DECISION SUPPORT SYSTEM FOR COST AND TIME ESTIMATION OF SELECTED FARM OPERATIONS

Revanth, K.¹*; Sushilendra²; Manjunatha, K.³; Sunil, S.⁴
¹, ², ³, ⁴Dept. of Farm Machinery and Power Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur, Karnataka, India
Corresponding Email- revanthkraju@gmail.com

Abstract: The cost of the production of any crop is highly dependent on various agricultural inputs. One of the major input is the cost incurred on machinery for various farm operations. Hence, there is a necessity to scientifically estimate the cost incurred during various farm operations through a computer based application to take proper decisions. This study presents a decision support system (DSS) for calculating the cost and time estimation of selected farm operations which was developed in accordance with IS: 9164 – 1979 (Reaffirmed in 2002). The developed database contains the information regarding agricultural tractor and farm equipments and all the data was compiled in the tabular format in MS Access. The DSS has been developed in the VB.net programming language as front end and MS Access as back end, by linking databases such as useful life of the equipment/machine in years and hours and percentage of accumulated repair cost to support the decision on custom hiring of farm implements and machinery. The DSS predicted average fuel consumption, custom hiring charge, breakeven point, payback period and time estimation for a selected farm operation. The software successfully predicted the average fuel consumption and operational time of field operation and the results were validated by considering real time case studies. Paired T-test was carried out between predicted and actual values which indicated that there was no significant difference between them at 5 per cent level of significance.

Keywords: VB.net, MS Access, Database and DSS

1. Introduction
Agricultural mechanization aims at sustainable agricultural production by bringing lands under cultivation, saving energy and other resources, protecting the environment and increasing the overall economic welfare of the farmers. Machine and equipment are major inputs to agriculture.
Availability of adequate farm power is very crucial for timely farm operations for increasing production and productivity and handling the crop production to reduce losses (Srivastava, 2004). The growth in tractor production and sales in India has increased considerably during the last six decades. As a result, today around 300,000 tractors are sold annually. The average availability of tractors in the country is one tractor per 64 ha and the most popular size of tractor is in the range of 23–30 kW.

There has been a progressive shift from draft animal power (DAP) to mechanical power in Indian agriculture because DAP and manual labour are not sufficient to cope with the work load of intensive agriculture. The use of mechanical power is becoming indispensable for making an optimal use of other resources and in-time completion of various farm operations under intensive agriculture. Mechanization saves time in completing different farm operations, which gives the crop more time to mature; allows the farmer to be more flexible in farming operations; and facilitates multi and relay cropping. This transition from animal power to mechanical power in some states has made the agriculture capital intensive. But, it has played a key role in modernization of Indian agriculture due to its benefits of improved labour efficiency and productivity, efficient use of expensive farm inputs, reduction of human drudgery and timeliness of farm operations.

The cost of farm machinery is the single largest input after land and buildings, which make up a significant part of the operating and overhead costs of any farm operation. If the capital invested in a machine is to be used efficiently, then the machine must be used over enough hectares or for enough hours to have costs comparable to or below the same operation being done by a custom operator.

The most accurate method of determining machine costs is complete records of the actual costs incurred (Singh and Mehta, 2015). When estimating costs, methods that require more data specific to the situation, the more accurate becomes the estimate. Machinery and equipment expenses represent a major category of cost in crop production. Purchasing equipment with the use of loans from financial institutions or equipment manufacturers has been the typical method of obtaining machinery services for most farm operations. Producers
are increasingly considering other options for obtaining machinery services due to increasing equipment costs, obsolescence of owned equipment and limited sources of outside debt capital.

Computer programs are being used to assist farm managers and scientists in decision-making about how to manage machines or production operation and how to select machinery and power requirements (Alam and Awal, 2001). Computer models and simulation programs for predicting tractor performance help researchers to determine the relative importance of many factors affecting field performance of tractors without conducting expensive, as well as time consuming, field tests. Decision support systems (DSS) is defined as an interactive computer-based system intended to help decision makers utilize data and models in order to identify and solve problems and make decisions.

