



FARM MACHINERY SIZE AND COST MANAGEMENT SYSTEM IN THE RAIN FED SECTOR OF GEDARIF AREA

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Abstract: Computer programs now can help greatly to solve complex machinery management problems and enable managers to take better decisions concerning the balance between production factors (machine capacity, expected time, and available budgets).

The objective of this study was to design and develop a computer system to be used as a decision-making tool to manage large scale schemes in Gedaref rain fed agriculture. The system designed to estimate variable capacities of machines on the basis of per hour unit area according to the recognized standard formulas and parameters and also to calculate fixed, variable and total costs of farm machinery. Published and field local data of machinery prices and performance in Gedaref area was used in the development of the system.

The predictions of the system which included machinery costs in SDG/h; and effective field capacity (EFC) in ha/h; were compared well with actual data and the comparative percentage was within 88.8% to 99%. The obtained results of the computation were verified and validated for applications. The system was tested for accuracy and sensitivity analysis was carried out. It was concluded that the developed system was user oriented, dynamic and responded well to alterations in the input data which affected the output parameters.

Keywords: Farm Machinery, Computer programs, cost management, Effective field capacity, Verification and Validation.

INTRODUCTION

Exploiting the full potential of expensive high output equipment involve better machinery management as well as better agribusiness management. It is no longer sufficient to match individual machines by trial and error. The financial penalty of an incorrect purchase is considerable and duration of mistake more protracted as machines are replaced less frequently (Witeny, 1988). Complete analysis of mechanization systems is sufficiently complex and time consuming to require the application of computer programs and understanding of the practical basis of the analysis is essential for the credibility of the output of the results.

Optimum farm machinery management occurs when the economic performance of the total machine system has been maximized. Successful business farm obtained when machinery considered as only tools of production and operated in a business-like manner to produce crops at a profit (Hunt, 2008). The economic performance of a machinery system is measured in terms of money per unit of output (cost/ha), and it composed of : machine, power, and operator performance.

Putting together an ideal machinery system is not easy, it need to be given support on the aspect of introducing advanced techniques like computers and software to be used as decision making aid tool to obtain the best solutions regarding control over machinery fleets in terms of suitable sizes, saving of costs, and utilization of available working days (Aderoba 1989, Isik and Sabanci 1993, Yousif 2011).

Opportunities now exist to augment managerial experience with analytical procedures to obtain more accurate estimate of machinery performance, operating costs with respect to available working hours (Edwards 2008). A lot of publications showed that computer program were used successfully to select farm machinery size as well as to estimate the whole costs (Ismail, 1998, Alam et al. 2001, Dahab and Omiaama M. 2006, Yousif and Dahab, 2010). Therefore, computers have become increasingly an accepted farm management tool and they are ranged from simple programs to very complicated and more compact packages that assist in farm management decision making (Bol et al., 2006).

The semi-mechanized rain fed agriculture sector in Sudan has been considered one of the viable sectors which may achieve food security. The area covers about (9) million hectares located in central clay plains, western and southern parts of the country. Sorghum, sesame,

sunflower, cotton, and millet are the main crops produced in the area. Towards the goal of effective contribution for strengthening the role of mechanized rain fed agriculture in Gedaref region. There are many farm tractors and farm machineries which are used to carry out the field operation within the available working hours and of variable costs. Management and selection of these machinery is complicated and need more powerful tools for proper decision making, therefore the main objectives of this study were;

(1) to design and development a friendly user oriented computer system to be used as a decision-making tool to predict farm machinery sizes and costs with respect to variable machine parameters

(2) to compare the computer system predictions with actual data from the field to validate the program

MATERIALS AND METHODS

Gedaref state was selected to conduct the study. It lays in the Eastern region of Sudan between latitudes 120 and 150 north, and longitudes 340 – 360 East. An estimated annual cultivated area is about 2.4 million hectares, and the maximum area reached 3 million hectares (MFC, 2006-2011). The soil in the area of the study is vertisols of the Central Clay Plains (CCP) of Sudan. The area has had an annual average rainfall of about 600 millimeters. There are different types and makes of tractors and machineries are used in the sector to carry out farm operations (from land preparation to crops harvest).

Program System requirements

Pc. Computer, processor Intel® Core™ i3-2350M CPU@2.30GHz. Installed memory (RAM): 4.00GB. System type: 64.bit operation system was used for the study.

- 1- The system needed installation of Microsoft office package which includes Excel, and Oracle 6 language, which work within Windows-7 or windows xp operational system medium.
- 2- Linear and integer programming software(simplex method).
- 3- System of International Units (SI) was used and in some instances followed by Metric Units in brackets, because expected engaged people in agriculture may use both systems.
- 4- All calculations of machinery costs were in Sudanese local currency (SDG).

