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ORIGINAL ARTICLES

A program for Predicting Performance of Agricultural Machinery in Visual Basic

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ABSTRACT

Agricultural Machinery performance program that predicts field efficiency, field capacity, selection of optimum equipment, draft power required to operate machines and PTO power was developed to meet the user requirements for machinery management and as educational and research tool. The program was written in Visual Basic programming language as user-friendly interactive program. The program provides an intuitive user interface by linking to built-in databases were made available for the standard values of machinery specifications parameters to predict the performance of a selected agricultural machine otherwise, the user is prompt to enter his relevant input data for the model. The program has been statistically validated in comparison to the published data from the ASAE (2003) and proven to be user friendly and efficient. The program was applied successfully to Gezira and Rahad irrigated schemes in the central clay plains of Sudan for predicting technical performance of three tillage implements: Standard Disk Plow, Offset and Tandem Disk Harrows.

Key words: Machinery technical performance; Soil-crop-machine parameters; Machine productivity; Machinery management; Simulation; Visual programming.

Introduction

Studies by UNEP (1998) indicated that the under developed countries possess 74% of the useable agricultural areas worldwide and more than 27% of the world agricultural tractors. To cultivate these areas to feed their population it is important for the under developed countries to direct high sums of money for buying new machines and equipment and replace old ones or to improve performance of existing machines. In fact, such less developed countries are frequently facing acute financing problems. This situation necessitates more effective machinery management. 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. For equipment that work best one year may not work well the next, because of changes in weather conditions or crop production practices. Improvements in design may make older equipment obsolete. Moreover, the number of hectares being farmed or the amount of labor available may change. Because many of these variables are unpredictable, the goal of a good machinery manager should be to have a monitoring system that is flexible enough to adapt to a range of weather and crop conditions while minimizing long-run costs and production risks (Edwards, 2001). Computer models and simulation programs may be used to determine the relative importance of many factors affecting field performance of field machinery without conducting expensive, as well as time consuming, field tests. They also help researchers and manufacturers to improve the tractor performance by comparing and analyzing various parameters that influence tractor performance. The rapid progress in developing new software and the trend in enhancing the existing application software and programming languages always tend to facilitate the interaction between users and computers. As a result, many computer modeling and simulation programs have been developed.

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Considerable research has been conducted in developing computer based models and simulation programs to service the educational and research needs in the farm machinery area of agricultural engineering (Al-Hamed and Al-Janobi, 2001).

Agricultural machinery management is the part of farm management that deals with the optimization of equipment phases of agricultural production (Sogaard and Sorensen, 1996). It is concerned with the efficient selection, operation, repair and maintenance, and replacement of machinery. The main aim of management studies is to complete a certain field operation effectively, during a specific period of time, and at a minimum total cost. Participating in a wide range of operations, from initial operations of soil cultivation to harvesting, agricultural machinery may represent from 40 to 50 % of the total production cost. Therefore, the right choices of equipment coupled with its rational use are extremely important decision-making factors in farm management.

Zoz (1970) presented a graphical method for predicting drawbar pull, drawbar power, travel speed, and travel reduction of 2WD tractors under various soil conditions. Wismer and Luth (1972) outlined a set of empirical equations for the tractive performance of tires on agricultural (cohesive-frictional) soils.
Clark (1985) and Brixius (1987) proposed generalized forms of the Wismer and Luth model for a wider range of actual field conditions. Zoz (1987) developed Lotus templates for predicting 2WD and 4WD: MFWD tractor performance and Grisso *et al*. (1992) demonstrated the flexibility of templates introduced by Zoz (1987) as an educational tool. Hamed *et al*. (1994) revised the Lotus compatible templates from the Zoz (1987) spreadsheets for predicting performance of tractors with both bias-ply and radial tires on agricultural soils. Noble and Course (1993) develop several spreadsheets programs to assist farm managers in decision making about how to efficiently manage their machinery (determination of leasing, hiring and determination of cost of operation).

