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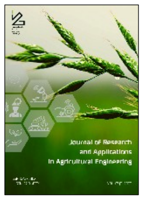

# Economic life for Belarus 800 farm tractors operated in Central Equatoria State, South Sudan

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The farm tractors are the basic source of power on large scale farms that do require high capital cost. Impact of farm tractors on farming is enormous and their costs do positively impact agricultural business. The purpose of this study was to develop and determine the mathematical model to predict the economic life for the Belarus 800 farm tractors operated in the Bilfam and Rajaf East Areas. Its specific objectives included the identification of the cost parameters pertinent to both ownership and variable cost, establishing the numerical values for them, determination of the economic life for the Belarus 800 farm tractors, and modelling their economic life. The economic data of the cost of repair and maintenance (R&M), cost of fuel, cost of tractor operator, in addition to the yearly hours of operation, and the list or the buying price for the Belarus 800 farm tractors were collected using questionnaires. Regression analysis was performed using Microsoft Excel (2010) on the cumulative values for the two parameters of the cumulative total cost per hour and the parameter of the age of operation. The polynomial model was determined to be the mathematical model that best fit for the prediction of the economic life for the Belarus 800 farm tractors, and the economic life was determined to be 9 years of operation with cumulative operating hours of 3,412.64 h.

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## 1. Introduction

Though the electrical-power-based soil-less farming types of hydroponics, aquaponics and aeroponics are making their way into global agricultural landscape, soil-based (geoponics) farming still dominates modern global agriculture. In this type of farming (geoponics), tractors are the main source of power. According to Al-Suhaibani and Wahby (2015), farm tractors are the basic source of power on the soil-based farms and they are utilized for carrying out all farming operations. The farm tractors are the basic source of power on large scale farms (Gifford & Rijk, 1980) that do require high capital cost. Impact of farm tractors on farming is enormous (Singh, 2006) and their costs do positively impact agricultural business.

The costs of farm tractors are the ownership costs which are the costs incurred for owning the farm tractors and they include depreciation, the interest on the investment, and the taxes, insurance and housing or shelter (Edwards, 2015) and the variable or the operating cost which are the costs for operating the farm tractors and the cost for repairing and maintaining the farm tractor, the cost of fuelling the farm tractor as well as the cost for the operator of the farm tractor (Edwards, 2015). These costs for farm tractors are always difficult to analyse due to the fact that they change with time. Depreciation, which is the biggest cost incurs due to owning the farm tractor measures

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the decrease in the market value of a farm tractor with time. The cost value for depreciation of the farm tractor is usually higher during the period of time following its purchase, but as time passes by, its value decreases. Similarly, whether the cost on the interest on the investment is in the form of cash paid back on a loan or whether it is in the form an opportunity cost, it decreases as the period of owning the farm tractor increases. The ownership costs of taxes, insurance and housing also decrease with an increase in the age of the farm tractor.

The costs for repairing and maintaining the farm tractors are small but relatively essential part for both the cost of owning and the cost of operating the farm tractors (Rotz, 1987). These costs are also the crucial part of the costs for operating the farm tractors (Khoubbakht et al., 2008). The costs for repairing and maintaining the farm tractors which included spare parts, workmanship, oils, oils and fuel filters, grease and tires replacement are the functions of both the age and use (hours) of farm tractors (Hunt, 2001). According to Al-Suhaibani and Wahby (2015), most studies revealed that the costs for repairing and maintaining farm tractors vary from one place to another even within the same country due to variation in the operating conditions of the farm tractors, the skills of the tractors' operators (labours), cropping patterns, weather conditions, lack of spare parts, maintenance policy, etc.

The operating costs differ from the ownership costs in that the ownership costs decrease as the operating time increases, but the operating costs increase as the operating time increases (Wilba et al., 2018). For example, the costs for repairing and maintaining the farm tractors increase with an increase in time. These costs are zero at ownership but as the farm tractors age their repair and maintenance costs increase (Rotz, 1987). The costs for repairing and maintaining the farm tractors are usually 10% of the operating costs at the beginning, but as time increases, they increase till they become the largest costs for both owning and operating the farm tractors (Rotz & Bowers, 1991). The costs for owning and operating the farm tractors amount to about 35% to 50% of the costs of agricultural production beside the cost of owning a land (Anderson, 1988). The information on the costs for owning and operating the farm tractors are primarily important for not only knowing the costs of agricultural production, but also for making decisions on which tractor make and model to purchase and how and when to replace the farm tractor.

The economic life for the farm tractor that is based on the total cost is the age of operation in which the total cost per an hour of operation falls to the lowest before it starts to rise again. It is that operation period after which continuing to operate or even own the farm tractor will not be economical or profitable. According to Wilba et al. (2018), the economic life for farm tractors are determined based on the operating costs. Since the ownership costs decrease with an increase in the operating time, most of the decisions taken by the farm power and machinery managers to replace the farm tractors are based on the operating costs of which the repairing and maintaining the farm tractors are vital (Wilba et al., 2018). The costs for repairing and maintaining the farm tractors which amount to about 10% to 15% of the total cost generally increase with an increase in the operating time and as a result they are vital in impacting the economic life of farm tractors (Rotz, 1987). The two variables of the accumulated costs for repairing and maintaining the farm tractors and the accumulated operating hours were mostly used to determine the economic life of farm tractors (Khoubbakht et al., 2008).

Studies have been conducted developed and developing countries on the both the determination of the economic life for the farm tractors as well as the development of the mathematical model to predict the economic life for the farm tractors and these include Nicola (2025) who carried out an study to determine the useful life of Sonalika DI-90 farm tractors operated in the Mapel area of the Capital City of South Sudan Juba and the result of his study revealed that the useful life for the Sonalika DI-90 farm tractors is 18 years. Pagare et al. (2019) which determined the economic life for the 50 HP farm tractors operated in the Indian Central Region of Madhya Pradesh to be 6 years with an accumulated operating hours of 4,566 and which concluded that the polynomial model is the appropriate mathematical model to predict the optimum life for the 50 HP farm tractors. Poozesh et al. (2012) whose study determined the economic life for the JD3140 farm tractors operated in the Debal Khazaei Agro-Industry Co. located in the Khuzestan province of the Islamic Republic of Iran to be 14 years with cumulative operating hours of 6,981. Shani and Musa (2018) whose study revealed that the ideal time for the replacement of the Mahindra 605 farm tractors operated in the Kaduna State of Nigeria is 9 years with cumulative operating hours of 4,515.

