Journal of Engineering Research and Reports

20(10): 113-121, 2021; Article no.JERR.71508
ISSN: 2582-2926

Repair and Maintenance Cost Estimation for Two Power Sizes of Agricultural Tractors as Affected by Hours of Use and Age in Years: A Case Study, Dongola Area, Sudan

Mohamed H. Dahab[1*], Montasir A. Gafar[1] and Abdul Gadir M. Abdul Rahman[1]

[1]Department of Agric. Engineering, Faculty of Agriculture, University of Khartoum, Sudan.

Authors' contributions

This work was carried out in collaboration between the authors MHD and MAG. Author AGMAR carried out data analysis and reviewing the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2021/v20i1017395
Editor(s):
(1) Dr. Guang Yih Sheu, Chang-Jung Christian University, Taiwan.
Reviewers:
(1) Farshad Abbasi, Mondragon University, Spain.
(2) Yaichi Mohammed, Research Unit in Renewable Energy in Saharan Medium, Algeria.
Complete Peer review History: https://www.sdiarticle4.com/review-history/71508

Original Research Article

Received 14 May 2021
Accepted 19 July 2021
Published 26 July 2021

ABSTRACT

Repair and maintenance cost is considered as one of important items for machinery management and selection especially agricultural tractors. The present study was carried out in Dongola area for tractor repair and maintenance costs estimation. The data was collected from records of Elshimalya Company for Agricultural services. Forty-four tractors representing two powers sizes, 75hp and 150hp used in the area were selected for this study. Based on the data collected, regression correlation analysis was carried out and mathematical models were derived to predict the accumulated repair and maintenance (R and M) costs as percent of purchase price in relation to accumulated hours of use and age (years) for each tractor size, and for the two sizes collectively. Five model forms (linear, logarithmic, polynomial, power and exponential) were derived and the power function was found the best fit to explain the relation. The accumulated Rand M costs as percent of purchase price (Y) was increased as the accumulated hours of use (x) and age (g) of the tractor in years were increased. A high correlation was found between the accumulated R and M cost and both accumulated hours of use and tractor age in years (Average R^2 = 0.93).

**Corresponding author: Email: mhdahabahmed55@yahoo.com;*

It was concluded that the power function was the best fit for repair and maintenance cost estimations and this relation may be used as an average of the two tractor powers, for estimation of the accumulated R and M costs as percent of purchase price (Y) with accumulated hours of use (x) and age (g): $Y=0.028x^{0.662}$ (mean) $Y=12.294g^{1.276}$ (mean).

Keywords: Repair and maintenance; mathematical model; hours of use; power; Dongola.

1. INTRODUCTION

Agricultural tractor is one of the most important energy and power sources in agricultural mechanization [1]. It requires high initial capital investment. The introduction of modern technology during the last century resulted in rapid growth of farm production. Tractors and farm machinery are important samples of this modern technology [2]. Tractor costs have great influence on farm business profit. Knowledge of tractor costs for farm operations has a prime importance in making management plans and decisions especially in comparing different tractor types and models thereby assisting in the selection of a more appropriate farm tractor [3]. Costs of owning and operating farm machinery represent 35% to 50% of the costs of agricultural production when the land is excluded [4]. The repair and maintenance (R&M) cost is an important item in the costs of ownership and operation. R&M cost is a function of machine age and use [5]. In general, the costs other than those for R&M usually decrease with increasing usage, but the reverse is true with respect to R&M costs. The cost of R&M is usually about 10% of the total cost; as the machine age increases the cost increases until it becomes the largest cost item of owning and operating the farm machines [6]. Agricultural engineers have carried out many studies regarding R&M of farm machines. Several studies were conducted in both developed and developing countries either to develop models to determine the cost during a certain period or to get absolute numbers to represent owning and operating certain equipment [7,8,9]and [10]. Using of American and European mathematical relations to estimate R and M costs in under developed and developing countries produced unrealistic and misleading results and therefore, these countries developed their own mathematical models e.g., [11,12] and [13]. Poor and irregular maintenance reduce tractor reliability, increases fuel consumption, deceases engine power and life and increases exhaust emission [14]. In Sudan, agricultural tractors introduced in early 1990 and there are many tractor makes, models and sizes now distributed between irrigated and rain-fed agricultural farms. These tractors are owned by people from both the private and public sectors and even some are owned by individual farmers and they often work for more than 1200hours per year [15]. Tractors have been used in Sudan, as a power source in agriculture for many years. The total number of tractors officially imported into the country between 1984 and 1994 increased from 23590 units to 32096 units [15]. In Sudan, machinery repair, maintenance, and fuel and lubricants consumption is not given enough attention. About 30- 40% of farm machinery could be out of work very quickly due to lack of proper maintenance and unavailability of genuine spare parts or using of spurious or second-hand spare parts of low prices. There are some prediction models for tractors repair and maintenance costs in the Sudan were developed [16,17] and [18]. They decided that the correlation between repair and maintenance costs as a percent of tractor initial purchase price and the tractor accumulated hours of use would be best described by a power function equation. There were variations between these models in the predictions for the different tractors. They were varied in structural components due to differences in tractors specifications and conditions and locations of work, therefore, the present study was carried to develop computer models for repair and maintenance costs estimation in relation to hours of use and age for two sizes of diesel engine agricultural tractors in Dongola area, northern of Sudan.

