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Development of Decision Support Software for Matching Tractor-Implement System Used on Iranian Farms

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Abstract:- A decision support software (DSS) was developed in Visual Basic 6.0 programming language for matching and selecting implements with tractors and time management of farm operations. The proper selection and matching of tractor and implements is now become very important and difficult in Iran because of availability of variety of tractor models and powers ranging from 5.5 to 60 kW and variety of implement sizes. The purpose of this study was development software for mechanized operation and its application in paddy's farms. The developed DSS was tested with a case study to demonstrate the flexibility of the software. This software has databases including variety of tractor models and implements sizes, existing data from five climatology stations from 1990 to 2010, tractors and implements performance and soil and operation conditions for the zone of this study. Tractors and implements were selected and matched for paddy fields by developed DSS. Finally, tillage operation in paddy fields was managed with selected tractors and implements. Use of DSS in this study indicated that tractors with power less than 35 kW are able to complete the tillage operations (plowing, harrowing and puddling) for paddy fields lower than 40 hectares. Also, results indicate that energy consumption for tillage operation on paddy's farms in case study was 17.36 percentages less than other paddies.

Keywords: *- Agricultural Mechanization, Decision Support Software, Energy use, Paddy cultivation, Tractor*

I. INTRODUCTION

The selection of proper tractor and its matching implements has now become more difficult than ever before. The matching and selection of a tractor-implement system involves many decision-making processes that depend on different factors. These factors include tractor and implement specifications, soil conditions (firm, tilled or soft) and operation conditions (depth and speed operation), etc.

Decision support systems (DSS) are 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 [1]. A correct matching of tractor-implement system would result in decreased power losses, improved efficiency of operation, reduced operating costs and optimum utilization of capital on fixed costs [2]. Currently, researchers are involved in developing decision support systems/computer programs/models that are effective and simple to access [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]. Siemens et al. [16] formulated a farm machinery selection and management program written in C language. The output included a list of machinery with prices and annual use, work schedule, cost of operation and the total machinery related costs. Butani and Singh [17]; Singh and Chandraratne [18] developed a decision support system (DSS) for optimization of farm machinery systems with the flexibility to incorporate regional variations in crops and cropping practices, farm characteristics, size of the farm equipment and cost of the resources and output. The DSS utilized least cost method for optimization of farm machinery system. Zoz [7] described a methodology for predicting tractor field performance based on drawbar performance for 4WD tractor. Grisso and Perumpral [19] demonstrated the use of spreadsheet for matching tractors and implements. They predicted tractor performance and implement draft based on the Brixius model and ASABE Standard D 497.5, respectively. They concluded that the optimization of weight distribution for maximum power delivery efficiency, computation of field capacity and fuel consumption was possible with the use of spreadsheet. Singh et al. [20] developed a model based on DSS for farm management. The model was developed for Indian farmers to access online interactive and flexible information for their farm management. They concluded that the model would help farmers in increasing productivity by raising the yield/hectare of food grains thus leading to their economic growth.

Sahu and Raheman [21] developed a decision support system in Visual Basic 6.0 programming language for matching tillage implements with 2WD tractors for predicting the field performance of tractor–implement system. Most of the developed DSS predict tractor field performance based on ASABE standards and other models and are supported by data of only a few tractors and implements [19, 20, 21, 22]. Only a few researchers in developed countries directed their effort to develop appropriate procedure for matching of tractors and implements based on estimated power requirement and power availability taking into consideration the terrain and equipment factors [1, 13].

Mehta et al. [23] developed a DSS for selection of tractor-implement system and used it on Indian farms. They calculated PTO power requirement of tractor for implements with various soil and operation conditions. They concluded that DSS helps in selection of a tractor or an implement of particular size farm various makes and models of commercially available tractors and implements. A few other researchers mentioned the general procedures for matching of tractor and implement on the basis of power availability and power required by considering the soil factor, unit draft, field efficiency, tractive efficiency and transmission efficiency [13, 24, 25, 26].

In this study a decision support software (DSS) for Iranian farms conditions was developed using Visual Basic 6.0 as programming language and Microsoft Access as database, which helps in the selection of implements and matching tractors and implements to increase production and productivity in Iranian farms and usage in mechanization cooperative.

II. MATERIALS AND METHODS

2.1 Development of decision support system (DSS)

Decision support software was developed in Visual Basic 6.0 programming language. This software is suitable for matching and selecting implements with tractors and for time management of farm operations. Database for the software was developed by Microsoft Access 2007. The complete DSS was divided into four modules; if the tractor is available, find out the optimum matching size of the equipment; if the equipment is available, find out the optimum size of tractor requirement; if the tractor and equipment are available, find out the best offer for better application and management of required days for all operations. The program starts with a window such as Fig. 1 and ends with the final result required by the user. The overall structure of the program is shown in Fig. 2.

Fig. 1. Main menu of DSS (window of program starting).

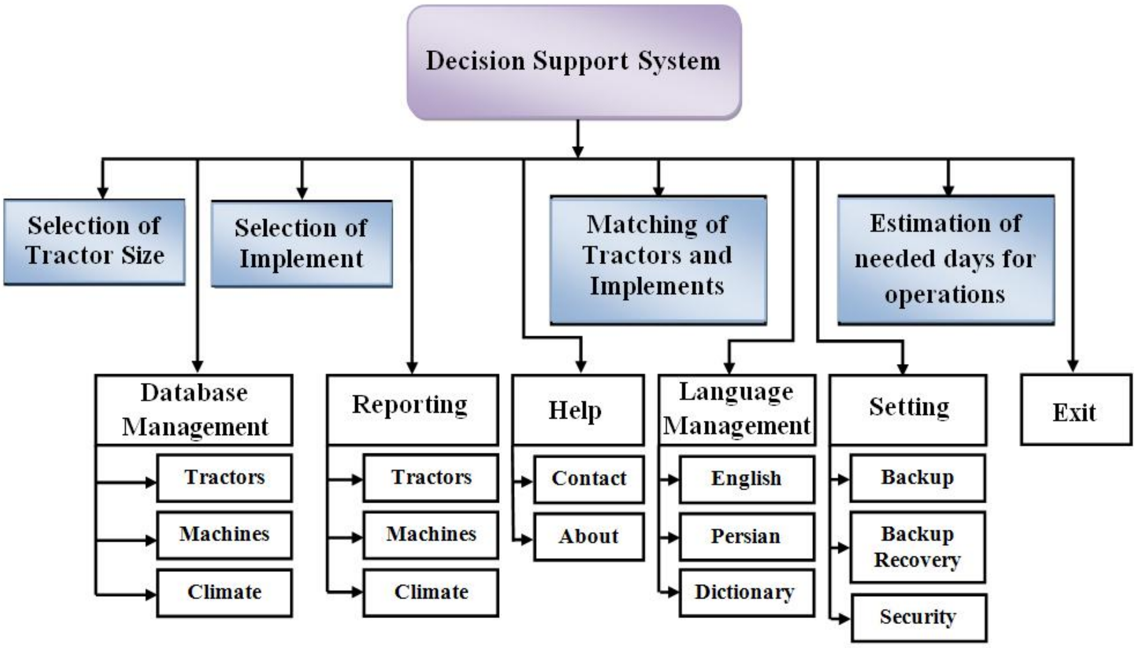

Fig. 2. Overall structure of developed DSS.

