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Cost reduction, yield and profit enhancement in maize cultivation through mechanization

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Abstract

Objectives: To assess the impact of different degrees of mechanization on cost reduction, productivity and profitability of maize cultivation.
Methods/Statistical analysis: A sample of 47 maize growers was selected from Shimoga district of Karnataka. Farms were post classified into highly, moderately and less mechanized based on the degrees of mechanization. Enterprise budgeting, energy indicators, dummy variable technique, data envelopment analysis are the tools employed in the study. The data on inputs used, labour use pattern, output, prices of inputs and output were elicited using structured schedule for the agricultural year 2016-17.
Findings: Mechanization in maize has led to cost saving and increased profit of 20.21% and 32.14% on HMF compared to LMF. Mechanization reduced dependence on human labour to an extent of 64.28% and 18.50% on HMF and MMF compared to LMF. Mechanical energy was found to be the cheapest energy source at ₹2.93% MJ. HMF was found to be economically efficient in resource use compared to MMF and LMF. The dummy variable analysis indicated that additional rupee spent on machine labour increases net returns by ₹4.45 while it was meager ₹0.38 from human labour.
Application/Improvements: Mechanization should be made affordable to marginal and small farmers through establishment of more number of custom hiring centres sponsored by Government in collaboration with NGO's/ private agencies.
***Keywords*:** Maize, Cost reduction, Yield, Profit, Mechanization.

1. Introduction

Maize is an important agricultural cash crop in Malnad region of Karnataka. In Malnad region, it is extensively cultivated in Shimoga district. It is cultivated on an area of 0.59 lakh ha with a production of 2.1 lakh tons. Shimoga has attained specialization in maize cultivation during last decade as indicated by the location quotient value of 3.81 [1]. It contributes 8.57% to district agricultural GDP. It is an active ingredient in poultry feed. The remunerative price of the crop attracts farmers to cultivate it on large scale [2]. Cultivation of maize is facing predicament of economic and physical scarcity of labor. As the crop demands intensive cultivation, the problem of human and bullock labour scarcity could be resolved through mechanization. Mechanization has got direct bearing on crop productivity and production. Besides, reduces drudgery and facilitates timely agricultural operations. The ultimate objective of farmer is to maximize profit attained either through increased returns or through cost reduction. Farmers in the locality can avail mechanical services from government sponsored agencies or private players. Large farmers could afford expensive implements and machineries whereas the small and marginal farmers being capital starved are not in position to afford machineries. In order to enable these farmers to adopt mechanization, state government in collaboration with SKDRDP, a NGO has established custom hiring service centres at hobli levels. These centres are equipped with implements and machineries required for cultivation of location specific crops. The centre provides services of machineries on rental basis at concessional rates to farmers. The services are provided to farming community on first come first serve basis. Farmers availing services should have to make down payment of 25% of the prescribed fee at the time of booking service and rest is paid after utilization of the services. Though, different sources of mechanical services are available in the region, the extent of adoption of mechanization varied across farming community. The present study attempts to ascertain the impact of different degrees of mechanization irrespective of sources on productivity and profitability of maize cultivation.

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2. Methodology

A sample of 47 farmers cultivating maize was selected from Shimoga district, representative of Malnad region of Karnataka. The sample farms were post stratified as highly mechanized farms (HMF), moderately mechanized farms (MMF) and less mechanized farms (LMF) based on degree of mechanization adopted in maize cultivation. Farms where land preparation, sowing and basal dose of fertilizer application, harvesting and threshing operations are mechanized were considered as HMF. MMF is those farms where sowing, basal dose of fertilizer application and threshing operations are mechanized and on LMF only land preparation and threshing operations are mechanized.

The primary data pertaining to operation wise use of machines, labour use pattern and material inputs used in maize cultivation was elicited from farmers using pretested schedule through personal interview method. The source of mechanization and rental charges levied on various mechanical services was obtained. In order to estimate the input energy and output energy of maize cultivation, the energy equivalents of human labour, machine labour, bullock labour and material inputs such as seeds, fertilizers (NPK), FYM, plant protection chemicals and weedicide was obtained from published sources. Tabular and budgeting techniques were used to estimate economics of maize cultivation across degrees of mechanization. Energy use indicators such as energy efficiency, energy productivity, specific energy, net energy, profit per MJ, cost per MJ of energy and other related ratios were estimated using relevant formulae [3-5].

