MODEL FOR PREDICTING OF FIELD MACHINERY OPERATION PERFORMANCE VARIABLES USING WEB TOOL TECHNIQUE (MOPWT)

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ABSTRACT:

Farm machinery planning, design and operation are complicated undertaking due to time and cost constraint and due to prevalence of complicated interacting and overlapping field operations involving capacity constraints and cooperating units. Size selection of operation machinery must necessarily base on anticipated performance and. Expected cost. In field machinery operation selection, the majority pertinent variable is size or capacity of the machinery. The classical (MOPWT) model that applied in the past to machinery planning and policy analysis as well as to performance assessment and simulation of machinery demand, and supplies are criticized by limitations in programming and the difficulty in manipulation and storing the bulky data usually encountered in machinery records. In contrast by application of a web-based decision support system (MOPWT) the user can enjoy the facility to store the data in the server. (MOPWT), is a user-friendly interactive program which permits the user to interact by entering the required input records .A (MOPWT) was developed to Predicting Of Field Machinery Operation

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Performance Variables parameters are total field operation time, effective field capacity, field efficiency and theoretical field capacity, for 1.0, 1.5 and 2 m width tool at operation speed of 4, 4.5, 5, 5.5 and 6 km/hr. the estimates machinery performance of various farm machines. It consists of one model, which helps the farm manager to take the correct optimum selection of his agricultural machinery. The (MOPWT) was successfully found that as speed and implement width increased, the complete field time decreased at the same time as theoretical field capacity and effective field capacity increased efficiency decreased. additionally , highest field efficiency was 85.5% 85.5%, it was registered by implement width of 2 m at 4.5 km/hr. speed although the lowest field efficiency was 80.7% 80.7%, it was recorded by implement width of 1 m 6 km/hr. The (MOPWT) result field was concluded that width of plow found to have higher effect than plow operating speed on increasing the effective field capacity, consequently, the field efficiency. The (MOPWT) model was applied to real case conditions in Wad Salma and Rahad irrigated schemes in the central clay Sudan.

Keyword: Web-Based, Machinery Operation Performance.

1 Introduction:

Size selection of machinery must necessarily base on predicted performance and expected cost. In field machinery selection, the most pertinent variable is size or capacity of the machinery. Forward speed and power found to affect field capacity and effectiveness of operation (Donnell 2001). Machinery selection is a vital element in planning implementation, and operation of agricultural services used for large-scale mechanized schemes or for small holders. Matching the tractor–implement size was reported to be a difficult task (Akinnuli, Akerele et al. 2014) Effective mechanization at the field level can only be achieved through the proper selection of machinery, together with proper machinery field management. Studies by (Feenstra, Burton et al.

1998)indicated that the developed countries, that use intensive mechanization technology, possess 26% of the useable agricultural areas worldwide and more than 73% of the world agricultural tractors; whereas, the Arab countries that possess about 3% of the total agricultural areas have less than 1% of the total number of tractors. In fact, such less-developed countries are frequently facing acute problems with regard to financing agricultural production operations. This situation necessitates making the correct decisions, especially when high sums of money are to be directed for buying new machines and equipment to expand existing agricultural areas or to replace old machines and equipment The effective field capacity is the actual rate of performance of land or crop processed in a given time, and it can be expressed in area / time or material / time. It was found that the effective field capacity was affected by implement size, (Ozpinar and Isik 2004)reported that heavy disc harrow showed the higher effective field capacity than light disc harrow (Serrano, Peça et al. 2007)reported that the lost time was the most important factor that affects the field capacity and Efficiency of a machine. It may be lost as a result of adjusting or lubricating the machine, break downs clogging turning at the ends, adding seed's fertilizer or operator personal time (Yohanna, Ode et al. 2014). The factors affecting field efficiency were reported by (Donnell 2001)as theoretical capacity of the machine, machine and severability, field shape, field patterns, field size, yield), soil and crop condition and system limitation Implement type and soil physical conditions were important factors affecting the field capacity and efficiency of tillage implement, when soil conditions are poor for machine operations, forward speed will generally be reduced (Zaied, El Naim et al. 2014)found that chisel plow recorded higher values of power requirement, theoretical field capacity and effective field capacity in loose clay soil as compared to disk plow, and moldboard plow(Akinnuli, Akerele et al. 2014) Developed computer software to select and evaluate alternative machinery complements and estimated their costs. he performance of a machine often depends on the skill of the operator or on weather and soil conditions(Olmstead and Rhode 2007). However, variances among machines can be estimated through field trials, research reports, and personal experience. Peterson et al. (Schrock 2002) establish that field efficiency decreased with increasing implement width when field operations were behaved between patios .therefore, selection of width implement can be estimated as the follows equation.

