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Utilization of tractors and implements owned by individual farmers in the Gezira Scheme, Sudan

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Abstract: Gezira Scheme, in Sudan, is the largest one in the region. Recently, many individual farmers owned tractors and implements. This study aimed to analyze the use of those tractors and implements. Data were collected through a questionnaire and analyzed statistically. 154 tractors (75 to 80 hp.) accompanied with 678 implements were studied. Massey Ferguson represented 58.4 % of the tractors. Tractors' average age was six years. Land preparation, seeding, spraying, threshing and post harvesting implements represented 86.7%, 4.1%, 2.1%, 6.0% and 1.1%, from the total number of implements, respectively. Implements average age was between two and six years. Sprayer obtained the highest work rate (9 fed/h). Disk plow consumed the greatest fuel (6.6 l/fed) and the highest annual working hours (310 hours). The ridger covered the highest annual area (365 fed). Tractor annual working hours was between 774 and 535 hours. Several combinations of implements accompanying a tractor were found. Combinations three and four implements were the most frequent, they repeated 36 and 35 times, respectively. The combination of disk plow, ridger and ditcher were repeated ten times; while the combination of disk plow, leveler, ridger and ditcher was repeated eight times. The information obtained helps determine which implements are necessary for the scheme. Economic feasibility of tractors and implements owned by individual farmers in the Gezira Scheme is suggested.

Keywords: Tractor, implements, performance, annual use, Gezira Rrrigated Scheme, Sudan.

استخدام الجرارات والمعدات الزراعية المملوكة للمزارعين الأفراد في مشروع الجزيرة، السودان

المستخلص: يُعد مشروع الجزيرة في السودان أكبر مشروع زراعي في المنطقة. حيث إنه في الآونة الأخيرة، امتلك العديد من المزارعين جرارات ومعدات زراعية، لذا هدفت هذه الدراسة إلى تحليل استخدام هذه الجرارات والمعدات، جُمعت البيانات من خلال استبيان، وحُللت إحصائيًا. دُرست 154 جرارًا (بقوة تتراوح بين 75 و80 حصانًا) مُرفقة بـ 678 أداة. مثّلت جرارات ماسي فيرجسون 58.4% من الجرارات. بلغ متوسط عمر الجرارات ست سنوات، ومثلت معدات تجهيز الأرض، والبذر، والرش، والدرس، وأدوات ما بعد الحصاد، 86.7%، و4.1%، و2.1%، و6%، و1.1% من إجمالي عدد المعدات، على التوالي. وتراوح متوسط عمر المعدات بين سنتين وست سنوات، وحققت آلة الرش أعلى معدل إنتاج (9 فدان/ساعة). استهلكت المحراثات القرصية أكبر كمية من الوقود (6.6 لتر/فدان) وأعلى ساعات عمل سنوية (310 ساعة). أما المحراث ذو الحافة، فقد غطى أكبر مساحة سنوية (365 فدانًا)، كما تراوحت ساعات العمل السنوية للجرار بين 774 و535 ساعة، ووُجدت عدة مجموعات من الأدوات المصاحبة للجرار، وكانت المجموعات الثلاث والأربع الأكثر شيوعًا، حيث تكررت 36 و35 مرة على التوالي، وقد تكررت مجموعة المحراث القرصي، والرافعة، والحفارة عشر مرات؛ بينما تكررت مجموعة المحراث القرصي، والتسوية، والرافعة، والحفارة ثماني مرات، تساعد المعلومات المُقدمة في تحديد الأدوات اللازمة للمشروع، ويُقترح الجدوى الاقتصادية للجرارات والأدوات المملوكة للمزارعين الأفراد في مشروع الجزيرة.

الكلمات المفتاحية: الجرارات، الأدوات، الأداء، الاستخدام السنوي، مشروع الجزيرة المروي، السودان.

INTRODUCTION

Farm mechanization, which is a part of agricultural engineering, refers to the use of tractor and implements for carrying out farm operations. The importance, advantages, and benefits of using farm machinery are numerous and have been well documented by several authors (Ampratwun, *et al.,* 2004; FAO and UNIDO, 2008; Abdel Rahman, *et al.,* 2022). However, farm mechanization will continue to play an important role in agricultural production and the demand for agricultural machinery is expected to increase (Omofunmi and Olaniyan, 2018).Gezira Scheme represents 47% of the total irrigated area and 10% of the total area under crop production in the Sudan (Abdalla, *et al.,* 2021). In the past, the Agricultural Engineering Department (AED), which affiliates to Sudan Gezira Board (SGB), owned a fleet of tractors and machinery. The AED was responsible for carrying out the mechanized operations for cotton and wheat crops. Besides, the AED, there were also some contributors in achieving the mechanized operations in the scheme, such as private sector companies, farmers' cooperatives, and some individual farmers who owned tractors and implements. However, Eldaw (2004) reported that there was dissatisfaction among farmers about the quality of work performed by the AED in the Gezira Scheme and the level of fees and costs charged. However, after the implementation of the Gezira Scheme's law for 2005, which regrettably proclaimed the dissolution of the AED and sale all of its machinery; and in order to compensate and offsetting the absence of the AED, some farmers began to purchase tractors and machinery to perform the mechanized operations in the scheme. The farmers in the Gezira Scheme have great and long experience in managing their farms and cultivating the grown crops. This experience is necessary for improving productivity. Ainembabazi and Mugisha0 (2014) suggested that farming experience is useful in early stages of adoption of a given technology. They mentioned that gradual advances in technology development and continuous retraining of farmers are essential for sustainable adoption of agricultural technologies. The use of tractors and implements is one of these technologies.

