# UNIVERSITY OF NAIROBI

## SCHOOL OF ENGINEERING

### DEPARTMENT OF ENVIRONMENTAL AND BIOSYSTEMS ENGINEERING

**MODELLING VARIABLE COST OF TRACTORS: CASE STUDY OF TEN TRACTOR MODELS IN JUBA - SOUTHERN SUDAN**


**By**

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## DECLARATION

I, Saman Nicola Wilba Nicola, hereby declare that this M.Sc. Thesis is my original work. To the best of my knowledge, this work has not been submitted for a degree programme in any University.

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## DEDICATION

This thesis is dedicated to Almighty God through whom everything is possible for his sustained providence and care for my entire life and especially during this study, to the soul of my late great father, my dear mother, my beloved wife and son, my brothers and sisters, to my neighbors and friends, and to those who are fighting hunger and cultivating happiness, the farmers of my beloved country.

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## ABSTRACT


Variable costs contrary to fixed costs increase with machine age. Decisions made by farm power to or not to replace the farm machinery are based on available variable cost records. This study aimed at developing a mathematical model for predicting variable costs of a farm tractor. Specifically, the study identified and established numerical values of cost parameters pertinent to variable costs of tractors in Juba, South Sudan and modelled the data obtained.

The study was carried out in Jubek State of South Sudan using questionnaires for collecting variable costs data of tractor models available. These were MF375, Belarus800, JD5503, MF385, JD5510, JD5425, Mahindra8000, Mahindra705DI, Sonalika DI-90, and Sonalika DI-75. Data collected included age of the tractor, cost of fuel, cost of oil, cost of filters replacement, labor cost and cost of workmanship.

The correlation regression method of statistic was used to analyze the data collected and to represent the correlation relationship between the (accumulated variable cost as percentage of purchase price) and the (accumulated operating hours). The relationship between the accumulated hours of use and the accumulated variable cost as percentage of purchase price for the ten models of tractor studied was represented by carrying out the correlation regression analysis on the data. Five mathematical regression models together with their coefficients of correlation were all evaluated and It was observed that among the five mathematical models evaluated, the polynomial model showed the highest coefficient of correlation ($R^2$) followed by the power model. However, the power model $y = ax^b$, where y is the accumulated variable cost as the percentage of purchase price, x is the accumulated hours of use, a and b are the constants was the best fit for the ten tractor models studied and accounted for 99% of the observed variations in accumulated variable costs as percentage of list price for each of the ten tractor models studied.

The results obtained indicated that the cost of repair and maintenance for all tractor models studied showed the highest cost percentage of the total percentage followed by the fuel cost, cost of labor, then oil cost respectively, for example, for belarus800, the repair and maintenance cost was $538 which represent 39.9% of the total cost, followed by the fuel cost which was $446 which is 33%, then labor (operator) cost which was $291 which is 21.6% and finally oil cost was $75 which represent 5.6% of the total cost.

This study suggested that the derived mathematical models could be used to predict the variable cost of tractor studied operating in the area of study, the study is also important in guiding farmers and other institutions on tractor model selection and/ or to make tractors replacement decisions.

**Keywords:** Modeling, South Sudan, Tractors, Variable Cost

## TABLE OF CONTENTS

**LIST OF FIGURES**

## LIST OF TABLES

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AcVC | Accumulated Variable Cost |
| AfDB | African Development Bank |
| BI | Borlaug Institute |
| CBO | Cost of Brake Oil |
| CEDASS | Canadian Economic Development Assistance for South Sudan |
| CEO | Cost of Engine Oil |
| CG | Cost of Grease |
| CHO | Cost of Hydraulic Oil |
| CL | Cost of Labour |
| CO | Cost of Oil |
| COFF | Cost of Oil and Fuel Filters |
| CSPE | Cost of Spare Parts for Engine |
| CSPES | Cost of Spare Parts for Electrical System |
| CSPHS | Cost of Spare Parts for Hydraulic System |
| CSPSS | Cost of Spare Parts for Steering System |
| CSPTS | Cost of Spare Parts for Transmission System |
| CTR | Cost of Tire Replacement |
| CW | Cost of workmanship |
| DAP | Draft Animal Power |
| FAO | Food and Agriculture Organization of the United Nations |
| FC | Fuel Cost |
| FCH | Fuel Cost for Harrowing |

| | |
|---|---|
| FCP | Fuel Cost for Ploughing |
| GDP | Growth Domestic Product |
| GoSS | Government of South Sudan |
| GRSS | Government of the Republic of South Sudan |
| JSMA | Jubek State's Ministry of Agriculture |
| KDA | Kolye Development Association |
| LGP | Length of Growing Period |
| NFB | National Fire Brigade |
| NGO | Non-Governmental Organization |
| NMA | National Ministry of Agriculture |
| NPP | National Prison Police |
| NPS | National Police Service |
| NWLS | National Wildlife Service |
| R&M | Repair and Maintenance Cost |
| SSA | Sub-Saharan Africa |
| SSP | South Sudanese Pound |
| VC | Variable Cost |
| WFP | World Food Program Organization of the United Nations |

# 1 INTRODUCTION

## 1.1 Background

The farming tractor is a standout amongst the most vital power and energy sources in agricultural Mechanization (Gifford and Rijk, 1980). It requires high starting capital venture. Impact of tractor power on farming is extremely immense (Singh, 2006). The presentation of current technology amid the most recent century brought about fast development of agricultural production. Tractors and agricultural implements are critical components of this cutting edge technology (Singh, 2000a; Singh, 2000b).

Tractor costs have incredible effect on the agribusiness benefit. Information of tractor costs for agricultural activities has a prime significance in making decisions and setting management plans particularly in the comparison of the types of tractor and models thus aiding in the determination of a more fitting tractor. Expenses of operating and owning agricultural implements represent 35 to 50% of the expenses of farming production when land is not included (Anderson, 1988).

The cost of Repair and Maintenance (R&M) is a vital item in the expenses of operation and ownership. The cost of R&M is a function of farm implement age and utilization (Hunt, 2001). Generally, costs other than R&M decrease with increasing utilization, however the reverse is true concerning the cost of R&M. The expense of R&M is usually around 10% of the aggregate expenses; as the implement ages, the expense increases till it reaches the point that it turns into the biggest cost of operating and owning the agricultural implements (Rotz and Bowers, 1991).

Many studies have been carried out in both developing and developed Nations either to create models to determine the expense during a specific timeframe or to obtain absolute numbers to represent operating and owning certain farm implement (Abimbola, 1989; Adekoya and Otono, 1990; Bowers and Hunt, 1970; Fairbanks *et al*., 1971; Farrow *et al*., 1980; Gliem *et al*., 1989; Gliem *et al*., 1986; Rotz, 1987; Ward *et al*., 1985).

Fairbanks *et al*. (1971) extensively surveyed 114 farms in Kansas USA and they created two models from their survey. One model was to compute the repair expense of diesel tractors and the second one was to compute the repair expense of combine harvesters. Fanasb and Henderson (1984) carried out a survey in Jordan on the expense of tractor utilization. Their survey demonstrated that there was a relative increment of costs of repair with tractor utilization.

Farrow *et al*. (1980) evaluated the performance of the prediction equations and evaluated the required changes required for seven agricultural implements including trucks. A standard model was developed for the prediction of the expenses of maintenance and repair of medium-size, two-wheel drive, diesel motor tractor in Sudan. The model was derived in light of data gathered over a 10-year time span, from many areas in Sudan, and it predicts Repair and Maintenance (R&M) costs as a power function of tractor combined (aggregated) utilization in hours. The model demonstrated that the tractor aggregated utilization in hours was the main determinant factor of the tractor R&M costs. The investigation closed with accentuation to enhance the current models for acquiring better exactness.

Ward *et al*. (1985) extensively carried out a ten years' study of Government records for the expenses of repair of four-wheel drive and two-wheel drive tractors and developed a model for the cost of every kind of tractor. Rotz (1987) came up with a model base on the operating hours and the price of the farm machine. Testing the model demonstrated that the expenses were more practical when the area operated was considered rather than the working hours.

### 1.2 Problem Statement and Justification

Variable costs are different from fixed costs in that they increase with the use of the machine in addition to the fact that most of the decisions made by the managers of farm machinery and power to replace a farm machine or a tractor are taken based on the variable cost of which costs of repair and maintenance are the most important.

The economic life of an agricultural implement which is the period of time starting from the time the implement was bought to the time before the implement experiences serious breakdowns or the time at which continuing to use an agricultural tractor or implement will no longer be economical is also identified based on the variable cost of tractor or an agricultural implement.

Predicting or estimating the variable costs of an agricultural tractor or implement is very important due to the fact that it makes the operators and managers of a tractor able to know the annual cost of crop production and accumulated costs for using a tractor or an implement and, therefore, make a decision on whether it is profitable to continue using the tractor or it is better to sell it and replace it with another one.

The Government of South Sudan has recently distributed one thousand tractors of different types to all states of the Country (inter press service ips, 2016, military economic corporation mec, 2016) but the operators have no idea of the operating cost of these tractors so the they can select the type and model that best fit their farm size, that best match their farm implements or the one that is of less operating cost in order to reduce the cost of annual and increase the profitability of their entire farm enterprises. In addition, most of them do not know the field capacity and the efficiency of those tractors.

Therefore, it becomes necessary to carry out studies concerning variable costs so as to help tractor operators and farm managers in the Country to have an idea about the rate of increase of a variable cost over periods of time.

## 1.3 Objectives

### 1.3.1 Broad Objective

This study broadly aimed at establishing a mathematical model for predicting or estimating variable costs of the ten tractor models available in South Sudan.

### 1.3.2 Specific Objectives

The specific objectives were to;

a) Identify the cost parameters pertinent to variable costs**.**

b) Establish the numerical values of the cost parameters identified in (a) above.

c) Model the variable costs of the ten tractor models using values identified in (b) above.

## 1.4 Scope of the Study

This study was carried out in Juba which is the Capital City of the Republic of South Sudan and which falls within the former Central Equatorial State and the current Jubek State after the division of the Country into thirty-two (32) states.

The study was conducted on ten tractor models. In this study, questionnaire was used which targeted data concerning the operating (variable) costs of the ten tractor models which include the cost of Repair and Maintenance (R&M), fuel, lubricants, labour, the manufacturing year, the purchase price and the number of years (hours) of use.

The data collected were analysed and modelled, then, the results obtained were applicable to other tractors of the same model operating in other parts of the Country under the same conditions.

# 2 LITERATURE REVIEW

## 2.1 Concept and Role of Mechanization in Agricultural Systems

Mechanization entails the provision and utilization of all types of power sources and mechanical help to farming, from basic hand apparatuses, to animal power and to mechanical power innovations (Sims *et al.*, 2006).

Mechanization is a key contributor to any agricultural system. It aims to accomplish the following:

a) To increase the yield per the unit of area cultivated as a result of better timeliness of the agricultural operations.
b) To expand the cultivated area in case of land availability as it is always the case when it comes to the Sub-Saharan Africa.
c) To accomplish the operations those are harder to carry out without the mechanical helps.
d) To improve the quality of produce and operations.
e) To reduce the drudgery in agricultural operations, thus, making the agricultural operations more attractive.

Mechanization systems are sorted into mechanical, animal and human (innovations) technologies. Depending on the power source, the innovative levels of mechanization have been comprehensively named mechanical power innovation, draft animal innovation, and hand-device innovation.

### 2.1.1 Global Extent of Mechanization

#### a. Farm implements and mechanical power in farming

There are around 25.9 million tractors being used everywhere throughout the world. The provincial (regional) distribution of these tractors (and other farming implements) is extremely unequal; Significant contrasts exist among industrialized and developing nations, as well as inside specific gatherings of nations (Pawlak *et al.*, 2002).

Considering the quantity of 4-wheel drive tractors as a pointer of progression in mechanization, FAO (2008) reports the following trends in the course of recent years.

i) In Asia the tractor numbers expanded fivefold somewhere in the range of 1961 and 1970, from 120 000 to 600 000 units. From that point the number expanded by 10 times to 6 million units by 2000. From that point forward numbers have kept on expanding, particularly in India, which had 2.6 million tractors in 2010 – FAO (2013a), and China which came to more than 2 million units by 2008 – FAO (2013b).

ii) In the Latin America and Caribbean area tractor numbers expanded 1.7 times somewhere in the range of 1961 and 1970, from 383 000 to 637 000 units and from that point tripled to 1.8 million units by 2000.

iii) In the Near East area, the picture is like Latin America, tractor numbers multiplied from 126 000 to 260 000 somewhere in the range of 1961 and 1970 and after that expanded 6.5 times to 1.7 million units by 2000.

iv) In SSA the pattern has been somewhat extraordinary. In 1961 the quantity of tractors being used was more than in both Asia and the Close East (at 172 000). After that the number expanded gradually to top at 275 000 by 1990 preceding declining to 221 000 by 2000.

**Table 2-1 Number of the Farming Tractors in the Developed Countries.**

| **REGION** | **TRACTORS** | | | |
|---|---|---|---|---|
| | **1979 - 81** | **1988** | **1989** | **1990** |
| **Developed Countries.** | 18,453,232 | 21,185,216 | 21,288,448 | 21,304,416 |
| **N. America** | 5,425,035 | 5,505,300 | 5,519,400 | 5,529,000 |
| **Europe** | 8,441,626 | 10,293,285 | 10,410,033 | 10,427,321 |
| **Oceania** | 423,783 | 410,400 | 409,000 | 408,000 |
| **Former USSR** | 2629333 | 2,780,000 | 2,689,000 | 2,609,000 |
| **Other** | 1,533,466 | 2,196,234 | 2,261,020 | 2,331,100 |

**Source:** FAO (1991).

**Table 2-2 Number of the Farming Tractors in the Developing Countries.**

| **REGION** | **TRACTORS** | | | |
|---|---|---|---|---|
| | **1979 - 81** | **1988** | **1989** | **1990** |
| **Developing Countries.** | 3,455,688 | 4,879,127 | 5,116,842 | 5,240,055 |
| **Africa** | 203,734 | 270,713 | 276,654 | 284,791 |
| **Latin America** | 1,117,980 | 1,382,770 | 1,399,778 | 1,413,144 |
| **Near East** | 658,234 | 988,733 | 1,012,014 | 1,044,060 |
| **Far East** | 1,468,493 | 2,229,313 | 2,420,769 | 2,490,414 |
| **Other** | 7,247 | 7,598 | 7,627 | 7,646 |

**Source:** FAO (1991).

**Table 2-3 Total Population, Agricultural Population and Economically Active Population for Developed Countries.**

| **REGION AND CLASSIFICATION** | **POPULATION IN MILLIONS** | | | |
|---|---|---|---|---|
| | **1975** | **1980** | **1985** | **1990** |
| **Developed Countries.** | | | | |
| **Total** | 1,124 | 1,168 | 1,209 | 1,251 |
| **Agricultural** | 167 | 144 | 122 | 102 |
| **Economically Active:** | | | | |
| **Total** | 519 | 552 | 579 | 601 |
| **Agricultural** | 80 | 70 | 60 | 50 |
| **Percentage in Agriculture** | 15.5 | 12.7 | 10.3 | 8.3 |

**Source:** FAO (1991).

**Table 2-4 Total Population, Agricultural Population and Economically Active Population for Developing Countries.**

| **REGION AND CLASSIFICATION** | **POPULATION IN MILLIONS** | | | |
|---|---|---|---|---|
| | **1975** | **1980** | **1985** | **1990** |
| **Developing Countries.** | | | | |
| **Total** | 2,955 | 3,280 | 3,641 | 4,046 |
| **Agricultural** | 1,932 | 2,052 | 2,167 | 2,287 |
| **Economically Active:** | | | | |
| **Total** | 1,244 | 1,404 | 1,584 | 1,765 |
| **Agricultural** | 851 | 923 | 993 | 1,051 |
| **Percentage in Agriculture.** | 68.4 | 65.7 | 62.7 | 59.6 |

**Source:** FAO (1991).

**b) Comparative increments in mechanization inputs**

In the 1970s, Asia progressed in thriving attached to expanding commercialization of farming by supporting enormous investments in high yielding varieties (seeds), manure and water system (irrigation) (the green revolution). This ran together with expanding power inputs, predominantly as tractors for land preparation and diesel motors for water system.

In generally semi-arid Africa, where agricultural systems were more unpredictable across agro-biological zones, quality seed and manure were not upheld by water system support or motorization inputs. Subsequently, Africa missed up the green revolution (FAO, 2008).

Table 2.5 illustrates the greater advances in mechanization in other regions compared with SSA. This suggests a major opportunity for Africa to catch up with other regions.

**Table 2-5 Growth in Tractor Numbers between 1961 and 2000.**

| REGION | INCREASE % |
|---|---|
| **Latin America and Caribbean** | 469 |
| **Asia** | 500 |
| **North Africa and Near East** | 1,350 |
| **Sub-Saharan Africa** | 28 |

**Source:** FAO (2004), Agricultural Mechanization in sub-Saharan Africa.

### 2.1.2 Mechanization Status in Africa

#### 2.1.2.1 Contribution of farming to the national economy

Most developing Nations and, without a doubt, African Nations have an economy emphatically overwhelmed by the farming segment (sector). Farming generates up to 50% of GDP (Gross domestic product), contributing in excess of 80% of trade in value and greater than 50% of crude materials to businesses. It gives work to the larger part of Africa's people. In spite of this domination and the truth that farming is upheld with great statements, strategy and policy documents, investment in the segment is still underdeveloped in most African Nations. Besides, 30 to 40% of farming produce is lost attributable to poor post-harvesting dealing with, capacity and handling techniques. Thus, there is high potential for parallel development of the farming sector at all levels.

The low level of designing innovation (technology) contributions to farming has been cited as one of the fundamental limitations upsetting the modernization of farming and food production systems in Africa (FAO, 2008).

#### 2.1.2.2 Farm Power in Africa

Farm power in African farming, particularly Sub-Saharan Africa (SSA), depends mostly on human muscle power, based on operations that depend on the hoe and other hand tools. Such tools have restrictions in terms of operational output and energy in a tropical environment (FAO, 2008). The connection (relation) between hand, animal and motor power sources in Africa in contrast to other developing nations appeared in Table 2.6.

Generally, tractor and animal power have both fallen in African farming in the previous couple of years, making farming yet more dependent on manual methods in a landmass (continent) where imperatives (constraints), for example, extreme medical issues and statistic shifts make difficult work a rare and powerless asset. These techniques put extreme constraints on the area of land that can be grown per family. They diminish the timeliness of farming activities and limit the efficacy of important activities operations, for example, cultivation and weeding, in this manner lessening crop yields (FAO, 2008).

**Table 2-6 Farm Power Sources (Percentages).**

| Region | Hand | Animal | Engine |
|---|---|---|---|
| **SSA** | 65 | 25 | 10 |
| **3 other developing regions*** | 25 | 25 | 50 |

*** Asia, Near East and North Africa, Latin America and Caribbean.**

**Source:** FAO (2005).

#### 2.1.2.3 An Overview of Farm Power in Sub - Saharan Africa (SSA)

A number of studies on farm power carried out by FAO in Sub – Saharan Africa in the years ranging from 2002 to 2004 have demonstrated that the main labor-demand hikes in the farming cycle are for land preparation and subsequent weeding.

**The constraints to increased farm production are due, to a large extent, to three factors**

i) An excessive reliance on human power;

ii) The low productivity of human labor;

iii) A decrease in the labor available.

- **Human Power**

With human power, production is for the most part low due to the absence of physical energy available and the constrained (restricted) scope of hand tools. The circumstance has been exacerbated by the HIV/AIDS pandemic and different elements, for example, movement, which lessen the numbers of youth, healthy individuals available for farming operations (Sims *et al.*, 2006).

- **Draught Animal Power (DAP)**

It is generally regarded as a sustainable and an affordable power source for the farmers in the small scale sector. Cows and Oxen are the best. But cows are forbidden to be used by women in some African cultures. In some areas, Horses and donkeys are more used nowadays as well as mules and camels. Apart from transport, tillage and other field operations, these animals are also used for rural road maintenance, pond excavation and logging.

In developing countries working animals are still an important source of power for agricultural production. Animals usually compete with population as "users" of potential areas for grain production. Animal power mainly exists in nations with a shortage of food but not in the nations with the surplus of food. In developed nations, some experts are calling on farmers and other stakeholders to go back to animal power in nations with the surplus of food. They argue that the utilization of animals as a power source would be good to the environment and could assist in reducing the fossil fuels consumption (Pawlak *et al.*, 2002).

- **Tractor Power**

The tractor hire project that are run by the Government in SSA, never generally compelling, are presently in a condition of fall following a decrease in government expenses on services that could be delivered by the private scheme.

Tractors that are owned by the Private sector have been gainful on large scale farming, however they have rarely demonstrated practical for the smallholder area in SSA, regardless of whether in individual or gathering possession, or in private hire services (Sims *et al.*, 2006).

**Table 2-7 Sources of Power for Land Preparation (% of Total).**

| | **Human Power** | **Animal Power** | **Engine Power** |
|---|---|---|---|
| **Sub-Saharan Africa** | 65 | 25 | 10 |
| **East Africa** | 40 | 40 | 20 |
| **South Asia** | 30 | 30 | 40 |
| **Latin America and the Caribbean** | 25 | 25 | 50 |

**Source:** FAO (2006).

**Table 2-8 Patterns of Utilization of Tractor, Animal and Human Power for Cultivation in Selected Regions of Developing Countries.**

| REGION | SOURCE OF POWER FOR CULTIVATION | | |
|---|---|---|---|
| | Tractor (%) | Animal (%) | Human (%) |
| **Northern Africa** | 5 | 81 | 14 |
| **Ethiopia** | 2 | 85 | 13 |
| **Southern Africa** | 3 | 15 | 82 |
| **Kenya** | 5 | 15 | 80 |
| **Latin America** | 28 | 16 | 56 |

**Source:** Gebresenbet and Kaumbutho (1997).

### 2.1.2.4 Tractor numbers

Current insights show that there are around 470 000 tractors in Africa, however little is known concerning both their working condition and age.

The aggregate number of working tractors would need to be around 3.5 million (7 times more) to put Africa on a standard with different areas.

Expecting that the current tractors are for the most part utilitarian, the yearly substitution rate should now be around 47 000 units/year (expecting a ten-year life). A simple estimation proposes that to convey the level of power to farming to what other developing nations have accomplished, this (annually) yearly market would need to grow by a factor of around ten to roughly 400 000 tractors for each year. Such a development in tractor deals can't be accomplished quickly however could be in, say, 10 or 12 years. This would require critical activity to invigorate the market to achieve a sale of about 100 000 units for each year within two or three years. As a correlation, tractor deals in India in 2005– 06 were 264 790 units (FAO, 2008).

### 2.1.2.5 Overall changes in farming power sources

For developing nations in general, the utilization of tractors will rise from around 33% of the grown area to more than half (50%). This will mostly supplant (replace) manual methods and furthermore to a lesser degree, Draft animal Power (DAP).

By 2030, tractors will be relied upon as the overwhelming source of power for cultivation in, the Near East, North Africa, Latin America, South and East Asia and the Caribbean. South East Asia is anticipated to move from draft animal to making more noteworthy utilization of tractors. Additionally, in a couple of nations, it is anticipated that the present state of farm power won't be maintained.

In East Africa, for instance, the quantity of draft animal has been pulverized (reduced) in some nations because of animal disease and cows rustling. Amid or in the following thirty years it is anticipated that some nations will return from tractors to expanding utilization of hand or draft animal power.

This will happen where access to fuel and information sources is winding up progressively troublesome and where farming isn't sufficiently productive or where government-based initiatives for presenting (providing) motorization are not perfect with the condition of financial advancement and political stability (Clarke *et al.*, 2002).

