SELECTION OF OPTIMUM SIZE OF FARM IMPLEMENTS FOR DIFFERENT TRACTORS

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ABSTRACT

This paper presents the details of studies conducted to determine the optimum size of farm implements suitable for tractors with different power ratings. An equation for optimum width of implement was developed by considering different cost functions. On the basis of this equation a computer program was written to obtain the optimum size of different implements. The existing data for a typical Indian farm condition and prevalent marketing prices were used as an input to computer model. The optimum size of implements for 15 hp, 25 hp and 35 hp tractor were obtained for 10 ha of farm having crop rotation of wheat and mustard in Rabi and paddy and maize in Kharif. The optimum sizes obtained in this study were found to be close to the actual implement sizes available in the market.

INTRODUCTION

In Asian countries the development of farm mechanization during last two decades had been very fast and this trend would likely continue for future also. Farm mechanization has replaced the human power by machine power substantially. Farmers and governments in the developing countries are facing difficulty of finding an appropriate level of mechanization. Higher level of mechanization is possible as the investment in mechanization could easily be balanced by eliminating the labour whose wages are increasing rapidly. However, small holding size is the main hindrance for complete mechanization.

The other problem which is faced by the farmers is the selection of optimum size of farm machinery. Very large or very small sizes of farm machines result in either increase in cost or inability to perform the required farm operations in a reasonable time. The selection of a machine size is a difficult task. In multiple cropping pattern a similar implement and power unit may require quite often at the same time. This makes the selection more complicated.

Considering the above factors this study was undertaken to compute the optimum size of implements for seed bed preparation, for sowing and for interculturing. It was also intended to find the optimum working hours of the tractors required for cultivation.

DEVELOPMENT OF THE MACHINERY SIZE SELECTION MODELS

Selection of optimization Technique

There are many optimization techniques available which can be used in selecting the optimum system of farm machinery. A method for finding a minimum value of the annual cost equation of any farm machine with respect to one of its variables is that of differential calculus. The minimum cost of the equation is given when the first derivative of the annual cost with respect to the size of the machine is equated to zero, provided the second derivative of the equation is positive.This technique has been used in developing the farm machinery model because the actual size of machines can be selected from the available market stock and thus give the system cost close to reality.

The system of farm mechinery selection was based on the assumptions that the crops and the area under each crop grown in the farm and various farm operations required for selected crops are knwn and remain fixed for whole life of the system. Similarly it was assumed that the purchase price of the farm machine is proportional to its size and fuel required for the tractor is directly proportional to the tractor power. The yield function with respect to farm operation completion time follows the curve as shown in Fig. 1. Crop yield suffers no loss as long as the operations are completed with in the optimum period. The yield of crops decreases with the same rate whether the farm operation is done before or after the optimum period of operation.

Procedure for selection of implement size

A. Annual Fixed Cost

It included the depreciation, interest on investment, taxes, shelter and insurance. The most reliable annual fixed cost approximation method is to use the simplest depreciation technique, the straight line method, and calculate all the annual fixed costs as a constant amount for each year of the implement's life. it is possibile

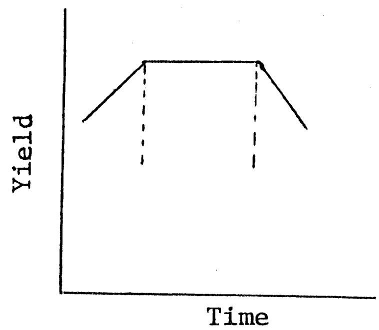

Fig. 1 : Yield vs time funtion

to combine the costs of depreciation, interest on investment, taxes, shelther and insurance into a single percentage of the purchase price called annual fixed cost percentage (FCP%) (3).

Annual fixed cost (Rs.*/yr) - (FCP%)*PP/100 ... (1)

where, FCP% - annual fixed cost percentage (Table 1)

PP - purchase price of the machine, in Rs.

(*1 US$ - 14.5 Indian Rs.)

B. Annual operating cost

The labour cost, fuel cost, repair and maintanence cost, and tractor cost, if the machine is not self-propelled, comparises the annual operating cost. The annual operating cost can be given as follows (3).

