the key research findings of this study:

In the case studies, there was no clear, well defined and documented departmental maintenance policy. There was some indication on the plan of action on machinery maintenance but it was outward that the plan of action was not documented and well defined in form of a policy document. The predominant maintenance strategy for machinery was corrective maintenance which based on emergency and priority with very limited preventive maintenance, where there was a maintenance plan, this was hardly observed to in the year for which it's intended. This has resulted in a backlog of maintenance works. From results indicated farm machinery cost management was poor. The enterprise dealt with improper methods for cost items determinations, especially for the more important items like depreciation and repair and maintenance. The actual cost records when applied, depreciation was observed to be the highest fixed cost items for new machinery, while fuel and lubricants were the highest variable cost items. By the way, the actual field operations costs have been inaccurately based, so the field operations scheduling and other management policies may also incorrectly considered. In line with this, clear data for implement was not available. The actual records for field operations rates of work were based only in field experiences. So, the actual implement records for speed not considered in the actual rates of work determination. Therefore, inaccurate machines capacities were a result.

5.2. Recommendations

In parallel to the implementation of improved maintenance management, old machinery should be sold and replaced gradually. The replacement plan should take in to account the following points:

- The useful life of the machinery

- The purchased year of the machinery
- Current performance of the machinery
- Frequency of break down and
- Repair and maintenance cost and availability of spare in the market.

Maintenance management requires selection of a course of action which will minimize the frequency of machinery emergency break down. Therefore, OSE should implement:

- Frequent inspection, cleanup, and lubrication.
- Replacing fast moving parts at a fixed time before failure.
- Replacing parts depending on the condition before failure.
- Replacing after failure as soon as possible.

Oromia Seed Enterprise must establish real machinery management systems through the following aspects:

- Efficient recording system for the individual machinery data, and efficient cost analysis methods are required.
- Proper maintenance should be carried out at the right time saves the enterprise from the cost of replacement parts and repair, and reduces the incidence of unexpected breakdowns and downtimes
- The systems of farm machinery repair and maintenance, as well as training programs for mechanics and operators required to be evaluated.
- Re-arrangement and compartment of the related field machinery administrations.
- Further investigation on-farm power and machinery systems selection and replacement are required.

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APPENDIX

Appendix A. Cost analysis

Appendix A1. Actual and calculated depreciation and remaining values of tractors

Age of tractors	Actual cost (birr)		Calculated cost (birr)			Type of tractors
	Depreciation cost(birr)-SLM	Remaining Value (birr)-SLM	Double DBM (birr)-Rn	Double DBM (birr)Rn+1	Depreciation cost(birr)-DBM	
0	-	198759	198759	182858	-	Massey Ferguson 399
1	39751.8	159007.2	182858	168230	15901	
2	39751.8	119255.4	168230	154771	14629	
3	39751.8	79503.6	154771	142390	13458	
4	39751.8	39751.8	142390	130998	12382	
5	39751.8	10	130998	120519	11391	
6	-	10	120519	110877	10480	
7	-	10	110877	102007	9641	
8	-	10	102007	93846	8870	
9	-	10	93846	86339	8161	
10	-	10	86339	79432	7508	
11	-	10	79432	73077	6907	
12	-	10	73077	67231	6355	
13	-	10	67231	61852	5846	
14	-	10	61852	56904	5378	
15	-	10	56904	52352	4948	
16	-	10	52352	48164	4552	
17	-	10	48164	44311	4188	
18	-	10	44311	40766	3853	
19	-	10	40766	37504	3545	
20	-	10	37504	34504	3261	
21	-	10	34504	31744	3000	
22	-	10	31744	29204	2760	
23	-	10	29204	26868	2540	
24	-	10	26868	24719	2336	
0	-	2732680.9	2732681	2514067	-	Landin
1	546536.18	2186145	2514067	2312941	218614	
2	546536.18	1639609	2312941	2127906	201125	
3	546536.18	1093072	2127906	1957673	185035	
0	-	1449732.2	1449732	1333753	-	Agro-track 150
1	289946	1159786	1333753	1227053	115979	
2	289946	869839	1227053	1128889	106700	
3	289946	579893	1128889	1038578	98164	
4	289946	289946	1038578	955492	90311	
0	-	791284.5	791285	727982	-	John Deere 6615
1	158256.9	633028	727982	669743	63303	
2	158256.9	474771	669743	616164	58239	

3	158256.9	316514	616164	566871	53579	
4	158256.9	158257	566871	521521	49293	
5	158256.9	10	521521	479799	45350	
6	-	10	479799	441415	41722	
7	-	10	441415	406102	38384	
8	-	10	406102	373614	35313	
9	-	10	373614	343725	32488	
0	-	2519421.9	2519422	2317868	-	John Deere 6165
1	503884.38	2015537.52	2317868	2132439	201554	
2	503884.38	1511653.14	2132439	1961844	185429	
3	503884.38	1007768.76	1961844	1804896	170595	
4	503884.38	503884.38	1804896	1660504	156947	
5	503884.38	10	1660504	1527664	144392	
6	503884.38	10	1527664	1405451	132840	

Appendix A2. Actual and calculated of depreciation and remaining values of combine harvesters