The purpose of this study was to determine and to develop the mathematical model to predict the economic life for the Belarus800 farm tractors operated in the Bilfam and Rajaf East Areas. Its specific objectives included the identification of the cost parameters pertinent to both ownership and variable cost, establishing the numerical values for them, determina--ion of the economic life for the Belarus800 farm trac--ors, and modelling the economic life for the Belarus 800 farm tractors.

## 2. Material and methods

### 2.1. Study location

The areas of this study were Bilfam which is located north of the Capital City of South Sudan Juba and Rajaf East which is located some few kilometers south of the Juba City during September and October 2016. The two study areas of Bilfam and Rajaf East fall within the Jubek State and now the Central Equatoria State whose Capital is also the Juba City.

### 2.2. Agro-ecological zone or livelihood zone description

The study areas of Bilfam and Rajaf East of the Central Equatoria State fall within the Greenbelt. It is situated in the Southern part of the country (MAFCRD, 2015; AfDB, 2013) and it is among the livelihood zones or the agro-ecological zones with the highest agricultural potential, having both a long growing period and relative high population density (AfDB, 2013). This zone includes Western Equatoria and parts of Central and Eastern Equatoria. The area has a bi-modal rainfall pattern with a rainy season of approximately 8 to 9 months, allowing double cropping (MAFCRD, 2015; AfDB, 2013). The main livelihood is subsistence agriculture with the potential for surplus production. The main crops cultivated are root crops (cassava, sweet potatoes), maize, millet, groundnuts and finger millet, upland rice and beans (MAFCRD, 2015; AfDB, 2013). The zone has approximately 500,000 ha of virgin land under tree cover, some of which can be converted into agricultural land (AfDB, 2013).

### 2.3. Tractor material

The Belarus 800 farm tractor is powered by a 4-cylinder liquid-cooled Belarus diesel engine of 80 HP (60 Kw) with a torque of 197 Ib-ft at 1000 Revolution Per Minute (RPM) and a displacement of 4.7 L (289.8 ci). It features a 14-forward and a 4-reverse transmission. It also features a hydrostatic power steering type with a maximum travel speed of 36 Km/h. The Belarus 800 farm tractor has an hydraulic system with a power regulator and two hydraulic pumps with a lifting capacity of 1800 Kg. The Belarus 800 farm tractor is of 3.9 tons weight, 3.84 m length, 1.97 m width, 2.78 m height with a wheelbase of 2370 mm.

**Figure 1.** The studied Belarus 800 farm tractors (source: author's own photograph)

### 2.4. Population size, sample size and sampling method

The Belarus 800 farm tractors were solely imported into Country by the Government of the Republic of South Sudan back in 2015 and their total number was 800. These tractors were then divided equally among the ten (10) administrative units or states of the Republic of South Sudan. So that the number of Belarus 800 farm tractors in each state including in the state where this study has been carried out at 80. Out of the 80 farm tractors, the survey covered 70 Belarus 800 farm tractors that were randomly selected.

### 2.5. Data collection

The data for this study was collected using questionnaires and they included the annual values for the following economic data of the repair cost which was made up of the costs for the spare parts, and the costs for repair (workmanship or mechanic); the maintenance cost which was made up of the costs for the engine oil, the costs for the gear oil, the costs for the break oil, and the costs for the hydraulic oil, the costs for the oil and fuel filters, the costs for the grease, and the costs for the tire replacement; the costs for fuel; and the costs for the tractor operators; in addition to the yearly hours of operation; and the list price for the Belarus 800 farm tractors.

### 2.6. Questionnaire's design

The questionnaires were made up of the bio data section which included the name, title or position, the age and the educational background of those interviewed, the tractor section which included the tractor make, the tractor model, the manufacturing year, the serial number, the purchase price, the number of tractor, the age or years of operation, and the hours of operation per each year of operation. The operating costs section included the costs of spare parts, costs for mechanics, costs for different types of oil, costs for the oils and fuel filters, costs of grease, cost for the tire replacement, fuel consumption per hectare, fuel cost per litre and gallon, and the cost of the tractor operator per hour and per hectare, in addition to the yearly cost of taxes, insurance, and housing.

### 2.7. Calculation of the cumulative ownership cost parameters for the Belarus 800 farm tractors

#### 2.7.1. Calculation of the cumulative depreciation cost for the Belarus 800 farm tractors

The annual values for the cost of depreciation for Belarus 800 farm tractors were calculated using straight line method as it is shown in equation (1) below (Hunt, 1983). The cumulative values for the cost of depreciation were calculated by first adding the annual value for the cost of depreciation for the first year of operation of Belarus 800 farm tractors to the annual value for the cost of depreciation for the second year of operation. The cost of depreciation for the second year of operation on ward was calculated by adding the cumulative value for the cost of depreciation for the year of operation in question to the annual value for the cost of depreciation for the next year of operation.

$$D = \frac{P-S}{L} \tag{1}$$

where
D = depreciation,
S = the selling or salvage value,
P = list (Purchase) price,
L = time between purchase (buying) and selling in years.

#### 2.7.2. Calculation of the cumulative cost of the interest on investment for the Belarus 800 farm tractors

The annual values for the cost of the interest on investment were calculated using equation (3) below. The annual values for the cost of the interest on the investment for the Belarus 800 farm tractors were calculated using the interest rate put forward by the Bank of South Sudan known as BOSS which is the Central Bank of the Republic of South Sudan for the fiscal year of 2016 which was the rate of 15%.