2. MATERIALS AND METHODS

The data of the study was collected from Dongola area-northern Sudan. The soil is sandy and clay particles, characterized by very low perm ability, deep cracking when dry, poor in nitrogen and organic matter. The climate of the area is classified as dry desert zone. There are many makes and sizes of tractors working in the area, but one of the most common make available is Massey Ferguson, and are chosen to carry out this study. Their sizes are mostly in the range of 75–150hp.The total number selected for this study was (44), from which twenty-two were

Table 1. Specifications of tractors used

Item	Tractor (A)	Tractor (B)
Country of make	UK	Brazil
Engine rated power	75 hp	150 hp
Engine speed rpm	2200	3600
Drawbar power	63.2 hp	127.5 hp
Engine type	4-cyl. Diesel	4-cyl. Diesel
PTO (rpm)	540/1000	540/1000
Fuel tank capacity	33.6 gal.	61 gal.
Base weight	3265 kg	5670 kg
Clutch	Hydr. Wet multi-disc	Hydr. Wet multi-disc
Brakes	independent hydraulic wet disc	independent hydraulic wet disc
Chassis	2WD	4WD
Steering	Electro-hydraulic,	Electro-hydraulic,

(75hp), and the other twenty-two were (150hp). The tractor's technical specifications are shown in Table (1). Many sources were used to collect data concerning tractors repair and maintenance costs they included Elshamalia Company of Agricultural services, Mechanics, Engineers, Agricultural Engineers, individuals and operators.

A questionnaire was prepared to collect the required data then a survey was carried out in the area of the study to interview the targeted sources of data. The questionnaire included information about; tractor age, model and make, initial purchase price ($), annual hours of use (hr), annual area covered (fed), annual repairs costs ($), annual maintenance costs ($), annual number of repairs and labor cost per year ($).

2.1Tractor Systems Failures and Repair and Maintenance Distribution Calculation

The total costs of repair and maintenance for the different tractor systems and types were carried out by summation of failures during the period of study and calculating the costs of repairing and maintenance for the systems and the two types of tractors.

2.2 Annual Hours of Use Calculation

The total accumulated hours of use was calculated by summation of the total mean annual hours of use which was calculated on the basis of effective working hours of the tractor up to the last year of the age for each of the selected tractor size [10].

2.3 Accumulated Repair and Maintenance Costs Computation

The annual repair and maintenance costs were calculated by adding the annual repair and maintenance costs together. The annual repair and maintenance costs were expressed as percentage of the initial purchase price of the tractor. The total accumulated repair and maintenance costs as a percentage of initial purchase prices were calculated by summation of mean annual repair and maintenance costs as a percentage of initial purchase prices for all years in the age of the selected tractors [10].

Using the SPSS computer program, the relationship between the accumulated annual repair and maintenance costs as a percentage of initial purchase price and accumulated annual hours of use was computed.

3. RESULTS AND DISCUSSION

3.1 Tractor Systems Failures and Repair and Maintenance Distribution

It was observed that the average repair and maintenance costs of different systems for the two tractor powers generally increased with size, but the rate of increase varies for the two tractor types. However, the mean R&M cost of the two tractor types generally showed relative increase with age except for the fuel system (Table 2). The engine and fuel systems accounted for more than 50% of the total accumulated R & M costs of the two tractor sizes when five years ownership was considered (Figs.1a and 1b). The distribution of the accumulated R & M cost of different tractor systems was almost similar for the two types, but the transmission system R & M cost was the highest for both types of tractors (Figs. 2a, 2b and 2c).

