Selection of Power Tiller and Matching Equipment using Computer Program for Mechanizing Hill Agriculture

D. K. Vatsa[1] and D. C. Saraswat[2]
[1] Department of Agricultural Engineering,
CSKHPAU, Palampur-176062 (HP) India.
[2] Department of Farm Machinery and Power Engineering,
AAI-DU, Allahabad-211007. (UP) India.

erdkvatsa@hotmail.com

ABSTRACT

Selection of appropriate farm power and equipment is more complex and tedious due to computational work involved in solving the equations for different cropping system, changing soil condition and varying areas with the farmers. Thus, a computer program was developed in turbo C++ language to compute power of power tiller and the size of equipment by entering the essential inputs like area under different crops, cropping pattern and soil type for a particular farm situation. The program processed these data with the help of two options i.e. pre-defined parameters (default values) and user-defined parameters. Actual power required as calculated through computer programming was compared with that of the power tiller owned by the farmers with respect to area. It is evident that the farmers owning land less than 2.0 ha, mostly possess high wattage power tiller than what is actually required. The difference in owned power and actually required power decreased as the size of the farm increased. Farmers having higher than 3.0 ha area have power tiller of less power than actually required.

The program-sensitivity was checked by changing the timeliness constant (K) and price of crop. The value of timeliness constant increased the power requirement for a particular farm also enhanced. This is due to the fact that as timeliness constant increased, the time period to complete a job decreased. Light soil required lesser power than heavy soil when K was constant. The power required increased with the increase in the price of crop. The crop price being the output of the farm, the higher it is, the greater would be the timeliness loss. The program-sensitivity was also checked by changing the power tiller unit price which indicated that the decrease in power required as per the increase in the price of power tiller. Thus a power tiller of low power has to be chosen to compensate the increased input cost at the farm. The selection of appropriate power source-equipment will be helpful for the farmers in mechanizing hill agriculture.

Keywords: Mechanization, selection, program, power tiller, equipment, hill farming, India

1. INTRODUCTION

Mechanization plays an essential role in agriculture and assures timely completion of farm operations as well as less expenditure per unit area. It was started from the development of the animal drawn implements and other farming tools. The hill farmers commonly have small scale and narrow fields of less than 0.6 ha and using traditional tools (Anonymous, 2003). The draft of National Policy of Agricultural Mechanization prepared by the Central Council for Agricultural Mechanization set-up by the Ministry of Agriculture in 1998, observed that with the emphasis on timeliness, precision and general improvement in the quality of work, farm mechanization has resulted in the increase in cropping intensity, yield and employment. Very little emphasis has yet been laid to modernize the farm particularly with improved farm tools and equipment for augmenting the crop production in the hilly state of Himachal Pradesh. The modern techniques of crop production have not only created an impact on increasing productivity but also on reducing drudgery involved in farming operations, which directly or indirectly attract the farming community (Vatsa, 2006; Asoegwu and Asoegwu 2007). Hill land farming was observed to be totally different from plain land farming and classified the problems as physical, social and economic (Ravalo et al 1986; Khatiwada and Sharma, 1995; and Pariyar and Singh, 1995). It was found that walking tillers had good applications for hill land operations. The tillers were relatively easy to operate on a narrow bench terrace of about 4 m width. The low level of mechanization is one of the factors responsible for the low productivity in agriculture. Singh and Singh (1990) studied energy inputs in agriculture in selected countries namely India, Thailand and Nepal. They developed the yield and farm mechanization ratio (MR) for quantifying the degree of mechanization and found that the average crop yields increased with the mechanization ratio with the different categories of farms. Farmers of the hilly region are interested to adopt the available newer technology for their farm but unable to realize which power source is suitable for the hill farm due to complexity of the power-machinery system. Therefore, agricultural development has more relevance in hills for obvious reasons of livelihood and socio-economic upliftment. In hills, hand tractors are quite handy to use for attaining higher working efficiency and accuracy than four wheel tractors (Sakai, 1999).

