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Mechanization Assessment of Field Operations for Production of Sugar Cane in the White Nile Area-Sudan

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

There are many types of machines and implements used for field operations and production of field crops such as sugar cane in the White Nile area of Sudan. Therefore the main objective of this study is to assess the mechanization used in the field operations for production of sugar cane crop. This study was based on data collected from the field operations and recorded information from the two sugar companies in the area. The field operations included, the up-rooting, harrowing, reharowing, leveling, ridging, planting, fertilization, spraying and harvesting. The measured parameters were the work rate of machinery, power requirement and the cost of mechanization of field operations. The actual field data was compared with the calculated ones. Some correjation regression analysis was carried out. The results showed that the calculated rate of work was positively correlated to the actual rate of work, speed and width of cut (r = 0.99). The highest calculated rate of work was for spraying operation as 36.2 fed/hr, while the lowest was for harvesting as 2.1 fed/hr. Most of the calculated rates of work were lower than the actual ones.

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Power requirements were found to increase with the weight of machines. Generally the calculated power requirements were lower than actual ones and the correlation between the machine weight (KN) and the actual power (kW) used for field operation was positive (r = 0.83). The highest calculated power requirement was recorded for the harvester as 350 kW whereas the lowest was for the fertilizer as 32.7 kW. The highest mechanization cost was for harvesting field operation as 253.4 $/hr and was mainly due to the higher cost of power requirement, while the lowest was for leveling operation as 25.8 $/hr. It was concluded that although most of the field operations are well mechanized, yet the power source and requirements for some operations to be reviewed to match the size and type of machinery used, to reduce costs of field operations and production and to protect the enviroment.

Keywords: Kenana; asslaya; sugar cane; mechanization; power; costs.

1. INTRODUCTION

Mechanized agriculture is the process of using farm machinery to carry out the work of field operations to increase the crops productivity. Mechanization was defined as the application of tools, implements and machinery in order to achieve proper agricultural production [1]. All around the global, agriculture has an important role to play for food security and as the population increases, the demand for food increased. The effective mechanization contributes to increase production in two major ways firstly the timeliness of operation and secondly the good quality of work [2]. Power source is one the determining factors for the level of agricultural development and stage of mechanization [3]. In Modern agriculture, powered machinery has replaced many farm operations mainly carried out by manual labor or by draft animals. Tractors of different power sizes and makes, are the primary source of mechanical power to modern farms and agricultural fields for production of crops [4]. The requirement of power for certain operations like seedbed preparation, cultivation and harvesting becomes so great that the existing human and animal power appears to be inadequate. Farm machinery management deals with the optimization of the equipment and power used for agricultural production; it is concerned with efficient selection, operation, maintenance, and replacement of machinery [5]. Farm machinery selection is fundamental in achieving the concept of sustainable agriculture, which becomes a global issue in agricultural sector development [6]. Many studies shown that tillage at least consumes half of engine power to operate the implement and around 30 percent of the total power consumption in the agricultural crop production [7,8]. Field machinery is a major component of farm production expenses and producers make decisions concerning to the replacement of individual machines, changing of tillage practices, and whether to own specialized equipment or custom hire for crops that require specialized equipment [9]. There is concern about the cost aspects of owning and operating these specialized equipments versus leasing or having field operations custom hired [10].

Although more than 50% of the population of Sudan are living and working in agricultural sectors, but out of 84 million hectares of cultivable lands only about 25% only are now under cultivation [11]. There are many cash crops are grown in the country such as cotton, sunflower, sesame groundnuts and sugar cane. Sugar is one of the major strategic sugar cane products in the country, and sugar production started for the first time in Gunied in 1962-1963. Later other sugar factories came into operation at New-Halfa 1965-1966, North West Sennar 1976-1977, Assalaya 1980-1981 and finally Kenana in1980-1981 [12,13]. In the last ten year, Sudanese sugar companies have been suffering from the high cost harvesting and high wages of labor in planting and harvesting sugar cane crop and even the and shortage of labor at the time of the peaks which was due to competition between sorghum, sesame and sugarcane harvesting operation for the available labor force [14]. Because of the difficulty of working in sugar cane crop most workers prefer to work in other crops, therefore the problem of labor shortage leads to the introduction of mechanical processes for the cultivation and production of sugar cane to overcome the scarcity of labor and to control the wages of labor and to improve production cost and quality [15]. The Mechanization application in field operations to produce sugar cane in Sudanese sugar companies requires deep study and analysis of mechanization characteristics used from planting to harvesting of the crop for proper decision making and management. In the