3.2 Development of Repair and Maintenance Costs Prediction Models

Regression analysis of the data was carried out to present the relation between the mean accumulated R&M cost as percent of purchase price and the mean accumulated hours of use of the two tractor types, on the models of linear, polynomial, logarithmic, power and exponential with correlation coefficient (Table 3). The lowest value of correlation coefficient among the presented models was related to exponential model with R^2 = 0.62 and the highest value of correlation was for power model with R^2 = 0.93 which is very close to the previous studies [19]. In the most published studies in this field [18] and [19], power models were found easy in calculations and gave better cost predictions than the other models [12]. Therefore, in the present study, power model was suggested as suitable form for repair and maintenance cost estimation. The power relations of accumulated R and M costs with accumulated hours of use and tractor age in years of study for the two tractor types and the average of the two types are given in Table 4 and Table 5 respectively. The average correlation coefficient was very high (R^2 = 0.93, 0.95) indicating that the tractor accumulated hours of use and age could adequately explain variations in R&M costs.

Fig. 3a and 3b show low predicted accumulated R & M costs of the early-stage tractor life, and then costs increased gradually with increasing age and accumulated hours of use in 75hp and 150 hp tractor types. The rate of increase in the accumulated repair and maintenance cost of the two tractor types varied with accumulated hours of use and age.

Table 2. Repair and Maintenance costs distribution for different tractor systems

Age	Engine	Transmission	Hydraulic	Fuel	Other
(A)75 hp tractor					
1	39820	45465	34275	59706	17055
2	5465	64270	45710	46320	14983
3	78908	94745	53925	34270	18340
4	81825	100677	53890	25098	25636
5	75361	86410	48060	13755	17590
Mean	56275.8	78313.4	47172	35829.8	18720.8
(B)150 hp tractor					
1	66353	83532	49778	114960	19120
2	109415	139647	83185	834564	38220
3	138072	165570	102735	111855	44140
4	165140	218095	120365	81675	34845
5	204415	250514	154290	75000	57175
Mean	136679	171471.6	102070.6	243610.8	38700

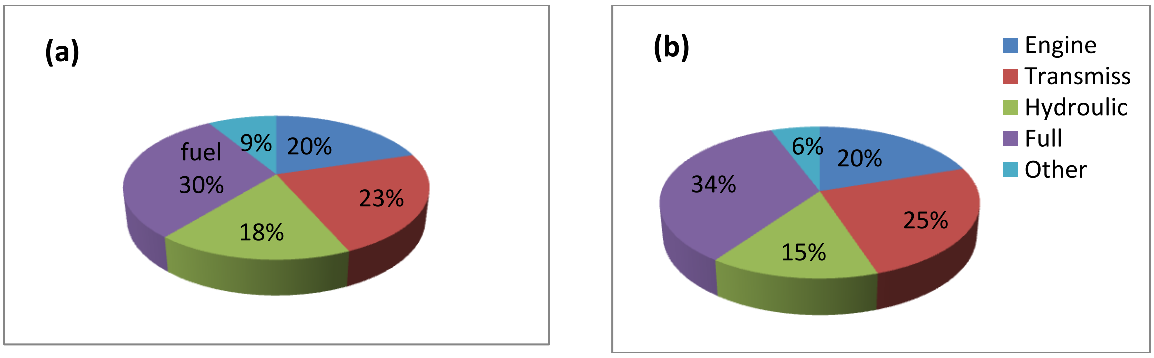

Fig. 1. Distributions of accumulated repair and maintenance of agricultural tractor systems as percentage (a) 75hp tractor type (b) 150hp tractor type

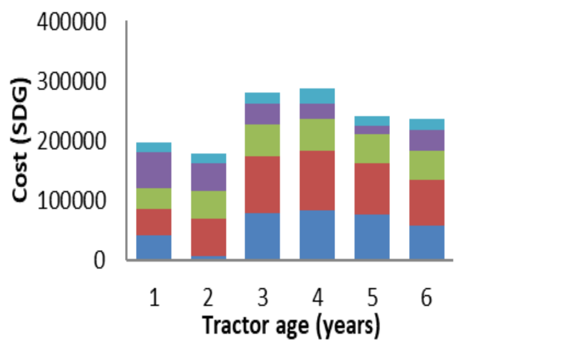

Fig. 2a. Distribution of accumulated R and M cost of agricul. tractor systems (75hp)