The hill region of Himachal Pradesh is presently having about 0.5 kW/ha power availability with mostly traditional tools to complete the farm operations (Vatsa and Saraswat, 2003). However, conducting timely operations under rain-fed conditions is very difficult. On the other hand, topography is restricting the introduction of large mechanical power like tractor in most of the region. Mechanization of the crop production system represents the largest single item of expenditure constituting about 50-60 % of the total farm investment. Mostly the farmers depend on their own experience or recommendation by other farmers or machinery dealers for purchasing agricultural equipment because a large number of variables and complex interactions are required during the proper selection procedure (Alam et al., 2001). In farm machinery management, mostly mathematical models are used, depending upon the need of a particular region or situation involved. The most common models used are: (a) least cost mathematical models, (b) linear programming models, (c) activity or event network analysis models and (d) heuristic and other models. Software developed in BASIC language for determining the optimum power requirement that could give the economical agricultural production for a known farm size, and farm operations using Hunt's least cost equation (Isik and Sabanci 1993; Murthy, 1999). For each farm size, the program gave the number of tractors needed, implements required, annual cost of operating the equipment per hectare and per hour, operating hours for each equipment, fuel and oil requirement. Similarly, Siemens et al, 1990, 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 (1994); Singh and Chandraratne (1995) 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. Oksanen and Visala (2007) studied the path planning algorithms for agricultural machines particularly for irregular plots. Therefore, appropriate selection of power-equipment system is extremely important for determining the net returns in agriculture for a given farming situation, which not only enhances the annual machine use but also limits the operational costs and energy consumption.

Thus, there is an ardent need to develop criteria of selecting the power units like power tiller and equipment for timely completion of agricultural operations at the minimum cost and reduced drudgery for hilly regions.

2. METHODOLOGY

Selection of power –equipment is associated with farm size, soil condition, cropping pattern, cultural practices, yield, purchase price of machines etc. in which crop data and machine prices were collected from the farmers and dealers. Optimum power required for the field and transport operations is calculated (Hunt, 1983) as:

$$P_{opt} = \left[\sum\left(Pd_i\right) + \sum\left(Pt_j\right)\right]^{1/2} \qquad \text{---------- (i)}$$

Where,

Pd	= Power required at drawbar for field operations
Pt	= Power required for transport operations
i	= subscript which refers to specific operations of implements
j	= subscript referring to specific crops in a year

Power required for drawbar (Pd) was calculated as under:

$$Pd = \frac{100 \times A \times E \times n}{r(Fc\%)Ppt} \times \left[L + \frac{K \times Y \times V \times A}{Sc \times Nt \times U \times h}\right] \qquad \text{----------- (ii)}$$

Where,

A	= Area under crop, ha
E	= Energy required by implement for drawbar operation, kWh/ha

$$= \frac{BHP \times LCF \times 10}{W \times S \times Ef}$$

Where,

BHP	= Brake power, kW
LCF	= load coefficient factor
W	= Width of implement, m
S	= Speed of implement, km/h
E*f*	= Efficiency, %
n	= Number of operation in tillage
r	= Ratio of drawbar power to rated engine power
Fc%	= Fixed cost percentage of power tiller
Ppt	= Power tiller price per unit rated power, Rs./kW

L = Power tiller operator's wages, Rs./h
K = timeliness loss factor
Y = Yield of crop, Tonnes/ha
V = value of crop, Rs./Tonnes
Sc = Constant, 2 for premature or delayed schedules and 4 for balanced schedules
Nt = Number of times area should be divided because of dispersed optimum times
U = Fractional utilization of total times, decimal
h = Actual number of hours utilized

Power required for transport operations (Pt) is calculated as:

$$Pt = \frac{100 \times 0.27(D)(W)(Lt)}{(Fc\%)(Ppt)} \qquad \text{------------- (iii)}$$

Where,

D = Distance to be transported, km
W = Amount of material to be transported, tonnes
Lt = Labour cost of transportation, Rs./h

To determine the value of power required, the specific value of different crop prices, yield and timeliness loss factor for different operations are given in Table 1. The potential yield and current price was considered but for timeliness loss factor the values were taken as discussed by Bector and Singh, 1999.