Annual operating cost (Rs/yr) - CA ((R&M)PP + L + F + T) / (S*W*E) ... (2)

where, C - constant, 10

A - annual area in use, ha

R&M - repair and maintenance cost

L - labour cost, Rs/hr

F - fuel cost, Rs/hr

T - tractor use cost, Rs/hr

- (P-s/N + fx)/t + Ft

P - purchase price of tractor

s - salvage value

fx - other fixed costs

N - Life of tractor, yr

t - annual usage of tractor

Ft - fuel cost of tractor

S - forward speed, km/hr

W - width of machine,m

E - field efficiency, decimal

Some of the variables which are discussed above can be written in terms of width, w, of the implement. The major variable so dependent is the purchase price (PP). It is now necessary to use a new statement of purchase price for selection of capacity, as the purchase price cannot be known until the size of the machine is known. Let 'pp' be understood to be the purchase price per additional width; then PP can be written as:

PP - pp* w ... (3)

The forward speed will be constant with different sizes of machines as long as the power is not limiting. The size of the machine may have an effect on the field efficiency, (E), but this effect was considered negligible.

The repair and maintenance cost must also be expressed in terms of 'w'. Let it be understood that the yearly cost of repair and maintenance (R&M*PP), will now be replaced by (r&m * pp * w), where r&m is the value of repair and maintenance cost per hour expressed as a decimal of the purchase price (pp*w).

Fuel cost per hour 'F' is known to be definitly proportional to the size of the equipment. For simplicity it is assumed that it is proportional to the size of the implement; therefore the variable 'F' can be expressed as (f*w) where f refer to the fuel cost per hour per unit of implement width.

The cost of labour 'L' is readily recognised as being essentially independent of the machine. The cost of tractor rent 'T' is assumed to be function of time only and independent of the size of the implement.

the statement of the annual cost of the machine where the appropriate variables are expressed on a basis of unit machine width may be given as:

Annual cost(Rs/yr) - (FCP%*pp*w/100) + (C*A (r&m*pp*w) +L (f*w) +T) ... (4)

To get the optimum width of the implements, by considering only the above two costs, the quation is differented with respect to the width of the implement and equated to zero.

We get optimum width as :

$$w - (100*C*A\ (L + T)/\ (FCP\% * pp * S * E))^{1/2} \qquad \ldots (5)$$

C. Timeliness cost

The timeliness cost can be given as (1):

$$\text{Annual timeliness cost (Rs/yr)} + (K*Y*V*A^2)/\ (Sc*nt*U*h) \qquad \ldots (6)$$

where,
K - timeliness cost factor, 1/day
Y - potential crop yield, kg/ha
V - value of the crop, Rs/kg
A - crop area involved, ha
Sc - 2 for premature of delayed schedule
- 4 for balanced schedule
nt - no of times 'A' should be divided because of dispersed optimum times - 2
U - fractional utilization of total time, fraction
h - hours worked per day

Eq. 5 now can be modified to include a charge for timeliness. thus, the optimum width may be written as:

$$W = \sqrt{\frac{(100*C*A)}{(FCP\%*pp*S*E)} L + T + \frac{(K*Y*V*A)}{(Sc*nt*U*h)}} \quad ....(7)$$

The above Eq. (7) is designated as the "Optimum width equation". It is a valuable aid in selecting the most economical implement. In this paper, the above equation is used for calculating the optimum width.

DEVELOPMENT OF COMPUTER PROGRAMME

A computer program was developed and written in BASIC language. The program included not only the derived equations but also additional equations for working hours, fixed cost, operating cost and timeliness cost etc. and logic to reach the desired optimum solution. The flow diagram illustrating the brief selection procedure and program logic for optimum size selection of the farm implement is shown in Fig. 2.