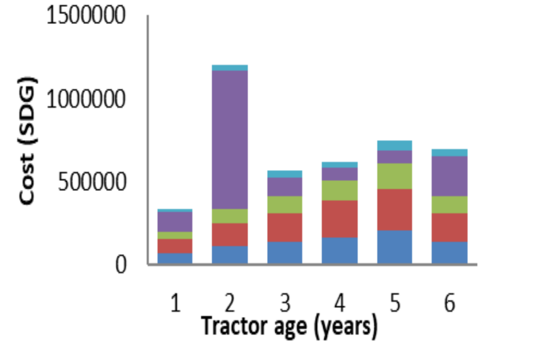

Fig.2b. Distribution of accumulated R and M costs of agricult. tractor systems (hp150)

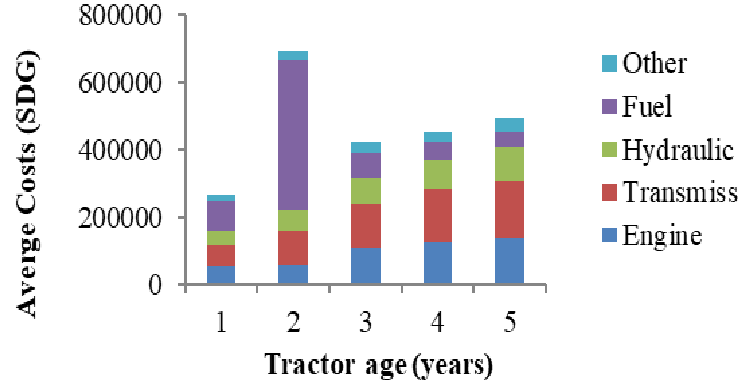

Fig. 2c. Distribution of accumulated R and M costs of agricult. tractor systems (mean)

Table 3. Regression analysis of the relation between the mean accumulated R&M cost as percent of purchase price and mean accumulated hours of use

Model	Equation	R square
Linear	$Y= 0.0003x+22.181$	0.73
Logarithmic	$Y=23.598Ln(x)- 209.025$	0.86
Polynomial	$Y=E-091.568x^{2}+0.001x+7.04$	0.86
Exponential	$Y=20.017e^{7.467E-6x}$	0.62
Power	$Y=0.028x^{0.662}$	0.93

Table 4. The power relation of accumulated R&M cost with accumulated hours of use of the two tractors

Tractor type	Power model	R square	F
Tractor 75Hp	$Y= 0.011x^{0.763}$	0.99	501.813**
Tractor 150Hp	$Y= 0.019x^{0.677}$	0.99	466.297**
Mean	$Y=0.028x^{0.662}$	0.93	101.534**

Table 5. The power relation of accumulated R and M cost with accumulated age (years) of the two tractors

Tractor type	Power model	R square	F
Tractor 75Hp	$Y= 14.14g^{1.14}$	0.99	465.008**
Tractor 150Hp	$Y= 10.689g^{1.412}$	0.94	50.601**
Mean	$Y=12.294g^{1.276}$	0.95	158.781**