The software was developed for mechanization cooperative. These cooperatives were created to provide mechanization services for farmers. These services in Iran are included mechanized operations, consulting about using of tractor and farm machinery and management of them. The complete structure of software for purpose of this study was divided into four main modules (Fig. 3). These four modules are very important in each mechanization cooperative in Iran.

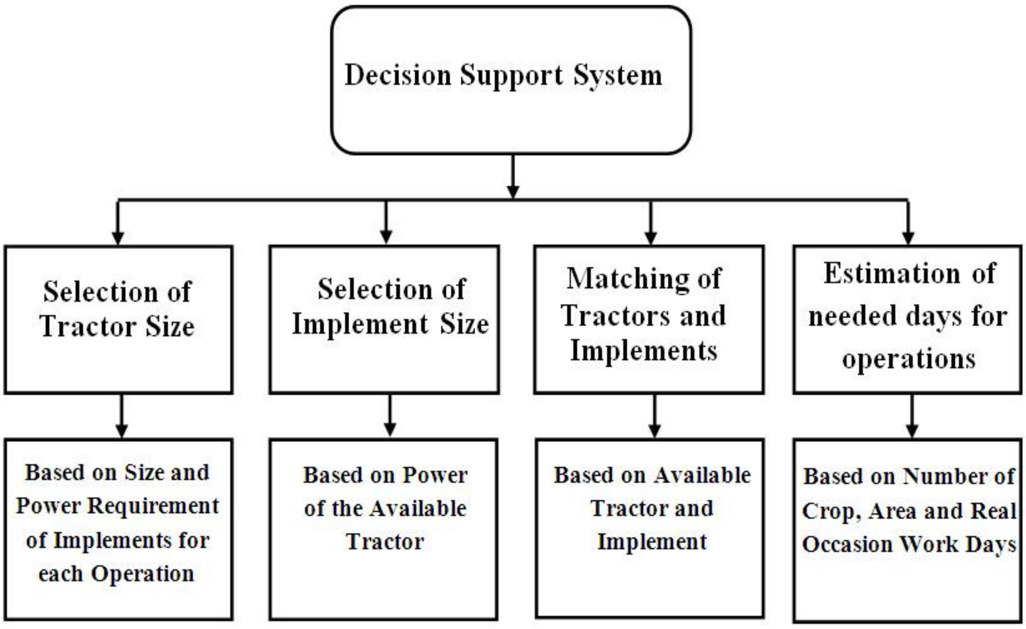

Fig. 3. Description of the DSS for four main modules.

2.2 Selection of tractor

The power requirement of a tractor for different field operations can be calculated after getting the preliminary details regarding land holding, total available working time, soil conditions and type of operations [27]. Selection of a tractor was calculated by Eq. (1) [28].

The logic of selection for this module was based on selection of different tractors (2WD, 4MFWD and 4WD) by manager for each operation.

The typical speed and the draft requirement for various implements, field operations and soil conditions are given in Table 1.

$$P_{PTO} = \frac{Speed \times D \times W \times SF}{2} \quad (1)$$

Where P_{PTO} is PTO power requirement for implement (kW), S is speed of operation (km h^{-1}), D is draft per unit of implement width (kN), W is width of implement and SF is soil factor that depends on tractor and soil type. The amounts of SF are shown in Table 2.

All tractors that exist in Iran were placed in software database. Also, database has good flexibility for changing data.

Table 1. Draft, recommended speed and field efficiency for various implements [27, 29].

Implements/equipment	Draft per metre of width, kN	Typical speed, km/h	Field efficiency, %
M B plough (200 mm depth)			
Heavy clay soil	15.70	4.5	80
Heavy soil	13.73	5.0	80
Medium soil	10.30	5.0	80
Light soil	6.87	6.0	80
One way disc plough			
Heavy soil	5.90	6.0	80
Medium soil	4.41	6.0	80
Light soil	2.94	6.0	80
Offset or heavy tandem disc harrow			
Heavy soil	5.90	6.0	80
Medium soil	4.91	6.0	80
Light soil	3.73	6.0	80
Duck foot cultivator			
Heavy soil	4.41	6.0	80
Medium soil	2.94	6.0	80
Light soil	1.47	6.0	80
Seed drill			
Heavy soil	1.47	5.0	70
Medium soil	0.88	5.0	70
Light soil	0.49	5.0	70
Planter			
Heavy soil	1.47	5.0	70
Medium soil	1.72	5.0	70
Light soil	1.77	5.0	70

Table 2. Soil factors for different types of tractor and soil Jain & [27, 29].

		Tractor Type		
		2WD	4MFWD	4WD
Soil Type	Firm	1.64	1.54	1.52
	Tilled	1.75	1.61	1.56
	Sandy	2.13	1.82	1.67

Fig. 4 shows the theoretical flowchart of tractor selection in this software. Selection of tractor size is based on implement size and power requirement for each operation.

2.3 Selection of implement sizes

The required width of implement can be calculated by knowing the available time, operating speed and power available for field operation. Type of soil (firm, tilled or soft) is important for calculation of required implement width. In this software, selection of implement size was done based on power of the available tractor. The maximum implement width calculated by Eq. (2) that was based on Eq. (1) [28].

$$Max.\ W. = \frac{PTO\ Power \times 21.58}{S \times D \times SF} \tag{2}$$

Where Max. W. is maximum implement width (m) that can work with available PTO power, soil type, working speed and draft per unit of implement width. Also, SF is soil factor that depends to the tractor and soil types (Table 2). Theoretical flowchart for implement selection in this software is shown in Fig. 5.