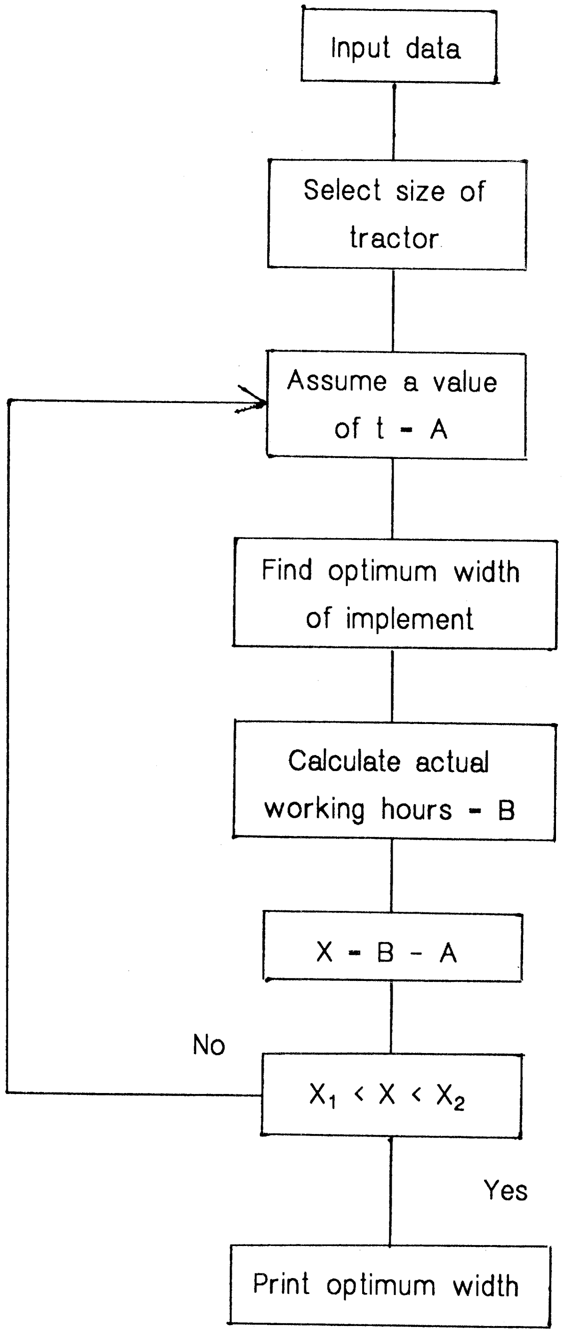

Fig. 2 : A flowchart for computer program development

Selection of area

The optimal selection of any system of farm machinery depends upon climate, crops and other conditions prevailing in a certain region. To illustrate the use of developed model and to determine the basis for recommending different levels of mechanization, a typical Indian farm was chosen as a reference area.

The annual average rainfall of India is approximately 67 centimeters. The soils are of alluvial origin varying from sandy to clay loam. About 50% of the area is under the holdings of less than 5 ha, 48% under the holdings of 5 to 20 ha and only 2% under the holdings of more than 20 ha in size.

Farm characterstics

A 10 ha farm land was selected for the study. In that wheat and mustard were assumed to be grown in rabi season, and rice and maize in Kharif. Generally farmers are able to take only two crops per year. Thus, these crops were chosen to represent the crop rotation.

Data used in the model

a. General

Rate of interest per year, decimal	- 0.10
Sale tax rate, decimal	- 0.03
Salvage value factor, decimal	- 0.10
Shelter charge per year, decimal	- 0.01
Working hours per day	- 8.00
Price of fuel, Rs/liter	- 1.50
Labour cost, Rs/hr	- 3.00

b. Tractor

Estimated tractor life, years	- 15
Purchase price per unit horse power of tractor, Rs/hp	- 1500
Repair and maintenance cost factor for tractor (percent of purchase price per 100 hours)	- 1.0
Specific fuel consumption, lit/hp-hr	- 0.3

c. Implements

The data about implements and their other details are given in table 1.

Table 1 : Data for tractor operated implements

Implement	Life (Yrs)	Purchase Price Rs/m	Speed km/hr	Field Efficiency	FCP%	K 1/day
1. M. b. plow	12	4250	4.5	0.9	14	0.0001
2. Disk harrow	10	2800	6.0	0.9	16	0.0001
3. Seed drill	8	2350	5.0	0.8	18	0.002
4. Cultivator	12	700	6.0	0.9	14	0.001

d. field operations

The information on the area for each operation, labour cost, optimum hours and yield loss was also needed. Labour (operator) cost in this case was taken as Rs. 3.00 per hours. Yield loss factor given by Hunt (1) was used in this study.