Energy use efficiency = $\frac{\text{Out put energy (MJ/acre)}}{\text{Input energy (MJ/acre)}}$

Specific energy or Energy intensity (MJ/kg): $\frac{\text{Input energy (MJ/acre)}}{\text{Crop yield (kg/acre)}}$

Energy productivity (kg/MJ): $\frac{\text{Crop yield (kg/acre)}}{\text{Input energy (MJ/acre)}}$

Net energy: $\text{Output energy (MJ/acre)} - \text{Input energy (MJ/acre)}$

Cost per MJ of input energy: $\frac{\text{Total cost per acre}}{\text{Total input energy (MJ/acre)}}$

Returns per MJ of input energy: $\frac{\text{Total returns per acre}}{\text{Total input energy (MJ/acre)}}$

Profit per MJ of input energy: $\frac{\text{Net returns per acre}}{\text{Total input energy (MJ/acre)}}$

2.1. Effect of different degrees of mechanization on profit of maize cultivation

Profit function was estimated to assess the effect of different degrees of mechanization on profit realized per acre in case of maize cultivation. The functional relationship was established between profit per acre (dependent variable) and expenditure on machine labour, expenditure on human labour, expenditure on bullock labour and dummy variable representing different degrees of mechanization (independent variables). To capture the influence of different degrees of mechanization i.e., highly mechanized, moderately mechanized and less mechanized situations, intercept dummies were considered. The dummy variables D_1 and D_2 respectively takes the value 1 and 0 in case of HMF, 0 and 1 in case of MMF and 0 and 0 in case of LMF. The functional form is expressed as below:

$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4D_1 + b_5D_2$ …… (1)

Y: Profit per acre (Rs.)

X_1: Expenditure on machine labour (₹)

X_2: Expenditure on human labour (₹)

X_3: Expenditure on bullock labour (₹)

D_1: Dummy variable to represent HMF which takes the value '1'for HMF and '0' for MMF and LMF

D_2: Dummy variable to represent MMF which takes the value '1' for MMF and '0' for HMF and LMF

b_1, b_2, b_3, b_4, b_5, are the regression coefficients a: intercept

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2.2. Derived profit functions of maize cultivation

a) Profit per acre on LMF: D_1 and D_2 takes the value '0' thus, the profit function (1) reduces to

$Y= a + b_1X_1 + b_2X_2 + b_3X_3$ …… (2)

b) Profit per acre on HMF: D_1 takes the value '1' and D_2 takes the value '0' thus, the profit function (1) becomes

$Y= a + b_5 + b_1X_1 + b_2X_2 + b_3X_3$ …… (3)

c) Profit per acre on MMF: D_1 takes the value '0' and D_2 takes the value '1' thus, the profit function (1) is written as

$Y= a + b_5 + b_1X_1 + b_2X_2 + b_3X_3$ …… (4)

The shift in intercept measures the effect of different degrees of mechanization. In case of HMF, the effect of mechanization is captured in the term $a + b_4$. The term $a + b_5$ captures the effect of moderate degree of mechanization in maize cultivation.

2.3. Data envelopment analysis (DEA)

It is a non-parametric and deterministic measure of efficiency. It is an alternative approach to stochastic production function and is devoid of assumptions pertaining to distribution or functional form. Cost efficient input oriented constant returns to scale model was employed to assess efficiency of mechanized maize farms. The analysis was performed using software designed by Coelli which encompasses technical efficiency, allocative efficiency and cost/ economic efficiency [6]. The term technical efficiency indicates the ability of the farm to produce maximum output from a given set of inputs, whereas cost efficiency aims at cost minimization, given the current prices and firms output. Mechanized maize farms were considered as decision making units (DMUs). Farms were categorized based on extent of mechanization (HMF, MMF and LMF). Farms aim at minimizing usage of inputs in general and labour in particular to attain desired level of output. To ascertain efficiency, production frontier was constructed in DEA approach based on linear programming. The term envelopment is derived from production frontier which envelops the set of observations. For each DMU, maize output in quintal (output category), human labour (mandays), bullock labour (pairdays), machine labour (hours) and their corresponding unit prices (input category) were considered in the calculation of cost- DEA efficiency score. The best DMU operates at 100% technical efficiency (efficiency score =1) and the DMU with lower technical efficiency (score <1) works at a percentage less than 100.