Singh and Mehta (2015) developed the database system consisting of data pertaining to 25 commonly used farm machines in Indian agriculture. The tables had information about agricultural implements, prime movers, name of machine and useful life of the machine in years and hours and data on percentage of accumulated repair cost of farm machinery. It presented a decision support system (DSS) for calculating the total operating cost and break-even units of farm machinery. The guidelines given in IS 9164 (1979) were followed for estimating operating cost of farm machinery. The DSS leading to computer software developed in Visual Basic TM. Author validated the developed DSS with a case study for its effectiveness in estimation of operating cost of farm machinery and calculation of breakeven units for custom hiring service.

Vaja et al. (2016) conducted a study on collection of information on various farm machinery from various villages of Junagadh Taluka in order to study the custom hiring status of this area. Profit-loss analysis was done in order to calculate the breakeven point and to determine the economic feasibility of the custom hiring services. They calculated annual fixed cost by taking depreciation, interest on investment, taxes and insurance, housing/shelter cost and annual variable cost was calculated by fuel cost, repair and maintenance cost, lubricating oil cost and operator and labour cost. It was observed that the return on
investment from a machine does not depend on its initial cost. It mainly depends upon the annual usages.

Yousif et al. (2013) developed a computer system for farm management and selection of required farm machinery to perform field operations. Excel and Visual Basic software were used to develop the program. The software estimated the size and number of machine, power requirement and fuel consumption for implements and operation. The validation of developed computer system was done by testing the model. The predicted and actual values of field capacity, fuel consumption and implement width were compared. The root mean square of error between predicted and actual values was found to be very low. Paired T-test was also conducted, which indicated no significant difference between predicted and actual values at 5 per cent level of significance.

2. Theoretical Consideration

**Fixed Costs** - Fixed costs could be predetermined as accumulating with the passage of time, rather than with the rate of work. These costs depend on how long a machine is owned rather than how much it is used.

**a) Depreciation** - Depreciation cost is designed to reflect the reduction in value over a period of time (Kaul and Egbo, 1985). The commonly and widely used is the straight-line method as recommended by IS: 9164 – 1979.

\[
D = \frac{P - S}{L \times H}
\]  

… (1)

Where,

- \(D\) - Depreciation cost, Rs h\(^{-1}\)
- \(P\) - Purchase price of the machine, Rs
- \(S\) - Residual or salvage value of the machine, Rs
- \(L\) - Useful life of the machine, yr
- \(H\) - Annual usage, h
b) Residual or salvage value of the machine - It is defined as the price of the equipment to which it possess at the time of its disposal. The salvage value often estimated as 5 or 10 per cent of the initial purchase price.

c) Average purchase price - It is defined as the mean of purchase price and salvage value. It was calculated using the following equation.

\[ A = \frac{P + S}{2} \]  \hspace{1cm} \text{... (2)}

Where,
- \( A \) - Average purchase price, Rs
- \( P \) - Purchase price of the machine, Rs
- \( S \) - Residual value of the machine, Rs

d) Interest - Annual charges of interest should be calculated on the basis of the actual rate of interest payable. If this information is not available, 12 per cent of average purchase price should be considered (IS: 9164 – 1979).

\[ I = \frac{A}{H} \times \frac{i}{100} \]  \hspace{1cm} \text{... (3)}

Where,
- \( I \) - Interest cost, Rs \( h^{-1} \)
- \( A \) - Average investment, Rs
- \( i \) - Interest rate, %
- \( H \) - Annual usage, h

e) Insurance and Taxes - Actual amount paid or to be paid annually for insurance and annual taxes, if any should be charged. If the information is not available, it may be calculated on the basis of 2 per cent of the average purchase price of the machine.

\[ I \& T = \frac{A}{H} \times \frac{2}{100} \]  \hspace{1cm} \text{... (4)}

Where,
- \( I\&T \) - Insurance and tax cost, Rs \( h^{-1} \)
A - Average investment, Rs
H - Annual usage, h

f) Housing - It should be calculated on the basis of 1.5 per cent of the average purchase price of the machine (IS: 9164 – 1979).

\[ H_S = \frac{A}{H} \times \frac{1.5}{100} \]  \hspace{1cm} \text{... (5)}

Where,

- \( H_S \) - Housing cost, Rs h\(^{-1}\)
- \( A \) - Average investment, Rs
- \( H \) - Annual usage, h


g) Total fixed costs (TFC) - It is the sum of depreciation, interest on investment, insurance and taxes and housing.

