

## Development of a Comprehensive Computer Program for Predicting Farm Energy

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**Abstract: Problem statement:** The agricultural industry is a major user of energy. Energy is used directly for operating agricultural machinery and equipment on the farm and indirectly in the manufacturing of fertilizers and pesticides and processing of agricultural products off the farm. In order to reduce the cost of agricultural production, energy uses on the farm must be identified and optimized using modern tools. **Approach:** A comprehensive and easy to use computer program was developed for the purpose of determining the farm energy requirements with the aim of reducing costs and maximizing profit. The program includes a main database composed of nine sub-databases: Tractors sub-database, agricultural machinery sub-database, pumps sub-database, stationary engines sub-database, planting dates sub-database, soil sub-database, operating variables of farm operations sub-database, draft and power equations sub-database and water requirement sub-database. The program was designed with visual C++ language. **Results:** The program was tested by comparing its results with the manually calculated results. The results showed that the program worked properly. The developed program was also illustrated using an example farm to show the different stages of determining the required farm energy. **Conclusion:** The program can be used: To determine the farm energy requirements, to assess the current status of farms in terms of energy use efficiency, for future planning of modern farms and as an educational tool. It has many advantages including: Ease of use when dealing with input through interactive windows, ease of addition or deletion or updating of sub-databases, ease of exploring the program windows and the potential for further future development of any part of the program. The program is unique as it includes all the information in a database and has a multi dimensional uses including: Evaluation of an existing system, selecting new machinery based on an optimum energy use and future planning of farm operations.

**Key words:** Farm energy, field operations, water pumps, fuel, visual programming

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### INTRODUCTION

The agricultural Industry is a major user of energy. Energy is used directly for operating agricultural machinery and equipment on the farm and indirectly in the manufacturing of fertilizers and pesticides and processing of vegetables, fruits and other crops off the farm (United States Department of Agriculture, 2006). Energy cost makes a large portion of the farm bill. Therefore, in order to reduce the cost of agricultural production, energy uses on the farm must be identified and optimized using modern tools.

There are several computer programs/models that have been developed for sizing farm equipment and optimizing farm operations. Al-Hamed and Al-Janobi (2001a; 2001b) designed two programs to determine the optimal operation of agricultural tractors and machine

system using Visual C language and adopting the ASAE Standards 2000 (ASAE, 2000). Sogaard and Sorensen (2004) developed a non-linear model for the optimal sizing of agricultural machinery based on the concept of least-cost inclusive of all fixed and variable costs for a limited farm area as well as crops. Camarena *et al.* (2004) develop a model for the selection of machine systems for several farms. The program was linked with a number of spreadsheet tables for the selection of farm machinery and selects a set of machines for each farm on the basis of the least annual cost. The required information consisted of fixed and variable costs, the schedule of operations, a set of machines and the area of each farm. Baruah and Panesar (2005a) modeled the components of a combine in terms of power and energy requirements using a number of processes including physical theories,

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mechanics and mathematics. The model incorporated crop, machine and soil factors. The crop factors included: The flexibility, determination inertia and the height and integrity of crop. The machine factors included: Corrective factors of machine forward speed and the total weight of the machine. In a subsequent study (Baruah and Panesar, 2005b), the model was verified and used to calculate the energy requirements for all farm operations. A Decision Support System (DSS) was designed by Recio *et al.* (2003) for planning agricultural projects. The system takes into account the factors which were not considered in the traditional method such as scheduling field tasks, investment analysis, machinery selection, cost to benefit ratio and other factors in agricultural production. It dealt with the medium and large farms and was linked to a framework for building decision support system in agriculture.

Although extensive research were carried out regarding farm energy measurements, the output from most of these studies was one dimensional models (such as selection or evaluation of one aspect) and all models shared the difficulty of filing the input data required for the model use.

This research aimed at developing a comprehensive interactive computer program that can be used to determine the farm energy requirement and select and evaluate agricultural equipment needed for a farm based on optimum energy requirement. The functions of the program include: (a) determining pump's power requirement for lifting water from wells and distributing it through the irrigation system, (b) determining the appropriate tractor's power according to the size and nature of the farm and (c) estimating the costs of fuel and oil consumptions for both the pumps and agricultural tractors. The program was developed using field data as well as a database for agricultural equipment for easy use.

## MATERIALS AND METHODS

**Farm energy model equations:** The Farm energy requirements considered in this study are (a): the energy required for performing farm operations and (b) the energy required for lifting and distributing water in the field through the irrigation system of the farm.

The Energy requirements for farm operations are determined by calculating the tractor power and the power of self-propelled machines used for all operations necessary for crop production. The maximum power for tractors is calculated and used in determining the agricultural machinery used for various farm operations and for estimating fuel and oil consumptions. The tractor power is determined based

on the use of a primary plow that requires high power for performing the tillage operation. The moldboard plow requires high power value followed by the disk plow and chisel plow.

The appropriate implement width for an area is calculated based on the field capacity. The Effective Field Capacity (Eff FC) is expressed in ha h<sup>-1</sup> as follows:

$$\text{Eff FC} = \frac{A}{\text{Hrs}} \quad (1)$$

Where:

A = The field area (ha)

Hrs = The hours of work during the season (h)

The hours of work during the season are calculated as follows:

$$\text{Hrs} = w_s \times d_w \times h_d \quad (2)$$

Where:

w<sub>s</sub> = The number of weeks of season (week)

d<sub>w</sub> = The number of weekly working days (day)

h<sub>d</sub> = The number of daily working hours (h)

The Theoretical Field Capacity (Th FC) is expressed as follows:

$$\text{Th FC} = \frac{\text{Eff FC}}{\text{FE}} \quad (3)$$

where, FE is the average field efficiency (%).