Owning and using of tractor and implements by smallholder farmers is usually beyond their financial capacities, especially in developing countries. However, wherever this situation is existed, it requires guarantees for sustainability and profitability.Several authors, worldwide, have investigated the usage of tractors and implements in agricultural production by using different methods (Saglam and Akdemir, 2002; Ampratwun, *et al.,* 2004; Nkakini and Etenero, 2019). The demand for tractor and implements vary from farm to another according to farm size, cropping pattern, weather conditions, type of agricultural operations… etc. Therefore, the study of the pattern of the tractor and implements utilization may be useful in many ways. It will not only provide information about different type of operations being carried out but also gives details of their utilization during the year. Moreover, it imparts knowledge about their size and age, work rate (field capacity), fuel consumption and annual use (hours and area). The generated information may be utilized in scheduling and planning of agricultural operations. Moreover, one can determine quantities of the necessary inputs such as fuel quantity, grease and spare parts to run them. In addition, to organize the preventive maintenances program during the lean periods of demand. Unfortunately, there is inadequate knowledge on the utilization of tractors and accompanied implements owned by smallholder farmers in the Gezira Scheme. Therefore, there is a need to carryout field survey to appraisal these tractors and implements in accordance with their present conditions, types of mechanized operations and performance, besides the fixture to assess the need for introducing new types and new ones.The main objective of this study was to analyze the usage of tractor and implements owned and managed by individual farmers in the Gezira Scheme, Sudan. The specific objectives were to:Identify the available tractor makes and implements types and to determine their presence percentage and age.Determine the number of

implements associated to each tractor.Identify the most popular combinations of implements accompanying a tractor and Analyze their performance in terms of work rate, fuel consumption and annual usage (area and hours).

MATERIALS AND METHODS

Study area : The Gezira Scheme is located between the Blue Nile and White Nile Rivers to the south of Khartoum. It is one of the largest irrigated scheme in the region, comprising about 2.2 million feddans (one feddan = 0.42 hectare). The scheme is located in semi-arid region. Where rainfall is ranged between 150 and 300 mm/year, which occurs during July to September. The soil is classified as Vertisols, which has high clay content (50-60%). The soil is characterized by cracks when dry and become hard to work. Each farmer has, on the average, 20 feddans, which is divided into 5 equal farms. Farmers are responsible for managing their farms including irrigation. Irrigation system consists of two main canals running from Sennar Dam. The main canals deliver the water to major canals and then to the minor canals. The minor canals convey water to farms canals, locally called Abu Ishreen and then to Abu Sitta (Elshaikh, *et al.*, 2018). The existence of this intensive network of irrigation system canals may impede the use of big and heavy machinery.

Crops and farming system: Nowadays, crop diversity is a common characteristic in the Gezira Scheme. Seven field crops in addition to vegetable crops are currently grown. These crops are grown in summer and winter seasons. These crops include cotton, groundnut, sorghum, soybean and pigeon pea, as summer crop; besides wheat and chickpea as winter crops. Since its establishment, a lot of crop rotations were applied (Mahgoub, 2014). However, due to rapid increase in population and the need for more production, 80% of the total area is cultivated one-time a year by adopting five-course crop rotation, and the remaining 20% are left as fallow lands. The summer and winter cultivated crops make the use of tractors and implements almost during the year.

Data collection and analysis: The required data, for the purposes of this study, was collected during season 2022/2023. The targeted individuals were farmers who owned tractor and machinery, which works in the Gezira Scheme. A total of 154 respondents were directly interviewed through structured questionnaire. The questionnaire was fairly distributed throughout villages in the scheme. Simple random sampling technique was followed. The questionnaire included data such as tractor make and model, purchase price and current age. implement types (names), purchase price, current age. In addition, to work rate, fuel consumption and annual covered area were also included. Moreover, data related to variable cost and operation custom price was included.The collected data were prepared in excel worksheets for each implements type. Then the data was subjected to descriptive statistical analysis indicators, such as maximum, minimum, average and percentage in addition to standard deviation. Annual working hours of use for each implement was calculated by dividing the annual covered area by its work rate. However, the annual working hours of use for each tractor was calculated by the summing the annual working hours of use for each implement associated with that tractor. Appendix A shows implements type, description and utilization that available in the Gezira Scheme.

