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Web based machinery fleet size selection model for paddy-wheat cropping system

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ABSTRACT

A fleet size selection model based on time window availability for different operations of paddy-wheat cropping system was developed for proper selection of machinery with optimum use hours.The developed fleet size selection model suggested a fleet of 3 cultivators, 3 harrows, 3 rotavator, 3 wheat seed drill, 2 combine harvesters, 1 straw combine, 2 balers, 1 laser leveler and 6 tractors with a total investment requirement of ₹ 98.7 lakh for a catchment area of 200 ha under paddy and 300 ha under wheat. The annual use hours for harrow, cultivator, rotavator, wheat seed drill, combine harvester, straw combine, baler, laser leveler and tractor predicted by the model for same catchment area and based on the selected fleet size were 347, 278, 514, 250, 563, 375, 286, 417 and 922, respectively. The annual use hours based on selected fleet size predicted by the model for tractor were 922 to 983; close to the recommended economic use hours of tractor (1000). Thus, the model can be used to select fleet size for a particular catchment area under paddy-wheat cropping system with optimum annual use hours of machine and completion of operation within given time window.

Key words: Catchment area, Cropping system, Fleet size, Time window

Increased use of improved technologies in Indian agriculture since the mid-sixties has brought about multi-fold increase in agricultural production. Modern agriculture with increasing use of commercial input has necessitated enhanced use efficiency through timely and precise application of inputs using efficient and precise machines, which in turn have raised demand for increased level of mechanization. There are seven vital inputs to agricultural production system - seed, fertilizer, irrigation water, plant protection chemicals, agro machinery, transfer of knowledge and credit. The efficiency of all non-engineering inputs depends on efficiency, accuracy and precision of engineering input i.e. agricultural machines. In fact, mechanization alone enhances productivity of crop by 15% and reduces cost of crop production by 20% (Lamidi 2013). Agricultural implements and machines enable the farmers to employ the power judiciously for production purposes. Besides its paramount contribution to the multiple cropping and diversification of agriculture, mechanization also enables timeliness of operations, a very important aspect of agricultural production system. Farm mechanization is key for agricultural productivity as it has positive correlation with level of farm mechanization. Cropping intensity also increased with an increase in per unit power availability (Mehta *et al*. 2014). It was 120% with power availability of 0.48 kW/ha during 1975-76 and increased to 139% with increase in power availability to 1.71 kW/ha in 2009-10 (ICAR 2013).

This is an indicative of the fact that slowly and steadily India has been progressing towards higher farm mechanization. However this increased level of mechanization has been found skewed towards some operations as evident from the fact that some operations are highly mechanized and in some operations a wide mechanization gap exists. Also mechanical power is largely consumed in large land holdings and is still beyond the reach of small and marginal farmers who own around 85% of the total land holdings (Anonymous 2015). This is due to the fact that small landholding and poor economic status render them economically unviable for single ownership of many of the high cost agricultural machinery and equipment especially tractors, rotavators, laser levellers and combine harvester. In fact small and marginal holdings of less than 2 ha account for 85% of the total operational holdings and 44% of the total operated area (Agriculture Census 2011). The average sizes of holdings for all operational classes have declined over the years and overall came down to down to 1.16 ha in 2011-12 from 2.82 ha in 1970-71. With continued shrinkage in average farm size due to land fragmentation, more farms will fall into small and marginal category thereby making individual ownership of

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agricultural machinery progressively more uneconomical. Increased and improved efficiency of utilization of machines available with farmers through custom hiring to neighbour farmers and/or through larger operational holdings makes ownership of machines economical. Even a very small farmer or an entrepreneur with no land can have a profitable business as a custom hiring service provider. The profitability of custom service provider depends upon the utilization hours of each machine and the catchment area received for custom hiring. Small catchment area for a custom service provider with multiple machines leads to underutilization of many machines and hence the poor economy of business. Similarly, a custom service provider travelling long distances without getting enough area to justify transportation cost and other variable cost also faces economic burden. Sometimes the profit gained in providing the services is spent in repairing cost. Currently there are few modes of agricultural machinery custom hiring services in the country extended through individual ownership or through farmer cooperatives and government-led institutions. However, custom hiring practices through the existing models are not properly regulated, so farmers rarely enjoy the benefits of new technology. The present system of custom hiring does not reach the objective of mechanization. Moreover, the system is very disorganized so that there is high competition in some places, but in others is very difficult to provide services. The machines kept at each hiring center should be selected based on the needs of the center's respective areas and should match the capacity of the respective area. Farmers' decision to avail of custom services need also be taken into consideration. Farmers' decision to avail custom services may also be influenced by various factors such as the technical suitability of the available technologies to suite the farmers' field conditions (farm size, topography and availability of irrigation facilities). In order to improve the techno economic feasibility of custom hiring services, an attempt was made to develop custom hiring model for appropriate farm machinery use protocol under paddy-wheat cropping system.