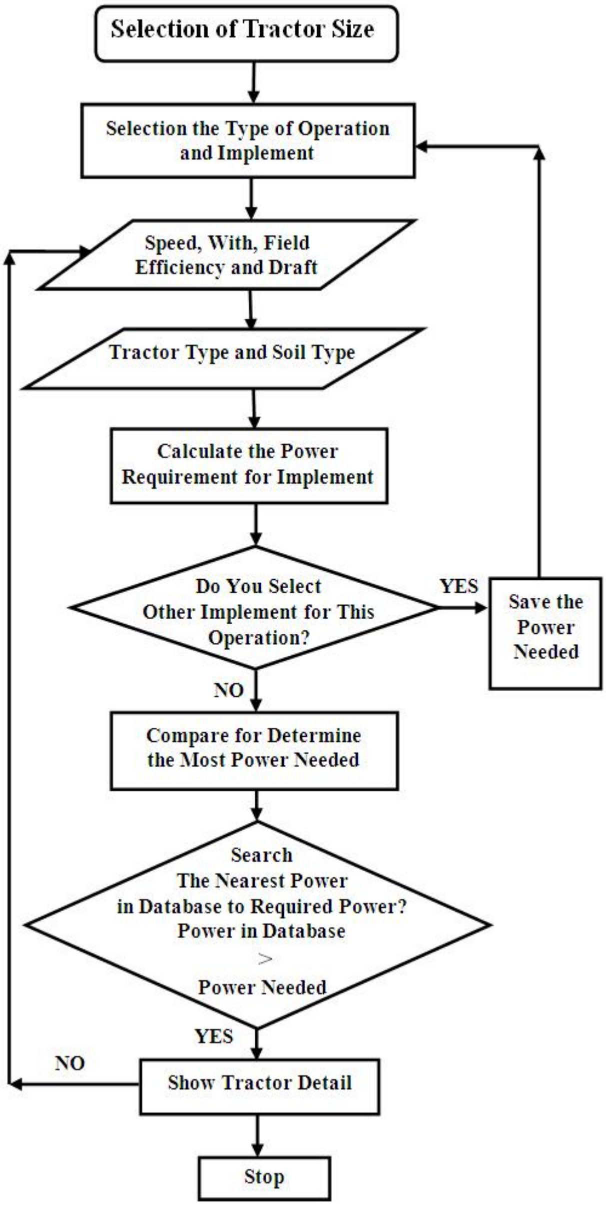

Fig. 4. Selection of tractor for various soil and operation conditions.

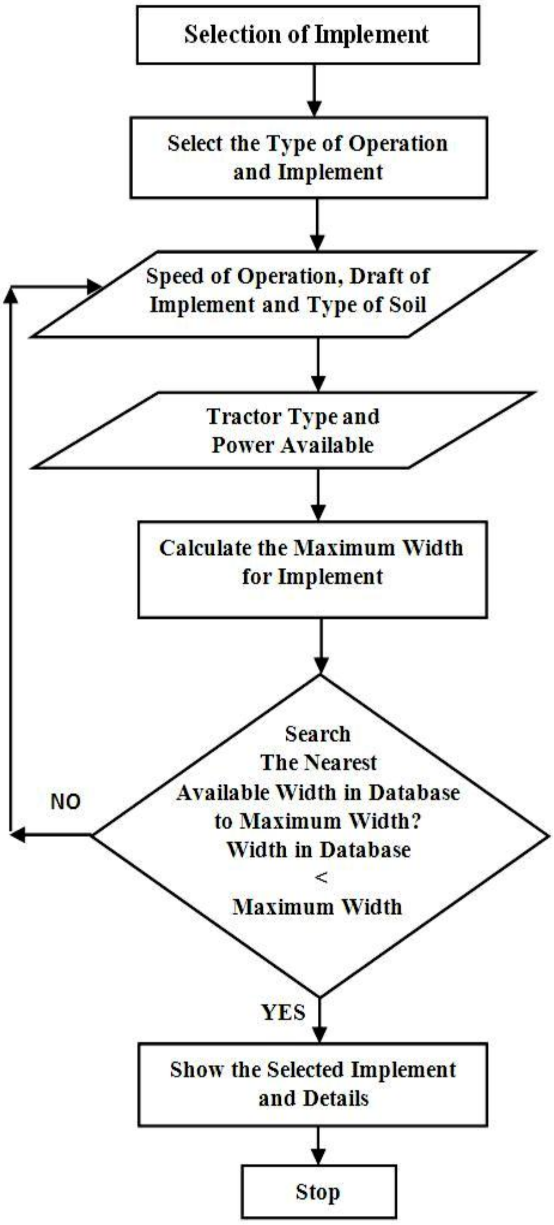

Fig. 5. Selection of implement for various soil and operation conditions.

2.4 Matching of tractors and implements

The correct matching of machinery should result in increased efficiency of operations, less operating costs, and optimum use of capital on fixed costs [13]. A decision support software (DSS) was developed for selecting the tractor and its matching equipment and vice versa for different soils and operating conditions. In this software, the purpose of this item was that whether the selection of tractor – implement system for the past agronomy- year's data is correct or not? If the answer was not, the software offers suggestions to manager for better matching of tractors – implement system. This software gives the manager three solutions for better matching of tractors – implement system. Fig. 6 shows flowchart for matching of tractors – implement system.

Solution includes maximum speed, maximum width and required power. Maximum width was calculated by the past agronomy-year's data and Eq. (2). The required power was calculated by available implement data in the past agronomy- year's data and Eq. (1).

The maximum speed calculated by the past agronomy- year's data and Eq. (3) [28].

$$Max.\ S. = \frac{PTO\ Power \times 28.94}{W \times D \times SF} \qquad (3)$$

Where Max. S. is maximum workable speed; PTO power is available power; W is available implement width; D is draft per unit of implement width in the past agronomy- year's data and SF is soil factor that depends on the tractor and soil types (Table 2).