RESULTS and DISCUSSION

In this study 154 tractors, of medium power size (75 to 80 hp.), were statistically analyzed. The results revealed that there were more than six makes of tractor owned by individual farmers in the Gezira Scheme (Table 1). These makes included Massey Ferguson, Tafe, John Deere, Hatat, New Holland and others. These tractor makes varied in frequency, presence and age. The results showed that the Massey Ferguson tractor is the most popular make as it recorded the highest frequency (90) and presence (58.4%). Dahab and Saeed (2022) reported similar result, they mentioned that Massey Ferguson represented 60% of the total number of tractors available in Sudan's

market during the period from 2000 to 2010. On the other hand, the age of Massey Ferguson tractors was ranged between one and 28 years with an overall average of 7 years. The frequency and presence of Tafe and John Deere tractor makes were 36, 12, 23.4% and 7.8%, respectively. It is evidence that Massey Ferguson tractor was introduced early whereas John Deere tractor recently introduced. The minimum values of age for all tractors' makes was one year, showing that tractor owners are purchasing tractors and tractor dealers providing and availing them in the market. The maximum age of for all tractors makes was ranged between 5 and 28 years. The overall age of the tractors was six years and the standard deviation was about five years this indicates that the age of the majority of the tractors was between one year and eleven years. The established information helps in scheduling replacement or overhauling programs needed, especially for oldest tractors. However, for planning purposes, a comprehensive enumeration of tractors in the Gezira Scheme is needed to explore their sufficiency and geographical distribution.

Table:(1). Tractor's make, frequency, percentage of presentence and ages in the Gezira Scheme

Tractor Make	Frequency	%	Current age (years)			
			Max	Min	Average	STD
Massey Ferguson	90	58.4	28	1	7	6.0
Tafe	36	23.4	12	1	4	2.7
John Deere	12	7.8	6	1	2	1.6
Hatat	6	3.9	7	1	4	2.1
Newholland	5	3.2	17	1	5	6.8
Others	5	3.2	5	1	3	1.7

The results showed that the above studied tractors were associated with 678 of implements, including 14 different types (Table 2). These implements types were classified in to five major groups according to the operations they performed. Nine types of these implements were allotted for land preparation operations. Two types of machines for planting operation (row-planter and seed drill). One implement for each of weed control (sprayer), harvesting (thresher) and post harvesting (cotton stalks up rooter) operations. Generally, and referred to the total number of implements and their groups, land preparation, planting, weed control, harvesting and post harvesting implements represented about 86.7%, 4.1%, 2.1%, 6.0% and 1.1%, respectively. These results indicated that the bulk of the available implements in the scheme were for land preparation operation. This in agreement with the findings of Awadalla, *et al.,* (2019). They mentioned that land preparation is fully mechanized operation in the Gezira Scheme, whereas other operations were of lower level of mechanization. The existence of higher number of land preparation implements indicate that there are many options for land preparation operation. This may due to diversity of crops grown farm specific conditions.

On the other hand, and referring to the total number of tractors studied (154), ridger implement recorded the highest frequency (124), this is because it is used either for ridging or for split-ridging or for re-ridging or for green ridging. The disk plow is ranked as a second famous tillage implement after ridger as its frequency was 117 and ditcher implement is ranked third one as it recorded 105 frequencies. Their respective accompanying presence was 82%, 76.5% and 69%, respectively (Table 2).

In addition, the results showed that row planter recorded the least frequency (4) among the other implements. This inferred that, although 60% of the total area is allotted to row crops, farmers still depend on hand sowing to seed their crops. This situation does not encourage the tractors' owners to possess this type of implements. The unwillingness of farmers to use seeding implement needs further investigation. In this regard, it is worth to mention that the use of row planter for sowing crops will save much effort, time and expense rather than manual sowing. We expected that if the performance of row planter is demonstrated in farms' farms for many crops they

will believe and pursue to adopt it. The results showed that, it seems that there is a good number of seed drills (24) (Table 2) as this implement is mainly used for sowing wheat crop in winter seasons in about 20% of total cropped area. The results showed that the recorded number of sprayers was 14 representing 9.2% of total number of tractors. The sprayer began to spread among farmers in recent years. However, no inter row cultivator was recorded in this study. These mean that farmers are greatly depend on hand labor for performing weed control. Availing such implement, as possible alternative for weed control, may decontrol the dependence on hand labor during peak periods and to avoid hazards from using chemicals.