Published data and information of standard machinery technical parameters were used to aid the users in correct utilization and development of the system (ASAE 2009)

Computer program development

The program was mainly designed and developed to be used as a decision-making tool to manage risks of performance in mechanized farm operations in rain fed sector and to help agribusiness managers and agricultural engineers to plan and successfully implement mechanized production operations in a timely fashion, and with optimization of available production resources. The program contains lists of different types of tractors and matched machinery. The lists include data of tractors power (kw), life span, purchase prices, and expected hours of use per year. Machinery data files contains the desired types of implements, which may be used to perform field operations, and information about the working width, operation speed, expected field efficiency..

Program description

The program allows users to interact with its components through input menus. It is immediately activated by the entered data then, expected results and reports can be obtained, Fig 1 shows a general flow diagram of the system. The computer system consists of machinery performance data section, and machinery operating cost section. Performance used to calculate machine capacities of different types entered by the user. The other section of the program used to compute costs of farm operations. According to the entered data, reports are ready to be displayed in tables to show resulted reports of machinery capacities in ha/hr., and different operation costs in SDG/h.

Program functions

The program functions are as follows:

- 1- It calculates different capacities of machines from the stored data files within the input parameters given by the program user.
- 2- The program computes ownership costs, and variable operating costs on an hourly basis of costs.
- 3- The program outputs include comprehensive reports of estimated costs per hour for both tractors and, different machinery sizes.
- 4- The program evaluates performance of machinery and its related costs, which can be used in machinery selection and replacement strategies.

Program features

Program features as shown in Fig 3.3 can be as follows:

- 1- The program was a menu driven by the interaction between the user and input data menu.
- 2- All permitted program users according to their status have identity numbers and names to enable them interact with the program through the entry data menus.
- 3- The user input data entry is made directly to the screen. The user has the choice to use the default data stored in program files or to enter his/her own data which could be entered directly to the selected menu.
- 4- From the main menu the user can select the relevant path to execute his/her selected option. The options may be tractors or machinery list menu, operations list, costs menu or, transactions menu.
- 5- The program was preloaded with the parameters and equations adopted by ASAE (2006); Hunt (2008); Witney (1988). The equations are used to compute machine capacities, estimated costs based on international system units (SI) as given in following paragraph.
- 6- The program outputs can be displayed in report screens or printed out or saved. The expected reports include tractors operating costs per hour, machinery operating cost, and field operations costs per hour.

Program input data files

1- Tractors file:

The file contains a list of different types of tractors with matched implements within the program. It has space for more than eight tractor sizes range from 60 to 165 kW. The file contains information of tractor power, expected hours of use per year, life span, and purchase price. The information in the file may be changed by the program user and stored.

2- Implements file:

It contains a list of implements that may be used to perform the desired farm operations in the main rain fed agriculture in the belt zone of vertisols soils in Sudan. The information in the file includes machine name and size, working speed, estimated field efficiency, and the required power. The information in the file may be changed by the program user and stored.

3- Farm operations file:

The most important information input by the user is the list of desired field operations to be executed and the related to these operations. One of the program objectives is to select the required machinery to compete desired operations in a timely fashion with least costs. The file contains a list of farm operations can be viewed on screen. The data include operation type, machine, start and end dates, the available working hours/day,

4. Economic files

In addition to the purchase price for each machine and effective field capacity of each power unit/attachments combinations (matching implements to tractors), economic data common to each machine are needed to estimate the fixed and variable costs of machines. Economic data stored in this file include labor cost SDG/h, depreciation, tax, insurance, shelter, returns on investment rates, repair and maintenance, fuel and lubricants, and purchase price.

Program process and transformation functions

The program functions composed of following modules:

Machinery performance equation

- **Machine capacity:** A method of measuring machine capacity is given by ASAE Standards (2009); Hunt (2008) and Witney (1988).

$$\text{Effective field capacity (EFC)} = \frac{S \cdot W \cdot E}{C}$$

Where:

EFC = Effective field capacity (ha/h).

S = machine working speed (km/h).

W = machine width (m).

E = field efficiency (%).

C = constant = 10

Farm operation cost determination module

The program was designed to compute costs of power units and machinery. Computation of cost depends on user input data and based on mathematical equations of ASAE Standards (2009); Hunt (2008) and Dahab (2000).

