International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 8 Issue 8 August - 2024, Pages: 125-133

Seed Drill Machinery Management and Optimization for Wheat Production in Dongola, Northern State, Sudan

Osama Elhabeeb Adam[1], Abdalla N. O. Kheiry[2,3], Mohamed Hassan Dahab[4] and Adam Bush Adam[5]*

[1] Department of Agricultural Engineering, Faculty of Agricultural Sciences, Dongola University, Sudan
[2] Shihezi University, Xinjiang Uygur Automnomous Regon, China -
[3]Department of Agricultural Engineering, College of Agricultural Studies, Sudan University of Science and Technology
[4] Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum, Sudan
[5] Department of Agricultural Engineering, Faculty of Natural Resources and Environmental Studies, Alsalam University, Sudan
*Corresponding Author: adambush99@gmail.com

ABSTRACT: *Farm machinery management is of great importance for field crops production. This study aimed to develop a computer program to be used as a decision-making tool for improving the efficiently mechanized field operations such as seed drilling for wheat production under Northern state, Dongola conditions. Some machinery data were collected for computer program development. The developed program contains three units namely; Machinery performance unit to estimate effective field capacity (ha/h), Fuel consumption unit to estimate fuel consumption rate (L/ha) and Field operations costs unit to estimate total cost in (SDG/h and SDG/ ha). Principles of operation research (OR) and linear programming (LP) mathematical modeling techniques were employed to formulate the main objective functions. T-test was used to analyze the collected data. The developed program was verified and validated using actual data from the field. The results showed positive and strong correlations between the predicted and actual effective field capacity and operation costs. For the planting operation, predicted effective field capacity of Baldan drill (4m) was increased by 28% of actual field capacity. Moreover, for same drill the predicted operation cost was lower than the actual costs by 17%. The same trend was observed for the other two seed drills. Sensitivity analysis and accuracy tests were carried out and the developed computer system was found significantly respond to changes of inputs with high accuracy. It was concluded that, after optimization, the best combination option for planting operation it was required 4 implements of size 3.30m, and field capacity 2.22 ha/h, in combination with 36 implements of size 4.00m and 2.69 ha/h to cover an area of 50,000 ha.*

Keywords—Seed drill, management, optimization, operation research, linear program

1. Introduction

The necessity of agricultural production is increasing day after day to face the rapidly increasing world population. The total cropped area throughout the world is increasing and the labor employed in farming is decreasing and the needs to use farm tractors and machineries are increased (Clarke, 2000). The agricultural sector has an important role to play in achieving food Security by increasing food production and providing employment opportunities in the rural area (Mohamed, 2011). In agricultural production, mechanization reduces human drudgery; improve timeliness and efficiency of various farm operations. The ultimate goal of the machinery manager is to maximize enterprise profits by getting the greatest output from machines at a minimum cost (Hunt, 2008).

The selection of machinery to perform field operations may include different sizes and capacities, which need different power units (Bowers, 1987). Machines system is an arrangement and use of two or more machines to achieve desired output. Machines are operated as an element of a system (ASAE, 2003). Timeliness is defined as the ability of available labor using a given set of machinery to complete each field operating within an optimum period of time. The total time required for machine operation depends on the capacity of the machine, the number of available working days and number of available working hours of use (Siemens, et al., 1999). It is important for efficient farm managers to understand how to estimate capacities of machines, then plan for future use, and to know machine capacity for selection of power units that can complete important field operations on time (ASAE, 2000). One of the most important costs influencing profit in farming operations is the cost of owning and operating machinery.

There is a continuous need for advanced machinery to meet higher production goals and full utilization of production resources. Optimization of farm machinery is a complex problem faces both individual farmers and other enterprises managers for crop production (David, 2004). There is a need to determine the most optimal machine type, size and capacity that satisfy the required field operations (Siemens, 1998). Machinery managers have to develop a plan or a system of setting up field operations based on previous machinery records in the area. Machinery management problems can be solved by accurate estimation of total working time that is available for major field operations, determine the required effective field capacity of machines, match power unit to machines and predict costs accurately for any machine application (Ismail, 1998, Edwards, and George, 2008). Modern technologies of farm management, such as computer programs and software are used as decision making aid tools (Alam et al., 2001, Bol, et al., 2006, Belel, et al., 2014).