$$W = \frac{FC * CF}{SE} \qquad (1)$$

.Where FC = field capacity, ha/h,CF = correction factor ,E = field efficiency ,W= width, m
S= speed, km/hr

Randal et al. (Taylor, Schrock et al. 2001) noted that field efficiency decreased with increasing planter width. Field size had the little impact on field efficiency. Steichen and Powell (Taylor, Schrock et al. 2001) displayed a farm's ability index for fields and concluded that field efficiency was a function of implement and terraces design. Field efficiency includes the effect of the time lost in the field and downfall to make use of the full width of the machinery (Bower, Rossby et al. 1985). It is not constant for a specific machine, but varies with the size and shape of the field, pattern of the field operation, crop yield, and moisture. (Zoz 1970) Presented a graphical technique for predicting drawbar pull, drawbar power, transportable speed, and transportable reduction of 2WD tractors under various soil conditions (Isik and Sabanci 1993)coded a selection algorithm on PC-computer using fundamental Language. The algorithm chooses the optimum sizes of farm machinery and tractor power by considering farm sizes, cropping pattern, soil environment and weather variability. The factors impressive field efficiency were recorded by Donnell (Donnell 2001), as theoretical capacity of the machine, machinery maneuverability, field shape, field patterns, field size, yield soil and crop condition and system limitation. Culpin (Crossley and Kilgour 1978)mentioned equation of theoretical field capacity as equation

$$TFC = \frac{S * W}{C} \qquad (2)$$

.Where TFC = theoretical field capacity, ha/h ,S = speed, km/hr,W = implement width, m

C = constant = 10

The effective capacity can be computation on Area base or material base as follow equation

$$C_a = SW * \frac{E_f}{10} \qquad (3)$$

Where,C_a= area capacity, ha/h., S = speed, km/h .,W = working width, m.,E_f = field efficiency

$$C_m = \frac{SWY * E_f}{10} \qquad (4)$$

Where,C_m = material capacity, t/h,S = field speed, km/h,W = i working width, mE_f= field efficiency,Y =yield unit of the field, t/ha.

Implement type and soil physical conditions are important factors affecting the field capacity and efficiency of tillage tool implement, when soil conditions are poor for machinery operations, forward speed will normally be reduced .(Belel and Dahab 1997) reported that chisel plow recorded higher values of power requirement, theoretical field capacity and effective field capacity as compared to disk plow, and moldboard plow.

The optimum capacity of a machine can be assessed from equation as follow

$$M_{CO} = \sqrt{\frac{100FA}{C_{OP} * K_p}[W_c + T_{OC} + \frac{T_c * A * W}{pwd}]} \qquad (5)$$

WhereM_{CO} = machine optimum capacity, ha/h (acre), **FA** = area, ha C_{OP}= ownership cost

W_c =Workers cost, dollars/ha , percentage, percent , K_p = unit price dollars/ha·h

T_{OC} =tractor ownership cost, dollars/ha, T_c = timeliness coefficient from ASAE;

A = area, ha Pwd=probability of a working day

The model was designed to minimize farm total cost. The physical method was described by the America Society of Agricultural Engineers in their standard yearbook of. The approach matched the tractor and implement width via consideration of soil conditions, soil attractive force, and engine power and speed .The main objective of this study was to develop (MOPWT) web-based system to predict theoretical field capacity, effective field capacity and field efficiency of a field operation for implement with different effective widths and different operating speeds , the (MOPWT) is a user–friendly interactive program. It estimates machinery performance of different agricultural machines to determine the properties of the operating parameters when using or choosing farm machinery to help the managers of the farm or scheme to take the correct optimum decisions in managing agricultural field machinery.

