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Tractors and implements required for crops cultivation in the Gezira scheme, Sudan

Lotfie A. Yousif[1] and Shaker B. Ahmed[2]
[1]Agricultural Engineering Research Program, Agricultural Research Corporation (ARC), Wad Medani, Sudan
https://orcid.org/0009-0000-1594-431x
2 Department of Agricultural Engineering, Faculty of Agriculture, Omdurman Islamic University, Sudan
***Corresponding Author** https://orcid.org/0000-0001-6112-5796*

ABSTRACT
Efficient agricultural production depends on optimal machinery availability and management. Estimating the required number of tractors and implements for farm tasks is complex process, especially in large areas like Gezira Scheme, Sudan, where cotton, groundnut, sorghum (summer crops), and wheat (winter crop) are cultivated in a five-course rotation. This study estimated tractors and implements need for land preparation and seeding under two operational scenarios: discrete and overlap operations. The estimation ensured that all crops were sown within their optimal sowing dates. Results showed that summer crops required more intensive machinery due to shorter operational windows, whereas winter crops had extended timeframes. The total number of tractors required for descrete operations was lower (2122 tractors) than that for overlap operations (2433 tractors), whereas reverse was true for the required number of implements. The total number of chisel plows, disk harrows, scrapers, ridgers, row planters and seed drill under discrete operations was 2185, 2056, 1028 2010, 2122 and 584, respectively. Whereas their respective numbers under overlap operations were 1733, 2098, 1028, 1964, 1564 and 584. Monetary assessment indicated that the discrete scenario was cost-effective. These findings highlight the importance of balancing time, implement needs, and cost when planning mechanized farming operations, offering valuable insights for improving resource management.
***Keywords:** Agricultural machinery, operations management, Gezira Scheme, Sudan*

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I. INTRODUCTION(

Agricultural mechanization is widely regarded as a key factor in ensuring sufficient food production [1, 2] (Haque et al., 2003; Mrema et al., 2008). Tractors and implements are ones of the important input in agricultural production, because they contribute to improve productivity, sustainability of production and achieving farming efficiency [3, 4] (Sims and Kienzle, 2006; Saeed, 2018) as well as they economically efficient [5] (Dawid, et al., 2022). Tractors are primarily used for dynamic drawbar work [6] (Zoz and Grisso, 2003). Proper tractor utilization can help farmers reduce operational costs per working hour and increase profitability [7] (Nkakini and Eguruze, 2008). Land preparation, a crucial aspect of agricultural mechanization, is among the most expensive operation due to its high tractor power requirements [8] (Andersson et al., 2005).

Deficiency in number of agricultural tractors and implements in any farming system will result in delayed farm operations from optimum time, which negatively affect crops productivity. Conversely, excess number of agricultural tractors and implements than required, lowers their annual hours of use, hence reduced their economic profitability.

Estimating the required number of tractors and implements to perform specific farm tasks is a complex process. It involves multiple factors, such as the types of crops grown, the mechanized operations required, the area allocated to each crop, and the time available for each operation. Additionally, how tractors and implements are managed and utilized also plays a critical role.

The type of crops grown directly influences the estimation because different crops require different farming operations. For example, crops competing for the same implement, particularly when cultivated during the same period, can complicate the estimation process. Similarly, the area allocated to each crop affects the number of tractors and Implements needed to complete tasks on time. Time availability for each operation is another critical factor and is influenced by seasonal weather conditions, the duration of operation windows, and daily working hours. Methods of managing machinery, such as discrete or overlap operations, also impact the time required and, subsequently, the number of machines needed. Furthermore, the work rate, functionality, and reliability of the implements affect the overall estimation.

The Gezira Scheme, largest irrigated agricultural area in Sudan, focuses on cultivates cotton, groundnut, sorghum, and wheat in a five-course rotation system. These crops contribute significantly to Sudan's economy and food security [9] (Eldaw, 2004) Cotton, groundnut, and sorghum are planted during the summer, while wheat is grown in winter. As a result, tractor and implements usage in the Gezira Scheme is most intensive during the summer season, specifically for land preparation [10] (Awadalla, et al., 2019). Land preparation operations in the scheme rely on several implements such as chisel plows, disk harrows, scrapers and ridgers, while seeding operations require row planters and seed drills. However, [11] Bashir, et al., (2015) found that different tillage treatments showed similar effects on physical properties of clay soils (Vertisols) and crops yield. On the other hand, disk harrow and seed drill was recommended as optimum seedbed preparation and seeding operations to produce wheat crop in Vertisols [12] (Dawelbeit and Babiker, 1997).

