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Efficient Matching of Tillage Implements with Tractors using a Computer Program

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***Abstract* – A comprehensive and easy-to-use computer program was developed for the purpose of matching tractors and tillage implements with the aim of reducing under or overloading of a tractor thereby maximizing power output and minimizing components breakdown. The program was designed with Visual basic.NET. The American Society for Agricultural and Biological Engineers (ASABE) standards equations for the prediction of drawbar power and draft requirements of implements were used. Tractor specifications were obtained from Nebraska Tractor Test Report (NTTR) for the creation of tractor database using Microsoft office access 2010. The program developed was driven by a graphical user interface (GUI) and had three windows for interactions. The program was tested and verified by comparing its results with manually calculated values. This user-friendly program could be run on windows with or without visual basic.NET environment.**

***Keywords* – Draft Requirements, Drawbar Power, Farm Machinery, Implements, Tillage, Tractor.**

I. Introduction

A tractor is an engineering vehicle specifically designed to deliver a high tractive effort at slow speeds, for the purposes of hauling a trailer or machinery used in agriculture or construction. It is a farm vehicle that provides the power and traction to mechanize agricultural tasks, especially tillage. Agricultural implements may be towed behind or mounted on the tractor and the tractor may also provide a source of power if the implement is mechanized [1].

Tillage is the agricultural preparation of the soil by mechanical agitation of various types, such as digging, stirring, and overturning. Primary tillage implements include plows, moldboard, chisel, disk harrows and power rotary tillers, while secondary tillage implements include harrows, spike, knife, ridger, rod weeders, amongst others [2].

The work done by Clarke [3] has emphasized the fact that poor selection and use of mechanization inputs have led to heavy financial losses and lowered agricultural production. Most often farmers depend very much on their experience to match tractors and implements. This may likely make the system to operate at less than optimum efficiency. It is thus important that both units be selected in such a way that power generated by the tractor is fully utilized [4]. Grisso et al. [5] claim that for proper matching of tractor and implements it is necessary to carry out the following:

i. Predict the draft and power requirement of the implement taking into consideration factors such as depth and speed of operation, implement width and soil condition.
ii. Predict the tractive capability and the drawbar power that can be available on the tractor by considering factors such as vehicle configuration, weight distribution, ballasting, tractive device type, and terrain conditions.

Taylor et al., [6] stated that a careful approach to matching tractors and implements can increase efficiency of operation and farm profitability. The results of correct matching include reduced power loss, improved operating efficiency, reduced operating costs and optimum use of capital on fixed costs.

The prediction of tractor - implement systems has engaged the attention of some researchers in the past. Tajudeen et al. [4] developed an event-driven, object-oriented, application program for predicting the performance of tractor-implement system using visual C++. The application is useful for simulation purpose but does not contain database for real-life tractors and implements. Computer based least cost models were developed in C programming language by Dash and Sirohi [7] for the selection of optimum size power and machinery system for paddy-wheat cropping system. The model was able to select the optimum tractor size from amongst the available sizes and its matching implements keeping in view the capacity of machinery to complete the operation in scheduled time for the given farm. The model output was found to be sensitive to various input parameters like farm size, tillage intensity and crop rotation. Vatsa and Saraswat [8] developed a computer program in Turbo C++ language to compute power of power tiller and the size of equipment by entering the essential inputs such as area under different crops, cropping pattern and soil type for a particular farm situation. Sahu [9] developed a decision support system using visual Basic 6.0 for matching implements with a two-wheel drive (2WD) tractor and predicting the field performance of the system.

Al-Hamed et al. [10] developed a program that uses the visual C++ to obtain a typical field speed for the tractor – implement combination. If the difference between the drawbar pull available on a selected tractor and the draft required by a selected implement is too large, the simulation will converge in a field that is out of the range specified in ASABE Standards [11].

The program developed in this work overcomes the deficiencies highlighted by providing a fast and cheap method of understanding the field performance parameters of tractor systems. The program is driven by a graphical user interface and is very user friendly.

