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Tillage Implements Management and Selection Using Computer Programming

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Abstract: *The study aimed to develop a computer program for Managing and selecting tillage implements. The required input data included machine initial purchase prices (SDG), expected No. of working days, working hours per day, repair and maintenance costs for each machine as (%) of initial purchase prices, machine age (years), area to be covered (ha) machine rent per hour (SDG), percentage of labor wage per hour, fuel unit price (SDG/L) and required tractor power (Kw). The program predicts the effective field capacity (ha/h) of tillage system namely; chisel plow 7 shanks (1.9m), Offset disc harrow 24(2.7m) and offset disc harrow 32 (3.65m), number of tractors and implements required for tillage operations, calculates the total operation cost (SDG) per fed, and finally giving the user an option to hire or own the machine (BEP). The program was successfully verified statistically and validated in comparison to the published data from the ASAE (2003) and proven to be user friendly and efficient. Validation, verification and sensitivity tests indicated that the program could be applied to any real-life case successfully and with confidence for wheat or any multi- crop farm. For technical machine performance, statistical analysis showed very positive strong correlations between predicted and actual field capacity. Moreover, actual field capacity significantly ($P \leq 0.05$) increased (2.1ha/h) as compared to predicted effective filed capacity (1.71ha/h). On the other hand, the lowest predicted total operation costs (155,039SDG/h) was recorded under offset disc harrow24 (2.70m) compared to the actual total operation costs of offset disc harrow 32 (3.65m) which ranked 273,794SDG/h. Therefore, the decision making for the best combination option for land preparation to cover 50, 000ha was 21 tillage systems (size 1.9 m – Efc 1.39 ha/h) with 34 implements (size 3.65 m and field capacity 2.66 ha/h). Hence it becomes evident from this study, computer program can be used for improving farm machinery planning and assist machinery managers in decision making in Northern state of Sudan.*

Keywords: **Computer Program; Management and selection, Tillage Systems**

INTRODUCTION

Machinery management significantly increased in recent farming operations because of its direct related to the success of management in mixing land, labor and capital to return a satisfactory profit. Efficient machinery requires accurate machine performance data in order to meet projected work schedules and to form balanced mechanization system by matching the performance separate times of equipment. Effective mechanization at the field level can only be achieved through the proper selection and operation of machinery. This may be achieved by predicting changes of machine performance through time as mentioned by Balel *et al.* (2014). Machinery managers have to develop a plan or a system of setting up field operations based on previous machinery records in the area (Edwards and George, 2008). Computer models are one of the latest management tools, which may be used to predict or monitor the effect of different cultural practices on the hydrologic properties of soil. The programs are used to determine the relative importance of many factors affecting field performance of field machinery without conducting expensive, as well as time consuming and field tests. They also help researchers and manufacturers to improve the tractor performance by comparing and analyzing various parameters that influenced tractor performance (Mysara *et al.*, 2018). With computer becoming more appropriate and available, the complexity of the farm machinery problem had led some scientists to develop several programs to assist farm managers in decision making about how to manage their machinery efficiently and effectively (Noble and Charles 1993). Mohammed (2007) develops computer program to estimate machinery performance of some farm tillage implements and determining the effects of operating parameters when using or choosing farm equipment. He found that, the program assists the manager to take the correct optimum decisions in managing agricultural machinery. In Sudan, there is a continuous need for advanced machinery to meet higher production goals and full utilization of production resources. In most area of Northern state of Sudan, there is a lack of machinery reliable data system concerning tractor power utilization, definite costs determination approach and there is no actual complete information of machinery field performance for wheat production. These parameters must be received more consideration and management to increase the crop production and productivity. Therefore, the study aimed to develop a computer program for Managing and selecting tillage implements.

MATERIALS AND METHODS

Study Area

The site is located in Northern State which lies between 16O - 22-´ N and 20o - 32- E. It is divided into seven localities namely Wadi Halfa, Dongola, Eldaba, Merowe, Algoid, 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 which extends from October to the end of March, where large areas cultivated by economic and cash crops, and summer season extends from April to the end of September where limited areas are cultivated. The total area of the state is about 85.5 million feddan, about 5% of this area is not fully mechanized.

The required Data

The required primary data for this program was collected using formal and personal contacts with individual agricultural engineers. The secondary data was collected from bulletins, operation manuals and specifications sheets of machinery and tractors, agricultural operations scheduling program and internal periodical routine reports. Other secondary data was collected from the most relevant published national and international data and periodicals. The main source data were the ASAE yearbook (2003) and Hunt (2008).The collected data include type and size of machines, field efficiency, machine speed, purchase price, purchase date, width of machine, and numbers of machines used and working hours per day.