Age of CH	Actual cost (birr)		Calculated cost (birr)			Combine harvester makes/ models
	Depreciation cost(birr)-SLM	Remaining Value (birr)-SLM	Double DBM (birr)-Rn	Double DBM (birr)-Rn+1	Depreciation cost(birr)-DBM	
0	-	713194	713194	656138	57056	New Holland TC-55
1	142638.8	570555.2	656138	603647	52491	
2	142638.8	427916.4	603647	555356	48292	
3	142638.8	285277.6	555356	510927	44428	
4	142638.8	142638.8	510927	470053	40874	
5	142638.8	10	470053	432449	37604	
6	-	10	432449	397853	34596	
7	-	10	397853	366025	31828	
8	-	10	366025	336743	29282	
9	-	10	336743	309803	26939	
10	-	10	309803	285019	24784	
11	-	10	285019	262217	22802	
12	-	10	262217	241240	20977	
13	-	10	241240	221941	19299	
14	-	10	221941	204186	17755	
15	-	10	204186	187851	16335	
16	-	10	187851	172823	15028	
17	-	10	172823	158997	13826	
18	-	10	158997	146277	12720	
19	-	10	146277	134575	11702	
0	0	3633688	3633688	3342993	290695	Claas Tucano 320
1	726737.628	2906951	3342993	3075554	267439	
2	726737.6	2180213	3075554	2829509	246044	
3	726737.6	1453475	2829509	2603149	226361	
0	0	988395.9	988396	909324	79072	New Holland TC50
1	197679.18	790716.72	909324	836578	72746	

2	197679.18	593037.54	836578	769652	66926
3	197679.18	395358.36	769652	708080	61572
4	197679.18	197679.18	708080	651433	56646
5	197679.18	10	651433	599319	52115
6	-	10	599319	551373	47946
7	-	10	551373	507263	44110
8	-	10	507263	466682	40581
9	-	10	466682	429348	37335

Appendix A3. Actual total operating cost per hour of 2010/11 season of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere 6165	5109-02A	210.65	28.86	31.06	21.24	291.81
	5109-03G	213.09	11.55	33.21	21.24	279.08
	5109-03L	296.55	26.12	4.24	21.24	348.15
	5109-04T	175.32	5.05	120.31	21.24	321.93
	Average	223.90	17.90	47.21	21.24	310.24
John Deere 6615	5109-01A	188.47	18.93	37.52	21.24	266.16
	5109-01T	60.54	22.24	896.03	21.24	1000.05
	5109-02G	203.57	36.11	83.78	21.24	344.69
	5109-02T	169.44	26.94	124.54	21.24	342.16
	5109-03T	147.52	19.86	85.41	21.24	274.04
	Average	153.91	24.82	245.46	21.24	445.42
Deutz-Fahr Agrotron 150	5109-04L	196.01	6.57	81.42	21.24	305.24
	5109-05L	178.05	6.54	78.96	21.24	284.78
	5111-01A	160.02	7.94	122.77	21.24	311.97
	5111-01G	209.77	17.82	72.44	21.24	321.27
	5111-01T	184.75	12.58	249.85	21.24	468.43
	5111-02A	110.46	10.59	144.39	21.24	286.68
	Average	173.18	10.34	124.97	21.24	329.73
Landini 7-215	5112-01G	411.12	39.03	137.07	21.24	608.47
	5112-01T	430.60	5.69	69.58	21.24	527.11
	Average	420.86	22.36	103.33	21.24	567.79
Messay Ferguson 399	5104-01L	90.39	19.25	295.29	21.24	426.18
	5104-04G	135.12	29.22	73.71	21.24	259.29
	5104-04L	151.91	22.78	81.45	21.24	277.38
	5104-06T	101.03	4.11	295.35	21.24	421.74
	5104-07T	53.68	6.65	274.86	21.24	356.43
	Average	106.43	16.41	204.13	21.24	348.20

Appendix A4. Calculated total operating cost per hour of 2010/2011 season of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere 6165	5109-02A	467.76	70.16	121.59	25.49	685.00
	5109-03G	467.76	70.16	116.15	25.49	679.56
	5109-03L	467.76	70.16	94.80	25.49	658.21
	5109-04T	467.76	70.16	137.29	25.49	700.69
	Average	467.76	70.16	117.46	25.49	680.87
John Deere 6615	5109-01A	340.19	51.03	53.58	25.49	470.29
	5109-01T	340.19	51.03	56.97	25.49	473.67
	5109-02G	340.19	51.03	56.97	25.49	473.67
	5109-02T	340.19	51.03	44.22	25.49	460.92
	5109-03T	340.19	51.03	53.14	25.49	469.84
	Average	340.19	51.03	52.98	25.49	469.68
Deutz-Fahr Agrotron 150	5109-04L	425.23	63.78	44.71	25.49	559.22
	5109-05L	425.23	63.78	44.34	25.49	558.85
	5111-01A	425.23	63.78	44.44	25.49	558.95
	5111-01G	425.23	63.78	55.14	25.49	569.64
	5111-01T	425.23	63.78	30.18	25.49	544.68
	5111-02A	425.23	63.78	35.17	25.49	549.68
	Average	425.23	63.78	42.33	25.49	556.84
Landini 7-215	5112-01G	609.50	91.43	48.64	25.49	775.05
	5112-01T	609.50	91.43	55.05	25.49	781.47
	Average	609.50	91.43	51.84	25.49	778.26
Messay Ferguson 399	5104-01L	283.49	42.52	60.29	25.49	411.79
	5104-04G	283.49	42.52	18.48	25.49	369.98
	5104-04L	283.49	42.52	16.63	25.49	368.13
	5104-06T	283.49	42.52	38.69	25.49	390.19
	5104-07T	283.49	42.52	36.01	25.49	387.51
	Average	283.49	42.52	34.02	25.49	385.52