II. Materials And Method

A. Implement Draft and Power Requirements

Draft refers to the force required to pull an implement in the horizontal direction of travel [4]. Draft and power requirements are important parameters for measuring and evaluating performance of tillage implements and are therefore considered as essential data when attempting to correctly match tillage implements to a tractor [12]-[13]. Machine selection and sizing require an estimate of draft requirements of the implement. The lack of information about implement performance forces the farmer to rely on past experience for selection of tractors and implements. With escalation in the size of equipment and speed of many new agricultural implements, the farmer's previous experience may be of little value in selecting new machines. Therefore, prediction of implement draft requirements is important for selection of machinery, matching of implements to tractors and estimating fuel consumption [14].

It is reported that for seeding implements and minor tillage tools operated at shallow depths, draft is primarily a function of the implement width and the speed at which it is pulled. For tillage tools operated at deeper depths, draft depends on soil texture, tillage depth, and geometry of the tool in addition to implement width and the speed [4].

Some research works have been carried out to determine the draft and power requirements of tillage implements in various kinds of soils. Harrigan and Rotz [15] proposed a function for a range of soil conditions to model tillage draft under general conditions, where draft per unit width or cross-sectional area of the tilled zone is a function of soil type and the speed at which the implements is pulled. In the model, soil is categorized as fine, medium, and coarse and these categories are described as corresponding to clay, loamy, and sandy soils. The draft prediction function used by the American Society of Agricultural and Biological Engineers is given in equation (1) ASABE Standards D497.5 [11].

$$D_f = F_i[A + Bs + Cs^2] \times W \times d \qquad (1)$$

In equation (1) D_f = Implement Draft (N) ; F_i is a dimensionless soil texture adjustment parameter where $i = 1$ for fine (clay), 2 for medium (loamy) and 3 for coarse (sandy) soil; A, B, C are machine specific parameters; s is the field speed (km/hr); W is the effective width of implement/machine (m); d is tillage depth (cm) for major tools but assumed to be 1 (dimensionless) for minor tillage tools and seeding implements.

B. Implement Power Requirement

Most farm tractors are rated power-wise according to the maximum observed power take off (PTO) horsepower as determined by the Nebraska tractor tests. Drawbar horsepower is the horsepower actually available to be transmitted by traction through the tractor drawbar to the implement and this is always less than the PTO due to a combination of power losses through the transmission train, rolling resistance and slippage losses of the tires when operating on a traction surface (White, 1977). Drawbar power for tractor-powered implements is computed according to equation (2) [17]:

$$P_{db} = \frac{Ds}{3.6} \qquad (2)$$

In equation (2) P_{db} is drawbar power required for the implement (kW); D is implement draft (kN); and s is travel speed (km/h).

C. Program Implementation

The program has two databases that contain data on tractors, tillage implements and soil types. The databases were created with the aid of Microsoft office access which is a relatively easy database management system to learn and manipulate [18].

D. Tractor Database

This database contains specifications for nine hundred and fifty eight (958) tractors that were obtained from the Nebraska tractor Tests Reports (NTTR). These specifications include the manufacturer, model, drive type (configuration), rated power (in kW and hp), drawbar power (in kW and hp), weight on front and rear axles, front and rear tires sizes, fuel consumption and total unballasted weight.

E. Agricultural Machinery (Implement) Database

This database consists of agricultural tillage implements. The total number of implements in the database is fifteen (15). This database also contains the constants of the equations necessary to calculate the draft and drawbar power of agricultural machinery.

F. Programming Language

Visual basic.NET was used as the programming language for this project. Visual basic.NET is an event driven programming language and is integrated into the Microsoft Visual Studio Development Environment (IDE). Programming in Visual basic.NET is a combination of visually arranging components or controls on a form, specifying attributes and actions of those components and writing of additional lines of code for more functionality [19].