2 Development of System Designs and Documentation

2.1 Overview: The MOPWT is a DSS formulated to assist designers and managers in the process of design planning, and improvements of machinery fleet in multi-farm fields. It includes a database, simulation modules, user-friendly interfaces and cost analysis modules. The developed system can be described as content management system (CMS) (Fig. 2.0). It is composed of various subsystems or modules with different files with different formats for database, input, output layouts, individual -machine interfaces, detailed design, processing logic, and external interfaces. The application of MOPWT is based on client-server architecture. It comprises a Web module and a simulation engine. The Web module controls the simulation engine, creates the user interface, importing and showing numerical and graphical data. The architecture of DSS Web Server and client are schematized in (Fig. 1.0). Basically the system have been developed using the Dynamic Web Content PHP, MySQL, JavaScript, CSS, and HTML5. All the computation is performed on the server side through the set of functions and stored procedures to achieve higher system flexibility, and to minimize client system requirements. The SQLServer is applied for database management, which allows a simultaneous connection of several users. The server is established by four component modules, each one responsible for a task (1) Communication – the interface with the Web applications using TCP/IP like transport way; (2) Logic – the control of execution and respective data flow; (3) Simulation the computation of simulation models; and (4) Data abstraction – the isolation and optimization data model and data modifications.

2.2 **System Technique and Style:** The system management and operation of agricultural machinery MOPWT is a button menu driven composing of sub-modules and interactive in nature. The general flow diagram of the system structure is illustrated in the (Fig. 2.0). The system is composed of an introductory interface and a main menu (Fig. 1.0). It derives through sub-modules distributed over the tables. The main menu controls the details of all program operations. Spreadsheets are either visible lists or hidden processing parameters have been built by the tool during the input. Visible input forms received input data from users, subjected them to conversions and directs them to hide processing data where all the processes are done through case specific transformation functions, based on information previously provided by the users. For example, when an operation is allocated from the field cultivation the user can choose from a main menu the program specialist for the operation from the list created by the system because the list includes machineries that have been inserted by the user (in the “machineries” data set).

2.3 **Individual Machine Interface:** This section provides the detailed design of the system and subsystem inputs and outputs relative to the user/operator. Any additional information may be added to this section and may be organized according to whatever structure best presents the operator input and output designs. Depending on the particular nature of the project, it may be appropriate to repeat these sections at both the subsystem and design module levels. Additional information may be added to the subsections if the suggested lists are inadequate describe the project inputs and outputs (Fig. 2.0).

2.4 System Architecture and Operation:

4.2.1 **System Data:** The data needed to run the system is two folds: user direct input data (with help by selecting from lookup tables) and resources data build in the system but can be modified by the user. These two types of data can be corrected or edited during data input process. The user direct input data is referred to as standardized data set.

2.4.1.1 **The user direct input Data Set:** This section is a description of the input data sets for the project used by the operator for providing information to the system. The main data set is the standardized data which includes data sets concerning: user profile, system control, project field information, Crops and crops rotation (season). (Fig. 2.0). shows and describes: the high-level data flows and the initial data sets including the general information for the system under study, the definition of the machinery that will be operated, the fields included in the production system, and the allocation of crop rotation to field areas. The tool allows users to insert input data through lists in system or input by user in more than one form depending on either personal preferences or the type of available data. For example, in the case of Spraying of the pesticide must enter process data (e.g. farm number, crop, area, name pesticide, dosage, implement and tractor). Based the data that have been previously provided by the user, the system provide the layout of all input data screens and also graphical user interfaces. This section contains edit criteria for the data elements, including specific values, range of values, and mandatory/optional alphanumeric values. It also addresses data entry controls to prevent edit bypassing. The standardized Data Set is built in data set and refers to: User profile, System Control data, Project Field Information data, and Crops and crops rotation (season) data.

2.4.1.2 **User profile**: Using the Web-based system interface, users may set up a profile that includes name, phone number, email address, and other PII (Personally-identifiable information). In addition, users may set up a password for continued access to their PII. Access any of their own provided personal information, of their social security number, and change profile information, including changing contact information. Based on the country selected, the system applies the appropriate databases listed by the country code, such as country-specific coefficients (e. g. Crop, machines, pesticide, and currency per country). The user can choose to remain anonymous or share information with other users.

2.4.1.3 **System Control data set:** The control data set consists of: title, name of the project, irrigation method, numerical parameters of interest rates and fuel prices and the selected parameters of the preferred currency, which creates the standardized data set, and the name of the program template to use to create the table. Table number is used in both as a title of the table and to name any resulting files used with other variables in the control data set of document and track the table production process.

4.2.2 **Tractors parameters data:** In this data set, the parameters of the available tractors for the operation are to be uploaded to the system. Every tractor should be identified by its serial number and reference is to be made for its purchase cost actual and annual use. This information is to be used in in driving the coefficients for the calculation of the fixed and variable costs of the tractor. The tractor type (2-wheel drive, 4- wheel drive, chain drive) and its power and time of use also need to be identified. Other coefficients for the calculation fixed and variable cost includes those related to repair and maintenance factor for each tractor, insurance cost, settled cost.