Appendix A5. Actual total operating cost per hour of 2011/12 season of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere 6165	5109-02A	110.54	35.21	72.68	21.24	239.67
	5109-03G	214.82	6.34	68.07	21.24	310.46
	5109-03L	242.63	6.62	29.48	21.24	299.97
	5109-04T	168.62	24.46	37.14	21.24	251.46
	Average	184.15	18.16	51.84	21.24	275.39
John Deere 6615	5109-01A	217.11	31.37	52.85	21.24	322.57
	5109-01T	60.54	22.24	396.61	21.24	500.63
	5109-02G	174.78	47.44	47.66	21.24	291.11
	5109-02T	203.98	34.30	72.99	21.24	332.51
	5109-03T	190.69	27.18	51.73	21.24	290.84

	Average	169.42	32.51	124.37	21.24	347.53
Deutz-Fahr	5109-04L	199.76	7.77	110.17	21.24	338.94
Agrotron 150	5109-05L	203.90	4.72	83.24	21.24	313.10
	5111-01A	247.64	18.91	151.43	21.24	439.22
	5111-01G	233.36	20.59	139.47	21.24	414.66
	5111-01T	250.55	17.06	72.83	21.24	361.68
	5111-02A	165.83	11.71	122.90	21.24	321.67
	Average	216.84	13.46	113.34	21.24	364.88
Landini 7-215	5112-01G	294.00	37.33	136.71	21.24	489.28
	5112-01T	176.22	57.02	281.70	21.24	536.18
	Average	235.11	47.18	209.20	21.24	512.73
Messay	5104-01L	61.27	4.76	64.81	21.24	152.09
Ferguson 399	5104-04G	86.65	7.38	66.50	21.24	181.77
	5104-04L	121.79	5.53	43.72	21.24	192.28
	5104-06T	135.40	11.70	414.15	21.24	582.50
	5104-07T	100.95	10.94	477.28	21.24	610.41
	Average	101.21	8.06	213.29	21.24	343.81

Appendix A6. Calculated total operating cost per hour of 2011/2012 season of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere	5109-02A	469.14	70.37	72.68	25.49	637.67
6165	5109-03G	469.14	70.37	68.07	25.49	633.06
	5109-03L	469.14	70.37	29.48	25.49	594.48
	5109-04T	469.14	70.37	37.14	25.49	602.14
	Average	469.14	70.37	51.84	25.49	616.84
John Deere	5109-01A	341.19	51.18	56.97	25.49	474.83
6615	5109-01T	341.19	51.18	56.97	25.49	474.83
	5109-02G	341.19	51.18	56.97	25.49	474.83
	5109-02T	341.19	51.18	48.42	25.49	466.27
	5109-03T	341.19	51.18	56.96	25.49	474.82
	Average	341.19	51.18	55.26	25.49	473.12
Deutz-Fahr	5109-04L	426.49	63.97	55.73	25.49	571.68
Agrotron 150	5109-05L	426.49	63.97	56.96	25.49	572.90
	5111-01A	426.49	63.97	53.66	25.49	569.61
	5111-01G	426.49	63.97	65.41	25.49	581.36
	5111-01T	426.49	63.97	33.42	25.49	549.37
	5111-02A	426.49	63.97	45.56	25.49	561.50
	Average	426.49	63.97	51.79	25.49	567.74
Landini 7-215	5112-01G	611.30	91.69	64.95	25.49	793.43
	5112-01T	611.30	91.69	65.55	25.49	794.03
	Average	611.30	91.69	65.25	25.49	793.73
Messay	5104-01L	284.33	42.65	10.36	25.49	362.82
Ferguson 399	5104-04G	284.33	42.65	11.47	25.49	363.93
	5104-04L	284.33	42.65	6.99	25.49	359.45

	5104-06T	284.33	42.65	58.76	25.49	411.22
	5104-07T	284.33	42.65	67.72	25.49	420.18
	Average	284.33	42.65	31.06	25.49	383.52

