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Evaluation of Mechanized Field Operations Energies for Production of Sugar Cane Crop: Kenana Sugar Company as Case Study

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Authors' contributions

This work was carried out in collaboration between both authors. Author MHD designed the study, wrote the protocol and the first draft of the manuscript. Author OAA managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Mechanization application in agriculture is important for timeliness of field operations and improvement of products quality. This study was conducted in a sugar company to evaluate the mechanization energy requirements for production of sugar cane crop. Mechanization index (MI), mechanization ratio (MR), mechanization productivity (MEP), specific mechanization energy (SME), total mechanization energy and mechanization energy use efficiency (MEU) were estimated. Data for the study was collected from field visits, agricultural engineers working in the company and also from the available information in literatures and other related resources. Results showed that the highest share of mechanized energy consumption belongs to land preparation operation (44%) followed by harvesting operation (30%), while the lowest was for the weeding and fertilization (5%). The highest share of mechanization energy expenses was found to be 72% diesel fuel. The total

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mechanization energy, overall mechanization index, specific mechanization energy, mechanization energy input ratio, mechanization energy use efficiency and mechanization energy productivity were 17176.3 MJha^{-1}, 97.8%, 0.18 MJkg-1, 0.20, 6.6, 5.6 kgMJ^{-1}. Although the mechanization index of all field operations was more than 90%, but the mechanization energy input ratio was still low, while the mechanization productivity energy was high.

Keywords: Mechanization; energy ratio; mechanization productivity; sugar cane; mechanization index.

1. INTRODUCTION

Agricultural mechanization plays an important role in cultivation of field operations and production of food and other crops. Tools, implements and powered machinery are important inputs applied for mechanization of agriculture [1]. It was reported that agricultural mechanization is an essential factor influencing agricultural output and the profitability of farming activities [2]. Agricultural mechanization is a critical input in any farming system as it improves farm labour productivity by applying machinery, implements, and tools to agricultural activities. The process also involves the invention and management of machines in different field operations for agricultural production [3,4]. The essence is to minimize human drudgery, enhance timeliness, economic growth, and efficiency of farm machinery. Nowadays, machinery and labour are the main resources for agricultural operations, but machinery is gradually replacing labour, where savings in time and improving the quality of agricultural operations [5,6]. Mechanization may be evaluated through three specific indicators, such as degree, level, and index of mechanization [7,8]. Mechanization Index (MI) and Machinery Energy Ratio (MER), may be chosen because they would allow to identify which farming systems would benefit from mechanization and to estimate the intensity of mechanization as part of an agricultural modernization program [9,10]. Mechanization index represents percentage of work done by machines and human efforts from the total energy used in the system of production [11,12]. Agricultural mechanization ratio and index were used to evaluate the level of mechanization used in all operation while the level of productivity for each farm settlement was determined as an inverse of the work output of the factors involved in production function [2]. To meet the growing demand of the increasing world population and economy, the productivity of land to be increased by considering mechanization inputs, this would substantially require higher energy input and better management of production system [13]. Energy utilization in field level usually varies with farm size, crop growing, production practices and physical environmental factors. However, availability of farm mechanization for high rate of application in specific time helps farmers to use different production strategies which resulted in increased food and crop production [14]. It has been experienced that the use of advanced machinery is very important which will help in saving of labour, timeliness of operations, reduces drudgery, improving quality of work, reduces cost of operation and ensures effective and efficient utilization of resources compared manual work [15,16].

Sugar cane is an important cash crop for production of sugar and other secondary products. It is grown in many countries worldwide, e.g. Brazil, India, Cuba, Mexico, and South Africa and the cane yield varies from 20 to 200 ton per hectare [17]. Energy used for production of sugar cane crop was observed to be of many sources [15,18,19] and was generally higher compared to other cash crops [20,21,22]. In Sudan sugar cane production started early nineteen sixty's and the total area cultivated exceeded two hundred thousand feddan. The energy used for field operations for production of sugar cane is mainly from human labour, chemicals and mechanical power [23]. Scarcity of labour at the peak times of crop production, forced to use farm machineries for timeliness of field operations and improved quality of products. Therefore, the main objective of the present study was to evaluate the mechanized energies used in field operations for production of sugar cane crop and to study some mechanization energy indicators.

2. MATERIALS AND METHODS

2.1 Location of Study Area

This study was carried out at Kenana sugar company which is located on the eastern bank of the White Nile, 240 km south of Khartoum. The scheme covers 40000 hectors and the soil of the scheme is classified as brown montmorillonite clays (more than 60% clay), within the tropical dry hot semi-arid climatic zone, with an average annual rainfall of 400 mm. The major cane variety is c6806 and grown in 60% of the area. Sugar cane crop produced through number of field operations, from proper land preparation, planting, fertilizer application, chemicals spraying, weeding and harvesting. Irrigation water supply is done by pumping water from the White Nile through six pumping stations to an elevation of 45 meter (Ganawa and Kheiralla 2011). Most of the field operations carried out mechanically with the help of manual labour.