The main crop production season in Dongola area is winter, where the two main grown crops are grown wheat and faba bean (MAAW,2015). This area faces many limiting factors which affect wheat production such as high cost of production, low crop productivity, high input costs. One of the main field operations for wheat crop production is planting (seeding), thus, must receive more consideration and management so as to increase the crop production and productivity. Unfortunately, there is no published information concerning machine management of this operation in Dongola area hence, there is a need for more investigation and study. The main objective of this study is to develop a machinery management system for wheat production and decision making by using computer programming.

The specific objectives of this study are:

1/ Estimation of effective field capacity (EFC), fuel consumption rate and field operations costs of crop planting operation.

2/ Employment of operation research (OR) and using linear programing (LP), as mathematical modeling technique based on algebraic solution analysis, for optimization sizes and costs of farm machinery used

3/ Validation, sensitivity and accuracy tests will be carried out for the computer systems.

2. Materials and Methods

2.1 Experimental area location

The Northern State lies between latitudes 16O-22O N and longitudes 20o-32o E. It is divided into seven (7) localities namely WadiHalfa, Dongola, Eldaba, Merowe, Algold, Elborgaig and Dalgo. The State lies in the arid and semi-arid zones, where the annual rain fall is less than 100mm.There are two distinct seasons, winter season (October to the end of March), and summer season (from April to the end of September) (AOAD, 1995). In the study area (Dongola, Algold and Eldaba localities (MAAW, 2017), the soils of the upper terrace soils classified as saline sodic soil constitute the largest portion of land available for cultivation. Garif and Gorier soils are the most fertile, whereas, the upper terrace soils are the least fertile.

2.2 The required Data

The required input data to run the computer system collected from literature and many different concerned resources such as Ministry of Agriculture and Animal Wealth (MAAW, 2015), Agricultural Research Station, Alshamalia company for agricultural machinery services, Agricultural bank of Sudan (Dongola branch) and Agricultural machinery dealers. Also some data collected through direct interview of agricultural engineering, operators and farm managers. The collected data included types and sizes of tractors, machineries, field efficiency, machine speed, purchase price, purchase date, width of machine, and numbers of machines used in each operation and start and end of each operation and working hours per day.

2.3 Types of machinery used

Three tractors of 70-90 hp of different models are the main source of farm power used with disc plough (3discs) and chisel plough (5&7 shanks) ,ridgers and levelers for land preparation and three seed drills for the planting operation.

2.4 Computer system requirements:

Personal computer, TOSHIBA, processor Intel CORE i3, RAM 4 Giga Bite, Widows 10 (32 bit), s Hard Disc (HD) 500 Giga Bites. Microsoft Office packages software which includes Excel 2010. Linear programing) software (simplex method).

The program pre-loaded with the published data and information of standard machinery technical parameters and equations adopted by ASAE (2000), Hunt (1979), Witney (1988) Siemens et al (1999) and Dahab (2001). System employs International System (SI) metric units. System employs Sudanese Goneh (SDG) as local Sudanese currency.

2.4.1 System function

The main functions of the whole developed system are the following:

1/ calculation of effective field capacity (EFC) for different machines

2/ Estimation of fixed cost (FC), variable cost (VC) and operation cost for tractors power and planting asr SDG/hr and SDG/ha

3/The system solved the generated farm machinery production problem (maximization), using linear programing (LP) software (Tora) and applying simplex method, wishing to obtain the optimization of machine sizes and costs.

2.4.2 System technical specifications

The developed computer system technical specifications are shown in Table (1)

Item	System	(LP)software (Tora)
System language	Cake Php frame work	Excel
System type	Button menu driven	Button menu driven
System dependability	Windows 7	Windows 7
System interface	Main menu	Spread sheet
Units used	SI units	SIunits

2.4.3 Program data files

a. Tractors file: The file contains a list of different types of tractors maybe used in land preparation, planting and harvesting operations. The file contains information include tractor make, tractor engine power (KW), PTO power, purchase price, purchase date and life span The information in the file may be changed by the program user and stored.

b. Implements file: It contains a list of different implements maybe used to perform land preparation, planting and harvesting operations. The information in the file includes machine name, size (width), working speed, estimated field efficiency, and power required. The information in the file may be changed by the program user and stored.

c. Field operations file: The most important information input by the user is the list of desired field operations to be achieved and the related to these operations. One of the program objectives is to select the required machinery to complete the desired field operations on optimum period and with least costs.