4.2.2 **Machinery specifications data:** The system provides the users the option to select the type of machines to be used in the system and enter the machine required input data in similar way as done previously for tractor. The machinery types listed in the system data set are connected with a database that provides all the correct coefficients needed for the calculation of the data related to operational performance. The system allocates each machine to specific number of task and gives a task number for each. For each machine when allocated for specific task the system identify: the field efficiency (%), and the operating width. Once machine inputs (Field length, Field width, Operating speed, Implement effective width, Productive time, Average time for turn, Time losses) are defined the system generates outputs typical to those assigned for the tractor.

4.2.2 **The System data base:** A database is an organized collection of data. The data are typically organized to model aspects of reality in a way that supports processes requiring information. Special storage procedure is required for data base organization.

4.2.3.1 **Stored databases:** Formally, database in the system provide the interface between the users and the database and supporting data structures. Databases are created to operate large quantities of information by inputting, storing, retrieving and managing that information. Databases are set up so that one set of software programs provides all users with access to all the data. The system provided a number of lists to support users when inserting the input data on programs.

4.2.3.2 **System Database Storage Procedure:** There are different ways of listing all databases within the SQL Server. The first method is the use of the sp-databases system stored procedure. The sp-databases lists databases that either reside in the SQL Server Database Engine or are accessible through a database gateway. Another way of getting a list of all databases within the SQL Server is with the sp-helpdb system stored procedure. The Sp-helpdb system stored procedure reports information about a specified database or all databases. If no database name is passed to the Sp_helpdb system stored procedure, it will display information about all databases on the server running SQL Server. Yet, the third way of getting a list of data bases within the SQL Server is by querying the sys.databases system view. Regardless of which method to use, all of these methods will return not just as user databases but as system databases as well (such as the master, model, msdb and tempdb databases). If the SQL Server instance has Reporting Services installed, the Report Server and Report Server Temp DB databases will also be included in the list

3 **System Processes**: The processes executed by the developed via evaluation of the technical field performance of machines. The function of part of the process is to compute the fleet size of power units and machinery required to complete the field operations during the specific period of time. The procedure to 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, draw bar or propulsion power, power at take-off shaft and unit power). Consequently, the model determined the minimum field capacity of tillage implements required to complete the operation in a reasonably short time. He also determines the minimum width of implement required attaining this goal, and the size and number of tractors required to perform the operation, the standard values of machinery technical parameters, which were adapted from ASAE (2009.)Data, are used as view look-up tables, to aid the user in the correct utilization of the program.

4.1 Study Areas: Study site: The study was conducted within the area of the irrigated central clay plains of Sudan, which includes: Rahad Scheme and Wad Salman Scheme. Rahad Scheme is one of the largest and most important irrigated schemes in Sudan. The scheme is located in the State of Gedarif (45% of the total area) and Wad Salma (55% of the total area), on the eastern bank of Rahad River at about 276 km from Khartoum Wad Salman project is located on the east bank of the Blue Nile about 60 km south of Sinnar and the actually cultivated area on average for the last seasons are about 10000 ha. The project extends from the Blue Nile to Dinder River and from the Suki- Gedarif railway line to the Rahad Supply Canal plus a small area on the southern side of the Rahad Supply Canal

4.2 **Data Collection:** The required input data for this study was categorized as primary and secondary source data. Primary data was collected using formal and personal contacts with individual agricultural engineers, from Rahad and Wad Salman agricultural schemes, in particular agricultural engineering organization. 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. The data given was for the season 2009-2010, 2010-2011, and 2011-2012 and 2012-2013. Other secondary data was collected from the most relevant published national and international data and periodicals. The main source data were the ASAE yearbook (2009) Hunt (1983), Witney (1988), Agricultural Bank of Sudan Reports (HQ), and information bulletins from many agricultural machinery dealers in Sudan and worldwide. These data were referred to when it is used in the texts

4 Statistical Analysis:

The Randomized Complete Block Design (RCBD), Duncan's Multiple Range Test (DMRT) for mean parting and Independent Paired t-test using MSTATC statistical package, was followed for the statistical analysis of variance for the data of MOPWT output parameters.