***=significant difference at P<0.01*

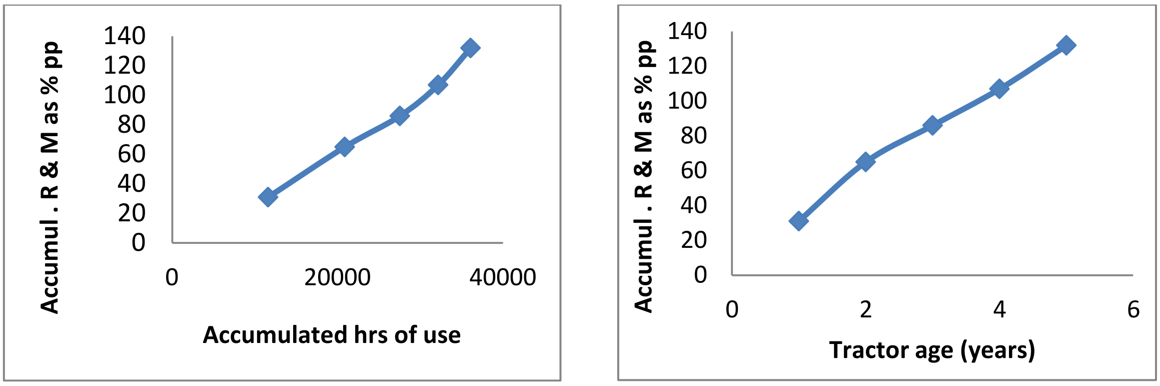

Fig 3a. Accumulated repair and maintenance costs as percent of purchase price as affected by hours of use and age (year) for the75Hp tractor

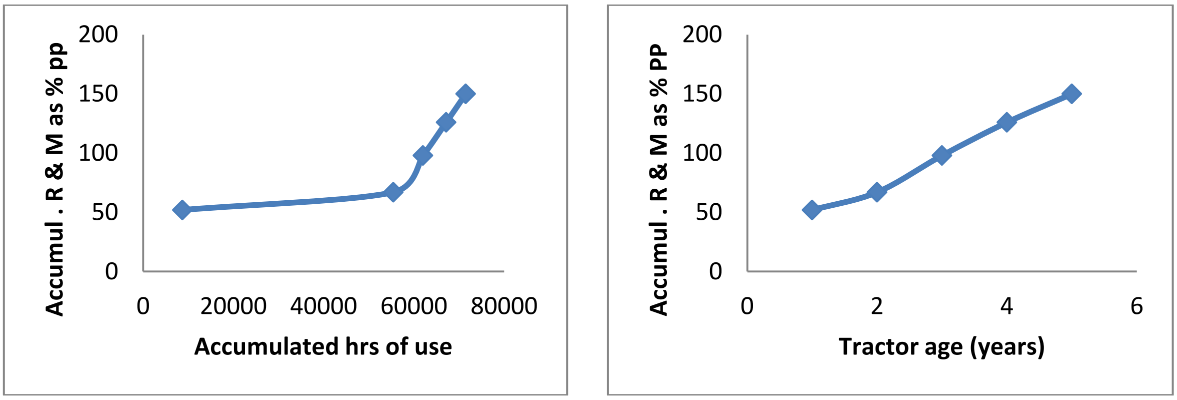

Fig 3b. Accumulated repair and maintenance costs as percent of purchase price as affected by hours of use and age (year)for the150 Hp tractor

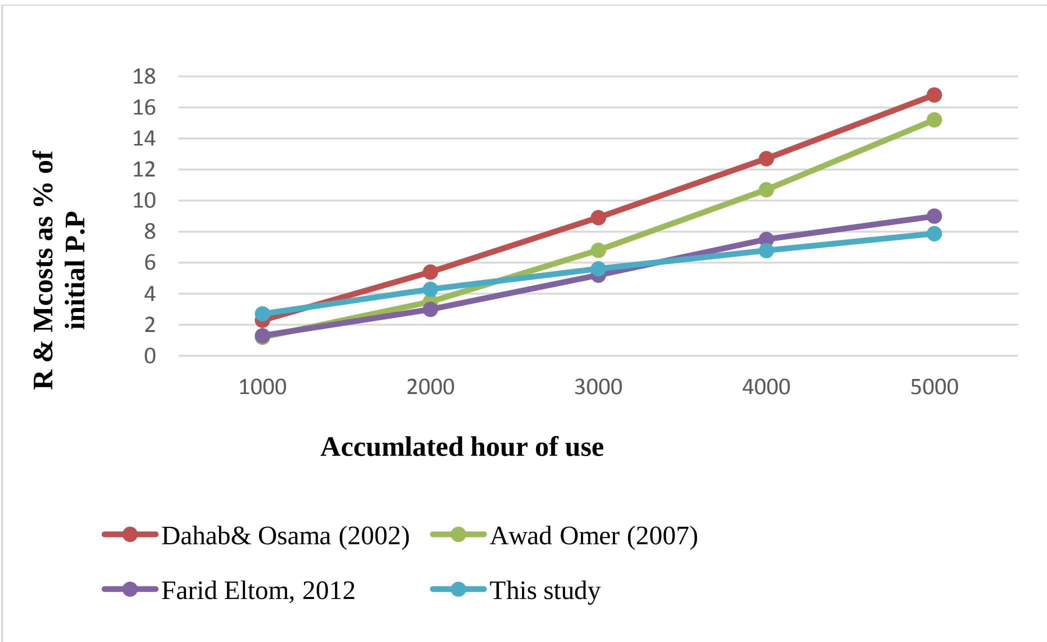

Fig. 4. Comparison of the present study prediction model with other models in Sudan

