Original Research Article

Evaluation ofMechanized Field Operationsfor Production of Sugar Cane in the Central Clay Plain of White Nile Area– Sudan

ABSTRACT: There are many types of machines and implements used for field operations and production of field cropssuch as sugar cane in White Nile area. Therefore the main objective of this study is to evaluate thelevel of mechanizationused in the field operations for production of sugar cane crop.This study was based on data collected from the field operations and recorded informationfrom three sugar companies in the area. The field operations included were,up-rooting, harrowing, reharowing, leveling, ridging, planting, fertilization, pests control and harvesting. The measured parameters werethe work rate of machinery, power requirement estimation,and the cost of mechanized field operations.Correjationregression analysis was also carried out.Thehighest estimated rate of work was for sprayingoperationas 36.2 fed/hr ascompared to the other field operations. While the lowest was for harvesting as 2.1 fed/hr. Most of the estimated rates of work were lower than the actual ones.Power requirements were found to increase with the weight of machines. Generally the calculated power requirements werelower than actualonesand thecorrelation between the machine weight (KN) and 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 mechanized field operation cost was for the harvesting as 253.4 $/hrand 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 andrequirementsfor some operations to be reviewed to match the size and type of machinery used,for reducing costs of field operationsand production and protect the enviroment.

Comment [AR1]: If it is also discussed about the economic analysis of the use of costs, this should also be stated in the objectives of this research

Comment [AR2]: If its possible please give more detail about the area

Comment [AR3]: This is general field operation in agriculture please describe more detail about how to choose area for this research.

Comment [AR4]: what does the correlation analysis mean, in this case what is the evidence for? optimizing the use of machines on agricultural land? optimizing costs by using the machine or implement that is used is effective enough so that it relates to the expected goals

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Keywords: *Kenana, Asslaya, sugar cane, mechanization, power, costs*

1. INTRODUCTION

Mechanized agriculture is the process of using farm machineryto 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 agricultural production [1].All around the global, agriculture has an important role to play for food securityand as the population increases, the demand for foodincreased.The effective mechanization contributes to increase production in two major ways firstly the timeliness of operation and secondly the good quality of work. Power source is one the determining factors for the level of agricultural development and stage of mechanization [2]. 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

[3].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 used for agricultural production; it is concerned with efficient selection, operation, maintenance, and replacement of machinery[4]. Farm machinery selection is fundamental in achieving the concept of sustainable agriculture, which becomes a global issue in agricultural sector development [5].Many studies shown thattillage at least consumes half of engine power tooperate the implement and around 30 percent of thetotal power consumption in the agricultural cropproduction [6,7]. 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 on a relatively small areas[8].There is concern about the economic aspects of owning and operating these specialized equipment items versus leasing or having field operations custom hired[9].
Although more than 50% of the population of Sudan are livingand working only in agricultural sectors, but out of 84 million hectares of cultivable lands only about 15% arenow under cultivation [10]. 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 Kenanain1980-1981[11,12].In the last ten year, Sudanese sugar companies have been suffering from the high cost of harvesting and high wages of labor in planting and harvesting sugar cane crop and even the labor shortage at the time of the peakswhich was due to competition between sorghum, sesame and sugarcane harvesting operation for the available labor force[13].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. The Mechanization application in field operations to produce sugar cane in Sudanese sugar companiesrequires deep study and analysis of mechanization characteristics used from planting to harvesting of the crop for proper decision making and management.In kenana Sugar Company, sugar cane crop produced through number of field operations[14]. 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 evaluate the field operations mechanization for production of sugar cane crop in the central clay plain of White Nile area ofSudan.

2. MATERIALS AND METHODS

2.1 Location and equipents used

The two sugar companies(Kenana, Asslaya) sugar are located nearKostiand Rabak cities, about240 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 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 season 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 canalsan.Commonly known types of tractor 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.