MATERIALS AND METHODS

The fleet size required for a particular area was computed under this sub-model. It computes the required power units and machinery fleet sizes from the user input parameters and the build-in data to complete the field operations during specific period of time (available time window). The user

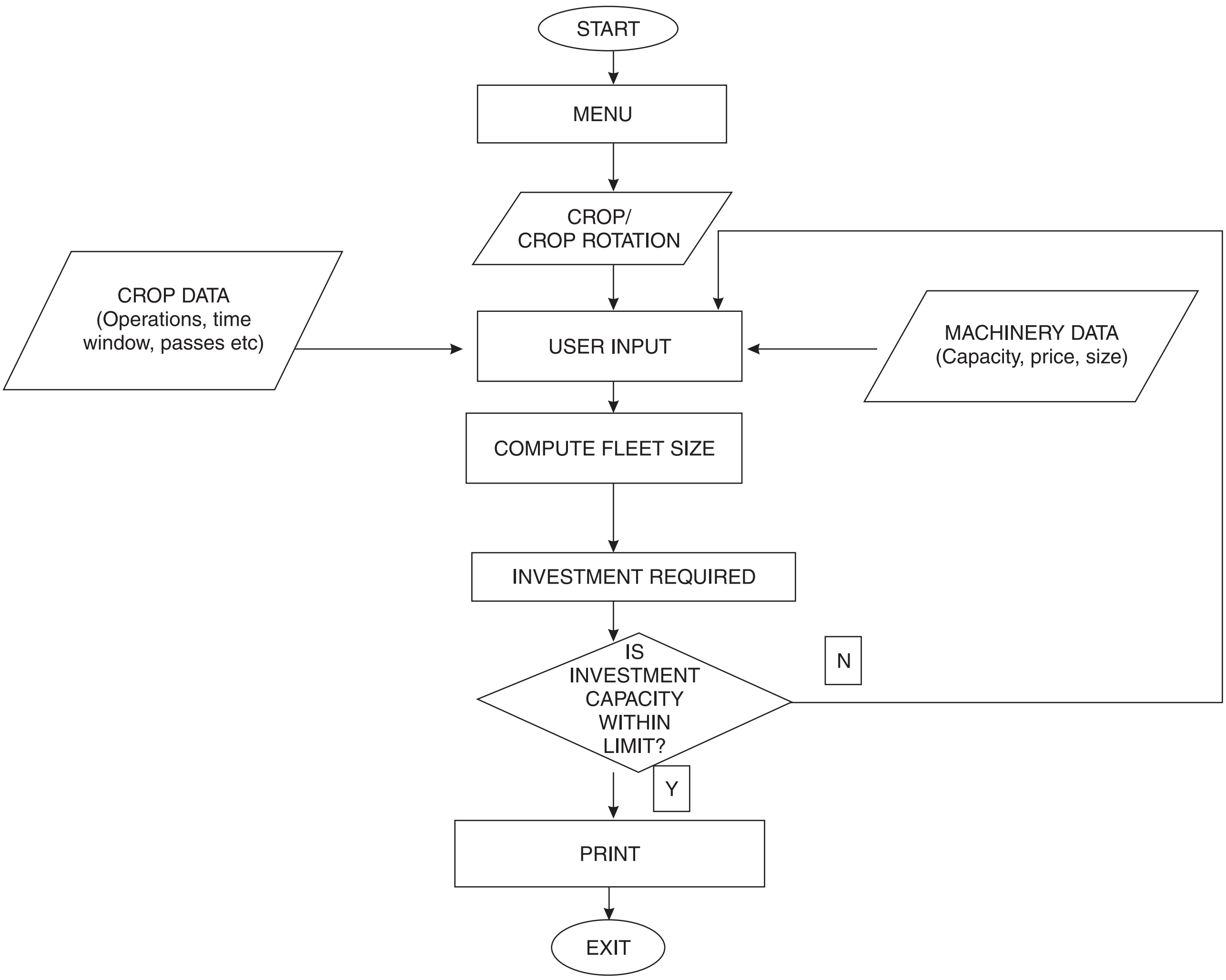

Fig 1 Algorithm for fleet size selection model.