Appendix A7. The actual mean of total operating cost per hour of two seasons of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere 6165	5109-02A	160.59	32.04	51.87	21.24	265.74
	5109-03G	213.95	8.94	50.64	21.24	294.77
	5109-03L	269.59	16.37	16.86	21.24	324.06
	5109-04T	171.97	14.76	78.73	21.24	286.69
	Average	204.03	18.03	49.52	21.24	292.82
John Deere 6615	5109-01A	202.79	25.15	45.19	21.24	294.37
	5109-01T	60.54	22.24	646.32	21.24	750.34
	5109-02G	189.18	41.77	65.72	21.24	317.90
	5109-02T	186.71	30.62	98.77	21.24	337.34
	5109-03T	169.11	23.52	68.57	21.24	282.44
	Average	161.66	28.66	184.91	21.24	396.48
Deutz-Fahr Agrotron 150	5109-04L	197.89	7.17	95.79	21.24	322.09
	5109-05L	190.98	5.63	81.10	21.24	298.94
	5111-01A	203.83	13.42	137.10	21.24	375.59
	5111-01G	221.56	19.21	105.96	21.24	367.97
	5111-01T	217.65	14.82	161.34	21.24	415.05
	5111-02A	138.14	11.15	133.64	21.24	304.18
	Average	195.01	11.90	119.16	21.24	347.30
Landini 7-215	5112-01G	352.56	38.18	136.89	21.24	548.87
	5112-01T	303.41	31.35	175.64	21.24	531.65
	Average	327.99	34.77	156.27	21.24	540.26
Messay Ferguson 399	5104-01L	75.83	12.01	180.05	21.24	289.13
	5104-04G	110.88	18.30	70.11	21.24	220.53
	5104-04L	136.85	14.16	62.58	21.24	234.83
	5104-06T	118.22	7.91	354.75	21.24	502.12
	5104-07T	77.31	8.80	376.07	21.24	483.42
	Average	103.82	12.23	208.71	21.24	346.00

Appendix A8. Calculated mean of total operating cost per hour of two seasons of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere 6165	5109-02A	468.45	70.27	97.13	25.49	661.33
	5109-03G	468.45	70.27	92.11	25.49	656.31
	5109-03L	468.45	70.27	62.14	25.49	626.34
	5109-04T	468.45	70.27	87.21	25.49	651.41
	Average	468.45	70.27	84.65	25.49	648.85
John Deere 6615	5109-01A	340.69	51.10	55.28	25.49	472.56
	5109-01T	340.69	51.10	56.97	25.49	474.25
	5109-02G	340.69	51.10	56.97	25.49	474.25
	5109-02T	340.69	51.10	46.32	25.49	463.60
	5109-03T	340.69	51.10	55.05	25.49	472.33
	Average	340.69	51.10	54.12	25.49	471.40
Deutz-Fahr Agrotron 150	5109-04L	425.86	63.88	50.22	25.49	565.45
	5109-05L	425.86	63.88	50.65	25.49	565.88
	5111-01A	425.86	63.88	49.05	25.49	564.28
	5111-01G	425.86	63.88	60.27	25.49	575.50
	5111-01T	425.86	63.88	31.80	25.49	547.02
	5111-02A	425.86	63.88	40.36	25.49	555.59
	Average	425.86	63.88	47.06	25.49	562.29
Landini 7-215	5112-01G	610.40	91.56	56.79	25.49	784.24
	5112-01T	610.40	91.56	60.30	25.49	787.75
	Average	610.40	91.56	58.55	25.49	785.99
Messay Ferguson 399	5104-01L	283.91	42.59	35.33	25.49	387.31
	5104-04G	283.91	42.59	14.97	25.49	366.95
	5104-04L	283.91	42.59	11.81	25.49	363.79
	5104-06T	283.91	42.59	48.73	25.49	400.71
	5104-07T	283.91	42.59	51.86	25.49	403.84
	Average	283.91	42.59	32.54	25.49	384.52

Appendix A9. Total operating cost per hour of 2010/2011 season of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere 6165	5109-02A	339.20	49.51	76.32	23.36	488.40
	5109-03G	340.42	40.86	74.68	23.36	479.32
	5109-03L	382.15	48.14	49.52	23.36	503.18
	5109-04T	321.54	37.61	128.80	23.36	511.31
	Average	345.83	44.03	82.33	23.36	495.55
John Deere 6615	5109-01A	264.33	34.98	45.55	23.36	368.22
	5109-01T	200.36	36.64	476.50	23.36	736.86
	5109-02G	271.88	43.57	70.37	23.36	409.18
	5109-02T	254.81	38.98	84.38	23.36	401.54
	5109-03T	243.85	35.45	69.27	23.36	371.94

	Average	247.05	37.92	149.22	23.36	457.55
Deutz-Fahr Agrotron 150	5109-04L	310.62	35.18	63.07	23.36	432.23
	5109-05L	301.64	35.16	61.65	23.36	421.81
	5111-01A	292.63	35.86	83.61	23.36	435.46
	5111-01G	317.50	40.80	63.79	23.36	445.46
	5111-01T	304.99	38.18	140.02	23.36	506.55
	5111-02A	267.85	37.19	89.78	23.36	418.18
	Average	299.21	37.06	83.65	23.36	443.28
Landini 7-215	5112-01G	510.31	65.23	92.85	23.36	691.76
	5112-01T	520.05	48.56	62.32	23.36	654.29
	Average	515.18	56.89	77.59	23.36	673.02
Messay Ferguson 399	5104-01L	186.94	30.89	177.79	23.36	418.99
	5104-04G	209.30	35.87	46.09	23.36	314.63
	5104-04L	217.70	32.65	49.04	23.36	322.75
	5104-06T	192.26	23.32	167.02	23.36	405.97
	5104-07T	168.58	24.59	155.43	23.36	371.97
	Average	194.96	29.46	119.08	23.36	366.86