White Nile area, sugar cane crop produced through number of field operations [16]. Mechanization application in these operations carried out through different types of machines. These operations include land preparation, planting, fertilizer application, spraying and harvesting. The main objective of this study was to assess the field operations mechanization for production of sugar cane crop in the White Nile area of Sudan.

2. MATERIALS AND METHODS

2.1 Location and Equipents Used

The two sugar companies (Kenana, Asslaya) are located near Kosti and Rabak cities, about 240 km south-wesr of Khartoum, The two schemes cover about 65000 hectors or about 70% of the total sugar cane cultivated in the Sudan. The soil of the area is brown and classified as heavy clays, which have been deposited by the White Nile, forming the central clay plains of the Sudan. The area lies within the tropical dry hot semi-arid climatic zone, with an average annual rainfall of 350-400 mm. The average cane yield for the last ten seasons was 60-70 tons/ha with an average of 11% sugar content. The irrigation water supply is pumped from the White Nile through six pumping stations to the irrigation canals. Commonly known types of tractors were used to pull the implements to carry out the field operations. The specification of the tractors are shown in Table 1. There are different types of implements and machine are used for field operations from land preparation to harvesting. The specification of these machines are given in Table 2.

2.2 Data Collection and Calculations

The data required for the study was collected from many sources such as, field visits, mechanics and machinery operators, production records, companies workshops and personal communications, and the folliwing parameters were calculated:

2.2.1 Rate of work

The rate of work (RW) of the different operations calculated according to Hunt [6] as follows:

$$RW = w \times s \times e/cf$$

Where,

w: operational width of cut, m.
s: speed of operations, km/h.,
e: field efficiency

Table 1. Specification of tractors used in the study

Tractor type	MF7726	MF 6499	Case steiger 550	Case 125
Mark country	UK	UK	USA	USA
model	Massey Ferg 7726	Massey Ferg 6499	Case steiger 550	Case 125
Power rate	149 kW.	186.6 kW	410 kW	115.7 kW
Fuel tank capacity	114 gal	93.8 gal	455 gal	56.8 gal
Wheels size/ base	118 inch	118 inch	154 inch	198 inch
PTO speed(rpm)	540/1000	540/1000	540/1000	540/1000
Age	5 years	7 years	7 years	4 years

Table 2. Specification of implements used in the study

Type of implement	**Weight-kg**	**Units No.**	**Width /m**	**Purch. price $**
Uprooting-Ripper	6425	7.0 shs	4.5	4800
Disc harrow	1200	21 disc	3.39	4600
Re-harrowing (breaker)	8,600	36 disc	6.25	9600
Leveling grader cat 160	188.2 kn	1 scrap	3.7	7690
Ridger	2764	2 units	4.0	5384
Fertilizer	1500	4.0	4.0	2520
Planter	7500	2 rows	3.5	30760
Sprayer	16147	2 boom	36.0	12750
Harvester	21440	2 rows	1.8	77000

2.2.2 Power requirement

Power requirements (PR) for the operations were calculatied according to Sumner et al. [17] as follows:

$$PR = s \times wt/ cf$$

Where,

s: speed of operations, km/h
wt: machinery weight, KN
cf: conservation factor 3.6.

2.2.3 Cost calculation of field operations

- The fixed cost of the tractor was assumed as 15-17% of the tractor purchase price.
- The annual cost of the tractor can be expressed by the relationship [6].

$$ACT = FC\%\ Pu + Annhrs\ of\ use\ (R\&M + Fu + O + L)$$

- For the agricultural machine, the average total annual cost can be estimated in the following relationship:

$$ACM = FC\%Pu + CfA/SWE(R\&M + Fu + O + L)$$

ACT: Average annual cost of tractor,
ACM: Average annual cost of the machine,
FC%Pu: Fixed cost as percentage of purchase price
Cf : Conversion factor, A: Area covered per year, S: Forward speed in the field,
W: Practical width of machine, E: Field efficiency of the machine
R&M: Cost of maintenance and repair per hour., Fu: Cost of fuel per hour
O: Cost of oils and grease per hour,
L: Cost of labor per hour,
T: cost of tractor per hour.