input data included the selection of crop, operation to be carried, catchment area, soil type. The built in data is in the form of field capacities of different machines and time window available for a particular operation. The algorithm used in fleet size calculation is shown in Fig 1. Stored data files were used to limit the amount the data required from the user and the stored data were kept flexible for any addition, deletion or modification in the future. However, the data files cannot be changed by user. The stored data files used in the programme were:

Crop data: This file contained data on equipment used for different field operations of paddy and wheat crop. Crop calendar, crop yield, crop price etc. Timeliness loss factor for various operations of paddy and wheat crop were also included in this data file.

*Machine data***:** This file contained the data related to the various available sizes of machinery for each crop production operation. The draft, field efficiencies, repair and maintenance factors, speed of operation, price per unit size were also part of this data file.

$$\text{Fleet size } (N_i) = \frac{A_i}{Fc \times N_d \times P_d \times W_h} \qquad (1)$$

where, A_i = area to be covered (Catchment area, ha), F_c= average field capacity of a particular machine to be used for particular operation (ha/h), N_d= number of days available for particular operation (crop calendar), W_h= working hours per day (h), $P_{d=}$ probability of utilization of a particular day (0.7) (Hertz and Esmey 1986).

$$\text{Investment required} = \sum_{(i=1)}^{(i=n)} N_i X_i \qquad (2)$$

where N_i= number of machines (Fleet size) of particular type, X_i= market price of particular machine.

If Investment required > Investment capacity

$$\text{Fleet size } (N_j) = \frac{A_i}{Fc \times N_d \times P_d \times W_{hi}} \qquad (3)$$

where, $A_j < A_i$ and $W_{hi} > W_{h,}$ A_j= reduced custom hiring area, W_{hi} = increased per day working hours.

A web based system named as Custom-Mach was developed by using PHP (*Hypertext Preprocessor*) to implement the model (Fig 2). The web based system was developed with the purpose to have access to the database at all times from multiple locations thus making it location neutral. PHP is a general-purpose scripting language with built-in integration with the most popular open source database MySQL. Web development with PHP through MySQL is free to use, hence economical. PHP code can be simply mixed with HTML code, or it can be used in combination with various templating engines and web frameworks. PHP code is usually processed by a PHP interpreter, which is usually implemented as a web server's native module or a Common Gateway Interface (CGI) executable. After the PHP code is interpreted and executed, the web server sends the resulting output to its user, usually in the form of a part of the generated web page, thus making it user friendly.

RESULTS AND DISCUSSION

The fleet size selection model was developed for fleet size selection and investment required for different area under paddy-wheat cropping system based upon the available time window and per day utilization hours (Table 1). The results were presented for a total cultivated area of 500 ha under paddy-wheat cropping system. It was observed that for a catchment area of 200 ha under paddy and 300 ha under wheat a fleet of 3 cultivators, 3 harrows, 3 rotavator, 3 wheat seed drill, 2 combine harvesters, 1 straw combine, 2 balers, 1 laser leveler and 6 tractors were required with a total investment requirement of ₹ 98.7 lakh. For a constant total catchment area of 500 ha, the required number of harrow, cultivator, rotavator, combine harvester, straw combine and tractors remained the same; however the fleet for wheat sowing machine, Baler and laser leveler changed depending upon the area under paddy and under wheat.

As the area under wheat crop went down below 240 ha, the fleet size requirement for wheat seed drill changed from 3 to 2 and the investment required changed from 109.70 lakh to 109.30 lakh. Similarly, upto an area of 200 ha under paddy the number of balers required were two. As the area under paddy shifted from 200 ha to 210 ha,

Fig 2 User interface for web based model.