Table 1. Cropping pattern of sample farmers

	Crops	Area(acre)	Proportion of GCA (%)
Kharif	Paddy	35	7.07
	Maize	264.25	53.38
	Ragi	2	0.40
	Groundnut	14	2.83
	Cotton	6	1.21
	Tomato	4	0.81
	Chilli	2	0.40
	Onion	8.5	1.72
	Sub total	335.75	67.83
Rabi	Sunflower	14	2.83
	Jowar	12	2.42
	Sub total	26	5.25
Summer	Paddy	18	3.64
	Leafy vegetables	3.5	0.71
	Sub total	21.5	4.34
Perennials	Arecanut	105.74	21.36
	Coconut	3	0.61
	Mango	3	0.61
	Sub total	111.74	22.57
Gross cropped area		494.99	100.00
Net cropped area		391.62	
Cropping intensity		126.3955	

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Allocative efficiency or otherwise called as pricing efficiency relies on cost of inputs. It is related to cost of inputs in relation to output, and equilibrium condition is attained when marginal cost equates average revenue. DMU's allocative efficiency is with regard to the allocation of inputs vis-a vis its price for a given level of output, so as to minimize the cost of production. The cost efficiency refers to the product of technical and allocative efficiencies expressed in percentage.

3. Results and Discussion

3.1. Cropping pattern of mechanized maize farms

Table 1 presents cropping pattern of mechanized maize farms. Maize formed 53.38% of the gross cropped area and cultivated by majority of farmers during kharif season. During rabi season, jowar is cultivated on minimal area of 12 acres accounting for 2.42% of the gross cropped area. Areca nut is another major crop accounting for 21.36% of the gross cropped area in the region. The cropping intensity was 126.40% in the area. It may be inferred that maize dominates the cropping scenario.

3.2. Extent of mechanization in maize cultivation

Maize crop is grown as cash crop. It requires intensive cultivation including operations such as land preparation, sowing, and inter-cultivation, harvesting and threshing. The above operations are mechanized in maize cultivation. The details pertaining to extent of mechanization in maize is given in Table 2. The degree of mechanization varies across maize growers. Depending upon the extent of mechanization, the maize farms were classified into HMF, MMF and LMF. It could be observed that 58% of sample farmers have adopted mechanization for land preparation and threshing operations as against meager 9% of farmers adopting mechanical devices for completing land preparation, sowing, application of basal dose of fertilizers, harvesting and threshing. This shows that very few farmers have awareness regarding mechanical devices for sowing and harvesting. In between these two extreme situations, there exist moderately mechanized farms wherein mechanical devices are being used for tillage, sowing, fertilizer application and threshing operations. This calls for wide publicity by KSDA for popularizing such machineries in the area.

Table 2. Extent of mechanization in maize cultivation

(n=47)

Extent of mechanization	Operations mechanized	Number of sample farmers
HMF	Land preparation, sowing & basal dose of fertilizer application, Harvesting, Threshing	4 (9)
MMF	Land preparation, Sowing & basal dose of fertilizer application, Threshing	16 (34)
LMF	Land preparation, Threshing	27 (58)

Note: Figures in the parentheses indicate percentage

3.3. Operation wise mechanization in maize cultivation

Table 3 indicates operation wise mechanization in maize. It could be observed that 100% of sample farmers have mechanized tillage and threshing operations. About 36% of sample farmers have used tractor drawn seed cum fertilizer drill for conducting sowing and application of basal dose of fertilizers. The maize farmers harvest cobs manually deploying women labour although harvesting machines (combined harvester cum thresher) are available perhaps due to inadequate knowledge regarding availability of machines. Loss of by-product (husk as a feed for cattle and rind as fuel) during combined harvesting and threshing operation is a major lacuna constraining adoption of mechanization in harvesting of maize.