Tractor cost calculations

Fixed costs (FC) (ownership cost):

1- Depreciation, straight-line method is used in the model to calculate depreciation due to its simplicity.

$$D = \frac{PP - S}{N}$$

Where:

D = annual depreciation value (SDG)

PP = purchase price (SDG)

S = salvage value (SDG)

N = tractor life span years (assumed 12years)

S = 10% ×(PP) or = (0.1×(PP) ---- (Dahab 2000)

2- Return on investment (ROI):

$$I = \frac{PP + S}{2} \times R$$

Where:

I = annual returns on investment (SDG)

R = annual interest rate (12% × PP)

ROI = 12%×PP (assumed depends on Central Bank of Sudan monetary regulations)

3- Taxes, insurance, and shelter (TIS): calculated as percentage of purchase price as follows:

Tax = 1.5%×PP

Insurance = 0.25%×PP

Shelter = 1%×PP

TIS = (0.0275×PP) ----- (Dahab 2000)

Total annual fixed costs (TFC) = (0.167×PP) ----- (Dahab, 2000)

TFC = (D + ROI + TIS)

Variable costs

Variable costs are calculated on per hour basis and include the following:

1- Annual repair and maintenance (R&M): It is computed as a percentage of purchase price as follows:

$$R\&M = 15\% \times PP$$

2- Fuel and lubricants (F&O): It can be calculated as follows:

Fuel cost = [fuel consumption liter/h \times fuel price]SDG/liter

Oil cost = [10% \times fuel cost]

3- Labor cost: it depends on market current rates of casual labor salaries.

Total variable costs = [R&M+FC+OC+LC]

Total annual cost (AC) is the summation of total fixed total + variable cost.

Unit area cost per hour can be derived from the following relation:

Unit area cost/hour = [operation cost per hr] \div [machine capacity]

Computer system validation and verification

Model validation is the process by which the model is tested for completeness, accuracy and forecasting ability. Validation concerns with effectiveness or suitability for satisfying the purpose of the model building to calculate different machine capacities and performance costs according to the used equations.

Verification is the process by which all equations are tested for accuracy in terms of answering the question of “Is the formula calculating the exact correct answer? This implies testing all formulas for arithmetic accuracy as well as testing if all the linkages between different equations are correct. According to Richardson (2003) verification of a model is concerned with establishing whether the model is true or correctly represents reality.

Table 1. System technical specification

Item	System	Win-Qsb
System language	Oracle	Excel
System type	Button menu driven	Button menu driven and spreadsheet user
System dependability	Windows-7	Windows xp
System interface	Main menu	Spreadsheet
Used units	SI- units	SI-units
Required space	15MB	4MB

Statistical list of the system accuracy

To test the system accuracy, a comparison was carried between computer system predicted results, and that calculated by Excel 2007 application. T-Test statistical technique is employed to detect computer program accuracy.

