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Development and Adoption of small farm mechanization for hilly area

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Abstract
Farm Mechanization of agricultural operations in plains has played a vital role in efficient and timely field operations, increased productivity, cost and labour savings, but mechanization almost untouched in hilly areas. The farmers are still using traditional methods. Considering these points, efforts was made to develop lightweight, simple and compact equipments Plough, Ridger, Seed Planter, Ferti- hoe, Solar Sprayer matching for the hilly existing farming situations. A bullock drawn package of implements for hilly area developed at AICRP on Utilization of Animal Energy, College of Agricultural Engineering and Technology, VNMKV, Parbhani and field trials performed at Dhamangaon, taluka Pathardi and district Ahmednagar. One person are required to operate this machines by using single or pair of bullock. The results from the study for single bullock showed that, the draft of plough, ridger, ferti-hoe is 411, 421 and 372 N and the theoretical field capacity is 0.035, 0.048 and 0.06 ha/hr. The field efficiency of plough, ridger, ferti-hoe, 85.71, 85.21 and 85.00% and the power requirement is 0.19, 0.19 and 0.20 kW and for pair of bullock the draft of plough, ridger, ferti-hoe, planter, solar sprayer is 392, 402, 343, 274 and 264 N and the theoretical field capacity is 0.040, 0.057, 0.069, 0.124 and 0.264 ha/hr. The field efficiency of plough, ridger, ferti-hoe, planter, solar sprayer 83.33, 84.21, 85.50, 79.03 and 84.35% and the power requirement is 0.22, 0.21, 0.22, 0.19 and 0.25 kW.

Keywords: Farm mechanization, bullock, hilly area, implements

1. Introduction
Maharashtra has limited mechanization in hilly area because to the state uneven terrain and small land division. With timely operations and precise input application, farm mechanization enhanced productivity. However, not all farmers may use improved agricultural machinery and tools at the same time or at the same rate since they may not have enough knowledge or awareness of them. In the hilly terrain, draft animals and human labor are the primary sources of agricultural power. The majority of agricultural operations are undertaken by hand using conventional hand tools due to the undulations of the terrain and the farmers' low financial situation. Improved hand tools and equipment may minimize energy consumption and time spent cultivating hill crops. As a result, the development of new small-scale tools seeks to save time and energy while reducing physical strain on farmers.

The steep and uneven terrain in hilly areas makes it difficult for machinery to operate effectively and safely. Accidents can occur during the operation of heavy machinery on uneven and sloped surfaces. Conventional machinery may not be well-suited to the irregular contours of hilly landscapes, leading to inefficient land use and suboptimal cultivation practices. Traditional ploughing methods and heavy machinery can disturb the soil structure in hilly areas. Standard farm machinery is often designed for flat landscapes, and adapting them for hilly terrain may require modifications that are not readily available or affordable.

The machinery designed for flat or gently rolling terrain may not be suitable for hilly areas. Specialized equipment, such as lightweight tractors and narrow-track vehicles, is often required. Specialized machinery for hilly agriculture can be expensive to purchase and maintain. Mechanized equipment can be challenging to maintain and repair in hilly areas due to limited access to service centers and skilled technicians. The weight of machinery can lead to soil compaction, which can negatively impact soil structure and fertility.

Adapting machinery for use in hilly areas may require modifications and investments in technology that some farmers cannot afford.

Maharashtra receives the majority of the irrigation. In the Scarcity regions includes Ahmednagar, Nasik, Pune, Dhule. Precipitation is quite low, with around 600 mm per year. The temperature and soil are comparable to those of the Western Hills and Plains. The soil is characterized as shallow to medium and deep black soils with sandy loam to clay loam texture and neutral to slightly alkaline reaction. Over two-third of the land is under cultivation, although irrigation facilities cover just around 17% of the total farmed area. Total Geographical area in the Ahmednagar district is 17048 sq.km having total hilly area is 266.89 sq.km. Sindhudurg, Pune, Yavatmal, Nashik, Nandurbar, Jalgaon, Amravati is the largest hilly area in Maharashtra. In the Maharashtra total geographical area is 3,07,713 sq.km which includes the hilly area about 50.89% having a slope in the range of 0-5 degree. About 1.73% of hilly area having a slope more than 30 degree.

Considering this points we designed the small and light weight implements for the hilly area and these implements has been developed for the field operation like Ploughing, Planting, Ridging, fertilizer application, weeding and spraying.

2. Materials and Methods

In this chapter the material and methods adopted in development or adoption of small farm mechanization for hilly area has been outlined. The evaluation procedure have also been discussed.