The cumulative values for the cost of the interest on investment for each and every year of operation were calculated by adding the annual value for the cost of the interest on investment for the first year of operation to the annual value for the second year of operation. From the second year of operation onward, the cumulative value for the cost of the interest on investment were calculated by adding the cumulative value for the cost of the interest on investment for the year of operation in question to the annual value for the cost of the interest on investment for the next year of operation. The interest rate can also be calculated using the below equation (2) below (Edwards, 2015).

$$I_r = \frac{Ip+Ig}{1+Ig} \tag{2}$$

where
I_r= is the real interest rate,
Ip = is a nominal interest rate,
Ig= is the rate of inflation.

The cost of the interest on the investment for the Belarus 800 farm tractor was calculated by using equation (3) below (Edwards, 2015).

$$I_n = V * I_r \tag{3}$$

where
Ir = is the rate of interest,
In = is the interest on investment in nth year ($),
V = is the remaining value at any time.

#### 2.7.3. Calculation of the cumulative cost of taxes, insurance and housing for the Belarus 800 farm tractors

The costs of taxes, insurance and housing or shelter for the Belarus 800 farm tractors were lumped (summed) together as 2% of the list price (Edwards, 2015), then, these costs were calculated for each and every year of operation of this farm tractor. The cumulative values for the costs of taxes, insurance and housing or shelter were calculated by summing up the annual value for the costs of taxes, insurance and housing for the first year of operation to the annual value for the costs of taxes, insurance and housing for the second year of operation. And starting from the second year of operation on ward the cumulative values for taxes, insurance, and housing were calculated by summing up the cumulative value for the costs of taxes, insurance and housing for the year of operation in question to the annual value for the costs of taxes, insurance and housing for the next year of operation.

### 2.8. Calculation of the cumulative ownership cost for the Belarus 800 farm tractors.

The cumulative ownership cost per each year of operation for the studied Belarus 800 farm tractors was obtained by summing up the cumulative cost values for the following ownership cost parameters of depreciation, interest on investment and taxes, insurance and housing

(TIH) for each and every year of operation of the studied Belarus 800 farm tractors.

### 2.9. Calculation of the cumulative variable cost parameters for the Belarus 800 farm tractors

#### 2.9.1. Calculation of the cumulative cost of maintaining and repairing the Belarus 800 farm tractors

The annual values for the cost of spare parts, workmanship, oils and oils replacement, oils and fuel filters, oils and fuel filters replacement, grease and greasing, and tire replacement were added together to obtain the annual value for the cost of repair and maintenance (R&M) for the studied Belarus 800 farm tractor. The annual values for the cost of repair and maintenance were then cumulated by first adding the annual value for the cost of repair and maintenance for the first year of operation to the annual value for the cost of repair and maintenance for the second year of operation. From the second year of operation of the Belarus 800 farm tractors on ward, the cumulative costs of repair and maintenance were calculated by adding the cumulative value for the cost of repair and maintenance for the year of operation in question to the annual value for the cost of repair and maintenance for the next year of operation (Ward et al., 1985).

The cumulative values for the cost of repair and maintenance for farm tractors can also be computed using equation (4) below (Hunt, 1983).

$$\frac{C_{rm}}{P_u} = RF1\left(\frac{t}{1000}\right)^{RF2} \tag{4}$$

where
RF1, RF2 = Repair factor,
Pu = Purchase price,
t = Accumulated use (h),
Crm = Accumulated repair and maintenance cost.

#### 2.9.2. Calculation of the cumulative cost of fuel for the Belarus 800 farm tractors

The annual values for the cost of fuel consumption for the studied Belarus 800 farm tractors operated in Bilfam and Rajaf East areas were collected using the questionnaires. Then, the cumulative values for the cost of fuel were calculated by adding the annual value for the cost of fuel for the first year of operation for the studied Belarus 800 farm tractors to the annual value for the cost of fuel for the second year of operation. From the second year of operation on ward the cumulative values for the cost of fuel were calculated by adding the cumulative value for the cost of fuel for the year of operation in question to the annual value for the fuel cost for the next year of operation (Ward et al., 1985).

The average fuel consumption in gallons per hour for the farm tractors can also be calculated on the year round basis without reference to specific farm equipment using the below equations (5) for the gasoline engines and (6) for the diesel engines (Edwards, 2015).

$$0.060 * \text{maximum PTO horsepower for gasoline engines} \tag{5}$$

$$0.44 * \text{maximum PTO horsepower for diesel engines} \tag{6}$$

where
PTO = Power take-off power.

#### 2.9.3 Calculation of the cumulative cost for the Belarus 800 tractors' operators

The annual values for the tractor operator cost for each and every year of operation were collected using the questionnaires. The cumulative values for the tractor operator cost for the studied Belarus 800 farm tractors were calculated by summing up the annual value for the tractor operator cost for the first year of operation to the annual value for the tractor operator cost for the second year of operation. Starting from the second year of operation to the rest of the years, the cumulative values for the Belarus 800 farm tractors were calculated by summing up the cumulative value for the tractor operator cost for the year of operation in question to the annual value for the tractor operator cost for the next year of operation (Ward et al., 1985).

The wages for the tractor operator (labour) were multiplied by 1.1 and 1.2 for operations of different wages because the real hours of operation is 10% and 20% more than the hours spent in the field which include time for refilling, lubrication, and maintenance (Edwards, 2015).

### 2.10. Calculation of the cumulative operating cost for the Belarus 800 farm tractors

The cumulative operating cost for the Belarus 800 farm tractors was made up of the accumulated cost values for the cost parameters pertinent to the operating or the variable cost which included the costs of repair and maintenance (R&M), fuel, and tractor operator cost. The cumulative operating cost were calculated by summing up the cumulative values for the operating cost of the studied Belarus 800 farm tractors for each and every year of operation (Ward et al., 1985).

### 2.11. Calculation of the cumulative total cost for the Belarus 800 farm tractors

The cumulative total cost for the Belarus 800 farm tractors was calculated by summing the cumulative cost values for the operating cost to the cumulative cost values of the ownership cost per each and every year of operation starting with the first year of operation.