**Table 2-9 The Farm Power - Present and Future Availability in Developing Countries.**

| Year | Tractor % | DAP % | Hand % |
|---|---|---|---|
| **1998** | 33 | 29 | 38 |
| **2030** | 55 | 20 | 25 |

**Source:** Clarke & Bishop (2002).

For the most part, motor power is on the expansion while draft animal is tending to decrease in numbers despite the fact that locally they can be critical. The move away from human muscle power towards motors and tractors for pumping and post-harvest tasks is substantially more fast in Asia and Latin America.

Draft animal numbers in China and India are falling drastically (from a pinnacle of more than 100 million in the two nations) and are being supplanted with four wheel tractors; while in Bangladesh draft animal have been supplanted by two wheel tractors and now 80% of land preparation is done with them (Ahmed. *et al.*, 2016).

### 2.1.3 Mechanization Status in South Sudan

#### 2.1.3.1 Current Status of Fisheries, Forestry and Farming

**The Setting**

Farming is the foundation of the economy of South Sudan. Predictions on value addition by forestry, fisheries and farming represented 36% of non-oil GDP (Gross domestic product) in 2010. It is obvious that around 80% of the South Sudanese lives up country, with farming, fisheries and forestry giving the essential livelihood to a dominant part of the families in every state. A great part of the rural activity is as of now centered around low-input low-production subsistence farming rather than production for business (AfDB, 2013). Among the noteworthy explanations behind this are

a) The requirement for enhanced farming techniques and inputs, for example, manures and seeds, advisory services and storerooms, and water system improvement.
b) The troubles encountered by farmers in getting to markets because of the poor street, absence of other modes of transport and aggravation expenses and charges, including bribes.
c) The absence of a minimum amount of farmers and up country producer’s associations as a method for entering the commercial center with the point of limiting the expense of inputs, getting loans at comfortable rates and effecting farm – gate prices.
d) Uncertainties relating to access to land and property rights.

With more than 95% of farming production being rain fed, climate inconsistency is a main consideration in deciding crop performance. In lowland regions, flooding is an ordinary event, however changeability of the water levels influences the production as well as the area harvested.

South Sudan has an enormous however mostly unrealized agricultural potential. The nation is lavishly enriched with a decent atmosphere and fertile soils rendering over 70% of its aggregate land territory reasonable for farming.

A couple of decades back in the 1980s, South Sudan was a net exporter of food commodities. Prolonged fighting in the following years resulted into a breakdown in farming support services, foundations, framework and hardworking attitude prompting the close crumple of the nation's farming production systems (World Bank, 2012).

Farming will be the way to the post-fighting recuperation and improvement of South Sudan. An expansive audit of research (Brinkman and Hendrix, 2010) focuses to a nexus between conflict and food insecurity and infers that food insecurity increases the danger of communal and civil conflict. Along these lines, South Sudan should instantly find a solution to its food insecurity challenges if the nation is to anchor sustained peace and recuperation and guarantee authenticity of the state. This would keep the nation from backsliding into fighting, as has occurred in some post-war nations where the state was not able to give food security to its residents (Collier, 2007).

Farming is prevalently rain fed with the level of (annually) yearly precipitation ascending from north to south and from east to west. It ranges from under 500 mm/year in the semi-arid areas of Eastern Equatoria to around 1,800 mm/year in the Green Belt zone. South Sudan has both bimodal and unimodal regimes of rainfall, the bimodal territories covering most of the Greater Equatoria (Easter, Central and Western Equatoria) whereas the unimodal zones include the rest of the nation. Farming production thus fluctuates extensively from one place to another and from one year to another, going from the likelihood of two harvest for each annum in Greater Equatoria between Kajo-Keji and Tambura to one harvest in the unimodal regions far north.

The area of South Sudan is usually the same as France, with a population less than 10 million, that gives the country a population density of 34 individuals for every square mile, identical to the population density of Norway. Presently, just 4% of land is under cultivation, generally in the fertile "greenbelt" region along the River Nile and its tributaries and in the southern part of the nation.

Presently around 80 percent of South Sudan's residents are involved in farming. Notwithstanding, most agriculturists prepare little plots and produce sufficiently just staple harvests, for example, corn and cassava, to bolster their families. Many don't produce enough for even their household; the World Food Program (WFP) and the UN Food and Agriculture Organization (FAO) assessed that South Sudan would confront a grain production shortfall of 390,000 tons in 2011, leaving 890,000 individuals seriously food insecure and an extra 2.4 million individuals moderately insecure. Indeed, even in regions with food surpluses, just a little amount of food is sold in markets. A little sum is sold in vast urban markets, where food running from essential to costlier foods are transported in from Uganda, and nothing is sold to traders outside of the nation. These perceptions bring up two issues: For what reason are farmers in South Sudan not exporting or selling their yield to traders from other countries in the region? Also, for what reason do farmers not contribute more to expand their productivity? (AfDB, 2013).

The survey carried out by the national ministry of agriculture and forestry of the Republic of South Sudan in 2016 found that about 10 million of the country's population which is 13.5 million are involved in farming. 80% of the land under cultivation was cultivated with human power which amounted for 8 million farmers, 1% was cultivated with animal power which amounted for 0.1 million farmers, whereas 19% of the land is cultivated with tractors which amounted for 1.9 million farmers.

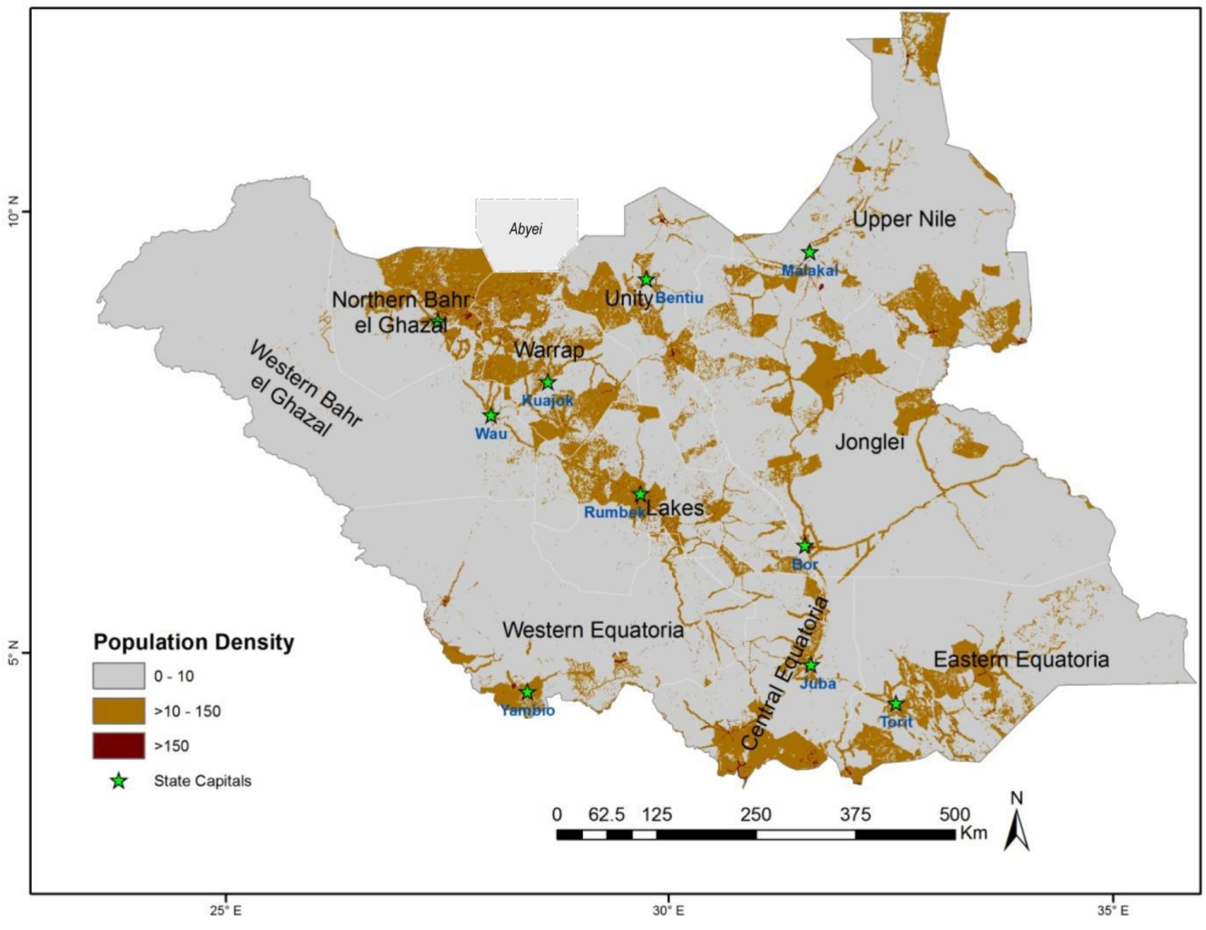


**Figure 2-1 Population Density in South Sudan** ( Source: World Bank , 2012).

In spite of land availability for cultivation, manual land preparation constrains the area family members can cultivate. Making utilization of animal traction would enable family members to cultivate bigger plots and seed in row (line) to ease weeding. The NGO, FAO and the Government of South Sudan (GoSS) based extension workers try endeavors to advance animal traction on a small-scale in Warrap, Western Equatoeia, Bahr el Ghazal States, Central Equatoria and Lakes State.

Notwithstanding cultural and social hindrances, absence of skills and spare parts to keep up shape (maintain) the mold-board plows and versatility of plows model to nearby soil (local) conditions are the primary imperatives.

Mechanized cultivation is done for the most part in the Upper Nile districts of Wadakona, Renk and Melut and to a limited degree in Bentiu and Malakal in the Unity State (AfDB, 2013).

Rain fed mechanized grain (crop) production is regularly honed on a large scale in the Upper Nile regions of Bailet, Renk, Fashoda, Melut, Malakal and Manyo following examples of land inhabitance built up before independence by farmers/traders from both Sudan and the South Sudan. Somewhere else, few (limited) numbers of both private and Government tractors provide plowing to farmer's association and people at costs running from SSP 50 (GRSS sponsored) to SSP 350 for every feddan for a single pass. Mechanization applies just to one pass preparation and sowing on a second pass with a seed penetrates situated over the universal plate harrows. The rest of the operations up to harvesting are done by hand. Significant problems related to operator skills, supply of fuel, maintenance and spare parts persevere, extremely restricting the efficiency of the service of the tractor. Experimental runs projects to present and bolster the utilization of 2-wheeled walking tractors offer a fiscally reasonable option in contrast to the distribution of large 4-wheeled tractors that are prematurely rejected (scrapped) because of insufficient maintenance (FAO/WFP, 2015).

Aside from the exercises of Aweil Rice scheme in Northern Bahr el Ghazal State, mechanized grain (crop) production is just noted to have been practiced on a vast scale in the Upper Nile areas of Bailet, Renk, Fashoda, Melut, Malakal and Manyo following examples of land inhabitance set up before autonomy (independence) by farmers/merchants from both Sudan and South Sudan. Somewhere else, few (limited) numbers of both private and Government tractors provide ploughing to farmer's associations and people at costs noted to run for the current year from SSP 120 (plus fuel) up to SSP 1 000 for every feddan for a single pass including the fuel. "Mechanization" as a term applies just to one-pass for land preparation and a second sowing pass with a seed bore situated over the universal circle harrows. The rest of the operation are performed manually. Significant problems related to operator skills, supply of fuel, maintenance and spare parts persevere, extremely restricting the efficiency of the service of the tractor with overall, three-four times more tractors, acquired over the most recent ten years lying inactive instead of working (FAO/WFP, 2016).

#### 2.1.3.2 Agricultural Land Use in South Sudan

**Estimates of the Cropped Area**

The nation lies totally inside the River Nile Basin and is covered by swamps, tropical backwoods and grassland. 75% of the nation's land territory is appropriate for farming while, around 330,000 square kilometers, or about 50% of the aggregate land space, is assessed to be arable. With its high potential for farming production, some experts have said that, with the advancement of fitting and sufficient infrastructure, South Sudan could turn into the bread basket of Africa (AfDB, 2013).

South Sudan has abundant virgin land under atmospheric conditions that are viewed as reasonable for farming. As indicated by Diao *et al.* (2009), over 70 % of South Sudan has a length of growing period (LGP) more than 180 days and is in this way appropriate for grain (crop) production. Notwithstanding, land cover and land utilization (FAO, 2009) demonstrate that the majority of the land that is reasonable for farming is still under regular vegetation.

Just 3.8 % (2.5 million ha) of the aggregate land area (64.7 million ha) is as of now cultivated, while the biggest piece of the nation (62.6%) is under bushes and trees. This proportion (cropland to aggregate land) is low in South Sudan contrasted with Kenya and Uganda, where in spite of less favorable LGPs, cropland represents 28.3 % and 7.8%, individually, of aggregate land region.

The vast majority of the cropland in South Sudan is rain fed. A two-step consecutive (sequential) process was utilized to determine land cover/land utilization from a 295 land utilization types portrayed in the FAO (2009) South Sudan land cover map. First, the 295 land utilization types were resampled and totaled into eighteen land utilization types, thirteen of them farming related (including tree crops and tree).

In the second step, the thirteen farming related land utilization types were further totaled into six classifications: tree land, grass with crops, Tree with crops, cropland, flood land, and grassland (Diao *et al*., 2011). Inundated zone is restricted to just 32,100 ha, basically in Upper Nile. Flood land utilized for rice production is additionally constrained, at around 6,000 ha, and is found principally in Northern Bahr el Ghazal (World Bank, 2012).

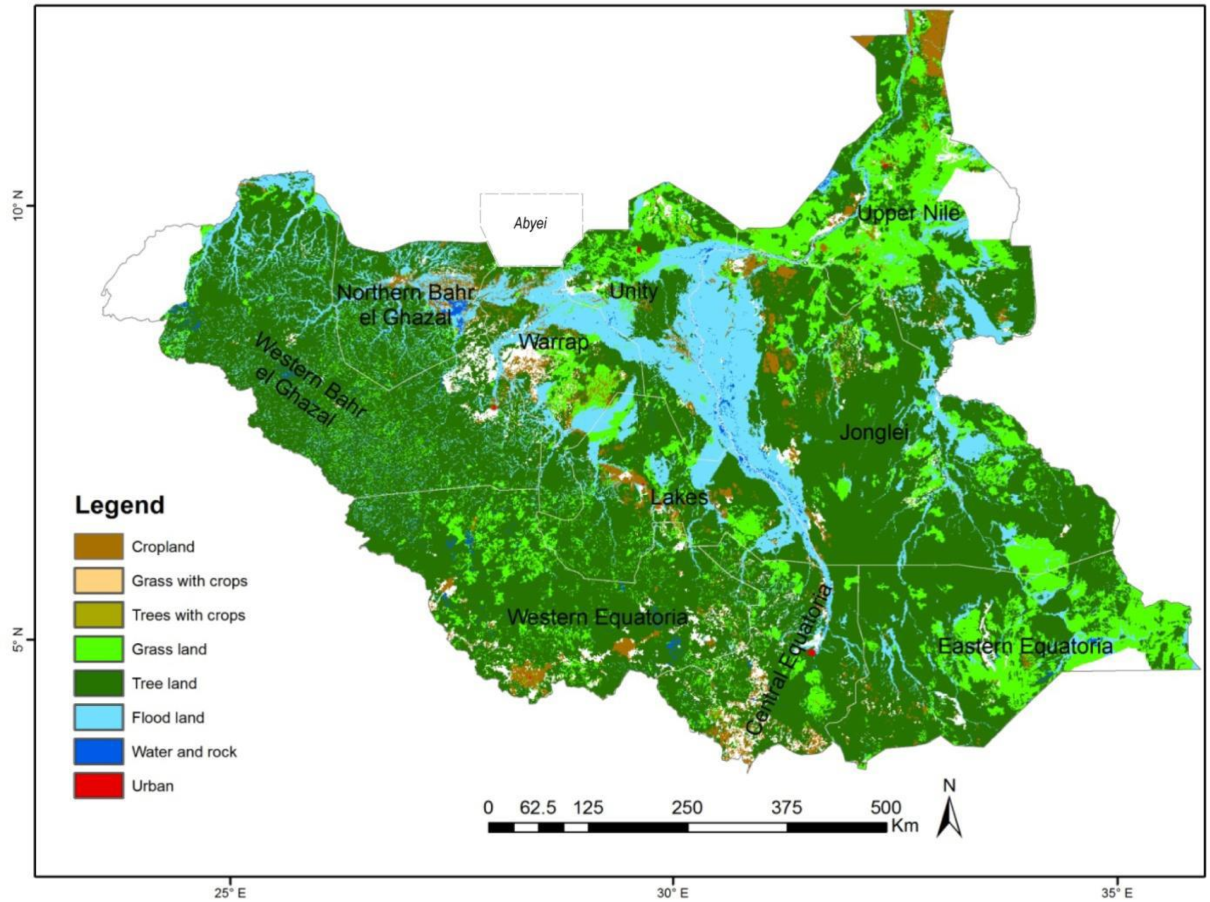


**Figure 2-2 Aggregated Land Use/Cover Map**.( Source: World Bank, 2012).

**Table 2-10 Area and Share of Aggregated Land Uses in Total National Land Area.**

| LAND USE | AREA (ha) | SHARE OF TOTAL LAND (%) |
|---|---|---|
| **Cropland** | 2,477,700 | 3.8 |
| **Grass with crops** | 325,100 | 0.5 |
| **Trees with crops** | 1,707,300 | 2.6 |
| **Grassland** | 9,633,800 | 14.9 |
| **Tree land** | 40,526,900 | 62.6 |
| **Flood land** | 9,497,600 | 14.7 |
| **Water and rock** | 482,700 | 0.7 |
| **Urban** | 37,000 | 0.1 |
| **Total** | 64,688,300 | 100 |

**Source:** World Bank (2012).

Most cropland is amassed in five states of Central Equatoria (11.2%), Western Equatoria (11.4%), Jonglei (14.3%), Warrap (15.3%), and Upper Nile (19.0%) of aggregate cropland. These five states represent 56 % of national territory and 70% of national cropland. All inundated harvests (predominantly rice) are in Upper Nile state; rice on flood land is all in the state of Northern Bahr el Ghazal. Tree plantations and Fruit trees are solely in the three states of Eastern, Central and Western Equatoria, most presumably because of the appropriate climatic conditions in these states (World Bank, 2012).

A number of policy papers were set up amid 2006-2007 for fisheries, forestry, animal resources, food and farming. In 2010, the FAO supported a survey of these papers regardless of having fifty percent of its arable land mass as prime farming land just four percent of this area is farmed continuously or periodically.

As per the World Bank, the genuine area cultivated in any single year in South Sudan is between 1% as a minimum and 2% as a maximum of the aggregate land area– that is, from around 650,000 to 1.3 million hectares. As per FAO-WFP reports, around 1 million hectares were put under farming in 2008. Cereals normally represent at least 80% of the cultivated area every year; for instance, the harvested area under cereals in 2008 was around 850,000 hectares.

Sorghum is the fundamental grain, trailed (followed) by millet and maize. The medium area cultivated by the family is regularly in the scope of 1-4 feddan (0.4-1.7 hectares) (AfDB, 2013).

According to the report of the National Ministry of Agriculture and Forestry of the Republic of South Sudan dated 17/05/2016, the government until 2015 imported 1300 tractors of different models as well as farming equipment and distributed them to all states of the country some of which can be seen in appendices N and O. That put the government as the big tractor importer in the country. The tractors imported were as follows:

- In 2008, 200 Mahindra tractors of models Mahindra8000 and Mahindra705DI.
- In 2009, the Government imported 200 MF385 tractors into the country.
- In 2015, 800 Belarus800 tractors in addition to 200 MF375 were also imported by the Government.

Another tractor dealer in the Country is Lon agro South Sudan LTD which is the sole importer of John Deer tractors in the Country, and it started in 2013 by importing few number of tractors of one model only which is JD5503 and until the date of the study, this was the only model imported by Lon agro that were operating on different farms because their effort to import more tractors have been hit by the ongoing war which started shortly after their start.

Ezentus ltd is also another Company that has started to import Massey Ferguson tractors into the Country. Thus, according to the report of the national ministry of agriculture and forestry, Belarus800 are the most available tractor in the Country and this could explain why most of tractors studied were Belarus800.

## 2.2 Farm Machinery Costs

The costs of agricultural machinery are partitioned into two classes, to be specific owning (fixed) and variable (operating) costs (Morris, 1988). Owning (fixed) costs includes interest on investment, housing, depreciation, taxes, and insurance whereas the variable costs include repairs, fuel, maintenance, labour and lubrication costs.

Variable costs rise relatively with the measure of operational utilization of the machine, while the ownership costs are independent utilization (Hunt, 2001). It isn't in every case clear concerning which classification a portion of the particular costs belong.

The costs of housing, interest on the machinery investment, insurance and taxes depend on the time (calendar-year) and are obviously independent of utilization whereas the costs of daily service, fuel, maintenance, labour, lubrication and power are obviously cost related with utilization. The rest of the two cost items which are the cost of repairing and depreciation appear to be the function of both time and utilization.

Estimations of annual costs are sufficient for deciding the costs of crop production and for drawing conclusions as to whether continuing owning the machine is still profitable; yet the time of substitution decision relies upon the gathered costs over a time of years.

The costs of maintenance and repair of agricultural machinery are hard to estimate as a result of variability among machines and working conditions that differ from one farm to another and furthermore because of inaccessibility or unavailability of good records keeping (Lazarus and Selley, 2005).

### 2.2.1 Ownership costs

Additionally, called capital or fixed costs include; insurance, interest on investment, housing, taxes and depreciation.

#### 2.2.1.1 Depreciation

The level of mechanical wear may make the estimation of a specific machine be to some degree above or beneath the normal value for the same machines when it is exchanged or sold. Presentation of new innovation or a noteworthy major design change may make a more established machine all of a sudden outdated, causing a sharp decrease in its remaining value. Be that as it may, aggregated hours of utilization and age more often than not are the most essential factors in deciding the remaining value (V) of a machine whenever.

Before an estimate of yearly deterioration (depreciation) can be computed, an economic life for the implement and a salvage value toward the end of the economic life should be determined. The economic life of an implement is the quantity of years over which costs are to be evaluated. Usually it is less than the service life of an implement due to the fact that most farmers exchange an implement with another one before it is totally exhausted.

A decent general guideline is to utilize an economic life of 10 to 12 years for most agricultural implements and a 15-year life for tractors, unless if you know you will exchange sooner.

Salvage value is a gauge (an estimate) of the sale value of the implement toward the end of its economic life. It is the sum (amount) you could hope to get as an exchange (trade-in) allowance, an estimate of the utilized market value in the event that you hope to sell the implement outright, or zero if you intend to keep the machine until the point when it is exhausted.

The methods used for evaluating depreciation and the equations used for the calculation in each method are shown in chapter three under sub-section 3.6.

#### 2.2.1.2 Interest on Investment

In the event that you borrow cash to purchase a machine, the bank (lender) will decide the interest rate to charge. If you utilize your own capital, the rate to charge will rely upon the opportunity cost for that capital somewhere else in your agricultural business.

If just part of the cash is borrowed, an average of the two rates should be utilized. The interest rate should be adjusted by subtracting the anticipated rate of inflation.

Capital recovery is the quantity of dollars (cash) that would need to be put aside every year to just repay the lost value because of pay interest costs and depreciation.

The interest on investment in an agricultural implement is included in operational cost estimates. Even if the investment cash is not actually borrowed, a charge is made since that cash cannot be utilized for some other interest-paying enterprise. Nominal interest rates include the anticipated inflation. In times of substantial monetary inflation, an implement manager must include the impacts of inflation on the implement planning. The inflation will result into rise in prices of services and goods in future years (Abdallah *et al.*, 2014).

The real interest rate, $I_r$, is a function of the nominal interest rate, $I_p$ and the rate of inflation, $I_g$, as shown in Equations (3.15) and (3.16) in chapter three.