5 Results:

6.1 MOPWT Model Verification: The verification of any software program is concerned with establishing whether the program is a correct or comprehensive representation of reality (Cheng et al., 1992). The verification aims to determine facts about the system under consideration in order to explain its structure and operation. However, to test a program validity it is continuously preferable to employ arithmetical tools for comparison and punishment. Frequently, verification is complete with an established target such as published programs or models or acknowledged field or research data.

6.2 MOPWT Validation: Validation of a MOPWT model refers to the study of model use or its suitability for satisfying the purpose for which it is constructed (Santhi, Arnold et al. 2001)In this context, the main purposes of building the MOPWT model were to assess the technical performance of field machinery, in particular, land preparation to minimizing agricultural machinery management risks. The input data for used were taken from, wad Salam and Rahad Schemes records. Three types of machines, namely: the Offset Disk Harrow (24), Standard Disk Plow, and Tandem Disk Harrow, were compared under the firm soil conditions with the recommended forward speed for each machine. Table (1) shows the output of the technical parameters studied. Analysis of difference for the technical parameters studied in the wad Salma and Rahad data, by using (RCBD) Randomized Complete Block Design and Duncan's Multiple Range Test (DMRT) for mean separation (Table 1), and Figures 3,4,5,6,7,8,9 and 10 showed the performance variables of a plow width 1, 1.5 and 2m effective; each operated at speeds of 4 km/hr, 4.5 km/hr, 5 km /hr, 5.5 km/hr and 6 km/hr. There were differences in field efficiency (%). From Table 1, Figure 2, Figure 3, Figure 4 and Figure 5 for 1 m implement width, it was proved that at 4 km/hr, the value of field operation time was present 0.588 hr, theoretical field capacity of machinery operation was 0.400 ha/hr, effective field capacity showed 0.340 ha/hr and field efficiency was really 85.0%. At 4.5 km/hr, the values of field operation time, theoretical field capacity, effective field capacity and field efficiency were present 0.530 hr, 0.450 ha/hr, 0.378 ha/hr and 84% relatively At 5 km/hr the values showed 0.483 hr, 0.500 ha/hr, 0.414 ha/hr and 82.8% for total field operation time, theoretical field capacity, effective field capacity and field efficiency individually in a situation of 5.5 km/hr, the value of total field operation time was0.445 hr; theoretical field capacity was real 0.550 ha/hr, effective field capacity subsisted 0.449 ha/hr and field efficiency was present 81.6%. At 6 km/hr the values of total field operation time, theoretical field capacity, effective field capacity and field efficiency were present 0.413 hr, 0.600 ha/hr, 0.484 ha/hr And 80.7% respectively. Though, those differences were not significant, and were due to the larger forward speeds used in the wad Salma and Rahad schemes as compared to that recommended in ASAE Standards .From Table 1, Figure 6, Figure7and Figure 8 for 1.5 m implement width, it was verified that at 4 km/hr, the value of total field operation time was 0.391 hr, theoretical field capacity was showed that 0.600 ha/hr, effective field capacity was 0.511 ha/hr and field operation efficiency was 85.2%. next to 4.5 km/hr, the values of total field operation time, theoretical field capacity, effective field capacity and field efficiency subsisted 0.352 hr, 0.675 ha/hr, 0.568 ha/hr and 84.1% individually. At 5 km/hr the values were showed 0.321 hr, 0.750 ha/hr, 0.623 ha/hr and 83.1% for total field operation time, theoretical field capacity, effective field capacity and field efficiency one-to-one. In case of 5.5 km/hr, the value of total field operation time was 0.296 hr, theoretical field capacity was 0.825 ha/hr, effective field capacity was present 0.676 ha/hr and field efficiency was 81.9%. At 6 km/hr the values of total field operation time, theoretical field capacity, effective field capacity and field efficiency were present 0.274 hr, 0.900 ha/hr, 0.729 ha/hr and 81.0% respectively. The differences in the theoretical field capacity (ha/h) were not considerable and were also due to the dissimilar forward speeds used In spite of the differences in the working rate (ha/h), since it is a job of field efficiency, those differences were showed not significant. ASAE data presented the maximum operational rate. In situation of Table1 Figure 8, Figure 9 and Figure 100 for 2 m implement width. It was established that at 4 km/hr, the value of total field operation time was 0.293 hr, theoretical field capacity existed 0.800 ha/hr, effective field capacity was real 0.684 ha/hr and field efficiency was present 85.5%. At 4.5 km/hr, the values of total field operation time, theoretical field capacity, effective field capacity and field efficiency were 0.263 hr, 0.900 ha/hr, 0.759 ha/hr and 84.3% respectively. At 5 km/hr the values were 0.240 hr, 1.00 ha/hr, 0.833 ha/hr and 83.3% for total field time, theoretical field capacity, effective field capacity and field efficiency respectively. In the case of 5.5 km/hr, the value of total field time was 0.221 hr, theoretical field capacity was 1.10 ha/hr, Effective field capacity was 0.905 ha/hr and field efficiency was 82.3%. At 6 km/hr the values of total field operation time, theoretical field capacity, effective field capacity and field efficiency were 0.205 hr, 1.20

ha/hr, 0.976 ha/hr and 81.3% respectively. The differences in soil and crop resistance (KN) were non-significant.