Variable costs - It varies in proportion to the amount of machine used. Operating costs vary directly with the rate of work. It includes costs of fuel, lubricants, repairs and maintenance, wages of operator and labour cost.

a) Fuel cost - Fuel consumption depends on the size of the power unit, load factor and operating conditions. Average fuel consumption can also be estimated by the following formulae (Singh and Mehta, 2015).

i) For diesel engines

\[ A = 0.15 \times B \]  \hspace{1cm} \text{... (6)}

Where,

- \( A \) - Average diesel consumption, l h\(^{-1}\)
- \( B \) - Rated power, kW

ii) For petrol engines

\[ C = 0.25 \times B \]  \hspace{1cm} \text{... (7)}

Where,

- \( C \) - Average petrol consumption, l h\(^{-1}\)
- \( B \) - rated power, kW
iii) The fuel consumption for diesel engine was also estimated according to the method described by Annon, 1976 as below.

\[ \text{Fuel Consumption, } 1h^{-1} = \text{Drawbar power, } kW \times 0.226 \]  

… (8)

The fuel cost per hour was obtained by multiplying the fuel consumption and the prevailing price of the fuel in the market.

b) Oil cost - The actual oil consumption should be recorded while the machine is working. In case oil consumption data is not available, oil consumption may be taken as 2.5 to 3 per cent of the fuel consumption on volume basis. Oil cost was estimated as the product of oil consumption and the current oil price per litre in the market.

c) Repair and maintenance - The accumulated repair and maintenance costs (TAR) at any point in a machine’s life can be defined as total cumulative repair and maintenance costs per year divided by the purchase of the machine expressed as percentage and can be estimated from the following formulae (Singh and Mehta, 2015).

For tractor, \( \text{TAR} = 0.100 \times X^{1.5} \)

For power tiller and stationary engine, \( \text{TAR} = 0.120 \times X^{1.5} \)

For agricultural trailer, \( \text{TAR} = 0.127 \times X^{1.4} \)

For chisel plough, subsoiler, ridger, bund former mouldboard plough, disc plough, disc harrow, planter, transplanter, leveller and cultivator, \( \text{TAR} = 0.301 \times X^{1.3} \)

For rotavator, seed cum fertilizer drill, sprayer, reaper, root crop harvesters and post hole diggers and thresher, \( \text{TAR} = 0.159 \times X^{1.4} \)

For self-propelled and tractor mounted combine harvester, \( \text{TAR} = 0.096 \times X^{1.4} \)

Where,

\( X \) - 100 times the ratio of accumulated hours of use to wear out life. (Singh and Verma, 2012)

The repair and maintenance cost was estimated as the per cent TAR value of the purchase value.

d) Wages and Labour Charges - Average cost per hour may be computed by dividing the total cost by the number of hours the operator has performed the work. This cost will be higher than the average per hour work on the farm because part of the time will be
used for travelling, interruptions and moving machines from one farm to another and which is not paid for directly by the customers.

**e) Total variable costs (TVC)** - It is the sum of fuel cost, lubricating oil cost, repair and maintenance cost and wages and labour charges.

**Total costs (TC)** - It is the sum of all fixed costs and variable costs.

\[
\text{Total costs} = \text{Fixed costs} + \text{Variable costs}
\]  \hspace{1cm} \ldots(9)

**Overhead charges (OHC)** - This includes charges for supervision and establishment and interest on working capital if applicable. It should be assumed as 20 per cent of the sum of fixed and variable costs (IS: 9164 - 1979).