2.2 The Mechanized Field Operations

The mechanized field operations considered for production of sugar cane are, the land preparation started by uprooting of the previous crop using heavy ripper and disc harrow of 20-disc units. then the land was re-harrowed also by the heavy breaker implement. The land was leveled using large tractor drawn scrapers or by motor graders. Big ridgers were used to make large furrows spaced 150-155cm. Planting carried out manually or mechanically by a planting machine at a seed rate of 6-8 ton/ha. Fertilization was carried out using machines for two types of fertilizers were applied, superphosphate and urea. Recently DAP fertilizer is used which includes the potassium element. Growth regulators and some herbicides were mechanically sprayed and used to control weeds at a rate of (5.0 l/ha+6.7 kg/ha). Harvesting of the crop was mechanically by combine sugar cane harvesters. Fig. 1 shows the mechanized field operation for sugar cane crop production. The number and duration of different mechanized field operations carried out, fuel consumption and amounts of human labour and machinery were also investigated. Data for the study was collected and obtained from field visits, agricultural engineers and other people working in the company and also from the available information in literatures and related other resources. Table 1 shows energy inputs, coefficients and sources for mechanized sugar cane production.

2.3 Mechanized Field Energies Calculations

The mechanized energy inputs included labour, machinery, tractor and fuel for different farm operations, from land preparation up to crop harvesting. The total energy inputs in mega-jule per hectare (MJ/ha) was calculated as total labour, machinery, and fuel energy. Labour energy input was calculated as hours of work of labour per hector for field operations, multiplied by energy coefficient. Fuel consumed by the machinery and tractors to carry out the field operations in liters per hectors was converted into energy as MJ/ha by using energy equivalent of diesel fuel. Machinery energy input was determined from the weight of the machine (kg) and annual area covered by the machinery during the season and energy coefficients (Table 1). The mechanization inputs were transferred into input units as per hectare for the field operations (Table 2).

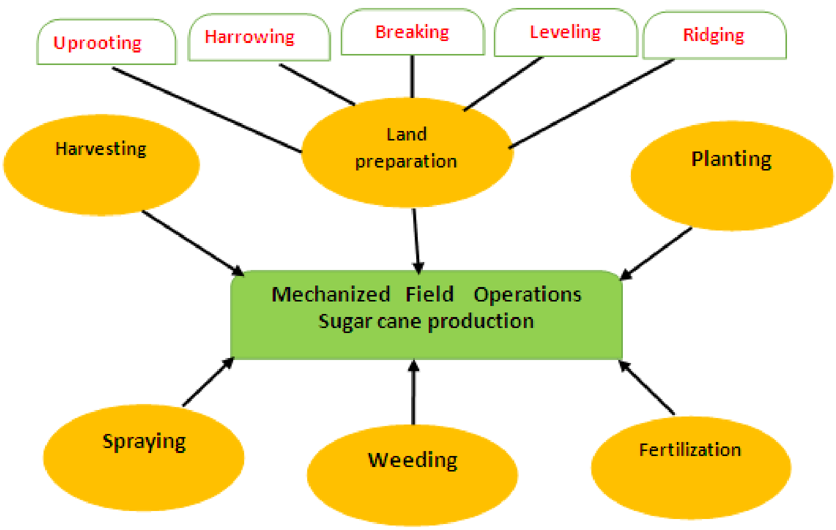

Fig. 1. Mechanized field operations for sugar cane production

Table 1. Input energy coefficients for mechanized sugar cane production

Input	Units	Equivalent MJ/unit	Source
Human labour	man-hour	2.0	Ramirez et al., 2007
Tractor	Kg	91.6	Karimi et al., 2008
Machinery	Kg	62.7	Karimi et al., 2008
Diesel	Lit/ha	56.3	Ebrahim et al., 2013
Sugar cane input energy	Mj/ha	86832.0	Dahab et al., 2022
Sugar cane output energy	Mj/ha	112812.0	Dahab et al., 2022
Sugar cane production	Kg/ha	94010	FAO, 2020

Table 2. Mechanization input units for field operations

Operation	Total units			Implement (kg/ha)
	Labour (hr/ha)	Fuel (lit/ha)	Tractor (kg/ha)	
Land preparation	36.2	96.2	12.0	16.32
Planting	13.8	21.6	3.25	3.75
Fertilization	7.6	11.0	1.75	0.33
Weeding	81.1	15.4	--	3.14
Spraying	9.8	15.4	--	3.14
Harvesting	28.6	71.0	--	18.08