3. RESULTS AND DISCUSSION

3.1 Field Machineries Rates of Work

The calculated and actual rates of work of the machines used for field operations are given in Table 3. Generally it can be observed that the rates of work were increased with the width of cut of machines. This is in line with the findings of Abdalla et al. [18]. The actual rates of work were observed usually higher than the calculated ones for most of machines, which my be attributed to the types of data used in calculations. The highest rates of work (calculated and actual) were recorded for the spraying machine (36.2, 50.5 fed/hr.) where as the lowest was for the harvester (2.1, 3.0 fed/hr.). This could be mainly due to the width of cut size. Generally, as the forward speed was increased, the average rate of work was increased for the field machineries and implements. This is in line with the findings of Dahab et al. [19-21].

Regression correlation analysis revealed that the actual rate of work was positively correlated with the calculated one (r = 0.99), when comparing the machineries used for the field operations (Fig. 1). The work rated of field machines ranged between 2-7 fed/hr, except for the sprayer. The average comparability between the actual and calculated rates of work was 84%.

3.2 Power Requirements of Field Operations

Power requirements for the field operations are shown in Table 4. It was observed that, the calculated power requirement was lower than the actual power for all field machineries used. Generally the power requirement was observed to increase with the weight of the machinery. The total actual power requirememts of field operations was about 1997 kW, while the calculated was 1271, and the higher power requirements was for the self-propelled machines. The highest calculated and actual power requirements were recorded for the cane harvester as 350 kW and 358 kW, while the lowest was recorded for the fertilizer applicator as 32.7 kW and 115 kW, respectively (Table 4). The higher power requirement of the harvesting operation is in line with that of Kumar and Kumar [22] and Austin et al. [23]. The difference between the actual and calculated power requirement of the field operations ranged between 2.2% - 248%. The tractor drawn lmplements recorded higher power requirement than the actual by 121% (Fig. 2). Therefore, power requirement of tillage implements have to be well considered when attempting to correctly match implements with tractor power for optimizing power use and reducing cost of production and protect environment [24]. Regression correlation analysis showed positive relation (r = 0.85) between the weight of the machine and power requirements and also between actual and calculated power requirements (r = 0.83) for the field operations.

Table 3. Calculated and actual rates of work of different field operations

Type of Implement	Spd km/hr	Width m	Field EFF %	Cal RW fed/hr	Act RW fed/hr	Compara (%)
Uprooting-ripper	5.6	4.5	75	4.5	5.0	90
Disc harrow	5.3	3.4	80	3.5	3.5	100
Re-harrowing	7.0	5.5	75	6.9	5.5	125
Leveling grader	5.5	3.7	80	3.7	4.2	88
Ridger	6.0	5.0	75	5.4	5.0	107
Fertilizer	8.0	4.0	70	5.3	6.2	85
Planter	7.0	3.5	70	5.0	4.5	111
Sprayer	6.5	30.0	60	36.2	50.5	72
Harvester	7.0	1.8	67.5	2.1	3.0	70