Table 1.Specification of tractors used in the study

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Tractor type	MF7726	MF 6499	Case 125
Mark country	UK	UK	USA
model	Massey Ferg7726	Massey Ferg 6499	Case 125
Power rate	200 hp.	250 hp.	155 hp.
Fuel tank capacity	114 gal	93.8 gal	56.8 gal
Wheels size/ base	118 inches	118 inches	198 inches
Pto speed(rpm)	540/1000	540/1000	540/1000
Age	5 years	7 years	4 years

Table 2.Specification of implements used in the study

Type of implement	Weight-kg	Width /m	Purch. Price $
Uprooting-Ripper(7 shs)	5425	4.5	4800
Disc harrow	1200	3.39	4600
Re-harrowing (breaker)	7,300	6.25	9600
Leveling grader cat 160	188.2 kn	3.7	7690
Ridger	2764	4	5384
fertilizer	1500	4	2520
planter	7500	3.5	30760
sprayer	16147	36	12750
harvester	21440	1.8	77000

2.2 Data collection and calculations:

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

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a, Rate of work:

The rate of work (RW) of the different operations calculatedas:

$RW = w \times s \times e$

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

b, Power requirement:

Power requirements (PR) for the operationswerecalculatied according to [20] as follows:
PR = s × wt/ 3.6

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

c, Cost calculation of field operations:

-The fixed cost of the tractor was assumedas 15-17% of the tractorpurchase price.
-The annual cost of the tractor can be expressed by the relationship [5].

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

- 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
A:Area covered per year, S:Forward speed of work 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 The rate of work estimation:

The calculated and actual rates of work of the machines used are given in table 3. Generally it can be observed that the rates of work were increased with the width of cut of machines. The actual rates of work were observed usually higher than the calculated ones for most of machines. The highest ratesof work were recorded for the spraying machine (36.2, 50.5 fed/hr.) where's the lowest was the harvester (2.1, 3.0 fed/hr.). This could be mainly attributed to larger and lowest width of cu respectively.Generally, as the forward speed was increased, the average rate of work was increased for the machineries used. implements. This is in line with the findings of [15,16,17].

Table 3. Calculated and actual Rates of work of different field operations:

Type of Implement	Spd km/h	Width m	Field EFF %	Cal RW fed/hr	Act RW fed/hr	Compara (%)
Uprooting-ripper7sh	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

Regression correlation analysis revealed that the actual rate of work was positively correlated with the calculated rate of work (r = 0.99).When comparing the actual and caculated rates of work of machineries used for the field operations, it's clear that there were no significant variation between most the machines used (Fig 1).

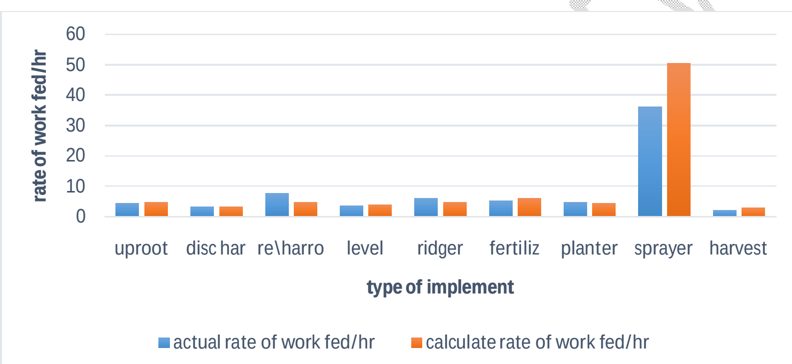

Fig 1. Comparison between the actual and calculated rates of work

3.2 The Power requirements estimation:

Power requirements for 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 machine. The highest power requirement was calculated for the cane harvester as 350 kW, while the lowest was recorded by the fertilizer applicator as 32.7 kW, although the actual power used were 358 kW and 115 kW, respectively (Table 4). The higher power requirement of the harvesting operation in line with that of Kumar and Kumar [18]and [19].The difference between the actual and calculated power requirement of the field operations ranged between 2.2% - 248%. This extra power is mainly for the tractor drawn machines and can affect the cost of production and environment (Fig 2). Regression correlation analysis showed positive relation (r = 0.85) between the weight of the machine

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Table 4: power requirement calculation of different field operations