G. Program Flowchart

The basic flowchart for the program is shown in figure 1. There are three windows namely Tractor, Details, and Implement windows. The Tractor window works together with the Details window and is used to activate the window containing tractors and their specifications. In this window one can filter tractors based on the parameters contained in the dropdown list. In the Implement window, soil types (fine, medium, or coarse which correspond to clay, loamy, and sandy soils respectively), tillage type (primary or secondary), and implement type can be selected using the various buttons contained in the window. Calculations of draft and drawbar power requirements for a selected implement are performed by specifying tillage depth, implement width, and expected speed of operation while other constant parameters (F_1, A, B, and C) display automatically upon selection of soil, tillage, and implement type. The constant parameter, A, is a function of soil strength while the coefficient of speed parameters, B and C, are related to soil bulk density. Typical values of these parameters are listed in ASABE Standards [17].

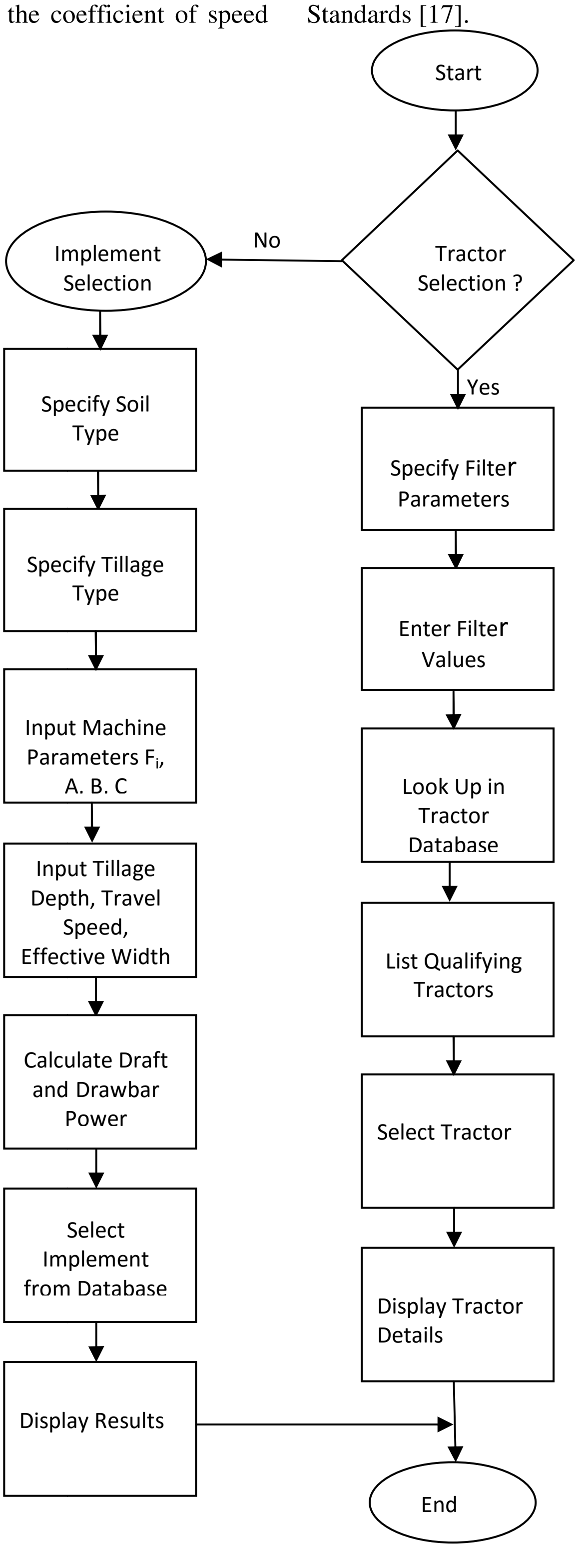

Fig.1. Flowchart for Program of Tractor and Implement Matching

III. Results And Discussion

The tractor window shown in figure 2 displays the pictorial representations of the tractors in the database. When the parameters of the tractor have been specified from the dropdown list and the refresh button is clicked, the tractors that match the specifications are displayed. A window showing an example of tractor details is shown in figure 3. Once the tractor has been selected, the matching implement can be obtained from the implement window as shown in figure 4. The effectiveness of the program was tested by verifying that the results of the program conformed with manually calculated results.