Types of machinery used

The tractors (70-90 hp) are the main source of farm power with three different sizes of tillage implements namely; chisel plow 7 shanks (1.9m), Offset disc harrow 24(2.7m) and offset disc harrow 32 (3.65m) were used.

Development program and description

Tora software (linear and integer programming) was employed to solve the formulated objective function problem for land preparation, which had been formulated to optimize machinery sizes and costs and maximize production area within the assumed constraints. The computer program was developed as a tool to help agricultural managers for decision making and planning. The program allows the user to interact with its components through the entered data then predicted results and reports can be obtained and printed out. The system composed of two sections as mentioned in Figure1:

Section one: It contains three units:

1/ Machinery performance unit: It is used to calculate effective field capacity (EFC) in (ha/hr) for tillage implements.

2/ Fuel consumption rate unit: It is used to estimate fuel consumption rate (L/ ha).

3/ Field operations cost unit: It is used to estimate fixed cost (FC) and variable cost (VC) (SDG/hr).

Section two: Is output reports

Machinery performance calculations procedure

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

$$\text{Effective field capacity (EFC)} = \frac{SWE}{C} \qquad \text{.............................. (1)}$$

Where:

EFC =Effective field capacity (ha/hr).

S= Machine working speed (km/h).

W =Machine width (m).

E= Field efficiency (%).

C= Constant= 10

Number of tractors and implements required

$$\text{No. of tractors and implements} = \frac{\text{operation total area}}{\text{number of hrs} \times \text{effective field capacity}} \quad \text{.. (2)}$$

Working Rate (WR)

Working rate (WR) is the field efficiency multiplied by area that would be covered if the equipment could work at a constant forward speed, with no stops or turns (Cuplin, 1975). Working rate in the field depends on forward speed, working width and field efficiency, and can be calculated using the following equation:

$$WR = (FE \times A) / t \quad \text{......................... (3)}$$

Where:

WR= Working rate (ha/hr); FE = Field efficiency (%); A = Area to be processed (ha). t = Time (h)

Model validation and verification

Validation concerns with effectiveness or suitability for satisfying the purpose of the developed system However, to test program validity it is always preferable to employ statistical tools for comparison and judgment while verification is concerned with establishing whether the program is a true or sound representation of reality (Cheng et al., 1992). The verification aims to discover facts about the system under consideration in order to explain its structure and operation.

Sensitivity analysis of the system

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The sensitivity analysis of the system carried to show the effect of changing one or more of the input data in each unit on the system outputs (results).

Statistical analysis of the computer system accuracy

T-test statistical techniques was applied to test the developed system accuracy compared with actually applied procedure.

RESULTS AND DISCUSSION

Validation and Verification tests

Validation Model involves usage of some statistical measures to compare the predicted results of model with the actual ones in real life. Published data collected from different relevant literature and records presented by concerned and authorities such as ASAE (2003) were used to verify the computer program to calculate the technical performance of different tillage implements namely; chisel plow 7 shanks (1.9m), Offset disc harrow 24(2.7m) and offset disc harrow 32 (3.65m). Moreover, validation and verification tests indicated that the program could be applied to any real-life case successfully and with confidence for wheat or any multi- crop farm. The validity of the model was evaluated by comparing the output of the model with field observed data collected from various farms. Results revealed that there was no significant difference ($P > 0.01$) between the observed and predicted finish day as presented in Table 1. The results were in agreement with the results obtained by Cheng et al. (1992) who mentioned that, to test program validity it is always preferable to employ statistical tools for comparison and judgment while verification is concerned with establishing whether the program is a true or sound representation of reality.

Sensitivity analysis of linear program (LP) solution

Sensitivity analysis was carried to investigate how (LP) solution is sensitive to change in data. The output of simplex method gives information about what happens when we change the right hand side (RHS) of a constraint equations on the objective function (max) value and on decision variables. Table 2 showed the sensitivity analysis of (LP) for land preparation and illustrated that the change by a decrease in right hand side (RHS) budget constraint (SDG) translated into changes in the feasible region of the solution, and it gives us a new optimal solution with a new objective value lower than the first optimal solution (109.02 ha/h - 59961 ha/season). On the other hand, decreasing the (RHS) number of available implements constraint, a new optimal solution of new objective value is obtained (122.20 ha/h - 67210 ha/season) which is lowest than the first optimal solution and more than the second optimal solution. While increasing the (RHS) annual hours of use constraint, translated into changes in feasible solution, a new optimal solution is obtained with a new objective value (161.64 ha/h - 88902 ha/season), which is the highest optimal solution among the others.