2.5 Machinery performance calculations procedure

2.5.1 Machine capacity equation: Based on the equation given by ASAE (2003).

Effective field capacity (EFC) = $\frac{SWE}{C}$

Where:
EFC =Effective field capacity (ha/hr).
S= Machine working speed (km/h).
W =Machine width (m).
E= Field efficiency (%).
C= Constant= 10

2.5.2 Tractor fuel consumption rate estimation
Tractor fuel consumption (TF) in liter per hour (L/hr) = PTOp x 0.223
PTOp = 0.87 x engine power (Eng. power) as mentioned by Siemens et al (1999).
Where: PTOp = Power- Take-Off shaft power (KW)。

2.5.3 Farm operation costs estimations:
The tractor and machinery operations costs depend on mathematical equations adopted by ASAE (2000), Hunt, (2008) Siemens et al (1999) and Dahab (2001).
Annual use (hrs.) = Available working days per season × working hours per day.

2.5.3 Number of required machines in field operations

estimated according to (Dahab, 2013) by the following equation:

Required Number of machines = Area to be covered (ha) ÷ effective machine capacity EFC (ha/hr) × total working hours per season (hr)

$$\text{No. of tractors and implements} = \frac{A}{\text{No. of hrs} \times EFC}$$

Where: A = operation total area
EFC= effective field capacity

2.6 Computer system verification and validation
The developed computer system will be verified by using data from literature and validated through comparing the system predictions with the actual data from the field and records.

2.7 Sensitivity analysis of the system
The sensitivity analysis of the system will be carried out by changing one or more of the input data in each unit and observing the effect on the system outputs.

2.8 Statistical analysis of the computer system accuracy
T-test statistical techniques will be applied to test the developed system accuracy compared that with actually applied procedure in the study area to calculate, effective machine capacity (EFC), fuel consumption and operations costs within the adopted date and equations.

2.9 Planting operation maximization problem
Planting budget assumed to be 12,000,000(SDG) for the total area to be covered 50000 ha (120000 feddan).
Total calendar days = 40 days (15/11 to 25/ 12)
Working hour per day = 13
Total working hours in field for the whole season = 40×13 = 520 hours
Total area covered 120000 feddan = 50000 hectare (ha)
Productivity (EFC) of the machinery system per day =
50000÷ 40 = 1250 ha /day
Effective field capacity (EFC) for the whole machinery system in ha/hr =
1250÷ 13= 96.15 ha/ hr.

Objective function
The objective function was done according to James and Leaven, (1998) as follows:
Max (Z) = A1X1 + A2X2+ A3X3
Subjected to: -
X1+X2 +X3 ≤ (total number of available machines used constraint)
C1X1 +C2X2+C3X3≤ budget constraint (assumed budget / total working hours, SDG/hr.).
W1X1+ W2X2+W3X3 ≤ time constraint (total working hours per season).
Where:
X1, X2, and X3 ≥ 0
X1, X2, and X3 are non-negative value

2.10 Sensitivity analysis of linear programming (LP)
It will be carried to detect how the basic solution is sensitive to the changes in the input data. This sensitivity done by changing the values of right hand side (RH) solution column (constraints) and changing the values of the objective functions coefficients. Through this process we can detect the effect of changing these values on the feasible basic solutions in each field operation.

3. RESULTS AND DISCUSSTION

3.1 COMPUTER SYSTEM DEVELOPMENT AND DESCRIPTION

The computer system was developed as a tool to help agricultural managers for decision making and planning. The system allows the user to inter-act with its components through the entered data then predicted results and reports can be obtained in the screen and/or printed out. The system contains lists and data of various types of tractors and matched machinery for the planting operations. The system composed of two sections:

Section one: This section contains three units: -
1/ Machinery performance unit: It is used to calculate and estimate effective field capacity (EFC) in (ha/hr) for different machines used in the selected operations.
2/ Fuel consumption rate estimation unit: It is used to estimate fuel consumption rate liter per hectare (l/ha) for different tractors
3/ Field operations cost unit: In this unit fixed cost (FC) and variable cost (VC) for different tractors power and seed drill used in each of the selected operation can be calculated and

consequently field operation cost per hour (SDG/hr) and operation cost (SDG/ ha) can be estimated.