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Type of implement	Speed km/hr	Weight/ KN	CalPower (KW)	Actpower (KW)
Uprooting-Ripper 7 shank	5.6	53.2	82.8	160
Disc harrow	5.3	29.2	42.8	149
Re-harrowing (breaker	7.0	71.6	139.2	186.4
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	143	149
Sprayer	6.5	123.1	222.3	258
Harvester	7.0	180	350	358

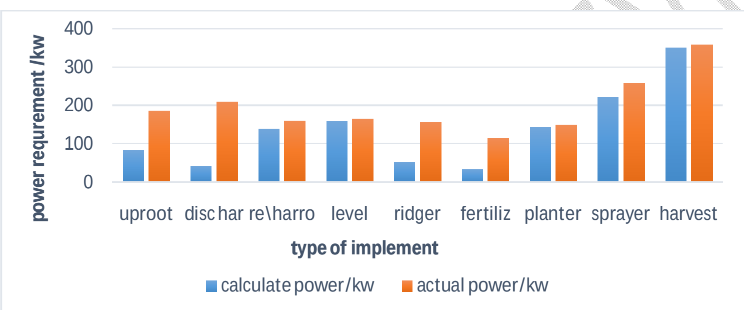

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Fig2. calculated and actual power requirement of field operations

3.3 Cost estimation of field operations:

The mechanized field operations costs carried out as fixed and variable costs for the tractors as power sources and machineriesused to carry out the operations. It was observed that the total annual cost of the tractors varied with power size (table 5).

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 215	15.8	22.5	38.3
Tractor case 125	21.6	24.1	45.7

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Table 6. total annual cost of field operation.

Type of	Fixed	Variable	Annual

operation	cost $/hr.	cost $/hr.	cost $/hr.
Uprooting	3.6	54.8	58.4
Disk harrow	1.4	54.0	55.4
Breaker	7.3	57.0	64.3
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

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Table 6 Illustrates the annual total cost of each field operation per unit time. It was observed that the highest annual total cost was for the harvesting operation as 253$/hr,which is about 32% of the total annual field operations cost, while the lowest was for the leveling operation as 25.8$/hr.The land preparation field operations together cost about 249.9$/hr (31%), which is the second highest field operation cost for sugar cane crop production. This is in line with the reports of [17]Dahab et al., 2022. For all field operations, the variable costs were higher than fixed costs (Fig 3), and the harvesting recorded the highest value as 222$/hr, while the spraying recorded the highest fixed costs as76.9$/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.

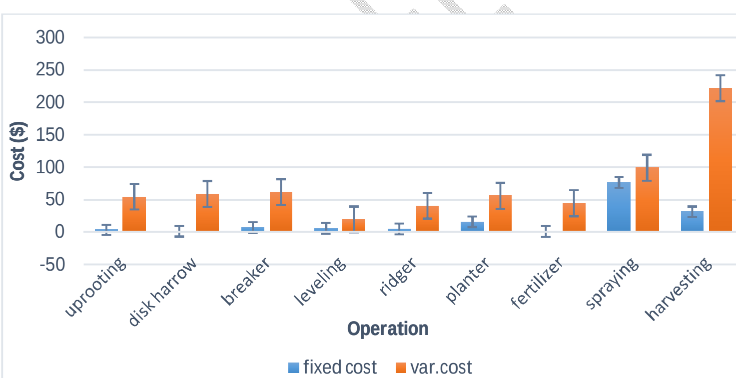

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Fig3. fixed and variable cost of field machines.

4. CONCLUSION

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

1. The rateof work increasedas the width cut of machineincreased andthe sprayer recorded the highest ratework as 50.5 fed/hr.

2. The energy requirements increasedwith the weight the of machine and the harvester recorded the highestcalculated power requirement as 350kW. Most of the calculated power requirements were lower than actualpowers used.
3. The highest estimated mechanized field operation cost wasfor the harvest operationas 253$/hrand the lowest was for the leveling.

COMPETING INTERESTS DISCLAIMER:

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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Comment [AR19]: please use related reference maximum in year of 2013

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