### 2.12. Calculation of the cumulative operating hours for the Belarus 800 farm tractors

The annual operating hours per each year of operation of the Belarus 800 farm tractors were collected using questionnaires. The cumulative hours of operation for the Belarus 800 farm tractors were calculated by first adding the annual value for the operating hours of the Belarus 800 farm tractors for its first year of operation to the annual value for the operating hours for its second year of operation. Starting from the second year of operation of the Belarus 800 farm tractors on ward, the cumulative hours of operation for the studied Belarus 800 were calculated by adding the cumulative value for its operating hours for the year of operation in question to the annual value for its operating hours for the next year of operation (Ward et al., 1985).

### 2.13. Calculation of the cumulative total cost per hour for the Belarus 800 farm tractors

The values for the cumulative total cost per hour for the Belarus 800 farm tractors were calculated from the following two parameters of the cumulative total cost and the cumulative operating hours and that is by dividing the cumulative total cost by the cumulative operating hours for each and every year of operation starting with the first year of operation.

### 2.14. Determination of the economic life for the Belarus 800 farm tractors

The economic life for the farm tractors is that particular year of the farm tractors in which the value for the accumulated total cost per hour falls to its lowest then starts to rise again. It is the year of operation appropriate for the replacement of the farm tractors. The economic life for the Belarus 800 farm tractor model was determined from both the table for the cumulative total cost per hour and the curve for the cumulative total cost per hour to be the lowest value for the cumulative total cost per hour and the lowest point for the curve of the cumulative total cost per hour (Nicola, 2025).

### 2.15. Development of a mathematical model to predict the cumulative total cost per hour and the economic life for the Belarus 800 farm tractors

The mathematical model for the prediction of the cumulative total cost per hour which in turn predicts the economic life for the farm tractors was developed from the two variables of the cumulative total cost per hour and the age of operation of this farm tractor (Nicola, 2025).

### 2.16. Data analysis

Regression analysis was performed using Microsoft Excel (2010) on the cumulative values for the two parameters of the cumulative total cost per hour for the Belarus 800 farm tractors and the parameter of the age of operation for the Belarus 800 farm tractors. In the process of running the regression analysis, the following regression models of exponential, logarithmic, linear, polynomial and power were all tested or validated (Nicola, 2025).

## 3. Results and discussions

### 3.1. The cumulative ownership cost in USD for the Belarus 800 farm tractors

The cumulative values in USD for the ownership cost parameters of depreciation, interest on investment and taxes, insurance and housing as well as the cumulative values for the ownership cost for each and every age of operation are shown in table (1) below.

### 3.2. The cumulative operating cost in USD for the Belarus 800 farm tractors

The cumulative values in USD for the operating cost parameters of the repair and maintenance (R&M), fuel and the tractor operator as well as the cumulative values for the operating cost for each and every age of operation are shown in table (2) below.

### 3.3. The cumulative total cost in USD for the Belarus 800 farm tractors

The cumulative in USD values for the operating cost, ownership cost as well as the total cost for each and every age of operation are shown in table (3) below.

### 3.4. The cumulative total cost in USD per hour for the Belarus 800 farm tractors

The cumulative values in USD for the total cost, operating hours and the total cost per hour for each and every age of operation are shown in table (4) below.

**Table 1.** The cumulative depreciation, the cumulative interest on investment, the cumulative taxes, insurance, and housing, and the cumulative ownership cost in USD for the studied Belarus 800 farm tractors

| Cumulative Depreciation | Cumulative Interest on Investment | Cumulative TIH | Cumulative Ownership Cost |
|---|---|---|---|
| **865.39** | 103.85 | 17.31 | 986.55 |
| **1765.39** | 211.85 | 35.31 | 2012.55 |
| **2702.89** | 324.35 | 54.06 | 3081.30 |
| **3681.15** | 441.74 | 73.62 | 4196.51 |
| **4703.88** | 564.47 | 94.08 | 5362.42 |
| **5775.31** | 693.04 | 115.51 | 6583.85 |
| **6900.31** | 828.04 | 138.01 | 7866.35 |
| **8084.52** | 970.14 | 161.69 | 9216.35 |
| **9334.52** | 1120.14 | 186.69 | 10641.35 |
| **10658.05** | 1278.97 | 213.16 | 12150.18 |
| **12064.30** | 1447.72 | 241.29 | 13753.30 |
| **13564.30** | 1627.72 | 271.29 | 15463.30 |
| **15171.44** | 1820.57 | 303.43 | 17295.44 |
| **16902.21** | 2028.27 | 338.04 | 19268.52 |
| **18777.21** | 2253.27 | 375.54 | 21406.02 |
| **20822.66** | 2498.72 | 416.45 | 23737.83 |
| **23072.66** | 2768.72 | 461.45 | 26302.83 |
| **25572.66** | 3068.72 | 511.45 | 29152.83 |
| **28385.16** | 3406.22 | 567.70 | 32359.08 |
| **31599.45** | 3791.93 | 631.99 | 36023.37 |
| **35349.45** | 4241.93 | 706.99 | 40298.37 |
| **39849.45** | 4781.93 | 796.99 | 45428.37 |
| **45474.45** | 5456.93 | 909.49 | 51840.87 |
| **52974.45** | 6356.93 | 1059.49 | 60390.87 |
| **64224.45** | 7706.93 | 1284.49 | 73215.87 |
| **86724.45** | 10406.93 | 1734.49 | 98865.87 |