Table 1 Data of crop price, yield and timeliness loss factor

Parameter	**Paddy**	**Maize**	**Wheat**
Yield, Tonnes/ha	3.5	3.5	4.0
Price, Rs./Tonnes	6500	6000	7000
Timeliness loss factor:			
- Tillage & sowing	0.0065	0.0046	0.00465
- Harvesting & Threshing	0.0066		0.00650

The fixed cost percentage (Fc %) of power tiller was calculated using expected life of 10 years. The actual number of hours utilized per day is assumed to be 8 hours and fractional utilization of total time is assumed to be 0.7. The work efficiency of implements is assumed to be 60 % due to small plots and terrain farming. The value of Nt is assumed the same as the number of operations of each implement.

Similarly, in field machinery selection, the most pertinent variable is size or capacity of the machine. Although forward speed and power availability affect field capacity, initially it is assumed that power is not lacking and the forward speed is the maximum value that does not reduce the effectiveness of operation. The annual cost of an implement can be expressed as

$$Ac = \frac{(Fc\%)P}{100} + \frac{c \times A}{S \times w \times e}\left(R\,\&\,M + L + O + F + T\right) \qquad \text{----------- (iv)}$$

Where,

Ac	= Annual cost of operation of implement, Rs/year
Fc%	= Fixed cost percentage of implement price
P	= Purchase price of the implement, Rs
c	= Constant, 10
A	= Area under the implement, ha
S	= Speed of implement, km/h
w	= Effective width of implement, m
e	= Field efficiency of implement
R&M	= Repair and maintenance cost, Rs/h
L	= Labour charges, Rs/h
O	= Oil cost, Rs/h
F	= Fuel cost, Rs/h
T	= Power tiller operating cost, Rs/h

The symbol, *w* will be used to represent the effective width of action of all field implements. All the variables that depend on the size of the machine will be expressed in terms of *w*. The major variable dependent is the purchase price, P. Let *p* be understood to be the purchase price per unit width, thus P can be written as P = *pw*.

The forward speed will be constant with different sizes of machines as long as power is not limiting. The repair and maintenance cost (R&M) now will be replaced by *rmpw*, where *rm* is the value of repair and maintenance cost per hour expressed as a decimal of the purchase price, *pw*.

Fuel and oil cost per hour are known to be definitely proportional to the size of equipment. For simplicity it is assumed that these are directly proportional to size and therefore the variables O and F can be expressed as *ow* and *fw* respectively, where *o* and *f* refer to the oil and fuel cost per hour per unit of implement width.

The cost of labour, L is readily recognized as being essentially independent of the size of the machine. The cost of power tiller rent, T is assumed to be a function of time only and independent of the size of the implement. Thus the above equation was transformed into statement of the annual cost of a machine where the appropriate variables are expressed on a basis of unit of machine width, i.e

$$Ac = \frac{(Fc\%)pw}{100} + \frac{c \times A}{S \times w \times e}\left(rmpw + L + ow + fw + T\right) \qquad \text{--------- (v)}$$

Equation defining the lowest point on the cost curve was represented by

$$w = \left[\left(\frac{100 \times c \times A}{(Fc\%) \times p \times S \times e}\left(L + T\right)\right)\right]^{1/2} \qquad \text{--------- (vi)}$$

2.1 Development of Program

A program was developed to determine the optimum size of power tiller and implements in Turbo C++ using above equations and the flowchart of program is given in Fig. 1. This program contains a default data on various parameters like price of power tiller, implement, optimum number of operations for different crops, yield of crop etc. However, if user wants to use his own data as elaborated above then there is a provision for changing by entering own data in the program. To find out the size of power source and the machine, user has to enter the data like area owned, crop sown and soil type to the program. The program consists of six files in which one is header file i.e. fmpm.h and the others are fmpm.cpp, size.cpp, use.cpp, energy.cpp and res.cpp. The Turbo C^{++} environment is not required to run the program and this can be run on operating systems like DOS and Windows with the help of an executable file.