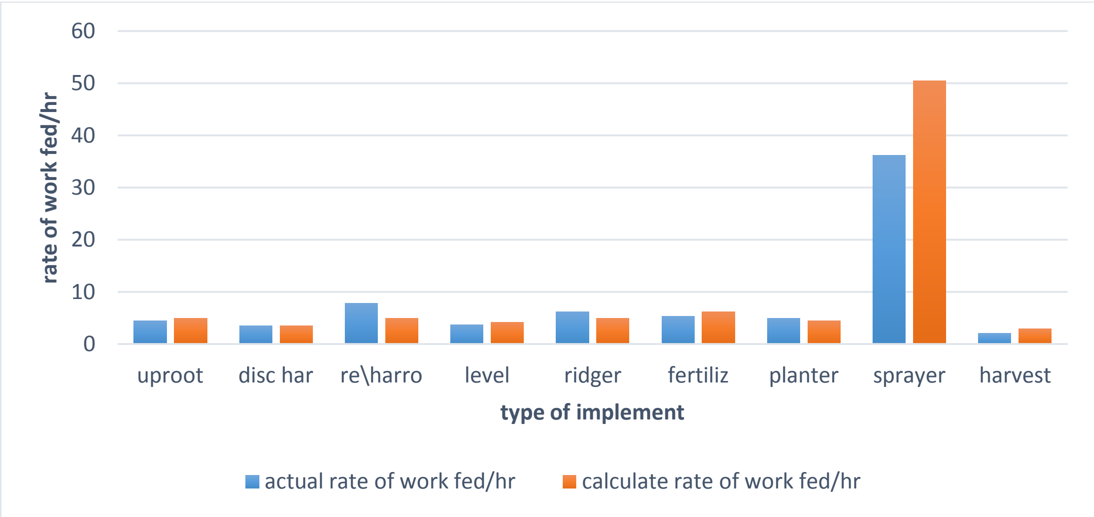

Fig. 1. Comparison between the actual and calculated rates of work

Table 4. power requirement calculation of different field operations

Type of implement	Speed km/hr	Weight/ KN	Cal power (KW)	Act power (KW)
Uprooting-Ripper 7 shank	5.6	64.3	100	186.6
Disc harrow	5.3	29.2	42.8	149
Re-harrowing (breaker	7.0	86.0	167.2	410
Leveling grader cat 160	5.5	103.2	157.7	165
Ridger	6.0	27.1	52.7	149
Fertilizer	8.0	14.7	32.7	115
Planter	7.0	73.6	145.8	186.6
Sprayer	6.5	123.1	222.3	258
Harvester	7.0	180	350	358

3.3 Mechanization Cost Estimation of Field Operations

The mechanized field operations costs carried out as fixed and variable costs for the tractors as power sources and machineries used to carry out the operations. It was observed that the total annual cost of the tractors varied with power size (Table 5). The highest cost was recorded for the largest power tractor steiger as 58.0 $/hr, while the lowest was for MF6499 as 38.3 $/hr. this is in line with the reports of Dahab and Al-Hashim [19] Rahul et al. [25].

Table 6 Illustrates the annual total cost of each field operation per unit time. It can be observed that the highest annual t otal cost was for the harvesting operation as 253 $/hr, which is about 32% of the total annual cost of all field operations, while the lowest was for the leveling operation as 25.8$/hr. The land preparation field operations together cost about 259.9$/hr (31%), which is the second highest field operation cost for sugar cane crop production. This is in line with the reports of Dahab et al. [21]. For all field operations, the variable costs were higher than fixed costs by 56-97% (Fig. 3), and the harvesting recorded the highest value as 222$/hr, while the leveling recorded the lowest as 19.8 $/hr. as compared to other field operations. The higher costs of some field operations mainly attributed to the higher power and repair costs of the machines used in these operations.

It is also important to consider the purchase price of the machine which affects directly the fixed cost of the machine, and this can be observed for planting, spraying and harvesting machineries.