Table 3. Operation wise mechanization in maize

(n=47)

Operations	Number
Land preparation	47(100)
Sowing and application of basal dose of fertilizer	17(36.17)
Harvesting	7(14.89)
Threshing	47(100)

Note: Figures in the parentheses indicate percentage to the total

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High capital requirement of harvesting machines is also another cause that prevents the farmers to go-in for mechanical harvesting. However, it is evident from the table that percent of maize farmers have adopted threshers since threshing of maize is highly laborious and time consuming.

3.4. Economics of maize cultivation by different degrees of mechanization

Economics of maize according to degrees of mechanization was worked out and depicted in Table 4. The cost of cultivation of maize has varied across the situations. As evident from the table it was highest in case of LMF at ₹18645.23 while lowest in case of HMF (₹14875.80) indicating the cost effectiveness of mechanization in maize. HMF could save ₹3769.43 (20.21%) compared to LMF due to mechanization of operations such as sowing cum fertilizer application and harvesting. On the other hand MMF has incurred ₹15227.70 towards maize cultivation which is 18% lower compared to LMF. Thus, could save ₹3367.53 due to mechanization of sowing cum fertilizer application operation. This shows that cost of cultivation decreased with the degree of mechanization. This trend could be attributed to reduced dependence on human and bullock labour, which in the recent past has encountered both physical and economic scarcity. Mechanization has reduced dependence on human labour by 64.28% (10 man days) and 18.50% (2.5 man days) in case of HMF and MMF as compared to LMF. Besides, reduced reliance on bullock labour by 66.67% in both the cases was observed. With regard to yield, the HMF could obtain highest yield of 31.25 quintals as against MMF (27.61q) and LMF (27.14 q). The HMF has witnessed increased yield of 13% due to maintenance of optimum crop stand and reduced competition for on- farm resources in comparison with other two situations. The gross returns obtained in case of HMF was found to be the highest attributable to productivity level. Net returns per acre were in the order of ₹30436.70, ₹28134.38 and ₹23033.34 on HMF, MMF and LMF, respectively. The net returns realized by HMF were 8.18% and 32.14% higher than that of MMF and LMF. It is evident that farmers with high degree of mechanization incurred lowest expenditure and reaped highest profit. This was possible only because of recent inventions made by Agricultural Engineers in the field of farm machinery and equipment. Few maize farmers could not adopt complete mechanization due to financial inadequacy and lack of knowledge regarding inventions. This calls for gearing up of extension machinery to educate the farmers about benefits of farm machineries so that non-adopters too could reap the benefits of mechanization.

Table 4. Economics of mechanization in Maize (₹/acre)

Particulars/ Extent of mechanization	HMF			MMF			LMF		
	Qty	Rate (₹	Value (₹)	Qty	Rate (₹)	Value (₹)	Qty	Rate (₹)	Value (₹)
I. Machine labour (h)									
a) Land preparation	3.18	490.00	1558.20	2.85	490.00	1396.50	3.50	700.00	2450.00
b) Sowing	1.75	750.00	1312.50	1.57	750.00	1177.50			
c) Harvesting &threshing	1.00	1675.00	1675.00						
d) Threshing				0.92	1350.00	1242.00	0.90	1500.00	1357.50
Sub total	5.93		4545.70	5.34		3816.00	4.40		3807.50
II. Human labour (man days)									
a) Sowing	1.00	300.00	300.00	1.00	300.00	300.00	2.00	300.00	600.00
b) Fertilizer application	1.50	300.00	450.00	1.00	300.00	300.00	1.62	300.00	486.00
c) Weeding	2.00	300.00	600.00	2.21	300.00	663.00	2.56	300.00	768.00
d) Weedicide application	1.00	300.00	300.00	1.00	300.00	300.00	1.00	300.00	300.00
e) Application of PP Chemicals							1.00	300.00	300.00
f) Harvesting				7.34	300.00	2202.00	7.22	300.00	2166.00
Sub total	5.50		1650.00	12.55		3765.00	15.40		4620.00
III. Bullock labour									
a) Sowing							2.00	1088.88	2177.76
b) Inter-cultivation	1.00	1300.00	1300.00	1.00	1153.84	1153.84	1.00	1088.88	1088.88
Sub total	1.00		1300.00	1.00		1153.84	3.00		3266.64
IV. Inputs									
1. Seeds (Kg)	6.87	230.00	1580.10	7.65	245.07	1874.79	8.38	180.59	1513.34
2.Ferilizer (50kg bag)									
a) DAP	2.25	1200.00	2700.00	1.46	1200.00	1752.00	1.31	1200.00	1572.00