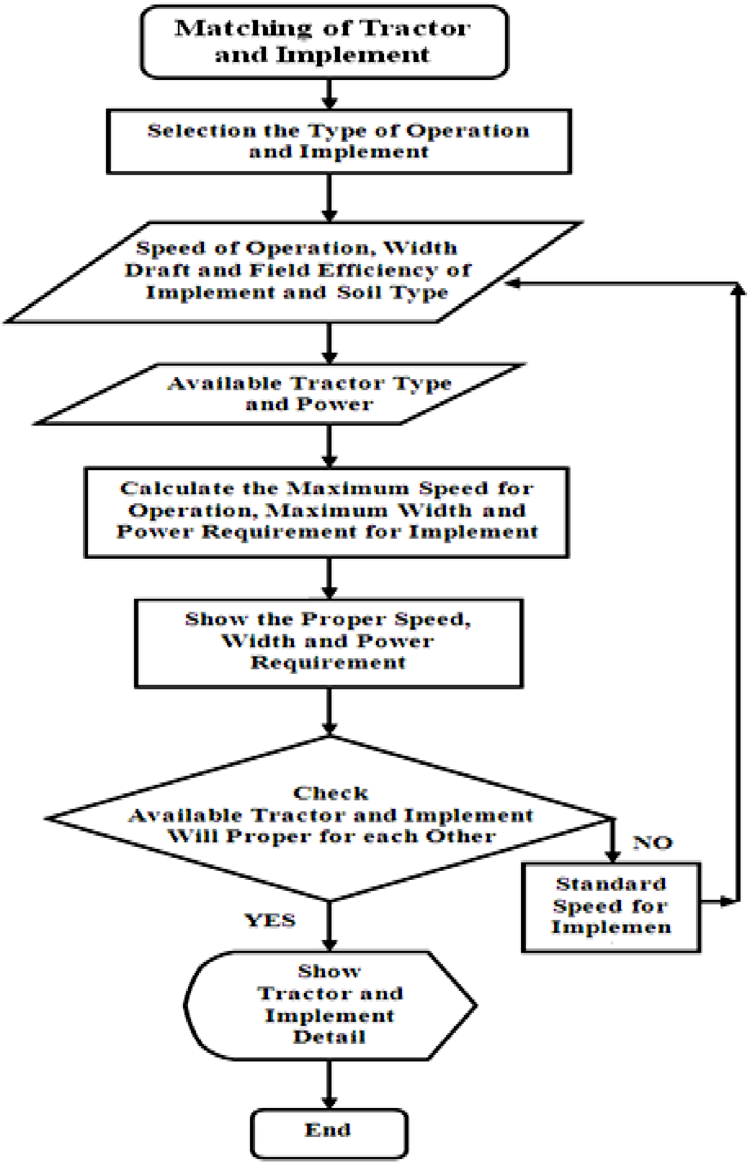

Fig. 6. Flowchart for matching of tractors – implement system.

Manager by these suggestions can select the proper tractor – implement system and improve the operation efficient, energy consumption and reduce the operations cost.

2.4 Estimating of needed days for operations

The prediction of weather constraints, especially wet days, represents an important tool for farmers and people working in agricultural activities to improve the agricultural-system efficiency. Optimum planning and scheduling of field work such as tillage and harvesting can reduce crop production losses [30]. Fig. 7 shows estimation of needed days for operations by software.

In this study, software can determine the required field days and manage it. It is very necessary for manager to know that how many days are required for each operation. This software by weather stations data's can determine really available days for each operation. The total field days needed was calculated by Eqs. (4) and (5). The real available days was calculated by Eqs. (6); (7) and (8). It is logical that real available days should be more than field days needed.

Field days needed for each implement (Hectare per day) = (Fe × W × S × T × N) / 10 (4)

Where: Fe= Field efficiency of current implement (%); W= Current implement width (m); S= Current implement speed (km h^{-1}); T= Available time per day (h); N= Number of operation by current implement

Total field days needed (Day) = Sum of Area of crop (hectare) / Field days needed for all each implement (5)

Available days for operation = Existing days from start to end of operation (6)

$$Pwd = Sd + (0.5 \times Cd) + (0.25 \times Pcd) + (0.125 \times Rd) \quad (7)\ [31]$$

Where: Pwd= Possibility of working days for each month; Sd= Sunny days in current month; Cd= Cloudy days in current month; Pd= Partly cloudy days in current month; Rd= Rainy days in current month Real available days for operation = Pwd × Available days for each working month (8)

Manager should change the selected tractor (power), implements (width, speed or other implements with better field efficiency) or available time per day if real available days for operation lower than total field days needed for operation, though the software offers suggestions to the manager.

III. RESULTS AND DISCUSSION

The case considered to validate the developed DSS for selection of tractor–implement system is presented in this section. To illustrate the above selection criteria, a case of growing a major crop was considered in a year for tillage operation (Paddy field) in a 30 ha farm in tilled soil. This case study was performed in Mazandaran province of Iran and managed by mechanization cooperative.

3.1 Paddy cultivation

The recommended time for tillage operation in Mazandaran province of Iran are given in Table 3. The weed control operation is usually done by hand or by releasing ducks in rice paddies in Mazandaran province. The power requirement for tillage operation was calculated by this software and its scheduling opportunity managed. The tillage operation usually starts by plowing (Depth= 10-15cm) and will be continue by harrowing operation. Tillage operation will be finish by puddling operation for paddy cultivation. One plowing operation in 40 ha (total area) and two harrowing operations in 40 ha i.e. 80 ha were required before puddling operation for paddy cultivation. Two puddling operations were recommended before transplantation. Time available usually is 8 h per day and actual available time was determined by data of five weather stations.

Table 3. Recommended times for tillage operation in paddy fields.

Operations	Scheduling Opportunity		
Tillage or Seed bed preparation	1 December to 30 December (Plowing)	20 February to 10 March (Harrowing)	1 April to 30 April (Puddling)