Edwards (2001) indicated that each piece of machinery must perform adequately and reliably under a variety of conditions or it is a poor investment, regardless of its cost. Tillage implements should prepare a satisfactory seedbed while conserving moisture, destroying early weed growth, and minimizing erosion potential. Planters and seeders should provide consistent seed placement and population, and properly apply pesticides and fertilizers. Harvesting equipment must harvest clean, undamaged grain while minimizing field losses.

The performance of a machine often depends on the skill of the operator or on weather and soil conditions (Edwards, 2001). Nevertheless, differences among machines can be evaluated through field trials, research reports, and personal experience.

Performance rates for field machines depend upon achievable field speeds and upon the efficient use of time (ASAE, 2001). Field speeds may be limited by heavy yields, rough ground, and inadequacy of operator control. Small or irregularly shaped fields, heavy yields, and raised capacity machines may cause a substantial reduction in field efficiency.

The objective of this study was to develop agricultural machinery performance program in Visual Basic as an integrated, decision-making aid, to help machinery owners to efficiently manage their farm equipments.
Specifically, the program has to predict the performance parameters including field efficiency, field capacity, selection of optimum equipment, draft power required to operate machines and power at take-off shaft for a given equipment soil resistance, by accessing databases concerning tractor specification, soil and farm information.

Materials and Methods

Program Development:

Visual programming provides a set of screens, object buttons, scroll bars, and menus. The objects can be positioned on a form, and their behaviors are described through the use of a scripting language associated with each one. Visual programming is used for applications development, systems design, and simulations. They let users put more effort into solving their particular problem rather than learning about a programming language. As it seems to be an excellent tool for developing flexible and user friendly software for various applications, it is considered as a new approach to develop a program for predicting tractor performance (Al-Hamed and Al-Janobi, 2001).

A flexible, object oriented, user friendly, application program was developed as decision-aid for improving machinery management via evaluation of the technical field performance of machines. The model is an interactive program where the user is prompt to enter his relevant input data for the model. Built-in data were made available for the standard values of machinery specifications parameters.

The developed program requires the installation of the Microsoft Office Access 2003 and Visual Basic which works within the Windows XP operational system medium. The standard values of machinery technical parameters, which were adapted from ASAE (2007) data, are used as view look-up tables, to aid the user in the correct utilization of the program.

The machinery performance program mainly consists of three sections, menu, Edit: View, and simulate as shown in Fig. 1. Each section has a number of subsections based on the design criteria for the program development. The program starts with an opening screen. The screen consists of a menu with options About and Exit, a panel with Edit: View button to access three databases and a simulate button to predict the performance of the selected machine. Corresponding to a selected machine and model, the various inputs from the different databases can be fed to the simulation part of the performance program. The input data set could be displayed to the user for any change if needed without affecting the databases. The performance of the selected machine may be predicted by clicking the simulate button (Vide: Fig. 1) on the opening screen. The flow diagram of the simulation part of the program is shown in Fig. 1. Prediction of performance parameters was done for a selected machine and model.

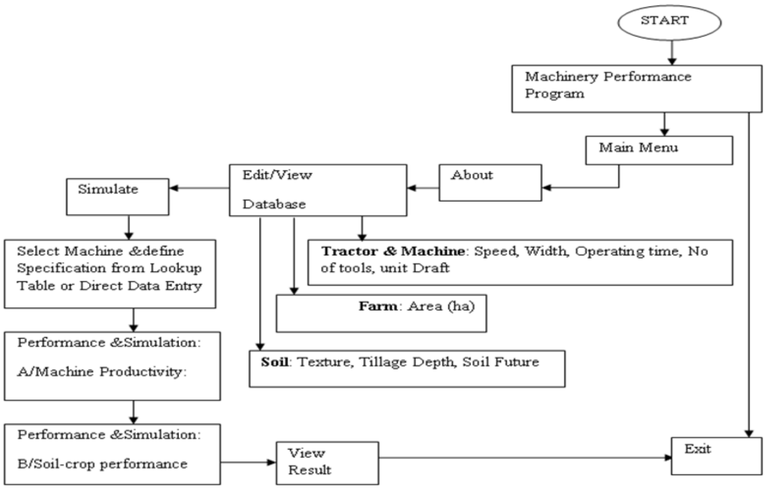

Fig. 1: Flow diagram of machinery performance program

Performance Indicators:

The computer program, Predicts the technical performance of field machinery by determining machine productivity (theoretical field capacity, effective field efficiency and working rate) and soil-crop-machine parameters (soil resistance, drawbar or propulsion power, power at take-off shaft and unit power).