**Custom hiring charge (CHC)** - It is the sum of value of profit per cent of total costs, total costs and overhead charges.

\[
\text{Custom hiring charges, } C = (P\times \text{Total costs}) + \text{Total costs} + \text{Overhead charges}
\]  \hspace{1cm} \ldots(10)

Where,

- **P** - Profit per cent

**Breakeven point (BEP)** - It is the point at which the total revenue is exactly equal to the total cost. It is the minimum operation of a machine hours in a year so that, loss is not incurred and was estimated using the following equation (Vaja et al. 2016).

\[
\text{Breakeven Point (h yr}^{-1}) = \frac{\text{Total fixed cost per year}}{\text{Custom hiring charges (Rs h}^{-1}) - \text{Total variable cost (Rs h}^{-1})} \hspace{1cm} \ldots(11)
\]

**Average net annual profit (ANAP)** - It is the average profit obtained in a year from a machine after its run in recommended annual usage hours and was calculated using following equation (Vaja et al. 2016).

\[
\text{ANAP (Rs yr}^{-1}) = \left[\text{CHC (Rs h}^{-1}) - \text{TVC (Rs h}^{-1})\right] \times \text{Annual usage (h yr}^{-1}) \hspace{1cm} \ldots(12)
\]
Payback period - It is the minimum number of years that the machine has to work so that money invested on it is recovered and was estimated using the following equation (Singh and Verma, 2012).

\[
\text{Payback period (yr)} = \frac{\text{Purchase price (Rs)}}{\text{ANAP (Rs yr}^{-1})}
\]  

… (13)

Time estimation

Field efficiency - Field efficiency is a measure of relative productivity of a machine under field conditions, it accounts for failure to utilize the theoretical operating width of the machine, operator’s capability and habits, operating policy and field characteristics. The formulae for calculating the field efficiency and theoretical field capacity is given below (Sahay, 2010).

Field efficiency, \( e \) (%) = \( \frac{\text{Effective field capacity (ha h}^{-1})}{\text{Theoretical field capacity (ha h}^{-1})} \)  

... (14)

Theoretical field capacity (ha h\(^{-1}\)) = \( \frac{\text{Width (m) \times Speed (km h}^{-1})}{10} \)  

... (15)

Effective field capacity - It is the actual area covered by performing a particular farm operation in unit time or it can also be defined as the time taken to cover unit area by performing a particular farm operation. It was estimated as below (Sahay, 2010).

\[
E (\text{ha h}^{-1}) = \frac{W \times S}{10} \times \frac{e}{100}
\]  

… (16)

Where,

- \( E \) - Effective filed capacity, ha h\(^{-1}\)
- \( W \) - Working width of the implement, m
- \( S \) - Speed of operation (km h\(^{-1}\))
- \( e \) - Field efficiency (%)
Time required to cover unit area - The time required to cover unit area of land is taken as the reciprocal of effective field capacity. It was calculated as below.

\[ E^O \ (h \ ha^{-1}) = \frac{1000}{W \times S \times e} \]  \hspace{1cm} \text{… (17)}

Time required to cover a particular area - It is the time required to cover a particular area ‘A’ for one pass and was calculated using the following equation.

\[ t = E^O \times A \]  \hspace{1cm} \text{… (18)}

Where,
- \( t \) - Time required to cover a particular area ‘A’ for single pass (h)
- \( E^O \) - Time required to cover unit area (h ha\(^{-1}\))

Total time estimation - It is the total time required to cover a particular area with number of passes and is estimated as below.

\[ T = t \times N \]  \hspace{1cm} \text{… (19)}

Where,
- \( T \) - Total time (h)
- \( t \) - Time required to cover a particular area ‘A’ for single pass
- \( N \) - Number of passes

Total cost of operation

It is the total cost incurred to perform a particular farm operation and is estimated as below.

\[ \text{Total cost of operation} = C \times T \]  \hspace{1cm} \text{… (20)}

Where,
- \( C \) - Custom hiring charge, Rs h\(^{-1}\)
- \( T \) - Total time, h
3. Development of decision support system

The decision support system for cost and time estimation of selected farm operation has been developed with visual basic dot net as front end and MS Access as back end support. The decision support system estimates the custom hiring charges and predicts the time of field operation. It was developed in the form of a computer program using the interactive controls and algorithms of Visual Basic dot net programming language.

The database contains the information regarding agricultural tractor, power tiller, stationary engine, equipments required for land development, primary tillage and secondary tillage, sowing, plant protection, harvesting machines, thresher and other miscellaneous equipment. The information of annual usage and useful life of all the agricultural implements and machinery were collected (Table 1). Speed of operation and field efficiency of different farm implements were also collected (Table 2). The conversion factor for calculation of drawbar power from maximum PTO power for various soil conditions were compiled (Table 3). The parameters such as draft, operational speed and field efficiency of various implements for different soil type were collected (Table 4).

