Original Research Article

Estimating level of mechanization for some selected crops in the Gezira scheme, Sudan

Abstract

Agricultural mechanization planning needs quantitative assessment to the required level of mechanization. Knowing level of mechanization helps in sustaining crop production. Level of agricultural mechanization means ratio between mechanical energy to total energy (sum of animal, human and mechanical energies) used in crop production. Crop production practices in the Gezira scheme depend on two energy sources, labor and machinery. The objectives of this study were to quantify and compare the level of mechanization for some selected crops in the Gezira scheme. The selected crops were cotton, wheat, groundnut, sorghum, pigeon pea, chickpea and onion. Data about production practices, from seedbed preparation to harvest, for these crops were collected from the farmers and engineers. Labor data included operated area, number of labors and daily working hours. Machinery data included machine type, work rate and fuel consumed. The collected data were entered into excel-sheets and energy was calculated using the standard procedures. The level of mechanization was calculated for two scenarios, the traditional and improved farming systems. The results showed that the level of mechanization in the traditional farming system varied from crop to another, it was 20.4, 25, 26.1, 41.8, 61.4, 80.6 and 96.7% for groundnuts, cotton, onion, pigeon pea, sorghum, chickpea and wheat crops, respectively. The results indicated that there are possibilities to improve level of mechanization by some interventions; this improve to groundnut, cotton, onion, pigeon pea, sorghum, chickpea and wheat will reach 69.1, 62.1, 54.9, 74, 98.7, 99.4 and 98.9%, respectively. However, this improvement require additional fuel by 99.9, 82.4, 79.7, 74.3, 66.2, 24.2 and 40 l/ha for these crops, respectively. The study concluded that the level of mechanization is weak for some crops and there are opportunities for improvement. Conducting further comparison between the costs of manual and mechanized operations for these crops is recommended.

Keywords: *Mechanized operations, Manual operations, Energy sources for fieldwork, Fuel consumption.*

Introduction

Agricultural machinery becomes a fundamental input in agricultural production. It aims at increasing the power inputs to agricultural activities hence intensify production, decrease cost of production and reduction of drudgery in farm activities. It also improves the timeliness and efficiency of farm operations (Verma and Tripathi, 2016). Moreover, it accomplishes tasks that are difficult to perform without mechanical aids. However, the successful implementation of the mechanization requires a considerable effort by stakeholders (Rehman *et al.,* 2016).

Different authors have defined the level of agricultural mechanization in diverse ways. For example, Mrema *et al.,* (2008) defined it as number of tractors per arable land (tractors/1000 ha), however, assessment of mechanization with the number of tractors is not suitable, as it does not consider time dimension (Sundaram *et al.,* 2012). Ozmerzi, (1998); Mrema *et al.,* (2008); Olaoye and Rotimi, (2010) defined it as power availability (kW/ha). Moreover, Olaoye and Rotimi, (2010); Taiwo and Kumi, (2015) have used the term terms of mechanical power as a ratio of total farm power (tractor power and human power). Furthermore, level of mechanization has also been defined as the ratio of machine energy to total energy (machine, animal, and human energy) (Ramirez *et al.*, 2007; Hormozi *et al.*, 2012; Zangeneh *et al.*, 2015; Abbas *et al.*, 2017). Level of mechanization is an indicator to what extend the mechanical power is used to perform farm operations. A higher value of mechanization level is the affirmation that most of the work has been done by machine (Abbas *et al.,* 2017).

The level of mechanization vary widely across regions, countries and farming system. The full-mechanized system has completed in most developed countries, while many developing countries have been striving to achieve the high level of the mechanization. The implementation of mechanization is influenced by many factors such as agricultural conditions, farming requirements, farm management scales, economic conditions, the technical level of manufactures, and farmer's experience (Ademiluyi and Oladele 2008; Diao *et al.*, 2014). However, sustainable agriculture production will not succeed unless there is a sufficient supply of farm machinery (Mrema *et al*., 2018). Alaeldin *et al.,* (2019), conclude that Mechanization is a key factor for agricultural development and farmers' well-being, not only had it helped improving labor productivity many times in comparison to agriculture without mechanical power, mechanization provides also the power to ensure that agricultural operations for the soil and the plants are done precisely in time and with the highest efficiency.