#### 2.2.1.3 Taxes, Insurance and Housing (TIH)

These three costs are typically significantly smaller than interest on investment and depreciation; however, they should be taken into consideration. Property taxes on agricultural implements have been eliminated in some states, with the exception of substantial (very large) inventories. For states that do still have property taxes on agricultural implements, an estimated cost equivalent to one percent of the medium value of the implement is charged.

Insurance should be done on agricultural implements in order to allow for substitution in case of an accident for example tornado or fire. If insurance is not done, the risk is assumed by the remain of the agricultural business.

There is an enormous difference in housing provided for agricultural implements. Providing tools, maintenance equipment and shelter, for implements will result in les repairs on the farm and less decay of mechanical parts and appearance from weathering. That should produce more reliability on the farm and a higher exchange (trade-in) value. An estimated charge of 0.5 percent of the average value is suggested for the cost of lodging (housing).

To easily compute the costs of taxes, insurance and housing, they can be summed together as two percent of the medium value where property taxes are not important.

#### 2.2.1.4 Total Ownership Cost

The estimated costs of housing, taxes, depreciation, interest on investment and insurance are summed together to get the total ownership cost.

### 2.2.2 Operating costs

Also known as the variable costs include operator (labour) cost, fuel cost, cost of maintenance and repairs, and lubrication (oil) cost.

#### 2.2.2.1 Repairs and Maintenance (R&M) Costs

The cost of repair happens due to tear, accidents, wear and routine maintenance. The cost of repair for a particular type of an agricultural implement differs broadly from one geographic area to another due to climate, rocks, terrain, type of soil and other conditions (William Edwards, 2015).

Within the same region, the cost of repair differs from one farm to another due to the difference in the operator skill and management policies.

The best data for evaluating the costs of repair are the kept records of your own past expenses of repair. Good records demonstrate whether an implement has had below or above average costs of repair and when major overhauls might be required. They will too provide information concerning your maintenance program and your mechanical capacity (ability). Without such data, however, the costs of repair must be evaluated (estimated) from average experience.

The cost of Repair and Maintenance can be calculated using equation (3.1) in chapter three.

#### 2.2.2.2 Fuel Cost

The cost of fuel can be evaluated (estimated) in one of the following two ways:

The average cost of per acre can be computed by multiplying the medium fuel utilized in gallons per acre as it is in the agriculture decision makers file A3 to 27 by the cost of fuel per gallon.

The average use of fuel in gallons per hour for an agricultural tractor on the basis of year-round without reference to particular implement can likewise be evaluated (estimated) using Equations (3.2), (3.4) and (3.5) in chapter three.

#### 2.2.2.3 Lubrication (Oil) Cost

Surveys show that total oil costs on the majority of farms average about 15 percent or 0.15 of the costs of fuel. Thus, once the cost of fuel per hour has been evaluated (estimated), it can easily be multiplied by 0.15 in order to estimate the total costs of oil.

The oil cost can be calculated using equation (3.6).

#### 2.2.2.4 Labor (Operator) Cost

Because machines of different size need labour of different quantities in order to accomplish such tasks as harvesting or planting, it is necessary to take into consideration the costs of labour when it comes to machinery analysis. The cost of labour is also an essential consideration when comparing between custom hire and ownership.

The actual hours of work (labour) for the most part surpass (exceed) field implement time by ten percent to twenty percent as a result of movement (travel) and the time needed to service and lubricate implements. Consequently, the costs of labour can be evaluated (estimated) by multiplying the wage rate of the labour by 1.1 or 1.2 (William Edwards, 2015). Different rate of wage can be utilized for tasks in need of different levels of operator skill.

#### 2.2.2.5 Total Operating Cost

The costs of lubrication, repair, labor and fuel are summed together in order to compute the total operating cost.

#### 2.2.2.6 Total cost per hour

After the estimation of the all machinery costs, the total operating cost per hour can be summed to the total ownership cost per hour to compute the total cost per hour of owning and operating the agricultural machine.

The table 2.11 shows the mathematical models developed by different researchers for the prediction of the cost.

**Table 2-11 The Models Developed by Different Researchers**

| **Models Developed by different researchers** | **Source(s)** |
|---|---|
| $y = 0.072\left(\frac{x}{120}\right)^{1.6}$ | Bowers and Hunt (1970) USA |
| $y = 0.00865x^{1}$ | Culpin (1975) |
| $y = 0.042\left(\frac{x}{1000}\right)^{2}$ | ASABE (1983) USA |
| $y = 0.042\left(\frac{x}{120}\right)^{1.895}$ | Ward *et al*. (1985) Ireland |
| $y = (0.00996x^{1.4775})10^{-3}$ | Morris (1987) UK |
| $y = (9.96x^{1.48})10^{-5}$ | Morris (1988) UK |
| $y = 0.07\left(\frac{x}{740}\right)^{2.34}$ | Rahama (1999) Sudan |
| $y = (4.0x^{1.25})10^{-4}$ | Dahab and Osama (2002) Sudan |
| $y = 0.005x^{1.2}$ | Abubakar *et al*. (2013) Nigeria |
| $y = (1.7x^{1.29})10^{-4}$ | Abdallah *et al.* (2014) Sudan |
| $y = (2.53x^{2.4})10^{-7}$ | Ahmed *et al*. (2016) Sudan |

## 2.3 Summary of Literature Review

The costs of operating farm machines to a large extent affect the profit of agricultural business therefore knowing these costs is important for managing, planning and making decisions particularly when it comes to comparison between tractor makes and models thereby helping the stakeholders in the process of selecting the appropriate tractor. The operating Costs of farm tractor of which cost of repair and maintenance is the most important one always increase with the time of operation and it represents 35 to 50% of the total costs of production without land

Usually the repair and maintenance cost is about 10% of the total production cost; but as the age of operation of a machine increase, it increases until it becomes the highest cost for operating and owning the machine. The operating costs generally increase with the machine use and the cumulative use of a machine in hours is the determinant factor of the operating costs.

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# 3 THEORETICAL FRAMEWORK

This chapter contains the theories, equations and principles necessary for the computation of the cost parameters pertinent to variable cost needed to carry out this study which are; R&M, Fuel, Oil and Operator (Labour) Costs.

## 3.1 Repair and Maintenance (R&M) costs

Equation 3.1 is used to calculate the accumulated repair and maintenance cost of a farm tractor (Hunt. D, 1983).

$$\frac{\mathrm{C_{rm}}}{\mathrm{P_u}} = \mathrm{RF1}(\frac{t}{1000})^{\mathrm{RF2}} \quad [3.1]$$

Where:

RF1, RF2 = Repair factor.

$P_u$ = Purchase price.

$t$ = Accumulated use (h).

$C_{rm}$ = Accumulated repair and maintenance cost.

## 3.2 Fuel Cost and Consumption

Equation 3.2 is used for the computation of the fuel cost per hectare for a farm tractor (Hunt. D, 1983).

$$\mathrm{C_S} = \mathrm{P}_L * \frac{Q_i}{C_a} \quad [3.2]$$

Where:

$P_L$ = Price of Fuel ($/L).

$C_s$ = per – hectare fuel cost.

$Q_i$ = Fuel consumption of the engine (L/h).

$C_a$ = the operation's Effective field capacity (ha/h).

The fuel consumed by engine ($Q_i$), can be found by first estimating the power of the engine needed to carry out the field operation done by computing the power at the draw bar and then converting it to the equivalent PTO. Equivalent PTO power will be multiplied by specific fuel consumption ($\mathrm{SFC_V}$) provided by ASABE Data D497 as in equation 3.3

$$\mathrm{SFC}_V = 3.91 + 2.64\mathrm{X} - 0.203\sqrt{173} + 738\mathrm{X} \quad [3.3]$$

Where:

$SFC_v$ = the Specific fuel consumption based on the volume (L/KW.h).

X = Ratio of equivalent Power Take Off required to the maximum PTO available.

Multiplying $SFC_V$ by the equivalent Power Take Off power required for the operation we get ($Q_i$) which is the estimated fuel needed to carry out the operation.

The values of X range from 0.2 for the operation of spraying to 0.85 for the operation primary tillage.

$SFC_V$ = 0.411 L/KW.h when X > 0.856,

**3.3 Fuel Cost**

The average use of fuel in gallons per hour for agricultural tractors on the basis of year-round without reference to particular implement can likewise be evaluated (estimated) with these following equations. (William Edwards, 2015).

$$0.060 * maximum\ PTO\ horsepower\ for\ gasoline\ engines \quad [3.4]$$

$$0.44 * maximum\ PTO\ horsepower\ for\ diesel\ engines \quad [3.5]$$

Where

PTO = Power take off power.

**3.4 Lubrication (Oil) cost and Consumption**

Equation 3.6 is used to calculate the cost of oil or lubricant per hectare for a farm tractor (Hunt. D, 1983).

$$C_S = P_L * \frac{Q_i}{C_a} \quad [3.6]$$

Where:

$P_L$ = Price of oil.

$C_S$ = per – hectare oil cost.

$Q_i$ = Oil consumed by the engine (L/h).

$C_a$ = Effective field capacity during the operation (ha/h).

ASABE Data D497 provides an equation for estimating oil consumption as follows

$$Q_i = \frac{21.69 + 0.59 * P_r}{1000} \quad [3.7]$$

Where:

$Q_i$ = the consumption of oil (L/h).

$P_r$ = the rate power of the engine (KW).

**3.5 Labour Cost**

Because different size machines require different quantities of labor to accomplish such tasks as planting or harvesting, it is important to consider labor costs in machinery analysis. Labor cost is also an important consideration in comparing ownership to custom hiring.

Actual hours of labor usually exceed field machine time by 10 to 20 percent, because of travel and the time required to lubricate and service machines. Consequently, labor costs can be estimated by multiplying the labor wage rate times 1.1 or 1.2. (William Edwards, 2015).

Different wage rates can be used for operations requiring different levels of operator skill.

**3.6 Depreciation**

The methods used for evaluating depreciation are

**3.6.1 Declining-balance Method:**

In the method of declining-balance, a uniform rate is used every year to the remaining value (include salvage value) of the implement toward the start of the year (Abdallah *et al*, 2014).

The deterioration (depreciation) sum (amount) differs for every year of the implement's life.

The equations below 3.8, 3.9 and 3.10 express the relationships.

$$D = V_n - V_{n+1} \quad [3.8]$$

$$V_n = p[1 - \frac{x}{L}]^n \quad [3.9]$$

$$V_{n+1} = p[1 - \frac{x}{L}]^{n+1} \quad [3.10]$$

Where:

D = the amount of depreciation.

V = is the remaining value at any time.

n = age of a tractor in years at the start of the year in question.

x= is the ratio of the rate of depreciation used to that of straight line method.

(x May have any figure from 1 to 2). If the value of x is 2, the method is called a double-declining-balance method and is the apex rate method allowed by the internal revenue service (IRS). For utilized farm implements and tractors, the apex rate of x is 1.5.

### 3.6.2 Straight-line Method

In this method, an early computed fix sum is charged as a devaluation (depreciation) every year and thus, it is regarded as one of the easiest method for assessing deterioration (depreciation). Or on the other hand, this method displayed deterioration (depreciation) as the difference) between the list price and selling or salvage price over the time between the buy (purchase) and offering (selling) (Hunt. D, 1983).

$$D = \frac{P - S}{L} \qquad [3.11]$$

Where:

D = Depreciation.

S = The selling or salvage value.

P = list (Purchase) price.

L = Time between purchase (buying) and selling in years.

### 3.6.3 Sum-of- the-Years-Digits Method

In this method, the figures of the assessed number of years of life of an agricultural tractor or an agricultural implement are summed together and after that divided by the number of years left for the implement not excluding the year in question.

The amount of depreciation charge every year will then be the fractional part of the difference between list price and the selling value as shown below (Hunt. D, 1983).

$$D = \frac{L - n}{YD} (P - S) \qquad [3.12]$$

Where:

D = Depreciation.

P = List (Purchase) price.

S = The selling or salvage price.

YD = sum – of – the – years – digits.

L = Time between buying (purchase) and selling.

n = age of a tractor in years not excluding the year in question.

### 3.6.4 Sinking-fund Method

This method for evaluating depreciation regards depreciation as building up a fund that will attract (draw) compound interest and to which a uniform yearly installments (payments) are of such a size, to the point that will buy another proportionate implement or tractor before the end of a tractor or an implement life. This method is utilized by engineering economist for evaluating devaluation (depreciation) (Hunt. D, 1983).

By equation:

$$\mathrm{SFP} = (\mathrm{p} - \mathrm{s})\frac{\mathrm{i}}{(1 + \mathrm{i})^{\mathrm{L}} - 1} \qquad [3.13]$$

$$\mathrm{V_n} = (\mathrm{P} - \mathrm{S})[\frac{(1+\mathrm{i})^{\mathrm{L}} - (1+\mathrm{i})^{\mathrm{n}}]}{(1+\mathrm{i})^{\mathrm{L}} - 1} + \mathrm{s} \qquad [3.14]$$

Where

SFP = Sinking Fund Price.

V = is the remaining value at any time.

n = age of a tractor in years at the start of the year in question.

P = Buying (Purchase) price.

S = The selling or salvage price.

L = Time between buying (purchase) and selling.

i = the Interest on investment.

### 3.6.5 Rapid and Slow Depreciation

Rapid depreciation of an agricultural tractor or a machine is a management accounting practice allowed by the internal revenue service (IRS) and it is utilized by some implement managers to recover the investment early in an implement' life before accident, out of date or wear-out ends the implement usefulness and also to avoid income tax.

Whereas other farm implement managers prefer slow deterioration (depreciation) schedules that scattered the reduction-in-tax benefits over the actual life of the implement (Hunt. D, 1983).

## 3.7 Interest on Investment

The real interest rate, $I_r$, is a function of the nominal interest rate, $I_p$ and the rate of inflation, $I_g$, as shown in Equation 3.15 here in;

$$I_r = \frac{Ip+Ig}{1+Ig} \qquad [3.15]$$

Therefore, the interest on investment is calculated by using Equation (2.9) here in;

$$I_n = V * I_r \qquad [3.16]$$

Where:

$I_r$ = is the rate of interest.

$I_n$ = is the interest on investment in nth year ($).

V = is the remaining value at any time.

# 4 MATERIALS AND METHODS

## 4.1 Study Area

Juba city was founded in 1922 by Greek traders who were mostly supplying the British army at the time and it was called Gondokoro. It is the Capital City of the Republic of South Sudan, the capital of the former central Equatoria state and the capital of the current Jubek state. It is located in central South of the Country west of the White Nile River some 140km south of Bor town.


**Figure 4-1 The Study Area (Juba).**

Juba has an estimated area of 22, 956 kilometer square. It has an elevation of 550m above sea level and falls between longitude 31° 34' 16.5036" E and latitude 4° 51' 33.7068" N. Juba has an estimated population of 300,000 inhabitants according to the world population review of 2017. The city is also the administrative center of the Country. It is a river port and serves as the agricultural commercial center in the area.

Juba has a tropical wet and dry climate and as it lies near the equator, temperatures are hot year-round. The summer Season starts from November to March, which is also the time of the year with the hottest maximum temperatures, reaching $38^{o}$ C in February. From April to October, more than 100 millimeters of rainfall per month. The annual total precipitation is nearly 1,000mm.

**4.2 The pertinent parameters.**

The pertinent parameters of this study which include; Repair and Maintenance (R&M), fuel, oil and operator (labour) costs were determined through an intensive review of the literature.

**4.3 Population and Sample Size**

According to the report of the National Ministry of Agriculture and Forestry of the Republic of South Sudan dated 17/05/2016, the Government until 2015 imported 1300 tractors of different models as well as farming equipment and distributed them to all states of the Country. That put the Government as the big tractor importer in the Country. The tractors imported were as follows:

- In 2008, 200 Mahindra tractors of which 100 tractors were of model Mahindra8000 and the rest of 100 tractors were of model Mahindra705DI.
- In 2009, the Government imported 200 MF385 tractors into the Country.
- In 2015, 800 Belarus800 tractors in addition to 200 MF375 were also imported by the Government.

Another tractor dealer in the Country is Lon agro South Sudan LTD which is the sole importer of John Deer tractors in the Country, and it started in 2013 by importing few number of tractors of one model only which is JD5503 and until the date of the study, this was the only model imported by Lon agro that were operating on different farms because their effort to import more tractors have been hit by the ongoing war which started shortly after their start.

Ezentus ltd is also another Company that has started to import Massey Ferguson tractors into the Country. Thus, according to the report of the national ministry of agriculture and forestry, Belarus800 are the most available tractor in the Country and this could explain why most of tractors studied were Belarus800.

These different tractor models were distributed equally among the ten states of South Sudan by the time, so that put the population of Mahindra8000 in the State in which the study has been conducted at 10 and the population of Mahindra705DI at 10 too. The population of MF385 tractor was 20, the population of MF375 was also 20 and the other 20 MF375 tractors covered by this study were imported into the Country by a private dealer called Ezentus which I visited and collected the information on the farmers that bought tractors from them and the names of the farms which I later visited. The population of Belarus800 was 80.

JD5503 tractors were solely imported into South Sudan by a Company called Lon Agro South Sudan Limited which started shortly before the war which hampered their effort to import more of this model of tractor can break out in 2013. I visited this Company while in juba for data collection and interviewed the sale Engineer and I was given the name of farms and community associations that bought tractors from them which I visited and collected the data for this study as well as I was given the prices of lubricants and spare parts sold by this Company to its customers.

The three tractors of model SolanikaDI-75 and two tractors of model SolanikaDI-90 were bought by what at the time before the separation of South Sudan called the Government of the Central Equatoria State and they were the only Solanika tractor available in the study area.

The rest of two tractor models covered by this study which were two tractors of model JD5510 and one tractor of model JD5425 were bought by the Canadian Economic Development Assistance for South Sudan (CEDASS) from Canada and donated to the Government of South Sudan and it is operating on the farm that is managed by this Organization located at Jebel Lado some few kilometers North of Juba City.

### 4.4 Data Collection

Questionnaires were constructed and used to collect the cost parameters pertinent to variable costs for 10 tractor models. The questionnaire seek the data related to both tractors characteristic and economic cost which include manufacturing year, the purchase price, the number of operating years, the use of a tractor in hours, the cost of repair and maintenance (R&M), the cost of fuel, the cost of oil, labor cost in addition to the age of a tractor. The questionnaires were administered by four research assistants who were students at the Department of Agricultural Engineering of the University of Juba and they underwent a one-day training at the Department on data collection. The questionnaires were tested at the National Ministry of Agriculture's farm which is located at Rajaf South of Juba. 169 questionnaires were administered of which 70 were used for collecting data on Belarus800, 40 on MF375, 40 on JD5503, 6 MF385, 2 JD5510, 1 JD5425, 3 Mahindra800, 2 Mahindra705DI, 2 Sonalika DI-90, and 3 Sonalika DI-75. from the (National Ministry of Agriculture's farm, Jubek State's Ministry of Agriculture farm, LONAGRO South Sudan LTD in Juba, the Borlaug Institute, kolye Development Association, National Police Service's farm, National Prison Police's farm, National Wild Life's farm, and the farm of the Canadian Economic Development Assistance for South Sudan (CEDASS).

For all the farms surveyed except the Canadian Economic Development Assistance for South Sudan, farm tractors are used for land preparation operation only.

The total accumulated costs of repair were computed as the percentage of the current purchase price of the implement, since the costs of maintenance and repair always change at about the identical rate as new purchase price.

The costs of repair are the expenses for labour and spare parts for installing replaced parts after the failure of a part and reconditioning parts that are renewable as a result of wear. The expected yearly cost of repair for any implement is highly uncertain (William Edwards, 2015).

## 4.5 Parameters Computation

### 4.5.1 Fuel Cost Computation

The annual cost of fuel was calculated, the mean annual cost of fuel was computed and the calculation of accumulated fuel cost which is the summation of mean annual fuel costs for the age of a tractor was also calculated by using equations [3.2] and [3.3] which are shown in chapter three.

### 4.5.2 Oil Cost Computation

Similarly, annual oil cost was recorded, the mean annual oil cost was also calculated and finally, the accumulated oil cost which is the summation of the mean annual oil cost was calculated for the years of operation of a tractor through the use of equations [3.2] and [3.4] shown in chapter three above. The oil cost includes cost of brake oil, engine oil, and hydraulic oil.

### 4.5.3 The Computation of the Cost of Repair and Maintenance

The annual cost of Repair and Maintenance (R&M) which includes the costs of filters replacement, greasing, spare parts, tire replacement and workmanship were recorded. The annual cost of repair and maintenance was calculated based on the market prices of spare parts, grease, filters, tire replacement and workmanship using equation [3.1] shown in chapter three above.

The mean yearly costs of maintenance and repair for every group of the ten tractor models studied was calculated, the accumulated costs of R&M were computed by addition of the mean yearly costs of maintenance and repair over years for every group of the selected tractor models (Ward *et al.*, 1985). After that, the accumulated costs of maintenance and repair were demonstrated as a percentage of a buying (purchase) price.

### 4.5.4 Labour (Operator) Cost Computation

The annual operator cost for all tractor models was calculated for the number of years of operation of each tractor model then the mean annual operator cost was calculated followed by the calculation of the accumulated operator cost which is the summation of the mean annual operator cost.

### 4.5.5 The Computation of the annual hours of use

The yearly hours of utilization for every tractor model was computed then the mean yearly hours of utilization of every age group was computed. The accumulated hours of utilization were also computed by addition of the mean yearly hours of utilization which was computed on the basis of effective operating hours of the tractor till the last year of the age for the selected tractor model (Ward *et al*., 1985).

### 4.5.6 Variable Cost Computation

The annual variable cost which includes, annual R&M cost, annual oil cost, annual operator (labour) cost, and annual fuel cost were recorded. Then the mean annual variable cost for each group of the ten tractor models surveyed was computed followed by the computation of the accumulated variable cost which was done by summation of the mean annual variable costs over years for each group of the selected tractor models. The accumulated variable cost was then presented as a percentage of purchase (list) price.

### 4.6 Questionnaires Analysis:

Statistical analysis was performed by using the statistical analysis software called (IBM SPSS Statistics 20). Using this software, a correlation regression analysis was performed on the collected data to find the correlation regression relations ($R^2$) between the accumulated variable cost as percentage of purchase price and the accumulated operating hours.

Power $y = ax^b$, exponential $= ae^{bx}$, polynomial $y = ax^2 + bx - c$, logarithmic $a\ln(x) - b$ and Linear $y = ax - b$ regression types together with their coefficient of correlation were all evaluated (Keshavarzpour, 2011).

### 4.7 Modeling and Statistical Analysis

The data collected were modelled in such a way that the accumulated variable costs as percentage of purchase price was considered as a dependent variable because its value depends on the operating hours and thus was plotted on Y-axis, whereas the accumulated operating hours in hours was regarded as an independent variable and was labelled on X-axis.

The relationship between the accumulated hours of use and the accumulated variable cost as percentage of list (purchase) price for the ten models of tractor was represented by carrying out the correlation regression analysis on the data.

The correlation regression method of statistic was used to analyze the collected data and to represent the correlation relationship between the (accumulated variable cost as percentage of purchase price) and the (accumulated operating hours).

The following mathematical regression models of Power $y = ax^{b,}$ exponential $y = ae^{bx}$, polynomial $y = ax^2 + bx - c$, logarithmic $y = a\ln(x) - b$ and Linear $y = ax – b$ together with their coefficients of correlation were all evaluated (Keshavarzpour, 2011).