2.1 Measurements of Different Parameters

During field performance working width, depth of operation force required to pull implement, angle of pull and time required to cover plot were measured. The speed of operation, area covered, effective field capacity, theoretical field capacity, field efficiency, power required, man hours per ha, were calculated.

a. Speed of operation

During the field trials of speed of operation time required for turning and total time for work are recorded. The speed of operation is calculated by using following formula.

$$\text{Speed (km/h)} = \frac{\text{Distance covered (m)} \times 60}{\text{Time required to cover that distance (min)} \times 1000}$$

b. Draft requirement

For draft measurement a digital Dynamometer was used. A dynamometer was attached between yoke and implement.

$$D = P \cos \theta$$

Where,
D = Draft in kg
P= Pull in kg
θ = Angle of pull w.r.t. horizontal.

c. Theoretical field capacity

For calculation of theoretical field capacity, the speed of travel and operated width are considered.

$$\text{Theoretical field capacity in ha/h} = \frac{\text{W (m) x S (km/h)}}{10}$$

Where,
W = Width of blade harrow in m.
S = Speed of operation km/h.

d. Effective field capacity

For calculation of effective field capacity, the time consumed for actual work and all associated activities such as turning, cleaning and adjustment during operation was considered effective field capacity calculated by following formulae:

$$EFC = \frac{A}{T1+T2}$$

Where,
EFC = Effective field capacity in ha/h.
A = Area covered in ha.
T_1 = Time required to cover the plot in h.
T_2 = Time loss in turning in h.

e. Field efficiency

The field efficiency has calculated by the following formula.

$$\text{Field efficiency} = \frac{\text{Actual area covered per h}}{\text{Theoretical are covered per h}} = \frac{\text{E.F.C.}}{\text{T.F.C.}}$$

f. Power output

By using computed draft and speed of bullock the power output was determined as follows.

$$\text{Power output (hp)} = \frac{\text{Draft (kg)} x \text{ Speed } (\frac{\text{km}}{\text{h}})}{270}$$

The power requirement was determined by following formula.
Power output (kW) = power output (hp) X 0.746

g. Man hours per ha.

Man hours per ha determined by following formula:

$$\text{man hours per ha} = \frac{\text{Area covered,(ha)}}{\text{E.F.C.}(\frac{\text{ha}}{\text{h}})}$$

2.2 Operational cost of UAE developed bullock drawn package of implements

This procedure involves determining both fixed and variable costs. Using standard methods, the cost of operation per hectare was calculated.

A. Fixed Cost

i. Depreciation

$$C = \frac{C-H}{L \times H}$$

Where,
D= Depreciation, Rs/h
C=Cost of machine, Rs
S=Salvage value @10% of cost of capital cost, Rs
L= Life of machine, yrs.
H= Annual hour use of machine, h

ii. Interest

$$I = \frac{C+H}{2} \times i$$

Where
I = Interest. Rs/h

C=Cost of machine, Rs
S= Salvage value @10% of cost of capital cost, Rs
i = Rate of interest
H = Annual hour use of machine, h

iii. Repair and maintenance cost 10 percent of initial capital per year
iv. Housing and Insurance @ 2 percent of initial cost per year
B. Variable cost

- Variable cost Repair and maintenance cost at 10 percent of initial cost
- Wage of operator in Rs for working 8 hours
- Therefore, hiring charges of bullock in Rs for working of 4 hours
- Total cost of operation is the sum of fixed cost and variable cost of the planter.
- Total cost, TC Fixed cost+ Variable cost
- Wages @Rs. 400/- per day of 8 hr.

3. Results and Discussion

Table 1: Field Performance of Package of implements for pair of bullocks

Sr. No.	Particulars	Plough	Seed Planter	Ridger	Ferti-Hoe	Solar Sprayer
1	Plot size (m^2)	800	750	800	600	700
2	Crop type	Soybean	Soybean	Soybean	Bajra	Bajra
3	Moisture content of soil (%)	6	12	11	11	15
4	Weight of bullocks (kg)		800			
5	Width of operation (mm)	200	480	300		1050
6	Depth of operation (mm)	300	80	250	70	-
7	Speed of operation (km/h)	2.0	2.6	1.9	2.3	2.7
8	Draft (N)	392	274	402	343	264
9	Theoretical field capacity (ha/h)	0.040	0.124	0.057	0.069	0.264
10	Effective field capacity (ha/h)	0.034	0.098	0.048	0.059	0.221
11	Field efficiency (%)	83.33	79.03	84.21	85.50	84.35
12	Power requirement (kW)	0.22	0.19	0.21	0.22	0.25
13	Man hours per ha	29.41	10.20	20.83	16.95	4.524
14	Total cost of operation per h (Rs)	150.16	152.89	150.49	150.02	156.87
15	Total cost of operation per ha (Rs)	4416.20	1559.47	3134.70	2542.83	709.05