In the case of Table1 Figure 9, Figure 10 and Figure 11 for 2 m implement width. It was proved that at 4 km/hr, the value of total field operation time was there 0.293 hr, theoretical field capacity showed 0.800 ha/hr, effective field capacity existed 0.684 ha/hr and field efficiency existed 85.5%. At 4.5 km/hr, the values of total field operation time, theoretical field capacity, effective field capacity and field efficiency were present 0.263 hr, 0.900 ha/hr, 0.759 ha/hr and 84.3% separately At 5 km/hr the values subsisted 0.240 hr, 1.00 ha/hr, 0.833 ha/hr and 83.3% for total field operation time, theoretical field capacity, effective field capacity and field efficiency correspondingly in the case of 5.5 km/hr, the value of total field operation time was present 0.221 hr; theoretical field capacity was 1.10 ha/hr, Effective field capacity was present 0.905 ha/hr and field efficiency was present 82.3%. At 6 km/hr the values of total field time, theoretical field capacity, effective field capacity and field efficiency subsisted 0.205 hr, 1.20 ha/hr, 0.976 ha/hr and 81.3% respectively. The results presented that as speed increased the total field operation time decreased and the theoretical and effective field capacity increased through the field efficiency decreased. It can be determined that it is not required to have a higher field efficiency at the higher speeds while the width of implement was found to have an observed effect in improving the field efficiency as exposed once the width increased from 1 m to 2 m that the field efficiency increased from 85% to 85.5% .

6 Conclusion:

A web-based decision support system (MOPWT) model friendly, self-guidance, reactive, menu driven and composed of sub modules with capabilities to predict the field performance parameters variable of machinery with different width operated at different speeds. The developed system predicted the field performance parameters of implement with different width operated at different speeds. Found Width of plow found to have higher effect than plow operating speed on increasing the effective field capacity; consequently, the field efficiency according to the results obtained from this research, the web tool can be used support decisions at different planning levels besides testing various input surrogates, and by employing sensitivity analysis. The tool can support decisions on the strategic level (e.g., number and adjust dimensioning of machines, machine capacity; crop chooses, and labour requirements).

Acknowledgements:

This work was part of the Sudan scheme's research project farm. This research was supported in part by a grant number BA2010055 from the CSC (Nanjing Agricultural University).

