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Research paper

Mechanization Index for Selected Crops in Rain-fed Large-scale Agricultural Schemes of Sudan; Case Study: Gedarif State

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Abstract

Assessment of mechanization status in rain-fed areas of Sudan is necessary to identify critical farm operations that are needed. This study aimed at evaluating the use of machinery in large-scale rain fed agricultural schemes of Gedarif State in terms of power availability, tractor density and power use efficiency. In addition, computation of all mechanization indexes for seedbed preparation, seeding, weed control and harvest operations for five crops namely; sorghum, millet, sesame, sunflower and cotton. The required data were collected through structured questionnaire for 54 farmers. The collected data for each crop was prepared in a separate excel worksheet and the intended indicators were computed using the standard procedures. The results indicated that power availability was 0.16 $kWha^{-1}$ and tractor density was found to be 2.7 tractors/1000 ha, whereas tractor power use efficiency was 63.7%. Seedbed preparation and seeding operations for all crops, which were fully mechanized, resulted in 98% mechanization index. The mechanization index for weed control operation in sorghum, millet, sesame, sunflower and cotton crops was 68, 67, 10, 90 and 58%, respectively. The overall average mechanization index of harvesting operation was 73, 71, 46.5 and 96% for sorghum, millet, sesame and sunflower, respectively. However, cotton harvesting was carried manually. The results showed that the total mechanization index for sorghum, millet, sesame, sunflower and cotton crops was 84, 83, 56, 97 and 35%, respectively. The overall mechanization index for all crops in the studied area was found to be 71%. The furnished information thought to help engineers, researchers and farmers to introduce and use the necessary machinery in the rain-fed areas of Sudan for the specified crops.

Keywords: Mechanization index, power availability, tractor density, field operations, rainfed crops, Sudan.

مؤشر الميكنة للمحاصيل المختارة في المشاريع الكبيرة للزراعة المطرية بالسودان: دراسة حالة ولاية القضارف

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المستخلص

إن تقييم حالة الميكنة في مناطق الزراعة المطرية في السودان ضروري للتعرف على العمليات الفلاحية الحرجة والمطلوبة. هدفت هذه الدراسة إلى تقييم استخدام الآلات الزراعية في المشاريع الكبيرة للزراعة المطرية بولاية القضارف من حيث توافر الطاقة وكثافة الجرارات وكفاءة استخدام الطاقة. إضافة إلى حساب مؤشرات الميكنة لعمليات إعداد الأرض، البذر، مكافحة الحشائش والحصاد لخمسة محاصيل هي: الذرة الرفيعة والدخن والسمسم وزهرة الشمس والقطن. تم جمع البيانات المطلوبة من خلال استبيان منظم من 54 مزارع. تم إعداد البيانات التي تم جمعها في ورقة عمل Excel منفصلة لكل محصول ومن ثم تم حساب المؤشرات المشار اليها باستخدام الطرق القياسية. أشارت النتائج إلى أن القدرة المتوفرة كانت 0.16 كيلوواط/هكتار وأن كثافة الجرارات كانت 2.7 جرار/1000هكتار، بينما بلغت كفاءة استخدام قدرة الجرارات 63.7٪. وجد أن عمليات إعداد الأرض والبذر لجميع المحاصيل كانت مميكنة بالكامل، بمؤشر ميكنة بلغ 98٪. كان مؤشر الميكنة لعمليات مكافحة الحشائش في محاصيل الذرة الرفيعة والدخن والسمسم وزهرة الشمس والقطن 68، 67، 10، 90 و58٪ على التوالي. كان متوسط مؤشر الميكنة لعمليات الحصاد 73، 71، 46.5 و 96٪ لكل من محاصيل الذرة الرفيعة، الدخن، السمسم وزهرة الشمس، على التوالي، بينما كان حصاد القطن يدويًا. أظهرت النتائج أن مؤشر الميكنة الكلي لمحاصيل الذرة الرفيعة، الدخن، السمسم، زهرة الشمس والقطن كان 84، 83، 56، 97 و35٪ على التوالي. وجد أن مؤشر الميكنة الكلي لجميع المحاصيل في منطقة الدراسة يبلغ 71٪. يعتقد أن هذه المعلومات تساعد المهندسين والباحثين والمزارعين على إدخال واستخدام الآلات اللازمة في مناطق الزراعة المطرية في السودان للمحاصيل المختارة.