Table 2: Field Performance of Package of implements for single bullock

Sr. No.	Particulars	Plough	Ridger	Ferti-Hoe
1	Plot size (m^2)	800	800	600
2	Crop type	Soybean	Soybean	Bajra
3	Moisture content of soil (%)	6	11	11
4	Weight of bullocks (kg)	400		
5	Width of operation (mm)	200	300	
6	Depth of operation (mm)	300	250	70
7	Speed of operation (km/h)	1.7	1.6	2.0
8	Draft (N)	411	421	372
9	Theoretical field capacity (ha/h)	0.035	0.048	0.06
10	Effective field capacity (ha/h)	0.030	0.041	0.051
11	Field efficiency (%)	85.71	85.21	85.00
12	Power requirement (kW)	0.19	0.19	0.20
13	Man hours per ha	33.33	24.39	19.60
14	Total cost of operation per h (Rs)	127.12	127.45	126.98
15	Total cost of operation per ha (Rs)	4236.90	3108.50	2488.80

Fig 1: Field Performance of bullock drawn implements

3.1 Field performance of two bullock drawn planter

Plough has been tested in the field and the results of field test are presented in table 4.20.

I. Depth of operation

The depth obtained for field test of bullock drawn planter was in the range of 7.5 to 8.5cm. The average value was found to be 8 cm.

II. Depth of seed placement

The depth of seed placement obtained for field test of bullock drawn planter was in the range of 4 to 5cm. The average value was found to be 4.5cm.

III. Speed of operation

Speed of implement depends upon the moisture content, draft of machine, working width. Average speed of implement should be such that man can comfortably operate i.e. 2.6 Km/h.

IV. Draft

The average draft required to pull the implement was found to be in the range of 27-30 kg, which can be easily available with medium size bullock.

V. Theoretical field capacity

The average Theoretical field capacity found to be 0.0124 ha/h.

VI. Effective field capacity

The average actual field capacity of implement was found to be 0.098 ha/h.

VII. Field efficiency

Average field efficiency was found to be 79.03 per cent. It is nothing but ratio of actual field capacity and theoretical field capacity.

VIII. Power output

Average power output was found to be 0.19 hp.

IX. Man hours required per hectare:

The man hours required for sowing of one hectare are 10.20 h/ha.

3.2 Field performance of bullock drawn Plough

I. Depth of operation

The depth obtained for field test of bullock drawn plough was in the range of 25 to 30 cm. The average value was found to be 30cm respectively.

II. Speed of operation

Speed of implement depends upon the moisture content, draft of machine and working width. Average speed of implement by single and pair of bullock should be such that man can comfortably operate *i.e.* 1.7 and 2.0 Km/h respectively.

III. Draft

The average draft required to pull the implement by single and pair of bullock was found to be in the range of 38-45 kg, which can be easily available with medium size bullock.

IV. Theoretical field capacity

The average theoretical field capacity by single and pair of bullock found to be 0.035 and 0.040 ha/h respectively.

V. Effective field capacity

Effective field capacity is always less than theoretical field capacity because it includes turning loss and other field losses. The average actual field capacity of implement by single and pair of bullock was found to be 0.030 and 0.034 ha/h respectively.

VI. Field efficiency

Average field efficiency by single and pair of bullock was found to be 85.71 and 83.33 percent respectively. It is nothing but ratio of actual field capacity and theoretical field capacity.

VII. Power output

Average power output by single and pair of bullock was found to be 0.19 and 0.22 hp respectively.

VIII. Man hours required per hectare

The man hours required for one hectare by single and pair of bullock are 33.33 and 29.41 h/ha respectively.

3.3 Field performance of bullock drawn ridger

I. Depth of operation

The depth obtained for field test of bullock drawn ridger was in the range of 20 to 30 m. The average value was found to be 25 cm.

II. Speed of operation

Speed of implement depends upon the moisture content, draft of machine and working width. Average speed of implement by single and pair of bullock should be such that man can comfortably operate *i.e.*1.6 and 1.9 Km/h respectively.

III. Draft

The average draft required to pull the implement by one bullock and two bullock was found to be in the range of 39-45 kg, which can be easily available with medium size bullock.

IV. Theoretical field capacity

It was considered for only design purpose because on the field we encountered a lot of problems. So, it is impossible to achieve actual field capacity equal to theoretical field capacity. The average TFC by single and pair of bullock found to be 0.048 and 0.057 ha/h respectively.