Unfortunately, no comprehensive data is currently available on the number of tractors and implements required to complete land preparation and seeding operations for the main crops of the Gezira Scheme within the optimal time frame. Such information would greatly assist managers and policymakers in making informed decisions and developing effective plans for the scheme. The objective of this study is to estimate the number of tractors and implements required to ensure timely land preparation and seeding operations for the main crops grown in the Gezira Scheme, under discrete and overlap management scenarios.

II. MATERIAL 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, covering about 2.2 million feddans (one feddan = 0.42 hectare). The scheme lies in a semi-arid region, where annual rainfall ranges from 150 mm in northern areas to 300 mm in the southern areas, with the majority (63.5%) occurring in July and August(Fig. 1).

The soil in the Gezira Scheme is classified as Vertisols, which has a high clay content (50–60%). This soil type develops cracks when dry and becomes both sticky and difficult to work when wet. Each farmer typically manages 20 feddans each, divided into five equal farms. For the purposes of crop rotation and irrigation management, the scheme's area is divided to 90 feddans, each known as a Number.

The irrigation system consists of two main canals originating from the Sennar Dam. These canals supply water to major canals, which then feed into minor canals. The minor canals deliver water to farm canals, locally known as *Abu Ishreen*, which irrigates Number. Finally, Abu Ishreen deliers irrigation water to smaller farm canals called "Abu Sitta"[13] (Elshaikh *et al.*, 2018). The dense irrigation network can limit the use of large heavy machinery.

Study procedures

To achieve the objectives of this study, the following steps were followed:

Step 1: Identifying crops and rotation

The major crops grown in the Gezira Scheme are cotton, groundnut, sorghum, and wheat. Cotton, groundnut, and sorghum are summer crops, while wheat is grown in winter. Since its establishment, a lot of crop rotations were applied[14] (Mahgoub, 2014). These crops are currently rotated using a five-course rotation, with 440,000 feddans allocated to each crop.

Step 2: Determining operation timelines

The following procedures were tracked:

a. Duration of key farming operations (e.g., sowing dates and growing period) were analyzed using Agricultural Research Corporation (ARC) records. Sowing dates and crop growing periods for each crop were shown in Table 1.
b. Land preparation operations were scheduled from the end of harvesting/residue management until the sowing of the next crop. Sowing dates were organized to ensure realistic scheduling. Periods for land preparation and sowing were adjusted in order to withhold the effect of weather conditions. Weather conditions, particularly rainfall, were accounted for by using probability ranges (0.9–0.95) to calculate available working days. The net available working days were multiplied by daily working hours (8 hours/day) to determine total available working hours.

Step 3: Identifying required implements

a. The implements required for land preparation included chisel plows, disk harrows and scrapers, along with ridgers. Row crop planter was used for sowing summer crops, and seed drill was used for wheat. These implements matched the standard tractor size of 70–80 horsepower.
b. Land preparation operations included primary tillage (chiseling) and secondary tillage (harrowing, leveling, and ridging). Table 2outlines the implements and methods required for each crop.
c. Operations were prioritized in sequence, ensuring the same implement could be used across all crops in rotation.

Step 4: Allocating working days

Equal working days were allocated to implements having the same or similar work rates. Implements having lower work rates were given more working days. The schedule ensured that land preparation for all crops must be completed before their respective sowing dates.

Step 5:Calculation procedures

Actual work rates of the six implements under the study were obtained from a surrey and agricultural engineers (Table 3)while their reliability factors were assumed. The reliability factors for a tractor and implement were taken as 80% for each. Therefore, the mixed reliability factor (R) values for both tractor and any implement were 0.64.

The following formulas were used to calculate the number of tractors and implements required to perform timely operations:

$$RNI = RNT = (A) / (AWR * NAWH * R) \quad (1)$$

$$NAWH = WD * P * DWH \quad (2)$$

Where:

RNI = Required number of implements
RNT = Required number of tractors
A = Area under operation (feddans)
AWR = Actual work rate (feddans/hour)
NAWH = Net annual working hours
WD = Working days
P = Probability of working days (0.9 - 0.95)
DWH = Daily working hours (8 hours per day)
R = Machinery reliability factor (0.64)

Step 6: operation management scenarios

The above equations were used to calculate number of tractors and implements under two management scenarios, discrete and overlap. In both scenarios, seeding operation has to be performed during the optimum period-range for each crop.