Table 1 Fleet size and investment requirement for different custom hiring areas based on 100% time window available

Crop area		Machinery									Investment required (lakh)
Paddy (ha)	Wheat (ha)	HW	CR	RO	WS	CH	SC	BR	LL	TR	
		Fleet size (No. of units)									
200	300	3	3	3	3	2	1	2	1	6	98.7
210	290	3	3	3	3	2	1	3	1	6	106.7
220	280	3	3	3	3	2	1	3	1	6	106.7
230	270	3	3	3	3	2	1	3	1	6	106.7
240	260	3	3	3	3	2	1	3	2	6	109.7
250	250	3	3	3	3	2	1	3	2	6	109.7
260	240	3	3	3	3	2	1	3	2	6	109.7
270	230	3	3	3	2	2	1	3	2	6	109.3
280	220	3	3	3	2	2	1	3	2	6	109.3
290	210	3	3	3	2	2	1	3	2	6	109.3
300	200	3	3	3	2	2	1	4	2	6	117.3

HW= harrow, CR= cultivator, RO= rotavator, WS= wheat seed drill, CH=combine harvester, SC= straw combine, BR= baler, TR=tractor.

an additional requirement of 1 more baler was projected by the model with a total investment requirement of ₹ 106.7 lakh. After 210 ha under paddy crop, the fleet size for balers remained three. The change in number of laser levelers was observed from 1 to 2 as soon as the area under paddy increased from 230 to 240 ha. For a total catchment area of 500 ha with paddy: wheat in the ratio of 3:2; the model predicted the fleet size of 3 harrows, 3 cultivators, 3 rotavators, 2 wheat seed drills, 2 combine harvesters, 1 straw combines, 4 balers, 2 laser levelers and 6 tractors with a total investment requirement of ₹ 117.30 lakh. Thus model was found to respond perfectly to the changing area under paddy and wheat.

Along with fleet size and investment capacity, the fleet size selection model also predicted, the annual working hours for a particular machine based on catchment area, and observed fleet size.

The annual use hours for harrow, cultivator , rotavator, wheat seed drill, combine harvester, straw combine, baler, laser leveler and tractor predicted by the model for a catchment area for paddy-wheat cropping rotation of 200 ha paddy and 300 ha wheat were respectively 347, 278, 514,

Table 2 Annual use hours of different machines based upon selected fleet size and 100% time window available

Crop area		Machinery								
Paddy (ha)	Wheat (ha)	HW	CR	RO	WS	CH	SC	BR	LL	TR
		Annual use hours (h)								
200	300	347	278	514	250	563	375	286	417	922
210	290	347	278	522	242	565	363	200	438	928
220	280	347	278	531	233	567	350	210	458	934
230	270	347	278	539	225	569	338	219	479	940
240	260	347	278	547	217	571	325	229	250	946
250	250	347	278	556	208	573	313	238	260	952
260	240	347	278	564	200	575	300	248	271	959
270	230	347	278	572	288	577	288	257	281	965
280	220	347	278	581	275	579	275	267	292	971
290	210	347	278	589	263	581	263	276	302	977
300	200	347	278	597	250	583	250	214	313	983

HW= harrow, CR= cultivator, RO= rotavator, WS= wheat seed drill, CH=combine harvester, SC= straw combine, BR= baler, TR=tractor.

250 , 563, 375, 286, 417 and 922 hours, respectively. The annual use hours of 347 for harrow and cultivator remained same irrespective of the area under paddy and under wheat while the annual use hours of rotavator changed although the fleet size was constant for all the three machines (Table 2). The model results were agreeable as tillage operations for wheat and paddy carried by harrow and cultivator are same, so the ratio does not have any effect on annual use hours of harrow and cultivator till the total catchment area was constant. However, in case of rotavator, although the tillage operation and tillage capacity was same for both paddy and wheat but the puddling use hours for rotavator depended upon the area under paddy.

Thus an increase in annual use hours of rotavator can be observed with increase in area under paddy for the same fleet size. The annual use hours predicted by the model for tractor were 922 to 983; close to the recommended economic use hours of tractor (1000).

A web based model (Custom-Mach) was developed to help the custom hiring service provider to decide the fleet size for a particular catchment area based on time window availability and to have economic use hours of particular machinery. The model was found to respond perfectly to the changes in catchment area with optimum annual use hours of machinery.

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