**Table 2.** The cumulative repair and maintenance cost, the cumulative fuel cost, the cumulative labour cost, and the cumulative operating cost in USD for the studied Belarus 800 farm tractors

| Cumulative R&M Cost | Cumulative Fuel Cost | Cumulative Tractor Operator Cost | Cumulative Operating Cost |
|---|---|---|---|
| 783 | 536 | 371 | 1690 |
| 1626 | 1122 | 782 | 3530 |
| 2479 | 1718 | 1203 | 5400 |
| 3342 | 2324 | 1634 | 7300 |
| 4215 | 2940 | 2075 | 9230 |
| 5098 | 3566 | 2526 | 11190 |
| 5991 | 4202 | 2987 | 13180 |
| 6894 | 4848 | 3458 | 15200 |
| 7807 | 5504 | 3939 | 17250 |
| 8730 | 6170 | 4430 | 19330 |
| 9663 | 6846 | 4931 | 21440 |
| 10606 | 7532 | 5442 | 23580 |
| 11559 | 8228 | 5963 | 25750 |

| Cumulative R&M Cost | Cumulative Fuel Cost | Cumulative Tractor Operator Cost | Cumulative Operating Cost |
|---|---|---|---|
| 12522 | 8944 | 6494 | 27960 |
| 13495 | 9670 | 7035 | 30200 |
| 14478 | 10406 | 7586 | 32470 |
| 15471 | 11152 | 8147 | 34770 |
| 16474 | 11898 | 8718 | 37090 |
| 17487 | 12654 | 9299 | 39440 |
| 18510 | 13420 | 9890 | 41820 |
| 19543 | 14196 | 10491 | 44230 |
| 20586 | 14982 | 11102 | 46670 |
| 21639 | 15778 | 11723 | 49140 |
| 22702 | 16584 | 12354 | 51640 |
| 23775 | 17400 | 12995 | 54170 |
| 24858 | 18226 | 13646 | 56730 |
| 25951 | 19062 | 14307 | 59320 |

**Table 3.** The cumulative operating cost, the cumulative ownership cost, and the cumulative total cost in USD per each year of operation of the studied Belarus 800 Farm Tractors

| Age | Cumulative Operating Cost | Cumulative Ownership Cost | Cumulative Total Cost |
|---|---|---|---|
| 1 | 1690.00 | 986.55 | 2676.55 |
| 2 | 3530.00 | 2012.55 | 5542.55 |
| 3 | 5400.00 | 3081.30 | 8481.30 |
| 4 | 7300.00 | 4196.51 | 11496.51 |
| 5 | 9230.00 | 5362.42 | 14592.42 |
| 6 | 11190.00 | 6583.85 | 17773.85 |
| 7 | 13180.00 | 7866.35 | 21046.35 |
| 8 | 15200.00 | 9216.35 | 24416.35 |
| 9 | 17250.00 | 10641.35 | 27891.35 |
| 10 | 19330.00 | 12150.18 | 31480.18 |
| 11 | 21440.00 | 13753.30 | 35193.30 |
| 12 | 23580.00 | 15463.30 | 39043.30 |
| 13 | 25750.00 | 17295.44 | 43045.44 |
| 14 | 27960.00 | 19268.52 | 47228.52 |
| 15 | 30200.00 | 21406.02 | 51606.02 |
| 16 | 32470.00 | 23737.83 | 56207.83 |
| 17 | 34770.00 | 26302.83 | 61072.83 |
| 18 | 37090.00 | 29152.83 | 66242.83 |
| 19 | 39440.00 | 32359.08 | 71799.08 |
| 20 | 41820.00 | 36023.37 | 77843.37 |
| 21 | 44230.00 | 40298.37 | 84528.37 |
| 22 | 46670.00 | 45428.37 | 92098.37 |
| 23 | 49140.00 | 51840.87 | 100980.87 |
| 24 | 51640.00 | 60390.87 | 112030.87 |
| 25 | 54170.00 | 73215.87 | 127385.87 |
| 26 | 56730.00 | 98865.87 | 155595.87 |

**Table 4.** The cumulative total cost, the cumulative total cost per hour in USD, and the cumulative operating hours per each year of operation for the studied Belarus 800 farm tractors

| Age | Cumulative Total Cost | Cumulative Operating Hours | Cumulative Total Cost Per Hour |
|---|---|---|---|
| **1** | 2676.55 | 276.96 | 9.66 |
| **2** | 5542.55 | 633.92 | 8.74 |
| **3** | 8481.30 | 1000.88 | 8.47 |
| **4** | 11496.51 | 1377.84 | 8.34 |
| **5** | 14592.42 | 1764.80 | 8.27 |
| **6** | 17773.85 | 2161.76 | 8.22 |
| **7** | 21046.35 | 2568.72 | 8.19 |
| **8** | 24416.35 | 2985.68 | 8.18 |
| **9** | 27891.35 | 3412.64 | 8.17 |
| **10** | 31480.18 | 3849.60 | 8.18 |
| **11** | 35193.30 | 4296.56 | 8.19 |
| **12** | 39043.30 | 4753.52 | 8.21 |
| **13** | 43045.44 | 5220.48 | 8.25 |
| **14** | 47228.52 | 5697.44 | 8.29 |
| **15** | 51606.02 | 6184.40 | 8.35 |
| **16** | 56207.83 | 6681.36 | 8.41 |
| **17** | 61072.83 | 7188.32 | 8.50 |
| **18** | 66242.83 | 7705.28 | 8.60 |
| **19** | 71799.08 | 8232.24 | 8.72 |
| **20** | 77843.37 | 8769.20 | 8.88 |
| **21** | 84528.37 | 9316.16 | 9.07 |
| **22** | 92098.37 | 9873.12 | 9.33 |
| **23** | 100980.87 | 10440.08 | 9.67 |
| **24** | 112030.87 | 11017.04 | 10.17 |
| **25** | 127385.87 | 11604.00 | 10.98 |
| **26** | 155595.87 | 12200.96 | 12.75 |

### 3.5. Data validation and reliability

Though the Republic of South Sudan has been hit by an economic crises since the broke out of the civil war back in December 2016 up to now except that the above mentioned data which were collected in 2016 remain both relevant and reliable because they were presented in the United States Dollars (USD) which is the standard currency for international trade. The local currency at the time this data were collected was traded at 7100 South Sudanese Pound (SSP) equals 100 USD but as of now in 2026 it is trading at 580,000 SSP equals 100 USD which is a clear indication that the local currency lost much of its value and this devaluation resulted into the inflation in the prices of the commodities in SSP but not in USD. The sky-rocketing price of commodities in local currency does not affect the prices in USD because when these big figures in SSP are converted into USD, the figure in USD remains the same as shown above. For this reason, all the costs data collected in SSP were converted to USD so that when the local currency (SSP) losses or gains its value, the data continue to be relevant and reliable.