a. ***Discrete operations***: Operations were programmed sequentially, avoiding overlaps, while ensuring adherence to optimum sowing periods.

b. **Overlap operations**: Operations were scheduled to allow simultaneous execution of multiple tasks. For all operations, the overlap period was fixed to 10 days, e. g., the subsequent operation starts 10 days before the end of the preceding operation. Overlapping was only use for summer crops because of the limited time. For the first overlap operation, disk harrow, comes after chisel plow, the number of tractors to complete area for ten days was calculated to be 700 tractors then the tractors for chisel plow joined the tractors for chiseling. So, the number of tractors for ridging and row planter for the ten days overlap period were, 335 and 469, respectively. Overlap operations require additional tractors.

Step 7: monetary assessment

Monetary assessment was calculated by using prices of tractor and implements and the differences in their number between the two scenarios. The difference in total monetary value of tractors was compared with the

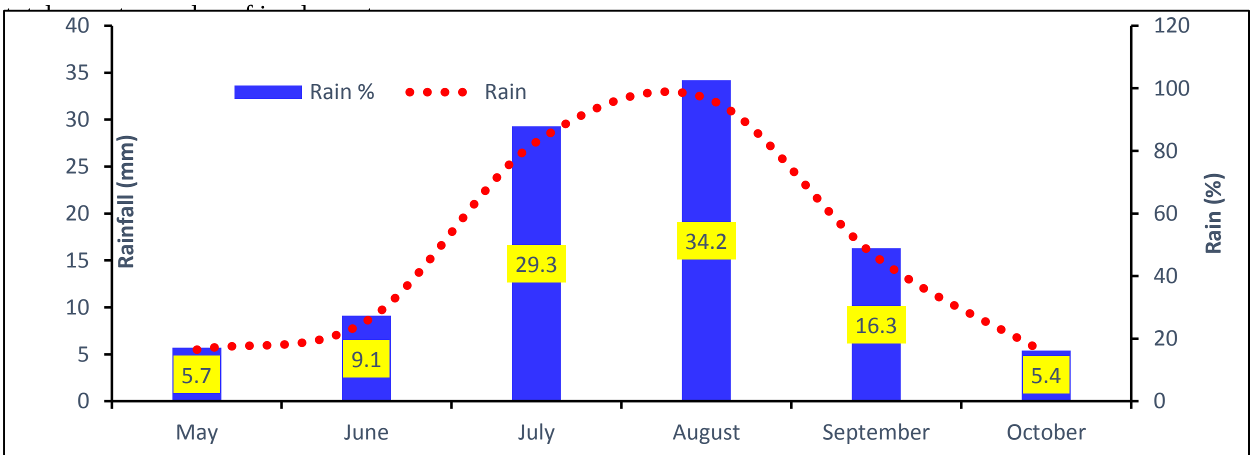

Fig. 1. Monthly rainfall (mm) and rain % at Wad Medani during the period from 1981 to 2010

Table 1. Sowing date, crops growing periods and rotation for the main crops in the Gezira scheme

	Cotton	Ground nut	Sorghum	Wheat
Sowing period	1-Jul to 10-Aug	15-Jun to 30-Jul	15-Jun to 15-Jul	1-Nov to 1-Dec
Growing periods	180	140	110	110
Subsequent crop	Wheat	Sorghum	Fallow/Cotton	Ground nut

Table 2. Land preparation methods for the main crops in the Gezira scheme

	Cotton	Groundnut	Sorghum	Wheat
Chisel plowing	✓	X	X	✓
Disk harrowing	✓	✓	✓	✓
Land leveling	X	X	X	✓
Ridging	✓	✓	✓	X

Table 3. Implements work rate and area allocated for summer and winter crops

Implement	Work rate (fed/h)	Total area (fed)
Chisel plow	1.8	880000
Disk harrow	4	1760000
Scraper	4	440000
Ridger	4.5	1320000
Row planter	4.5	1320000
Seed drill	5	440000

III. RESULTS AND DISCUSSION

DURATION OF FARM OPERATIONS

The results (Tables 4 and 5) indicated that land preparation and sowing operations for cotton, groundnut, and sorghum must be completed between May 15 and August 8, as these crops share the same summer growing season. These crops account for 60% of the total scheme area. The limited time for summer crop operations increases the demand for tractors and implements. However, one of the most critical factors in achieving high crop yields is timeliness, as performing operations at delayed time can result in the loss of potential yield [15] (Say and Sumer, 2011). [16] Khafizov, *et al.*, (2021)found that with an increase in volume of works, the required optimal number of tractors increases. In contrast, wheat, the sole winter crop, has a longer land preparation and sowing window (August 15 to December 1), as it occupies only 20% of the area allocated to summer crops. This extended timeframe affects the machinery requirements.