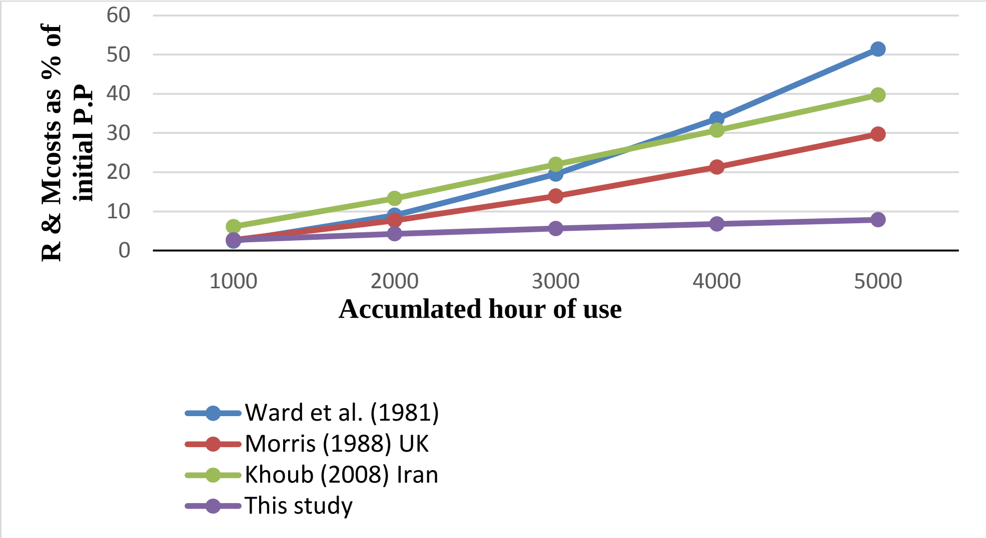

Fig. 5. Comparison of the present study prediction models with other models in the world

3.3 Comparison of the Present Predictions Model with other Models Developed in Sudan

The predicted model in this study was compared to other models from Sudan as shown in Fig. 4. It can be observed that the present model accounted for lower values than [16] model for accumulated repair and maintenance costs, after 1000 accumulated hours of use and forward. This may be attributed to variations in tractors specifications, ages and makes, however when the prediction model of this study was also compared to [20] and [21], the estimates of the present model accounted for larger values until about 3000 accumulated hours of use, after which this model accounted for lower values. This may be attributed to variations in tractors specifications and makes, condition of work and skills of mechanics, operators and labor used. Generally, the present models' predictions of accumulated repair and maintenance costs were lower than other compared models.

3.4 Comparison of the Present Study Prediction Models with Other Models in the World

The model of the average accumulated repair and maintenance costs predicted in this study was compared to other similar models from USA [10], UK [22] and Iran [12] as shown in Fig. 5. It was clear that the present derived average model accounted for relatively lower values of accumulated repair and maintenance costs compared to the world mentioned models. These variations may be attributed to the differences in spare parts prices between Sudan and the industrial countries, or may be due to variations in soil type, climate, preventive maintenance program applied and field operation conditions. This lower value of repair and maintenance costs may be also due to the procurement and usage of spurious and second-hand spare parts, variations in tractors technical specifications and lower labor charges for repairing and maintaining tractors in Sudan compared to the industrial world countries.

4. CONCLUSIONS

The following conclusion may be drawn from the present study:

1- The relationship between accumulated repair and maintenance costs as percentage of the initial purchase price of the tractor and accumulated hours of use and age in years for the two tractors in studied area could better be described by the power function equation.