### 3.6 Determination of economic life for the Belarus 800 farm tractors operated in the Bilfam and Rajaf East Areas of the Central Equatoria State

The economic life of a farm tractor is that particular year of operation in which the cumulative total cost per hour falls to its lowest value before it starts to rise again. As can be seen in column (4) of the above table (4), the cumulative total cost per hour for the studied Belarus 800 farm tractors operated in the Bilfam and Rajaf East areas of the Central Equatoria State started to decrease all from the first year of operation to the ninth year of operation then it started to increase from the tenth year of operation onward. Therefore, continuing to operate the studied Belarus 800 farm tractors after the ninth (9) year of their operation will cost their owners more money than any year of operation before. Therefore, the ninth (9) year of operation is said to be the economic life for the studied Belarus 800 farm tractors operated in the Bilfam and Rajaf East areas of the Central Equatoria State of the Republic of South Sudan because it is the number of the years of operation within which the operating costs for the studied Belarus 800 farm tractors are economic. This is to say the owners of the studied Belarus 800 farm tractors operating in the study areas of Bilfam and Rajaf East should replace their Belarus 800 immediately after the ninth (9) year of operation, because continuing to operate the Belarus 800 farm tractors after their ninth (9) year is not economic. Therefore, the ninth (9) year of operation is the economic life for the studied Belarus 800 farm tractors. As it can clearly be seen in column three (3) of table (4), the economic life or the age of replacement for the studied Belarus 800 farm tractors which is nine years arrives when they were operated for an average of 3,412.64 hours.

The economic life for the Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East is also said to be the lowest point of the curve for the cumulative total cost per hour as it is shown in figure (2) below which corresponds to the age of operation of 9 years.

Taking into account the fact that the economic life for the farm tractors differs from one tractor make to another, one tractor model to another, one country to another, and even from one area to another within the same administrative area based on the operational factors of terrain, operator skills, type of soil, environmental factors of temperature and humidity, and the management factors of the ownership cost, the operating cost, and therefore, should not be generalized, the result of this study on the economic life determined for the studied Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East which is 9 years of operation corresponded with the result reported by Shani and Musa (2018) which revealed that the economic life for the Mahindra605 farm tractors operated in the Kaduna State of Nigeria is 9 years.

But the above result differ from the findings obtained by Nicola (2025), which concluded that the economic life for the Sonalika DI-75 farm tractors operated in the Mapel Area of the Central Equatoria State is 18 years with cumulative operating hours of 4,096.10 h. The above result is also inconsistent with the findings arrived at by Khoubbakht et al. (2008), which revealed that the economic life for the MF 285 farm tractors operated in the Khansar and Golpayegan areas of the Central Region of Iran is 20 years of operation with cumulative hours of 18000 h. The findings of the current study also disagree with the ones arrived at by Khoubbakht et al. (2010) which also reported that the Khansar and Golpayegan areas of the Central Region of Iran is 20 years. Once more, the result of this study disagrees with the finding obtained by Chenarbon et al. (2014) which indicated that the economic life for the John Deere 3140 operated in the Varamin Pishva region of Iran is 8 years. The result of this study also does not correspond with the finding reported by Poozesh et al. (2012) which concluded that the economic life for the Massey Ferguson 285 farm tractors operated in the Ahvaz area of Iran is 14 years.

### 3.7 Development of a mathematical model to predict the cumulative total cost per hour for each and every year of operation as well as to predict the economic life for the Belarus 800 farm tractors.

The mathematical model for the prediction of the economic life for the Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East was developed from the two variables of the age of operation for the Belarus 800 farm tractors which was regarded as an independent variable because it's value doesn't depend on any other variable and thus, it was labelled on the X-axis, and the cumulative total cost per hour which was regarded as a dependent variable because it's value depends on the age of operation for the Belarus 800 farm tractors and thus, it was labelled on the Y-axis (Nicola, 2025).

### 3.8 The mathematical model developed by this study for the prediction of the economic life for the Belarus 800 farm tractors.

The mathematical model developed by the current study for the prediction of the economic life for the Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East is shown in figure (2) below.

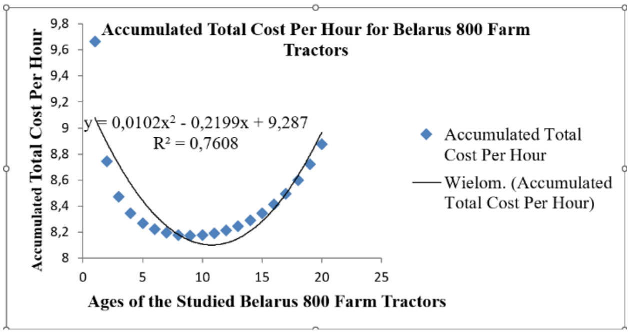


**Figure 2.** The cumulative total cost per hour per each year of operation of he studied Belarus 800 farm tractors and the mathematical model developed for the prediction of their economic life

During the development of the mathematical model shown in the figure (2) above, the following models of exponential, linear, logarithmic, polynomial and power were all validated or verified and it was found that the polynomial model Y=0.0102X2-0.2199X+9.287 is the best mathematical model for estimating or predicting the cumulative total cost per hour as well as the economic life for the studied Belarus 800 farm tractors and this is because the estimated or the predicted values for both the cumulative total cost per hour and the economic life were closer to the calculated values of both the cumulative total cost per hour as well as the economic life for the studied Belarus 800 farm tractors. Again the polynomial model was determined to be the best mathematical model for estimating or predicting both the cumulative total cost per hour and the economic life for the studied Belarus 800 farm tractors operated in the Bilfam and Rajaf East areas of the Central Equatoria State because the value of its regression coefficient (R2) which is 0.7608 is the highest among all the other four mathematical models of exponential, linear, logarithmic, and power.

The five mathematical models that were tested, validated, or verified by this study are shown in table (5) below.