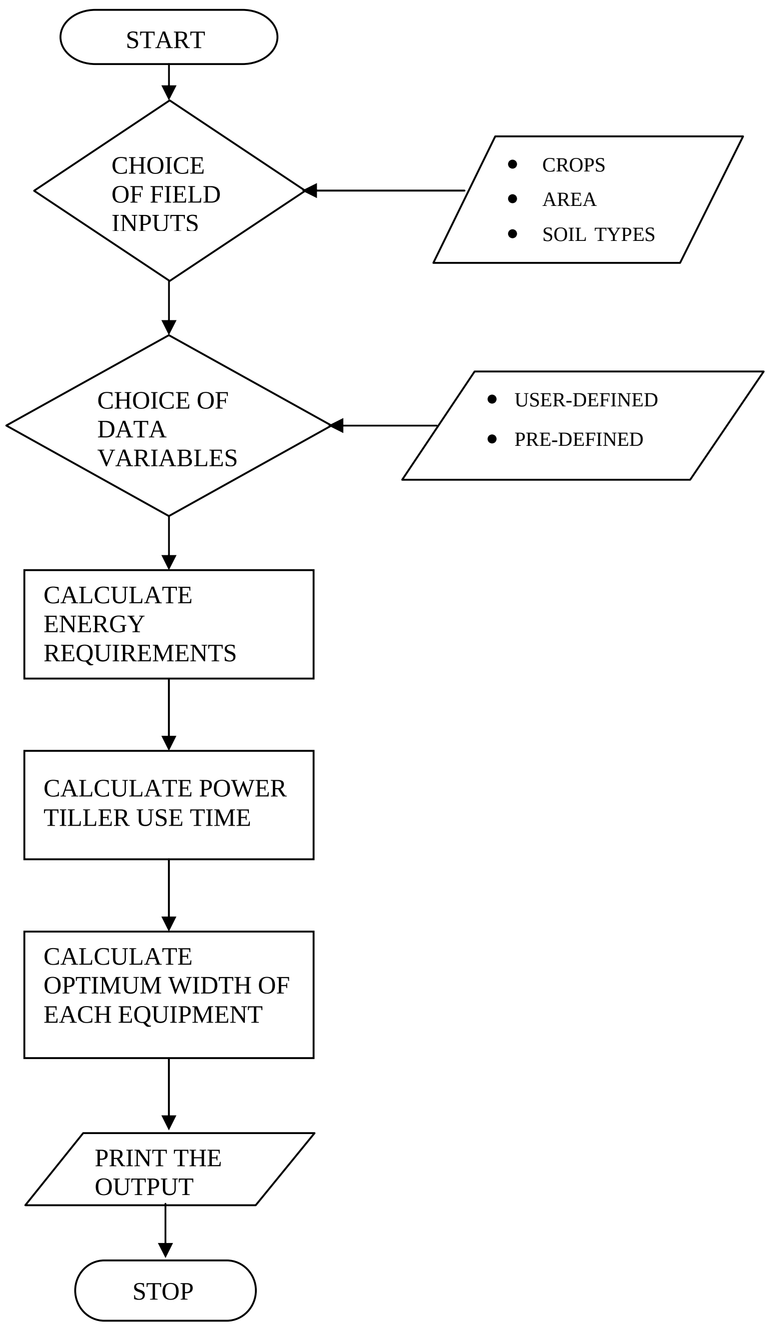

Figure 1. Flow chart for optimum selection of power tiller-equipment

2.2 Validation of Model

To validate the model, farmers' data were compared with the observed values from the model. For this purpose, a survey was again carried out amongst the 40 farmers owning power tiller through simple random sampling without replacement because of low concentration of power tiller in the state. Field data from these owners were collected by personally interviewing all the cultivators through a well-designed pre-tested questionnaire. Information pertaining to power tiller horse-power, implement size, custom hired machines etc. were recorded. Cropping pattern, area under crop, soil type and number of operations in tillage were also recorded. These values would be used as input to computer program for selection of optimal power and machinery in respect of the different land holdings. The sensitivity analysis of the program was also done by changing the values of timeliness cost, crop price and crop yield.

3. RESULTS AND DISCUSSION

3.1 Selection of Power Tiller and its Matching Equipment