Thresher is the only implement recorded for threshing grain crops. In the present study, the 41grain threshers were recorded representing 27% of presence of implements those accompanying tractors (Table 2). This mean that the Scheme is lacking to harvesting implements for crops other than grain crops, such as peanut and cotton. Cotton-stalks up rooter is the only implement registered for post-harvest operation in this study. Its frequency and presence was 7 and 4.6%, respectively. This result suggests the introduction of other post-harvest implements like mower, rake and balers in the Gezira Scheme.

Table:(2). Type, frequency and percentage of presentence of the surveyed implements accompanying tractors in the Gezira Scheme

Operations/ Implements and their types	Frequency	%
Land preparation	588	86.7
Disk plow	117	76.5
Chisel plow	52	34.0
Moldboard plow	34	22.2
Disk harrow	38	25.0
Leveler	57	37.0
Ridger	124	82.0
Ditcher-row	56	37.0
Ditcher	105	69.0
Bond maker	5	3.0
Planting	28	4.1
Row-planter	4	3.0
Seed drill	24	15.8
Weed control	14	2.1
Sprayer	14	9.2
Harvesting	41	6.0
Thresher	41	27.0
Post harvest	7	1.1
Cotton Up rooter	7	4.6

Table 3 shows the statistical analysis of age for the studied implements included average, maximum, minimum and standard deviation. Generally, the average age was ranged between two and six years, indicating that these implements were in the middle age of lifespan. The minimum age was ranged between one to two years indicating that tractor owners are still purchasing these implements and the dealers avail them in the market. This reflects that the farmers accept these machines to execute farm jobs to alleviate the problem of labor shortage. The maximum age was ranged between five and 21 years. However, the age of implement may increase total operation cost, through its effect on repair and maintenance costs (Dahab, *et al.*, 2021).

Table 4 shows the average, maximum and minimum work rate of the surveyed implements. The results showed that there were big variations between the implements in work rate. These variations may due to their function nature, working width and working conditions. Implement performance, in term of covered area per unit time, is one attractive factors to the investors.

Table:(3). Age (yrs.) of the surveyed implements accompanying tractors in the Gezira Scheme

Implement	Average	Max	Min	STD
Disk plow	5	20	1	4.23
Chisel plow	3	15	1	2.82
Moldboard	2	7	1	1.48
Disk harrow	3	18	1	3.06
Leveler	6	20	1	3.98
Ridger	5	21	1	4.5
Ditcher-row	3	15	1	2.53
Ditcher	5	20	1	**4.61**
Bond maker	5	7	2	2.64
Row-planter	6	12	1	5.44
Seed drill	4	22	1	4.89
Sprayer	2	5	1	1.28
Thresher	3	11	1	2.58
Cotton Up rooter	6	15	1	4.99

Sprayer has the highest work rate (9 fed/h) among implements, followed by bond maker (8 fed/h). Whereas, disk plow and ditcher-row obtained the lowest work rate, 0.75 and 0.6 fed/h, respectively. The obtained values of work rate for the various implements are reasonable considering their working width and working conditions. Knowing the work rate of implements will help in determining the total number of implement to accomplish the specific tasks in specified period. The obtained results are in line with that reported by Abdalla *et al.* (2021). They found that chisel plow was superior in work rate over disk plow and moldboard plow. Moreover, the values of work rate obtained in this study were in the range used by Mohamed, *et al.,* (2017) for some implements in Elsuki Irrigated Scheme, Sudan. They reported that the work rate for chisel plow, disk harrow, ridger, row-planter and sprayer was 2.5, 3.0, 4.0, 3.0 and 10.8 fed/h, respectively.On the other hand, the statistical analysis showed that the standard deviations were close to the average values of the work rate of the studied implements, indicating the obtained average values of work rate were homogeneous for each specific implement.

Table:(4). Work rate (fed/h) of the surveyed implement accompanying tractors in the Gezira Scheme

Implement	Average	Max	Min	STD
Disk plow	0.75	1	0.5	0.24
Chisel plow	1.9	1	0.5	0.24
Moldboard	1	1.25	0.5	0.0
Disk harrow	3.4	4	3	0.74
Leveler	4	8	1	1.46
Ridger	4.5	5	3	0.65
Ditcher-row	0.6	1.0	0.5	0.18
Ditcher	5.4	10	2	1.32
Bond maker	8	10	6	3.5
Row-planter	5	5	5	2.24
Seed drill	4.1	6	3	0.98
Sprayer	9	24	5	5.13
Thresher	2	6	0.5	1.36
Cotton Up rooter	2.3	4	2	1.07

1 feddan = 0.42 ha

Table 5 shows the amount of fuel consumption by the surveyed tractor when attached to each implement. The results revealed that disk plow consumed the greatest amount of fuel (6.6 l/fed) followed by ditcher for bed (5.9 l/fed), moldboard plow (5.3 l/fed) and thresher (4.1 l/fed). On the other hand, sprayer consumed the lowest fuel (0.43 l/fed). The other implements consumed fuel ranged between 1.4 and 3.6 l/fed. Fuel price is increasing everywhere, and any deficiency in fuel

affects the completion the mechanized farm operations and this in turn affects crop productivity. Therefore, the obtained results of fuel consumption may help in determining the total amount of fuel required for the whole cropped area each season. However, Abdalla, *et al*. (2021) reported that moldboard plow consumed higher fuel compared to chisel plow and disk plow.