كلمات مفتاحية: مؤشر الميكنة، توافر القدرة، كثافة الجرارات، العمليات الفلاحية، المحاصيل المطرية، السودان.

Introduction

The mechanized rainfed sub-sector in Sudan exists in the clay plains of the country, extending from east to west through Gedarif, Sennar, Blue Nile, White Nile, and Southern Kordofan States. These areas are almost similar in soil type, growing season characteristics and grown crops as well as the type of the used machinery. The average annual area occupied by this sub-sector is about 13.7 million hectares, and the average holdings sizes are of 420 hectares. The grown crops include sorghum, millet, sesame, sunflower and cotton. The farmers in these areas owned fleet of machinery. The 2-WD tractors of medium size (56 kW and 60 kW) are common. Wide level disk (WLD) harrow with seeder box is the popular implement used for seedbed preparation and seeding operations. In addition, farmers also use trailed sprayers, tractor-operated threshers and combine harvesters. On the other hand, hand labors are also employed in the crop production process, such as weed control and harvesting operations. However, farmers face difficulties to perform these operations in these large-scale schemes due to the labour scarcity and in turn, their high costs.

Agricultural mechanization is the process of using available farm power, machinery and other tools to boost productivity by ensuring timely field operations and quality of outputs. However, sustainable agriculture production will not succeed unless there is a sufficient supply of farm machinery (Mrema *et al*., 2018), especially in large-scale agricultural schemes. The demand for agricultural mechanization depends on several factors, such as the intensity of farming operations, market access for the agricultural products, labor market situations, capacity to utilize machines and availability of supportive technologies (IFPRI, 2016). However, maximum mechanization benefits rely on the availability and the use of other complementary inputs, such as improved seeds and agrochemicals. In order to maximize the efficiency of mechanization, the farming system should be characterized to identify possible resource constraints to capture the diversity of farming systems (Zangeneh *et al.,* 2015).

Mechanical power (tractors) and human muscles power are the main sources of farm power in the mechanized rainfed sub-sector of Sudan. Planning and selection of appropriate power source and machinery depends on the work to be carried out, affordability, availability and technical efficiency of these options. Therefore, mechanization planning requires quantification of level of mechanization for each crop production. Quantification of mechanization is essential to identify the variables that having highly impact towards the mechanization.

Several studies were conducted for mechanization assessment with reference to different ways. Mrema *et al*. (2008) and FAO (2008) considered it relies on the number of tractors per arable cultivated area (tractors/1000ha). However, assessment of mechanization with the number of tractors is not suitable, as it does not include time dimension (Sundaram *et al.,* 2012). Also, Mrema *et al*. (2008) and Olaoye and Rotimi (2010) have used the term power availability per hectare (kW/ha) to identify level of agricultural mechanization. Further, the mechanical power as a ratio of the total farm power was used to determine level of agricultural mechanization (Olaoye and Rotimi, 2010; Taiwo and Kumi, 2015). Furthermore, mechanization index had also been presented as the ratio of machine energy to total energy (machine, animal, and human energy) (Singh, 2006; Ramirez *et al.,* 2007; Hormozi *et al.,* 2012; Zangeneh *et al.,* 2015; Abbas *et al.,* 2017).

In this regard, the assessment of mechanization status in rainfed areas of Sudan is necessary to reveal not only the level of the used energy, but also to identify the critical operations that are needed for mechanization introduction and use. Currently, there are no documented studies or available information with regard to the level of mechanization in the large-scale schemes in the rainfed areas of Sudan. Provision of such information will assist farmers, agricultural policy makers, researchers and private sector in filling the mechanization gaps in rainfed areas to enhance crop production and productivity.

This study aimed at evaluation of the machinery use in large-scale agricultural schemes in rainfed areas of Gedarif State in terms of power availability, tractor intensity and power use efficiency. In addition to compute specific and total mechanization indexes for seedbed preparation, seeding, weed control and harvest operations for main five crops namely sorghum, millet, sesame, sunflower and cotton.