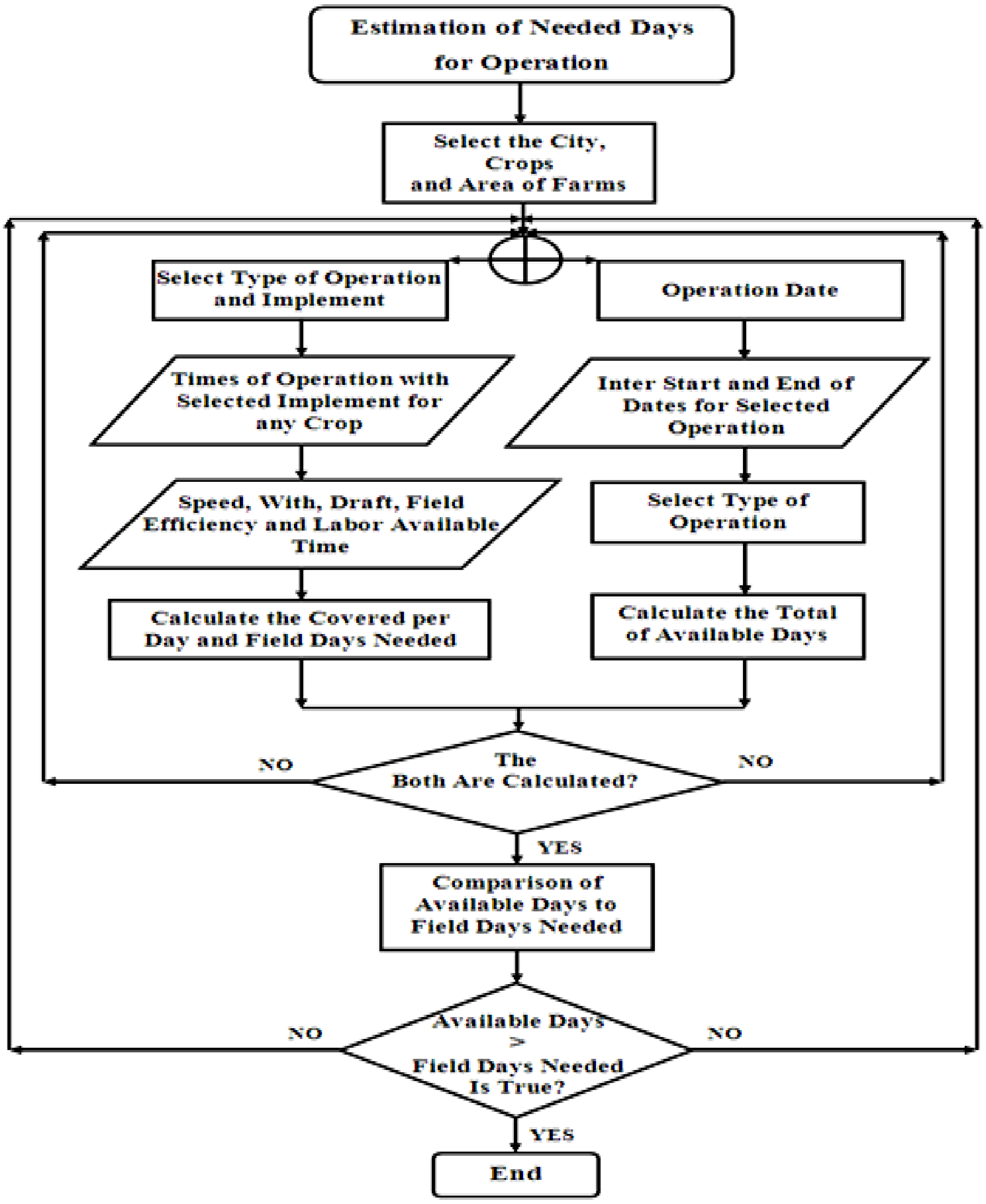

Fig. 7. Flowchart for estimation of needed days and really available days for each operation.

3.2 Selection of implement size according to actual available time

At the first stage, actual available time was predicted by time available and recommended times (Table 3) for operations by DSS. It was calculated by Eqs. (6); (7) and (8). According to the recommended times, time available for plowing operation was 30 days. Also, times available for harrowing and puddling operations were 48 and 29 days, respectively (Table 3). For determining the optimum size of implement, which can complete the operation in available time, it needs to know how many days is the real available time for operation. Figures 8, 9 and 10 illustrate the real available times for plowing, harrowing and puddling operations, respectively.

According to predictions, actual available times for plowing, harrowing and puddling operations were 18.9, 31.27 and 17.36 days, respectively. DSS was selected proper implements for actual available times. All implements selected can complete the operations in recommended times. Fig. 11 shows the proper size of implements selected for plowing, harrowing and puddling operations. All implements selected were existed in mechanization cooperative of case study.

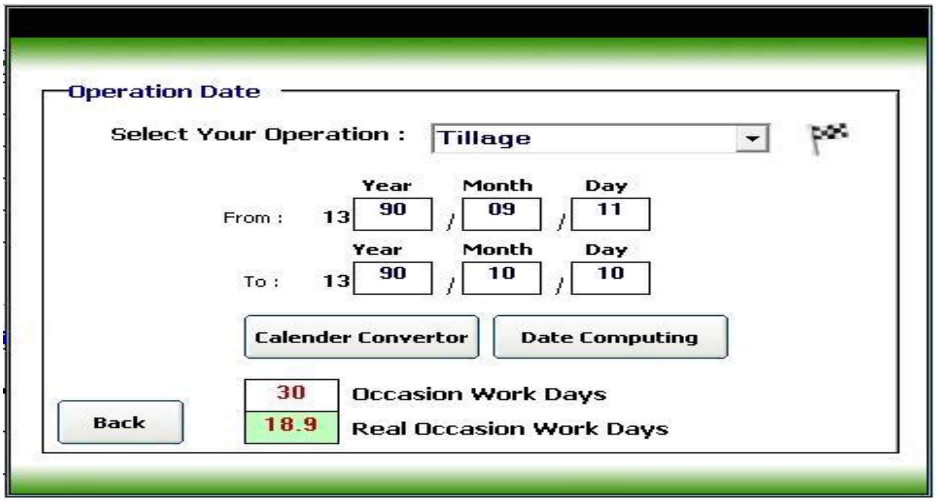

Fig. 8. Prediction of real available time for plowing.

Fig. 9. Prediction of real available time for harrowing.

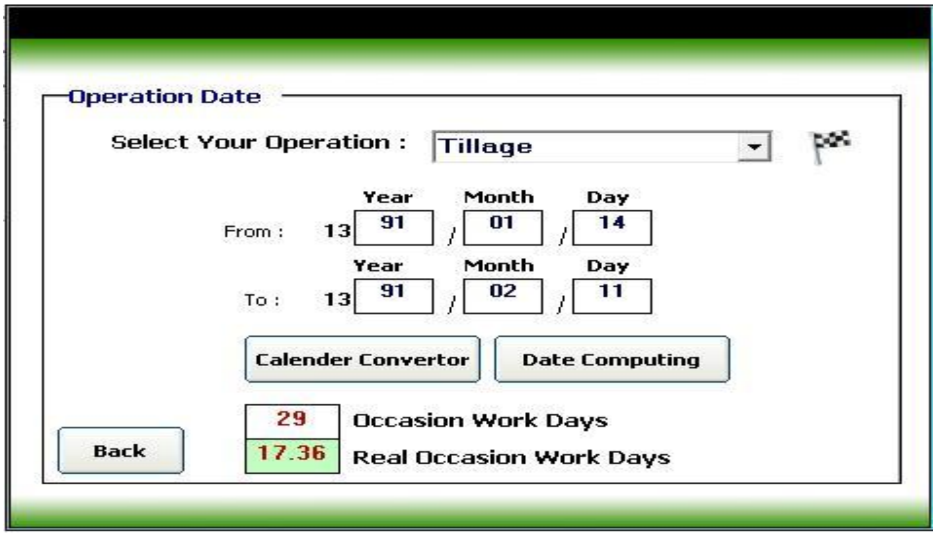

Fig. 10. Prediction of real available time for puddling.

The moldboard plow, Harrow disc and rotivator were selected for plowing operation, harrowing and puddling operations. According to the Fig. 11, field days needed were lower than real available times for each operation. Available implements size for plowing operation were 0.6, 0.9 and 1.2 m. Operation speed and field efficiency for moldboard plow was taken as 6 km/h and 75%, respectively (Table 1). A moldboard plow with width of 0.6 m was selected by DSS. Work days needed for plowing operation was calculated 18.51 days (say 19 days) or 152 h by Eq. (4). Also, a harrow disc was selected with width of 1.5 m among three sizes (0.8, 1.1 and 1.5 m) for harrowing operation. Two harrowing operations in 40 ha i.e. 80 ha were required before puddling operations. Field days needed for harrowing operations was calculated 12.69 days (say 13 days) or 104 h by Eq. (4). Two puddling operations in 40 ha i.e. 80 ha were required for puddling operation. Work days needed for puddling operations was calculated 16.56 days (say 17 days) or 136 h by Eq. (4). A rotivator with width of 1.15 m was selected by DSS among three available sizes (0.75, 0.9 and 1.15 m) for puddling operation. Work days needed for puddling operations was calculated 16.56 days (say 17 days) or 136 h by Eq. (4).