Also, the Theoretical Field Capacity (Th FC) is expressed as follows:

$$\text{Th FC} = \frac{s \times W}{10} \quad (4)$$

Where:

s = The forward speed (km h<sup>-1</sup>)

W = The implement operating width (m)

The implement operating Width (W) is calculated using the following equation:

$$W = \frac{\text{Th FC} \times 10}{s} \quad (5)$$

The required Draft (D) for an implement is computed based on specified depth and speed. Equation 6 shows a general form for calculating the draft (ASAE, 2000):

$$D = F_i [A + B s + C s^2] W d \quad (6)$$

Where:

- D = The required draft (N)  
 d = The tillage depth (cm)  
 A, B, C = Constants, depend on the type of implement (-)  
 F = A modification factor of the constants depending on soil type (-)  
 i = A representative value of soil type (1 = heavy, 2 = medium, 3 = sandy)

The drawbar ( $P_{db}$ ) power is the product of drawbar pull and the forward speed and is expressed in kW as follows:

$$P_{db} = \frac{D \times s}{3.6} \quad (7)$$

The total tractor Power (P) is expressed as follows:

$$P = \frac{P_{db}}{T_e} \quad (8)$$

where,  $T_e$  is the average tractive efficiency, depends on the field condition and soil type (%).

The recommended tractor Power ( $P_r$ ) considering a Reserve factor ( $R_f$ ) is calculated as follows:

$$P_r = \frac{P}{R_f} \quad (9)$$

In the operation with the highest draft requirement, which is the basis for determining the required tractor power, the loading factor equals the reserve factor. For the rest of field operations, the drawbar power and the total power are calculated using the same procedure as for the first operation, but the loading factor is calculated by dividing the total power required for an operation by the recommended tractor power.

The power of a self-propelled machine is calculated using the following equation, which can also be used for machines that draw their power from the tractor through the PTO:

$$P_{PTO} = a + b W + c F \quad (10)$$

Where:

- $P_{PTO}$  = The required power by the machine engine (kW)  
 F = The feeding rate ( $t h^{-1}$ )  
 a, b, c = Equation constants depending on the machine type

The fuel consumption is calculated using the following ASAE recommended equation for diesel tractors (ASAE, 2000):

$$Q_f = 2.64 r + 3.91 - 0.203 \sqrt{738 r + 173} \quad (11)$$

Where:

- $Q_f$  = The quantity of fuel consumption ( $L kW \cdot h^{-1}$ )  
 R = The load factor (-)

The fuel cost is calculated as follows:

$$C_f = Q_f \times P_r \times P_f \times Hrs \quad (12)$$

Where:

- $C_f$  = The fuel cost (SR)  
 $P_f$  = The fuel price per liter ( $SR L^{-1}$ )

The oil consumption is calculated using the following recommended equation (ASAE, 2000):

$$Q_o = 0.00059 P_r + 0.02169 \quad (13)$$

where,  $Q_o$  is the quantity of oil consumed ( $L h^{-1}$ ).

The oil cost is calculated as follows:

$$C_o = Q_o \times P_o \times Hrs \quad (14)$$

Where:

- $C_o$  = The oil cost (SR)  
 $P_o$  = The oil price per liter ( $SR L^{-1}$ )

For determining the required energy to lift the water, the power of the stationary engine operating the pump is calculated. The pump discharge is calculated based on the crop type, water requirement, irrigation period, daily operating hours for irrigation and type of irrigation system. Equation 15 was used for estimating water requirement ( $ET_c$ ):

$$ET_c = ET_o \times K_c \quad (15)$$

Where:

- $ET_o$  = The evapotranspiration ( $mm day^{-1}$ )  
 $K_c$  = The crop coefficient (-)

The values for Evapotranspiration ( $ET_o$ ) and the values for crop coefficient ( $K_c$ ) for Saudi Arabia were obtained from the Guide for Crop Irrigation Requirements in the Kingdom of Saudi Arabia (Al-Zaid *et al.*, 1988).

Irrigation systems used in Saudi farms are often sprinkler irrigation, central pivot, surface irrigation, or drip irrigation in the field or in greenhouses. Equation 16 was used to calculate the required discharge for a water pump (Q) in the case of intensive crops such as wheat or barley which has water requirement units of “mm day<sup>-1</sup>” and the irrigation system used is one of the systems used in the Kingdom of Saudi Arabia:

$$Q = k \frac{A ET_c}{h E_i} \quad (16)$$

Where:

- Q = The discharge (L s<sup>-1</sup>)
- A = The area (ha)
- ET<sub>C</sub> = The water requirements (mm day<sup>-1</sup>)
- E<sub>i</sub> = The irrigation efficiency
- h = The operating hours (h day<sup>-1</sup>)
- k = A constant equal to 2.778

In the case of trees such as palm trees, which are irrigated by surface or drip irrigation systems and their water requirement units are “L day<sup>-1</sup>”, the required discharge of the pump (Q) is calculated as follows:

$$Q = n \frac{ET_c}{k h E_i} \quad (17)$$

Where:

- ET<sub>C</sub> = The water requirements (L day·tree<sup>-1</sup>)
- k = The constant equal to 3600
- n = The trees count, calculated by dividing the area by planting distances

In the case of crops cultivated in the greenhouses such as vegetables where drip irrigation system is used, the required pump discharge (Q) is calculated as follows:

$$Q = \frac{n q}{k E_i} \quad (18)$$

Where:

- q = The discharge of a single line (L h<sup>-1</sup>)
- n = The number of drip lines
- k = The constant equal to 3600

The discharge of one drip line is calculated by multiplying the number of drips per line by the discharge of the drip.