Materials and Methods

Study area

Gedarif State lies in the Eastern part of Sudan between latitudes 12.67º and 15.75º N and longitudes 33.57 º and 37.0º E, covering 71000 km^2. The state extends through three climate zones from arid zone in the North to dry monsoon zone in the South (Adam, 2008). The total suitable area for cultivation is about 3.4 million hectares with heavy clay soil (Vertisols). The effective rainfall occurs during June - July and extended to September - October and accordingly there is a single growing season a year. The major crops grown are sorghum, sesame, millet, sunflower and cotton. The crop production in the study area practiced by private farmers.

Cultural practices for crop production

The basic operations which are carried by farmers for crops production in large-scale rainfed schemes in Gedarif State could be summarized as follows:

Seedbed preparation: This operation usually carried out with the use of wide level disk (WLD) harrow for all crops. This implement resulted in a 5 to 8 cm plowing depth. On the average, the farmers plow their farms twice. This operation is carried out often during June - July depending on the onset of rainy season.

Seeding operation: The WLD is the common seeding implement, which delivers the seeds in broadcasting patterns. Seeding operation is usually carried out in July and extend up to late August.

Weed control: There are three options available for farmers to execute weed control operation; with the use of hand labor, chemical control or mechanical weeding (an operation known as *Sarwala*, which use the WLD specifically for weed control in sorghum and millet farms). Table 1 describes the actual practiced weed control options for each crop; the operation starts 4 weeks after crop emergence.

Table (1): Weed control options for the selected crops in large-scale agricultural schemes in Gedarif State

Crop	Description of the used weed control options
Sorghum	Hand weeding Mechanical weeding (Sarwala operation) + supportive hand weeding Spraying post emergence herbicide + supportive hand weeding
Millet	Hand weeding Sarwala operation + supportive hand weeding Spraying post emergence herbicide + supportive hand weeding
Sesame	Hand weeding two times (common practice) Spraying post emergence herbicide + supportive hand weeding
Sunflower	Spraying pre emergence herbicide
Cotton	Spraying post emergence herbicide + supportive hand weeding

Harvesting: There are three options for crop harvesting, manual, semi-mechanized and fully mechanized. Table 2 describes the actually practiced harvesting options for each crop. Harvesting operation starts in late October and extended up to February.

Data collected

Data was collected through structured questionnaire from 54 farmers in 2018/2019 growing season, farmers were randomly selected. The number of the respondent farmers were considered sufficient for the purposes of the study, as all farmers use similar implements, adopting similar operations and farming systems besides that they face similar constrains. The questionnaire considered the general information of the grown crops and their cultivated areas as well as the total land area owned by specific farmer. In addition, the questionnaire included data on type, size and performance indicators of the used machinery (tractors and implements). Moreover, the questionnaire included data on the number of hand labors, needed time (hours per ha) and work rate to execute specific operation manually. Generally, the collected data focused on the basic farm operations such as seedbed preparation, seeding, weed control and harvesting for the five crops namely, sorghum, millet, sesame, sunflower and cotton.

The collected data for each crop was prepared in a separate excel worksheet and thereafter, the intended indicators computed by using the following calculation procedures.

Table (2): Harvesting options for the selected crops in large-scale agricultural schemes in Gedarif State

Crop	No. of available harvesting options	Description of the used harvesting options
Sorghum	2	Manual cutting + mechanical threshing by tractor operated thresher or by combine harvester Direct combine harvesting
Millet	2	Manual cutting + mechanical threshing by tractor operated thresher or by combine harvester Direct combine harvesting
Sesame	3	Manual cutting and binding + manual threshing Mechanical cutting + manual binding + manual threshing Mechanical cutting and binding + manual threshing
Sunflower	1	Direct combine harvesting
Cotton	1	Manual picking

Calculation procedures

Power availability

Power availability ($kWha^{-1}$) was determined using equation 1 as described by (Ozmerzi, 1998; Sharabiani and Ranjbar, 2008; Mrema *et al.,* 2008; Olaoye and Rotimi, 2010) as follows:

$$PA = T_P \times TNT/A \qquad (1)$$

Where:

PA = Power availability ($kWha^{-1}$)

T_P = Average power of the working tractors (kW).