Section two: output reports of machine field capacity (EFC in ha/hr) and field operation cost (SDG/hr). Through employing operation research (OR) using linear programing (LP) software and applying simplex method, with consideration of machine effective field capacity (ha/hr) as objective function coefficients, (machine numbers, working hours/ day and operation cost per hour) as decision variables coefficients and (total machine numbers, total operation cost per hour according to the assumed budget and annual hours of use) as constraints (available resources) for the planting operation. This case considered as linear programing production problem (maximization) that can be solved by application of simplex method maximization technique.

3.2 System validation by predicted and actual effective field capacity EFC (ha/h) for planting machinery

Published data collected from different relevant literature and records were used to verify the computer system and the validity of system output of effective field capacity was tested and compared with the actual effective field capacity. Table 2 revealed that the predicted effective field capacity was higher as compared to the actual field capacity for the three types of planting machines. The predicted EFC was higher by 20%, 17% and 28% For ATTESPAR drill, Agro-master drill and BALDAN drill respectively. Width of the implement was found to have a noticed effect in improving and determining the field efficiency, this mainly due to that, width is fixed for one machine as reported by Dahab and Mohamed (2006) and Hunt (2008). Statistical analysis of paired samples correlations (predicted and actual EFC) for planting machinery. showed positive and very strong correlations between two parameters (R2=0.974). This proves that the developed program is valid to estimate EFC for planting machinery with a high level of accuracy.

3.3 System validation by estimation of machinery costs for planting operations.

Table 2 showed that for planting operations, the system predicted lower total operation cost as compared to the actual total operation costs for the three drills. The variations between actual and predicted machinery may be attributed to the high market prices of spare parts due to the high percentage rate (%) of inflation. The rate of repair and maintenance costs (R&M) costs increased with the increased of machine life in years, but this cost is differ from one machine to another due to variation in management policies and operator skills as mentioned by Dahab (2001). Moreover, in developing countries, the cost of repairs is considerably higher due to high prices of spare parts and sometimes lack of knowledge of proper operation and maintenance as stated by Hunt (2008). Statistical analysis of paired samples correlations (predicted and actual total operation costs) for the planting operation showed strong positive correlations between predicted and actual total costs (R2=0.964). The results confirmed that the developing program is valid to estimate total operation costs for the planting operation machinery with a high level of accuracy.

Table 2. Comparison between system predicted and actual effective field capacity EFC (ha/h)

Operation	Machine	Predicted	Actual	Comparative (%)
EFC	ATTESPAR drill(3.00m)	2.02	1.68	120
	Agromaster drill (3.30m)	2.22	1.89	117
	Baldan drill (4.00m)	2.69	2.1	128
Operation Costs	ATTESPAR drill(3.00m)	177166.76	205400	86
	Agromaster drill(3.30m)	171353.52	195700	88
	Baldan drill(4.00m)	187210.66	225600	83

3.4 Sensitivity analysis of the system to estimate machinery effective field capacity (ha/h)

The sensitivity analysis of the system was carried out to show the effect of changing one or more of the input parameters on the program outputs. The input variables include, machine width or size (m), speed (km/h) and expected field efficiency (%). The system is flexible to change input variables as presented in Table 3. increasing ATTESPAR drill width from 3.0m to 3.25m, the EFC by 0.17 ha/h considering working hours per day (13h), while for Agro-master drill the ffective field capacity increased by (0.11ha/h) when the machine width was increased from 3.30m to 3.45m. On the other hand, Baldan drill gave the highest increased effective field capacity, 0.22 ha/h when machine width increased from 4m to 4.3m. Therefore, increasing working width of machine significantly increased the effective field capacity as mentioned also by Siemens et al. (1990) and Dahab (2000).