A-Machine productivity:
1-Theoretical Field Capacity (ha/h):

Theoretical field capacity (TFC) is the maximum possible capacity obtainable at a given speed, assuming the machine is using its full width, and it can be determined with the following equation (Ajit *et al*, 2006):

$$TFC, ha/hr = \frac{Speed, km/hr \times Width, m}{10} \qquad (1)$$

2- Effective Field Capacity (ha/h):

The effective field capacity (EFC) is always less than theoretical field capacity, and the best way to determine EFC of a machine is to make an accurate check of the area actually covered or weight handled over a long period of time (John Deere, 1999). It could be expressed in hectares per hour as follows:

$$EFC, ha/hr = \frac{Speed, km/hr \times Width, m}{10} \times FE, percent \qquad (2)$$

Where: FE = Field efficiency (percent).

3- Field Efficiency (%):

The theoretical time (T_t) required to perform a given field operation varies inversely with the theoretical field capacity and can be calculated using the following equation (Ajit *et al*, 2006):

$$Tt = \frac{A}{TFC} \quad (3)$$

Where: T_t = Theoretical time required to perform the operation, h, TFC = Theoretical field capacity, ha/h., A = Area to be processed, ha.

The actual time required to perform the operation will be increased due to overlap, time required for turning on the ends of the field, time required for loading or unloading materials, etc. Such time losses lower the field efficiency below 100%. The following equations can be used to calculate the field efficiency:

$$FE = \frac{Tt}{Te + Th + Ta} \quad (4)$$

Where: T_e = Effective operating time, h. T_e = T_t / Kw. Kw = Fraction of implement width actually used, %.T_a = Time losses that are proportional to area, h. T_h = Time losses that are not proportional to area, h.

$$FE, \% = \frac{EFC, ha/hr}{TFC, ha/hr} \times 100 \quad (5)$$

4-Working Rate (ha/h):

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:

$$WR, ha/hr = (FE \times A)/t \quad (5)$$

Where: WR= Working rate, ha/hr. FE = Field efficiency, percent. A = Area to be processed, ha. t = Time, h.

B-Soil-crop-machine parameters:
The Soil Factor:

The soil factor (SF) explains the relationship between the implement and soil (Edwards, 2001). The main soil factors involved are 1.5, 1.8, and 2.1 for firm, tilled and sandy or soft soil respectively.

1- Draft (kN):

Draft and power requirements are important in selecting tractors and implements, because tractors must be large enough to meet the implement draft requirements. Moreover, the engine in tractors or self-propelled machines must be large enough to supply the power requirements of the field operations. Draft requirements for implements can be estimated by the following equation (Ajit *et al*, 2006):

$$D_I = F_i\,(A + Bv + Cv^2)MWd \quad (6)$$

Where: D_I = Implement draft, kN. F_i = Dimensionless texture adjustment factor. i = 1 for fine, 2 for medium, or 3 for coarse textured soils. A, B, and C= Implement-specific constants. MW= Machine width, m, or number of tools.

d= Tillage depth, cm (1.0 for minor tillage tools and seeders) (Vide: ASAE, 2001).

2- Soil and Crop Resistance (SCR) (kN):

Resistance is the force parallel to the direction of travel resulting from the contact between the soil or crop and the working components of the implement, and can be calculated using the following equation (ASAE, 1983):

$$SCR, kN = UD, kN/m \times MW, m \quad (7)$$

Where: SCR = Soil and crop resistance, kN. UD = Unit draft, kN/m. MW= Machine width, m.

3-Drawbar or Propulsion Power (DBP-kW):

After the implement draft is determined, the drawbar power for tractor-powered implements (and propulsion power for self –propelled implements) is computed using the following equation (Ajit *et al*, 2006):

$$P_{db} = \frac{D_I \times s}{3.6} \quad (8)$$

Where: D_I = Implement draft, kN., and P_{db} = Drawbar power, kW. s = Travel speed.