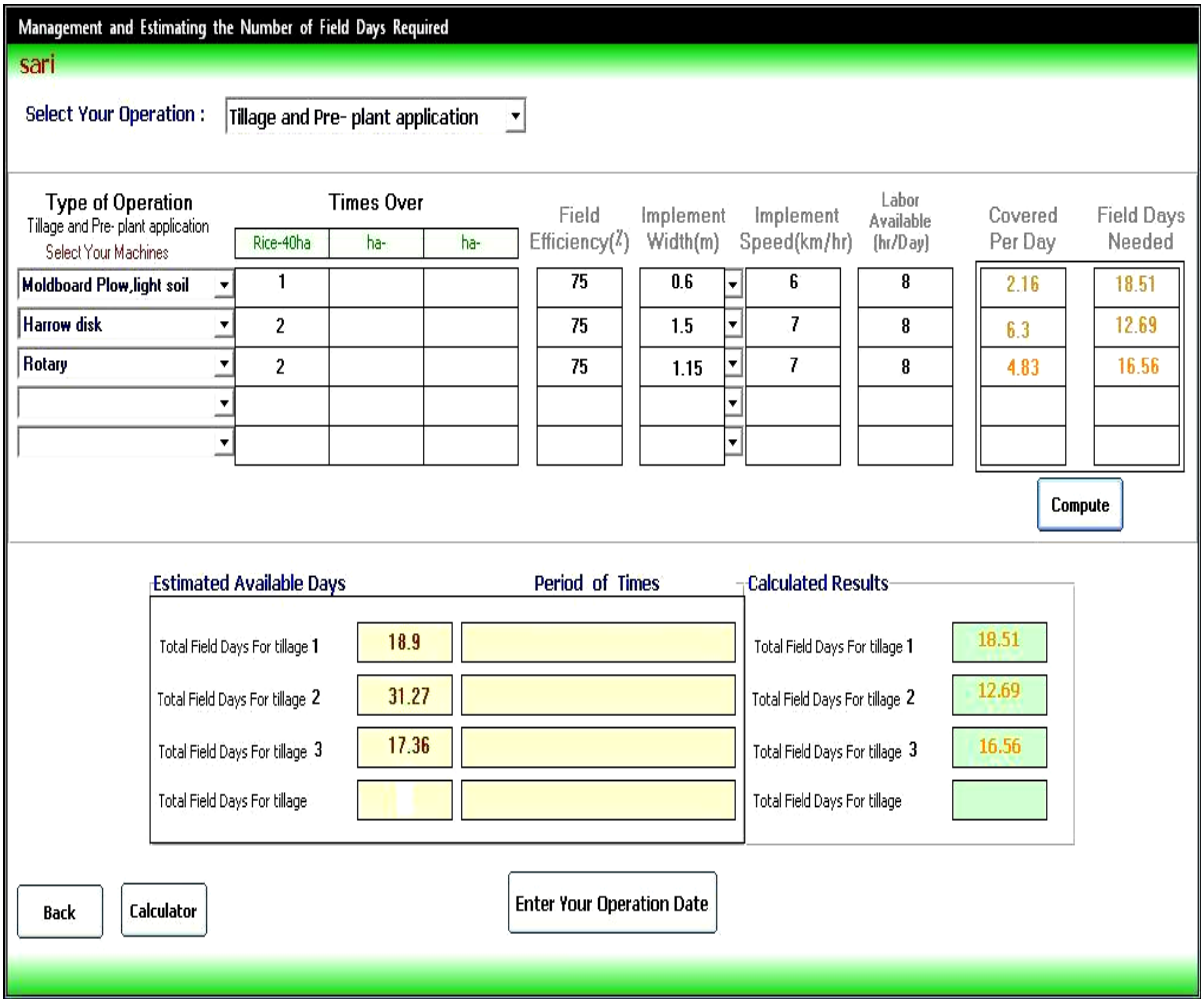

Fig. 11. Selection of proper implement size by comparison of real available times with field days needed.

3.3 Selection of tractor sizes for each operation

A tractor must be sized for job. On farms with one principal field tractor, that job is usually primary tillage. Even when it is known how much power is needed for a given field operation, knowing the size of tractor to use still presents a problem. When matching a tractor and implement, three important factors must be considered:

a. The tractor must not be overloaded or early failure of components will occur.

b. The implement must be pulled at the proper speed or optimum performance cannot be obtained.

c. The soil conditions and their effects on machine performance must be considered.

After selection of implement size for each operation, proper tractor sizes were selected by DSS. Tractors were selected from mechanization cooperative and they were available. Selection of proper and optimum tractor size is very important for mechanization cooperative. To prevent waste of energy and capital, most proper tractor size should be selected. Fig. 12 shows the selection of tractor for plowing operation. PTO power required was calculated by Eq. (1). Similarly, PTO power for harrowing and puddling operations were calculated.