Table 4 showed the effect of increasing the working speed on effective field capacity for planting operations. It was observed that Effective field capacity was significantly increased by increasing working speed for the planting machines. The highest effective field capacity was recorded under Baldan drill, 0.39 ha/hr followed by Agro-master drill 0.32 ha/hr and ATTESPAR drill 0.29 ha/hr. The obtained results showed that any increase in the implement working speed increases effective field capacity (ha/h), but this increase should be limited to an extent that keeps the implement operate to its optimum quality. The results are in agreement with that obtained by Siemens et al. (1990) and Elbashir (2015).

Table 5 showed that the effective field capacity significantly affected by changing the effective field efficiency. As the field efficiency was decreased from 70% to 65%, the machine EFC was decreased by 0.15 ha/h, 0.16 ha/h and 0.19 ha/hr for of ATTESPAR drill, Agro-master drill and Baldan drill respectively. The obtained results showed that any decrease in field efficiency resulted in decreasing machine effective field capacity (ha/h). The results were in agreement with the result obtained by Elbashir (2015).

3.5 EFFECT OF DEVELOPED SYSTEM ON DECISION MAKING

Table 6 showed that, according to the developed system, the planting operation requires 48 small machine size ATTESPAR drill (3.00m) and 96 labors to accomplish planting operation and operation costs per hour of 340.71 SDG/h. Relying on small machines will increase the risk of inability to perform the operation in time due to its small capacity (EFC), while medium machine sizes need less number of machines and labors than small ones, but higher costs should be considered. On the other hand, the large machines requires less number of machines and labors to operate. Risk of timeliness is reducing during the peak period to its minimum due to large machine capacity (EFC). Hence**,** optimization of different machine capacities (EFC) becomes the best choice to be adopted to utilize time, operation costs (SDG/h) and other production resources as mentioned by Dahab (2013). Moreover. The model outputs enable Agricultural System Managers (ASM) to better manipulate and save production resources since optimization operation defined as finding an alternative with most costs effective or higher achieved performance under the given constraints by maximizing desired factors and minimizing undesired ones.

3.6 Feasible solutions for planting operation problems

According to study objective, Tora software (linear and integer programming) was employed to solve the formulated objective function problem for feasible solution of planting operations objective function as shown in Tables 7. The results showed that, the total performance value represents the final objective value according to its maximum capacity. Therefore, the highest productive area for planting operation was achieved due to the best selection of appropriate machinery fleet size capable to perform operations. The results agreed with the results obtained by Hunt (2008).

3.7 Satisfaction of the system purpose for planting operation

Since optimization means finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing the desired factors and minimizing undesired ones. As shown in Tables 8, the program system had achieved the study goals (optimization costs and maximizing of machinery performance according to machine sizes for the planting operation), in addition to the developed system will be validated by testing the achievements of these targeted objectives. Moreover, the developed system predicted the required machine before and after optimization as well as the No. of labor before and after optimization (Table 8).

As presented in Tables 9, the reduction in machines number after optimization significantly decreased the overall operation cost per hour for planting operations machinery. Small size implements (3.0m) reduced cost operation from 11210.30658SDG to zero cost (reduction percentage 100%), while for medium size implements (3.3m) reduction percentage was 54%. On the other hand, the overall operation costs per hour for large size implements (4.30m) does not change because the required number of machines does not change after optimization (Taha, 2011).

3.8 Sensitivity analysis of linear program (LP) solution for planting operation

Table 10 showed the sensitivity analysis of (LP) for planting operation and revealed that, decreasing (RHS) budget constraint (SDG) leads to changes in the feasible region of the solution, and it gives a new solution with a new objective value (89.60ha/h) which is lower than the first optimal solution. While increasing the (RHS) annual hours of use constraint, translated into changes in feasible solution and therefore a new optimal solution is obtained with a new objective value (164.86 ha/h) which is the highest among the others. The results agreed with result obtained by Belel et al. (2014) who mentioned that selection the optimum width of implements in addition to adjusting machines were found to have a noticed effect in improving the field capacity and efficiency.