Figure 1 illustrates the number of implements associated with a tractor and their replications appeared in the surveyed sample. Irrespective to the implement type, the obtained results showed there were several combinations (1 to 10) of implements that accompanying a tractor. For example, seven different implements accompanying a tractor were appeared nine times in the surveyed sample.

Table:(5). Fuel consumption (l/fed) of the surveyed implement accompanied tractors in the Gezira Scheme

Implement	Average	Max	Min	STD
Disk plow	6.6	7.88	4.5	0.74
Chisel plow	3.6	4	3	0.6
Moldboard	5.2	6.75	4.5	1.21
Disk harrow	2.5	2.5	2.5	0.41
Leveler	2.13	2.83	1.13	0.44
Ridger	2.5	3.3	2.25	0.44
Ditcher-row	5.9	9	4.5	1.33
Ditcher	1.5	2.3	0.6	0.54
Bond maker	1.4	2.25	1.125	0.71
Row-planter	2.4	2.5	2.25	1.06
Seed drill	2.25	2.25	2.25	0.45
Sprayer	0.43	0.43	0.43	0.11
Thresher	4.1	6.75	2.25	1.36
Cotton Up rooter	3.3	4.25	2.25	1.56

1 feddan = 0.42 ha

Three and four types of implements that accompanying a tractor were the most frequent ones, they were repeated 36 and 35 times, respectively. Followed by five and six implements that work with a tractor which were repeated 28 and 15 times, respectively. Moreover, the results showed that one, eight, nine and ten implements associated with a tractor were repeated less than six times (Fig.1). These variations in the number of implements that worked with a tractor reflect and confirmed the random distribution of the questionnaire among the tractors' owner. The number of implements that accompanying a tractor in any region is governed by many factors. These factors include fanatical capacity of tractor owners, type of grown crops and their required management practices in addition to availability of implements and allotted area around each tractor.

Figure 2 demonstrates in details the most frequent implements type (names) in the numbers of implements accompanying a tractor. For example, in six implements that accompanying a tractor, disk plow, leveler, ridger, ditcher for beds, ditcher and thresher implements were repeated four times (Fig.2). The results showed that the combination of disk plow, ridger and ditcher were repeated ten times in the surveyed sample. This confirmed the above findings (Table 2) as these implements are the most popular ones in the Gezira Scheme. In addition, it was found that the combination of disk plow, leveler, ridger and ditcher was repeated eight times in the surveyed sample. The combination of two implements (disk plow and ridger) as well the combination of (disk plow, leveler, and ridger, ditcher for bed and ditcher) were repeated five times in the surveyed sample. There is need to study the economic feasibility of these implements combinations to determine the most profitable combination.