# 5 RESULTS AND DISCUSSIONS

## 5.1 Preamble:

This chapter contains the cost parameters pertinent to the variable cost which include the operator cost, cost of Repair and Maintenance (R&M), oil cost and the fuel cost, their numerical value and their percentage share to the total variable cost as well as their graphical representation. It contains the accumulated variable cost as the percentage of list price and the accumulated hours of operation per each year of operation. It also contains the results of the regression analysis performed, the variable cost mathematical models developed for the ten tractor models studied, the coefficients of correlation ($R^2$) and the comparison of the ten cost models developed by this study.

## 5.2 Pertinent parameters

Table 5.1 shows the pertinent parameters, studies done by different researchers and the year of study.

**Table 5-1 Pertinent Parameters, Studies and Researchers**

| **Pertinent Parameters** | **Study** | **Author** |
|---|---|---|
| R&M Cost | Tractor repair and maintenance cost in Sudan- I: Development of a standard model. AMA, Agricultural Mechanization in Asia, Africa and Latin America. Impact Factor: 0.01. | Ahmed *et al.* (2016). |
| | Estimation of repair and maintenance cost of a tractor base on HP and Working hours: Case study of Sudan. 1:1 Journal of Environmental and Agricultural Sciences. ISBN: 2313. 8629. | Abdallah *et al*. (2014). |
| | A comparison of ASAE estimated tractor and Combine Repair and Maintenance Costs to Actual Repair | Gliem *et al*. (1989). |
| | Repair and Maintenance cost data for Agricultural Equipment. ASAE Paper. No. 91-1531. | Rotz and Bowers. (1991). |
| | Prediction of repair and maintenance costs of John Deere 4955 tractors in Ardabil Province, Iran. World Applied Science Journal. Impact Factor: 0.23. | Niari *et al*. (2016). |

| | | |
|---|---|---|
| | Determination of a Mathematical Model to Predict the Repair and Maintenance cost of three Models of farm tractors in Iran, Msc Thesis, Faculty of Agricultural Engineering and Technology, Department of Agricultural Machinery Engineering, University of Tehran, Iran. | Sharifi, A. (1994). |
| | Determination of a Mathematical Model to Predict the Repair and Maintenance cost of three Models of Farm Tractors in Parsabad Agro-industry Co., Msc Thesis, Department of Agricultural Machinery Engineering, university of Tabriz, Iran. | Taheri, M. R. (1998). |
| | Modelling Variable Cost of Tractors: Case Study of Ten Tractor Models in Juba – Southern Sudan | Gitau *et al*. (2018) |
| Fuel Cost | Fuel Required for Field Operation. | Mark Hanna. (2005). |
| | William Edwards. (2015). Estimating Farm Machinery Costs PM710 (A3 – 29) – Iowa State University – Extension and Outreach. | William Edwards. (2015). |
| Oil Cost | William Edwards. (2015). Estimating Farm Machinery Costs PM710 (A3 – 29) – Iowa State University – Extension and Outreach. | William Edwards. (2015). |
| Labour Cost | Fieldwork Days in Iowa | Mark Hanna. (2014). |
| | William Edwards. (2015). Estimating Farm Machinery Costs PM710 (A3 – 29) – Iowa State University – Extension and Outreach. | William Edwards. (2015). |

### 5.3 Determination of the variable costs of the ten tractor models

The variable cost of the ten models of tractor was determined from these following cost parameters: cost of fuel, cost of oil, cost of labor and cost of repair and maintenance which include (spare parts, filters, tires, grease, and workmanship). The variable cost of the ten tractor models studied are shown in the following Table (5.2).

Lack of refineries in S. Sudan could be the cause of high fuel cost. Also, most of the tractors in S. Sudan were old and therefore their consumption would be higher than the consumption of a new tractor.

**Table 5-2 Mean Annual Variable Cost in USD and as Percentage Share of the Total Variable Cost for the Ten Tractor Models Studied.**

| | Labour Cost | | R&M Cost | | Oil Cost | | Fuel Cost | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ($) | % | ($) | % | ($) | % | ($) | % | ($) | % |
| **Belarus800** | 291 | 21.6 | 538 | 39.9 | 75 | 5.6 | 446 | 33.0 | 1,350 | 100.0 |
| **MF375** | 311 | 25.2 | 441 | 35.8 | 61 | 5.0 | 419 | 34.0 | 1,232 | 100.0 |
| **JD5503** | 320 | 26.0 | 438 | 35.5 | 55 | 4.5 | 420 | 34.1 | 1,233 | 100.0 |
| **MF385** | 382 | 25.5 | 524 | 34.9 | 75 | 5.0 | 519 | 34.6 | 1,500 | 100.0 |
| **JD5510** | 713 | 26.6 | 1,014 | 37.8 | 110 | 4.1 | 845 | 31.5 | 2,682 | 100.0 |
| **JD5425** | 831 | 26.6 | 1,167 | 37.3 | 128 | 4.1 | 999 | 32.0 | 3,125 | 100.0 |
| **Mahindra 8000** | 258 | 20.3 | 501 | 39.4 | 127 | 10.0 | 387 | 30.4 | 1,273 | 100.0 |
| **Mahindra 705DI** | 290 | 21.7 | 504 | 37.6 | 79 | 5.9 | 466 | 34.8 | 1,339 | 100.0 |
| **Sonalika DI-90** | 275 | 20.2 | 540 | 39.6 | 131 | 9.6 | 417 | 30.6 | 1,363 | 100.0 |
| **Sonalika DI-75** | 344 | 25.2 | 487 | 35.7 | 62 | 4.5 | 472 | 34.6 | 1,365 | 100.0 |

Figures 5.1 to 5.4 show the comparison of the mean annual operator (labour) costs, mean annual Repair and Maintenance (R&M) costs, mean annual oil costs, and the mean annual fuel costs as shown in the above table among the ten tractor models studied.

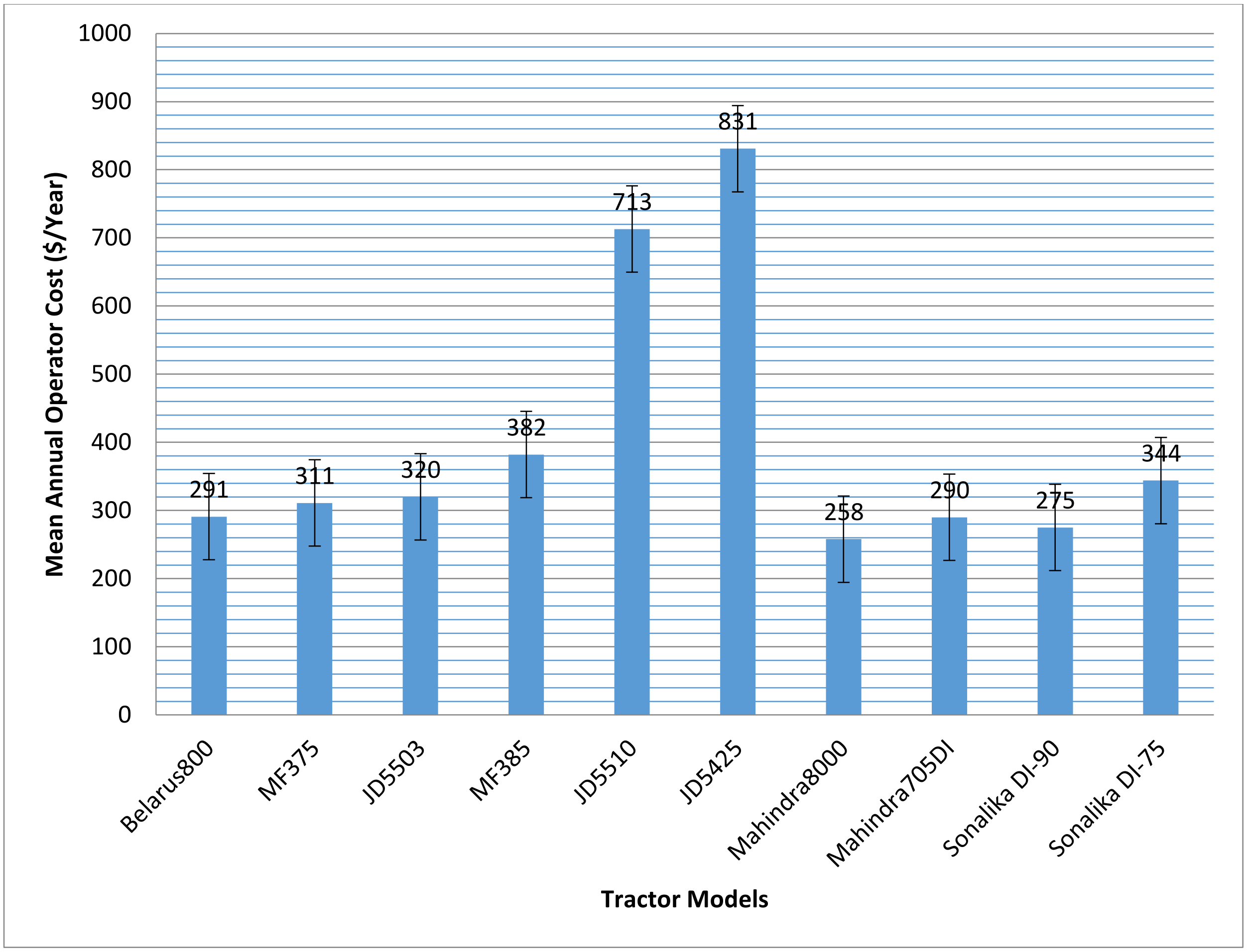


**Figure 5-1 The Mean Annual Operator Cost for the Ten Tractor Models.**

Figure 5.1 shows the mean annual operator costs for the ten tractor models as it is shown in the second column of Table 5.2. The mean annual operator cost for JD5425 and JD5510 models were the highest among the rest and this could be due to the area of the farm where these two tractor models have been operating which is an area of 147 hectares or it could be due to the age of operation of these two tractor models which is eight years each. This high mean annual operator cost could also be because of the scarcity of tractor operators in the area of the study thus resulting into high pay rate for tractor operators.

The least mean annual operator costs recorded were for Mahindra8000 and Sonalika DI-90 respectively which could be due to the area of the farm where these two tractor models have been operating which is 25 hectares or it could be due to the relatively low operator cost in this particular area.

In a study titled (Modeling of Repair and Maintenance Costs of John Deere 4955 Tractors in Iran) done by Niari *et al*. (2012), it was found that the cost of tractor operator had the third highest percentage share compared to other cost parameters. The resulted values of operator cost for JD-4955 was 23.5%.

In a study titled (Predicting Repair and Maintenance Costs of Agricultural Tractors in Nigeria) carried out by Obinna *et al*. (2016) it was found that the cost of tractor operator had the third highest percentage share compared to other cost parameters. The resulted values of operator cost were 18.95%.

These findings are similar to the findings of this study which found the operator cost to be the third highest in term of percentage share to the total variable cost as shown in Table (5.2).

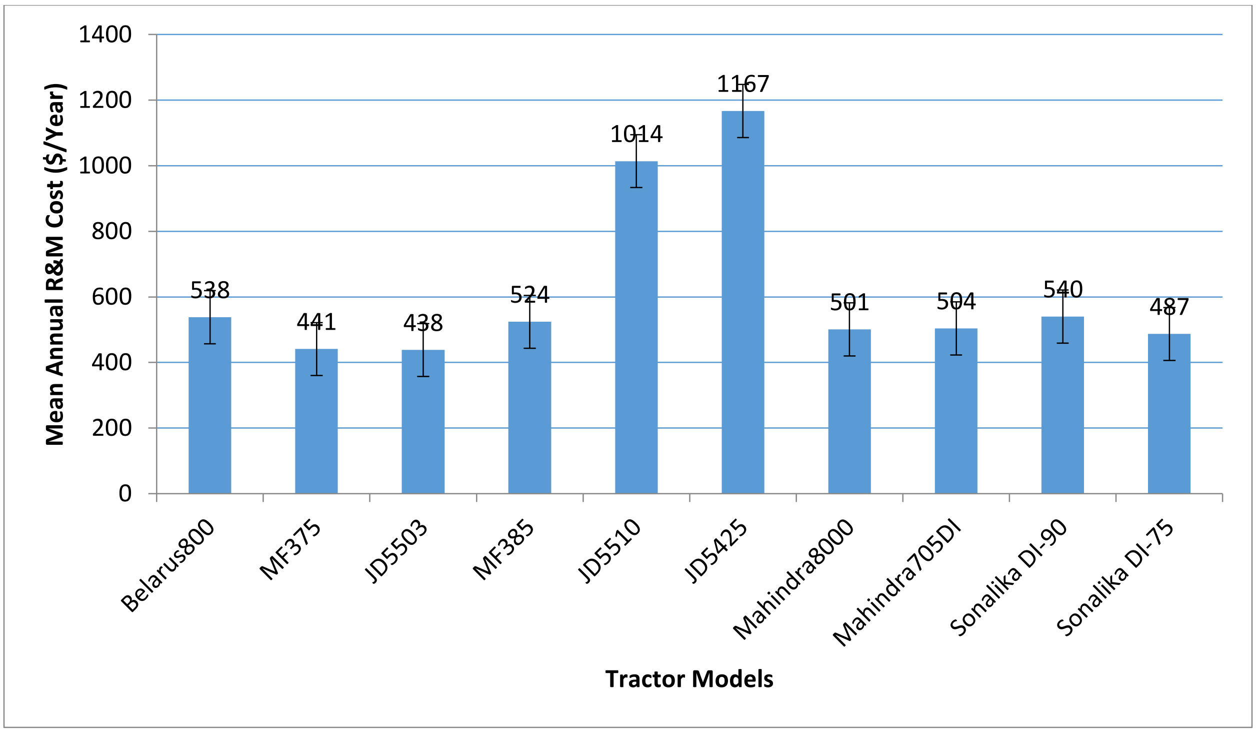


**Figure 5-2 The Mean Annual Cost of Repair and Maintenance of the Ten Models of Tractor.**

Figure 5.2 shows the mean annual costs of repair and maintenance (R&M) for the ten tractor models. As shown above in the third column of Table 5.2. The mean annual costs of repair and maintenance is the mean annual costs for the spare parts, mean annual costs for replacing oil and fuel filters, mean annual costs of grease, mean annual costs of workmanship, in addition to the mean annual costs for replacing tires. These costs were high for JD5425 and JD5510 respectively which could be due to the area of the farm where these two tractor models have been operating which is 147 hectares or it could be due to their age of operation which is eight years each or it could be due to the filters' replacement time interval or it could be due to some technical faults that are operator oriented such as when a tractor is operated by an operator who is of less experience which could cause frequent break down or it could also be due to their operating conditions such as operating on a stony soil.

The least mean annual costs of repair and maintenance recorded were for JD5503 and MF375 respectively and this could be because of the area of the farm where these two tractor models have been operating which is 25 hectares or it could also be due to the filter's replacement time interval.

In the study titled (Repair and Maintenance Cost Analysis of John Deere 5403 Tractor in the Gambia) done by Théodore *et al.* (2017), it was observed that the cost of tractor spare parts replacement had the highest percentage share compared to other cost parameters. The resulted values of spare parts cost for JD-5403 was 52%. The large share of tractor spare parts cost can be due to numerous factors such as making use of substandard tractor spare parts and unsuitable use of tractor by inexperience operators.

In another study titled (Modeling of Repair and Maintenance Costs of John Deere 4955 Tractors in Iran) done by Niari *et al*. (2012), it was also found that the cost of tractor spare parts replacement had the highest percentage share compared to other cost parameters. The resulted values of spare parts cost for JD- 4955 was 69.3%. This is similar to the findings of this study which found the R&M cost to be the Highest in term of percentage share to the total variable cost.

Result of the study done by Abubakar *et al.* (2013). titled (Determination of Repair and Maintenance Cost for MF375 Tractor: A Case Study in Kano Metropolis, Nigeria) showed that the cost of tractor spare parts replacement had the highest percentage share (54.2%).

According to the study titled (Determination of optimum life for MF285 tractor based on repair and maintenance costs: A case study in center region of Iran) carried out by Bakht *et al*. (2008), it is found that tractor spare parts cost with 66.7 percent have the most share compared to other costs. The large share of tractor spare parts cost can be due to numerous factors such as making use of substandard tractor spare parts, unsuitable use of tractor, novice driver, undesirable repairs, and making use of tractor more than its optimum life that can be seen as the most important factor.

In the study titled (Predicting Repair and Maintenance Costs of Agricultural Tractors in Nigeria) carried out by Obinna *et al*. (2016), it was observed that the cost of tractor spare parts replacement had the highest percentage share compared to other cost parameters. The resulted values of the cost of spare parts was 57.77%.

These findings are similar to the findings of this study which found the R&M cost to be the Highest in term of percentage share to the total variable cost as shown in Table (5.2).

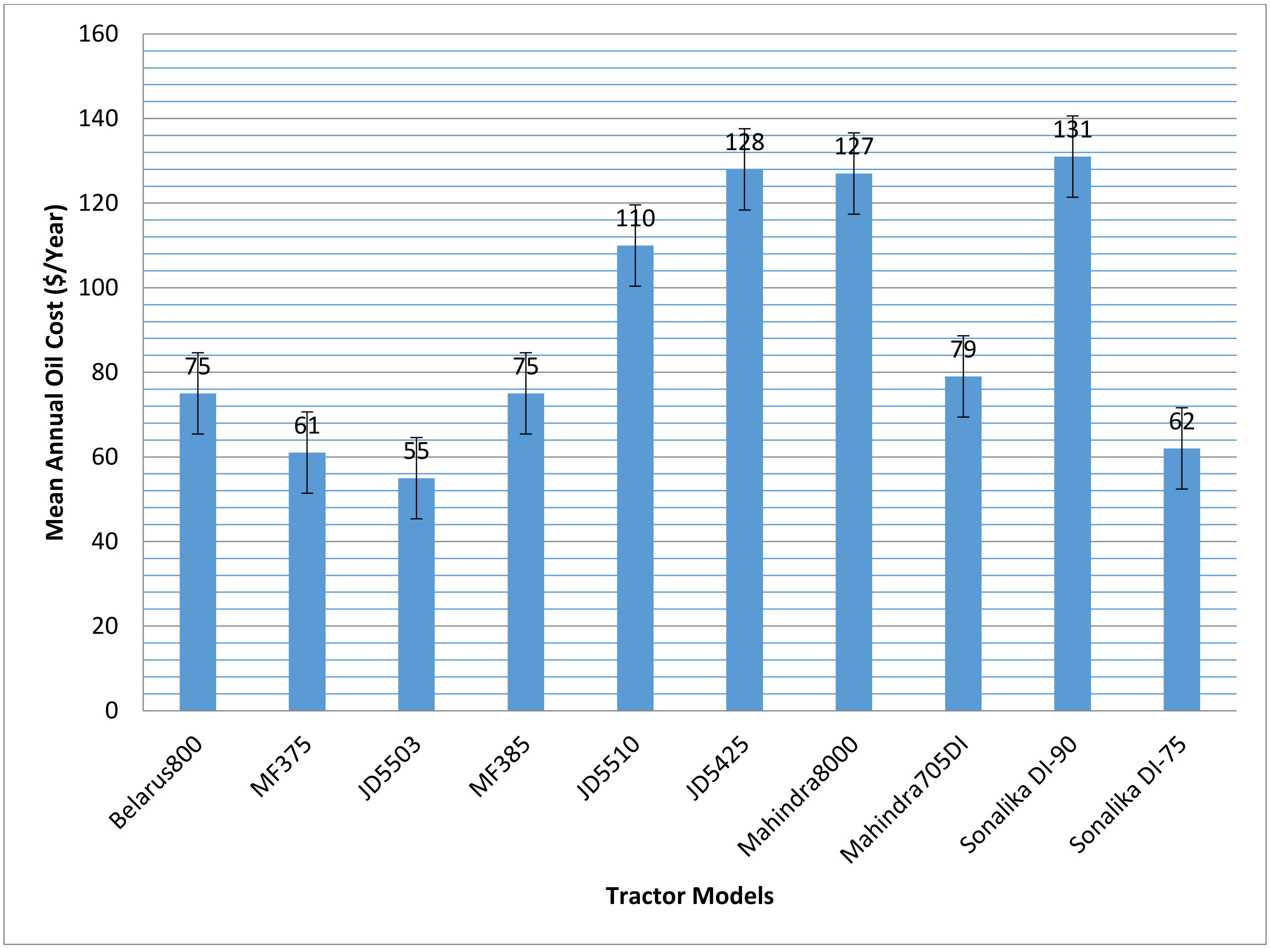


**Figure 5-3 The Mean Annual Oil Cost for the Ten Tractor Models.**

Figure 5.3 shows the mean annual costs of oil for the ten tractor models. As shown above in the fourth column of Table 5.2. The mean annual oil costs involve the mean annual costs of brake oil, hydraulic oil, and engine oil. As it is seen, the mean annual costs of oil for Sonalika DI-90 and JD5425 were the highest among the rest and this could be due to the high prices of oil for these two tractor models or due to the age of operation of these two tractor models which is nine and eight years respectively.  This high mean annual cost of oil could also be because of the area of the farm on which this two tractor models have been operating which is an area of 147 hectares or it could also be due to the short oil replacement interval.

The least mean annual costs of oil were recorded for JD5503 and MF375 respectively which could be due to the area of the farm on which these two tractors have been operating which is 25 hectares or could be due to the relatively low prices of oil for these two tractor models or it could also be due to their age of operation which is 3 and 2 years respectively.

In the study titled (Repair and Maintenance Cost Analysis of John Deere 5403 Tractor in the Gambia) which was carried out by Théodore *et al.* (2017), it was observed that the least cost was obtained from oil and fuel filters parameter valuing 3% for JD-5403.

In another study titled (Modeling of Repair and Maintenance Costs of John Deere 4955 Tractors in Iran) done by Niari *et al*. (2012), it was also found that the cost of tractor lubricants or oil had the lowest percentage share compared to other cost parameters. The resulted values of oil cost for JD- 4955 was 7.2%.

Result of the study done by Abubakar *et al.* (2013), titled (Determination of Repair and Maintenance Cost for MF375 Tractor: A Case Study in Kano Metropolis, Nigeria) showed that the cost of tractor lubrication oil had the lowest percentage share (10.3%).

In another study titled (Predicting Repair and Maintenance Costs of Agricultural Tractors in Nigeria) carried out by Obinna *et al*. (2016), it was also found that the cost of tractor lubricants or oil had the lowest percentage share compared to other cost parameters. The resulted values of the cost of oil was 2.87%.

These findings are similar to the findings of this study which found the oil cost to be the lowest in term of percentage share to the total variable cost as shown in Table (5.2).

