Utilization of optimization model for machinery planning in multi-crop farms in wad salman project-sudan

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ABSTRACT: Farm machinery management plays an important role in agricultural production because machinery contribute a major capital input cost in most agricultural business. Hence, improvement of farming system depends on development of a planning strategy that considers the determination of optimum machinery sets and power units in order to reduce farm expenses, manage agricultural machines efficiently, schedule field operations effectively and timely and decrease crop losses.To achieve these objectives a machinery management optimization model was utilized to establish machinery service centre for executing mechanized cultural operations for multi-crop farms in Wad Salman Project-Sinnar State-Sudan. Machinery operating programs and their time scheduling in the form of bar chart was generated by application of the model. The schedule of tractors demand and time for running maintenance activities were specified and optimized for the four crop rotation used in Wad Salman Project for seasons 1999/2000 to 2004/2005. Utilization of the model resulted in total direct costs saving of 49 % for the four course rotation. The model succeeded in reducing labor demand by 42%.Tractors distribution efficiency was improved slightly by 2% where the optimization model affected positively the power and machine utilization by 70% and 60%, respectively.

KEYWORDS*:* Farm machinery planning, Pert and Critical Path techniques.

INTRODUCTION

Efficient machinery management requires future planning to perform mechanized field operations at their optimum time and to estimate expected costs. To perform these objectives it is essential to acquire accurate performance data on effective machine field capacity, timeliness, and duration of field operations. A system of scheduling of field operations must be established taking into account crop types, areas, rotation, and duration of cultural practices required for each crop.

Ahmed [1] estimated numbers of machinery required for both kenaf and groundnut crops in two course rotation at Abu Naama Scheme by manual scheduling of agricultural mechanized operations using bar chart. Optimum activity scheduling can only be practiced by making use of the appropriate capacity of farm equipment , the number of available working days, the effective working time and number of acres farmed [2] Ademosun [3] reported that production of any crop on the farm involves a number of unit operations. These unit operations increase with increasing number of crops on a multi-crop farm. Some of the operations can be performed simultaneously, while others must be preceding or succeeding certain operations. In practice, the proper scheduling of these operations is not easy to be performed manually. Ismail [4,5], developed a crop production machinery model to predict machinery requirements and concluded that multiple crops in a rotation increase machinery and tractor utilization and reduce machinery costs.

Hetz and Esmay [6] used TRIGO program to analyze the effects of area, tillage system and crop rotation upon machinery system requirements and associated costs .The results showed that, all machine sizes increased with increased areas, and as the number of crops in the rotation increased, the cost per hectare decreased.

Critical Path and Pert techniques, have proved to be extremely useful as evidenced by their wide spread and acceptance in many segments of government and industry. Pert was used by Link [7] as an activity network technique applied to a farm machinery selection problem, for scheduling and probability estimation. Modeling of machinery management in multi-farms was made by Masoud [8] for estimating the size of the required machinery fleet on basis of predicting available working days. However, in these models the estimated size of needed machinery is not the optimally required size.

To answer these questions the general objective of this study was to utilize an analytical, user-friendly computer model for farm machinery management as an aid for selecting optimum machinery sets, operations costs and their scheduling program for multiple farms, in general and for Wad Salman Irrigated Project-Sudan in particular.

MATERIALS and METHODS

Model development (Main functions and features):

The Decision–aid model for agricultural machinery management is a computer interactive model developed based on the decision- aid concept which allows the user to interact directly with the program. The computer model consists of machinery programming section and machinery cost section. The main functions of the model is to compute scheduling of field operations at total minimum costs, generates the optimum machinery sets to complete field operations and calculate the total cost for each field operation. The program computes the power units and machinery fleet size from the user input parameters with help from build-in data. A monthly programming technique was used on basis of output of machinery performance and operations. Integer linear programming technique was used to evaluate program output on basis of technical machinery performance indicators, and economic parameters of tractor-machine costs. The model was equipped with Pert and Critical Path technique to analyze field operations scheduling and calculate time probability (%) to complete the scheduled operations within the programmed time.

Study site: Wad Salman Project is located on the eastern bank of the Blue Nile; about 60 km south of Sinnar and the actually cultivated area on average for the last seasons was about 10000 ha .The climate of the project area has a marked seasonal pattern. The rainy season ends in late September. The mean rainfall (1966 – 2006) was 545mm. The soils of the project area are non-saline heavy clays, typical of those of the central clay plain. The proposed crop rotation is four course rotations (sunflower, groundnut, maize and sesame) without an traditional fallow period or sorghum crop. The planning of agricultural mechanization for the rotation must take into account the present practices and experience on other schemes (Gezira and Rahad), labor requirements and availability, the local climate and the limitation on water availability for pre–irrigation. The farm machinery working program, costs of the machinery and equipment required sequence and timing of mechanized operations proposed for the four crops are required for the mechanized program.