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b) Urea	1.00	300.00	300.00	1.57	300.00	471.00	1.20	300.00	360.00
c) Potash	0.50	900.00	450.00	0.58	900.00	522.00	0.70	900.00	630.00
d) Complex	1.00	1000.00	1000.00	0.80	1000.00	800.00	1.00	1000.00	1000.00
3.Weedicide			1350.00			1123.07			859.09
4.Plant protection chemicals									1016.66
Sub total			7380.10			6542.86			6951.09
Total cost (₹)			14875.80			15277.70			18645.23
Yield (qtl.)	31.25			27.61			27.14		
Price / qtl			1450.00			1510.76			1488.88
Returns from main product (₹)			45312.50			41712.08			40408.20
By-Product (₹)						1700.00			1270.37
Gross returns (₹)			45312.50			43412.08			41678.57
Net returns (₹)			30436.70			28134.38			23033.34

Note: HMF - Land preparation, sowing & basal dose of fertilizer application, Harvesting, Threshing
MMF- Land preparation, showing& basal dose of fertilizer application, Threshing LMF -Land preparation, Threshing

3.5. Input energy and output energy of maize cultivation across different degrees of mechanization

The details of input and output energy in maize cultivation are given in the Table 5. The input energy comes from machineries, bullocks, humans and material inputs. The output energy was obtained from grain. The input energy consumed by HMF and MMF was 6304 MJ. LMF used input energy of 5955 MJ. In case of HMF, mechanical input energy (1552.46 MJ) shared 24.63% in the total. The human energy (86.24 MJ) was 1.37% of the total energy requirement (TER). The share of mechanical input energy in case of MMF (1361.51 MJ) and LMF (1139.24) was 21.6% and 19.12%, respectively. The mechanical input energy consumed was highest in case of HMF followed by MMF and LMF. The energy contributed by in case of LMF was found to be higher due to wide usage bullock labour for sowing and intercultural operations. With regard to human labour, LMF was found to consume more energy (241.47 MJ) due to more reliance on human labour for performing harvesting and threshing operations. As regards the energy of farm inputs, it ranged widely from 4247.65 MJ to 4569.43 MJ across LMF and MMF. The resultant output energy was estimated to be 45397.50 MJ, 40586.70 MJ and 39895.80 MJ in case of HMF, MMF and LMF.

Table 5. Details of input and output energy in Maize cultivation

		HMF			MMF			LMF		
Particulars/ Extent of mechanization	Energy equivalents (MJ)	Qty /acre	Total Energy Requirement (TER)	Share in Total input energy (%)	Qty /acre	Total Energy Requirement (TER)	Share in Total input energy (%)	Qty /acre	Total Energy Requirement (TER)	Share in Total input energy (%)
A. Input Energy										
a) Machine labour										
1)MB plough(h)	2.51	1.87	4.69	0.07	1.76	4.41	0.07	2.25	5.65	0.09
2)Cultivator(h)	3.14	1.31	4.11	0.07	1.09	3.42	0.05	1.25	3.93	0.07
3)Sowing(seed drill)(h)	8.65	1.75	15.14	0.24	1.57	13.58	0.22			
4)Tractor(h)	62.70	4.93	309.11	4.90	4.42	277.13	4.40	3.50	219.45	3.68
5)Harvesting &threshing(h)	47.03	1.00	47.03	0.75						
6)Threshing(h)	7.52				0.92	6.91	0.11	0.905	6.80	0.11
7) Fuel (L)	51.33	22.84	1172.38	18.60	20.58	1056.11	16.75	17.60	903.41	15.17
Sub total			1552.46	24.63		1361.51	21.6		1139.24	19.12
b)Human labour(h)	1.96	44.00	86.24	1.37	100.40	196.78	3.12	123.20	241.47	4.05
Sub total			86.24	1.37		196.78	3.12		241.47	4.05
c)Bullock labour(pair days)	64.56	1.00	64.56	1.02	1.00	64.56	1.02	3.00	193.68	3.25