4-Take-off Shaft Power (PTO-kW):

Power take-off (PTO) shaft power is the power required by the implement from the PTO shaft of the tractor or engine (ASAE, 1983).

Tractors are often rated by brake power or PTO power rather than drawbar power (Ajit *et al*, 2006). After the drawbar power is calculated, the PTO power and/or net flywheel power can be estimated using Fig. (3.1) as follows:

$$\text{PTO, kW} = \frac{\text{MW} \times \text{S} \times \text{UD} \times \text{SF}}{3.6} \quad (9)$$

Where: PTO = Power take-off shaft power, kW. MW= Machine width, m., S= Travel speed, UD= Unit draft, kN/m., SF= Soil factor, unit-less.

Some machines have rotary power requirement, where the power is supplied via the tractor PTO or, in the case of self-propelled machines, from the engine. Equation (3.9) can be used to estimate rotary power requirements as follows (Ajit *et al*, 2006):

$$\text{Prot} = a + bw + c\,C_m \quad (10)$$

where: Prot = Rotary power, kW, a, b and c = Machine specific constants, w = Machine working width, m., C_m = Field capacity on a material basis, Mg/h. Ajit *et al* (2006) mentioned that, for some machines, drawbar power requirement must be added to the rotary power requirement to obtain the total power requirement.

Data Collection:
Study Areas: Gezira Scheme Site:

The site is located in the State of Gezira, which lies between the blue and the White Nile south of Khartoum with the Sudan rail way line between Sennar and Kosti forming its third triangular side. The climate is hot and semi-arid with summer rains (200 - 300 mm) falling mainly during July, August and September. The soil of the site is vertisole with a clay content of 40 to 65%, a pH 8 to 9.6, and an organic matter content of less than 0.5%. The soil has a bulk density of about 1.5 g/cm³, and its slope is less than 1%.

Rahad Scheme Site:

The site is located in the States of Gedarif (45% of the total area) and Gezira (55% of the total area), on the eastern bank of Rahad River at about 276 km from Khartoum. It is subtended by latitudes 13º 08' 0" and 14º 05' 0"North and longitudes 33º 06' 0" and 34º 01' 0" East. The climate is semi-arid with summer rains (300 - 600 mm) falling mainly during May to October. The average temperature is 20.6º C. The soil is classified as a vertisole with high clay content (60 - 70%), low organic matter (0.03%) and alkaline (pH 8.78 to 9.4).

For the purpose of the program verification, validation, application, sensitivity Analysis, and comparison with Gezira and Rahad schemes, secondary data about working rate for three types of machines: Standard Disk Plow, Offset Disk Harrow 24" and Tandem Disk Harrow, were taken from Gezira and Rahad Schemes records (Table -5.1-- and -5.2---). The published data used in this context were from ASAE (2003) standards, Srivastava (2006), ASAE (2007) and Deere and Company (1994) (Vide: Table--(4.1).

Descriptive statistics: randomized complete block design (RCBD), Duncan's multiple range test (DMRT) for mean separation and Independent Paired t-test using MSTATC statistical package, was followed for the statistical analysis of variance for the data of MMCP output parameters.

Table 1.0: Gezira Scheme Machinery's Data (2005 – 2006).