TNT = Total number of working tractors.

A = Total cultivated a

Tractor density

Tractor density refers to the number of working tractors per unit area and it indicates the available numbers of tractors. Tractor density was computed by equation 2 as described by Singh and Kumar (2017).

Tractor density (No/000 ha) = NWT/CA (1000 ha)………………………. (2)

Where:

NWT = Number of working tractors.

CA = Cropped area (1000 ha).

Mechanization index

The index of mechanization was restricted to the prevailing available power sources in the study area (hand labor and machineries). The degree of mechanization at the two available power sources were defined as follows:

Energy input of labor (kWh/ha)

Number of working labors in each operation was considered. It was taken into account that a normal person can produce on average of 0.075 kW (approximately 0.1 kW) during a working day. The average energy input of work provided exclusively by a labor per hectare was calculated as reported by (Bawatharani and Karunarachchi, 2017) as follows:

$$L_E = 0.1\, N_H\, T_H/A \qquad (3)$$

Where:

L_E = Average energy input or work provided per hectare by a labor ($kWhha^{-1}$).
0.1 = Theoretical average power of an average man working optimally (kW).
N_H = Average number of labor employed.
T_H = Average working time of manual operation (h).
A = Area of cultivated land (ha).

Machinery input energy (kWh/ha)

Average energy input by motorized machinery was calculated as reported by Olaoye and Adekanye (2014) by using equation 4 as follows:

$$M_E = 0.2 \times T_P \times T_M \quad (4)$$

Where:
M_E = Average energy input per hectare by motorized machine ($kWhha^{-1}$).
T_P = Average power of the used tractors (kW).
T_M = Rated working time ($h\ ha^{-1}$).

Mechanization Index (%)

The mechanization index represents the percentage of work (energy) performed by machinery to the total work performed by hand labor and machinery. The mechanization index was determined for each single operation (from seedbed preparation to harvest) for each crop and for the entire crop production. Equation 5 was used to calculate the mechanization index as described by (Fortune and Tawanda, 2013; Olaoye and Adekanye, 2014; Bawatharani and Karunarachchi, 2017).

$$MI\ (\%) = M_{ET} \times 100 / (M_{ET} + L_{ET}) \quad (5)$$

Where:
MI = Mechanization Index (%).
M_{ET} = Average sum of all mechanical operation work performed by the machines ($kWhha^{-1}$).
L_{ET} = Average sum of all manual work done by labors ($kWhha^{-1}$).
A higher value of MI indicates that the machine has carried out most of the work.

Power use efficiency

The power use efficiency gives a measure of how much of the available energy had been utilized and estimated by comparing the total used and the total available energies (Stubbs, 2013) as follows:

$$\text{Power use efficiency (\%)} = 100 \times \text{used energy } (kWha^{-1}) / \text{available energy } (kWha^{-1}) \quad (6)$$

The used energy is the summation of energy used to perform all operations (seedbed preparation, seeding, weed control and stationary threshing) by tractor for the grown crops. The available energy was determined by using equation 7 as mentioned by Stubbs (2013).

$$A_E = (T_P \times T)/A \quad (7)$$

Where:

A_E = Available energy ($kWha^{-1}$).
T_P = Total power of the used tractors (kW).
T = Total annual working time (h).
A = Total annual cropped area (ha).

The power use efficiency only restricted to the operations carried out by tractor.

Results and discussion

Results indicated that the power availability of tractors in the studied area was 0.16 $kWha^{-1}$ (Table 3). The obtained value of power availability was much lower compared to that reported in the literature. Singh (2006) found that the power availability in India increased from 0.32 kW ha^{-1} in 1970 to 1.22 kW ha^{-1} in 2001. Gimenez and Milan (2007) found that the value of $kWha^{-1}$ in Parana and Sao Paulo States in Brazil was between 0.46 and 0.99. Furthermore, Sharabiani and Ranjbar (2008) reported 0.62 kW ha^{-1} (0.83 $hpha^{-1}$) in Sarab Region in Azarbayjan. The variability in $kWha^{-1}$ reflects the different soil characteristics of each region and the different farming practices.