**Table 5.** Comparison between different five mathematical or regression models developed by this study

| No | Mathematical model | Type of the mathematical model | Regression Coefficient ($R^2$) |
|---|---|---|---|
| 1 | $Y=8.484e^{-6E-04X}$ | Exponential | 0.0066 |
| 2 | Y=0.0058X+8.5018 | Linear | 0.0091 |
| 3 | $Y=8.8312X^{-0.022}$ | Power | 0.1885 |
| 4 | Y=-0.196ln(X)+8.8566 | Logarithmic | 0.1989 |
| 5 | $Y=0.0102X^2-0.2199X+9.287$ | Polynomial | 0.7608 |

Therefore, from the above mentioned mathematical models and their regression coefficients, it can be said that the regression coefficient (R2) is the statistical justification for selecting the polynomial model to be the best model for predicting both the cumulative total cost per hour and the economic life for the studied Belarus 800 farm tractors. The regression coefficient (R2) is an indicator of the strength in relationship between the cumulative total cost per hour on one side and the age of operation for the studied Belarus 800 farm tractors on the other side. As the regression coefficient (R2) increases, the accuracy of the mathematical model increases. Another way round, the values for both the cumulative total cost per hour and the economic life for the studied Belarus 800 farm tractors predicted or estimated by the developed mathematical model becomes closer to their calculated values as shown in column (4) of the above table (4) each and every time the value for the regression coefficient (R2) increases. That is to say the estimated or the predicted value for the cumulative total cost per hour exactly equals the calculated value for the cumulative total cost per hour if and only if R2=1. If R2 is less than 1, then, the value for the estimated or the predicted cumulative total cost per hour decreases.

Therefore, the above mathematical model of Y=0.0102X2-0.2199X+9.287 is the mathematical model developed by this study for the prediction of both the cumulative total cost per hour and the economic life for the studied Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East of the Central Equatoria State of the Republic of South Sudan and its type is polynomial model.

Though the economic life of the farm tractors differ from one region to another, one country to another, and even from one administrative unit to another within the same country based on the opera--ional factors of the terrain, the skills of the operator of the farm tractor, whether the spare parts are genuine or not, the environmental factors of the temperature and humidity, the management factors of the tractor make, tractor model, and the operating costs and therefore cannot be generalized, the result of this study on the type of the mathematical model determined to be the best for the prediction of the economic life for the Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East which is the polynomial model corresponds with the result reported by Khoubbakht et al. (2008), whose study revealed that the polynomial model is the best mathematical model for the prediction of the economic life for the MF 285 farm tractors operated in the Khansar and Golpayegan areas of the Isfahan Province of the Islamic Republic of Iran. The finding of this study on the mathematical model also agrees with the result reported by Khoubbakht et al. (2010), which indicated that the polynomial model is the best mathematical model for predicting the economic life for the MF 285 farm tractors operated in the Khansar and Golpayegan areas of the Isfahan Province of the Islamic Republic of Iran. Once more, the result of this study concur with the result obtained by Nicola (2025), which concluded that the polynomial model is the suitable mathematical model to predict the economic life for the Sonalika DI-90 farm tractors operated in the Mapel area of Juba - the Capital City of South Sudan. But the result of this study on the type of the mathematical model suitable for the estimation or the prediction of the economic life for the studied Belarus 800 farm tractors which is the polynomial model disagrees with the finding revealed by Shani and Musa (2018) which reported that the best mathematical model for the prediction of the economic life for the Mahindra 605 farm tractors operated in the Kaduna state of Nigeria is the Quadratic Model. The finding of this study on the type of mathematical model suitable for the estimation or the prediction of the economic life of the farm tractors which is a polynomial model also disagrees with the result arrived at by Chenarbon et al. (2014) which concluded that the best mathematical model for estimating or predicting the economic life for the John Deere 3140 farm tractors operated Varamin Pishva region of the Islamic Republic of Iran is the Quadratic Model.

### 3.9. Model validation and reliability

Though it has taken some time since the cost data for this study has been collected, except that the polynomial regression model developed for the estimation or the prediction of the economic life for the studied Belarus 800 farm tractors can still be used for predicting or estimating the economic life for the Belarus 800 farm tractors operating in the study areas of the Bilfam and Rajaf East of the Central Equatoria State today and this is because the collected cost data in South Sudanese Pound (SSP) were converted to the United States Dollars (USD) in order to overcome the volatilities or the fluctuations of the local currency (SSP) with respect to the USD, as well as to compensate for the two problems of the devaluation and inflation that is hitting South Sudan today.

## 4. Conclusions

The economic life for the Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East was determined by this study to be nine (9) years of operation with cumulative operating hours of 3,412.64 hours of operation.

This economic life for the Belarus 800 farm tractors operated in the two areas of Bilfam and Rajaf East was determined based on the total cost of owning and operating the Belarus 800 farm tractors which included "Depreciation, Interest on Investment, Taxes, Insurance, and Housing (Shelter)" and "Repair and Maintenance (R&M), Fuel, and Tractor Operator.

The determined economic life for the Belarus 800 farm tractors was positively influenced by all the ownership cost parameters of "Depreciation, Interest on Investment, Taxes, Insurance, and Housing or Shelter" as well as by all the operating cost parameters of "Repair and Maintenance (R&M), Fuel, and Tractor Operator".

The polynomial model was determined to be the best mathematical model for predicting or estimating the economic life for the Belarus 800 farm tractors operating in the Bilfam Area of Juba City and Rajaf East.

The determined economic life or the age of replacement of nine (9) years for the studied Belarus 800 farm tractors is applicable only to those Belarus 800 farm tractors operating within the study area of Bilfam and Rajaf East Areas of the Central Equatoria State but not for those Belarus 800 farm tractors operating in other Counties of the state.

The polynomial regression model developed by this study for the estimation or the prediction of the accumulated total cost per hour as well as the economic life for the studied Belarus 800 farm tractors is applicable only for those Belarus 800 farm tractors operating within the study areas of Bilfam and Rajaf East of the Central Equatoria State but not for those operating in other Counties of the state.