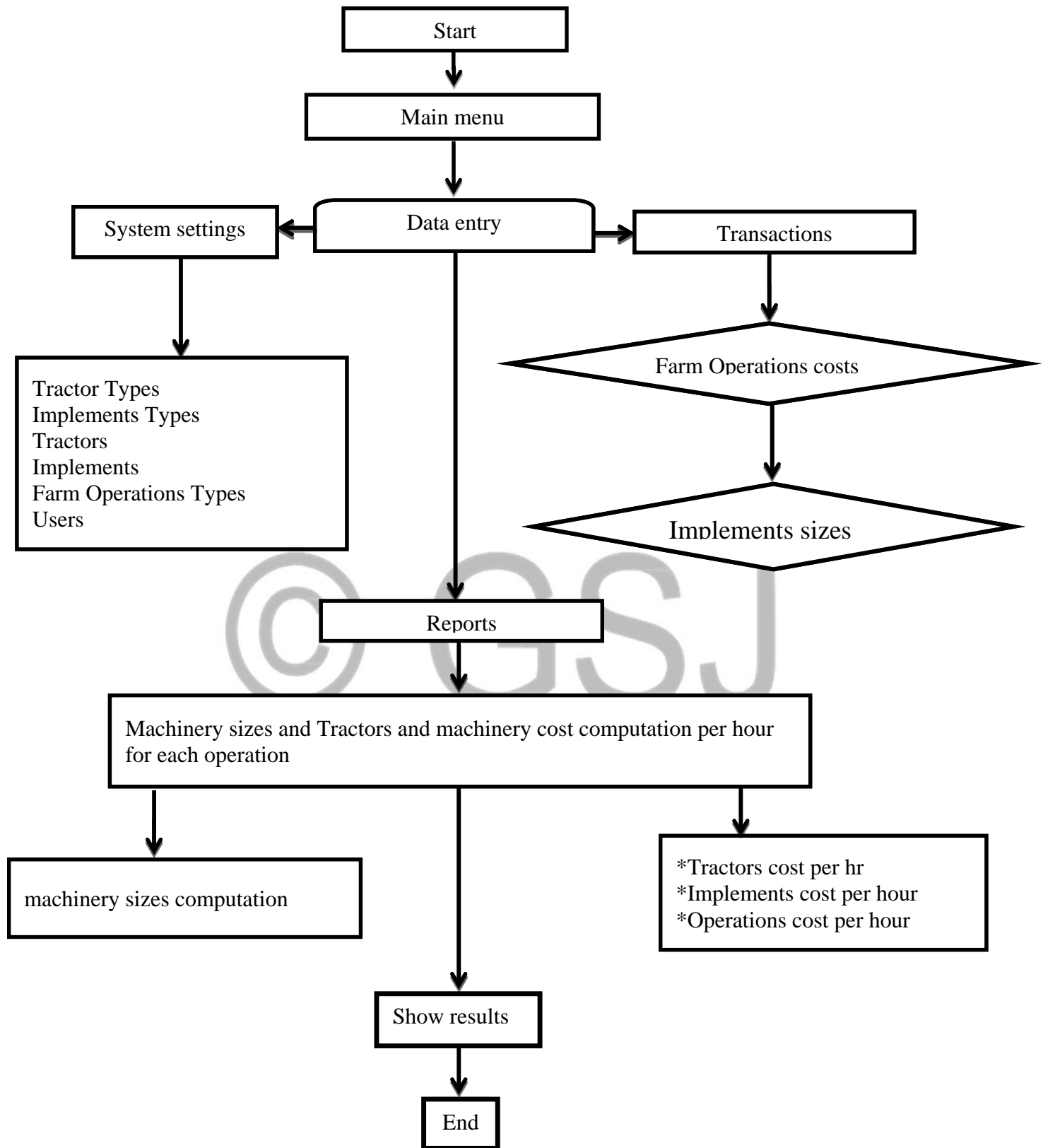


Fig 1. Program flow chart

RESULTS AND DISCUSSION

System verification to estimate machinery performance

Published data of test reports (MAI, 2008-2011) was used to verify the model accuracy to calculate different machines capacities. Implement width (m), speed (km/h), and expected field efficiency (%) are the input variables, which were used to verify output parameters of effective field capacity.

Five types of implements, wide level disk (WLD), offset disk harrow(18-discs), chisel plow7-shanks, 4-row crop planter, and 4-row ridger have been used to compare their actual and predicted EFC to test the model validity. The results of comparison showed a very little difference between the predicted and actual field capacities for all investigated implements (Table 1).

Table 1. System verification to estimate machinery performance

Machine type	Input data			Output data	
	Width (m)	Speed (km/h)	Efficiency (%)	Actual (ha/h)	Predicted (ha/h)
WLD	3.6	9	75	2.66	2.43
Offset disk18-discs	2.2	9	85	1.42	1.68
Chisel plow	1.9	8	85	1.29	1.29
4-Row crop planter	3.2	9	65	1.87	1.87
4-Row ridger	3.2	9.54	80	2.43	2.44

System verification to estimate machinery costs

Data obtain from Agricultural Bank of Sudan (ABS, 2008), and other agents of machinery companies were used to test the system accuracy for calculating field machinery costs in terms of Sudanese pounds per hour (SDG/h). Purchase price (PP), expected annual hours of machine use, amount of consumed diesel fuel (L/h), fuel unit price (SDG/L), and the needed drawbar power (kW) are the input variables of a tractor with 3.06m width WLD. The obtained results were found very close to the actual ones. The program managed to compute the operating costs for both tractors and implements according to the preloaded relations and parameters (Table 2).

Table 2. System verification to estimate machinery costs

Input variables:	Tractor and machine type	
	Tractor	WLD 3.6 m
Purchase price (SDG)	162000	60000
Years of life (years)	12	7
Hours of use	540	250
Fuel consumption(L/h)	11	0
Fuel price(SDG/L)	3.11	0
Output parameters:	Tractor	WLD
Total fixed costs(TFC)	8.27	1.83
Total variable costs(TVC)	41.63	1.23
Total Actual costs(TC)	52.96	3.06
Total predicted costs	51.04	3.00

System predictions to estimate machinery capacity

The developed program was used to predict EFC of five types of machinery include wide level disk (WLD), offset disk harrow (18-discs), chisel plow (7-shanks), 4-row crop planter, and 4-row ridger. The actual EFC was compared with the program predicted results to test the system validity. The comparison showed a very little difference according to the used parameters and equations to estimate the investigated machine capacities (Table 2).