4. CONCLUSIONS

The following conclusions may be drawn from the results of present study:

1. A computer system program was designed and developed to estimate effective field capacity (EFC), fuel consumption, fixed costs (FC) and variable costs (VC) for different sizes of planting machinery used for wheat production in Dongola area.
2. The developed system was verified, validated and statistically analysed by comparing the predicted with the actual field data and proved to be fairly accurate.
3. Linear and integer programming (LP) software (Tora) was used in the maximization problems to optimize machinery sizes and costs for machinery used and results revealed that using different machine capacities was the best option among many other alternatives considering time and costs and available machine numbers as main constraints that restricts maximization. Hence, the model outputs enable Agricultural System Managers (ASM) to better manipulate and save production resources since optimization operation defined as finding an alternative with most costs effective or higher achieved performance under the given constraints by maximizing desired factors and minimizing undesired ones.
4. The developed computer program showed that after optimization the numbers of planting machines predicted were four of 3.3m and thirty six of 4.0 m in size and costing 1318.1 and 1296o.7 SDG/h respectively.
5. Towards better utilization of time and machinery sizes and power required, working hours per day must be exceeded.

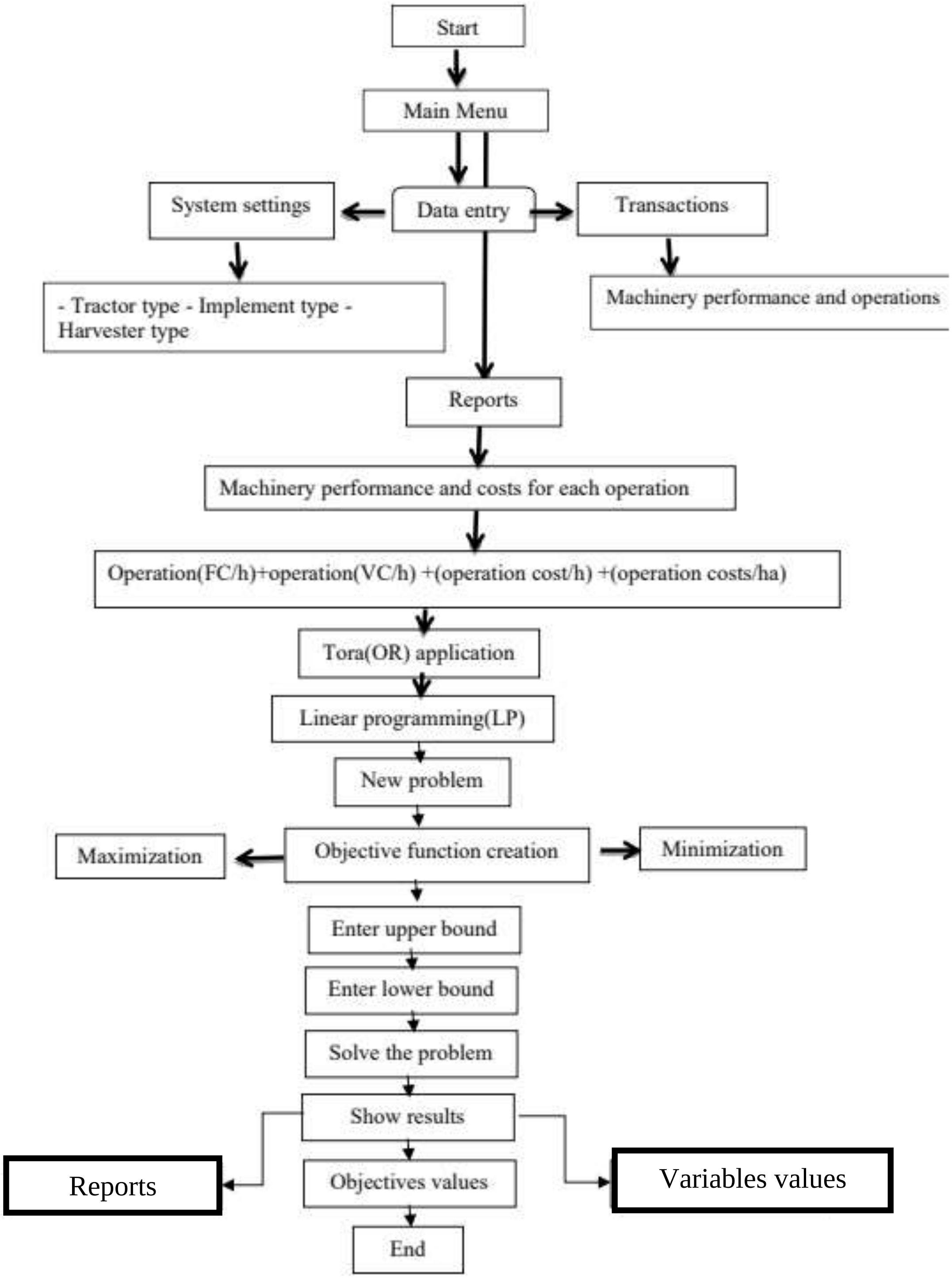

Figure 1 Program flowchart

International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 8 Issue 8 August - 2024, Pages: 125-133

Table 3. Effect of increasing machine width on effective field capacity (ha/h)

Operation	Implement	Width (m)	Speed (Km/h)	Efficiency (%)	EFC (ha/h)
Planting	ATTESPAR drill	3.00	9.6	70	2.02
		3.25			2.18
	Agro-master drill	3.30	9.6	70	2.22
		3.45			2.32
	Baldan drill	4.00	9.6	70	2.67
		4.30			2.89

Table 4. Effect of increasing working speed on machine EFC (ha/h)

Operation	Machine	Width (m)	Speed (km/h)	Efficiency (%)	EFC (ha/h)
Planting	ATTESPAR DRILL	3.00	9.6		2.02
			11	70	2.31
	Agromaster drill	3.30	9.6		2.22
			11	70	2.54
	Baldan drill	4.00	9.6		2.69
			11	70	3.08

Table 5. Effect of decreasing machine efficiency on EFC (ha/h)