The decision support system was developed in the form of a computer program using the interactive controls and algorithms of Visual Basic programming language. The DSS model runs on a platform of Windows 95™ or above versions. The decision support system was developed in visual studio platform, which is one of the leading technology in IT industry from recent past. It is best viewed at the screen resolution of 1366 × 768 pixels. The graphical user interface is the combination of pop-up windows, pull down menus, button controls and is more driven. The two components of the developed decision support system are described in Fig. 1 and 2.

The developed decision support system was validated by testing of the model. The validation of developed decision support system for cost and time estimation of selected farm operation was carried out with a real time case studies by performing selected field operations in the field to know the effectiveness of the developed decision support system. The fuel
consumption was measured by fixing an auxiliary fuel tank of 5 litre capacity (Fig. 3). The time of field operation was recorded from tractor hour meter.

The predicted and actual values of average fuel consumption, field capacity and implement width were analysed using data analysis tools. Paired T-test was conducted to test the significance between predicted and actual values. Root mean square of error values were also calculated using the following equation.

\[
\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (\text{predicted} - \text{actual})^2}
\] … (21)

Where,

\[n = \text{number of observations}\]

4. Results and Discussion

The developed decision support system starts with the splash screen displaying the name of the software version of it and the ‘start’ button. Then displays the login page where user id and password has to be entered which verifies the genuine user as many user ids and passwords are pre-set in the database of the software. Once the user id and passwords are verified, the main home screen of the software will be displayed. It consists of title bar, menu bar, date and calendar and other details.

Estimation of average fuel consumption

The estimated fuel consumptions for a mouldboard plough of width 0.6 m was found to be 2.70 l h\(^{-1}\) for heavy draft soil under firm conditions (Fig. 4), disc harrow of width 1.72 m was found to be 2.45 l h\(^{-1}\) for light draft soil under tilled conditions and cultivator of width 1.89 m were found to be 2.13 l h\(^{-1}\) for medium draft soil under tilled conditions (Fig. 4).

Custom hiring charges estimation

The custom hiring charges of all machines and machinery were in estimation in four successive screens viz., selection screen, fixed costs screen, variable costs screen and total
costs screen. The estimation of custom hiring charges for tractor is illustrated (Fig. 5 to 8). The results of average fuel consumption, custom hiring charges, breakeven point and payback period were calculated and found be 5.6 l h\(^{-1}\), 887.49 Rs h\(^{-1}\), 327.43 h yr\(^{-1}\) and 1.86 yr, respectively. The same procedure was followed for all other machines and machinery.

**Time estimation**

The mouldboard plough of width 0.6 m was selected based on which the recommended speed of operation and the field efficiency were displayed. Then the make and model of the implement was selected from which the working width of the implement was obtained. The field capacity was estimated as 0.19 ha h\(^{-1}\). The values of area to be covered and the number of passes is entered. The total time required for the operation was calculated. The time required to cover 1 ha was calculated to be 5.21 h (Fig. 9). The same procedure was followed for other implements. The time required to cover 1 ha by disc harrow of width 1.72 m was found to be 1.21 h, 1.1 h by cultivator of width 1.89 m whereas rotavator of width 1.8 m required 3.47 h to cover one ha area.

Selected field operations have been conducted for the validation of the developed DSS. The time required to cover a particular area is also noted and actual effective field capacity is calculated. The predicted and actual values of average fuel consumption and field capacity were analysed in SPSS correction tool to test their significance between them.

The actual values of fuel consumption and field capacity of mouldboard plough were found to be 2.72 l h\(^{-1}\), 0.185 ha h\(^{-1}\), respectively. The actual values of fuel consumption and field capacity of disc harrow were found to be 2.46 l h\(^{-1}\), 0.79 ha h\(^{-1}\), respectively. The actual values of fuel consumption and field capacity of cultivator were found to be 2.15 l h\(^{-1}\), 0.88 ha h\(^{-1}\), respectively. The actual values of fuel consumption and field capacity of rotavator were found to be 5.63 l h\(^{-1}\) and 0.28 ha h\(^{-1}\), respectively (Table 5).