Recent estimates show that African farming systems remain the least mechanized of all continents. Seventy percent 70 % of the farmers cultivate areas of less than two hectares by hand hoe (Pingali, 2007). The majority of work across African farms (50% to 85 %) continue to be done manually through human muscle (Kirui, 2019). Migration from rural to urban areas has led to a rapid decline in farm labor supply (Goldsmith *et al*., 2004; Zhou, 2013; FAO, 2018). With the rising cost of labor, farmers are more inclined to make use of machinery where they are available and affordable (Diao *et al.,* 2017). Although machineries are expensive, having the appropriate access to machineries at the right time can help in efficiently manage inputs in farms and overall productivity, thus improving income (Ayodele, 2012).

Crop production practices in the Gezira scheme, Sudan depend on two energy sources, hand labors and machinery. Agricultural mechanization planning needs quantitative assessment to the required level of mechanization. Knowing level of mechanization helps in sustaining crop production. There is lack of documented articles about the level of mechanization in the scheme. The objectives of this study were to quantify and compare the level of mechanization for some selected crops in the Gezira scheme.

Materials and methods

Study area

This study was carried out in the Gezira scheme, Sudan during season 2021/2022 to quantify and to compare the level of agricultural mechanization for some selected crops. The total area of the Gezira scheme is 0.9 million ha. The scheme lies in the central clay plain and irrigated through surface irrigation system from the Sennar damp established in the Blue Nile since 1925. There are two cropping seasons each year, summer and winter seasons. Farm size ranged between 0.84 hectare and 1.26 hectares.

Selected crops and their production practices

Seven main crops grown in the Gezira scheme were selected. These crops were cotton, groundnut, pigeon pea and sorghum as summer crops and wheat, check pea and onion as winter crops. All these crops are produced under surface irrigation system. The majority of farmers hold small-scale farms, so tractors and implements used for farm operations are small to medium sizes. The production practices, from land preparation to harvest were either manual or mechanized operations.

Data collection

Data were collected from farmers and engineers by field surveys and direct interviews. Data on the prevailing production practices (mechanical and manual) for the selected crops were collected. Hand labor data included operated area, number of labors and daily working hours for manual operations such as construction of Tagamet and Gadual, sowing, thinning and re-sowing, addition of fertilizer, weeding and harvesting (Table 1). The machinery data included machine type, work rate and fuel consumption for mechanized operations such as seedbed preparation, water channels preparation, sowing, addition of fertilizer, weeding and harvesting (Table 2). The collected data were entered into excel-sheets, and then energy was calculated for the manual and mechanical operations using the standard methods.

Table 1. Hand labor hours (man.h/ha) for manual operations and the selected crops in the Gezira scheme

Crops	Taganet and Gadual	Sowing	Thinning and re-sowing	Adding fertilizer	Weeding	Harvesting
Cotton	10.2	41.9	22.1	9.8	156.1	751.4
Groundnut	11.2	46.6	12.9	0.0	235.1	462.7
Pigeon pea	8.1	36.2	20.9	6.9	97.6	233.7
Sorghum	8.6	37.4	21.2	6.9	99.0	254.2
Wheat	10.7	0.5	0.0	7.1	0.5	1.2
Check pea	12.4	41.7	10.7	6.7	75.7	131.4
Onion	14.3	259.2	0.0	11.9	420.5	841.8

Table 2. Work rate and fuel consumption for some implements used in the Gezira scheme