Appendix A10. Total operating cost per hour of 2011/2012 season of tractors

Tractor type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
John Deere 6165	5109-02A	289.84	52.79	72.68	23.36	438.67
	5109-03G	341.98	38.35	68.07	23.36	471.76
	5109-03L	355.89	38.49	29.48	23.36	447.22
	5109-04T	318.88	47.42	37.14	23.36	426.80
	Average	326.64	44.26	51.84	23.36	446.11
John Deere 6615	5109-01A	279.15	41.27	54.91	23.36	398.70
	5109-01T	200.86	36.71	226.79	23.36	487.73
	5109-02G	257.99	49.31	52.31	23.36	382.97
	5109-02T	272.59	42.74	60.70	23.36	399.39
	5109-03T	265.94	39.18	54.34	23.36	382.83
	Average	255.31	41.84	89.81	23.36	410.32
Deutz-Fahr Agrotron 150	5109-04L	313.12	35.87	82.95	23.36	455.31
	5109-05L	315.19	34.35	70.10	23.36	443.00
	5111-01A	337.06	41.44	102.55	23.36	504.41
	5111-01G	329.92	42.28	102.44	23.36	498.01
	5111-01T	338.52	40.52	53.12	23.36	455.52
	5111-02A	296.16	37.84	84.23	23.36	441.59
	Average	321.66	38.72	82.56	23.36	466.31
Landini 7-215	5112-01G	452.65	64.51	100.83	23.36	641.35
	5112-01T	393.76	74.36	173.63	23.36	665.11
	Average	423.20	69.44	137.23	23.36	653.23
Messay Ferguson 399	5104-01L	172.80	23.71	37.59	23.36	257.45
	5104-04G	185.49	25.01	38.99	23.36	272.85
	5104-04L	203.06	24.09	25.35	23.36	275.86

	5104-06T	209.86	27.18	236.46	23.36	496.86
	5104-07T	192.64	26.79	272.50	23.36	515.30
	Average	192.77	25.36	122.18	23.36	363.66

Appendix A11. Actual total operating cost per hour of 2010/11 season of combine harvesters

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	346.79	1.06	63.60	27.92	439.37
	5704-001L	331.53	9.37	183.37	27.92	552.19
	5704-001G	347.14	10.30	81.24	27.92	466.60
	Average	341.82	6.91	109.40	27.92	486.05
New Holland TC5060	5703-001A	305.31	14.82	37.88	27.92	385.93
	5705-005T	215.82	13.04	221.65	27.92	478.42
	Average	260.56	13.93	129.76	27.92	432.18
New Holland TC55	5703-001A	218.64	136.55	677.60	27.92	1060.70
	5705-002G	193.64	17.66	119.07	27.92	358.29
	5705-003T	262.98	19.95	275.58	27.92	586.43
	5705-004L	177.56	13.65	220.39	27.92	439.52
	5705-004T	188.96	9.88	198.58	27.92	425.35
	Average	208.36	39.54	298.24	27.92	574.06

Appendix A12. Calculated total operating cost per hour of 2010/11 season of combine harvesters

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	694.55	104.18	348.86	33.50	1181.10
	5704-001L	694.55	104.18	268.83	33.50	1101.06
	5704-001G	694.55	104.18	269.24	33.50	1101.47
	Average	694.55	104.18	295.64	33.50	1127.88
New Holland TC5060	5703-001A	481.93	72.29	264.76	33.50	852.49
	5705-005T	481.93	72.29	264.76	33.50	852.49
	Average	481.93	72.29	264.76	33.50	852.49
New Holland TC55	5703-001A	340.19	51.03	191.04	33.50	615.76
	5705-002G	340.19	51.03	191.04	33.50	615.76
	5705-003T	340.19	51.03	191.04	33.50	615.76
	5705-004L	340.19	51.03	191.04	33.50	615.76
	5705-004T	340.19	51.03	191.04	33.50	615.76
	Average	340.19	51.03	191.04	33.50	615.76

Appendix A13. Actual total operating cost per hour of 2011/12 season of combine harvesters

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	255.22	11.30	34.10	27.92	328.54
	5704-001L	330.42	3.79	157.95	27.92	520.07
	5704-001G	309.03	4.65	99.87	27.92	441.47
	Average	298.22	6.58	97.30	27.92	430.03
New Holland TC5060	5703-001A	193.42	4.85	10.45	27.92	236.64
	5705-005T	171.43	1.88	174.64	27.92	375.88
	Average	182.43	3.36	92.55	27.92	306.26
New Holland TC55	5703-001A	174.76	11.57	247.42	27.92	461.67
	5705-002G	214.50	13.13	121.81	27.92	377.36
	5705-003T	193.34	5.48	142.24	27.92	368.98
	5705-004L	210.27	4.39	620.04	27.92	862.62
	5705-004T	193.29	1.48	153.77	27.92	376.45
	Average	197.23	7.21	257.06	27.92	489.42