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1.Seed drill	1.25							8.00	10.03	0.17
Sub total			64.56	1.02		64.56	1.02		203.71	4.42
d) Materials										
1)Seeds(kg)	14.70	6.87	100.99	1.60	7.65	112.45	1.78	8.38	123.19	2.07
2)Fertilizer(kg)										
a)Nitrogen	66.14	48.25	3191.26	50.63	53.25	3521.95	55.86	44.39	2935.95	49.30
b)Phosphorous	12.44	64.75	805.49	12.78	43.98	547.11	8.68	43.13	622.80	10.46
c)Potassium	11.15	28.00	312.20	4.95	27.80	309.97	4.92	34.00	379.10	6.37
3)Weedicide(L)	238.00	0.80	190.40	3.02	0.80	190.40	3.02	0.80	190.40	3.20
4)Plant protection chemicals(L)	199.00							0.6	119.4	2.00
Sub total			4499.35	71.38		4569.43	72.48		4247.65	71.33
Total input energy			6303.59	100.00		6304.82	100.00		5955.26	100.00
B. Output Energy										
Maize grain yield(kg)	14.70	3125.00	45937.50		2761.00	40586.70		2714.00	39895.80	

3.6. Energy indicators in maize cultivation across different degrees of mechanization

The energy indicators related to maize cultivation across different degrees of mechanization is presented in Table 6. Energy use efficiency being the ratio of output energy to input energy was the highest in case of HMF (7.29) followed by LMF (6.70) and MMF (6.44)indicating every mega joule of input energy consumed in maize cultivation yields 7.29 mega joule of output energy on HMF,6.44 on MMF and 6.70 on LMF. Energy productivity is the ratio of maize output and total input energy consumed in cultivation. It was found to be 0.5 in case of HMF indicating that 2 mega joule of input energy is required to produce one kg of maize grain. It was relatively lesser in case of MMF and LMF. The value of specific energy ranged between 2.02 (HMF) to 2.28 (MMF). Economic efficiency of input energy is reflected in terms of profit per MJ of input energy. The HMF were found to be economically more efficient in terms of input energy use as reflected by 4.83 indicating every MJ of input energy consumed on HMF could earn profit of ₹4.83 on HMF. It was least in case of LMF (3.87) and moderate in case of MMF (4.46).

Table 6. Energy indicators in Maize cultivation

Sl. No.	Particulars/ Extent of mechanization	HMF	MMF	LMF
1	Total output energy (MJ)	45937.50	40586.70	39895.80
2	Total input energy (MJ)	6303.59	6304.82	5955.26
3	Maize Yield in Kg/ acre	3125.00	2761.00	2714.00
4	Energy use efficiency (1/2)	7.29	6.44	6.70
5	Specific energy in MJ/Kg (2/3)	2.02	2.28	2.19
6	Energy productivity in Kg/MJ (3/2)	0.50	0.44	0.46
7	Net energy in MJ (1-2)	39633.91	34281.88	33940.54
8	Total cost per acre (₹)	14875.80	15277.70	18645.23
9	Gross returns per acre (₹)	45312.50	43412.08	41678.57
10	Net returns per acre (₹)	30436.70	28134.38	23033.34
11	Cost per MJ of input energy in ₹(7/2)	2.36	2.42	3.13
12	Returns per MJ of input energy in ₹(8/2)	7.19	6.89	7.00
13	Profit per MJ of input energy in ₹(9/2)	4.83	4.46	3.87