The total dynamic head of the pump is the main parameter for calculating the power of the pump. The

depth of water in the well represents the amount of static head plus the amount of depth of the decline due to pumping water, because at the beginning of the operation of a pump, water level becomes lower forming a water cone in the well. In addition, the head required at the beginning of the irrigation system is added. The total of these pressures is the total dynamic head necessary for the pump to meet its operational requirements. Based on the total dynamic head, the required power for the pump and engine is calculated. The Water Power Value (WHP) of the pump can be calculated as follows:

$$WHP = \frac{\gamma Q H}{76} \quad (19)$$

Where:

- γ = The specific weight of water (equals 1)
- H = The total dynamic head (m)

Then, the power of the engine required to operate the pump is calculated. The engine power is greater than pump power, due to the loss in power as a result of mechanical parts and the high power requirement at start-up. Usually, engine power should not be less than 130% of pump power.

**Farm energy program:** The program was designed using the object programming language of Visual C++ using Borland C++ Builder 2006 (Borland Software Corporation, 2006). The application type is Multiple Document Interface (MDI) application. In addition, QuickReport Pro 4.06 package (QBS Software, 2006) was installed in the program in order to cover part of the development of software for the designing of reports. The program includes a main database and 9 sub-databases, containing information and data on farm energy. The program determines the appropriate power values of water pumps and tractors which are suitable for a given farm size and conditions. Then, the appropriate agricultural equipment (agricultural machines or pumps) can be selected from the equipments database for specific farm conditions. These include: Type of crop, type of soil and depth of well. Also, the program estimates the costs of fuel and oil consumed on the farm.

The program is useful in evaluating the current status of a group of farms in terms of appropriateness of energy consumption and in the future planning of modern farms by identifying the amount of energy required and the selecting of agricultural equipment. It is very useful as an education tool and can be used by consultants. The program was used to analyze the status of energy use in the farms of Saudi Arabia

The flow diagram (Fig. 1) shows the main components of the program used to determine the optimum energy. The program inputs include: Farm data such as the name of the farm, farm location, cultivated crops, cultivated area, soil type, agricultural operations and the depth of water in well. The database is useful as an additional input to the program with the possibility of updating its data using the program. The program depends on experimental models derived from field research and mathematical formulas. The program outputs include: An estimate of energy for agricultural equipment such as pumps, stationary engines, tractors and other agricultural machines.

A database for information and data on farm energy was established. The information were obtained (a) from data collected from farms using a questionnaire (b) from data obtained from measurements made on the farms during field visits and (c) equipment specifications from manufacturers. The data available in this database is used in the calculations of the required energy of the farm using the mathematical models that form the core of the developed program. The program is user friendly and it has the following 9 sub-databases:

**Tractors sub-database:** This sub-database containing tractors specifications for more than 800 tractors gathered from Nebraska Tractor Tests reports. These specifications include: The manufacturer, model, drive type, power, weight on front and rear axles and front and rear tires sizes.

**Agricultural machinery sub-database:** This sub-database consists of 26 kinds of agricultural machinery in terms of the type of farm operation. Each kind includes many implements of different manufacturers and models. The total number of implements in the sub-database is 355. The information in this sub-database includes: the manufacturer, model, hitch type, width, number of tools (or bodies, disks, or rows), tank capacity, power and operation depth.

**Pumps sub-database:** This sub-database includes: The manufacturer, model, discharge, power, efficiency, number of fans and pipe diameter.

**Stationary engines sub-database:** This sub-database includes: The manufacturer, model, power and efficiency.

**Planting dates sub-database:** This sub-database contains the planting dates of 14 crops for the study areas. Some crops are planted twice while others are planted once.

**Soil sub-database:** This sub-database includes: Soil type, soil classification and cone index.

**Operating variables of farm operations sub-database:** This sub-database includes: Operating variables for each implement. It consists of hitch type, operating speed, field efficiency, tractive efficiency and the dates of beginning and ending of farm operation.