The result of this study may serve not only the farm power and machinery managers which it does, but also the farmers, tractor owners and operators to economically evaluate their Belarus 800 farm tractors, as well as, it provides them with the appropriate age of operation for the replacement of Belarus 800 farm tractors operating in the Bilfam and Rajaf East Areas of the Central Equatoria State.

The results of this study may also help in deciding which tractor makes and models should be imported into South Sudan.

Since the costs of owning and operating farm tractors are important not only for knowing the production cost but also for knowing the replacement age of farm tractors, both the national and the state Governments should incorporate the economic life of farm tractors' makes and models into decision making concerning the importation of farm tractors into the Country.

## 5. Data availability statement

All the data concerning this study are presented in the above mentioned tables of (1, 2, 3, and 4) whose annual values could be obtained by subtracting the value for the previous year of operation from the value for the year of operation in question.

## References


AfDB. (2013). South Sudan: An Infrastructure Action Plan - A Program for Sustained Strong Economic Growth - Chapter 6 - Development of Agriculture in South Sudan (pp.130-167). African Development Bank. https://www.afdb.org/sites/default/files/documents/projects-and-operations/south_sudan_infrastructure_action_plan_-_a_program_for_sustained_strong_economic_growth_-_full_report.pdf .

Al-Suhaibani, S. A., & Wahby, M. F. (2015). Farm tractors breakdown classification. *Journal of the Saudi Society of Agricultural Sciences,* vol. 16, pp. 294-298. http://dx.doi.org/10.1016/j.jssas.2015.09.005 .

Anderson, A. W. (1988). Factors affecting machinery costs in grain production. *ASAE Paper*. No. 88-1057. American Society of Agricultural Engineers (ASAE), Nile Road, St. Joseph, Michigan.

Chenarbon, H. A., Afsar, A., & Ebrahimzadeh, M. R. (2014). Determining Replacement Age of Agricultural Tractor (JD3140) in Varamin Region (Case Study). *African Journal of Agricultural Research*, Vol. (9), pp. 2012-2017, doi.org/10.5897/AJAR11.639 .

Edwards, W. (2015). Estimating Farm Machinery Cost. Iowa State University-Extension and Outreach.

Gifford, R. C., & Rijk, A. G. (1980). Guidelines for Agricultural Mechanization Strategy in Development. ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC. REGIONAL NETWORK FOR AGRICULTURAL MACHINERY.https://repository.unescap.org/server/api/core/bitstreams/b94cef7b-54cb-4765-8b61-0a38df5b00ed/content .

Hunt, D. (2001). Farm Power and Machinery Management, 10th Edition. Iowa State University Press, Ames, Iowa.

Hunt, D. (1983). Farm Power and Machinery Management, 8th edition. AGRIS-International System for Agricultural Science and Technology-United Nations Food and Agriculture Organization (FAO).

Khoubbakht, G., Ahmadi, H., Akram, A., & Karimi, M. (2008). Determination of Optimum Life (Economic Life) for MF 285 Tractor: A Case Study in Center Region of Iran. *American-Eurasian Journal of Agricultural and Environmental Sciences*, vol. 4(1), pp. 81-85.

Khoubbakht, G., Ahmadi, H., & Akram, A. (2010). Determination of optimum life for MF285 tractor based on repair and maintenance costs: A case study in central region of Iran. *Journal of Agricultural Technology*, vol. 6, pp. 673-686.

Ministry of Agriculture, Forestry, Cooperatives and Rural Development (MAFCRD). (2015). The Comprehensive Agricultural Development Master Plan “CAMP”. Ministry of Agriculture, Forestry, Cooperatives and Rural Development, Republic of South Sudan. Japan International Cooperation Agency. JIN Corporation.

Nicola, S. N. W. (2025). Mathematical Model for the Prediction of the Useful Life of Sonalika DI-90 Farm Tractor Operated in Juba City. Economic evaluation of tractor useful life as a decision-making tool for agricultural productivity and rural development in South Sudan. *Global Economic Horizons*, vol. 01, pp. 141-150, https://doi:10.61552/GEH.2025.01.018 .

Pagare, V., Nandi, S., & Khare, D. K. (2019). Appraisal of Optimum Economic Life for Farm Tractor: A Case Study. *Economic Affairs*, vol. 64(1), pp. 111-118. https://doi.org/10.30954/0424-2513.1.2019.15 .

Poozesh, M., Mohtasebi, S. S., Ahmadi, H., & Asakereh, A. (2012). Determination of appropriate time for farm tractors replacement based on economic analysis. *Elixir Control Engineering*, 47, pp. 8684-8688.

Rotz, C. A. (1987). A Standard Model for Repair Costs of Agricultural Machinery. *Applied Engineering in Agriculture*, 3(1), 3-9. https://doi.org/10.13031/2013.26633 .

Rotz, C. A., & Bowers, W. (1991). Repair and maintenance cost data for agricultural equipment. ASAE Paper No. 91-1531. American Society of Agricultural Engineers (ASAE), Nile Road, St. Joseph, Michigan.

Shani, B. B., & Musa, A. (2018). Economic Analysis of Ideal Time for Farm Tractor Replacement: A Case Study of Tractor Owners and Operators Association of Nigeria, Kaduna State. *Iconic Research And Engineering Journals*, Vol. 2(6), pp. 32-38. https://www.irejournals.com/formatedpaper/1700867.pdf .

Singh, G. (2006). Estimation of a mechanization index and its impact on production and economic factors—a case study in India. *Biosystems Engineering*, vol. 93(1), pp. 99–106. https://doi.org/10.1016/j.biosystemseng.2005.08.003

Ward, S. M., McNulty, P. B., & Cunney, M. B. (1985). Repair costs of 2 and 4 WD tractors. *Transactions of the American Society of Agricultural Engineers*, vol. 28(4), pp. 1074-1076. DOI:10.13031/2013.32390

Wilba, S. N., Gitau, A. N., Mbuge, D. O., & Mwangi, S. T. (2018). Modelling Variable Cost of Tractors: Case Study of Ten Tractor Models in Juba City-South Sudan. *Agricultural Mechanization in Asia, Africa and Latin America (AMA)*, vol. 49(2), pp. 104-111.