Under the proposed organization of the project, all the agricultural machinery would be based at Wad Salman project head quarters. With critical timing of some of the operations and the large complement of machinery required, it is essential that the tractor fleet is based on the project, under the full control of the project management. All routine servicing and maintenance would be done at a well–equipped workshop to be set up at the project headquarter. Currently, there is no well defined machinery management service units at the project headquarter. For executing mechanized field operations, farmers depend on companies from private sector (Green Company and Sinnar).

Data collection and analysis:

The required input data for the machinery programming was collected for seasons 1999/2000 to 2004/2005 from primary and secondary sources. Primary data was collected using formal and personal contacts from Wad Salman irrigated project. The primary data included: typical field working speeds (km/hr), recommended field operations efficiency (%) and draft (KN/m) requirement for agricultural machines according to soil type. It also included type and size of machines and tractors

Available, crops grown, area programmed for each crop, type of field, operations, operations calendar dates, machinery capacity, i.e., output, working hours per day, cost of field operation/ha, fuel consumption, number of power units required for field operation, labor wage charge, tractor and machines service, life in hours, and contract (hiring) charge per ha or by operation and monthly budget. The secondary data was collected from the most relevant published data and periodical reports [9,10,11,12]. The secondary data collected included machinery cost data that include: purchase price ($) for tractors and machinery, interest rate of investment on machinery (%), taxes, insurance, shelter (TIS %) and R&M rate%. All collected data were given for this study in the form of tables and displayed on the computer screen when necessary during the entry of input data. Statistical techniques used to analyze the model result data include: t-test, chi-sq., and analysis of variance. Linear programming as operation research tool and Pert theory for determination of Critical Path which are part of the model building and were utilized to evaluate the data using probability analysis.

RESULTS and DISCUSSION

Model utilization for design of machinery service unit: For the case of establishing a new machinery service unit and management system in Wad Salman Project in the Blue Nile the available input data for four course rotation were entered in the model to generate machinery scheduling program and machinery time flow bar chart, the operating costs and technical parameters (Tables 1 and 2).Table 2 shows that the peak tractor demand is 43 tractors in late October. The time schedule reflects work seasonality where it is at maximum activity in the period of March to early April with minimum demand of 36 tractors and maximum demand of 40

During this period the project manager may plan to fill tractor deficiency by hiring 7 tractors from private sector. To maintain the agricultural machinery, it is practical to utilize the time of no field works (two periods: end of December to early February and July to early September). To reduce the tractor demand and to improve other technical parameters (labor parameters, tractor distribution efficiency and power and machine utilization) the optimization module was employed. As given in table 3 the model succeeded in reducing labor demand by 42%. Tractor distribution efficiency was improved slightly by 2% where the optimization model affected

positively the power and machine

utilization by 70% and 60%, respectively.

Table 1.Program of Work for Wad Salman Project (input Data)

Agricultural Operation	Area (fed)	Starting date	Finishing date	Days available	Output (fed/day)	No. of Tractors	Working hrs/year	Fuel cons. Gal/fed
a/ Sunflower								
Heavy disking (120 hp)	6000	15/9	30/10	42	100	2	1320	1.1
Light Disking (75 hp)	6000	20/9	30/10	38	60	3	2200	0.8
Leveling	6000	20/9	5/11	43	60	3	2200	0.5
Ridging	6000	25/9	10/11	44	60	3	1650	0.5
Planting	6000	1/10	15/11	45	35	4	2829	0.4
Fertilizer + G. ridging	6000	21/10	7/12	48	35	4	2829	0.6
Harvesting	6000	30/1	28/2	28	180	1	733	1.1
Abu VI Construction	6000	25/9	10/11	44	440	1	871	0.03
Abu XX Construction	6000	15/9	5/11	47	2600	1	930	0.1
b/G/N								
Light disking (75 hp)	6000	1/3	1/5	61	60	2	2200	0.8
Leveling	6000	10/3	5/5	55	60	2	2200	0.5
Ridging	6000	15/3	10/5	55	60	2	1650	0.5
Planting	6000	15/5	1/6	15	35	13	2829	0.4
Green ridging	6000	10/6	25/6	13	35	15	2829	0.6
Harvesting – Digging	6000	30/9	10/10	10	30	22	4400	1
Harvesting-threshing	6000	5/10	15/10	10	30	22	4400	0.5
Abu VI Construction	6000	15/3	10/5	55	440	1	1089	0.03
Abu XX Construction	6000	1/3	5/5	65	2600	1	1287	1

Table 2 . Continued --program of work for Wad Salman Project (input Data)