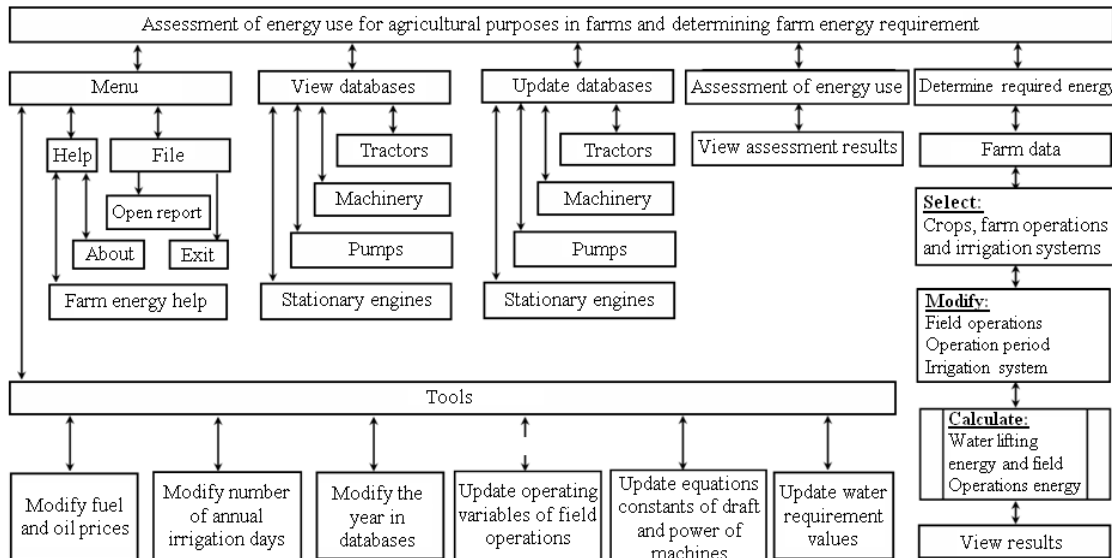


Fig. 1: Flow diagram of the farm energy program

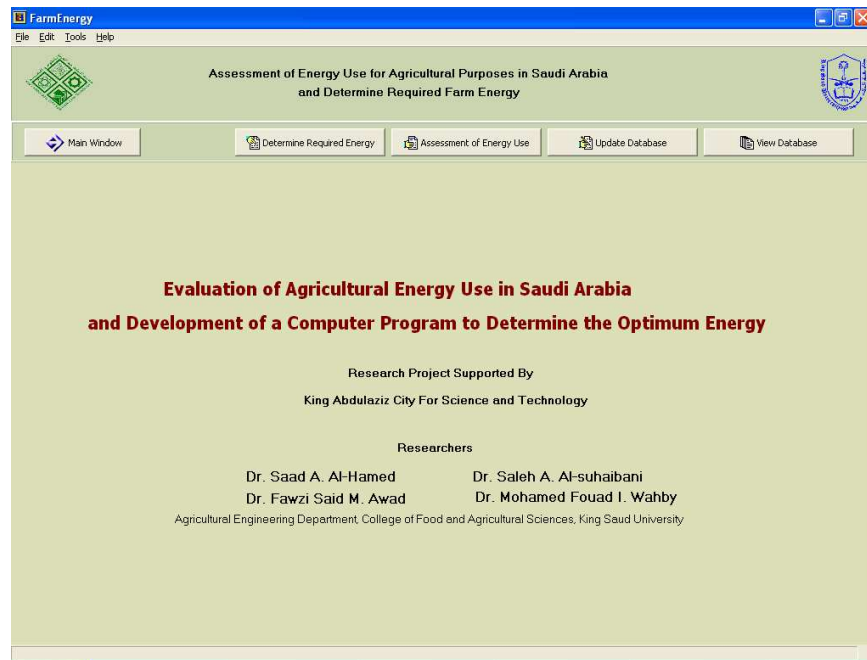


Fig. 2: Opening screen of the program shows the main window

**Draft and power equations constants sub-database:**

This sub-database includes: The constants of the equations necessary to calculate draft and power of agricultural machinery. These constants for most of machines were adopted from the ASAE Standards 2000 with some modifications based on field experiments conducted in this study.

**Water requirements sub-database:** This sub-database includes: Values of water requirements of all crops based on farm location.

**RESULTS AND DISCUSSION**

The program consists of five main windows: (a) a main window containing the title of the research project and the names of researchers in the project (Fig. 2), (b) a database view window, (c) a database updating window, (d) an assessment of energy uses window and (e) a required energy window for a new farm. The transition from a window to another is done through buttons in the upper part of the application interface. The program also contains a toolbar at the top of the application interface. The toolbar includes four options: File, edit, tools and help. The option “File” allows opening a previously saved report of farm energy. The report is of the form of QuickReport (qrp) and was formed using the program. The option “File” allows exiting the program. The option “Edit” allows the use of three elements: Copy, paste and cut. The option

“Tools” allows the use of three elements: Modify the price of fuel and diesel, Modify the number of days of annual irrigation and Revise the year in the database. The option “Help” has two elements: “About” and “Farm Energy Help”.

Given the importance of the inputs of appropriate data (integer or real numbers, or date) in different fields in all parts of the program, a procedure was developed within the program to ensure entering appropriate input values in the fields. In the case where the user enters invalid values, the program notifies the user through a warning window. The verification of the validity of inputs in some windows is performed at the end of filling the required fields and after the button that accompanies them is clicked. In most windows validity of inputs is performed directly during data entry in the fields.

**Database view window:** The database view window contains six buttons linked to dialog forms concerning databases of agricultural tractors, agricultural machinery, pumps, stationary engines, planting dates and soil specifications.

**Database updating window:** The database updating window also contains six buttons linked to dialog forms concerning the sub-databases of agricultural tractors, agricultural machinery, pumps, stationary engines, planting dates and soil specifications. These dialog forms permits changing, deleting and adding data to the database.