Mechanized operations	Work rate (ha/h)	Fuel (L/h)	Mechanized operations	Work rate (ha/h)	Fuel (L/h)
Seedbed preparation			Row crop planter	1.68	8.8
Disk plow	0.42	10	Seed drill	1.89	9.9
Chisel plow	0.84	9	**Weed control**		
Disk harrow	1.47	9.5	Green Ridging	1.68	8.8
Leveler	1.68	8.8	Interop cultivator	1.89	9.9
Ridger	1.68	9.6	Sprayer	4.20	7.5
Fertilizer addition			**Harvesting**		
Distributor	2.52	7.8	Plant Stalks uprooting	0.84	9
Water channels preparation			Stationary thresher	0.63	10.1
Abu XX	37.82	26.1	Combine harvester	2.10	18
Ditcher Abu VI	2.52	11.4	Mower	1.26	9.6
Tangent and Gradual	1.68	8	Digger shaker	0.84	11.2
Sowing			groundnut thresher	0.84	10.8

Farming system

Two scenarios of farming system (A and B) were adopted in this study. These scenarios were developed according to the operations implemented and suitable for each crop (Table 3). Scenario A represented the traditional farming system whereas scenario B represented the improved (mechanized) farming system (Table 3).

Calculation procedures

The level of mechanization was restricted to the prevailing available power sources in the Gezira scheme (hand labor and machineries). The level of mechanization at the two available power sources were calculated. The following calculations were used for each crop and its operations.

Man-hour per unit area

For each manual operation and crop, man-hour per hectare was calculated according to the following equation (1) as described by (Fortune and Tawanda, 2013).

Man.h/ha = N L x N WD x DWH/ A…………………………………………………… (1)

Where:

Man.h/ha = Man hours/hectare
NL = Number of labors worked the operation
NWD = Number of working days
DWH = daily working hours
A = Worked area, ha.

Energy input of labor (kWh/ha)

Manual energy input in crop production was calculated according to the procedure described by (Bawatharani and Karunarachchi, 2017) by using the following equation:

Man.EI = Man hours/ha x 0.1……………………………………………………….. (2)

Where:

Man.EI = Manual energy input (kW.h/ha)
0.1 = Theoretical power of average person working optimally, kW.

Table 3. Field operations for two scenarios of farming systems in Gezira scheme

Farming operations	Farming system A	Farming system B
Land preparation	Ridging + re-ridging or split ridging Leveling for wheat crop only	Chisel plowing + disk harrowing (except sorghum crop) + leveling + ridging (except wheat crop)
Abu XX	Mechanical	Mechanical
Abu VI	Mechanical	Mechanical
Tagnent and Gadual	Manual	Mechanical
Sowing	Manual: for all crops except wheat it is mechanical	Mechanical: for all crops (except onion crop)
Weed control	Manual (except wheat crop)	Spraying or Green ridging + Manual (except wheat crop spraying only)
Harvest	Manual: for cotton, onion, pigeon pea and groundnut Semi mechanized: for sorghum and check pea Combine harvester: for wheat	Manual: for cotton, onion and pigeon pea Semi mechanized: for groundnut and check pea

		Combine harvester: for wheat and sorghum
Residue management	Manual: for all crops and none for wheat	Manual: except for cotton it is mechanical and none for wheat

Mechanical energy

On the other hand, the mechanical energy was calculated by using equation 3 as follows:

$$MEI = TP \times TPF \times NO/IWR \qquad (3)$$

Where:

- MEI = Mechanical energy input, kW.h/ha
- TP = Tractor power, kW = 59.7 kW
- TPF = Tractor power factor
- NO = Number of operations
- IWR = Implement work rate, ha/h

Total energy

The total energy is the summation of all manual and mechanical energies as follows:

$$TEI = Man.EI + MEI \qquad (4)$$

Level of mechanization

The level of mechanization represents the percentage of work (energy) performed by machinery to the total work performed by hand labor and machinery. Equation 5 was used to calculate the level of mechanization for each crop as described by (Fortune and Tawanda, 2013; Bawatharani and Karunarachchi, 2017).

$$ML = MEI \times 100 / TEI \qquad (5)$$

Where:

ML = level of mechanization (%).