Appendix A14. Calculated total operating cost per hour of 2011/12 season of combine harvesters

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	696.60	104.49	290.01	33.50	1124.60
	5704-001L	696.60	104.49	302.39	33.50	1136.98
	5704-001G	696.60	104.49	337.21	33.50	1171.80
	Average	696.60	104.49	309.87	33.50	1144.46
New Holland TC5060	5703-001A	483.35	72.50	264.76	33.50	854.12
	5705-005T	483.35	72.50	264.76	33.50	854.12
	Average	483.35	72.50	264.76	33.50	854.12
New Holland TC55	5703-001A	341.19	51.18	191.04	33.50	616.92
	5705-002G	341.19	51.18	191.04	33.50	616.92
	5705-003T	341.19	51.18	191.04	33.50	616.92
	5705-004L	341.19	51.18	191.04	33.50	616.92
	5705-004T	341.19	51.18	191.04	33.50	616.92
	Average	341.19	51.18	191.04	33.50	616.92

Appendix A15. The actual mean of total operating cost per hour of two seasons of combine harvesters

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	301.00	6.18	48.85	27.92	383.95
	5704-001L	330.97	6.58	170.66	27.92	536.13
	5704-001G	328.09	7.48	90.55	27.92	454.04
	Average	320.02	6.75	103.35	27.92	458.04

New Holland TC5060	5703-001A	249.37	9.83	24.17	27.92	311.29
	5705-005T	193.62	7.46	198.15	27.92	427.15
	Average	221.49	8.65	111.16	27.92	369.22
New Holland TC55	5703-001A	196.70	74.06	462.51	27.92	761.19
	5705-002G	204.07	15.39	120.44	27.92	367.83
	5705-003T	228.16	12.72	208.91	27.92	477.70
	5705-004L	193.91	9.02	420.22	27.92	651.07
	5705-004T	191.13	5.68	176.17	27.92	400.90
	Average	202.80	23.37	277.65	27.92	531.74

Appendix A16. Calculated mean of total operating cost per hour of two seasons of the combiner

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	695.57	104.34	319.43	33.50	1152.85
	5704-001L	695.57	104.34	285.61	33.50	1119.02
	5704-001G	695.57	104.34	303.22	33.50	1136.64
	Average	695.57	104.34	302.76	33.50	1136.17
New Holland TC5060	5703-001A	482.64	72.40	264.76	33.50	853.30
	5705-005T	482.64	72.40	264.76	33.50	853.30
	Average	482.64	72.40	264.76	33.50	853.30
New Holland TC55	5703-001A	340.69	51.10	191.04	33.50	616.34
	5705-002G	340.69	51.10	191.04	33.50	616.34
	5705-003T	340.69	51.10	191.04	33.50	616.34
	5705-004L	340.69	51.10	191.04	33.50	616.34
	5705-004T	340.69	51.10	191.04	33.50	616.34
	Average	340.69	51.10	191.04	33.50	616.34

Appendix A17. Total operating cost per hour of 2010/2011 season of combine harvesters

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	520.67	52.62	206.23	30.71	810.23
	5704-001L	513.04	56.78	226.10	30.71	826.63
	5704-001G	520.85	57.24	175.24	30.71	784.03
	Average	518.18	55.55	202.52	30.71	806.96
New Holland TC5060	5703-001A	393.62	43.55	151.32	30.71	619.21
	5705-005T	348.87	42.66	243.20	30.71	665.45
	Average	371.25	43.11	197.26	30.71	642.33
New Holland TC55	5703-001A	279.41	93.79	434.32	30.71	838.23
	5705-002G	266.92	34.34	155.06	30.71	487.03
	5705-003T	301.58	35.49	233.31	30.71	601.10
	5705-004L	258.87	32.34	205.72	30.71	527.64
	5705-004T	264.58	30.46	194.81	30.71	520.56
	Average	274.27	45.28	244.64	30.71	594.91

Appendix A18. Total operating cost per hour of 2011/2012 season of combine harvesters

Combine harvester type	Plate number	Fuel (Birr/hr)	Oil (Birr/hr)	R&M (Birr/hr)	Labour (Birr/hr)	Total operating (Birr/hr)
Claas Tucano 320	5706-001A	475.91	57.90	162.05	30.71	726.57
	5704-001L	513.51	54.14	230.17	30.71	828.52
	5704-001G	502.81	54.57	218.54	30.71	806.64
	Average	497.41	55.54	203.59	30.71	787.24
New Holland TC5060	5703-001A	338.39	38.68	137.61	30.71	545.38
	5705-005T	327.39	37.19	219.70	30.71	615.00
	Average	332.89	37.93	178.65	30.71	580.19
New Holland TC55	5703-001A	257.97	31.38	219.23	30.71	539.29
	5705-002G	277.85	32.15	156.43	30.71	497.14
	5705-003T	267.27	28.33	166.64	30.71	492.95
	5705-004L	275.73	27.78	405.54	30.71	739.77
	5705-004T	267.24	26.33	172.40	30.71	496.68
	Average	269.21	29.19	224.05	30.71	553.17