Based on the data of mechanized field operations for sugar cane crop production and energy coefficients, mechanization index (MI), mechanization ratio (MR), mechanization productivity (MEP), specific mechanization energy (SME), total mechanization energy and mechanization energy use efficiency (MEU) were estimated according to [11, 9], as follows:

$$MI = MaE/(MaE + HuE), \quad (1)$$
$$MR = ME/TInE, \quad (2)$$
$$OMR = OME/ ME \quad (3)$$
$$MEP = Yld/ME, \quad (4)$$
$$SME = ME/ Yld \quad (5)$$
$$MEU = TopE/ ME \quad (6)$$

Where; MaE is the machinery energy in MJ/ha, HuE is the human energy input in the production system MJ/ha, ME is the total mechanization energy in MJ/ha, TinE is the total input energy in MJ/ha, OMR is the field operation ratio, OME is the field operation energy, Yld is yield in kg/ha, SME is the specific mechanization energy in MJ/ha, MEU is mechanized energy use efficiency, TopE is total output energy of the crop in MJ/ha and MEP is energy productivity in kg/MJ. These relations are similar to that reported by [10, 21].

3. RESULTS AND DISCUSSION

3.1 Mechanization Energy Inputs

The amounts of mechanization energy inputs used of different operations for sugar cane production and percentages of different inputs are illustrated in Table 3 and Fig. 3. It can be observed that, the total mechanized energy consumption for sugar cane production was 17176.3 MJha^{-1}. This is closer to those reported by [20]. The highest amount contribution was from fuel energy 72%, while the lowest from the human 2.5% (Fig. 2). Weeding was the most labourus operation (45.8%), while land preparation consumed most of the fuel (43.1). More than 40% of the mechanized input energy was used in land preparation operation while less than 5% was used for weeding and fertilization (Fig. 3). This can be explained that land preparation is a very intensive operation for sugar cane crop. The second intensive mechanization energy source in sugar cane production was harvesting operation followed by planting, with a share of 30% and 10% respectively (Fig. 3).

3.2 Determination of Mechanization Energy Indicators

Mechanization ratio and index were used to evaluate the level of mechanization used in all field operation. Energy inputs of labour and machines for each field operation were determined and accordingly the mechanization ratio and index were calculated from the total energy inputs for each operation. It was observed that land preparation recorded the highest mechanization ratio and index as o.44 and 99%, while weeding record the lowest values as 0.04 and 79.7% respectively (Table 4). This may be due to large number of machines used for land preparation and more manual labour used for the weeding operation. Mechanization ratio was observed to be lower than index which is mainly because the ratio calculated as rates from total energy used while index was calculated as percentage of total energy used for each operation. Regression correlation analysis showed positive correlation between mechanization ratio and index (r = 0.76). The mechanization energy efficiency of sugar cane production may be expressed by some other energy indicators, i.e., specific energy, mechanization energy efficiency, mechanization energy productivity. The specific mechanization energy input gives the information about how much of mechanized energy is spent on the yield obtained. The overall mechanization index, specific mechanization energy input, mechanization energy input ratio, mechanization energy use efficiency and mechanization energy productivity of the present study were 97.8%, 0.18 $MJkg^{-1}$, 0.20, 6.6, 5.6 $kgMJ^{-1}$ (Table 5). Generally, the mechanization energy used for sugar cane production as per unit area was low. As for the energy ratio, it was stated that if it is higher than one, the production system is earning energy [24]. The mechanization input energy ratio of sugar cane production of this study shows a value higher than one, therefore, the crop production system earned energy. MEP gives an idea about how much product is produced per unit of input energy and can be used for evaluation of how efficiently energy is used in the production systems. It was observed that, the average mechanization energy productivity of sugar cane production in Iran, was 2.1 $kgMJ^{-1}$ while in India it was 4.5 $kgMJ^{-1}$, respectively [15, 25], compared to this study which was 5.6 $kgMJ^{-1}$.