Table 1: Validity test

Tillage implements	**Field performance**			**Total operation cost**		
	Predicted EFC	***Actual EFC***	***Comparative (%)***	***Predicted total operation costs (SDG/h)***	***Actual total operation costs (SDG/h)***	***Comparative (%)***
Chisel plow 7shanks(1.9m)	1.40	2.1	66	93419.2	125520	74
Offset disc harrow24(2.70m)	1.97	2.1	94	155038.9	177184	88
Offset disc harrow32(3.65m)	2.67	2.81	95	182657.6	273794	67

Table 2 Sensitivity analysis of linear program (LP) solution

Type of the changed constraint	**Constraints value**	**Decision variables**	**Solution value**	**Objective function (max) value**
Budget/h (SDG)	152727.27	x1	0	132.02
Available number of implements	133	x2	21	
Annual hours of use (h)	550	x3	34	
Decreasing RHS (Budget/h)	13500	x1	29.39	109.08
	133	x2	0	
	550	x3	25.61	
Decreasing RHS (total number of implements)	152272.27	X1	0	122.20
	50	X2	16	
	550	X3	34	
	152272.27	X1	0	161.64

Increasing RHS (annual hours of use)	133	X2	36	
	700	X3	34	

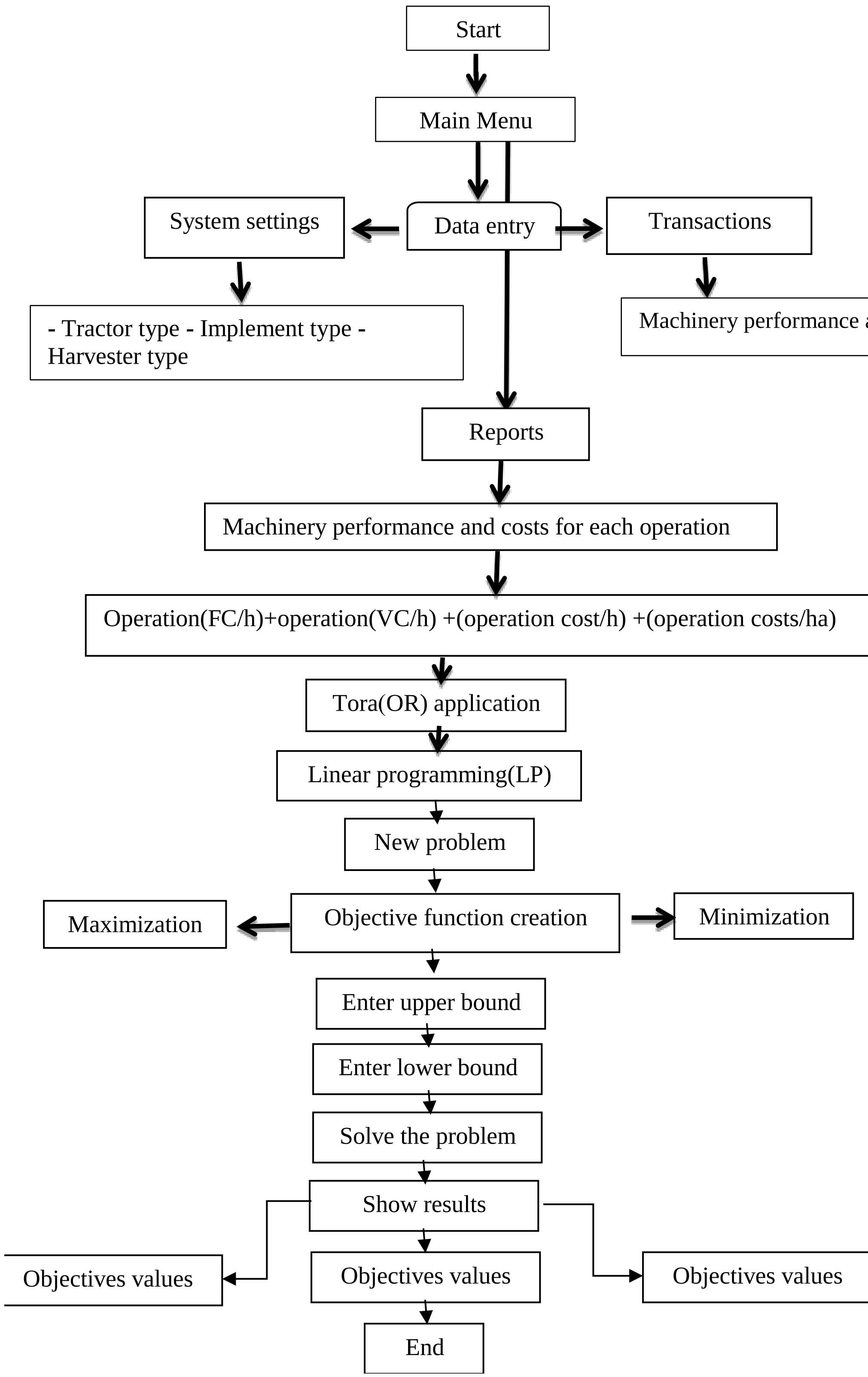

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Figure 1 Program flowchart

Machine Performance and total operation costs

As presented in Table 3, actual field capacity significantly increased as compared to predicted effective filed capacity. Actual field capacity calculated from actual records of technical performance of tillage systems. The results were in conformity with the results obtained by Siemens (1998) and Yousif (2011) who mentioned that, field capacity is significantly affected by machine working speed and field efficiency.

Table 3 also showed that, computer program predicts the lowest total operation costs as compared to the actual total operation costs. The variations between actual and predicted total operation costs may be attributed to the high market prices of spare parts due to the high percentage rate of inflation as well as 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, lack of knowledge of proper operation and maintenance and operator skills. The result were in agreement with the results obtained by Dahab (2013) who mentioned that whenever annual working hour's increase, average annual costs decrease till it reaches the lowest value then it start to increase gradually with the increase of area till the area becomes larger than the machine capacity and it should be replaced by another machine.

Effect of developed program on decision making

Developing program had ability to predict No. of required machine and No. of required labors in addition to the total operation costs and machine performance for tillage implements (Table 3). Computer program predicts 66 small size machine of chisel plow 7 shanks (1.9m) with effective field capacity (1.38776 ha/h) to cover an area of 50,000ha as presented in Table 2. Relying on small machines will increase the risk of inability to perform the field operation. Therefore, 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 Hunt (2008).