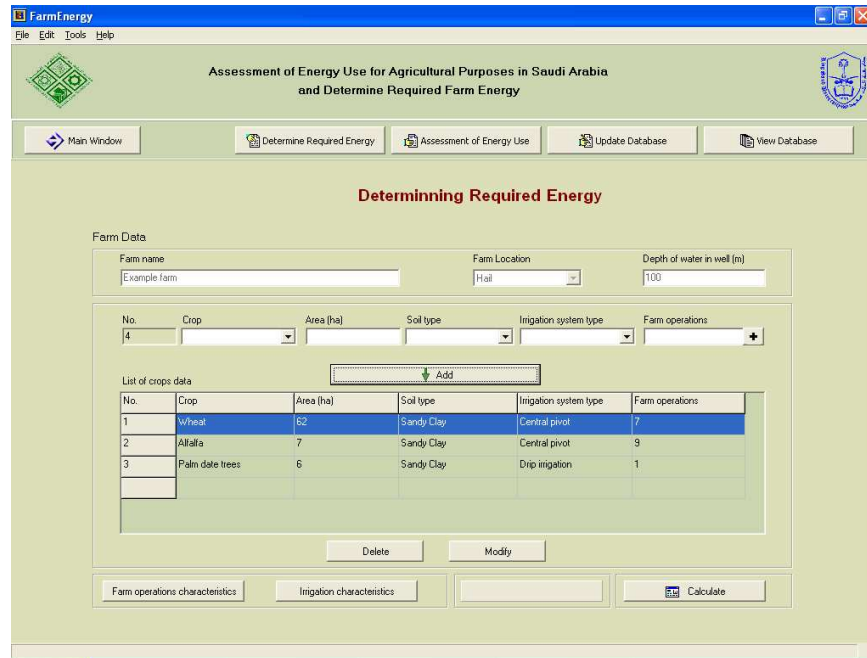


Fig. 3: Required energy window

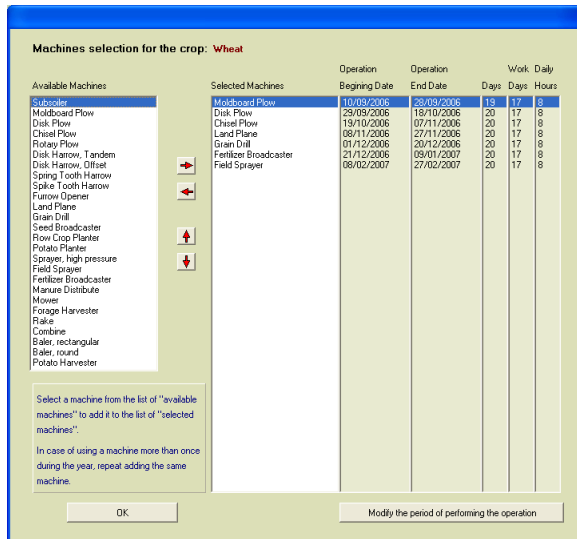


Fig. 4: Selection of agricultural machinery

**Assessment of energy uses window:** This window contains four sets of options of the type "Radio Group". The first group includes options for the study areas, the second group includes crop types, the third group includes soil types and the fourth group is related to agricultural companies. When selecting one of the elements of a group, the associated results of the evaluation of energy uses are presented graphically and digitally based on the results of the questionnaire. The

results include power index for water lifting, power index for farm operations and total power index based on cultivated area and overall farm area.

**Required energy window:** This window is used to determine required energy for a new farm. It contains a number of fields such as the name and location of the farm, water depth in the wells, farm crops, cultivated areas, soil type, irrigation system and farm operations for each crop.

Figure 3 shows an example of a farm in Hail Region, where the depth of water in the wells is 100 meters and the farm contains three crops (wheat, alfalfa and palm date trees). Crops are selected from the drop-down list containing 14 crops (wheat, barley, alfalfa, palm date trees, oranges, lemons, figs, mangoes, bananas, sorghum, corn, Rhodes grass, vegetables and potatoes). The field areas are 62, 7 and 6 ha for wheat, alfalfa and palm trees, respectively. The soil type is sandy clay which was selected from the drop-down list contains ten types of soil. The irrigation system "central pivot" is also selected for both wheat and alfalfa from the drop-down list containing different irrigation systems (spray, central pivot, surface, drip irrigation and drip irrigation for greenhouses). For palm trees, drip irrigation was used. Farm operations for the crop are selected by clicking the button (+) at the left of the field of farm operations. As a result, a dialog form (Fig. 4) appears for the selection of agricultural

machinery for wheat. The dialog form contains a list of available agricultural machinery which includes 26 machines, as well as six lists related to the crop: Selected machines, beginning date of the operation, end date of the operation, number of days of operations, days of work to perform the operation and daily working hours.

Appropriate machines for the selected crop are included in the list of selected machinery automatically from linked sub-database, as well as for the five lists related to the duration of performing farm operations. Modification of the data can be made by adding, deleting or rearranging the machines using the four buttons located between the list of available machines and the list of selected machines. For the modification of data related to the duration of performing an operation, the user can click on the button below the lists after identifying the required machine by clicking on the list of selected machines to show the dialog form on Fig. 5. The dialog form contains the name of the crop and the machine and the date of the beginning and end of the operation. Dates must be in the same year. Objects used for dates are of the type "Date Time Picker". Thus, the dates can be changed by clicking the object which shows a monthly calendar window. As a result, the number of days and the number of working days depending on the options weekly leave (none, Friday, or Thursday and Friday) are calculated. If the user wants to change the date of the beginning and end of the operation keeping the period or number of days constant, he/she can move the green object that represent the duration right or left through the months of the year indicated in Fig. 5. Daily working hours can also be changed without affecting the database.

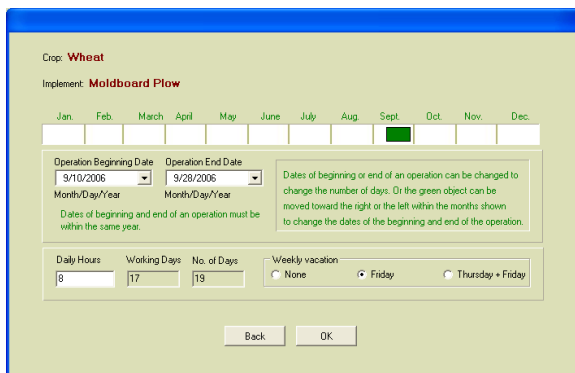


Fig. 5: Modification of data related to the duration of performing an operation

Upon the completion of selecting the operations for the crop, the required energy window (Fig. 3) is enabled and the number of operations is added in the specified field. And now the button "Add" can be pressed to add the crop and associated information to the table of the type "String Grid". The variables or characteristics related to the irrigation system and all farm operations are stored in the memory of the program. The program verifies that all information is complete and the type of irrigation system is compatible with the crop before adding the information to the table. The user can continue adding more crops by following same steps and adding them to the table. Modification to the information associated with added crop can be done by clicking on the crop in the table, then pressing the button "Modify". Removing a crop and all associated information can also be done by selecting the crop from the table and then pressing the button "Delete" without affecting the database. When the button "Calculate" is clicked in the Fig. 3 the process of determining farm energy begins depending on the flow charts (Fig. 6 and 7) for estimating the power requirements and costs of farm operations and irrigation, respectively.