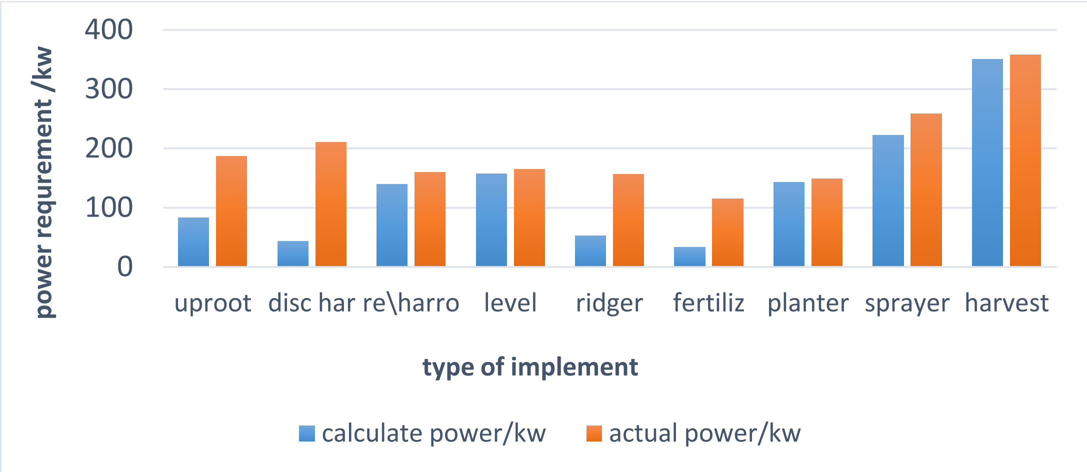

Fig. 2. Calculated and actual power requirement of field operations

Table 5. Total annual cost of tractor

Type of tractor	Fixed cost $/hr.	Variable cost $/hr.	Total cost $/hr.
Tractor MF 7726	16.2	37.0	53.2
Tractor M F 6499	15.8	22.5	38.3
Tractor case 125	21.6	24.1	45.7
Tractor steiger	17.0	41.0	58.0

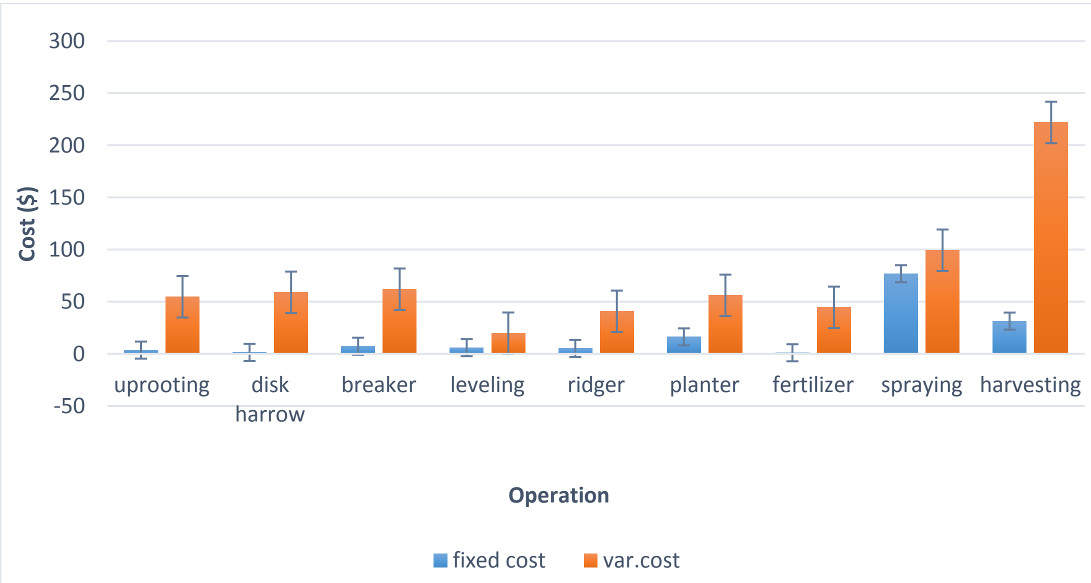

Fig. 3. Fixed and variable cost of field machines

Table 6. Total annual cost of field operation

Type of operation	Fixed cost $/hr.	Variable cost $/hr.	Annual cost $/hr.
Uprooting	3.6	54.8	58.4
Disk harrow	1.4	59.0	60.4
Breaker	7.3	62.0	69.3
Leveling	6.0	19.8	25.8
Ridging	5.2	40.8	46.0
Planting	16.3	56.1	72.4
Fertilizing	1.1	44.6	45.7
Spraying	76.9	99.4	176.3
Harvesting	31.4	222	253.4

4. CONCLUSION

Based on the analysis of data obtained in this study, the following conclusions can be drawn:

1. The rate of work increased as the width cut of machine increased and the sprayer recorded the highest rate work as 50.5 fed/hr.
2. The energy requirements increased with the weight the of machine and the harvester recorded the highest calculated power requirement as 350kW. All calculated power requirements were lower than actual powers used by an oerall difference of 57%.
3. The highest estimated mechanized field operation cost was for the harvest operation as 253$/hr and the lowest was for the leveling. The variable costs were higher than the fixed costs for all field operations by 56-97%.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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