Cost optimization for land preparation

According to study objective, Tora software (linear and integer programming) was employed to solve the formulated objective function problem for land preparation, which had been formulated to optimize machinery sizes and costs and maximize production area within the assumed constraints. As presented in Tables 4, optimization operation finding an alternative with most costs effective or higher achieved performance under the given constraints by maximizing desired factors and minimizing undesired ones. The reduction in number of machines after optimization significantly decreased the overall operation cost per hour for land preparation. Hence, the model output enables Agricultural System Managers (ASM) to select, operate, and utilize different machine capacities in critical time for sensitive operations as well as to take better decisions concerning the balance between production factors (machine capacity, expected time, and available budgets) as reported by Armaghan et al. (2018).

Table 3: Machine Performance, total operation costs and decision making

Operation	Machine	Size (m)	Actual EFC (ha/h)	Predicted EFC (ha/h)	No. of required machine	No. of required labors	Cost per hour (SDG)
Land preparation	***Chisel plow7shanks***	1.90	2.01	1.38	66	132	169.8
	Offset disc harrow24	2.70	2.11	1.97	46	92	295.9
	Offset disc harrow32	3.65	2.81	2.66	34	68	332.1

Table 4: Effect of optimization on implements operation cost per hour for land preparation operation

Implement name &size	Required No. before optimization	Required No. after optimization	Operation cost (SDG/h)	Overall implements cost (SDG/h) before optimization	Overall implements cost (SDG/h) after optimization
Chisel plow 7 shanks(1.9 m)	66	0	169.8	11210.3	0
Offset disc harrow 24 (2.70 m)	46	21	295.9	13613	6214.6

Offset disc harrow 32 (3.65 m)	34	34	332.1	11291.6	11291.6
Total operation costs (SDG/h)				36114.9	17506.2

CONCLUSION

Validation, verification and sensitivity tests indicated that the program could be applied successfully to any real-life case and with confidence for wheat or any multi- crop farm. Actual field capacity significantly ($P \leq 0.05$) increased (2.1ha/h) as compared to predicted effective filed capacity (1.71ha/h). For operation costs, computer program predicts the lowest total operation costs (155,039SDG/h) using offset disc harrow24 (2.70m) while actual total operation costs using offset disc harrow 32 (3.65m) gave the highest values. Hence, computer program can be used for improving farm machinery planning and assist machinery managers in decision making. So the best combination option for land preparation to cover 50,000ha was 21 tillage systems (size 1.9m– EFC 1.39 ha/h) with 34 implements (size 3.65 m and field capacity 2.66 ha/h).

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