Actual power required as calculated through computer programming was compared with that of the power tiller owned by the farmers with respect to area and has been shown in Fig 2. It is evident that the farmers owning land less than 2.0 ha, mostly possess high wattage power tiller than what is actually required. The difference in owned power and actually required power decreased as the size of the farm increased. Farmers having higher than 3.0 ha area have power tiller of less power than actually required.

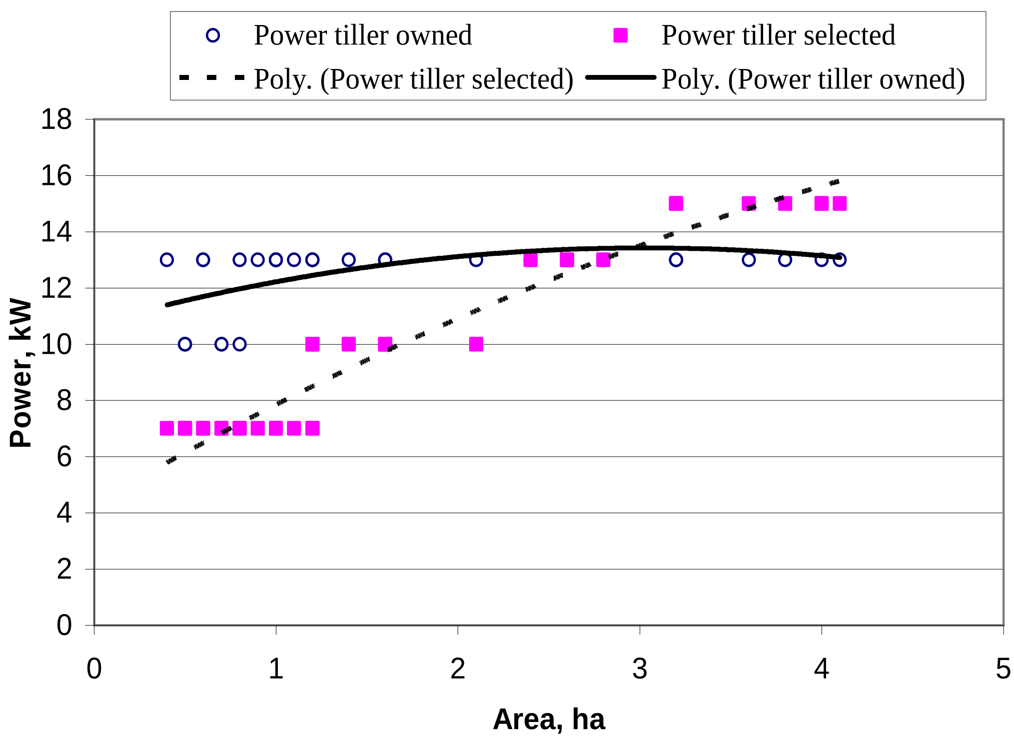

Figure 2. Power tiller owned by the farmer vs obtained through computer program

Similar trends were also observed for selection of rotavator size as shown in Fig. 3 as this equipment is an integral part of the power tiller. The other equipment such as mould board plough, cultivator and seed drill were very less in number with the farmers, hence the size of equipment was not compared with the size selected through the computer. Thus, this program will help the farmers in taking quick decision for the purchase of power tiller as per their requirement.