Tractor density in the studied area was found to be 2.7 tractor/1000 ha (Table 3). This is almost double of the average tractor density in Sub-Saharan Africa in 2012, (1.3/1000 ha); and much lower compared to that of South Asia and Latin America which amounted to around 9.1 and 10.4 tractors/1000 ha, respectively (FAO, 2012). However, recent estimates had showed that African farming systems remain the least mechanized of all continents (Pingali, 2007). It would be better if the number of tractors in the mechanized rainfed areas of Sudan increased to 7.1 tractors/1000 ha (i.e., 3 tractors/1000 feddans) for a timely execution of field operations and to cope with application of modern production technologies and continuous techniques changes. Keeping in mind that there are several factors that may limit the use of mechanization, such as access to machinery and its spare-parts, an inadequate technical staff and skilled labors to operate and repair farm machinery.

On the other hand, the available and the used energy by tractor was found to be 164.3 and 104.6 $kWhha^{-1}$, respectively (Table 3); indicating that the power use efficiency of the tractor was about 63.7%. The obtained efficiency reflects the use of available time and power of the tractor.

Table (3): Available power, tractors density and power use efficiency in in large-scale agricultural schemes, Gedarif State, Sudan

	Unit	Value
Total cropped area	ha	120042
Number of working tractors	-	324
Average power of tractors	kW	59.1
Average working hours of tractor	hyr^{-1}	1030
Power availability	$kWha^{-1}$	0.16
Tractor density	No of tractors/1000 ha	2.7
Available energy	$kWhha^{-1}$	164.3
Used energy	$kWhha^{-1}$	104.6
Power use efficiency	%	63.7

Table 4 shows that both of seedbed preparation and seeding operations for all crops were fully mechanized as indicated by higher mechanization index (98%). A few manual energies exerted by the driver and his assistant in performing these two operations. The mechanical energy needed for seedbed preparation ranged between 9.83 and 11.23 $kWhha^{-1}$, while the mechanical energy needed for seeding ranged between 5.09 and 5.40 $kWhha^{-1}$. It was noticeable that seedbed preparation operation consumed double the energy that consumed by seeding operation, although both operations use the same implements and tractors. This was mainly due to the fact that the seedbed preparation often carried out twice while seeding operation carried out once, for all tested crops.

The mechanization index for weed control operation of sorghum and millet was 68% and 67%, respectively (Table 4). Results indicated that although mechanical weed control practiced by the use of the WLD and tractor-operated sprayer but hand labors are still used for the practice. Mechanization index for weed control operation of sesame crop was only 10% (Table 4). This is because the majority of the farmers use manual labors to carry weeding operations for sesame twice, with the average consumed manual weed control energy of sesame fields was 12.74 $kWhha^{-1}$. Sunflower fields required relatively few manual and mechanical energy for weed control, averaging 0.17 and 1.51 $kWhha^{-1}$, respectively. The mechanization index for weed control operation of sunflower was 90%. Cotton fields consumed 0.99 and 1.36 $kWhha^{-1}$ for manual and mechanical energy for weed control, respectively, resulting in 58% mechanization index. Much effort is required to improve mechanization index for weed control operation especially for sesame. This could be realized by introducing inter-row cultivator, as a mechanical weed control method; which in turn needs to shift from the currently broadcasting operation of sowing pattern to row planting.