For determining the required energy for agricultural equipment, the program depends on estimating power of tractors and self propelled implements. Figure 6 shows a flow chart to estimate power value of tractors for each crop in the farm taking into account the crop type, cultivated area, soil type and farm operations. The maximum power for tractors is calculated and used in determining agricultural machinery for various farm operations and estimating fuel and oil consumption.

For determining the required energy to raise the water, the program depends on estimating power of pumps and stationary engines. Figure 7 shows a flow chart to estimate power values of pumps and stationary engines for each crop in the farm taking into account the location, crop type, cultivated area, soil type and irrigation system.

The program takes into account the appropriate type of irrigation system with the type of crop. The program includes the irrigation systems used in Saudi farms, which are often spray irrigation, central pivot, surface irrigation, or drip irrigation in the field or in greenhouses. For example, the user can only chose the surface irrigation or drip irrigation in the case of palm trees. But, for the intensive crops such as wheat or barley, the user can chose surface irrigation system or spray irrigation or central pivot system.



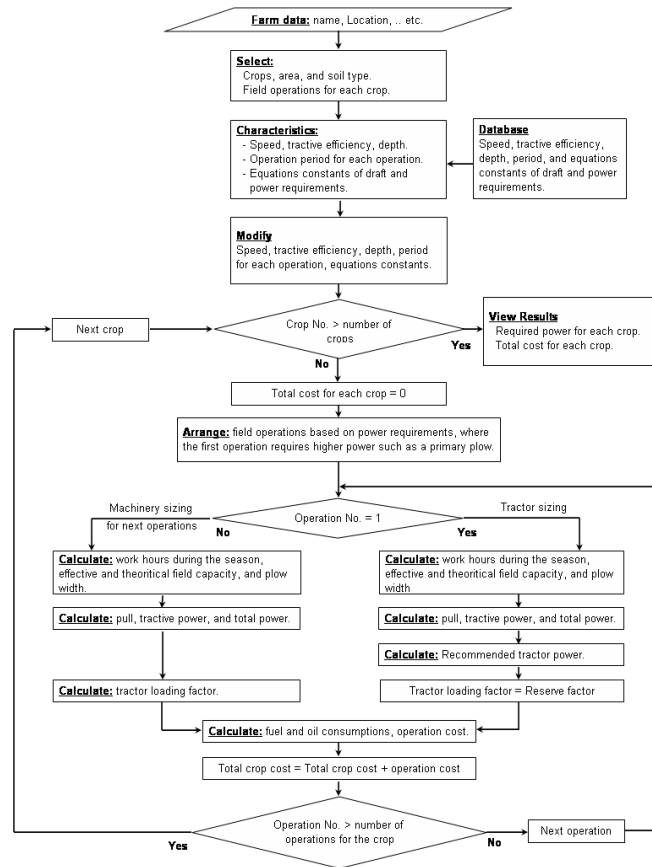


Fig. 6: Flow chart for estimating the tractors power for field operations

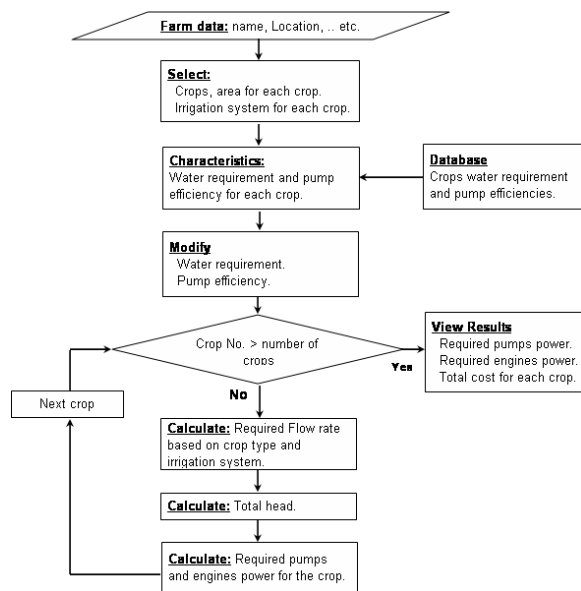


Fig. 7: Flow chart for estimating the power values of water pumps and engines

The program takes into account the total dynamic head of the pump as a main parameter for calculating the power of the pump. The user enters data for the depth of water in the well, which represents the amount of static head plus the amount of depth of the decline due to pumping water, because at the beginning of the operation of a pump, water level becomes lower forming a water cone in the well. In addition, the head required at the beginning of the irrigation system is added (depth is measured in meters). The total of these pressures is the total dynamic head necessary for the pump to meet its operational requirements. Based on the total dynamic head, the required power values of the pump and engine are calculated.

Figure 8 shows the results window of the required farm energy. The window contains a table of type “String Grid” consisting of six rows sufficient to six crops and increasing the number of rows automatically in the event of more crops. The table includes ten columns: Crop type, pump power, engine power, fuel consumption for water pumping, oil consumption for

water pumping, machine name or main operation used for tractor selection, tractor power, self-propelled machinery power, fuel consumption for all farm operations of the crop and oil consumption for all operations of the crop. There are eight fields below the table which represent the total power values and fuel and oil consumptions. There are also four fields showing costs for fuel and oil used for pumping water and farm operations. The results window also contains five buttons associated with the power index of crops, farm power index, printing a summary report, printing a detailed report and viewing the database of agricultural equipment.