Parameters	Value of itern		
1 Macchine Type	Standard Disc Plow	Offset Disc Harrow	Tandem Disk Harrow
2 Manufacturer	MASSEY FERGUSON	NARDI	NARDI
3 Model	765	36FCI/D	——
4 Width of Machine (m)	146	4.2	4.2
5 Forward Speed (km/h)	6.5	7.5	8
6 Effective Field Capacit (ha/h)	0.731	2.470	2.63
7 Area Covared per Hour (ha/h)	0.630	1.47	1.365
8 Unit Draft (kN/m)	8.41	4.93	2.98
9 Soil Factor (Unit less)	1.5	1.5	1.5
10 Purchase Price ($)	2500	22500	17500
11 Life on Farm (years)	10	20	20
12 Resale Value (% of P.P)	0	0	0
13 Other Fixed Cost (% of P.P)	3	3	3
14 Economic Life (h)	7500	2700	24000
15 Repair & Maintenance Cost over economic life (% of P)	15	15	15
16 Fuel Use (liter/h)	7.55	3.30	4.35
17 Fuel Price ($/L)	0.687	0.687	0.687
18 Oil & Filters Costs (% of Fuel Cost)	15	15	15
19 Drivers & Helpers Wage ($/h)	2.5	2.5	2.5
20 Field Efficiency (%)	77	78.41	78.27
21 Interest Rate (%)	10	10	10
22 Rale of Inflation (%)	8	8	8
23 Standing Charge ($)	245	593	580
24 Charge per Hectare ($/HA)	30	72.5	70.9
25 Repayment Period (years)	5	5	5
26 Marginal Rate of Tax (%)	10	10	10
27 First Year Allowance (%)	20	20	20
28 Annual Capital Allowance (%)	20	20	20
29 Discounl Rate (%)	10	10	10
30 Writing Down Allowance (%)	20	20	20

Source: Gezira Scheme (Season 2005-2006).

Table 2.0: Rahad Scheme Machinery's Data (2005 – 2006).

Parameters	Value of itern		
1 Macchine Type	Standard Disc Plow	Offset Disc Harrow	Tandem Disk Harrow
2 Manufacturer	MASSEY FERGUSON	NARDI	NARDI
3 Model	765	36FCI/D	——
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27 First Year Allowance (%)	20	20	20
28 Annual Capital Allowance (%)	20	20	20
29 Discounl Rate (%)	10	10	10
30 Writing Down Allowance (%)	20	20	20

Source: Rahad Scheme (Season 2005-2006).

Table 3.0: The standard values of machinery technical parameters

Parameter	Width of Machine (m)	Forward Speed (km/h)	Effective Field Capacity (ha/h)	Area Covered per Hour (ha/h)	Unit Draft (kN/m)
Machine Type					
Moldboard Plow	0.98-1.56	5-9	0.31-1.02	0.52-0.61	8.76-17.51
Disk Plow	0.98-1.56	5-9	0.34-1.08	0.55-0.63	8.3-17.2
Subsoiler Plow	1.64-3.46	5-10	0.63-2.66	0.45-0.56	6.2-8.9
Chisel Plow	1.26-2.59	6-9	0.58-1.79	0.51-0.71	5.84-8.39
Field Cultivator	2.25-4.41	8-10	1.39-3.40	0.62-0.82	3.94-5.69
Offset Disk Harrow	2.02-5.75	6-10	1.01-4.32	2.1-2.52	6.28-7.66
Tandem Disk Harrow	3.07-5.19	7-12	1.74-5.04	1.47-1.68	4.38-5.84
Spike Tooth Harrow	2.2-5.5	3-7	0.47-2.73	0.38-0.65	2.7-8.1
Spring Tooth Harrow	4.2-5.5	3-7	0.89-2.73	0.41-0.85	1.1-4.2

Source: ASAE (2001). **Note:The effective field capacity: is the accurate check of the area actually covered or weight handled over a long period of time. Area covered per hour is the working rate.

Results and Discussions

Model Verification:

The verification of any computer program 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. However, to test program validity it is always preferable to employ statistical tools for comparison and judgment. Usually verification is made against established target such as published programs or models or accepted field or research data.

Comparison with Published Data:

The data of Tandem Disk Harrow published by ASAE (2003) was used as input to the developed model. The results obtained included theoretical field capacity, field efficiency, working rate, soil and crop resistance, unit drawbar power, and take-off shaft power as shown in Table (1).

As given in Table (1), the percentage deviation between results obtained by the developed model and ASAE actual data are in the range of 0 to 5.5%. The root mean square error (RMSE) value was calculated by the following equation:

$$RMSE = \sqrt{1/n\sum_{i=1}^{n=6}((\text{MAPCP data})_i - (\text{ASAE actual data })_i)^2} \quad (1)$$

The results showed that there was a very low RMSE (0.1865) (Table 4). According to Ventura *et al* (1999) the obtained discrepancy indicates a high consistency between the two data. Paired t-test comparison, as shown in Table (4), indicates no significant difference between the two models (probability = 0.05). This is due to the adoption of the same theoretical basis for estimating the evaluation parameters under question in the model and ASAE published data.