Operation	Machine	Width (m)	Speed (Km/h)	Efficiency (%)	EFC (ha/h)
Planting	ATTESPAR drill	3.00	9.6	70	2.02
				65	1.87
	Agro-master drill	3.30	9.6	70	2.22
				65	2.06
	Baldan drill	4.00	9.6	70	2.69
				65	2.50

Table 6. Machinery options for planting operations

Operation	Machine	Size (m)	EFC (ha/h)	No.of required machine	No. of required labors	Cos per hour(SDG)
Planting	ATTESPAR drill	3.00	2.016	48	96	340.7053
	Agromaster drill	3.30	2.218	43	86	329.5260
	Baldan drill	4.00	2.688	36	72	360.02049

Table 7. Feasible solution of planting operation objective function

Variable (machine)	Value	Size (m)	Obj. coeff (EFC)	Obj.value contribution
X_2 (Agro-master drill)	4	3.30	2.22	8.87
X_3 (Baldan drill)	36	4.00	2.69	96.77
Total performance value				105.64
Objective value(max) = 105.64				

Table 8. Satisfaction of system purposes for planting operation

Machine	Size (m)	Required No. before optimization	Required No. after optimization	Needed No. of labors before optimization	Needed No. of labor after optimization
ATTESPAR drill	3.00	48	0	96	0
Agro master drill	3.30	43	4	86	8
Baldan drill	4.00	36	36	72	72

Table 9. Effect of optimization on planting implements operation costs (SDG/h)

Implement name &size	Req.No. before optimization	Req. No.after optimization	Operation cost (SDG/h)	Overall implement costs (SDG/h) before optimization	Overall implements cost (SDG/h) after optimization
ATTEPAR drill (3.00)	48	0	340.7053	16353.8544	0
Agro master drill (3.30)	43	4	329.5260	14169.618	1318.104
Baldan drill (4.00m)	36	36	360.0204	12960.7344	12960.7344
Total operation costs (SDG/h)				43484.2068	14278.8384

Table 10. Sensitivity analysis of linear program (LP) solution for planting operation

Type of the changed constraint	Constraints value	Decision variables	Solution value	Objective function (max) value
Budget/h (SDG)	23076.92	x_1	0	105.64
Available no. of implements	88	x_2	4	
Annual hours of use (h)	520	x_3	36	
Decreasing RHS (Budget/h)	12000	x_1	**0**	89.60
	88	x_2	0	
	520	x_3	33.33	
Decreasing RHS (total number of implements	23076.92	x_1	0	80.64
	30	x_2	**0**	
	520	x_3	30	
Increasing RHS (annual hours of use)	23076.92	x_1	0	164,86
	88	x_2	30.7	
	900	x_3	**36**	

REFRENCES

Alam, M., Hussain, M.M and Awal, M.A. (2001). Selection of Farm Power by using a computer program. Agricultural Mechanization in Asia, Africa and Latin America.AMA.32(1).