Appendix B. Actual and calculated field rate work

FOP*	Machinery models	Width (m)	Speed (km/hr)	A.E.F.C* (ha/hr)	T.F.C** (ha/hr)	FE %	C.E.F.C$^{\%}$(ha/hr)	Variation (%)
Ploughing	JD 6165	1.50	7	0.81	1.05	85	0.89	8.80
	JD 6615	1.00	7	0.78	0.70	85	0.60	23.38
	Agro-track	1.00	7	0.87	0.70	85	0.60	31.24
	Landini	2.50	7	1.05	1.75	85	1.49	29.55
Disking	JD 6165	4.00	10	2.37	4.00	80	3.20	25.83
	JD 6615	3.60	10	1.94	3.60	80	2.88	32.62
	Agro-track	3.60	10	2.50	3.60	80	2.88	13.06
	Landini	4.00	10	2.63	4.00	80	3.20	17.80
Sowing	JD 6165	12.00	11	12.51	13.20	70	9.24	26.16
	JD 6615	10.00	11	10.35	11.00	70	7.70	25.58
	Agro-track	10.00	11	11.33	11.00	70	7.70	32.06
	MF 399	8.00	11	10.55	8.80	70	6.16	41.62
Fertilizing	JD 6165	12.00	11	11.05	13.20	70	9.24	16.41
	JD 6615	10.00	11	13.10	11.00	70	7.70	41.21
	Agro-track	10.00	11	14.26	11.00	70	7.70	46.02
	MF 399	8.00	11	11.55	8.80	70	6.16	46.66
Urea top dressing	JD 6615	10.00	11	19.16	11.00	70	7.70	59.81
	Agro-track	10.00	11	12.26	11.00	70	7.70	37.18
	MF 399	8.00	11	16.46	8.80	70	6.16	62.58
Seed coving	JD 6165	4.00	10	3.11	4.00	80	3.20	2.81
	JD 6615	3.60	10	2.47	3.60	80	2.88	14.24
	Agro-track	3.60	10	2.88	3.60	80	2.88	0.00
	MF 399	3.00	10	2.18	3.00	80	2.40	9.09

Ant-Weed chemical	JD 6165	18.00	10.5	9.87	18.90	65	12.29	19.68
	JD 6615	18.00	10.5	9.23	18.90	65	12.29	24.88
	Agro-track	18.00	10.5	12.01	18.90	65	12.29	2.26
Anti-Pest chemical	JD 6165	18.00	10.5	9.78	18.90	65	12.29	20.42
	JD 6615	18.00	10.5	9.17	18.90	65	12.29	25.37
	Agro-track	18.00	10.5	10.43	18.90	65	12.29	15.07
Harvesting	Tucano	4.90	5	2.48	2.45	70	1.72	30.77
	TC-5060	4.57	5	1.73	2.29	70	1.60	7.78
	TC-55	4.00	5	1.18	2.00	70	1.40	15.49

Note: FOP*-Field operation
A.E.F.C*-Actual effective field capacity
T.F.C**-Theoretical field capacity
FE-Field efficiency
C.E.F.C$^{\%}$ -Calculated effective field capacity

Appendix C. Machinery history life

S.N	Tractor type	Model	HP	Unit no.	Purchased year(E.C)	Purchased price	Service year	Origin
1	John Deere 6165J	J6165	165	4	2006	2519421.90	6	German
2	John Deere 6615	J6615	120	8	2001	791284.5	11	German
3	New Holland 8030	NH8030	120	8	2002	703117.6	10	Brazil
4	New Holland 100/90	NH100/90	100	9	1993	274796	19	Brazil
5	Massey Ferguson399	MF399	105	16	1988	198759	24	England
6	Massey Ferguson465	MF465	120	14	1996	297106.24	16	England
7	ZTZLG-Landin	Landin	215	2	2009	2732680.9	3	Italy
8	DeutzFAHRagro	Agro-150	150	6	2008	1449732.17	4	Germany
Combiner type								
1	Class Tucano 320	Tucano	245	3	2009	3633688.1	3	Brazil
2	New Holland	TC-5060	170	3	2003	988395.9	9	Brazil
3	New Holland	TC-55	120	16	1993	713194.0	19	Brazil

D. Machinery estimated parameter

Field Efficiency, Field Speed, and Repair and Maintenance Factors for Field Operations

	Field Efficiency		Field Speed			EUL Est. Life	Total Life	Repair Factors	
	Range %	Typical %	Range mph	Typical mph	Typical km/h	hours	Cost %[a]	RF1	RF2
TRACTORS									
2WD & stationary						12,000	100	0.007	2
4WD & crawler						16,000	80	0.003	2
TILLAGE & PLANT									