Table 4: Comparison between results from the developed model and actual ASAE data for Tandem Disk Harrow

PARAMETERS	Model Output	ASAE Data	Deviation (%)	Variance of the difference between the means	0.404
Theoretical field capacity (ha/h).	4.2	4.2	0	Standard deviation of the difference	0.636
Field efficiency (%).	80	80	0	Effective degrees of freedom	5.000
Working rate (ha/h).	1.172	1.172	0	Probability of t	0.200
Soil and crop resistance (kN).	17.2	18.2	5.5	f-calculated	1.046
Unit drawbar power (kW/m).	11.4	12.03	5.2	t-calculated	1.477
Take-off shaft power (kW).	71.8	75.8	5.3	t-tabulated	2.571
RMSE	0.1865				

Program Validation:

Validation of a computer model refers to the study of model effectiveness or its suitability for satisfying the purpose for which it is built (Summers *et al*, 1999). In this context, the main purposes of building this model were to evaluate the technical performance of field machinery, in particular land preparation to minimize machinery management risks. The input data for land preparation used were taken from Gezira and Rahad Schemes records. Three types of machines: the Standard Disk Plow, Offset Disk Harrow 24" and Tandem Disk Harrow, were compared under firm soil condition with the recommended forward speed for each machine.

Table (5) shows the results of analysis of variance for the technical parameters studied in Gezira and Rahad data compared with ASAE published data (2007), using Randomized Complete Block Design (RCBD) and Duncan's Multiple Range Test (DMRT) for mean separation. Table (6), revealed that: There were differences in field efficiency (%). However, those differences were not significant, and were due to the greater forward speeds used in the Gezira and Rahad schemes as compared to that recommended in ASAE Standards. The differences in the theoretical field capacity (ha/h) were not significant, and were also due to the different forward speeds used In spite of the differences in the working rate (ha/h), due to the fact that it is a function of field efficiency, those differences were not significant. ASAE data gave the highest working rate .The differences in soil and crop resistance (kN) were not significant. However, the Offset Disk Harrow recorded the highest level of resistance because its unit draft was higher than recommended in ASAE Standards. In spite of differences in forward speeds, there were no significant differences in unit Drawbar Power (kW/m).

Table 6: Results of the studied technical parameters.

Machine Type	Standard Disk Plow			Offset Disk Harrow			Tandem Disk Harrow			Parameter	C.V
Site	Gezira	Rahad	ASAE	Gezira	Rahad	ASAE	Gezira	Rahad	ASAE	Mean	(%)
Technical Parameters											
Field Efficiency (%).	75.1	77	80	79	78.4	85	77.7	78.3	80	78.94	1.8
Theoretical Field Capacity (ha/h).	0.99	0.95	0.9	3.4	3.2	2.94	4	3.4	2.2	2.66	11
Working Rate (ha/h).	0.43	0.49	0.53	1.2	1.2	1.38	1.1	1.1	1.17	0.96	52
Soil & Crop Resistance (kN).	11.9	12.3	12.2	20.6	20.7	20.2	13.2	12.5	12.3	15.1	2.3
Drawbar Power (kW).	23.1	22.2	20.4	45.8	43.1	39.4	34.7	27.8	34.1	32.29	8.6
Unit Drawbar Power (kW/m).	16.3	15.2	13.6	10.9	10.3	9.4	8.3	6.6	8.1	10.97	7.9
Take-off shaft power (kW).	34.6	33.3	30.6	68.7	64.7	59.1	52	41.8	51.1	48.43	8.6

Model Application:

As previously indicated, this study was applied for the case of the Sudan central clay plains where the major irrigated schemes of Gezira and Rahad are situated. Land preparation in the two schemes is directed mainly for summer crops. It starts during the dry summer season by employing Disk Plows or Heavy-Duty Disk Harrows or using Disk Plows as primary tillage implements followed by light Disk Harrow as secondary tillage operation. In the Rahad scheme light disking was mostly used as the primary tillage operation.