V. Effective field capacity

Effective field capacity is always less than theoretical field capacity because it includes turning loss and other field losses. The average actual field capacity of implement by single and pair of bullock was found to be 0.041 and 0.048 ha/h respectively.

VII. Field efficiency

Average field efficiency by single and pair of bullock was found to be 85.21 and 84.21 per cent respectively. It is nothing but ratio of actual field capacity and theoretical field capacity.

VIII. Power output

Average power output by single and pair of bullock was found to be 0.19 and 0.21 hp respectively.

IX. Man hours required per hectare

The man hours required for one hectare by single and pair of bullock are 24.39 and 20.83 h/ha respectively.

3.4 Field performance of bullock drawn Ferti-hoe

I. Depth of operation
The depth obtained for field test of bullock drawn Ferti-hoe was in the range of 7 to 8cm. The average value was found to be 7 cm.

II. Speed of operation
Speed of implement depends upon the moisture content, draft of machine and working width. Average speed of implement by single and pair of bullock should be such that man can comfortably operate *i.e.* 2.0 and 2.3 km/h respectively.

III. Draft
The average draft required to pull the implement by single and pair of bullock was found to be in the range of 35-38 kg, which can be easily available with medium size bullock.

IV. Theoretical field capacity
It was considered for only design purpose because on the field we encountered no. of problems. So, it is impossible to achieve actual field capacity equal to theoretical field capacity. The average TFC by single and pair of bullock found to be 0.060 and 0.069 ha/h respectively.

V. Effective field capacity
Effective field capacity is always less than theoretical field capacity because it includes turning loss and other field losses. The average actual field capacity of implement by single and pair of bullock was found to be 0.051 and 0.059 ha/h respectively.

VI. Field efficiency
Average field efficiency was found to be 85.00 and 85.50 percent respectively. It is nothing but ratio of actual field capacity and theoretical field capacity.

VII. Power output
Average power output by single and pair of bullock was found to be 0.20 and 0.22 hp respectively.

VIII. Man hours required per hectare
The man hours required for one hectare by single and pair of bullock are 19.60 and 16.95 h/ha respectively.

3.5 Field performance of two bullock drawn Solar Sprayer
I. Speed of operation
Speed of implement depends upon the moisture content, draft of machine and working width. Average speed of implement should be such that man can comfortably operate 2.7 Km/h.

II. Draft
The average draft required to pull the implement by single and pair of bullock was found to be in the range of 25-30 kg, which can be easily available with medium size bullock.

III. Theoretical field capacity
The average TFC found to be 0.2620 ha/h.

V. Effective field capacity
Effective field capacity is always less than theoretical field capacity because it includes turning loss and other field losses. The average actual field capacity of implement was found to be 0.221 ha/h.

VI. Field efficiency: Average field efficiency was found to be 84.35 per cent. It is nothing but ratio of actual field capacity and theoretical field capacity.

VII. Power output
Average power output was found to be 0.25 hp.

VIII. Man hours required per hectare:
The man hours required for one hectare was found to be 4.524 h/ha.

4. Conclusion
A bullock drawn package of implements developed at AICRP on Utilization of Animal Energy, College of Agricultural Engineering and Technology, VNMKV, Parbhani. The field trials performed at Dhamangaon village in Ahmednagar district. It is concluded from the result that for plough, ridger, ferti-hoe, planter and solar sprayer for single bullock and pair of bullock are:
It was found that the field test of plough, ridger, ferti-hoe for single bullock are: The draft of plough, ridger, ferti-hoe is 411, 421 and 372 N and the theoretical field capacity is 0.035, 0.048 and 0.06 ha/hr. The field efficiency of plough, ridger, ferti-hoe, 85.71, 85.21 and 85.00% and the power requirement is 0.19, 0.19 and 0.20 kW. The cost of operation per hectare for plough, ridger, ferti-hoe is Rs. 4236.9, 3108.5 and 2488.80.
It was found that the field test of plough, ridger, ferti-hoe, Planter, Solar Spayer for pair of bullock are: The draft of plough, ridger, ferti-hoe, planter and solar sprayer is 392, 402, 343, 274 and 264 N and the theoretical field capacity is 0.040, 0.057, 0.069, 0.124 and 0.264 ha/hr. The field efficiency of plough, ridger, ferti-hoe, planter and solar sprayer 83.33, 84.21, 85.50, 79.03 and 84.35% and the power requirement is 0.22, 0.21, 0.22, 0.19 and 0.25 kW. The cost of operation per hectare for plough, ridger, ferti-hoe, planter and solar sprayer is Rs. 4416.20, 3134.70, 2542.83, 1559.47 and 709.05.

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