AOAD (1995). Arab Organization for Agricultural Development. Annual Report.

ASAE (2000). Agricultural Machinery Management. EP 496.2-ASAE Standards. St. Joseph. U.S.A.

ASAE (2003). Uniform Terminology for Agricultural Machinery Management. MI 49085-9659. American Society of Agricultural Engineers (ASAE) Standards. St. Joseph.U,S.A.

B0l, M.B; H,I. Mohamed and M.A. Ali (2006). Development of Computer Model for Machinery Selection and Management. U of K. J. Agric, Sci. 14(2), 135-149.

Belel, M.;. El Naim, A. and Mahmoud, T. (2014). Computer Modeling for Prediction of Implement Field Performance Variables. World Journal of Agricultural Research, Vol. 2, No. 2, 37-41.

Bowers, W. (1987). Machinery Management. John Deere Service Training, Dept. John Deere Rd., Moline, IL, U.S.A.

Clarke, G. (2000). Strategies for agricultural mechanization development. The role of private sectors and government. Agricultural Engineering Branch, Agricultural Support System Division FAO, Rome, Italy,

Dahab, M.H. (2000). Source of Farm Power and Machinery Selection. 1stedition(in Arabic) Uof K press. Khartoum, Sudan.

Dahab, MH. and Mohamed O.E (2006). A computer Model for Selection of Farm Machinery. U. K. J. Agric. Sci. 14(2);167-181.

Dahab, M. H. (2013). Farm Power and Agricultural Machinery management 1st edition (in Arabic). U of K press. Khartoum, Sudan.

David Shoup, W. (2004). Agricultural Systems Management-Optimizing Efficiency and Performance Robert M. Peart- University of Florida; Gainesville, Florida U.S.A. - Southern Illinois University; Carbandale, Illinois U.S.A.

Edwards, W and George, A.(2008).Estimating Farm Machinery Costs- Agric. Decision Maker- PM 710.November.Iowa State University.U.S.A.

Elbashir,M.A.(2015). Management and Optimization of Cost and Size of Farm Machinery in the Mechanized Rainfed Agriculture of Gedaref Area (Sudan).Unpublished Ph.D. Thesis.Uof k.

Hunt, D. (2008). Farm Power and Machinery Management. Lowa State University Press Ames, Lowa, USA.

Ismail, W.I.B.W. (1998). Cost Analysis Model for Crop Production Machinery System. Agricultural Mechanization in Asia, Africa magazine AMA, 29(4):56-60.

James, E.R.and Leaven good, S. (1998). Operation Research – using the Simplex Method to Solve Linear Programming Maximization Problems. EM 8720-.- Oregon State University- Extension Service. U.S.A.

MAAW, (2015) .Ministry of Agriculture and Animal Wealth. Northern State, Annual report.

MAAW, (2017) .Ministry of Agriculture and Animal Wealth. Northern State, Annual report, Dongola.

Siemens, J.C. (1998). Field Machinery Selection using simulation and optimization. In: Agricultural Systems Modeling and Simulation. Peart, R.M.; Curry, R.B., Eds; Marcel Dekker. New York.

Siemens, J.C.; Hamburg, K.; T.A.(1990).Farm Machinery Selection and management program. J. Prod. Agric., 3, 212-219.

Siemens, J.C., Bowers, W. and Holmes, R.G. (1999). Machinery Management,5thedition.DEERE&COMPANY,Moline.

Taha, H, A. (2011). Operation Research an Introduction(in Arabic) Dar elmerickh press, Alriyadh, Kingdom of Saudi Arabia (KSA).

Witney, B. (1988).Choosing and Using Farm Machines .AVI Publishing Com.Inc,West Port. UKhence better optimization of sizes and costs can be done.