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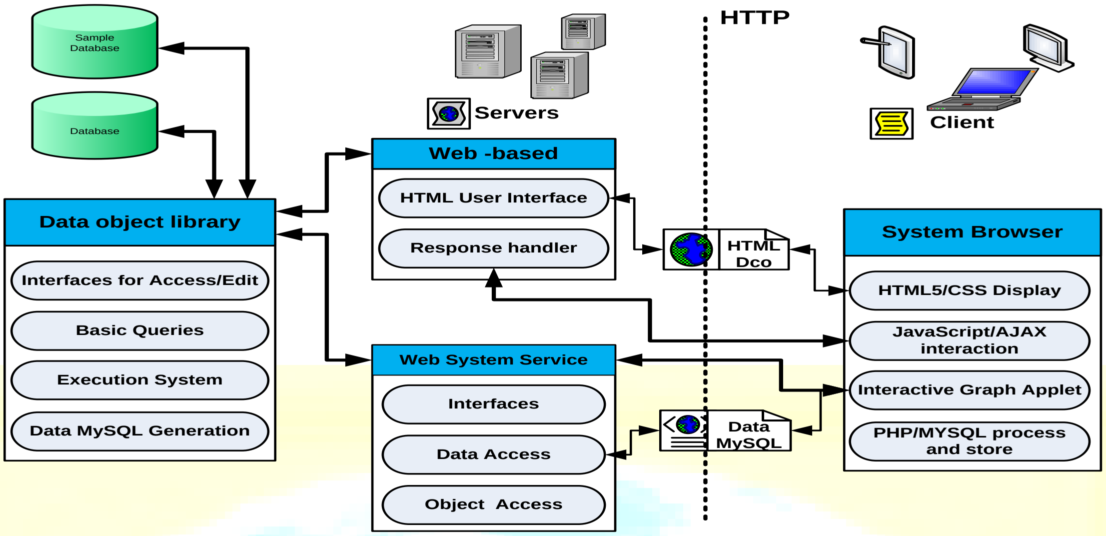
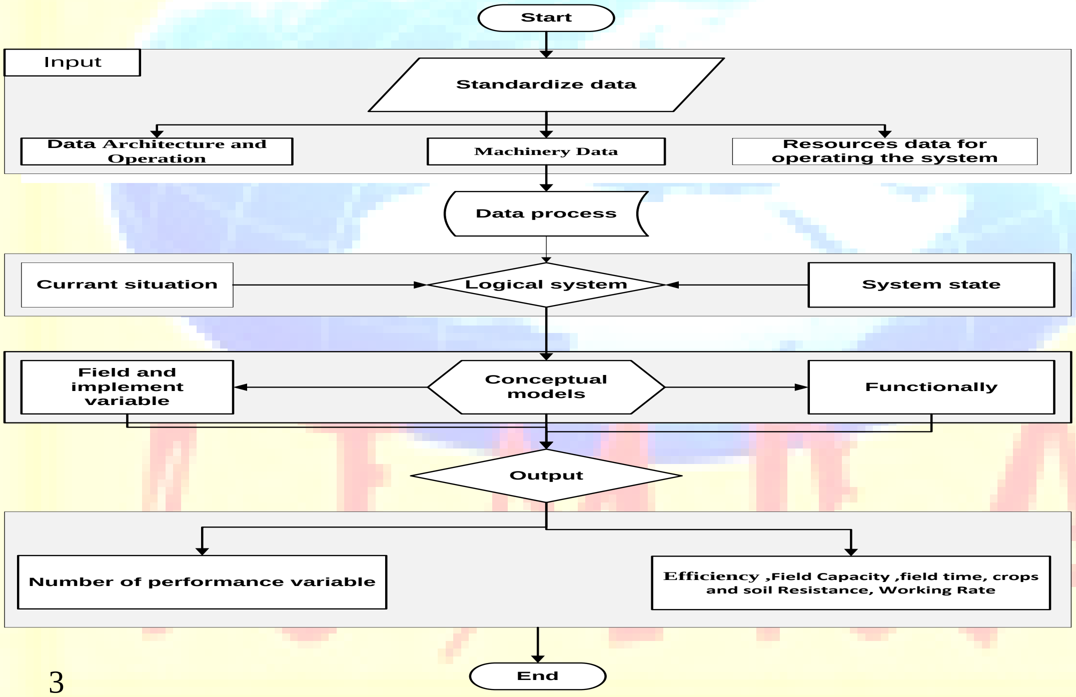


1

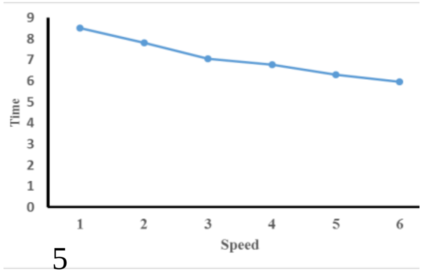
Fig. 1.Conceptual structure of DSS Web Server and client.

2



3

Fig. 42. General flow diagram data base components in relation with respective



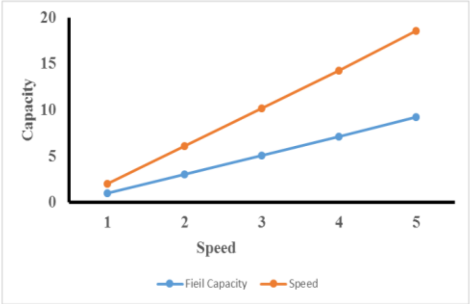


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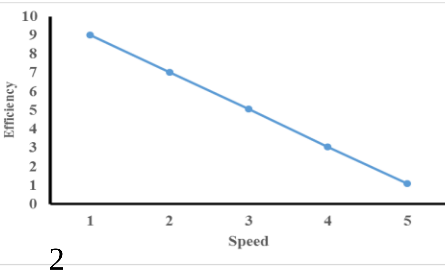
Fig36 Field Operation time for