Harvesting operation for the five crops indicated high variability in the consumed manual energy, mechanical energy as well as mechanization index (Table 4). On the average the two sorghum harvesting options consumed 2.60 $kWhha^{-1}$ by hand labor and 9.41 $kWhha^{-1}$ by tractor, resulting in a mechanization index 73%. Likewise, millet harvesting consumed 2.99 $kWhha^{-1}$ energy by hand labor and 10.61 $kWhha^{-1}$ energy by tractor, resulting in 71% mechanization index. Figures 1 and 2 showed further details on the effect of harvesting method on harvesting index for sorghum and millet, respectively. Sorghum harvesting methods influenced both the mechanization index of harvesting operation and the total mechanization index (Fig. 1). The use of stationary threshing for sorghum harvesting resulted in 46% and 76% mechanization index for the harvesting operation and the total mechanization index, respectively. Whereas, the use of direct combine harvesting gave 99% mechanization index for sorghum harvesting and improved the total mechanization index to 92%. Also, millet harvesting methods influenced both the mechanization index of harvesting operation and the total mechanization index (Fig. 2). The use of stationary threshing for millet harvesting resulted in 43% and 75% mechanization index for the harvesting operation and the total mechanization index, respectively. Whereas, the use of direct combine harvesting gave 99% mechanization index for millet harvesting and improved the total mechanization index to 92%. Yousif and Babiker (2018a) confirmed that the direct combine harvesting of field crops was profitable in the large-scale agricultural schemes of eastern Sudan.
Sesame harvesting occurs in three steps. The first step is to cut plant stems, binding the stalks and heaping the banded plant vertically; this step has three options of harvesting methods (Table 2). The second step is to leave the crop plants for two to three weeks on an open space for natural drying. The third step is to perform threshing, cleaning and sacks filling and tying; this step is manual. On the average of the three harvesting options, sesame harvesting consumed more energy (4.72 $kWhha^{-1}$) by hand labor compared to the energy consumed by tractor (3.28 $kWhha^{-1}$), resulting in about 46.5% mechanization index. Figure 3 shows the effect of sesame harvesting options on mechanization index of harvesting operation and on the total mechanization index of all production operations.

The results indicated that the mechanical cutting and manual binding resulted in 49% mechanization index of harvesting operation, while the mechanical cutting and binding improved the mechanization index of harvesting to 90%. However, the introduction of cutter-binder help a lot in solving the problem of sesame harvesting (Yousif *et al.*, 2016). The results showed some variation in the total mechanization index as the result of sesame harvesting methods (Fig. 3). The shift from manual harvesting to mechanical cutting and binding improved the total mechanization index from 43% to 70%.

To improve the mechanization of harvesting operation the third step should be fully mechanized. Researchers, farmers and private sector need to sit together and combining efforts to solve the problem of fully mechanization of sesame.

Table (4): Manual and mechanical input energy and mechanization index for the basic operations of the selected crops grown in large-scale agricultural schemes, Gedarif State, Sudan

	Seedbed preparation	Seeding	Weed control	Harvesting
		Sorghum		
Manual energy (kWhha^{-1})	0.17	0.09	2.45	2.60
Mechanical energy (kWhha^{-1})	9.83	5.09	5.23	9.41
Mechanization index (%)	98	98	68	73
		Millet		
Manual energy (kWhha^{-1})	0.17	0.09	2.63	2.99
Mechanical energy (kWhha^{-1})	10.25	5.21	5.45	10.06
Mechanization index (%)	98	98	67	71
		Sesame		
Manual energy (kWhha^{-1})	0.17	0.09	12.74	4.72
Mechanical energy (kWhha^{-1})	9.92	5.11	1.41	3.28
Mechanization index (%)	98	98	10	46.5
		Sunflower		
Manual energy (kWhha^{-1})	0.18	0.09	0.17	0.54
Mechanical energy (kWhha^{-1})	10.40	5.24	1.51	13.52
Mechanization index (%)	98	98	90	96
		Cotton		
Manual energy (kWhha^{-1})	0.19	0.09	0.99	32.00
Mechanical energy (kWhha^{-1})	11.23	5.40	1.36	0.00
Mechanization index (%)	100	100	58	0