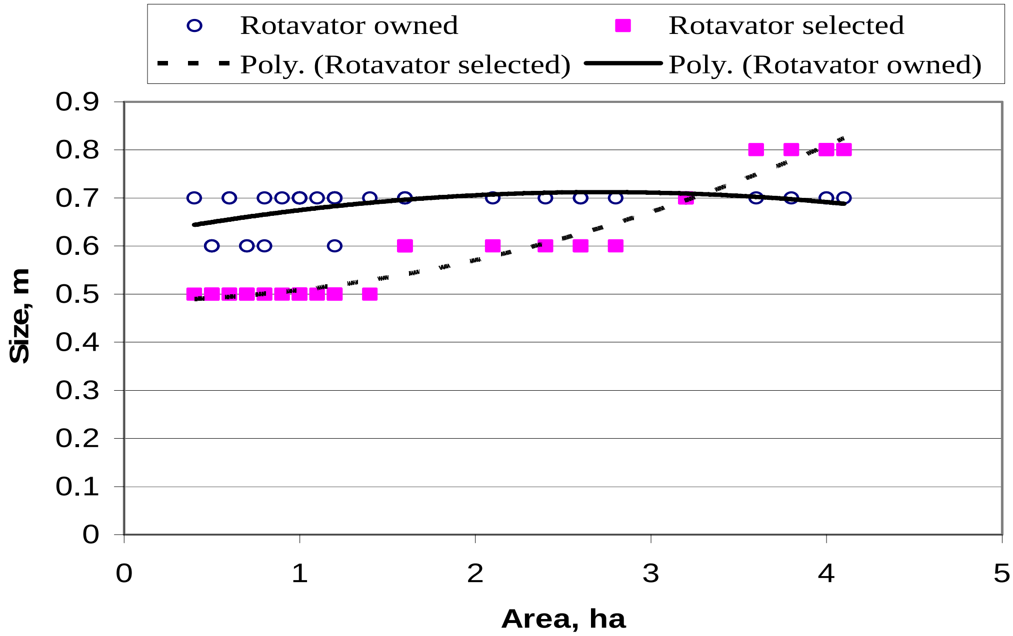

Figure 3. Rotavator owned by the farmer vs obtained through computer program

3.2 Sensitivity Analysis

Fig. 4 is the plot between power requirement and timeliness constant, K. The figure showed that as the value of timeliness constant increased the power requirement for a particular farm also enhanced. This is due to the fact that as K increased, the time period to complete a job decreased. Thus, higher power was required to complete the operations within that time period. The figure also indicated the power requirement under different soil conditions. Light soil required lesser power than heavy soil when K was constant. This was due to the fact that the number of operations of equipment increased as we moved from light to heavy soil.

To check the sensitivity of the computer program against crop price, maize-wheat rotation was taken with 4 ha area under cultivation. The price of wheat was changed from 5000-12000 Rs/Tonnes and that of maize was assumed as Rs 6000 per Tonnes (fixed) for calculating the value of power. The illustration between crop price and actual power required is shown in Fig. 5. All other parameters like area, timeliness constant and crop rotation were kept constant. The plot showed sensitivity of the model with respect to economic parameter i.e. price of the crop. The power required increased with the increase in the price of crop. The crop price being the output of the farm, the higher it is, the greater would be the timeliness loss. Thus, higher power is required to compensate the higher loss of timeliness particularly under rainfed conditions where the farm operations have to be completed within a very short span of time.