Table 3. Predicted and actual field capacity (ha/h)

Machine type	Machine capacity (EFC)		Comparative%
	Predicted	Actual	
Wide level disk	2.43	2.66	91.4
Offset disk harrow	1.38	1.42	97.2
Chisel plow	1.29	1.29	100
4-row crop planter	1.66	1.87	88.8
4-row ridger	2.44	2.43	100

System predictions to estimate machinery costs

Model validation involves usage of some statistical measures to compare the predicted results of model with the actual ones in real life. Input of total costs variables for different power tractors include: depreciation (D), tax (T), insurance (I), shelter(S), returns on investment (ROI), fuel and oil (F&O), repair and maintenance (R&M), and labor (L) were used to compare the program predicted results with the actual ones. Table 3 showed no significant difference between

predicted and actual results. This revealed that the program was valid to calculate total and variable costs for different field operations correctly.

Table 4. System validation to estimate machinery costs

Tractor power (kW)	Predicted costs	Actual costs	Comparative%
60 kw(80hp)	51.07	52.96	97.7
104 kw(140hp)	109.63	121.37	90
151kw(202hp)	157.85	171.14	92

Comparison between predicted and actual fuel consumption (L/h)

One of the model objectives is to estimate fuel consumed by machinery (L/h) to perform programmed mechanized farm operations. Table 5 illustrates the comparison results between predicted and actual fuel consumption for WLD, offset disk harrow-18 discs, chisel plow, 4- row crop planter, and ridger. Results show no significant difference between predicted and actual fuel consumption (Table 5).

Table 5. Comparison between predicted and actual fuel consumption (L/h)

Machine type	Predicted (L/h)	Actual (L/h)	Comparative%
WLD	10.98	11.12	98
Offset disk harrow	8.33	8.74	95
Chisel plow	6.99	7.18	97
4-row crop planter	3.98	3.8	95
Ridger	5.99	7.7	77

Sensitivity analysis of the system to estimate machinery performance

The sensitivity analysis of the system was carried to show the effect of changing one or more of the input parameters on the program outputs. The input variables include, machine size (m), speed (km/h), and expected efficiency (%).

Effect of increasing machine width or changing field working speed (km/h)

Three sizes of WLD are used to show the increase of the implement width on its capacity. The system responded to changes in input variables as shown in Table 6, the EFC of the machine increases with the increase in its width.

Table 6 showed that any increase in the machine working speed increases its EFC, but this increase should be limited to an extent that keeps the operation to its optimum quality.

Table 6. Effect of changing field working speed (km/h) or machine width (m)

Machine type	Width (m)	Speed (km/h)	Efficiency (%)	EFC (ha/h)
WLD- single	3.6	8	70	2.02
		10	70	2.52
WLD- double	7.2	8	70	4.03
		10	70	5.04
WLD-triple	11	8	70	6.16
		10	70	7.70

Sensitivity analysis for (costs)

Sensitivity analysis of the system was carried to detect its ability to response to changes in variables values, which used as input data and its effect on the model output. Purchase prices (SDG), hours of use, required power (kW) are used as input variables. The following tables show the effects on the model outputs.

Effect of changing purchase price or on number of working hour's total costs

Machinery prices always change due to different economic factors. When the new machine price (SDG) entered, the system responded and all cost calculations were resettled according to the changed price. Table 7 showed that, total cost increased with increase in purchase price.

Whenever annual working hours 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. Table 7 showed that total costs was increased with the decrease in hours of use, as hrs for use decreased by 44%, the fixed costs increased by only 9%.

Table 7. Effect of changing purchase price or number of working hours on total costs

Machine type	Purchase price	Hours of use	Needed power	Predicted cost
WLD-3.6 m	60000	540	56	60.71
WLD-3.6 m	80000	540	56	71.66
WLD-3.6 m	60000	300	56	78.26

Statistical list of the system accuracy

T-Test statistical techniques was applied to test computer program system accuracy compared with that of Excel .7 software to calculate machinery EFC, and total operations cost

within the adopted parameters and equations .Cost parameters includes: depreciation (D), returns on investment (ROI), tax, insurance, shelter (TIS) and total variable cost (TVC). Results showed that there was no difference between the developed computer model and Excel application, and the Null-hypothesis was accepted

CONCLUSIONS

The following conclusions may be drawn from the present study:

- 1- A computer system program was designed and developed to calculate and predict sizes, fixed and variable costs for different farm machine and tractors.
- 2- The system was validated and verified. The obtained results showed that the system was capable to compute machinery and farm operations costs correctly,
- 3- Comparisons between system results and actual ones showed no significant differences

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