Moreover, other calculations and comparisons were carried out this included difference in fuel consumption and mechanization level between traditional and improved farming systems, percentage of improvement in mechanization level and ranking the crops in response to the improvement.

Results and discussion

Table 4 shows the share of manual and mechanical energies (kWh/ha) for the conventional and improved farming systems to produce the selected crops in the Gezira scheme. Generally, the share of labor energy for all the crops grown under conventional farming system was higher compared to the mechanical energy, except wheat, check pea and sorghum crops. This because, in the Gezira scheme, the machinery are mainly used for seedbed preparation and reconditioning the in-farm water channels. This is a sign that the scheme did not witness noticeable and sustainable application of modern mechanization techniques for the other farm operations. Besides that hand tools such as jaraya, shovel, hoe, sickle, etc. are the common tools used to execute farm operations like seeding, weeding, fertilizer application and harvesting. However, due to continuing education to university and the young villagers prefer to find a job in the city rather than in their villages this has caused shortage of hand labor thus necessitate the use of machines in all farm operations. There was big variation in labor energy among the grown crops. Groundnut followed by cotton and onion are the most labor-intensive crops, mainly at harvest. Wheat crop resulted in the lowest labor energy input. This in agreement with the finding of Kheiry and Dahab (2016). They reported that the contribution of labor energy input for wheat production was less than that of sorghum and cotton due to higher mechanization level used for production of wheat crop compared to other crops.

On the other hand, the results showed that the contribution of mechanical energy input was generally higher for all crops compared to the labor energy in the improved farming system. However, sustainable agriculture production will not succeed unless there is a sufficient supply of farm machinery (Mrema *et al*., 2018). Because the mechanized farming operations can help in increasing the productivity of land and labor, reducing production costs and drudgery on the farm labors, besides improving the timeliness and quality of farm works (Verma and Tripathi, 2016). Moreover, mechanization becomes a fundamental input in agricultural production process and is an essential element to improve agricultural production (Verma and Tripathi, 2016). Definitely, any enhancement in the level of farm mechanization, elsewhere, requires further quantities of diesel fuel, and that has to be considered in the planning process.

Table 4. Manual and mechanical energies (kWh/ha) for the conventional and improved farming systems to produce the selected crops in the Gezira scheme

Crops	Conventional farming system			Improved farming system		
	Manual energy (kW.h/ha)	Mechanical energy (kW.h/ha)	Total energy (kW.h/ha)	Manual energy (kW.h/ha)	Mechanical energy (kW.h/ha)	Total energy (kW.h/ha)
Cotton	78.20	26.02	104.22	47.50	77.95	125.45
Groundnut	95.14	24.33	119.47	40.30	89.97	130.27
Pigeon pea	36.22	26.02	62.24	24.32	69.28	93.60
Sorghum	31.89	50.71	82.60	1.17	91.39	92.56
Wheat	1.95	57.81	59.76	0.82	77.29	78.11
Check pea	11.81	49.03	60.84	0.53	92.29	92.82
Onion	68.79	24.33	93.12	62.00	75.50	137.5

Table 5 shows the consumed fuel (l/ha) for the two scenarios of farming systems to produce the selected crops in the Gezira scheme. Generally, the conventional farming system consumed lower fuel compared to the improved one; this because in the conventional farming system the majority of the farm operations are carried out by hand labors. Whereas in the improved farming system the manual labors are substituted by machinery. In the conventional farming system, the lowest amount of fuel was consumed by groundnut crop (19.4 l/ha) and the highest (55.4 l/ha) by wheat crop. On the other hand, in the improved farming system, the lowest and the highest amount of fuel was consumed by wheat crop (95.4 l/ha) and check pea (124.2 l/ha), respectively. This was mainly due to the variation in the used farming operations. In addition, Table 5 depicted the difference between the two systems in the consumed fuel. The results revealed that there is big variation between the grown crops in the consumed fuel. The highest and the lowest difference needed in fuel to improve the level of mechanization were 99.9 l/ha and 24.2 for groundnut and wheat crops, respectively. This indicated that any improvement in the level of farm mechanization requires additional diesel fuel. These findings will help the decision makers, field managers and the engineers in estimating and providing or availing the sufficient amount of fuel for Gezira scheme.