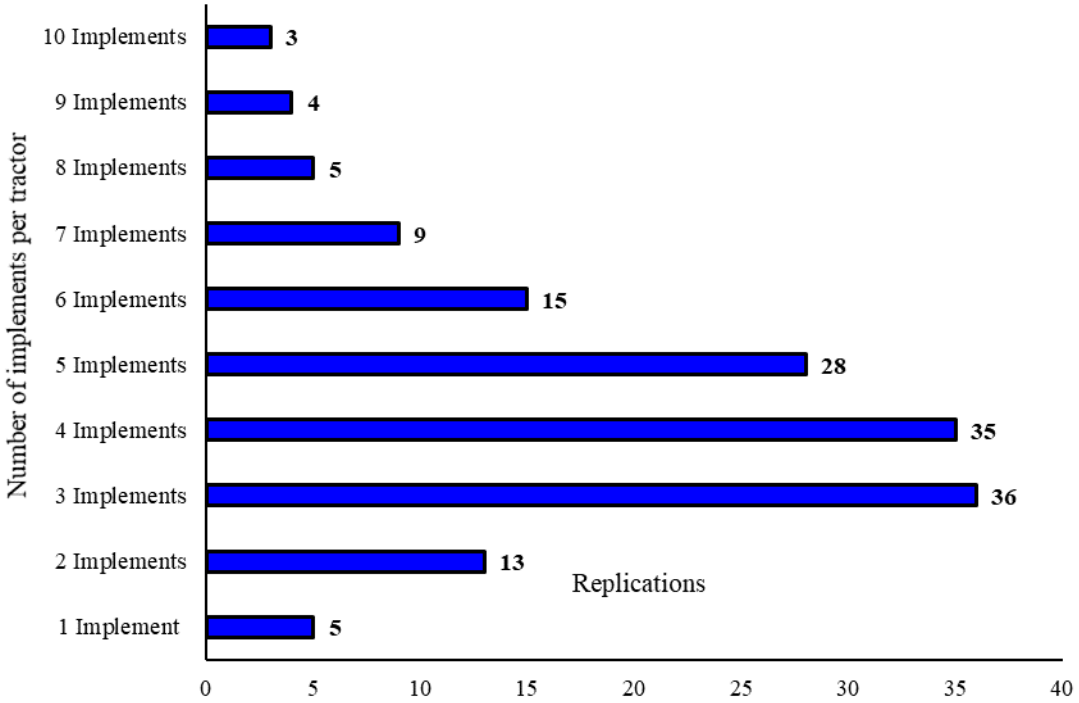

Figure: (1). Number of implements that accumpany a tractor and its replication in the samples surveyed in the Gezira scheme

Figure 3 illustrates the average annual use of the surveyed implements in terms of annual working hours and covered area (feddans). The results showed that, as expected, there was wide variations between the implements in the annual use. The highest annual working hours (310 hours) were achieved by disk plow and row planter obtained the lowest (14 hours). This confirmed that the disk plow is widely used and the use of row planter is very limited. Although, at certain cropped area, the annual hours of use of a given implement are inversely proportional to its work rate, but the disk plow resulted in high annual hours of compared to row planter. This suggests more investigation is needed on why farmers do not prefer to use row planter to seed their crops.

On the other hand, the results of annual covered area by these implements also showed wide variations. Row planter again resulted in the lowest annual area (68 feddans). This indicates that the use of row-planter is limited in the Gezira Scheme. The ridger resulted in the highest annual area (365 feddans). This is real as the majority of the crops in the Gezira Scheme are grown in ridge-furrow system to facilitate irrigation process. These results indicate that the ridger is the prevailing implement in the Gezira Scheme. The annual use of the surveyed tractor makes is illustrated in Figure. 4. There was variation between tractor makes in annual hours of use. The highest hour of use (774 hrs) was obtained by Tafe make and the lowest (535 hrs) was obtained by New Holland make. The result showed that the overall average annual hour of use was 620 hrs. Nkakini and Etenero (2019) reported a similar result, they found that the average annual use of private owned tractors was 572.6 hrs in Nigeria. The obtained annual hours of use did not meet the standards of 1000 hrs per tractor annually. This few hours of use by tractor in the Gezira Scheme offer the opportunity to introduce and use other types of implements.

The furnished information by this study can help in deciding which implements are necessary to be introduced in the Scheme to enhance crop production through improving operations timeliness.