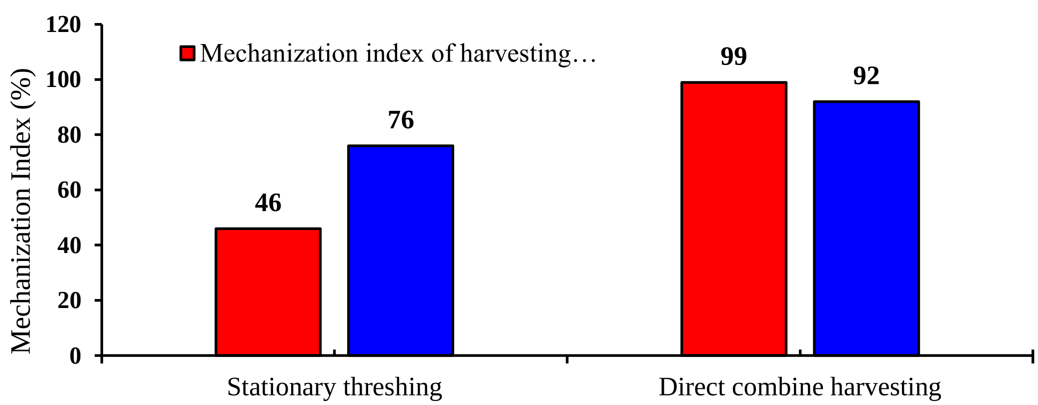

Fig. 1. Effect of harvesting method on the mechanization index of harvesting operation and total mechanization index for sorghum crop

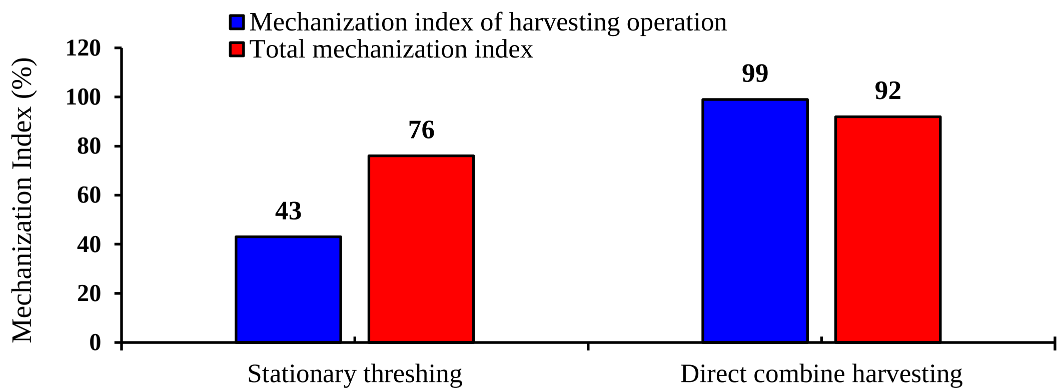

Fig. 2. Effect of harvesting method on the mechanization index of harvesting operation and total mechanization index for millet crop

Sunflower harvesting was completely mechanized by combine harvester which consumed 13.52 kWhha^{-1}, while hand labor just used 0.54 kWhha^{-1} for sacks filling, tying and handling. The mechanization index for sunflower harvesting was 96%. Yousif and Babiker (2018b) reported that the performance of combine harvesters for direct combine harvesting of sunflower in the large-scale schemes in rainfed areas was satisfactory. Cotton harvesting was manual and the consumed energy was 32.0 kWh ha^{-1}. This is because of non-availability of mechanization inputs to serve the harvesting operation for cotton.

Mechanization index for harvesting operation need to be improved especially for sesame and cotton because they are the main cash crops in the rainfed areas. Availing sesame cutter-binder machines at a reasonable cost and solving the problem of manual threshing by innovating or developing a threshing machine are suggested solutions to improve the mechanization index for sesame harvesting. For cotton, mechanical harvester (picker or stripper) should be availed.

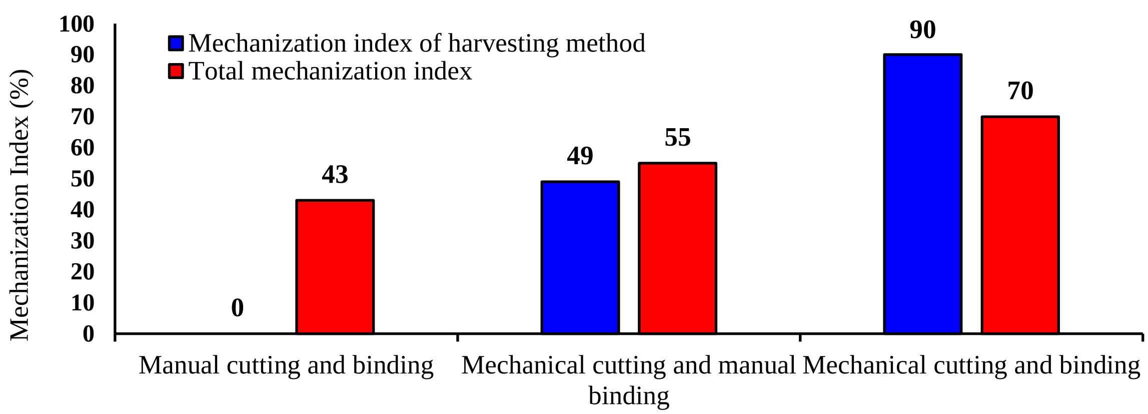

Fig. 3. Effect of sesame harvesting method on the mechanization index of harvesting operation and the total mechanization index