Table 2 gives the optimum period and number of different operations required to be performed for different crops used in the system.

e. Agricultural implements and machinery available in the marker

To select the farm machinery from those available in the market in order to know the system cost close to real situation, the sizes and prices of various implements and machines were collected. These are given in Table 3.

Table 2: Calender of crop activities

Crop	ACtivity	Operation	Area	Optimum operation time
wheat	A	Ploughing after pre-irrigation	2*A	31 Oct - 14 Nov
	B	Harrowing	A	01 Nov - 15 Nov
	C	Sowing	A	1 Nov - 15 Nov
Mustard	A	Ploughing after pre-irrigation	A	28 Oct - 10 Nov
	B	Harrowing	A	1 Nov - 10 Nov
	C	Sowing	A	1 Nov - 15 Nov
Paddy	A	Ploughing after pre-irrigation	2*A	25 June - 01 July
	B	Harrowing	A	28 June - 02 July
	C	Sowing	A	30 June- 07 July
Maize	A	Ploughing after pre-irrigation	2*A	24 June - 08 July
	B	Harrowing	2*A	01 July - 15 July
	C	Sowing	A	01 July - 15 Aug
	D	1st Interculture	A	19 July - 02 Aug
	E	2nd Interculture	A	03 Aug - 17 Aug

Table 3: Size and price of different implements

Name of implement	Size	Price
M. b. plough	51 cm	2250
	71 cm	3375
	107 cm	4000
Disk harrow	1.40 m	4000
	2.24 m	6250
Seed drill	1.15 m	3900
	2.07 m	4200
	2.53 m	4700
	3.45 m	7150
Cultivator	1.61 m	1100
	2.07 m	1450
	2.53 m	1900

RESULTS AND DISCUSSION

The developed computer program was used to determine the optimum size of farm machinery for various tractor powers. This corresponds to the crop rotaion of wheat and mustard in rabi and paddy and maize in kharif season.

For a farm size of 10 ha, 15, 25, and 35 hp tractors were chosen to find the optimum size of the implements. The optimum size of implements for 15 hp tractor was 0.929 m plough , 0.927 m disk harrow, 1.278 m seed drill, and 2.13 m of cultivator For 25hp tractor, it was 1.22 m m.b. plough, 1.21 m disk harrow, 1.59 m of seed drill, and 2.72 m of cultivator. And finally for 35 hp tractor, it was 1.50 m m.b. plough, 1.50 m disk harrow , 1.90 m seed drill, and 3.298 m cultivator. The total usage time per year for 15, 25 and 35 hp tractors was 870, 670, and 545 hours respectively. Twenty percent of this usage time was used by the farmer for the seed bed preparation, seeding, and interculture operation.

The standard sizes of implements which are available in the market and their prices are given in Table 3. The sizes of the implements which are obtained in this study for 15 hp tractors were close to the sizes of the implements which are avilable in the market. However, forr 35 hp tractor the size of the m.b. plough calculated is too big. Moreover the working hous were only 545 hours per year. Thus it may be adviced that a former having only 10 ha of land should buy a tractor of not more than 25 hp. If he buys a tractor of more than 25 hp, it would not be economical as it needs a lot of capital investment.

Table 4 shows the optimum matching of implements available in the market with 15 hp and 25 tractor.

Table 4: Implement matching with different tractors

Tractor hp	Implements	Size	No	Price, Rs
15	M. b. plough	107 CM	1	4000
	Disk harrow	140 CM	1	4000
	Seed drill	115 CM	1	3900
	Cultivator	207 CM	1	1450
25	M. b. plough	107 CM	1	4000
	Disk harrow	140 CM	1	4000
	Seed drill	115 CM	1	3900
	Cultivator	253 CM	1	1900

The sizes of m.b. plough, disk harrow and seed drill are the same in both the cases. Only the cultivator size is chaged from 207 cm for 15 hp tractor to 253 cm for 25 hp tractor. For 15 hp tractor the size of the implements calculated were slightly less than the recommended in Table 4. It means that there would be slight change in the annual usage time i.e. it will be less for 15 hp tractor and more in a 25 hp tractor.

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