Agricultural Operation	Area (fed)	Starting date	Finishing date	Days available	Output (fed/day)	No. of Tractors	Working h/year	Fuel cons. Gal/fed
a/Maize								
Light Disking (75 hp)	6000	1/10	30/10	30	60	4	2200	0.8
Leveling	6000	1/10	5/11	24	60	5	2200	0.5
Ridging	6000	25/10	10/11	16	60	7	1650	0.5
Planting	6000	1/11	15/11	15	35	13	2829	0.4
Harvesting	6000	30/1	15/2	16	80	5	1650	1.1
Abu VI Construction	600	10/10	5/11	24	440	1	4752	0.03
Abu XX Construction	60000	1/10	5/11	35	2600	1	693	0.1
b/ Sesame								
Heavy disking (120 hp)	6000	10/2	30/3	48	100	1	1320	1.1
Light disking (75 hp)	6000	15/2	15/4	59	60	2	2200	0.8
Leveling	6000	20/2	20/4	59	60	2	2200	0.5
Ridging	6000	25/2	25/5	87	60	1	1650	0.5
Split ridging	6000	25/2	15/6	18	60	6	2200	0.6
Planting	6000	1/6	20/6	17	35	11	2829	0.4
Harvesting	6000	10/9	30/9	16	50	8	2640	0.5
Abu VI Construction	6000	25/2	25/5	87	440	1	1723	0.03
Abu XX Construction	6000	10/2	15/4	64	260	1	1267	0.1

Table 3 Program Time Schedule for Wad Salman Project

Crc	Operatio	Jan	Feb	Mar	Apr	Ma	June	Jul	Aug	Sept	Oct	No	Dec

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n					y		y				v	
	31*	28	31	30	29	26	21	21	24	30	30	31
Sunflower									→	→	→	
Heavy disking												
Light Disking									→	→	→	
Leveling										→	→	
Ridging										→	→	
planting										→	→	→
Fertilizer										→	→	→
Abu VI Construction									→	→	→	→
Abu XX Construction									→	→	→	
a/G/N												
Light disking			→	→	→							
Leveling												
Ridging				→	→	→						
planting												
Green Ridging												
Abu VI Construction				→	→	→	→					
Abu XX Construction			→	→	→							
b/ Sesame												
Heavy disking												
Light disking		→	→	→	→							
Leveling			→	→	→							
Ridging			→	→	→	→	→					
Split ridging												
planting (seed drill)												
Abu VI Construction	→	→	→	→	→							
Abu XX Construction												
C /Maize												
Light disking												
Leveling												

Ridging planting																								
Abu VI Construction																								
AbuXX Construction																								
Total Number	0	0	6	25	39	40	36	22	17	29	17	15	0	0	0	0	0	13	22	43	33	4	4	0

These results are in agreement with the values cited by Atia [13] for Africa and Asia, and that given by Nor [14] for Gazira Scheme. Hence, this efficient scheduling program generated by the model application eliminates the need to hire additional tractors. Moreover, application of the model resulted in improving direct costs elements. As given in Table 4 labor cost, fuel cost, repair and maintenance, depreciation, and total costs are improved by 69%, 48%, 52%, 65%, and 50%, respectively. Similar results were reported by Ali [15] when she applied a computer program for machinery planning and scheduling in the multi-crop farms of Rahad Scheme-Sudan.

Table 4 . Technical evaluation for Wad Salman Project before and after optimization

Technical parameter	Before optimization	After optimization
Labor parameter	0.012	0.0070
Power – area utilization (Kw/ha)	0.080	0.0240
Tractor distribution efficiency %	0.960	0.9400
Machine utilization parameter	0.001	0.0004

Moreover, application of the model resulted in improving direct costs elements. As given in Table 5 labor cost, fuel cost, repair and maintenance, depreciation, and total costs are improved by 69%, 48%, 52%, 65%, and 50%, respectively. Similar results were reported by Ali [15] when she applied a computer program for machinery planning and scheduling in the multi-crop farms of Rahad Scheme-Sudan.............................

Table 5. Wad Salman Agricultural Project – Direct costs before and after optimization (Four course rotation)

Parameters	Before Optimization	After Optimization
Labor cost (US. $ / ha)	35318	10893
Fuel cost (US. $ / ha)	2575331	1334857
Repair and Maintenance (US. $ / ha)	227123	108087
Depreciation (US. $ / ha)	219426	76611
Total costs (US. $ / ha)	3057198	1530447

CONCLUSIONS

The results of the study indicated that it is possible to utilize the model to generate a complete machinery scheduling program for building a new machinery service center. For the case of intensive cropping in Wad Salman Project; application of the model succeeded in optimizing the estimation of machinery fleet size, and determination of total costs for mechanized cultural operations.

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