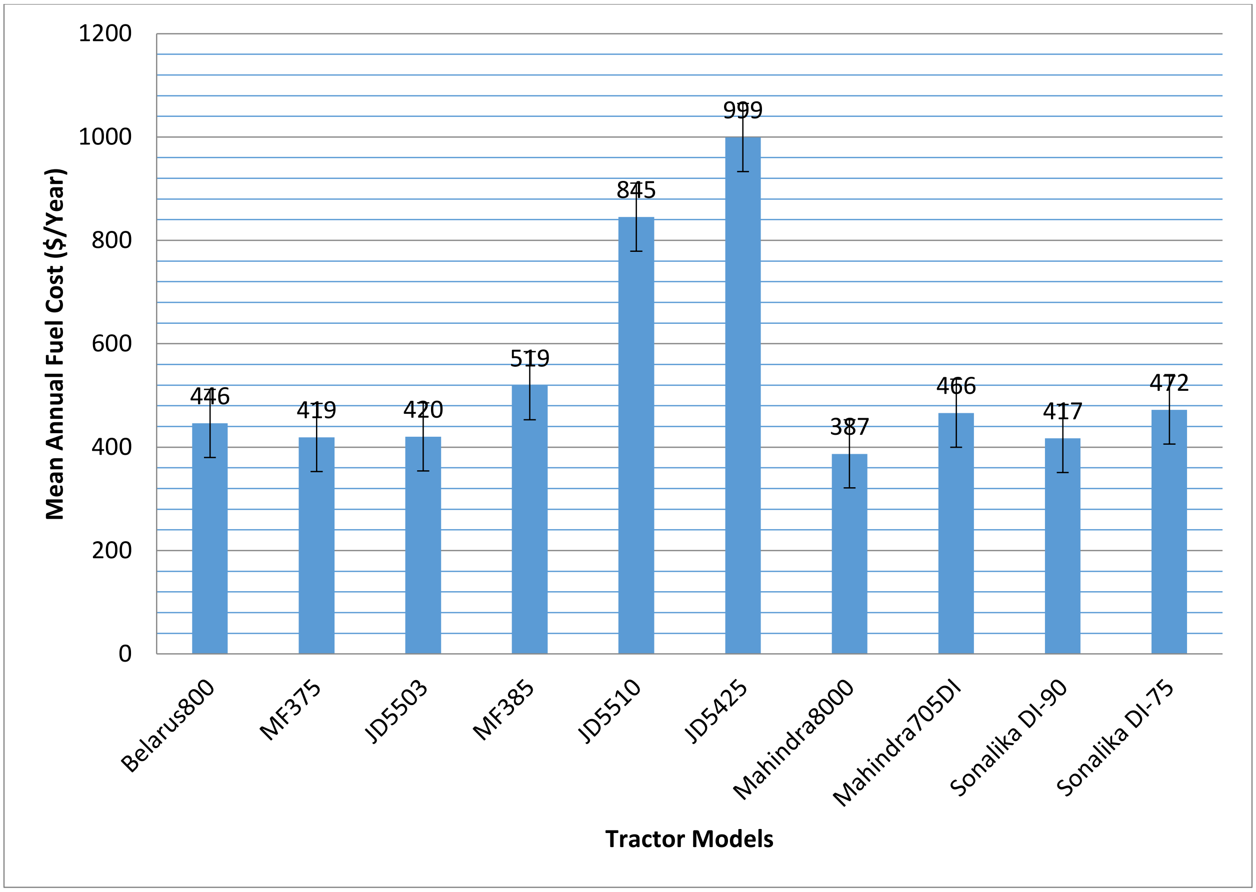


**Figure 5-4 The Mean Annual Fuel Cost for the Ten Tractor Models.**

Figure 5.4 shows the mean annual fuel costs for the ten tractor models. As shown in the fifth column of Table 5.2. As it is seen, the mean annual fuel costs for JD5425 and JD5510 tractor models were found to be the highest among the rest and this could be due to the area of the farm where these two tractor models have been operating which is 147 hectares each. This high mean annual cost of fuel could be due to the high price of fuel in the local market because though the country is an oil producing yet it does not have an oil refinery and as a result the fuel is imported and sometimes due to its scarcity at fuel stations which force the farmers to buy fuel from black market. In addition to that the government partially lifted the fuel subsidy which led to increase in fuel prices or it could also be due to the age of operation of these two tractor models which is eight years for each model.

The least mean annual costs of fuel recorded were for Sonalika DI-90 and MF375 respectively and this could be due to the area of the farm where these two tractor models have been operating which is 25 hectares each or it could also be due to their age of operation.

Result of the study done by Abubakar *et al.* (2013), titled (Determination of Repair and Maintenance Cost for MF375 Tractor: A Case Study in Kano Metropolis, Nigeria) showed that the cost of tractor fuel had the second highest percentage share (20.4%). Again this conclusion is similar to the findings of this study which found the fuel cost to be the second highest cost in term of percentage share to the total variable cost as shown in Table (5.2).

Another study titled (Predicting Repair and Maintenance Costs of Agricultural Tractors in Nigeria) carried out by Obinna *et al*. (2016), showed that the cost of tractor fuel had the second highest percentage share (20.24%). These findings are similar to the findings of this study which found the fuel cost to be the second highest cost in term of percentage share to the total variable cost as shown in Table (5.2).

### 5.4 The breakdown of the systems of tractors and the distribution of the variable cost

The results obtained from the analysis performed on the data indicated that the accumulated variable cost of all the ten models of tractor studied in general increased as the age of operation of a tractor increased, but the increase rate differs from one parameter to another. However, the accumulated variable cost for most tractor models studied showed that the variable costs start to increase drastically from year 4 and above as is shown in the following table.

**Table 5-3 The Accumulated Variable Cost in USD/Year of Operation**

| Tractor Model | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|
| **Belarus800** | - | - | - | - | - | - | - | 1,260 | 2,700 |
| **MF375** | - | - | - | - | - | - | - | 1,137 | 2,463 |
| **JD5503** | - | - | - | - | - | - | 1,088 | 2,320 | 3,698 |
| **MF385** | - | - | 1,203 | 2,590 | 4,075 | 6,265 | 7,490 | 9,300 | 10,500 |
| **JD5510** | - | 1,663 | 3,627 | 5,893 | 8,461 | 11,331 | 14,504 | 17,978 | 21,453 |
| **JD5425** | - | 1,696 | 3,736 | 6,112 | 8,828 | 11,885 | 17,000 | 20,800 | 25,000 |
| **Mahindra8000** | - | 880 | 1,900 | 3,050 | 4,240 | 5,500 | 6,940 | 8,540 | 10,180 |
| **Mahindra705DI** | - | 978 | 2,060 | 3,244 | 4,532 | 5,922 | 7,416 | 9,013 | 10,712 |
| **Sonalika DI-90** | 927 | 1,962 | 3,107 | 4,360 | 5,723 | 7,194 | 8,775 | 10,464 | 12,263 |
| **Sonalika DI-75** | 945 | 1,995 | 3,150 | 4,410 | 5,775 | 7,245 | 8,820 | 10,500 | 12,285 |

Table (5.4) shows the accumulated variable cost, the mean annual accumulated variable cost and their values per area for the ten tractor models studied.

**Table 5-4 The Accumulated Variable Cost, the Mean Annual Accumulated Variable Cost and Their Values per unit Area.**

| Tractor Model | Accumulated Variable Cost | Mean Annual Accumulated Variable Cost | Accumulated Variable Cost Per Hectare | Mean Annual Accumulated Variable Cost Per Hectare |
|---|---|---|---|---|
| **Belarus800** | 2,700 | 1,350 | 60 | 30 |
| **MF375** | 2,463 | 1,232 | 45 | 23 |
| **JD5503** | 3,698 | 1,233 | 57 | 19 |
| **MF385** | 10,500 | 1,500 | 198 | 28 |
| **JD5510** | 21,453 | 2,682 | 146 | 18 |
| **JD5425** | 25,000 | 3,125 | 170 | 21 |
| **Mahindra8000** | 10,180 | 1,273 | 407 | 51 |
| **Mahindra705DI** | 10,712 | 1,339 | 429 | 54 |
| **Sonalika DI-90** | 12,263 | 1,363 | 164 | 18 |
| **Sonalika DI-75** | 12,285 | 1,365 | 164 | 18 |

Figures 5.5 to 5.8 show the accumulated variable cost, the mean annual accumulated variable cost and their values per unit area for the ten tractor models studied.

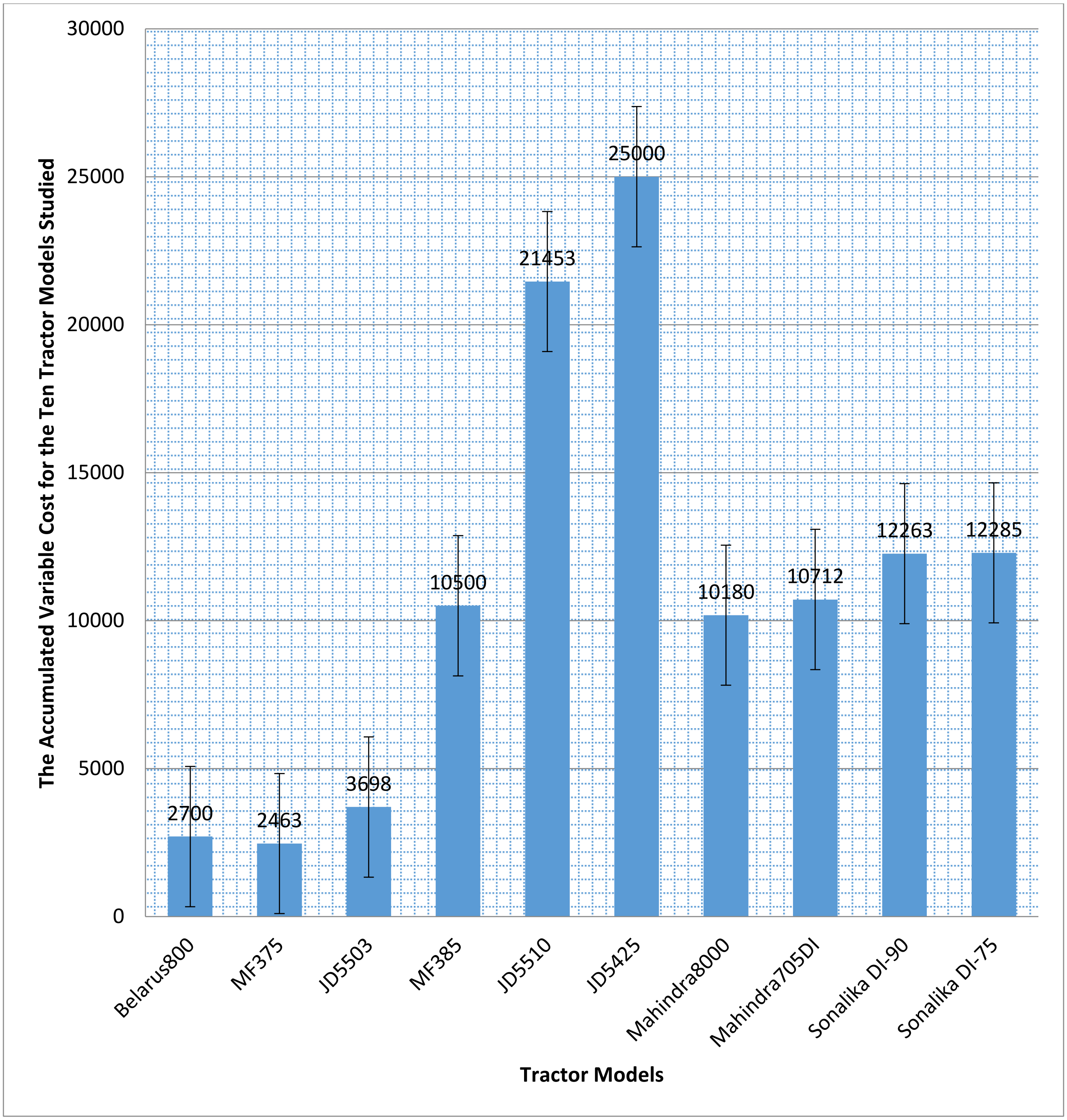


**Figure 5-5 The Accumulated Variable Cost for the Ten Tractor Models Studied.**

Figure 5.5 shows the accumulated variable cost for the ten tractor models studied and for their age of operation as shown in the second column of Table 5.3. As it is clear from the figure, the highest accumulated variable cost was recorded for JD5425 followed by JD5510, both of them operates on the largest farm covered by this survey which has area of 3381 hectares and both of them operates for eight years. The least accumulated variable cost recorded was for MF375 followed by Belarus800.

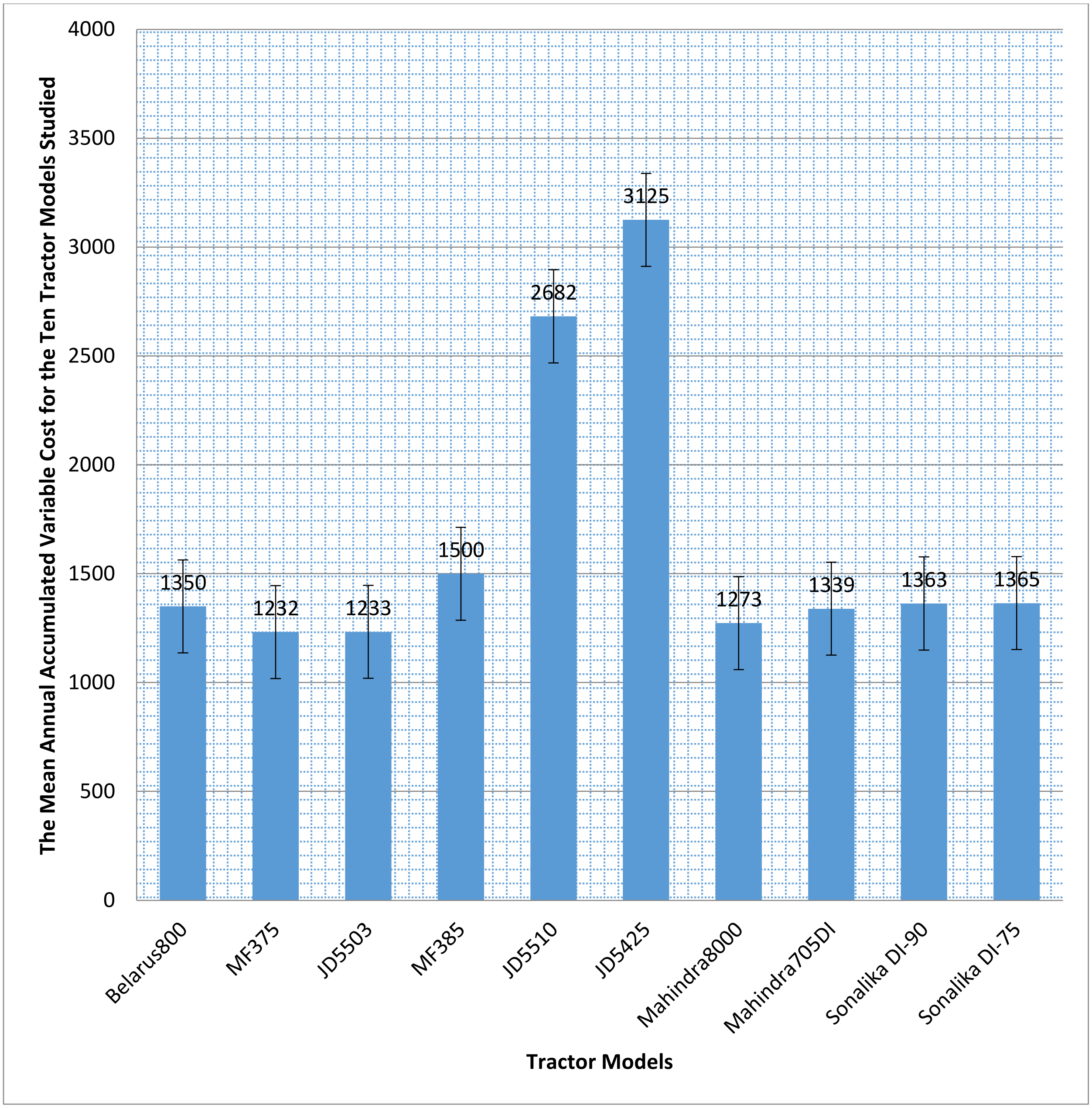


**Figure 5-6 The Mean Annual Accumulated Variable Cost for the Ten Tractor Models Studied.**

Figure shows the mean annual accumulated variable cost for the ten tractor models studied and for their age of operation as shown in the third column of Table 5.3. As it is clear from the figure, the highest mean annual accumulated variable cost recorded was for JD5425 followed by JD5510, both of them operates on the largest farm covered by this survey which has an area of 3381 hectares and both of them operates for eight years. On the other hand, the least mean annual accumulated variable cost was for MF375 followed by JD5503.

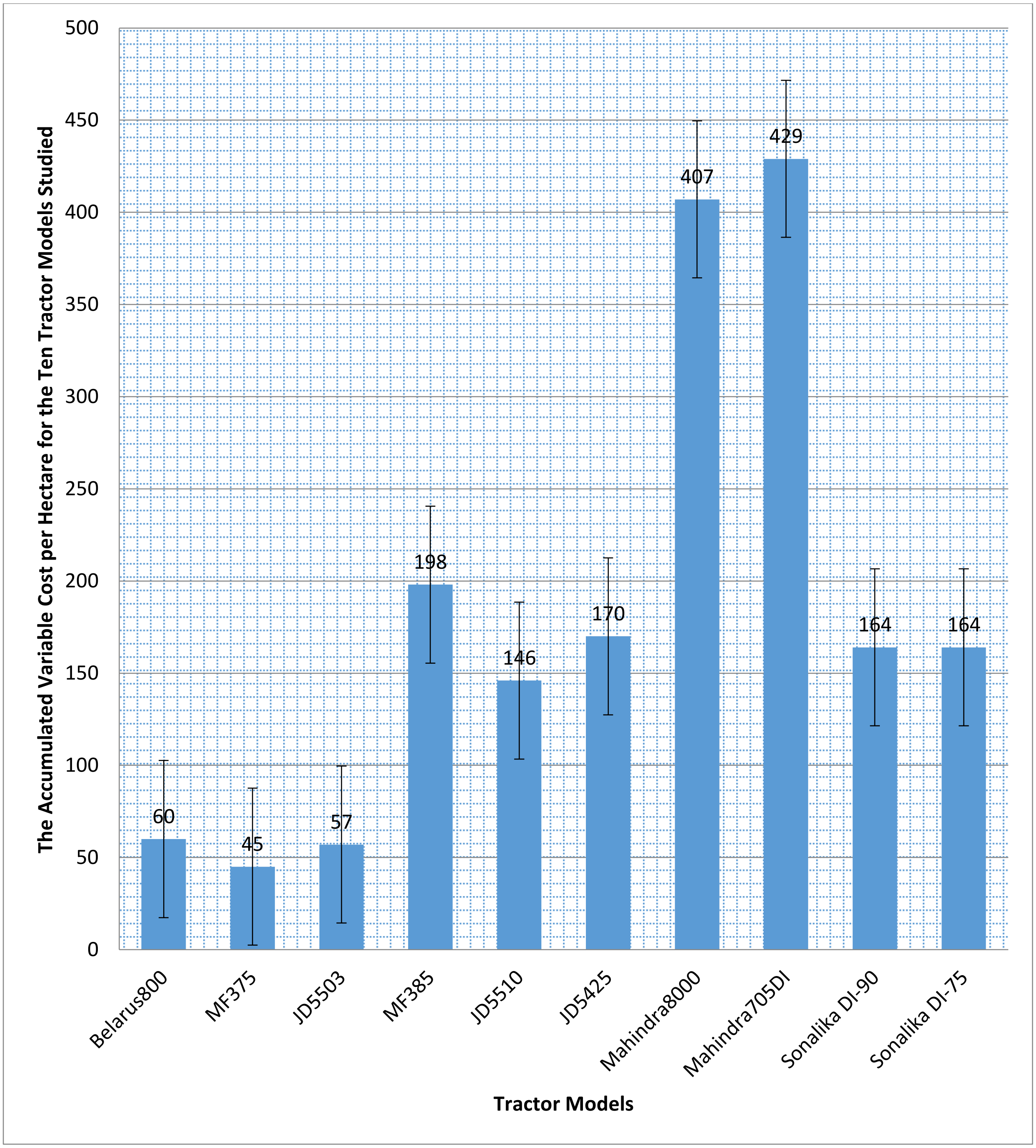


**Figure 5-7 The Accumulated Variable Cost Per Hectare for the Ten Tractor Models Studied.**

Figure shows the accumulated variable cost per hectare for the ten tractor models studied as it is in the fourth column of Table 5.3. As shown in the figure, the highest accumulated variable cost per hectare recorded was for Mahindra705DI followed by Mahindra8000 whereas the least accumulated variable cost per hectare was for MF375 followed by JD5503.

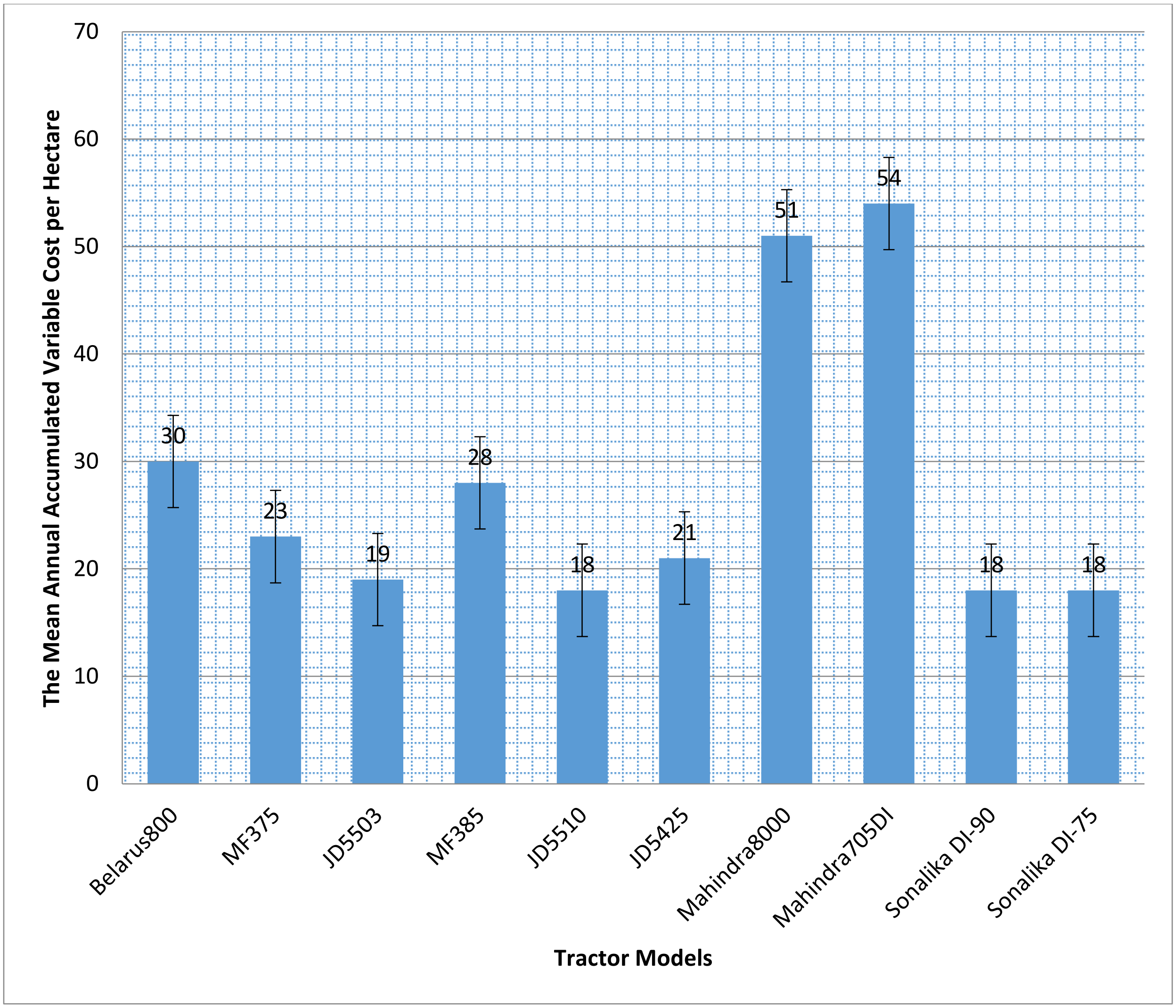


**Figure 5-8 The Mean Annual Accumulated Variable Cost per Hectare for the Ten Tractor Models Studied.**

Figure shows the mean annual accumulated variable cost per hectare for the ten tractor models studied as it is shown in the fifth column of Table 5.3. As shown in the figure, the highest mean annual accumulated variable cost per hectare was recorded for Mahindra705DI followed by Mahindra8000 whereas the least mean annual accumulated variable cost per hectare were for JD5510, Sonalika DI-90 and Sonalika DI-75 followed by JD5503.