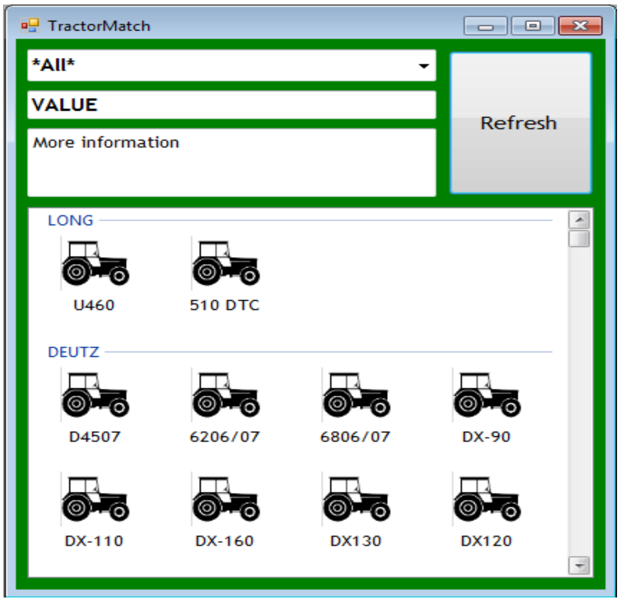

Fig. 2. The Tractor Window

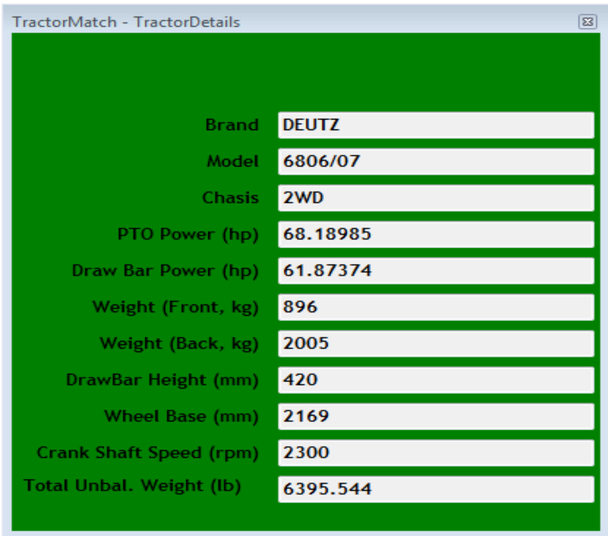

Fig. 3. Tractor Details Window

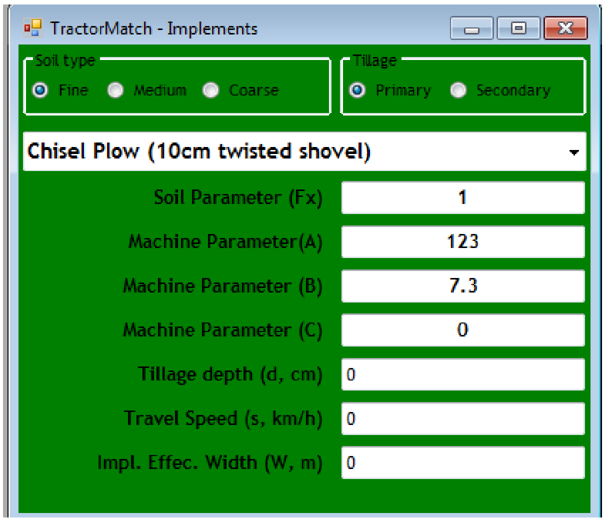

Fig.4. The Implement Window

IV. Conclusion

A Visual basic.NET program that can be used to match an implement to a tractor has been successfully developed for use in farm machinery management and educational research purposes. The program is user friendly and can be run on a windows environment with or without Visual studio environment.

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