The level of mechanization is one of the quantitative indicators by which different operations in a farm can be judged and evaluated. Fig. 1 illustrates and compares the mechanization level between the conventional and improved farming systems for seven crops. In the traditional farming system, there was a wide variation in mechanization level from crop to another. Wheat crop scored the highest mechanization level (96.7%) followed by check pea crop (80.6%) and sorghum crop (61.4%). The higher values of mechanization levels are the affirmation that most of the work had been done by machine (Abbas *et al.*, 2017). The highest level of mechanization of these crops was mainly due to the use of machines in harvest operations (Table 3). The lowest mechanization level was recorded by groundnut, cotton and onion crops, which scored 20.4%, 25% and 26.1%, respectively. The main reason behind the lower mechanization level for these crops is manual harvesting. On the other hand, in the improved farming system, there was a wide variation in mechanization level from crop to another too. Check pea crop scored the highest mechanization level (99.4%) followed by wheat crop (98.9%) and sorghum crop (98.7%). Onion, groundnut and cotton crops recorded the lowest mechanization level, which scored 54.9%, 62.1% and 69.1%, respectively. The mechanized farming system make agriculture more attractive job and reduce the rural-urban movement. However, the successful implementation of the mechanization requires a considerable effort by policymakers, researchers and extension workers, to introduce new mechanical techniques, and adapts the techniques in agricultural production (Rehman *et al.*, 2016). These results revealed that the level of mechanization in the Gezira scheme is weak for some crops and there are opportunities for improvement.

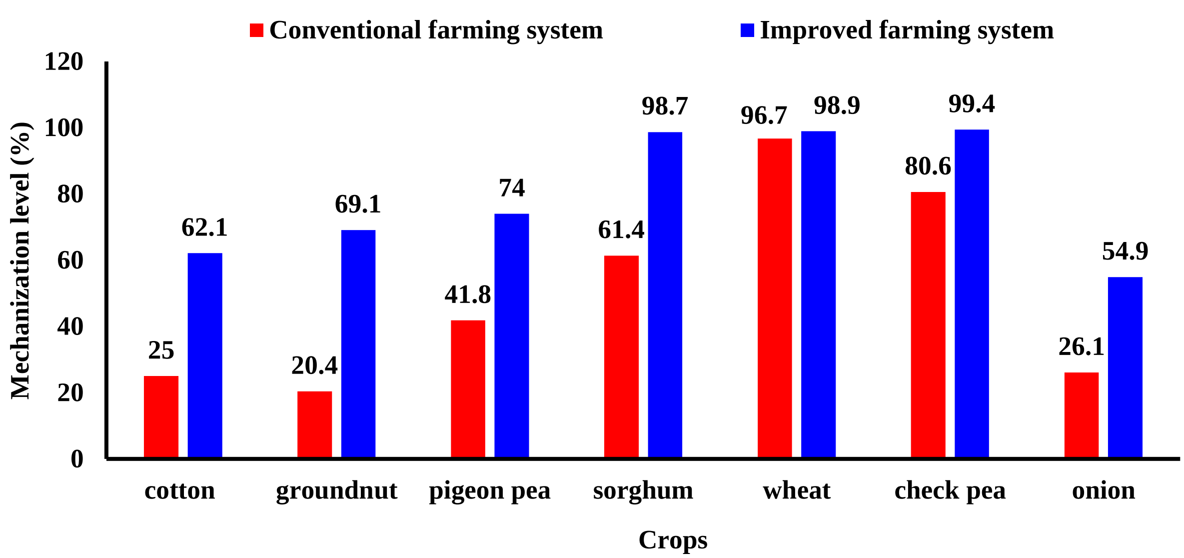

Fig. 1. Comparison between the conventional and improved farming systems in level of mechanization for different crops in the Gezira scheme