The following figures 5.9 to 5.11 show the area in hectares of the nine farm surveyed by this study, the area in hectares operated by a single tractor owns by each one of the nine farms surveyed by this study, and the mean annual area in hectares operated by a single tractor of the ten models studied.

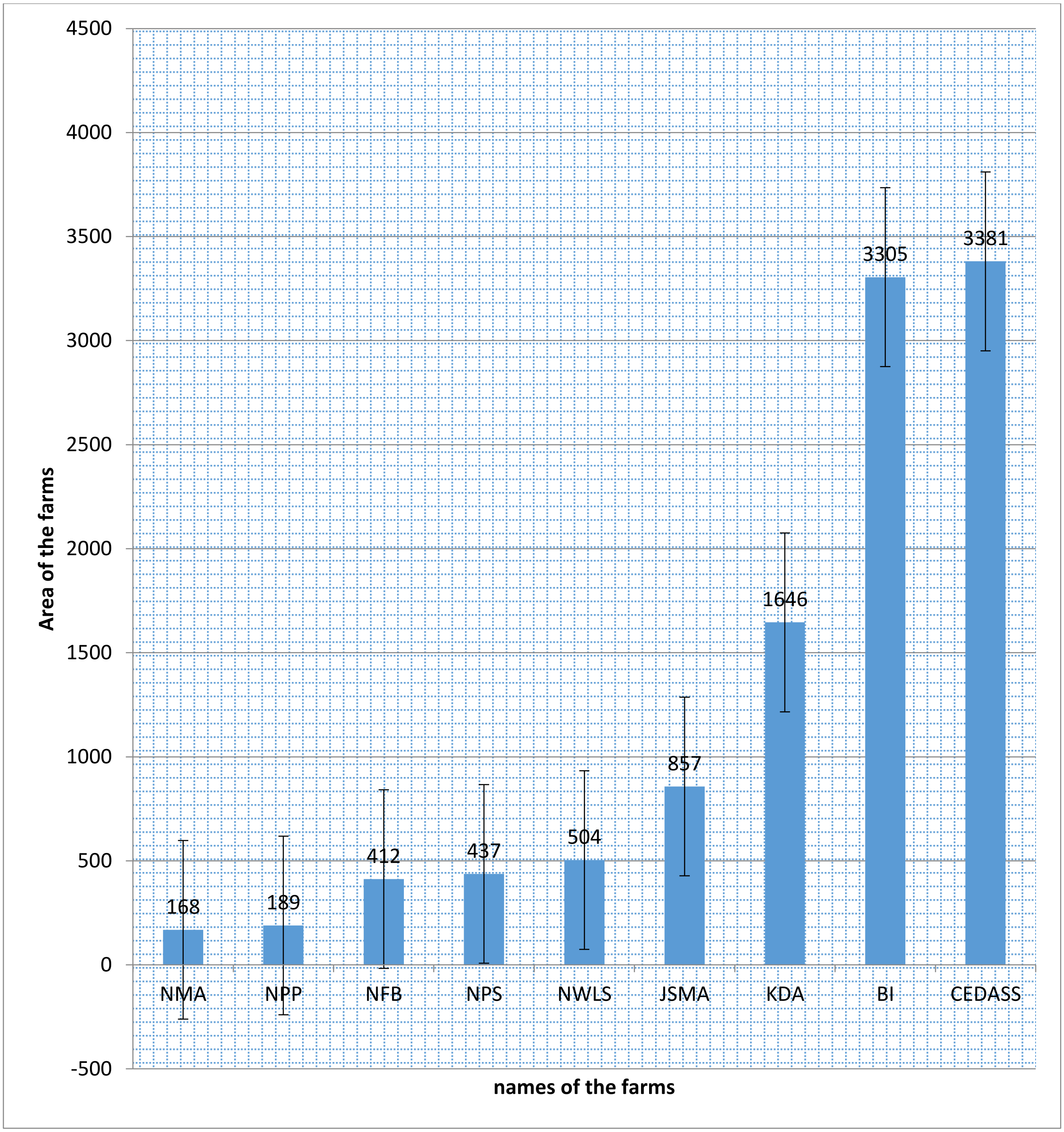


**Figure 5-9 The Area in Hectares of the Nine Farm Surveyed by this Study.**

Figure 5.9 shows the area of the farms in hectares on which the ten tractor models surveyed have been operating.

As it can clearly be seen, the largest farm is the one that belongs to the Canadian Economic Development Assistance for South Sudan (CEDASS) followed by the farm owns by the Borlaug Institute whereas the smallest farm belongs to the national fire brigade.

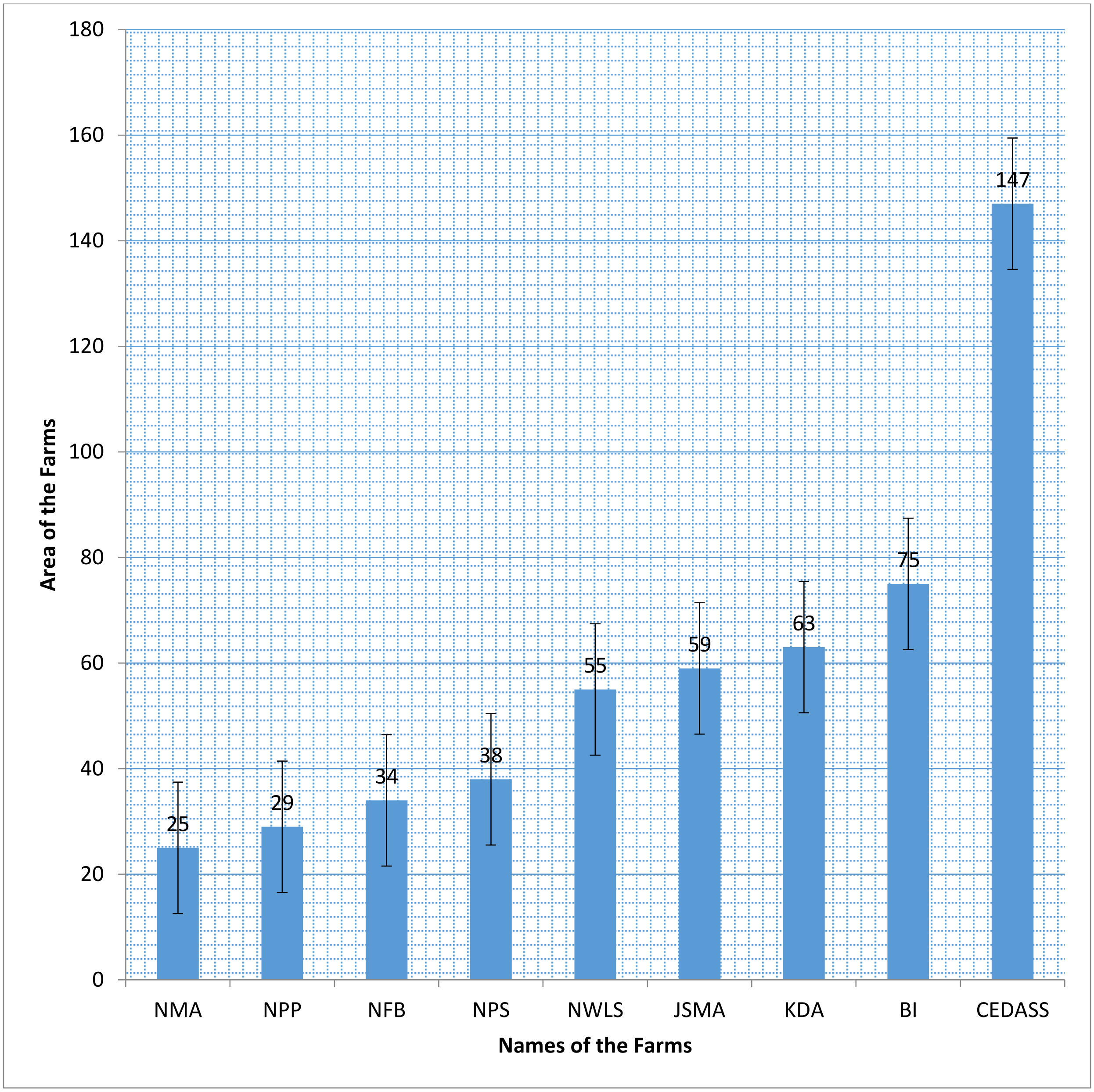


**Figure 5-10 The Area in Hectares Operated by a Single Tractor Owned by Each One of the Nine Farms Surveyed by this Study.**

Figure 5.10 shows the area in hectares operated by a tractor owned by the farms (institutions) surveyed. As it can clearly be seen, the area operated by each tractor owned by the Canadian Economic Development Assistance for South Sudan (CEDASS) was the largest compared to the area operated by every tractor owns by the rest of the institutions (farms). The area operated by each tractor owned by the national ministry of agriculture and forestry was the smallest compared to the area operated by each tractor that is own by the rest of the institutions (farms).

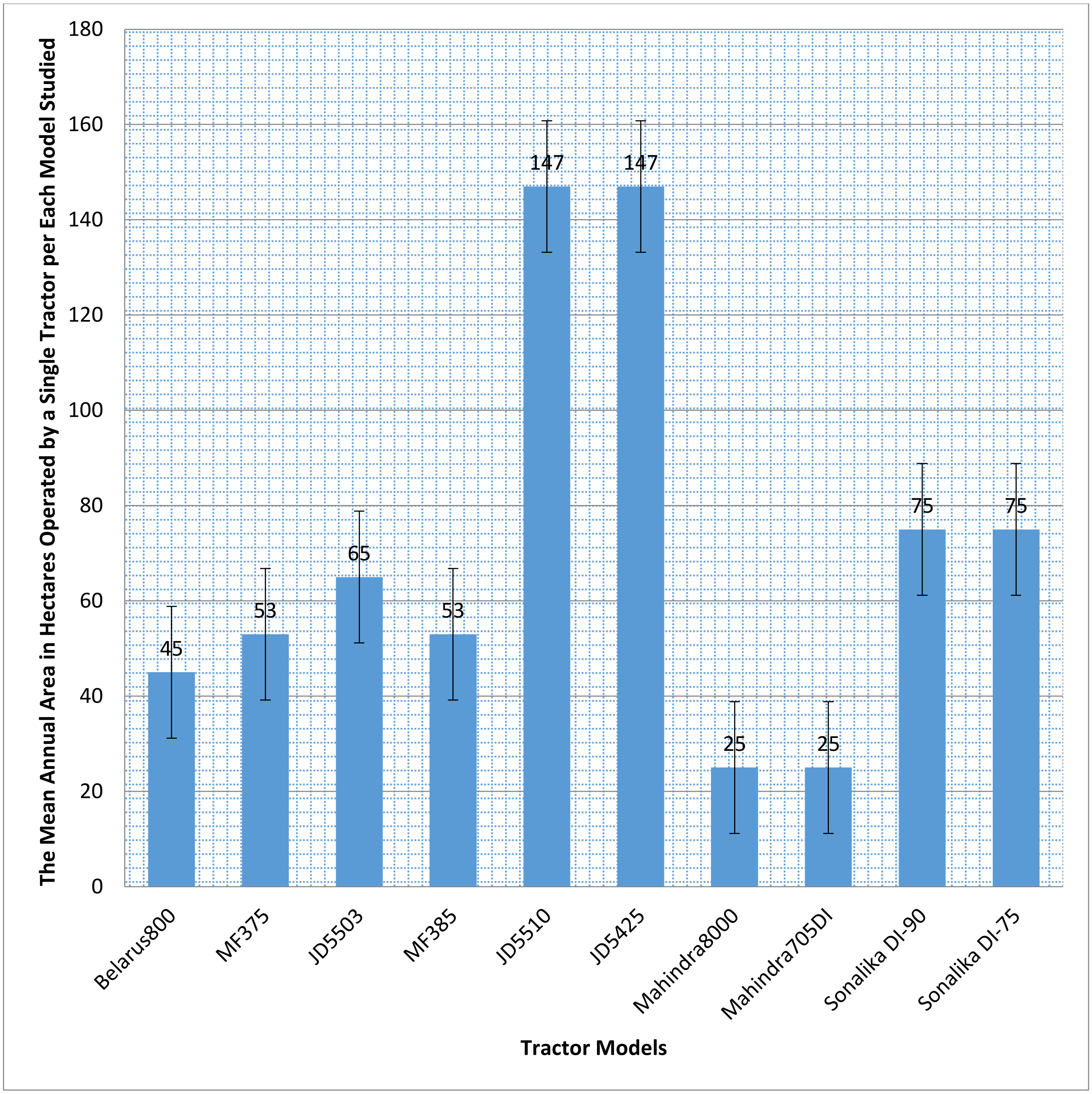


**Figure 5-11 The Mean Annual Area in Hectares Operated by a Single Tractor of the Ten Models Studied.**

Figure (5.11) shows the mean annual area in hectares operated by a single tractor for the ten tractor models studied. And as it can clearly be seen, the mean annual area operated by JD5510 and JD5425 was the biggest among all and that is because both of them are operating on the biggest farm covered by this study which is the Canadian Economic Development Association for South Sudan (CEDASS) which has an area of 3381 hectares. On the other hand, the mean annual area operated by Mahindra8000 and Mahindra705DI was the least.

### 5.5 Derivation of Variable Cost Estimate Models for all the ten models of tractor studied

Tables 5.5 & 5.6 present the result of the calculated accumulated variable costs as percentage of list price in USD and the accumulated operating hours for the ten tractor models studied. The values of the accumulated variable costs as percentage of list price in USD and the accumulated hours of operation were utilized in the process of analyzing the data and to derive the cost models.

**Table 5-5 The Accumulated Variable Cost as Percentage of List Price in USD per Each Year of Operation for the Ten Tractor Models Studied.**

| The Accumulated Variable Cost as Percentage of List (Purchase) Price | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Tractor Model** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** |
| **Belarus800** | - | - | - | - | - | - | - | 7.00 | 15.00 |
| **MF375** | - | - | - | - | - | - | - | 6.00 | 13.00 |
| **JD5503** | - | - | - | - | - | - | 7.50 | 16.00 | 25.50 |
| **MF385** | - | - | 6.50 | 14.00 | 22.03 | 33.86 | 40.49 | 50.27 | 56.76 |
| **JD5510** | - | 5.50 | 12.00 | 19.50 | 28 | 37.50 | 48.00 | 59.50 | 71.00 |
| **JD5425** | - | 5.00 | 11.00 | 18.00 | 26.00 | 35.01 | 50.07 | 61.27 | 73.64 |
| **Mahindra 8000** | - | 8.00 | 17.27 | 27.73 | 38.55 | 50.00 | 63.09 | 77.64 | 92.55 |
| **Mahindra 705DI** | - | 9.50 | 20.00 | 31.50 | 44.00 | 57.50 | 72.00 | 87.50 | 104.00 |
| **Sonalika DI-90** | 8.50 | 18.00 | 28.50 | 40.00 | 52.50 | 66.00 | 80.50 | 96.00 | 112.50 |
| **Sonalika DI-75** | 9.00 | 19.00 | 30.00 | 42.00 | 55.00 | 69.00 | 84.00 | 100.0 | 117.00 |

**Table 5-6 The Accumulated Operating Hours per Each Year of Operation for the ten tractor models studied.**

| **The Accumulated Operating Hours Per Each Year of Operation** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Tractor Model** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** |
| **Belarus800** | - | - | - | - | - | - | - | 252 | 504 |
| **MF375** | - | - | - | - | - | - | - | 238 | 476 |
| **JD5503** | - | - | - | - | - | - | 146 | 292 | 441 |
| **MF385** | - | - | 245 | 495 | 743 | 989 | 1,236 | 1,485 | 1,736 |
| **JD5510** | - | 398 | 796 | 1,193 | 1,600 | 2,000 | 2,396 | 2,798 | 3,199 |
| **JD5425** | - | 512 | 1,036 | 1,551 | 2,066 | 2,580 | 3,097 | 3,721 | 4,232 |
| **Mahindra 8000** | - | 97 | 196 | 299 | 397 | 496 | 592 | 694 | 789 |
| **Mahindra 705DI** | - | 139 | 280 | 425 | 567 | 716 | 856 | 995 | 1,137 |
| **Sonalika DI-90** | 107 | 213 | 320 | 430 | 561 | 671 | 781 | 896 | 998 |
| **Sonalika DI-75** | 124 | 248 | 371 | 497 | 622 | 746 | 871 | 998 | 1,126 |

### 5.6 The development of the estimate model of the Variable costs

Statistical analysis was performed by using the statistical analysis software called (IBM SPSS Statistics 20). Using this software, a regression analysis was performed to find the correlation regression relations ($R^2$).

The following models of exponential $y = ae^{bx}$, logarithmic $y = a\ln(x) - b$, linear $y = ax - b$, power $y = ax^b$ and polynomial $y = ax^2 + bx – c$ together with their respective coefficients of correlation were all evaluated.

The relationship between the accumulated hours of use and the accumulated variable cost as percentage of list price for the ten models of tractor studied was represented by carrying out the correlation regression analysis on the data and it was observed that among the five mathematical models evaluated, the polynomial model showed the highest coefficient of correlation ($R^2$) followed by the power model.

However, the power model $y = ax^b$, where y is the accumulated variable cost as the percentage of purchase price, x is the accumulated hours of use, a and b are the constants (estimate parameters) was the best fit for the ten tractor models studied and accounted for 99% of the observed variations in accumulated variable costs as percentage of list price for each of the ten tractor models studied, in addition to that the power model has been found to be the best for estimating variable cost by different researchers including (Ahmed *et al*., 2016; Abdallah *et al.*, 2014; Abubakar *et al*., 2013; Dahab and Osama, 2002; Morris, 1988; Morris, 1987; Culpin, 1975).

The accumulated variable costs as percentage of purchase price was considered as a dependent variable because its value depends on the operating hours and thus was plotted on Y-axis, whereas the accumulated operating hours was regarded as an independent variable and was labelled on X-axis.

### 5.7 Regression analysis

**Table 5-7 The Predicted Mathematical Power Models and Coefficients of Correlation for the Ten Tractor Models Studied**

| **Tractor Model** | **Power Model** | **$R^2$** |
|---|---|---|
| | | |
| **Belarus800** | $y = 0.016x^{1.0996}$ | 1.0000 |
| **MF375** | $y = 0.0135x^{1.1139}$ | 1.0000 |
| **JD5503** | $y = 0.0303x^{1.1053}$ | 0.9999 |
| **MF385** | $y = 0.0128x^{1.1315}$ | 0.9974 |
| **JD5510** | $y = 0.004x^{1.2017}$ | 0.9994 |
| **JD5425** | $y = 0.0015x^{1.2885}$ | 0.9953 |
| **Mahindra8000** | $y = 0.0382x^{1.1611}$ | 0.9985 |
| **Mahindra705DI** | $y = 0.0334x^{1.1371}$ | 0.9986 |
| **Sonalika DI-90** | $y = 0.0989x^{1.0335}$ | 0.9575 |
| **Sonalika DI-75** | $y = 0.0317x^{1.1632}$ | 0.9987 |

Where:

y = Accumulated Variable costs as the percentage of list price.

x = Accumulated operating hours.

The power mathematical models developed in this study have similarities with models developed by other researchers as mentioned earlier in Table 2.11.

Figure 5.12 shows the Comparison of the predicted mathematical power models or the Accumulated Variable Cost for the Ten Tractor Models Studied.

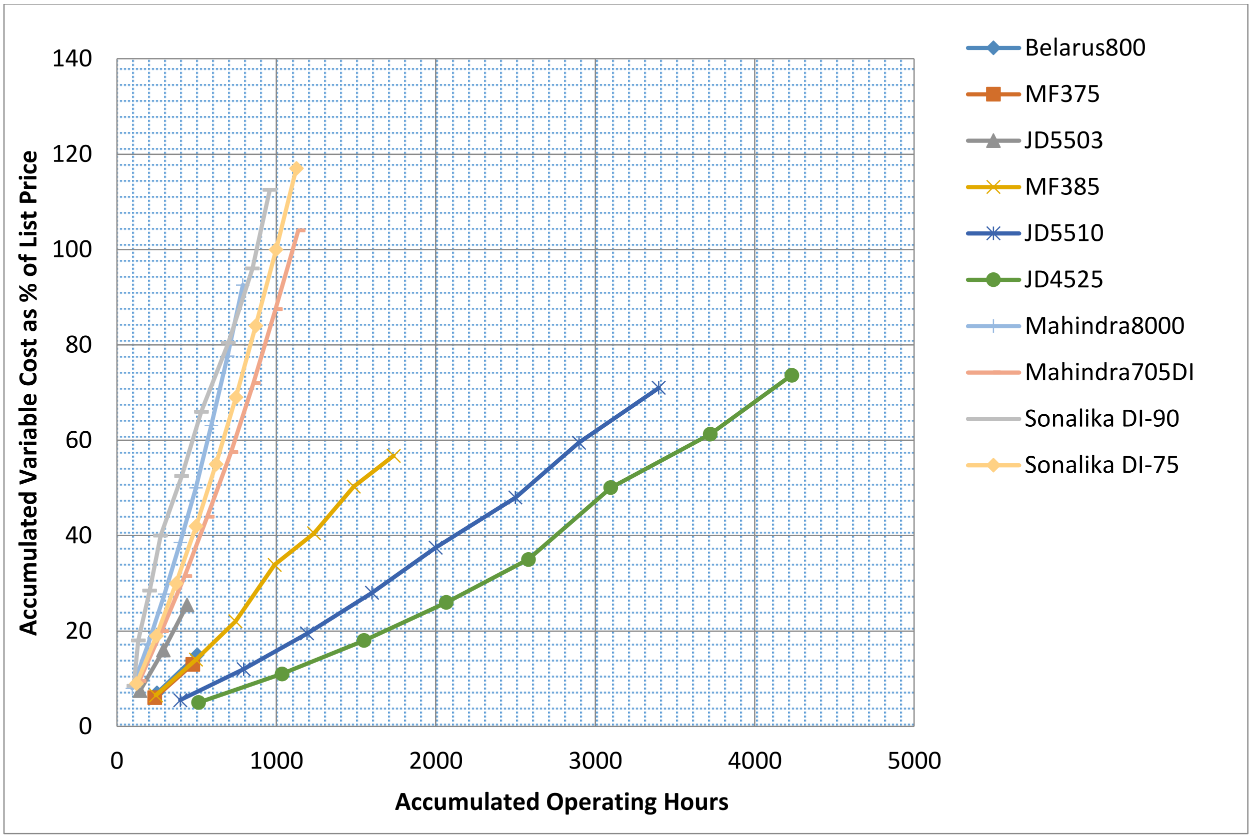


**Figure 5-12 Comparison of the Accumulated Variable Cost for the Ten Tractor Models Studied.**

Figure 5.12 shows the comparison of the ten variable cost prediction power models for the ten tractor models. As shown in the figure, the mathematical power models for SolanikaDI-90, Mahindra800 and SolanikaDI-75 tractor models showed the highest values of the accumulated variable cost as percentage of purchase price among the rest of the tractor models and this could be due to the age of operation of these three tractor models which is nine years, eight years and nine years respectively.

The mathematical power models for JD5425, JD5510, and MF385 tractor models showed the least values of the accumulated variable cost as percentage of purchase price among the rest of the tractor models which could be due to the area of the farm on which the two tractor models of JD5425 and JD5510 have been operating which is an area of 147 hectares or it could be due to the age of operation of these three tractor models which is eight years, eight years, and seven years respectively.

# 6 CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

The variable costs increased as the hours of operation of all the ten models of tractor studied increased, for example, the variable cost of MF375 increased from $1137 to $2463 as its hours of operation increased from 238hrs to 476hrs. The annual variable costs as well as the average variable costs increased as the age of operation of all the ten tractor models increased, for instance, the annual variable cost for JD5503 increased from $1088 to $1378 as its age of operation increased from one to three years. The accumulated variable costs increased with tractor age and hours of operation, for instance, the accumulated variable cost for Belarus800 increased from $1260 to $2700 as its age of operation increased from one to two years and as its hours of operation increased from 252hrs to 504hrs. There are clear differences in the variable cost between different tractors of the same model as well as between the ten tractor models studied, for instance, the variable cost for JD5510 was $3199 in eight years while for JD5425, the variable cost was $4232 in the same eight years.