Table 4. Operations dates and duration under discrete and overlap scenarios for summer crops

Operation	Cotton	Groundnut	Sorghum
	Discrete operations scenario		
Chiseling	Apr 15 - May 7 (23 days)	-	-
Harrowing	May 30 - Jun 9 (11 days)	May 8 - 18 (11 days)	May 19 - 29 (11 days)
Ridging	Jun 30 - Jul 9 (10 days)	Jun 10 - 19 (10 days)	Jun 20 - 29 (10 days)
Planting	Jul 30- Aug 8 (10 days)	Jul 10 - 19 (10 days)	Jul 20 - 29 (10 days)
	Overlap operations scenario		
Chiseling	Apr 15 - May 13 (29 days)	-	-
Harrowing	May 30 -Jun 11 (13 days)	May 4 - 16 (13 days)	May 17 - 29 May (13 days)
Ridging	Jun 28 - Jul 10 (13 days)	Jun 2 - 14 (13 days)	Jun 15 - 27(13 days)
planting	Jul 27 - Aug 8 (13 days)	Jul 1 - 13 (13 days)	Jul 14 - 26 (13 days)

Table 5. Operations dates and duration under discrete and overlap scenarios for winter wheat crop

Operations	Discrete	Overlap
Chisel plow	Aug 15- Sept 17 (33 days)	Aug 15 - Sept 9 (26 days)
Disk harrow	Srpt 17 - Oct 8 (22 days)	Sept 17 - Oct 1 (15 days)
Scraper	Oct 9 - 30 (22 days)	Oct 9 - 23 (15 days)
Seed drill	Nov 1 - Dec 1(31 days)	Nov 1 - Dec 1 (31 days)

Time allocated to each operation

Available total working hours to perform land preparation and seeding operations for summer crops in both scenarios is shown in Table 6. The results showed that under a discrete operations scenario, the area allocated to groundnut and sorghum each required 232 hours, with 69% of the time dedicated to land preparation and 31% to seeding. For cotton, a total of 406 hours was required, with the same distribution of 82.3% for land preparation and 17.7% for seeding. These results show that discrete operations scenario required less time than overlap operations scenario; 20.3% less for groundnut and sorghum and 20.7% less for cotton. Under overlap operations scenario, groundnut and sorghum required 291 hours each for land preparation and seeding, with 68% of the time allocated to land preparation and 32% to seeding. Cotton required 512 hours, with 82% of the time spent on land preparation and 18% on seeding.

On the other hand, the available total working hours to perform land preparation and seeding operations for winter crop in both scenarios is shown in Table 7. The total available working hours across both scenarios was 799 hours, with land preparation accounting for 70.5% and seeding 29.5%. The reduced time pressure for winter crop operations highlights the impact of seasonal differences on machinery needs. Winter operations required less machinery due to the extended timeframe and small area compared to summer crops.

For all crops, land preparation requires geater time because it compose of two or more operations. These results agreed with the findings of [8] Andersson *et al.*, (2005), they mentioned that land preparation is one of the most time-and energy-intensive operation in crop production. However, farmers can increase efficiency by performing seedbed preparation and seeding operations simultaneously, reducing both time and fuel consumption [17, 4] (Shrivastava and Jha, 2011; Saeed, 2018). On the other hand, when tractor mission times are reduced, timeliness costs decrease substantially, as the tractor can be serviced and returned to operation more quickly [18] (Poozesh and Tarighi, 2020).