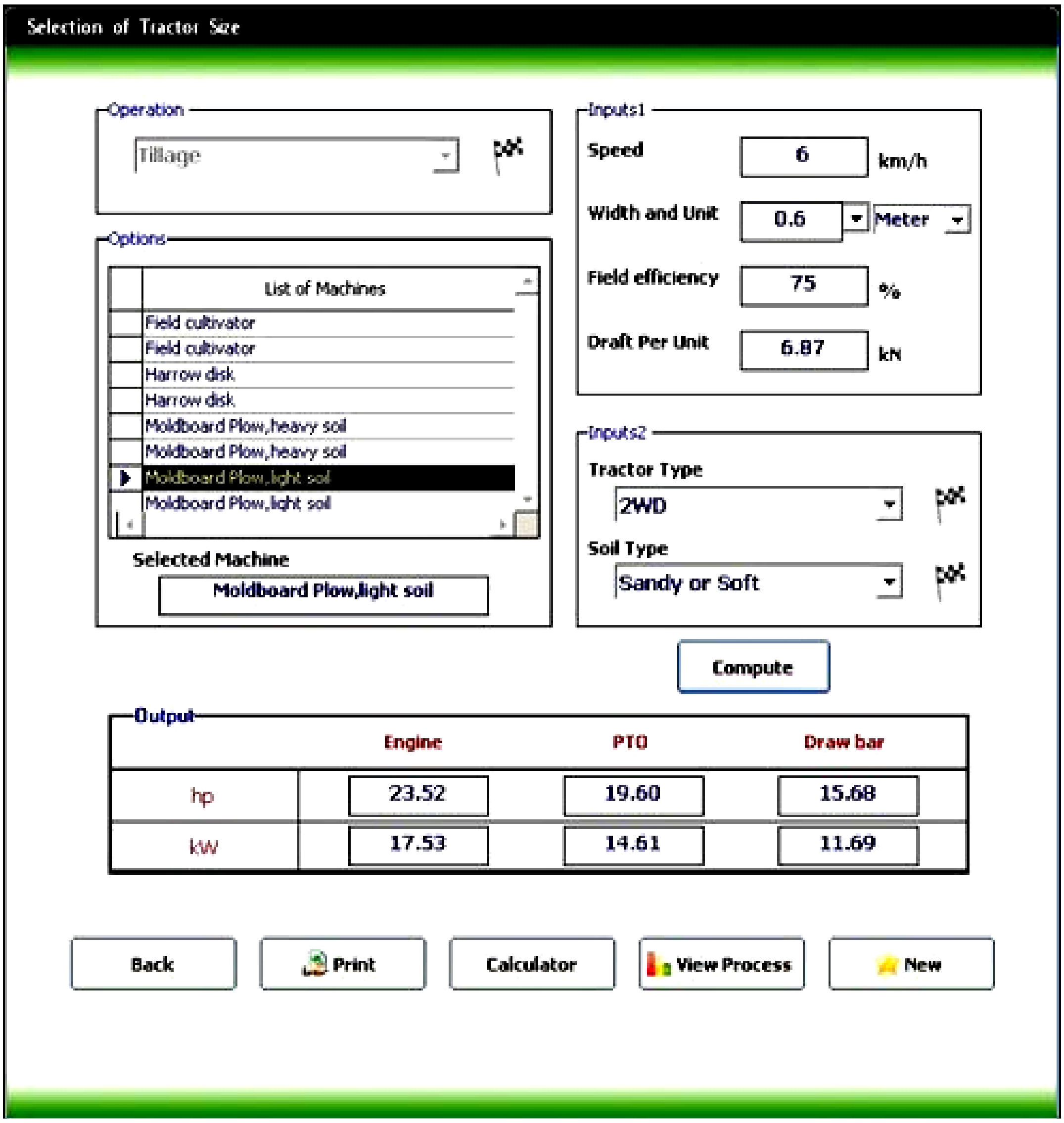

Fig. 12. Selection of tractor size for plowing operation.

According to the Fig. 12, a tractor was selected for moldboard plow with width of 0.6 m and other data from Table 1. Type of selected tractor was 2WD among 2WD, 4WD and 4MFWD tractors. Also, soil type was selected soft among the firm, tilled and soft soils. Finally the required PTO power was calculated 14.61 kW and was searched by DSS for find nearer tractor size to it according to Fig. 4. By clicking on “View Process”, a new form opens for show of selected tractors. Fig. 13 shows the selected tractors for each operation. According to Fig. 13, DSS was selected three tractors for each operation. Always, selected tractors were existed in database or mechanization cooperative. The form of Fig. 13 includes two frames. The upper frame shows maximum power required in all operations. The maximum power required shows by green text. For this study, maximum power required was related to puddling operation. DSS was selected a tractor with ITM 942 model, a tractor with Darvana 604 model and a tractor with Universal model for plowing, harrowing and puddling operations. Power needed for plowing operation was 14.61 kW and power of selected tractor for it was about 15 kW. Also, the selected tractors for harrowing and puddling operations had power about 25 kW and 35 kW, respectively. Fig. 13 shows an image for selected tractors by clicking on “View Image”.

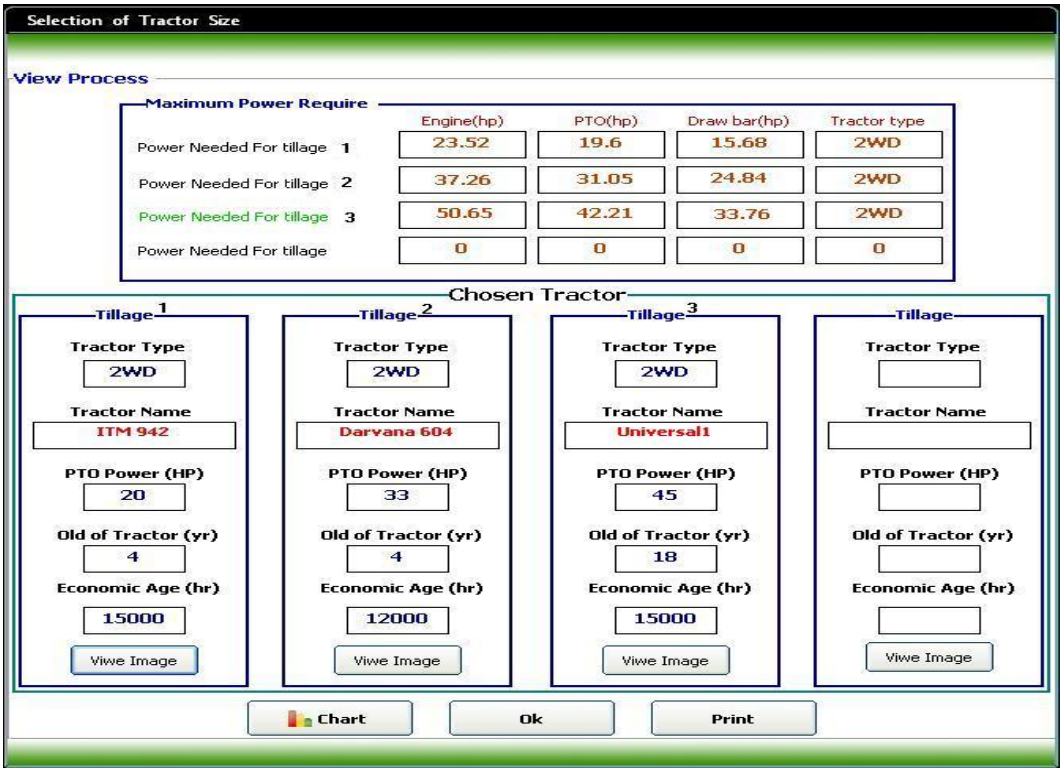

Fig. 13. Selected tractors for each operation.

Finally, the average of energy consumption in tillage operation for case study paddies was calculated and compared with other paddies. Energy inputs for calculation were Tractor and machines, diesel fuel and labour. Amounts of energy use on case study paddies were placed in group 1 and other paddies were placed in group 2. Results of amounts of energy consumption for tillage operation on 2 groups of paddies show in Table 4.

Table 4. Energy consumption in tillage operation on 2 groups of study.