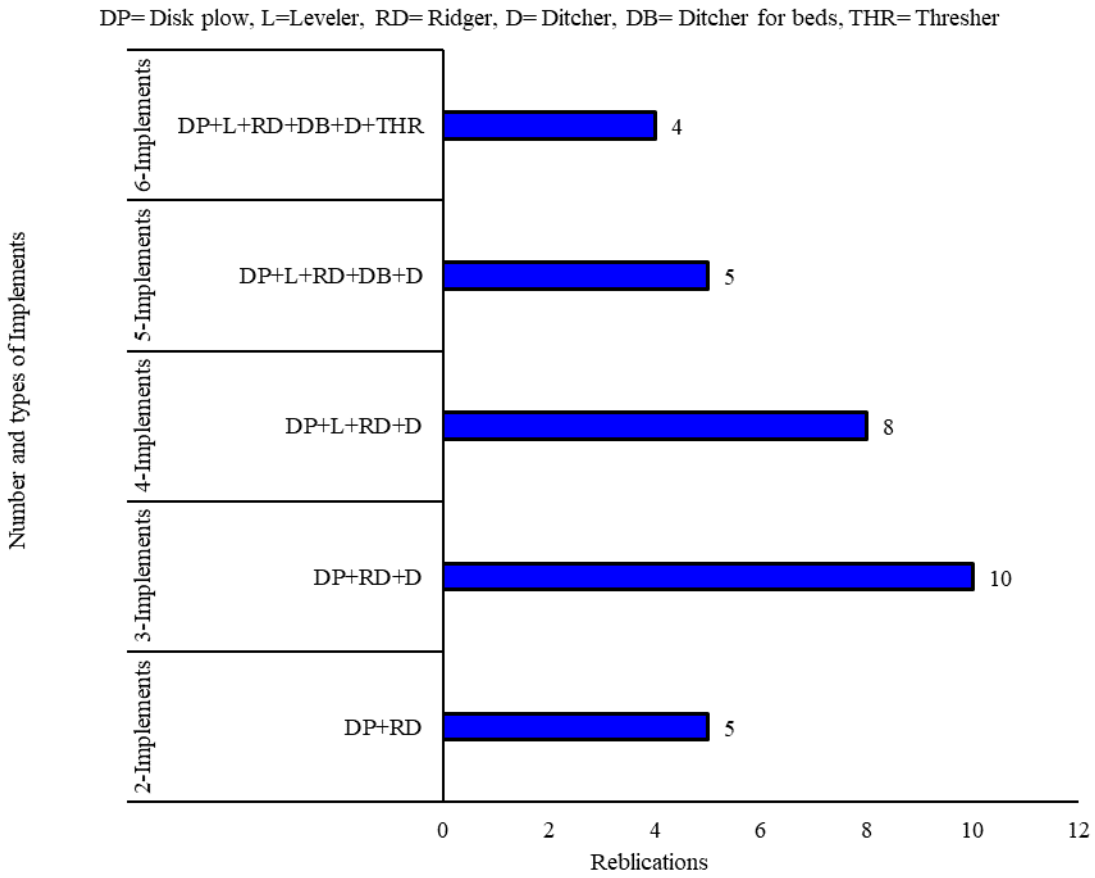

Figure: (2). Replications of type and number of implements that accumpany a tractor in the Gezira scheme

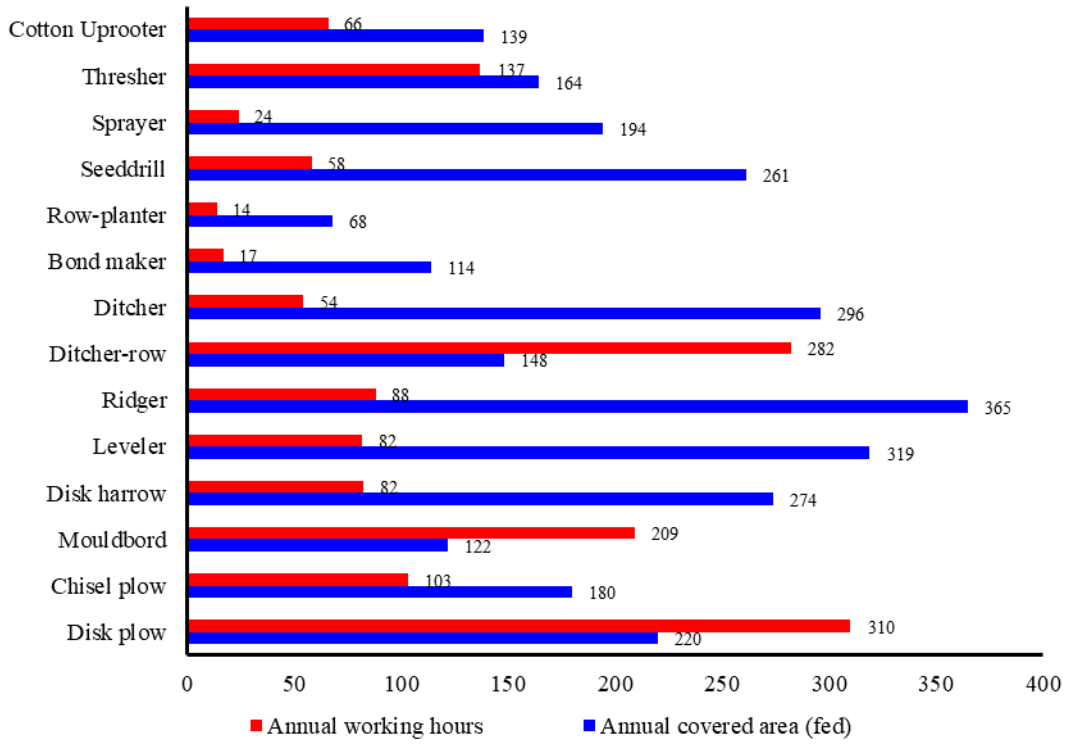

Figure: (3). Annual use (hours and area) of the implement surveyed in the Gezira scheme