Table 6. Working hours for summer crops under discrete and overlap operations scenarios

Crops	Cotton	Groundnut	Sorghum	Total
Discrete operations scenario				
Chisel plow	174.8	0	0	174.8
Disk harrow	83.6	83.6	83.6	250.8
Ridger	76.0	76.0	76.0	228.0
Row planter	72.0	72.0	72.0	216.0
Total	406.0	232.0	232.0	870.0
Overlap operations scenario				
Chisel plow	220.4	0	0	220.4
Disk harrow	98.8	98.8	98.8	296.4
Ridger	98.8	98.8	98.8	296.4
Row planter	93.6	93.6	93.6	280.8
Total	512.0	291.0	291.0	1094.0

Table 7. Working hours for winter wheat crop under discrete and overlap operations scenarios

Operation	Discrete	overlapped	Percentage
Chisel plow	238	238	29.8
Disk harrow	158	158	19.8
Scraper	167	167	20.9
Seed-drill	236	236	29.5
Total	799	799	100.0

Number of tractors and Implements

Tables 8 shows the number of tractors and implements required for summer crops under both operation scenarios. The number of tractors matched the number of implements in all cases. The results showed that, for summer crops under the discrete operation scenario, the required numbers of chisel plows, disk harrows, ridgers, and row planters were 2185, 2056, 2010, and 2122, respectively. However, under the overlap operation scenario, these numbers were lower; 1733, 2098, 1964, and 1564, respectively. This indicates that the discrete operation scenario demands more implements due to the reduced time. The results also, revealed that there were variations in number of implements required within the same operation scenario. The maximum number of tractors for summer crops under descrete and overlap operations scenarios was 2122 and 2433, respectively. These differences were mainly due to the variations in total allocated hours.

On the other hand, for winter crops, the required numbers of chisel plows, disk harrows, land levelers, and seed drills were 1608, 1085, 1028, and 584, respectively, and these values remained constant across both scenarios (Table 9).Winter crop operations required fewer implements than summer crops due to the fewer allocated area coupled with ample timeframe available.

The estimated number of tractors and implements in this study for cultivating the main crops in the Gezira scheme provides valuable information to managers and decision makers. It helps in determining the total amount of fuel requirements, allocating skilled operators and identifying their needs. This information also supports decisions making on planning repair and maintenance schedule, and the number and locations of necessary service centers. Additionally, it helps in better in distribution of farm machinery throughout the scheme areas.

Table 8. Number of tractors and implements required under the two scenarios for summer crops

Implement	Discrete operations scenario		Overlap operations scenario	
	tractors	implements	tractors	implements
Chisel plow	2185	2185	1733	1733
Disk harrow	2056	2056	2098	2098
Ridger	2010	2010	1964	1964
Row planter	2122	2122	1564	1564
Maximum number of tractors	2122		2433	

Table 9. Number of tractors and implements required under the two scenarios for winter crop

Implement	Discrete operations scenario		overlap operations scenario	
	tractors	implements	tractors	implements
Chisel plow	1608	1608	1608	1608
Disk harrow	1085	1085	1085	1085
Scraper	1028	1028	1028	1028
Seed-drill	584	584	584	584

Monetarily appraisal

Table 10depictes monetarily assessment for the difference between discrete and overlap operation scenarios in number of tractors and implements. While the overlap scenario required a higher number of tractors, the discrete scenario necessitated more implements (except for scrapers and seed drills, which were consistent across both schedules). The results showed that the monetary values of additional tractors required for overlap scenario was greater than the monetary values of all additional implements required for discrete scenario. The descrete operations scenario was cost effective compared to overlap operations scenario, indicating the superiority of discrete scenario, making it the preferable option. These results imply that the procedure followed in farm machinery management save a lot of money.

Table 10. Monetary assessment for tractors and implements required under the two scenarios

Implements	price (SDG)	difference	Value (SDG)
Chisel plow	1218958	452	550969016
Disk harrow	1861621	-42	-78188082
Scraper	416326	0	0
Ridger	1180000	46	54280000
Row planter	3625000	558	2022750000
Seed-drill	1882608	0	0
Monetary value of extra tractors	14000000	311	4354000000
Monetary value of extra implements			2549810934
Difference			1804189066
Assessment	value of overlap > Value of discrete		

IV. CONCLUSION

Number of tractors and implements required to accomplish land preparation and seeding operations for the main summer and winter crops in the Gezira scheme was estimated under two operations scenarios, descrete and overlap operations scenarios. The estimation was performed without delaying the optimum range of sowing dates.

- Land preparation for summer crops under descrete and overlap operations scenarios took more time compared to seeding operations.

- The maximum number of tractors required under descrete operations scenario was lower (2122 tractors) than that under overlapped operations scenario (2433 tractors), whereas reverse was true for the required number of implements.
- The maximum number of chisel plows, disk harrows, scrapers, ridgers, row planters and seed drill under discrete operations scenario was 2185, 2056, 1028 2010, 2122 and 584, respectively. Whereas their respective numbers under overlap operations scenario were 1733, 2098, 1028, 1964, 1564 and 584, respectively.
- Descrete operations scenario was cost effective compared to overlapped operations scenario.
- These findings will facilitate better resource management and enhance agricultural productivity.