Moldboard plow	70-90	85	3.0-6.0	4.5	7.2	2,000	100	0.29	1.8
Heavy-duty disk	70-90	85	3.0-6.0	4.5	7.2	2,000	60	0.18	1.7
Tandem disk harrow	70-90	80	4.0-7.0	6	9.7	2,000	60	0.18	1.7
(Coulter) chisel plow	70-90	85	4.0-6.5	5	8.0	2,000	75	0.28	1.4
Field Cultivator	70-90	85	5.0-8.0	7	11.3	2,000	70	0.27	1.4
Spring tooth harrow	70-90	85	5.0-8.0	7	11.3	2,000	70	0.27	1.4
Roller-packer	70-90	85	4.5-7.5	6	9.7	2,000	40	0.16	1.3
Mulcher-packer	70-90	80	4.0-7.0	5	8.0	2,000	40	0.16	1.3
Rotary hoe	70-85	80	8 - 14.0	12	19.3	2,000	60	0.23	1.4
Row crop cultivator	70-90	80	3.0-7.0	5	8.0	2,000	80	0.17	2.2
Rotary tiller	70-90	85	1.0-4.5	3	4.8	1,500	80	0.36	2
Row crop planter	50-75	65	4.0-7.0	5.5	8.8	1,500	75	0.32	2.1
Grain drill	55-80	70	4.0-7.0	5	8.0	1,500	75	0.32	2.1
HARVESTING									
Corn picker Sheller	60-75	65	2.0-4.0	2.5	4.0	2,000	70	0.14	2.3
PT Combine	60-75	65	2.0-5.0	3	4.8	2,000	60	0.12	2.3
SP Combine	65-80	70	2.0-5.0	3	4.8	3,000	40	0.04	2.1
Mower	75-85	80	3.0-6.0	5	8.0	2,000	150	0.46	1.7
Mower (rotary)	75-90	80	5.-12.0	7	11.3	2,000	175	0.44	2
Mower-conditioner	75-85	80	3.0-6.0	5	8.0	2,500	80	0.18	1.6
Mow-Cond (rotary)	75-90	80	5.-12.0	7	11.3	2,500	100	0.16	2
SP Windrower	70-85	80	3.0-8.0	5	8.0	3,000	55	0.06	2
Side delivery rake	70-90	80	4.0-8.0	6	9.7	2,500	60	0.17	1.4
Square baler	60-85	75	2.5-6.0	4	6.4	2,000	80	0.23	1.8
Large square baler	70-90	80	4.0-8.0	5	8.0	3,000	75	0.1	1.8
Large round baler	55-75	65	3.0-8.0	5	8.0	1,500	90	0.43	1.8
Forage harvester	60-85	70	1.5-5.0	3	4.8	2,500	65	0.15	1.6
SP Forage harvester	60-85	70	1.5-6.0	3.5	5.6	4,000	50	0.03	2
Sugar beet harvester	50-70	60	4.0-6.0	5	8.0	1,500	100	0.59	1.3
Potato harvester	55-70	60	1.5-4.0	2.5	4.0	2,500	70	0.19	1.4
SP Cotton picker	60-75	70	2.0-4.0	3	4.8	3,000	80	0.11	1.8
MISCELLANEOUS									
Fertilizer spreader	60-80	70	5.-10.0	7	11.3	1,200	80	0.63	1.3
Boom-type sprayer	50-80	65	3.0-7.0	6.5	10.5	1,500	70	0.41	1.3
Beanpuller/windrower	70-90	80	4.0-7.0	5	8.0	2,000	60	0.2	1.6
Beet topper/chopper	70-90	80	4.0-7.0	5	8.0	1,200	35	0.28	1.4

Source: ASAE Standards 1993, American Society of Agricultural Engineers, St. Joseph, Michigan, 1993, p.332.

[a] percent of current list price

E. Questionnaire

Part I. General Information.

i. Name of respondent…….. ….ii. Name of company……

iii. Name of working department …… iv. Working section/unit……...

Part II. Maintenance characteristics

1. A commitment to management in maintenance job schedules to reduce the cost of maintenance?

Very Good ☐ Good ☐ Fair ☐ Poor ☐

2. Does the department have a well-defined and documented policy on the maintenance?

Yes ☐ No ☐

If yes, how would you evaluate its implementation?

Very Good ☐ Good ☐ Fair ☐ Poor ☐

3. Does the departments prepare an annual maintenance work plan?

Yes ☐ No ☐

If yes, how would you rate its implementation?

Very Good ☐ Good ☐ Fair ☐ Poor ☐

4. Does the department have a policy on the training of staff at all levels?

Yes ☐ No ☐

5. The frequency of formal maintenance training is provided to all maintenance workers is

Very Good ☐ Good ☐ Fair ☐ Poor ☐

6. Availability of maintenance planners is

Very Good ☐ Good ☐ Fair ☐ Poor ☐

7. Lack of supply the spare parts.

Very Good ☐ Good ☐ Fair ☐ Poor ☐

8. Briefly enumerate other challenges faced in implementation of maintenance works

Part III. Structured Interview for Maintenance Staffs

Date_____Sex _____Age.____ Department_____.

Job-title_____Workexperience_____Qualification_____.

1) Is the maintenance workshop suitable for maintenance work? If no, why?
2) Do you keep a record of all your daily activities? Are these records stored also as computer records?

3) Do you think that preventive maintenance increases the life of the machines? If yes, how?
4) Are there machines that are out of work, due to other than a spare part problem? If yes, what are the causes?
5) Would you say that you have sufficient training and skills to execute your work/ if no what way can this be improved?
6) In your opinion the departmental maintenance processes and procedures effective in addressing the maintenance needs of the agricultural machinery?
7) Is there on job training related to your works? If yes, where, at what frequency?