For all the models of tractor, the accumulated hours of operation were the determining factor.

It was observed that among the five mathematical models evaluated, the polynomial model showed the highest coefficient of correlation ($R^2$) followed by the power model. However, the power model $y = ax^b$, where y is the accumulated variable cost as the percentage of purchase price, x is the accumulated hours of operation, a, b are the constants was the best model for predicting the operating cost of all tractor models studied.

The relationship between the accumulated variable cost as the percentage of the list price (y) and the accumulated operating hours (x) for all the ten models of tractor studied is represented by the following general equation of the power model

$$y = ax^b$$

Where;

y = accumulated variable cost as the percentage of the list price

a, b = estimate parameters

x = accumulated hours of operation.

## 6.2 Recommendations

1) Farmers can use the results of this study for selection of tractor of less accumulated variable cost with respect to the area of the farm with the assistance of Government extension officers.
2) The study should be replicated in other parts of South Sudan and on different type of soil in order to be able to provide the farmers and other stake holders with the precise cost on different type of soil.
3) Farmers and other stakeholders should keep clear and updated records of the operating cost and the hours of operation in order to make the policy makers able to know the effect of the hours of operation on the economic life of the tractor.

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# 8 APPENDICES

## Appendix A: Figures of Different Tractor Models Studied.


A1: Belarus 800 Tractor.


A2: Massey Ferguson 375 (MF375) Tractor.


A3: John Deere 5503 (JD5503) Tractor.


A4: Massey Ferguson 385 (MF385) Tractor.

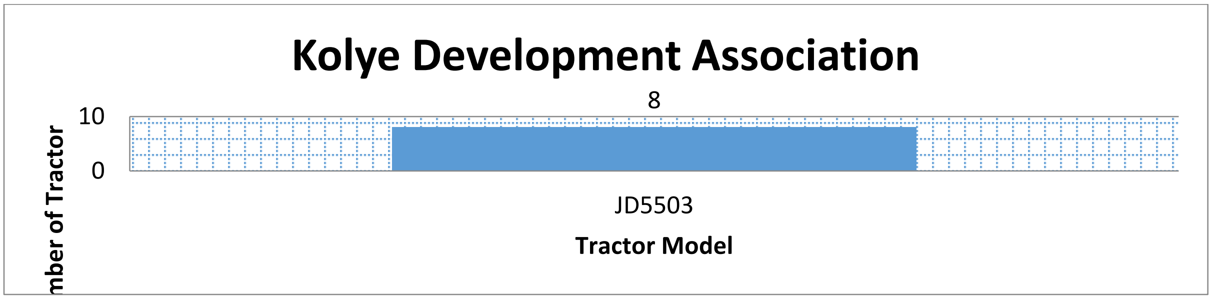

A5: John Deere 5510 (JD5510) Tractor.


A6: John Deere 5425 (JD5425) Tractor.


A7: Sonalika DI-90 Tractor.

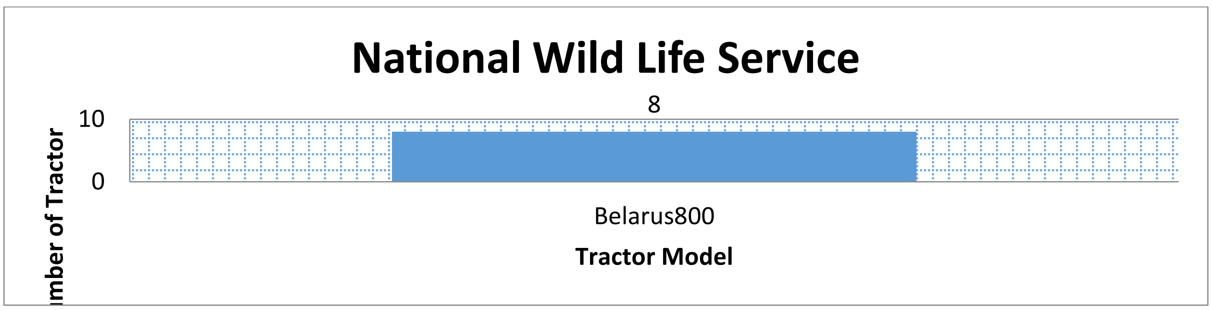
A8: Sonalika DI-75 Tractor.

**Appendix B: The Number of Tractor Per Each Model Owned by Each Farm Surveyed:**



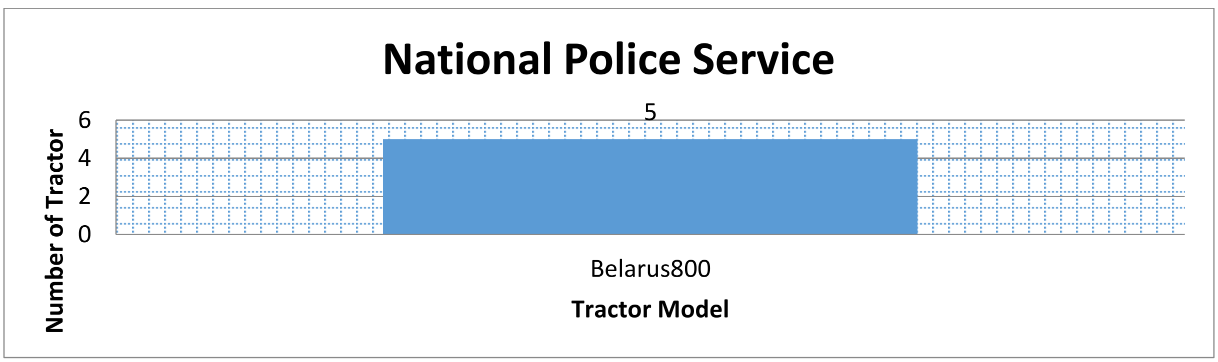

B1: Kolye development Association

Kolye development Association has eight tractors of the same model which is JD5503.



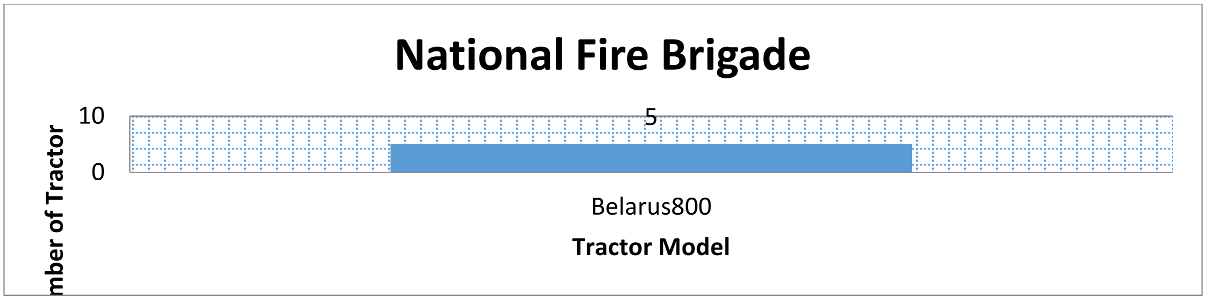

B2: National wild life service

National wild life service has eight tractors of the same model which is Belarus800.

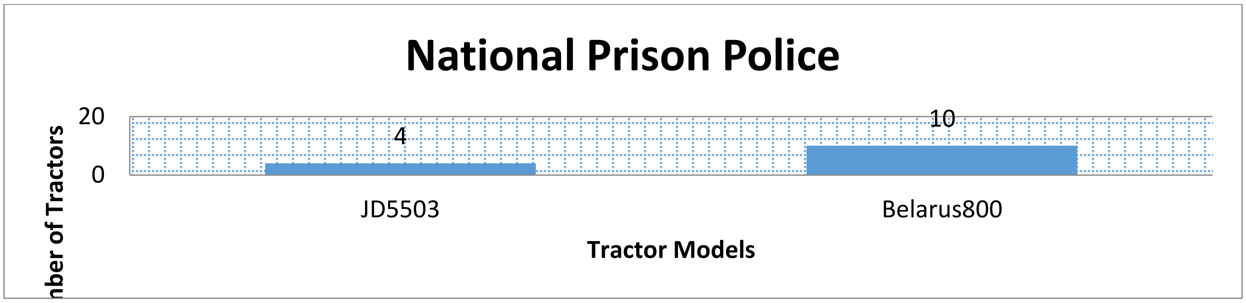



B3: National police service

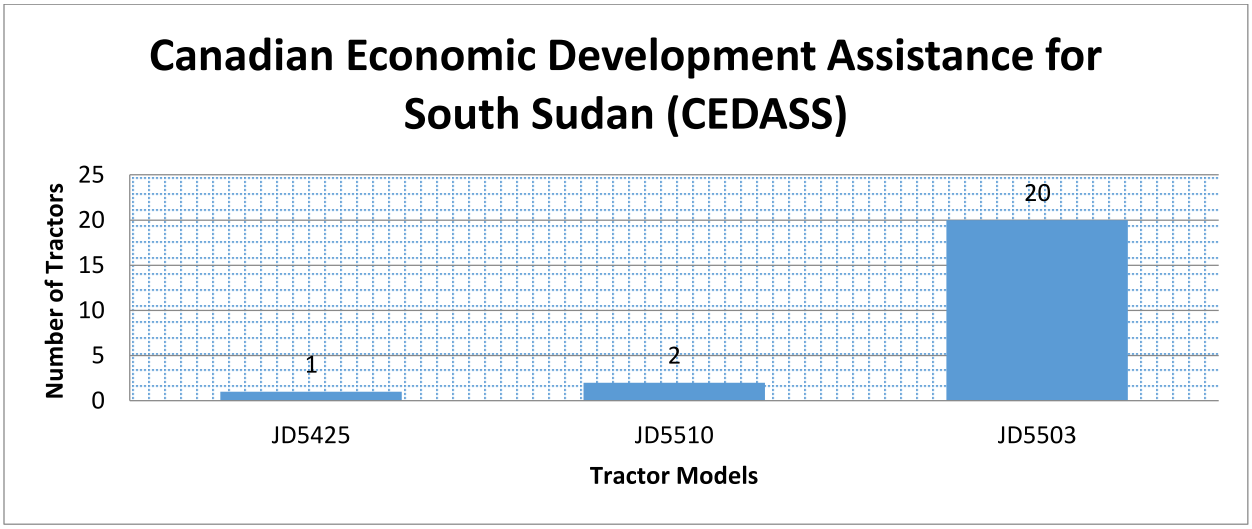
National police service has five tractors of the same model which is Belarus800.



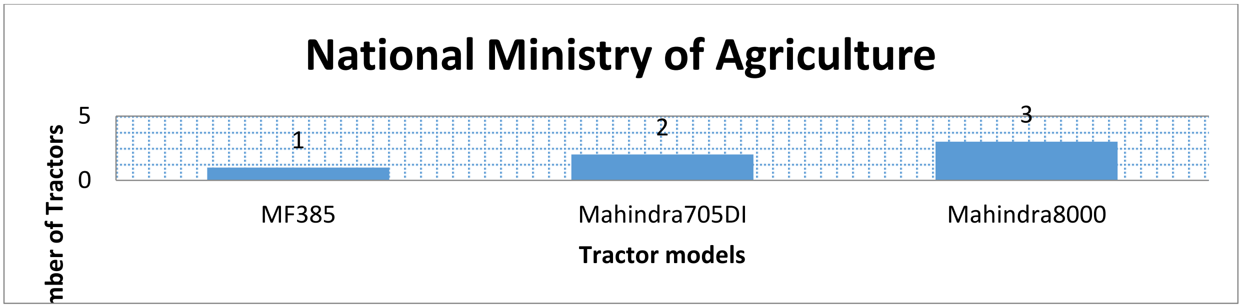

B4: National fire brigade has five tractors of the same model which is Belarus800.



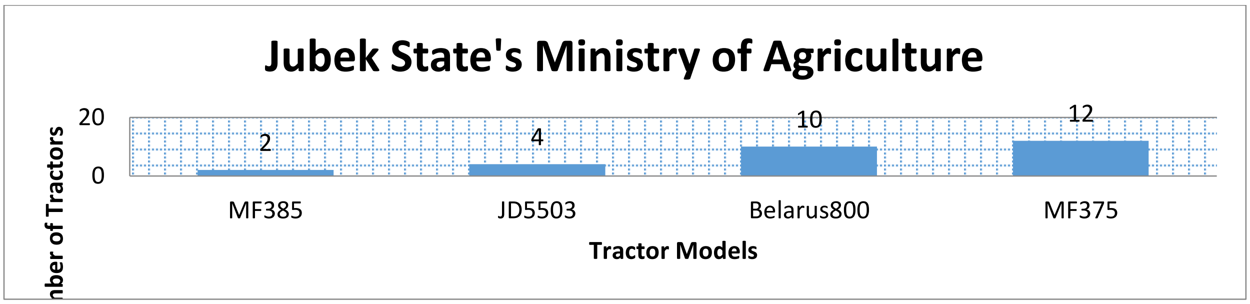

B5: National prison police has fourteen tractors of which ten are of model Belarus800 and four are of model JD5503.



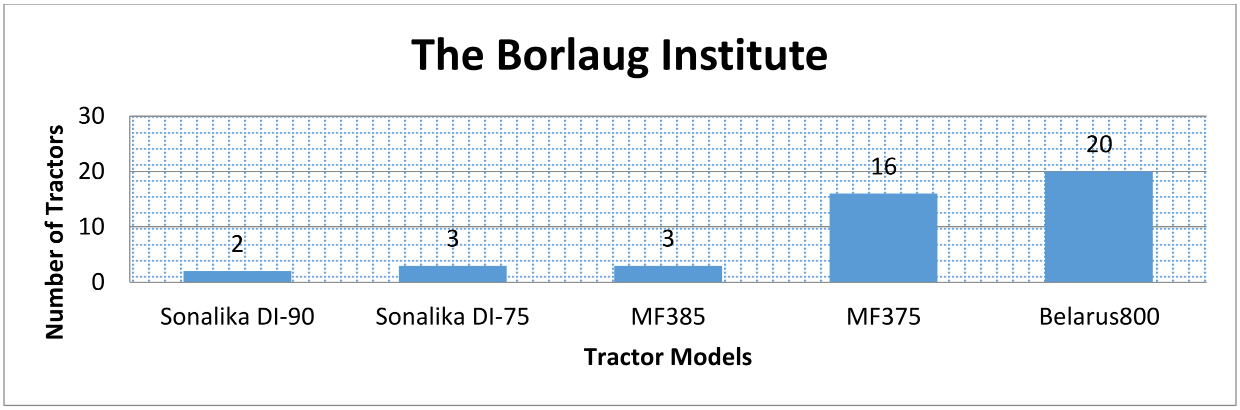

B6: The Canadian economic development assistance for South Sudan (CEDASS) has twenty three tractors of which twenty are of model JD5503, two are of model JD5510, and one is of model JD5425.




B7: The national ministry of Agriculture has six tractors of which three are of model Mahindra8000, two are of model Mahindra705DI, and one is of model MF385.

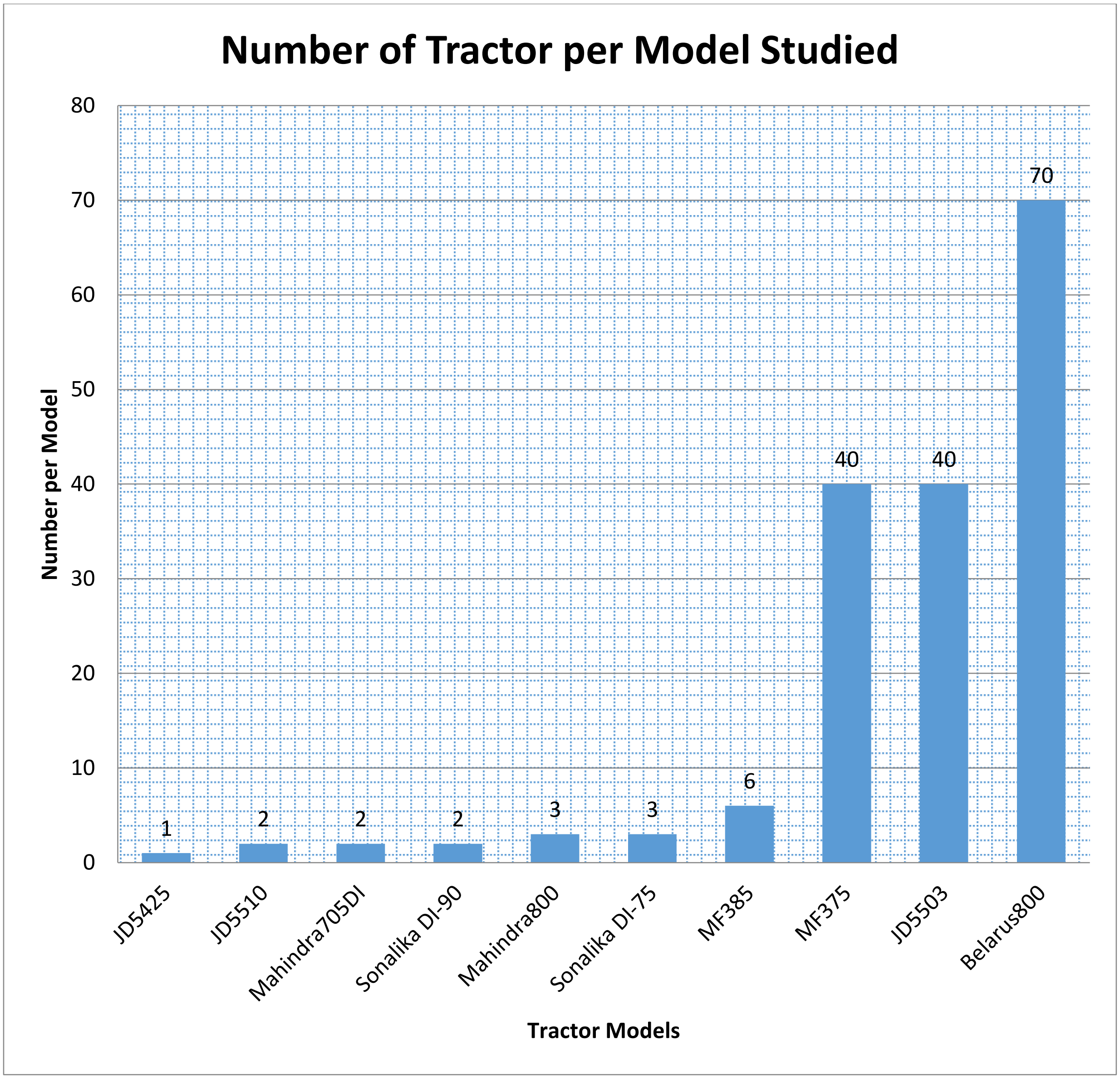



B8: The Jubek state's ministry of Agriculture has twenty eight tractors of which twelve are of model MF375, ten are of model Belarus800, four are of model JD5503, and two tractors of model MF385.



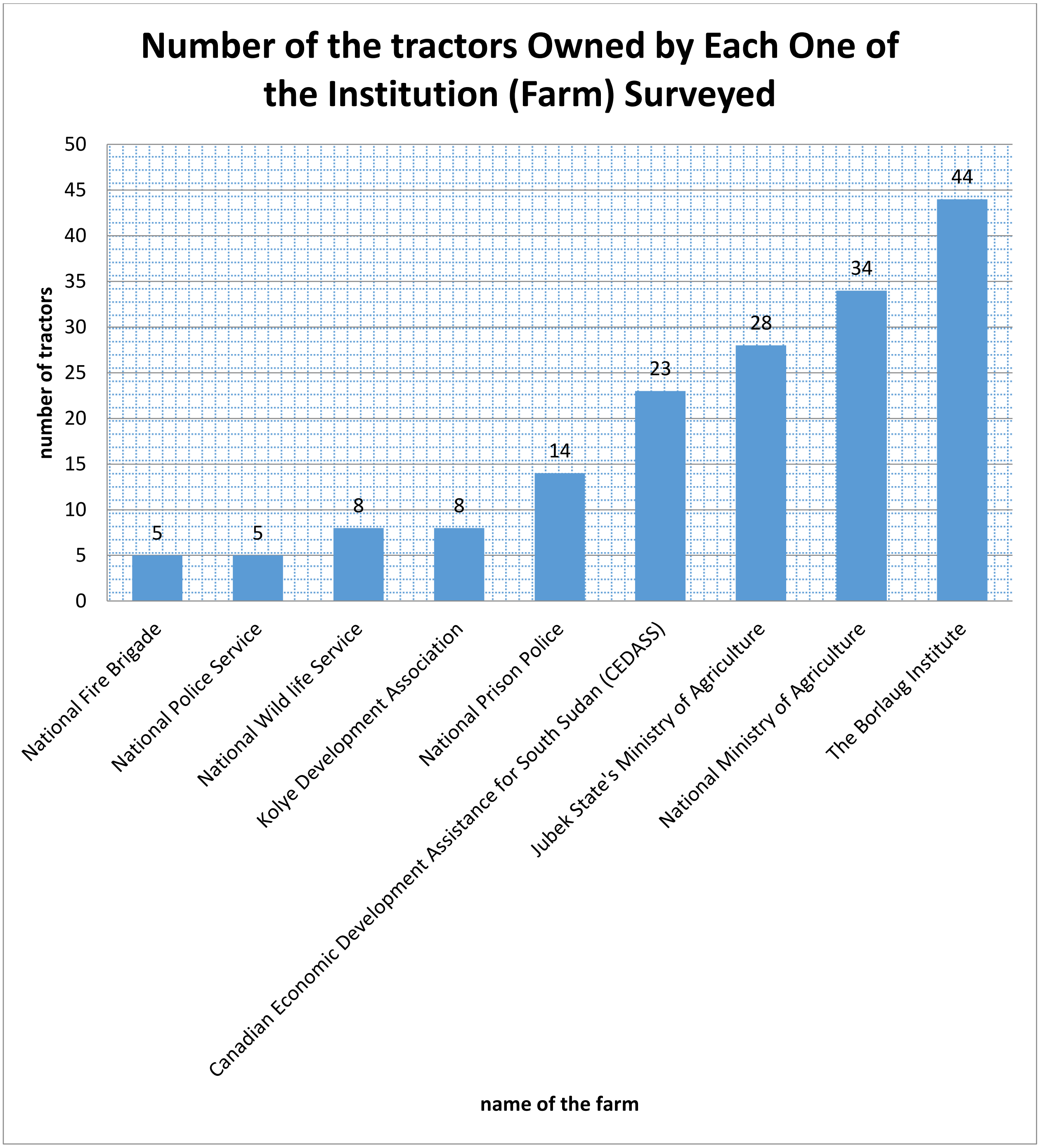

B9: The Borlaug Institute has forty four tractors of which twenty are of model Belarus800, sixteen are of model MF375, three are of model MF385, another three are of model Sonalika DI-75, and two tractors are of the model Sonalika DI-90.