Conflict of interest: The authors have not declared any conflict of interest.

References

[1]. Haque, M. A., Bobboi, U., and Arku, A. Y. (2003). A comparative analysis of tractor uses in Borno State of Nigeria. Arid zone Journal of Engineering, Technology and Environment, 3:22-26.

[2]. Mrema, G. C., Baker, D., and Kahan, D. (2008). Agricultural mechanization in sub-Saharan Africa: time for a new look. Agricultural management, marketing and finance Occasionall paper No 22. Food and Agriculture Organization of United Nations, FAO., Rome, Italy.

[3]. Sims, B. G., and Kienzle, J. (2006). Farm power and mechanization for small farms in sub-Saharan Africa, Agricultural and Food Engineering Technical Report No 3. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy.

[4]. Saeed, A. B. (2018). Farm mechanization in Sudan: Historical development, present status and fiture prospects of industry, research and policies, *Agricultural Mechanization in Asia, Africa and Latin America, AMA, 49(2): 95-103.*

[5]. Dawid, I., Gebiso, T., and Boka, E. (2022). Comparative advantage of tractor utilization in Southeastern Oromia, Ethiopia, *International Journal of Developing and Emerging Economies, 10(2): 75-101.*

[6]. Zoz, F., and Grisso, R. D. (2003). Traction and tractor performance. ASAE, series # 27. St. Joseph Mich. USA.

[7]. Nkakini, S. O., and Eguruze, B. V. (2009). Farm tractor utilization pattern for various agricultural operations, Journal of agricultural engineering and technology, 17(2): 33 - 43. Special edition on mechanization of agriculture in Nigeria, Nigerian Institution of Agricultural Engineers@www.niae.net.

[8]. Andersson, H., Lars'en, K., Lagerkvist, C. J., Andersson, C., Blad, F., Samuelson, J., and Skargren, P. (2005). Farm cooperation to improve sustainability. AMBIO: J. Human. Environ. 34(4): 383 - 387.

[9]. Eldaw, A. M. (2004). The Gezira scheme: prospective for sustainable development, German Development Institute, report and working paper 2/2004.

[10]. Awadalla, A. M. E., Sukwon, K., Taek-Ryoun, K., and Haider, S. A. (2019). Agricultural mechanization status for some crops in irrigated sector in River Nile State, Sudan, Journal of agricultural Science, 11(13): 127 – 133.

[11]. Bashir M. A., Dawelbeit, M. I., Eltom, M. O., Tanakamaru, H. (2015). Performance of different tillage implements and their effects on sorghum and maize grown in Gezira Vertisols, Sudan. International journal of scientific and technology research, 4(4): 237 - 242.

[12]. Dawelbeit, M. I., and Babiker, E. A. (1997). Effect of tillage and methods of sowing on wheat yield in irrigated Vertisols of Rshad, Sudan. Soil & Tillage Research 42: 127 - 132.

[13]. Elshaikh, A. E., Yang, S., Jiao, X., and Elbashier, M. M.(2018). Impacts of legal and institutional changes on irrigation management performance: A case of the Gezira irrigation scheme, Sudan, *water, 10 (1579): 1 – 14.*

[14]. Mahgoub, F. (2014). Current status of agriculture and future changes in Sudan, Nordic Africa Institute. Available at: http://nail.diva-ortal.org, Viewed at 5 May 2024.

[15]. Say, S. M., and Sumer, S. K. (2011). Failure rate analysis of cereal combined drills. African Journal of Agricultural Research, 6(6): 1322 - 1329.

[16]. Khafizov, C. A., Khafizov, R. N., Nurmiev, A. A., and Galiev, I. G. (2021). Energy justification of the number of tractors for agricultural operations, BIO Web of conferences 37, 00136, available at https://doi.org/10.105/bioconf/20213700136

[17]. Shrivastava, A. K., and Jha, S. (2011). Modification and performance evaluation of tractor drawn improved till plant machine under Vertisol. Agric. Eng. Int: CIGR journal, 13(2): 1-7. Open access at http://www.cigrjournal.org.

[18]. Poozesh, M., and Tarighi, J. (2020). Determination of timeliness cost using method of average workability robability based on reliability function of farm tractors. Emirates journal for engineering research, 25(2): 1 - 16.