2- The accumulated repair and maintenance costs were increased with tractor age and hours of use. The prediction models for repair and maintenance costs of tractors in Sudan were found lower than those of other countries; therefore, each area or country develops its own models of R&M costs to its operational and field conditions.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bohm M. Breakdowns in agricultural tractors. Agricultural Engineers. 1993;48(3):79-83.
2. Singh G. Estimation of a mechanization index and its impact on production and economic factors; A case study in India. Biosystems Engineering. 2006;93(1):99–106.
3. ASAE, American Society of Agricultural Engineers Standards. St. Joseph, Michigan U.S.A. 1986;159–165:300-3003.
4. Beppler D, Hummeida M. Repair costs of agricultural machinery in developing countries. ASAE paper No. 85-1026, St. Josph, Michigan, U.S.A. 1985;18.
5. Hunt D. Farm power and Machinery Management 9th ed. Iowa State University, Press Ames, Iowa 50014, USA; 1995.
6. Kumar A, Ahmed T. Maintenance of farm tractors in Allahbad Districa. Agricultural Mechanization in Asia, Africa and Latin America. 1996;27(2):15-17.
7. Adekoya L, Otono PA. Repair and maintenance costs of agricultural tractors in Nigeria. Tropical agriculture (Trinidad). 1990;67(2):119-122.
8. Gliem JA, Persinger KM, Carpenter TG, Holmes RG. A comparison of ASAE estimated tractor and combine repair and maintenance costs to actual repair and maintenance costs of selected farms. ASAE paper No. 89-1024. St. Josph, Michigan, U.S.A; 1989.
9. Rotz CA. A standard model for repair costs of Agricultural machinery. Trans. of ASAE. 1987;30(1):3-9.
10. Ward SM, McNulty PB, Cunney MB. Repair costs of two- wheeled drive and four- wheeled drive tractors. Trans. of the ASAE. 1985;28(4):1074-1076.
11. Mpanduji S, Wendi AG, Dihenga OH, Lazaro EL. Investigation on tractor repair costs under Tanzanian conditions. Agricultural Mechanization in Asia, Africa and Latin America. 2001;2(4):71-75.
12. Khoub bakht GM, Ahmedi H, Alram A, Karimi M. Repair and maintenance cost models for MF285 tractors; case study in central region of Iran. American-Eurasian J. Agric. and Environ. Sci. 2008;4(1):76-80.
13. Suhaibani S, Wahby M. Repair and maintenance costs model for tractors in Saudi Arabia. Emirates. Journal of Agric. Sci. 1995;(7):193-208.
14. FMO, Fundamentals of Machine operation. Preventive maintenance. Deere and company. Moline, Illinois, John Deere service publications. Dept. F., John Deere Road, Moline, Illinois, 61256, U.S.A; 1987.
15. FAO. Agricultural mechanization policy and strategy formulation. Sudan Technical Report, TCP/SU/4451. Rome, Italy. 1995;(2):5-22.
16. Dahab MH, Osama HA. Development of mathematical models for estimation of tractors R&M costs in the main irrigated schemes of the Sudan. University of Khartoum Journal of Agricultural Sciences. 2002;10(2):251-256.
17. Ahmed MH, Saeed AB, Ahmed AH, Haffar 1. Tractor repair and maintenance costs in SudanII : A comparative study among major agricultural schemes. Agricultural Mechanization in Asia, Africa and Latin America. 1999;30(2):19-22.
18. Dahab MH, Awad OM, Kheiry NO. Repair and maintenance costs estimation as affected by hours of use and age of agricultural tractor in new halfa area – Sudan. International Journal of Agriculture Innovations and Research. 2016;4(5):824-830.
19. Abdallah FE, Weiming D, Dahab MH, Idris AE, Alhadi M. Estimation of repair and maintenance cost of a tractor base on HP and working hours: Case study of Sudan. Journal of Environmental and Agricultural Sciences. 2014;1:1.
20. Omer AM. Repair and maintenance costs estimation as affected by hours of use and age of agricultural tractor in new halfa area – Sudan. M.Sc. thesis, Faculty of

Agriculture, University of Khartoum, Sudan; 2007.
21. Farid EA. Estimation of repair and maintenance cost of a tractor base on HP and working hours. M.Sc. thesis, Faculty of Agriculture, University of Khartoum, Sudan; 2012.
22. Morris J. Estimation of tractor repair and maintenance costs. Journal Agric. Eng. Res. 1988;40:191-200.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/71508