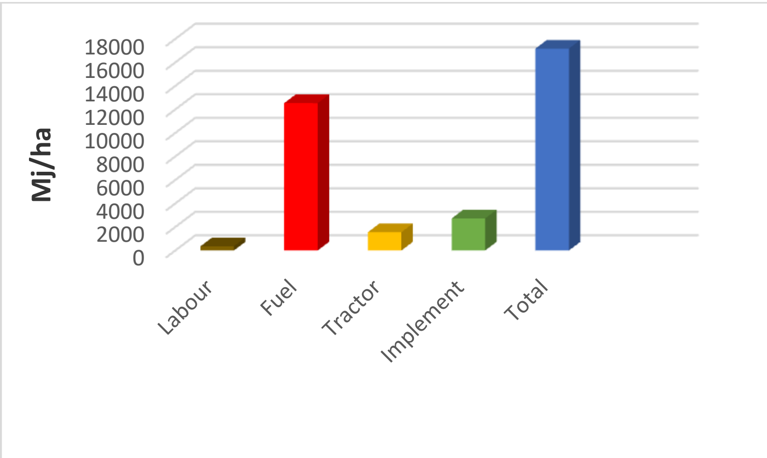

Fig. 2. Mechanization energy inputs

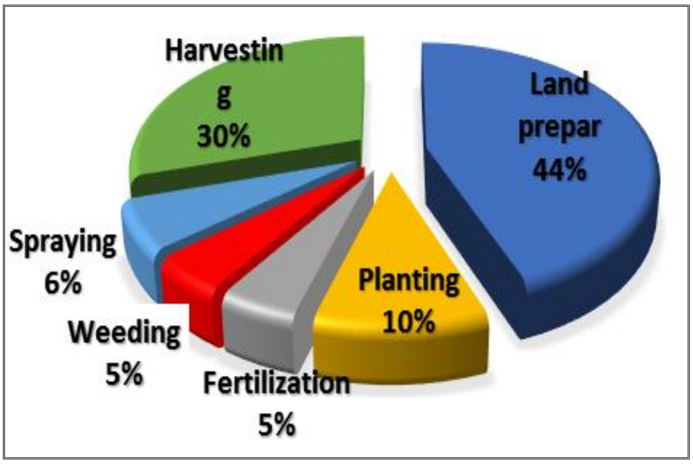

Fig. 3. Mechanization energy ratios of field operations for production of suger cane

3.3 Mechanization Energy Input Ratio and Index of Sugar cane and other Crops in Sudan and in Other Developing Countries

It was observed the mechanization energy ratio and mechanization index of sugarcane were higher compared to some crops produced in Sudan where, wheat recorded the highest MI while cotton and sugar beet crops recorded the lowest [16,26], indicating the lower mechanization application (Table 6). The mechanization energy ratio of these crops ranged between 0.22 – 0.29. The mechanization energy input and MI of sugarcane production in Kenana-Sudan was also compared with that in some developing countries. Iran recorded the highest mechanization input energy as 45300 MJ/ha, while Pakistan recorded the lowest MI as 60.8%. The MI of the other compared countries (Iran, Thailand, Morocco, India and Sudan were over 90% [27,15,21,24,19]. This explains that mechanization application in these countries is high compared to Pakistan.

Table 3. Mechanization energy inputs (Mj/ha) of the field operations

Operation	Labour	Fuel	Tractor	Implement	Total
Land preparation	72.4	5404.3	1099.2	1023.5	7599.4
Planting	27.6	1216.1	297.7	235.1	1776.5
Fertilization	15.2	619.3	160.3	20.4	815.2
Weeding	162.2	433.5	0.0	203.2	798.9
Spraying	19.6	867.0	0.0	203.2	1089.8
Harvesting	57.2	3997.3	0.0	1042.0	5096.5
Total	**354.2**	**12537.5**	**1557.2**	**2727.4**	**17176.3**

Table 4. Mechanization energy ratio and index for the field operations

Field operation	Machinery energy ratio	Mechanization index
Land preparation	0.44	99.0
Planting	0.12	98.4
Fertilization	0.05	98.1
Weeding	0.04	79.7
Spraying	0.05	98.2
Harvesting	0.30	98.8
Overall	-	97.8

Table 5. Mechanization energy indicators for sugar cane crop production

Item	Units	Energy relation
Overall mechanization index	%	97.8
Mechanization productivity	$kgMJ^{-1}$	5.6
Specific mechanization energy	$MJkg^{-1}$	0.18
Total mechanization energy	$MJha^{-1}$	17176.3
Mechanization energy use efficiency	--	6.6
Mechanization energy input ratio	--	0.20

Table 6. Comparison of mechanization energy input ratio and Index of sugar cane with other crops in Sudan and other countries

a) Crops

E. indicator	Wheat	Sorghum	Sunflower	Cotton	Sugar beet	Sugar cane
MER	0.29	0.25	0.29	0.22	0.23	0.26
MI (%)	98.0	87.0	97.0	64.5	69.0	97.8

b) Countries

E. indicator	Iran	Thailand	India	Pakistan	Morocco	Sudan
MEIn (MJ/ha^{-1})	45300	12400	20700	23180	16215	17176
MI (%)	94.3	98.4	97.6	60.8	96.6	97.8

4. CONCLUSION

- Mechanization energy inputs analysis of sugar cane crop production in Kenana Sugar Company showed that, the highest energy consumer field operations are land preparation (44%) and harvesting (30%), whereas the energy share of labour was the lowest (2,5%).
- Using of new farm mechanization techniques in sugarcane cultivation and timely care of field operations may reduce energy costs and improve the quality of sugarcane production.
- Although the mechanization energy inputs share was not high (0.20), but was efficient in increasing crop productivity (5.6 $kgMJ^{-1}$).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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