**Appendix C: The Number of Tractors Studied per Each Model.**



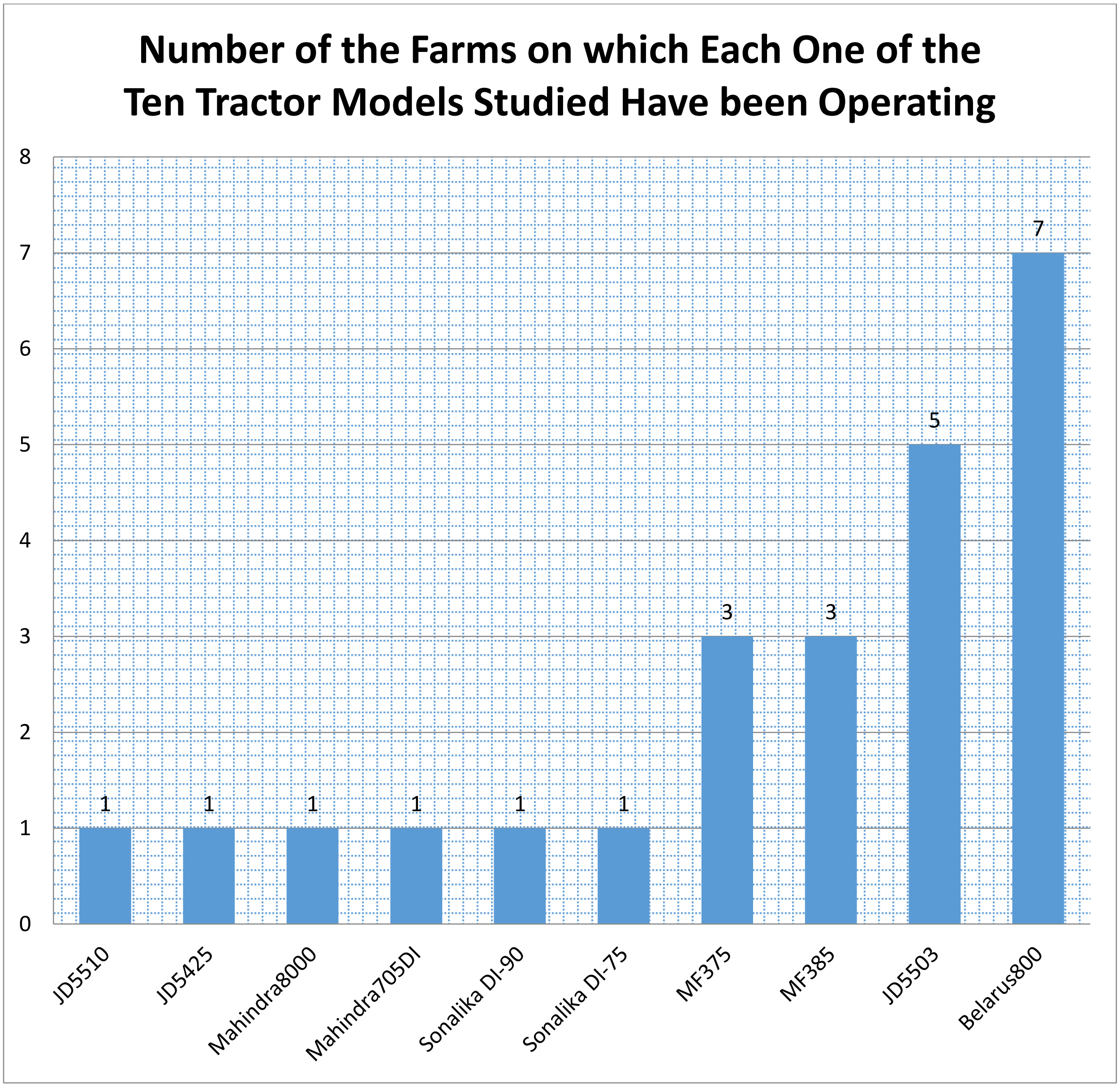

This figure shows the number of tractors per model studied. The total number of tractors studied are 169 the highest of which 70 tractors of Belarus800 and lowest number of tractor studied is one which is JD5425.

**Appendix D: The number of tractors own by each farm (institution) surveyed.**



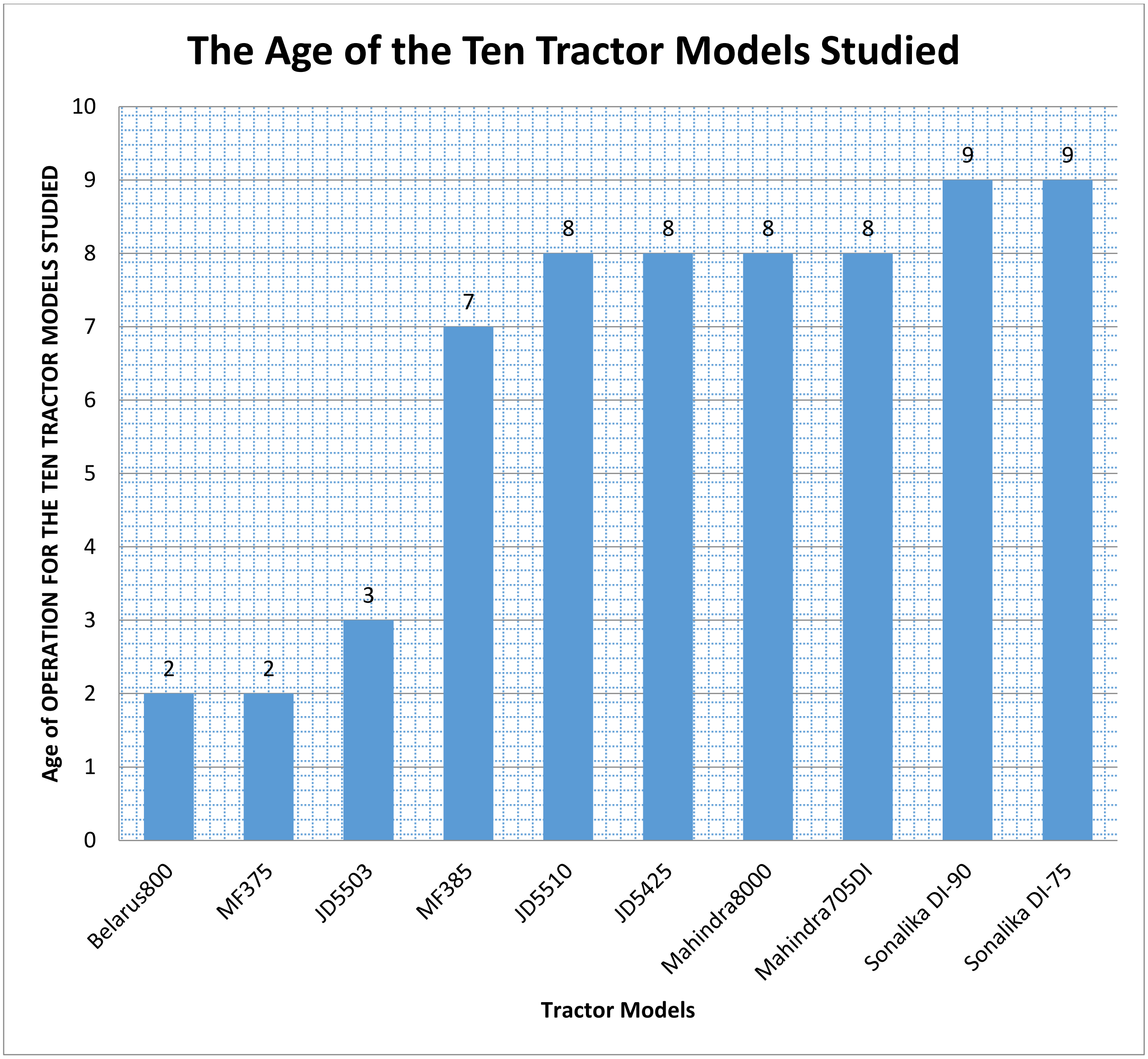

As it can be seen, the Borlaug institute owned more number of tractors than the rest of the institutions whereas the least number of tractors is own by both the national fire brigade and the national police service.

**Appendix E: The number of farms on which each one of the ten tractor models studied Operates.**




The above figure shows the number of farms on which each one of the ten tractor models studied operates. And as it can be seen, Belarus800 operates on seven of the nine farms surveyed followed by JD5503 which operates on five farms whereas MF385 and MF375 both operates on three farms and the rest of the tractor models operates on a single farm only.

**Appendix F: The Ages of operation for the Ten Tractor Models Studied.**




This figure shows the ages of the ten tractor models studied. And as it can be seen, the oldest tractor models are Sonalika DI-90 and Sonalika DI-75 each of which is nine years old followed by Mahindra8000 and Mahindra705DI each of which is eight years old.

The tractor model of least age is Belarus800 and JD5503 of which some are two years old and some are three years old.

**Appendix G: A Sample of a filled questionnaire.**

UNIVERSITY OF NAIROBI

Ref No: ------/ -------/------131

MODELING OF VARIABLE COSTS FOR TRACTORS: A CASE STUDY OF MF375, BELARUS 800, AND JOHN DEERE IN JUBA CITY OF SOUTH SUDAN.

A VARIABLE COSTS QUESTIONNAIRE.

SECTION A: INTRODUCTION.

Hello, my name is [ ]. We have been contracted by Saman Nicola Wilba Nicola a Masters Student at the Department of Environmental and Biosystems Engineering, School of Engineering, College of Architecture and Engineering of the University of Nairobi to collect data on the variable costs for a scientific research purpose for three models of farm tractors that include MF375, Belarus 800, and John Deere. This study will help us to develop a model that will be used to predict or estimate a variable costs for three tractor models mentioned above.

Name of respondent. Lubaju Moses ---------- Contact of respondent. Juba South Sudan +211955098455

Respondent ID. No. 000043671 ---------- Institution of respondent. CEDASS

Location. Jebel Lado farm ----------State. Jubek state

County. Juba ----------Payam. Northem Bari payam

Date of interview. ----------Name of interviewer. ----------

(NOTE: this questionnaire shall be administered only to the institutions, persons, or farms that operate, purchase or sell, and keep records of tractors operation costs in addition to other non- governmental organizations that specialize in agriculture such as FAO … Etc.).

1

**SECTION B: BIOGRAPHIC DATA.**

| B1 | B2 | B3 |
|---|---|---|
| **Gender of the Respondent.** | **How Old Are You?** | **Education Level.** |
| 1. Male ( ✓ ). | 1. < 18 Yrs. ( ). | 1. Primary. ( ). |
| | 2. 18 – 25 Yrs ( ). | 2. Secondary. ( ). |
| | 3. 26 – 35 Yrs. ( ✓ ). | 3. Tertiary ( ✓ ). |
| | 4. 36 – 45 Yrs. ( ). | 4. Others Specify |
| 2. Female. ( ). | 5. 46 – 60 Yrs. ( ). | ………………………………… |
| | 6. Above 60. ( ). | |

**SECTION C: KEY INFORMANTS DATA.**

| What is the post of a key Informants? |
|---|
| 1. Manager. ( ✓ ). |
| 2. Supervisor. ( ). |
| 3. Superintendent ( ). |
| 4. Others Specify. ……………………………………………………… |

2

SECTION D: LEVEL OF MECHANIZATION DATA.

| D1<br>What is the level of mechanization? | | D2 | D3 |
|---|---|---|---|
| Type | | Number | Percentage |
| 1. Human powered such as hard hoe, etc. | ( ). | ( ). | ................. % |
| 2. Animal powered | ( ). | ( ). | ................. % |
| 3. Tractors. | ( ✓ ). | ( . ). | ................. % |

3

**SECTION E: TECHNICAL DATA.**

| E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|
| **Which tractor Model do you have?** | **What is the manufacture date of the tractor?** | **What was the purchase price?** | **What is the age of operation of the tractor?** | **What is the Engine Power?** |
| **MF375** ( ). | 1986 – 1996 ( ). | Donated | 1 – 5 Yrs. ( ). | 75 HP |
| | 1997 – 2006 ( ). | | 6 – 10 Yrs. ( ). | |
| **Belarus 800** ( ). | 2007 – 2016 ( ). | | 11 – 15 Yrs. ( ). | |
| | Others Specify………………… | | 16 – 20 Yrs. ( ). | |
| | | | 21 – 25 Yrs. ( ). | |
| **John Deere** ( ✓ ). 5510 old. | | | 26 – 30 Yrs. ( ). | |
| | | | Others Specify………….. | |

| E6 | E7 |
|---|---|
| What is the tractor engine number? | Is your tractor a 2-Wheel Drive (2WD) or 4-Wheel drive (4WD)? |
| *CD404508263* | 2WD ( ). |
| | 4WD ( ✓ ). |

4

SECTION F: REPAIR AND MAINTENANCE (R&M) COST DATA.

| F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|
| What is the schedule of service of a tractor? (in hours) | How often does a tractor breakdown? | What was the cost of spare parts per each year of tractor age? | What was the cost of replacing oil and fuel filters? | What was the cost of tires replacement per each year of a tractor age? |
| 250 Hrs ………… | twice ………… a Year | 1 – 5 Yrs. ( ). <br> 6 – 10 Yrs. ( ). <br> 11 – 15 Yrs. ( ). <br> Others Specify <br> most donated ………… | 1 – 5 Yrs. ( 7500 ). <br> 6 – 10 Yrs. ( ). <br> 11 – 15 Yrs. ( ). <br> Others Specify <br> ………… | 1 – 5 Yrs. ( ). <br> 6 – 10 Yrs. ( ). <br> 11 – 15 Yrs. ( ). <br> Others Specify <br> donated ………… |

| F6 | F7 |
|---|---|
| What was the cost of grease per each of a tractor age? | What was the cost of workmanship (mechanic) for each year of a tractor age? |
| 1 – 5 Yrs. ( 1500 0SSP ). <br> 6 – 10 Yrs. ( ). <br> 11 – 15 Yrs. ( ). <br> Others Specify <br> ………… | 1 – 5 Yrs. ( ). <br> 6 – 10 Yrs. ( ). <br> 11 – 15 Yrs. ( ). <br> Others Specify <br> mostly government mechanics used ………… |

5

SECTION G: LABOUR (OPERATOR) COST DATA.

| G1 | G2 | G3 |
|---|---|---|
| Operator Cost per faddan | Operator Cost per Hour | Operator Cost for each Year of Operation |
| What was/ is the cost of a hired operator (driver) per one faddan of operation?<br>450SSP/faddan for Plowing,<br>250SSP/faddan for Harrowing | What was/is the cost of a hired operator (driver) per one hour of operation?<br>………………………………… | What was the cost of hired operator (driver) for each year of operation of a tractor age?<br>1 – 5 Yrs. (  ).<br>6 – 10 Yrs. (  ).<br>11 – 15 Yrs. (  ).<br>16 – 20 Yrs. (  ).<br>21 – 25 Yrs. (  ).<br>26 – 30 Yrs. (  ).<br>Others Specify<br>………………………………… |

or 800SSP/faddan

6

SECTION H: LUBRICATION AND OIL COST DATA.

| H1 | H2 | H3 |
|---|---|---|
| What was the cost of brake oil for each year of operation? | What was the cost of hydraulic oil for every year of operation? | What was the cost of engine oil for every year of operation? |
| 1 – 5 Yrs. ............................ | 1 – 5 Yrs. 3500 SSP | 1 – 5 Yrs. 2400 SSP |
| 6 – 10 Yrs. ............................ | 6 – 10 Yrs. ............................ | 6 – 10 Yrs. ............................ |
| 11 – 15 Yrs. ............................ | 11 – 15 Yrs. ............................ | 11 – 15 Yrs. ............................ |
| 16 – 20 Yrs. ............................ | 16 – 20 Yrs. ............................ | 16 – 20 Yrs. ............................ |
| 21 – 25 Yrs. ............................ | 21 – 25 Yrs. ............................ | 21 – 25 Yrs. ............................ |
| 26 – 30 Yrs. ............................ | 26 – 30 Yrs. ............................ | 26 – 30 Yrs. ............................ |
| Others Specify ............................ | Others Specify Donated mostly | Others Specify Donated mostly. |

No brake oil

SECTION I: FUEL COST DATA.

| I1 | I2 | I3 |
|---|---|---|
| What was/is the cost of a diesel fuel per liter/gallon? | What was/is the fuel consumption per Faddan of operation? | What was the fuel cost per each year of operation? |
| Cost/liter...22 SSP................ | 1 – 5 Yrs. ............................ | 1 – 5 Yrs. ............................ |
| Cost/gallon...88SSP.................. | 6 – 10 Yrs. ............................ | 6 – 10 Yrs. ............................ |
| | 11 – 15 Yrs. ............................ | 11 – 15 Yrs. ............................ |
| | 16 – 20 Yrs. ............................ | 16 – 20 Yrs. ............................ |
| | 21 – 25 Yrs. ............................ | 21 – 25 Yrs. ............................ |
| | 26 – 30 Yrs. ............................ | 26 – 30 Yrs. ............................ |
| | Others Specify............................ | Others Specify............................ |

SECTION J: REPAIR AND MAINTENANCE COST PER EACH SYSTEM OF THE TRACTOR DATA.

| J1 | J2 | J3 | J4 | J5 |
|---|---|---|---|---|
| What was R&M cost of the Engine for each year of a tractor age/ operation? | What was R&M cost of the electrical system for each year of a tractor age/ operation? | What was R&M cost of the transmission system for each year of a tractor age/ operation? | What was R&M cost of the hydraulic system for each year of a tractor age/ operation? | What was R&M cost of the steering system for each year of a tractor age/ operation? |
| 1 – 5 Yrs. 5000Sp | 1 – 5 Yrs. .................. | 1 – 5 Yrs. 5000Sp | 1 – 5 Yrs. .................. | 1 – 5 Yrs. .................. |
| 6 – 10 Yrs................ | 6 – 10 Yrs................ | 6 – 10 Yrs................ | 6 – 10 Yrs................ | 6 – 10 Yrs................ |
| 11 – 15 Yrs. ............... | 11 – 15 Yrs. ............... | 11 – 15 Yrs. ............... | 11 – 15 Yrs. ............... | 11 – 15 Yrs. ............... |
| 16 – 20 Yrs................ | 16 – 20 Yrs................ | 16 – 20 Yrs................ | 16 – 20 Yrs................ | 16 – 20 Yrs................ |
| 21 – 25 Yrs. ............... | 21 – 25 Yrs. ............... | 21 – 25 Yrs. ............... | 21 – 25 Yrs. ............... | 21 – 25 Yrs. ............... |
| 26 – 30 Yrs. ............... | 26 – 30 Yrs. ............... | 26 – 30 Yrs. ............... | 26 – 30 Yrs. ............... | 26 – 30 Yrs. ............... |
| Others Specify<br>............................ | Others Specify<br>............................ | Others Specify<br>............................ | Others Specify<br>............................ | Others Specify<br>............................ |

9

## SECTION K: TRACTOR USE DATA.

| What was/were the type of crop the tractor was used for? | |
|---|---|
| Maize | ( ✓ ). |
| Sorghum | ( ). |
| Sesame | ( ). |
| Cassava | ( ). |
| Sunflower | ( ). |
| Soya bean | ( ). |
| Beans | ( ). |
| Others Specify | vegetables |

## SECTION L: SOIL TYPE DATA.

| What was/is the type of soil in which the tractor operates? | |
|---|---|
| Sandy Soil | ( ). |
| Clay Soil | ( ✓ ). |
| Loamy Soil | ( ). |
| Silty Soil | ( ). |
| Peaty Soil | ( ). |
| Saline Soil | ( ). |
| Acidic Soil | ( ). |
| Alkaline Soil | ( ). |
| Chalky Soil | ( ). |
| Alluvial Soil | ( ). |
| Clay-loam Soil | ( ). |
| Silt-loam Soil | ( ). |
| Others Specify | ........................................ |

10

SECTION M: NUMBER OF TRACTOR MODEL AND DEALERS DATA.

| M1 | M2 |
|---|---|
| What is the total number of tractor dealers in juba? | What is the total number of tractors from each of the models mentioned above that is possessed by you or your institution? |
| ........................................................ ........................................................ ........................................................ | 4 tractors from 3 models. |

Signature ..............................................

Stamp ..............................................

Thank you so much for providing the information.

11

## Appendix H: Definition of Terms.

### 1) Mechanization

The term "mechanization" is used to describe tools, implements and machinery applied to improving the productivity of farm labour and of land; it may use either human, animal or motorized power, or a combination of these. In practice, therefore, it involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to draught animal power and to mechanical power technologies (Sims *et al.*, 2006).

### 2) Mechanization systems

Mechanization systems are categorized into human, animal and mechanical technologies. Based on the source of power, the technological levels of mechanization have been broadly classified as hand-tool technology, draught animal technology and mechanical power technology (Sims *et al.*, 2006).

### 3) Depreciation

Depreciation is a cost resulting from wear, obsolescence and age of a machine.

### 4) Interest on Investment

Is the interest rate or the amount of money charged by the lender if the farmer borrows money to buy the farm machinery?

### 5) Taxes, Insurance and Housing (TIH)

These three costs are usually much smaller than depreciation and interest on investment, but they need to be considered.

i) Taxes:

Taxes are amount of money paid annually by the farmer to the state's Government for owning and operating the farm machine. Property taxes on farm machinery have been phased out in some states, except for very large inventories. For states that do have property taxes on farm machinery, a cost estimate equal to 1% of the average value of the machine is paid by the farmer.

ii) Insurance:

Insurance is the amount of money paid annually by the farmer to the insurance company in order to allow for replacement in case of a disaster such as a fire or tornado. If insurance is not carried, the risk is assumed by the rest of the farm business (William Edwards, 2015).

iii) Housing:

Housing is the cost of sheltering the farm machinery. There is a tremendous variation in housing provided for farm machinery. Providing shelter, tools, and maintenance equipment for machinery will result in fewer repairs in the field and less deterioration of mechanical parts and appearance from weathering. That should produce greater reliability in the field and a higher trade-in value. An estimated charge of 0.5% of the average value is suggested for housing costs (William Edwards, 2015).

To simply calculate TIH costs, they can be lumped together as 2% of the average value where property taxes are not significant.

**6) Total Ownership Cost:**

Total ownership costs are the estimated costs of depreciation, interest, taxes, insurance, and housing added together.

**7) Repairs and Maintenance (R&M) Costs:**

Repair costs are costs that occur because of routine maintenance, wear and tear, and accidents. Repair and maintenance (R&M) costs of farm machinery are difficult to estimate because of variability among machines and operating conditions from one farm to another and also due to unavailability of good records keeping (Lazarus and Selley, 2005).

**8) Fuel Cost:**

This is the amount of money paid for fuel needed to carry out different farm operations starting from land preparation to harvesting and post harvesting.

Fuel costs can be estimated in two ways:

Average fuel cost per acre can be calculated by multiplying the average fuel use in gallons per acre listed in the agriculture decision maker file A3 to 27 by the fuel cost per gallon.

Average fuel consumption (in gallons per hour) for farm tractors on a year-round basis without reference to any specific implement can also be estimated with these equations:

0.60 *maximum PTO horsepower for gasoline engines.

0.44 *maximum PTO horsepower for diesel engines.

**9) Lubrication (Oil) Cost:**

This is the amount of money used to buy the lubrication oil for maintaining the farm machinery. Surveys indicate that total lubrication costs on most farms average about 15% or 0.15 of fuel costs. Therefore, once the fuel cost per hour has been estimated, you can multiply it by 0.15 to estimate total lubrication costs (William Edwards, 2015).

**10) Labor (Operator) Cost:**

This is the amount of money used to hire the tractor operator for carrying out different farm operations. Because different size machines require different quantities of labour to accomplish such tasks as planting or harvesting, it is important to consider labour costs in machinery analysis. Labour cost is also an important consideration in comparing ownership to custom hiring (William Edwards, 2015).

Actual hours of labour usually exceed field machine time by 10% to 20%, because of travel and the time required to lubricate and service machines. Consequently, labour costs can be estimated by multiplying the labour wage rate times 1.1 or 1.2 (William Edwards, 2015). Different wage rates can be used for operations requiring different levels of operator skill.

**11) Total Operating Cost:**

Total Operating Costs Are Costs of Repair, fuel, lubrication and labour added together.

**12) Total cost per hour:**

Total cost per hour is the summation of the total ownership cost per hour and the total operating cost per hour.