Inputs	**Energy use in group 1 (MJ ha^{-1})**	**Energy use in group 2 (MJ ha^{-1})**
Tractor and machines	254.3	305.5
Diesel fuel	1005.2	1124.5
Labour	75.8	185.8

Results in table 4 show that energy use for paddies of group 1 that developed DSS used for them was lower than paddies of group 2. Results indicate that energy consumption on paddies of case study was 17.36 percentages less than other paddies. Most of the difference in energy inputs was labour with 59.2 percentages. This result shows that selection and matching of tractors and implement on paddies of case study was improper. It will increase the energy consumption and decrease the economic profitability.

IV. CONCLUSION

The purpose of this study was creation of Decision Support Software for Mechanized operation and its utilization for Iranian farms. The following conclusions can be drawn from the study:

1. The DSS provides flexibility to either select an implement to match the tractor or to select a tractor to match the implement based on various soil and operating parameters.
2. The DSS helps to manager to know that the selected tractor and implement based on the past agronomy-years data is proper or not.
3. The developed DSS manages the operations times and predict the real available time without the geographical restrictions.
4. Use of this software can help farmers and mechanization cooperative in selection of the right size of tractor–implement system based on soil, weather and operating parameters.
5. Use of DSS shows that tractors with power less than 35 kW are able to complete the tillage operations (plowing, harrowing and puddling) for paddy cultivation.

6. Use of developed DSS can reduce the energy consumption in agricultural operation. In this study, energy consumption on paddies of case study was 17.36 percentages less than other paddies.

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REFERENCES

[1] Power, D.J., 1999. Decision support systems glossary. http://dssre-sources.com/books/48.php. 2009.04.18.
[2] Taylor, R., Schrock, M., Wertz, K., 1991. Getting themost fromyour tractor. http://www.oznet.ksu.edu/library/ageng2/mf588.pdf. 2003.06.05.
[3] Gee-Clough, D., McAllister, M., Pearson, G., Evernden, D.W., 1978. The empirical prediction of tractor-implement field performance. J. Terramech. 15(2):81–94.
[4] Ozkan, E., Edwards, W.M., Saulmon, A., 198). A Machinery Selection Model for Farmer Decision Making. ASAE, 89-1018. ASAE, St. Joseph, MI.
[5] Upadhyaya, S.K., Williams, T.H., Kemble, L.J., Collins, N.E., 1984. Energy requirement for chiseling in coastal plain soils. Trans. ASAE, 27(6):1643-1649.
[6] Brixius, W.W., 1987. Traction Prediction Equations for Bias Ply Tires. ASAE, 87-1622. ASAE, St. Joseph, MI.
[7] Zoz, F.M., 1987. Predicting Tractor Field Performance (Updated). ASAE, 87-1623. ASAE, St. Joseph, MI.
[8] Colvin, T.S., McConnell, K.L., Catus, B.J., 1989. TERM: a computer model for field simulation. Trans. ASAE, 32(2), 391-396.
[9] Evans, M.D., Clark, R.L., Manor, G., 1989. A Traction Prediction and Ballast Selection Model. ASAE, 89-1054. ASAE, St. Joseph, MI.
[10] Grisso, R.D., Al-Hamed, S.A., Taylor, R.K., Zoz, F.M., 1992. Demonstrating tractor performance trends using Lotus templates. Applied Engineering in Agriculture, 8(6):733-738.
[11] Al-Hamed, S.A., Grisso, R.D., Zoz, F.M., Von Bargen, H., 1994. Tractor performance spreadsheet for radial tires. Computers and Electronics Agriculture, 10(1):45-62.
[12] Harrigan, T.M., Rotz, C.A., 1994. Draft of Major Tillage and Seeding Equipment. ASAE, 94-1533. ASAE, St. Joseph, MI.
[13] Gould, N.S., Lund, R.D., Hill, J., 1999. Matching tractors and implements-the economic way. http://www.agekon.com/Machsem/Webroom1.html. 2003.08.24.
[14] Al-Hamed, S.A., Al-Janobi, A.A., 2001. A program for predicting tractor performance in Visual C++. Computers and Electronics Agriculture, 31(2):137-149.
[15] ASAE standards. 2001. D497. 4. Agricultural Machinery Management Data. ASAE, St. Joseph, MI.
[16] Siemens, J., Hambarg, K., Tyrrell, T., 1990. A machinery selection and management program. Journal of Production Agriculture. 3(2):212-219.
[17] Butani, K.M., Singh, G., 1994. Decision support system for the selection of agricultural machinery with a case study in India. Computer and Electronics in Agriculture, 10(2):91-104.
[18] Singh, G., Chandraratne, I.W.D.T., 1995. Decision support system for crop planning and equipment selection for developing countries. International Agricultural Engineering Journal, 4(1&2):17-27.
[19] Grisso, R., Perumpral, J., 2006. Spreadsheet for matching tractors and implements. ASABE, 061085. MI: St. Joseph.
[20] Singh, M., Singh, P., Singh, S.B., 2008. Decision support system for farm management. Proceeding of World Academic Science, Engineering and Technology, 29:346-9.
[21] Sahu, R.K., Raheman, H., 2008. A decision support system on matching and field performance prediction of tractor-implement system. Computers and Electronics in Agriculture, 60:76-86.
[22] Suarez de Cepeda, M., Recio, B., Rubio, F., 2004. Decision support system for farms mechanization. ASAE/CSAE meeting, 043040. MI: St. Joseph.
[23] Mehta, C.R., Karan Singh, M.M., 2011. A decision support system for selection of tractor–implement system used on Indian farms. Journal of Terramechanics, 48:65-73.
[24] Downs, H.W., Taylor, R.K., Al-Janobi, A.A., 1990. A decision aid for optimizing tractor-implement system. In: Proceedings of the ASAE Winter Meeting, USA, pp. 18-21.
[25] Downs, H.W., Hansen, R.W., 1998. Equipment: selecting energy-efficient tractor. http://www.colostate.edu/pubs/farmgt/05007.pdf. 2003.08.06.
[26] Powell, G., 2001. Selection and matching of tractor and implements. http://www.pdi.gld.gov.au/fieldcrops/3492.html.2003.04.04.
[27] Jain, S.C., Philip, G., 2003. Farm machinery-an approach. 1st ed. Delhi: Standard Publishers Distributors.
[28] Edwards, W., 2009. Ag.D.M. File A3-28, Matching Tractor Power and Implement Size http://www.extension.iastate.edu/agdm/decisionaidscd.html#mach. 2009.10.01.
[29] IS 9164, 1979. Guide for estimating cost of farm machinery operation. New Delhi: Bureau of Indian Standards.
[30] Ozkan, E., Edwards, W.M., Saulmon, A., 1984. A Machinery Selection Model for Farmer Decision Making. ASAE Paper No. 89-1018. ASAE, St. Joseph, MI.
[31] Witiney, B., 1988. Choosing and Using Farm Machinery. Longman Scientific and Technical. New York. USA. 442pp.