To investigate the applicability of developed model for land preparation in both schemes collected input data were entered in the program to generate evaluation performance indicators for the use of Standard Disk Plow, Offset Disk Harrow (24") and Tandem Disk Harrow under firm soil conditions and recommended forward speed for each machine.

Model Performance for Land Preparation in Gezira Scheme:

output results for the technical parameters studied for land preparation by Standard Disk Plow in the Gezira Scheme is shown in Table (7). From Table (7) the model calculated results for field efficiency, and working rate were fairly identical to the actual Gezira data. The percentage deviation range was between 8.8 and 11.0%. However, theoretical field capacity and drawbar power predicted by model were found to be slightly higher than actual field data. This may indicate that the forward speed actually used was high resulting in increase in theoretical field capacity and drawbar power.

Table 7: Model output values for the machinery technical parameters studied in the Gezira Scheme for Standard Disk Plow.

Technical Parameters	The Model	Gezira	Deviation (%)
Field Efficiency (%)	75.1	69.0	8.8
Theoretical Field Capacity (ha/h)	0.99	1.1	10.0
Working Rate (ha/h)	0.43	0.40	7.5
Drawbar Power (kW)	23.1	26.0	11.0

Model Performance for Land Preparation in Rahad Scheme:

Input data needed for model were taken from collected primary and secondary sources in the Rahad scheme. The results of the technical parameters studied are as shown in Table (8).

It is evident from Table (8) that model field efficiency, theoretical field capacity, working rate and drawbar power results is fairly identical to the actual Rahad data. The percentage deviation range is in the range of 5.3 to 10.4%. As the case of Gezira, theoretical field capacity and drawbar power predicted by the model were higher than actual field data due to use of higher forward speed by tractor driver in order to finish their assignment in less time.

Table 8: Model output values of the machinery technical parameters studied in the Rahad Scheme for Standard Disk Plow.

Technical Parameters	Model	Rahad	Deviation (%)
Field Efficiency (%)	77	72	7.2
Theoretical Field Capacity (ha/h)	0.95	1	5.3
Working Rate (ha/h)	0.49	0.46	6.5
Drawbar Power (kW)	22.2	24.5	10.4

Comparison of model Output for Land Preparation in the Gezira and Rahad Scheme in working rate:

The results of the comparison between Gezira and Rahad schemes in working rate of the three mentioned tillage implements are as shown in Table Fig. (2). The Fig. shows that the working rate of Offset and Tandem Disk Harrows in Gezira is higher than that of Rahad scheme. In contrast working rate of Standard Disk Plow was greater by 12.2% in Rahad scheme than in Cezira scheme. T-test comparison between Gezira and Rahad schemes in working rate of the three tillage implements indicated no significant difference between the two means(probability 0.05%).

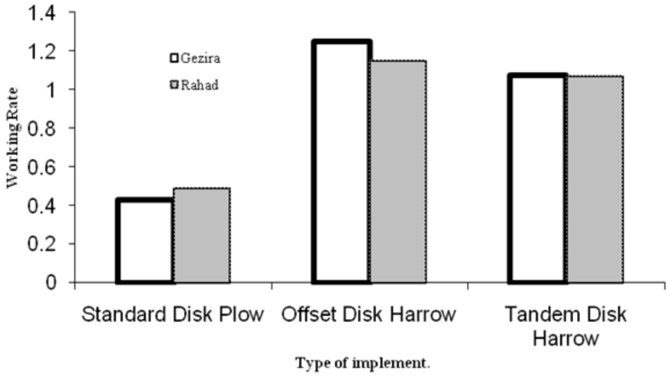

Fig. 2: Comparison between Gezira and Rahad Schemes in Working Rate for the Three Tillage Implements

Recommendations:

From the results obtained from this study the following conclusions could be made:

The developed model is a user-friendly interactive model which could be run on computers available in most agricultural institutions and organizations.

The model was successfully validated statistically in comparison to the data published by the American Society of Agricultural and biological Engineering and field data collected from Gezira and Rahad Schemes.

These results in general, indicate that the model could be applied to any real life case successfully and with confidence as decision-aid tool for improvement of farm machinery management.

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