Figure 9 shows the window of power index of crops. It contains two bar charts: Power index for field operations and power index for raising water. The vertical axis represents the power index ( $\text{kW ha}^{-1}$ ), while the horizontal axis represents the number of the crop. In this example where three crops exist in the farm (wheat, alfalfa and palm date trees), the chart

includes two bars for the crops. When the user clicks on one of the bars with the mouse, the color of the bar changes from green to blue and the data associated with it are presented in the fields at the left side of the window. These fields include farm area, crop type, crop area, the power values of pumps, stationary engines, tractors and self-propelled machines and the power index values for lifting water and field operations.

Figure 10 shows the window of farm power index. It contains a bar chart for of the farm power index. The vertical axis represents the power index ( $\text{kW ha}^{-1}$ ) and the graph consists of three bars (total power index, power index for lifting water and power index for farm operations). The window also contains nine fields: Farm area, number of crops, the overall power values of the pumps, stationary engines, tractors and self-propelled machines, the total power index and the power index values for lifting water and field operations.

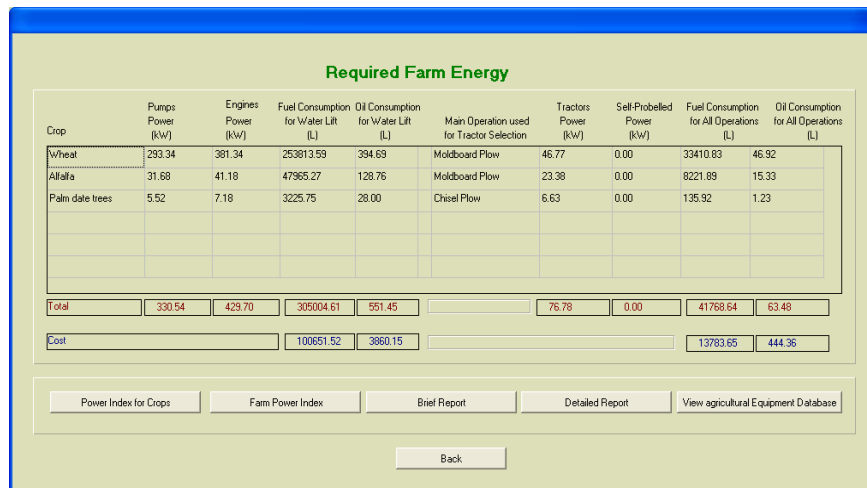


Fig. 8: Results window of the required farm energy

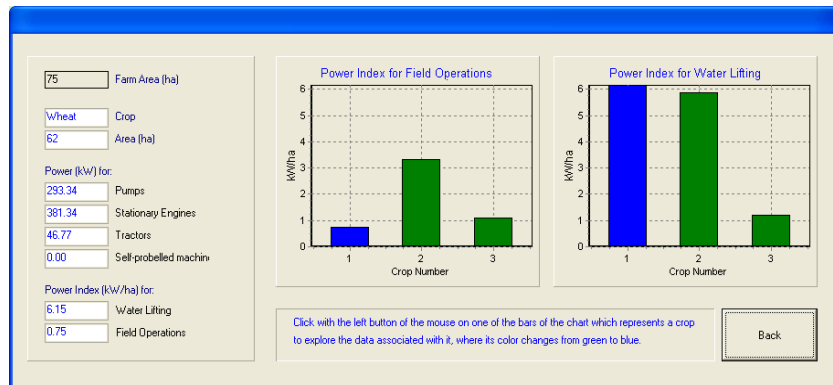


Fig. 9: Power index of crops

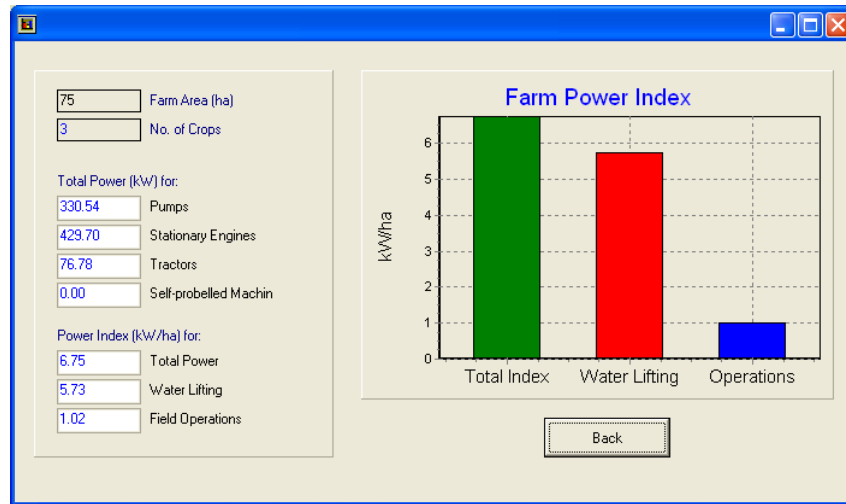


Fig. 10: Farm power index

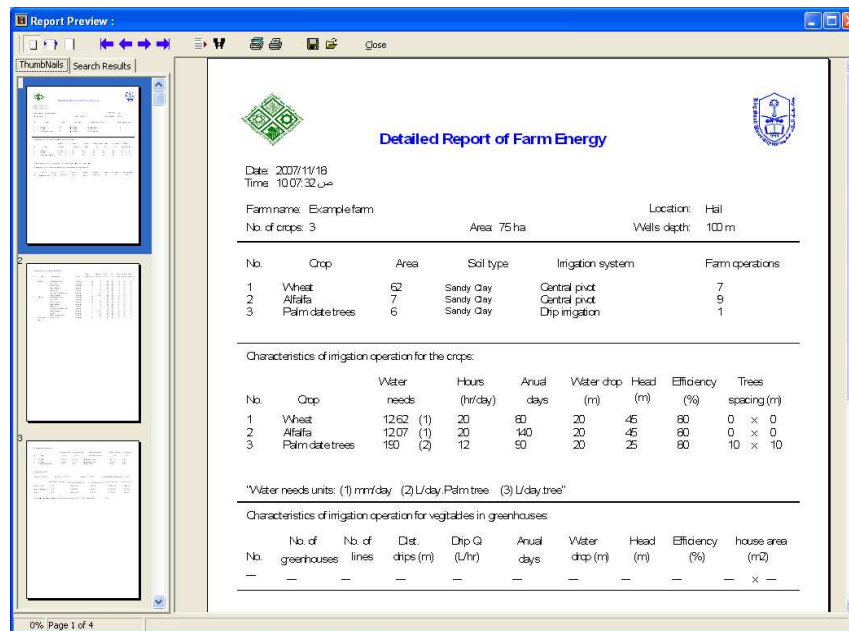


Fig. 11: A detailed report of farm energy for the example farm (page 1)

**Validation of the model:** The effectiveness of software was evaluated by comparing the results obtained for a number of farms using the program with manually calculated results of the same farms. One of the farms included in the questionnaire, performed for the research project, was used as an example to illustrate the different stages of the developed program (Fig. 4, 5 and 8-14). The farm location is in Hail Region and has a sandy clay soil. The farm is used for