The analysis of paired T-test between predicted and actual values was done as shown in Table 6. The calculated T values for fuel consumption and field capacity were found to be -1.496, 2.517, respectively.
The selected field operations were performed to verify the predicted average fuel consumption. The actual fuel consumption values were found to be almost on par with predicted value. The percentage error between predicted and actual values were found to be 0.74, 0.40, 0.93 and 0.53 for mouldboard plough, disc harrow, cultivator and rotavator, respectively. The value of RMSE was found to be 0.021 which is very low. The percentage error between predicted and actual values of field capacity were found to be 2.63, 4.81, 3.29 and 3.44 for mouldboard plough, disc harrow, cultivator and rotavator, respectively. A low RSME value between predicted and actual values of field capacity was found to be 0.025. The paired T-test indicates that there is no significant difference between actual and predicted values of both average fuel consumption and field capacity at 5 % level of significance and results found were in accordance with the results of Yousif et al., 2013.

5. Conclusions

- Decision support system for cost and time estimation of selected farm operations was built successfully using the visual studio platform.
- The developed DSS was more flexible and user friendly and most of the data was displayed on the screen.
- The system can be used quickly, to explore the effect of changing one or more of input parameters on output values and thus helped in quick decision making.
- The developed DSS helped in calculating the custom hiring charges, breakeven point and payback period of all agricultural machineries and implements.
- The developed DSS accurately estimated the time required to perform selected field operations.
- The validation of developed DSS shows its effectiveness in predicting the cost and time of farm operations.
- The developed Decision Support System was validated and analysed with paired T-test in SPSS statistical package and was found to be non-significant between sample mean predicted and actual values at 5 % level of significance.
References


Table 1. Life and annual usage of various agricultural machines and implements

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type</th>
<th>Life (years)</th>
<th>Annual usage (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tractor</td>
<td>10</td>
<td>1000</td>
</tr>
<tr>
<td>2</td>
<td>Power tiller</td>
<td>10</td>
<td>800</td>
</tr>
<tr>
<td>3</td>
<td>Stationary engine</td>
<td>10</td>
<td>1000</td>
</tr>
<tr>
<td>4</td>
<td>Agricultural trailer</td>
<td>12</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>Laser leveller</td>
<td>10</td>
<td>200</td>
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<td>6</td>
<td>Leveller</td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>7</td>
<td>Subsoiler</td>
<td>10</td>
<td>300</td>
</tr>
<tr>
<td>8</td>
<td>Chisel plough</td>
<td>10</td>
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<tr>
<td>9</td>
<td>Ridger</td>
<td>12</td>
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<td>10</td>
<td>Bund former</td>
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<td>125</td>
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<tr>
<td>11</td>
<td>Mouldboard plough</td>
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<td>12</td>
<td>Disc plough</td>
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<td>13</td>
<td>Offset disc harrow</td>
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<tr>
<td>14</td>
<td>Blade harrow</td>
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<tr>
<td>15</td>
<td>Rotavator</td>
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<td>16</td>
<td>Cultivator</td>
<td>10</td>
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<td>17</td>
<td>Seed cum fertilizer drill</td>
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<td>18</td>
<td>Planter</td>
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<td>Trans planter</td>
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<td>20</td>
<td>Power and tractor mounted sprayer</td>
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<td>21</td>
<td>Reaper</td>
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<td>Self-propelled combine harvester</td>
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<tr>
<td>Sl. No</td>
<td>Type</td>
<td>Operational speed (km h⁻¹)</td>
<td>Field Efficiency (%)</td>
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<td>-------</td>
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<tr>
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<td>Cultivator</td>
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<td>8</td>
<td>Seed cum fertilizer drill</td>
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<td>Planter</td>
<td>5</td>
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<td>10</td>
<td>Trans planter</td>
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</tr>
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<td>Tractor mounted sprayer</td>
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<td>75</td>
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<tr>
<td>12</td>
<td>Reaper</td>
<td>3.5</td>
<td>70</td>
</tr>
<tr>
<td>13</td>
<td>Self-Propelled combine harvester</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>14</td>
<td>Tractor mounted combine harvester</td>
<td>2.5</td>
<td>70</td>
</tr>
</tbody>
</table>