. **Fig4.** Field capacity for 1 m wide implement

1 m wide implement 1



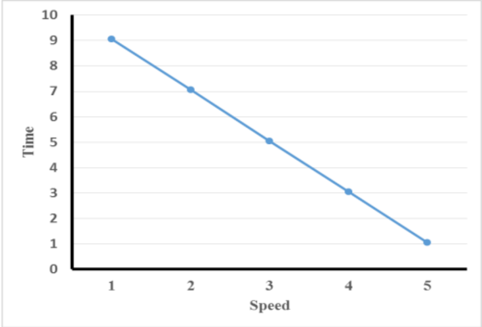


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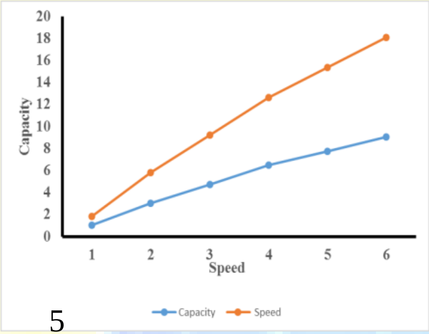
Figure 5. Field efficiency %for 1 m wide implement

Fig 6. Field time for 1.5 m wide implement

4



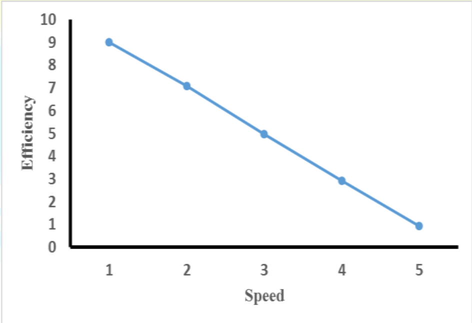


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Fig7. Field capacity for 1.5 m wide implement

Fig 8. Field Efficiency for 1.5 m wide implement

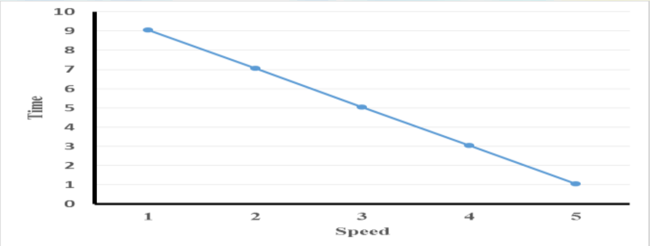

Fig9. Field operation time for 2 m wide implement 7
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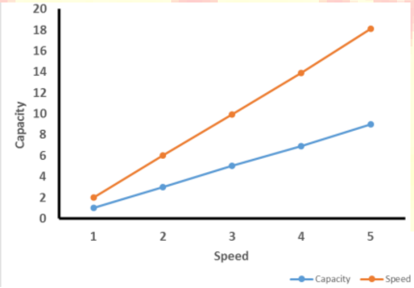

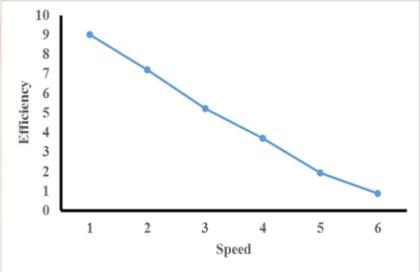

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Fig10. Field capacity for 2 m Wide implement

Fig11. Field efficiency for 2m wide implement

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	Performance parameters				
	Speed km/hr	total field time TT Hr)	theoretical field capacity (TFC a/hr)	effective field capacity EFC ha/hr	field efficiency FE %
performance at 1.0 m effective width					
	4	0.588	0.4	0.34	85
	4.5	0.53	0.45	0.378	84
	5	0.483	0.5	0.414	82.8
	5.5	0.445	0.55	0.449	81.6
	6	0.413	0.6	0.484	80.7
performance at 1.5 m effective width					
	4	0.391	0.6	0.511	85.2
	4.5	0.352	0.675	0.568	84.1
	5	0.321	0.75	0.623	83.1
	5.5	0.296	0.825	0.676	81.9
	6	0.274	0.9	0.729	81
performance at 2.0 m effective width					
	4	0.293	0.8	0.684	85.5
	4.5	0.263	0.9	0.759	84.3
	5	0.24	1	0.833	83.3
	5.5	0.221	1.1	0.905	82.3
	6	0.205	1.2	0.976	81.3

Table 1. Plow performance parameters at 1.0, 1.5, 2.0m effective width.