growing wheat, alfalfa and palm

date trees. The cultivated area covers the entire area of the farm of 75 ha, where the cultivated areas for wheat, alfalfa and palm date trees were 62, 7 and 6 ha, respectively. Irrigation systems used for wheat and alfalfa were central pivot systems and drip irrigation system for palm date trees. The depth of water in the wells is 100 m. Figure 11-14 show a detailed report of farm energy for the example farm. The program proved its effectiveness and ease of use in terms of meeting the purpose of it.

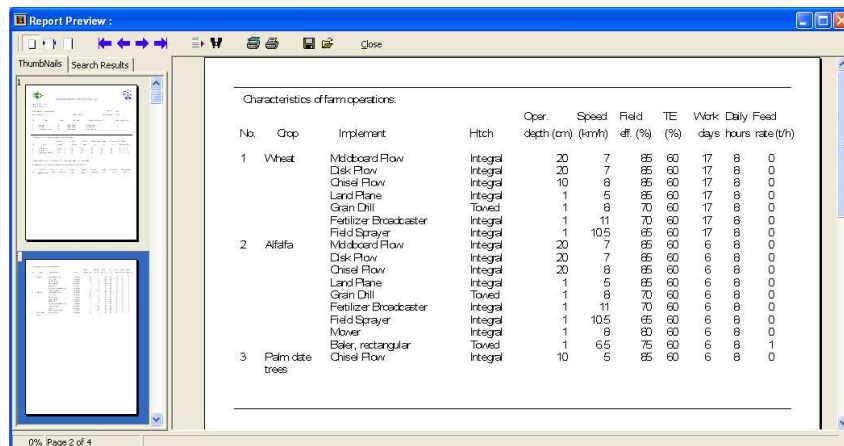


Fig. 12: A detailed report of farm energy for the example farm (page 2)

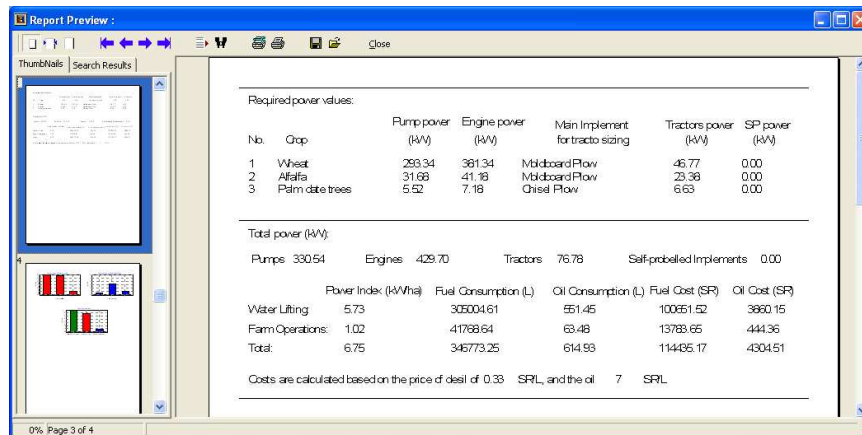


Fig. 13: A detailed report of farm energy for the example farm (page 3)



Fig. 14: A detailed report of farm energy for the example farm (page 4)

## CONCLUSION

A computer program has been developed using the visual language C++ for use in: (a) determining the required energy for assessing the current status of farms in terms of energy consumption, (b) future planning of modern farms and (c) advisory and educational purposes. The program includes a main database composed of nine sub-databases: Tractors, agricultural machinery, pumps, stationary engines, planting dates, soil, operating variables of farm operations, draft and power equation constants and water requirements.

The effectiveness of the program was tested by comparing the results of the computer program with the manually calculated results. The results showed that the program works properly and it has a number of advantages: (a) ease of use when dealing with inputs through interactive windows, (b) ease of addition, deletion or modification of the records in the databases and (c) ease of reviewing the program windows and navigating between them. The program was built with 50 files to facilitate the future development of any part of the programs

## ACKNOWLEDGEMENT

This research is part of a research project (No. AR-23-52). The authors are very grateful to the King Abdul-Aziz City for Science and Technology for granting the funds for the research project.

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