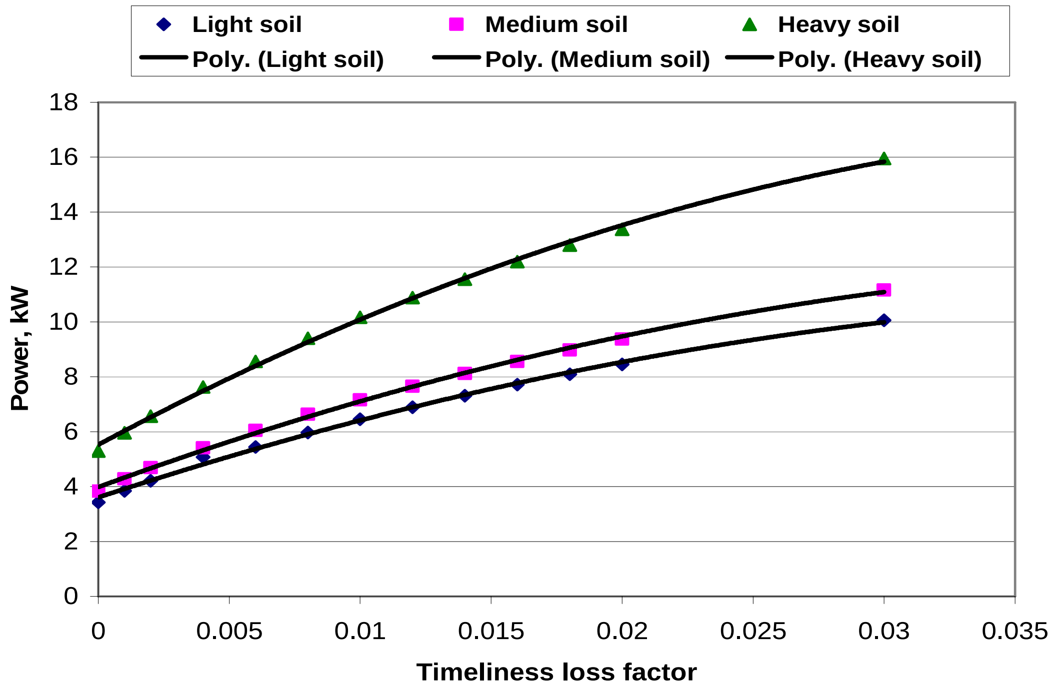

Figure 4. Effect of timeliness loss factor on power requirement

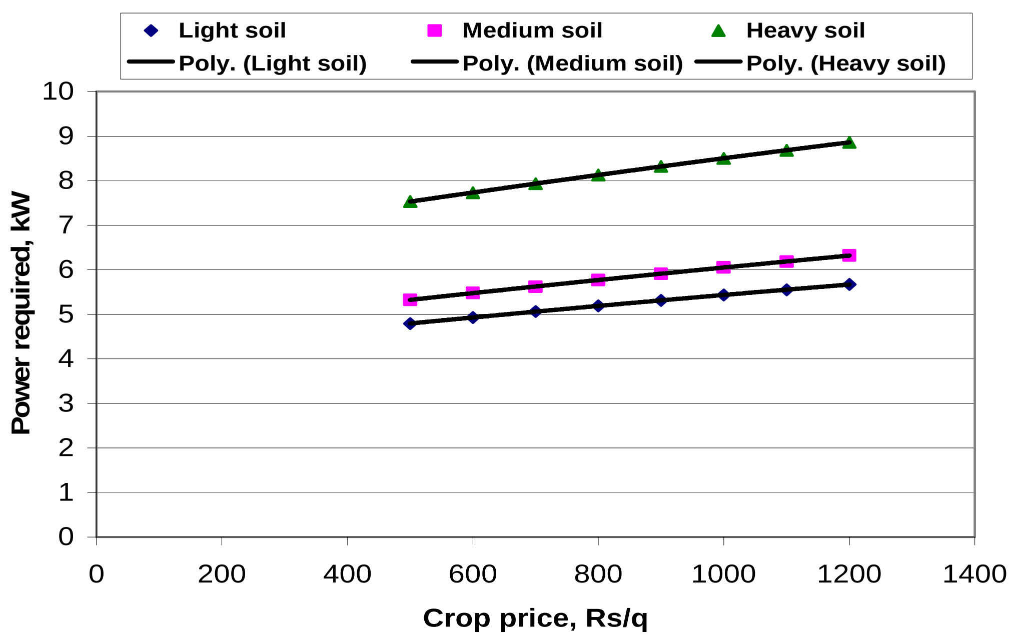

Figure 5. Effect of crop price on power requirement

The program-sensitivity was also checked by changing the power tiller unit price (Rs/kW) for maize-wheat rotation with an area of 4 ha under cultivation. The plot between power required and the price of power tiller is shown in Fig 6. The power was calculated by changing the price of power tiller from 5000 to 16000 Rs/kW.

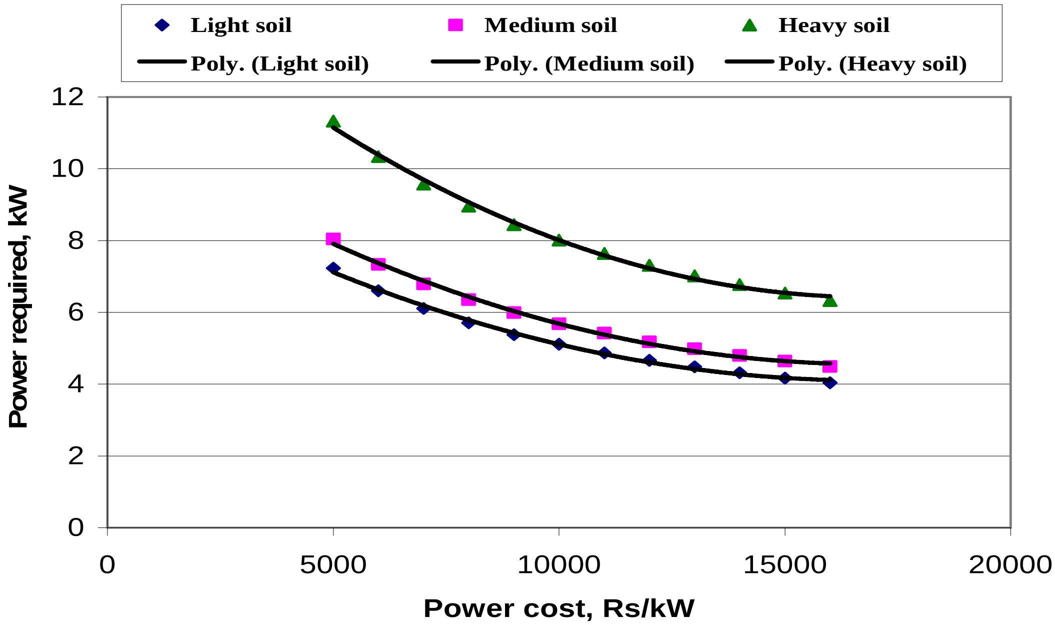

Figure 6. Power requirement as affected by cost of power tiller

All other parameters like area, timeliness constant, crop rotation and crop price were kept constant. It indicated the decrease in power required as per the increase in the price of power tiller. This was due to the fact that the power required is inversely proportional to the price of power tiller. The cost of energy being a major input in the farm, it increases the input cost in agriculture. Thus a power tiller of low power has to be chosen to compensate the increased input cost at the farm. In addition, low wattage power tiller or any other power source would always be beneficial to the hill farmers where land holding and topography is a constraint.

4. CONCLUSIONS

1. Farmers owning land less than 2.0 ha, mostly possess power tiller of higher power than what is actually required. The difference in power owned and actually required decreased as the size of the farm increased. Farmers having area higher than 3.0 ha possess power tiller of less power than the actual requirement. Similar trends were also observed for the selection of rotavator size as this equipment is an integral part of the power tiller.
2. Power requirement for a farm increased linearly with the increase in timeliness constant (K) and the price of crop. However it decreased exponentially with the increase in power tiller price (Rs/kW).

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