(IS: 9164 – 1979)
Table 3. Maximum PTO power to DBHP ratio for different soil conditions

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Soil conditions</th>
<th>Max. PTO HP to DBHP ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Firm soil conditions</td>
<td>1:1.5</td>
</tr>
<tr>
<td>2</td>
<td>Tilled soil conditions</td>
<td>1:1.8</td>
</tr>
<tr>
<td>3</td>
<td>Soft soil conditions</td>
<td>1:2.1</td>
</tr>
</tbody>
</table>

Table 4. Draft, operational speed and field efficiency of various implements for different soil

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Implement</th>
<th>Soil type</th>
<th>Draft (Kg m⁻¹)</th>
<th>Speed (km h⁻¹)</th>
<th>Field efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mouldboard plough</td>
<td>Clayey or heavy draft</td>
<td>1600</td>
<td>4.5</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>silty or medium draft</td>
<td>1400</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sandy or light draft</td>
<td>1050</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>Disc plough</td>
<td>Clayey or heavy draft</td>
<td>1600</td>
<td>4.5</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>silty or medium draft</td>
<td>1400</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sandy or light draft</td>
<td>1050</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Disc harrow</td>
<td>Clayey or heavy draft</td>
<td>600</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>silty or medium draft</td>
<td>500</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sandy or light draft</td>
<td>380</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>Cultivator</td>
<td>Clayey or heavy draft</td>
<td>450</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>silty or medium draft</td>
<td>300</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sandy or light draft</td>
<td>150</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>Seed cum fertilizer drill</td>
<td>Clayey or heavy draft</td>
<td>150</td>
<td>5</td>
<td>70</td>
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<td>silty or medium draft</td>
<td>90</td>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sandy or light draft</td>
<td>50</td>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>Planter</td>
<td>Clayey or heavy draft</td>
<td>175</td>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>silty or medium draft</td>
<td>150</td>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td></td>
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<td>sandy or light draft</td>
<td>120</td>
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</tr>
</tbody>
</table>

(Jain and Philip, 2012)
Table 5. Comparison of predicted and actual values of fuel consumption and field capacity

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Implements</th>
<th>Fuel consumption, l h⁻¹</th>
<th>Field capacity, ha h⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Predicted</td>
<td>Actual</td>
</tr>
<tr>
<td>1</td>
<td>Mouldboard plough</td>
<td>2.7</td>
<td>2.72</td>
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<tr>
<td>2</td>
<td>Disc harrow</td>
<td>2.45</td>
<td>2.46</td>
</tr>
<tr>
<td>3</td>
<td>Cultivator</td>
<td>2.13</td>
<td>2.15</td>
</tr>
<tr>
<td>4</td>
<td>Rotavator</td>
<td>5.6</td>
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<tr>
<td></td>
<td>RMSE</td>
<td>0.021</td>
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</tr>
</tbody>
</table>

RMSE – root mean square of error

Table 6. Paired T- test for evaluation of predicted and actual values

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameter</th>
<th>Fuel consumption, l h⁻¹</th>
<th>Field capacity, ha h⁻¹</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Predicted</td>
<td>Actual</td>
</tr>
<tr>
<td>1</td>
<td>Mean difference</td>
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<tr>
<td>2</td>
<td>Standard deviation difference</td>
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<td>3</td>
<td>Standard error mean</td>
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<tr>
<td>4</td>
<td>Degrees of freedom</td>
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<td>5</td>
<td>T value</td>
<td>-1.496</td>
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<td>6</td>
<td>Probability of P, Significance (2 tailed)</td>
<td>0.231</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 1. Flowchart for estimation of custom hiring charges,

Fig. 2. Flowchart for time estimation of selected field operation
Fig. 3. Supplementary tank fixed to tractor

Fig. 4. Estimation of fuel consumption.
Fig. 5. Selection screen

Fig. 6. Fixed costs screen
Fig. 7. Variable costs screen

Fig. 8. Total costs screen
Fig. 9. Time estimation of mouldboard plough