Figure 4 shows the total mechanization index for the main crops that grown in the large-scale in rainfed schemes of Gedarif State. Results indicated that sorghum and millet resulted in 84% and 83% mechanization index, respectively. This result implies that there is still some manual operations for these two crops. Sesame and cotton crops resulted in a lower total mechanization index compared to sorghum and millet crops, they obtained 53% and 35%, respectively. This revealed that the energy input per hectare by human work is greater than the energy input of a machine for producing sesame and cotton, which contributed to low level of mechanization. Thus, much effort is required to improve the level of mechanization of these two crops. However, sunflower crop resulted in the highest total mechanization index (97%) compared to the other crops, which indicated easiness to produce this crop by mechanization. The overall average total mechanization index for all crops in the studied area was 71% (Fig. 4). This average mechanization index was higher compared to that found in some African countries. Olaoye and Adekanye (2014) found that the total mechanization index in agricultural schemes in southwestern Nigeria ranged between 43.2% and 53.6%.

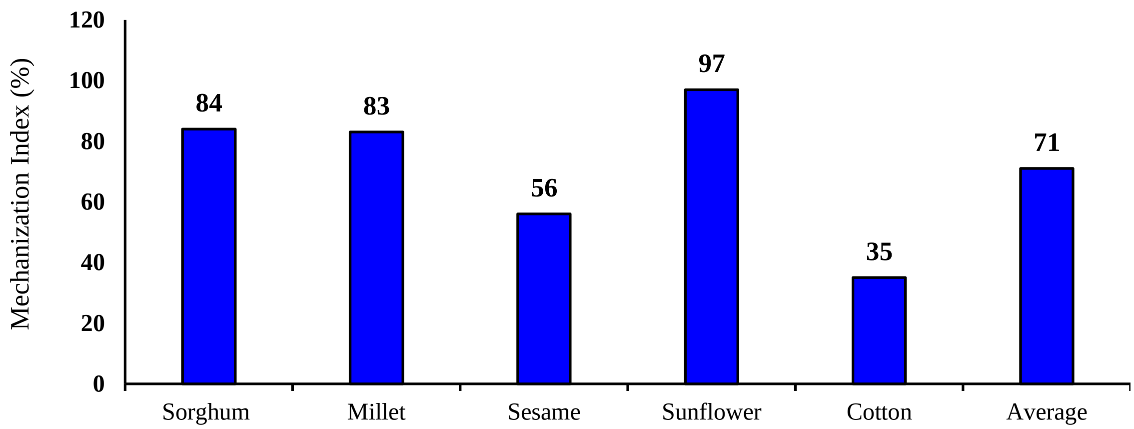

Fig.4. Mechanization index of the main crops in large-scale rainfed schemes

Conclusion

The use of agricultural machinery in the large-scale schemes in rainfed areas of Gedarif State to produce five crops was evaluated.

- Power availability and tractor density in the study area need to be increased for a timely execution of farm operations and to cope with continuous changes in production technologies.
- Not all crops were uniformly mechanized, the sunflower received the highest level of mechanization followed by sorghum and millet, whereas sesame and cotton received the lowest level of mechanization.
- The basic production operations varied in the received level of mechanization. Seedbed and seeding operations were fully mechanized for all crops. However, weed control and harvesting operations, especially for cotton and sesame were less mechanized.
- Proper planning and integration efforts are needed for improvement of the level of agricultural mechanization to enhance agricultural production and productivity to achieve proper crops growth and yields.
- Strengthening the supply chains for agricultural machinery and its associated logistical services to ensure sustainability of agricultural mechanization.

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