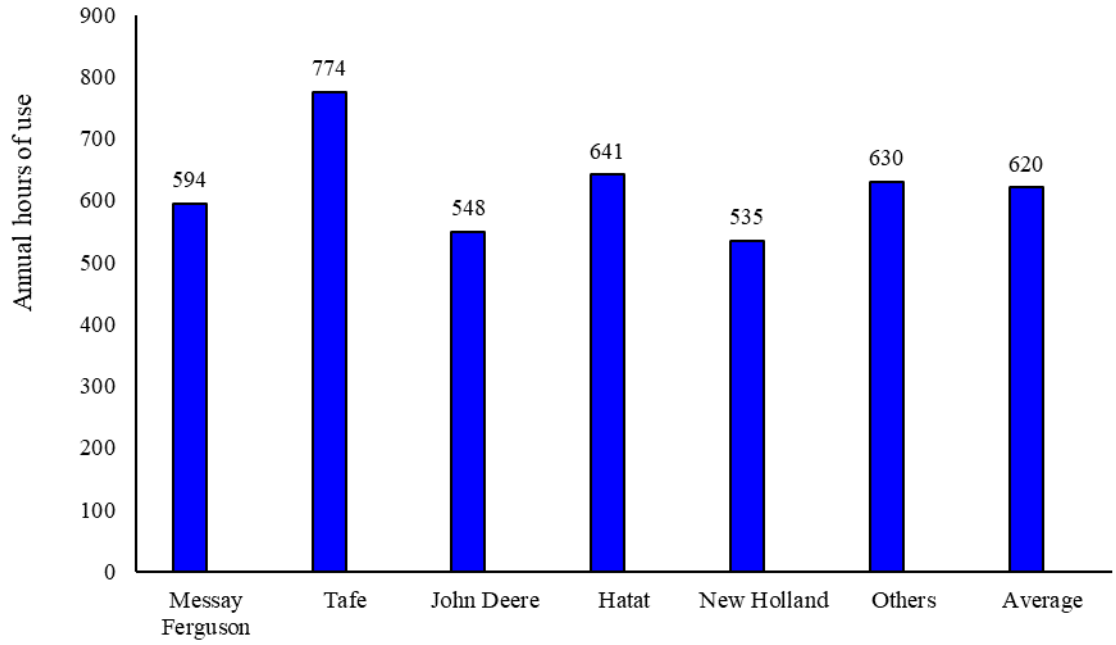

Figure: (4). Average annual hours of use for the surveyed tractor makes in the Gezira scheme

CONCLUSION

154 tractors of different makes (75 to 80 hp.) and 678 implements type associated with these tractors owned by individual farmers in the Gezira Scheme were studied. These tractors were in mid aged, the overall average age was six years. Referred to the total number of implements, land preparation, planting, spraying, threshing and post harvesting implements represented 86.7%, 4.1%, 2.1%, 6.0% and 1.1%, respectively. The age of these implements ranged between two and six years. There were big variations between the implements in work rate. Sprayer obtained the highest work rate (9 fed/h), while the ditcher-row obtained the lowest (0.6 fed/h). Disk plow consumed the greatest fuel (6.6 l/fed) and the sprayer consumed the lowest (0.43 l/fed). There were several combinations of implements that accompanying a tractor. Three and four types of implements were the most frequent ones, they were repeated 36 and 35 times, respectively. The combination of the disk plow, ridger and ditcher was repeated ten times, and the combination of disk plow, leveler, ridger and ditcher was repeated eight times. The disk plow achieved the highest annual working hours (310 hrs) and the row planter obtained lowest (14 hrs). The ridger resulted in the highest annual covered area (365 fed) and the row planter resulted in the lowest one (68 fed). Tractor annual working hours were ranged between 774 hrs obtained by Tafe and 535 hrs obtained by New Holland. The overall average annual use of tractor was 620 hrs. The furnished information can help in deciding which implements are necessary to be introduced in the Scheme to enhance crop production through improving operations timeliness.

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Appendix Implement types, description and utilization

Implement types	Description	Utilization
Disk plow	3 - bottoms, rear mounted, 0.8 to 1.0 m	Primary tillage
Chisel plow	5 to 7 shanks, rear mounted,	Primary tillage
Moldboard plow	4-units, rear mounted	Primary tillage
Disk harrow	18 disks arranged in 2 gangs, rear mounted	Secondary tillage
Scraper	One unit, rear mounted, 1.5 m	Leveling the farms
Ridger	4-units, rear mounted, 3.2 m width.	Constructing ridges and furrows spaced at 0.8 m.
Ditcher-row	Single unit, rear mounted, less than 1 m width	Constructing ditches and beds, deeper furrows than ridges, spaced
Ditcher	Single unit, rear mounted, 1 m width	Constructing Abu VI, a water channel in a farm
Bond maker	Single unit, rear mounted, 0.8 to 0.9 m width	Constructing *tangents and gradual* inside farms perpendicular to Abu VI to control irrigation water
Row-planter	4 - units, rear mounted, 3.2 m width	Seeding crops
Seed drill	Rear mounted or towed, 2.5 to 3.5 m width, with or without fertilizer box	Broadcasting and covering wheat seeds on flat soils.
Sprayer	Rear mounted, 400 to 600 liters capacity, 10 to 14 m width	Herbicides application
Thresher	Rear towed on two wheels, different sieves size	Threshing grain crops
Cotton up rooter	Rear mounted, two cutting plates, 1.6 m width	Cutting or uprooting standing stalks