Table 5. Comparison between the conventional and improved farming systems in fuel consumption (l/ha) to produce the selected crops in the Gezira scheme

	Conventional farming system	Improved farming system	Difference
Cotton	20.7	103.1	82.4
Groundnut	19.4	119.3	99.9
Pigeon pea	20.7	95.0	74.3

Sorghum	50.9	117.0	66.2
Check pea	50.0	124.2	24.2
Wheat	55.4	95.4	40.0
Onion	19.4	99.0	79.7

Table 6 shows the difference in mechanization level between improved and traditional farming systems for the seven crops grown in the Gezira scheme. The selected crops showed dissimilar response to the improvement in level of mechanization. The difference in mechanization level was ranged between 2.2% and 48.7%. Wheat and cotton crops obtained the lowest the highest difference, respectively. This means that there is possibility and opportunity to improve the level of mechanization of cotton crop.

The groundnut, cotton and onion crops showed high response to improvement in mechanization level as they obtained 237.8%, 148.4% and 110.3% increase in level of mechanization, respectively (Table 6). The pigeon pea and sorghum crops resulted in medium response; they obtained 77.0% and 60.7% increase in level of mechanization, respectively. While check pea and wheat crops obtained the lowest response they obtained 23.3% and 2.2% increase in level of mechanization, respectively. These variations was mainly due to the unavailability of harvesting machinery as different crops varies in harvesting methods while implements for seedbed preparation are almost similar and available for all crops. The possible interventions that can improve the mechanization level of farm operations include mechanical sowing, weeding and harvesting.

On the other hand, the results ranked the selected grown crops in response to improvement in level of mechanization (Table 6). Table 6 ranks the crops from high to low response to mechanization level improvement as follows; groundnut, cotton, onion, pigeon pea, sorghum, check pea and wheat crops. Some crops showed very high response to improvement in mechanization level.

Table 6. Difference in mechanization level for the improved and traditional farming systems, percentage of improvement in mechanization level and ranking the crops in response to improvement for the selected crops in the Gezira scheme

Crops	Difference in mechanization level	% of improvement in mechanization level	Ranking the crops in response to improvement
Groundnut	37.1	237.8	1
Cotton	48.7	148.4	2
Pigeon pea	32.2	77.0	4
Sorghum	37.3	60.7	5
Wheat	2.2	2.2	7
Check pea	18.8	23.3	6
Onion	28.8	110.3	3

Conclusions

Evaluation of the level of agricultural mechanization in the Gezira scheme for the main seven grown crops was determined for two scenarios, traditional and improved farming systems. The level of agricultural mechanization was established by deriving a relationship between the two source of farm power; hand labor and machinery. The results revealed that the level of agricultural mechanization was varied among the crops and farming systems. The level of mechanization in the traditional farming system was 20.4, 25, 26.1, 41.8, 61.4, 80.6 and 96.7% for groundnuts, cotton, onion, pigeon pea, sorghum, chickpea and wheat crops, respectively. The results indicated that there are possibilities to improve level of mechanization by some interventions; this improve to groundnut, cotton, onion, pigeon pea, sorghum, chickpea and wheat will reach 69.1, 62.1, 54.9, 74, 98.7, 99.4 and 98.9%, respectively. However, this improvement require additional fuel by 99.9, 82.4, 79.7, 74.3, 66.2, 24.2 and 40 l/ha for these crops, respectively. The study concluded that the level of mechanization is weak for some crops and there are opportunities for improvement. Some types of farm implements need to be available to make full-mechanized operations for the studied crops. Therefore, to promote utilization farm machines, custom hiring should be encouraged as a business opportunity.

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