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3.7. Cost of input energy across different degrees of mechanization

Cost of input energy across different degrees of mechanization is presented in Table 7. It was found that cost per MJ of mechanical energy was cheaper as compared to energy derived from human and bullock labour across the situations. Mechanical energy constituted the major chunk in total energy across the situations. Mechanical energy of 1552.45 MJ worth ₹4545.70 was utilized to perform land preparation, sowing cum fertilizer application, threshing and harvesting in case of HMF. In case of MMF, mechanical energy of 1361.59 MJ worth of ₹3816 was consumed to complete land preparation, sowing cum fertilizer application and threshing operations. The LMF utilized least amount of mechanical energy of 1139.23 worth ₹3807.50 to perform land preparation and threshing operations. Human labour was another source of energy utilized to perform sowing, fertilizer application, weeding, and application of weedicide and plant protection chemicals in maize cultivation. It could be seen in the table that HMF required lesser amount of human energy (86.24 MJ) as compared to MMF (196.78 MJ) and LMF (241.47 MJ). The use of higher amount of human energy was more pronounced on MMF and LMF as they have not adopted complete mechanization. A cursory look at cost per MJ of human energy reflects its expensiveness (₹19.13/MJ). Hence, mechanization of sowing and harvesting operations, on MMF and LMF could reduce use of human energy and cost of cultivation. Bullock labour is another source of energy used in maize cultivation. The cost per MJ of bullock labour energy ranged between ₹16.87/MJ to ₹20.14/MJ. It is used to perform sowing and inter-cultural operations. It is evident that LMF depended more on bullock labour to perform the above operations. Further, it could be noticed that mechanical energy (₹2.8 to ₹3.34/ MJ) is the cheapest source of energy as compared to bullock energy (₹16.87 to ₹20.14/MJ) and human energy (₹19.13/MJ).

Table 7. Cost of input energy across different sources

	HMF			MMF			LMF		
Source of input energy/ Extent of mechanization	Cost (₹)	Total energy equivalents (MJ)	Cost/MJ of energy (₹)	Cost (₹)	Total energy equivalents (MJ)	Cost/MJ of energy (₹)	Cost (₹)	Total energy equivalents (MJ)	Cost/MJ of energy (₹)
Machine labour	4545.70	1552.45 (91.15)	2.93	3816	1361.59 (83.90)	2.80	3807.5	1139.23 (72.36)	3.34
Human labour	1650	86.24 (5.06)	19.13	3765	196.78 (12.12)	19.13	4620	241.47 (15.34)	19.13
Bullock labour	1300	64.56 (3.79)	20.14	1153.84	64.56 (3.98)	17.87	3266.64	193.68 (12.30)	16.87
Total labour	7497.70	1703.25 (100)			1622.93 (100)			1574.38 (100)	
Materials	7380.1	4600.33	1.60	6542.86	4681.89	1.40	6951.09	4247.65	1.64

3.8. Effect of different degrees of mechanization on profitability of maize cultivation

The estimated profit function was found to be statistically significant at 1% level of significance as reflected by the significant F statistic (6.31). The goodness of fit of model in terms of coefficient of determination was 0.44 indicating that included independent variables could explain 44% of the total variation in the dependent variable (profit per acre). The coefficient of independent variables i.e., expenditure on machine labour (**X_1**) and bullock labour (**X_3**) were found to be statistically significant at one percent and five percent level of significance, respectively. The intercept dummy variables D_1 and D_2 capturing the influence of degrees of mechanization were also found to be statistically significant. The results indicated that on incurring additional rupee on machine labour, farmers could reap additional profit of ₹4.45 and ₹2.25 on bullock labour. On the contrary, spending additional rupee on human labor, farmers could reap only ₹0.38.

This clearly demonstrates that mechanization result in increased profits in maize cultivation. The magnitude of increased profits due to high degree of mechanization and moderate degree of mechanization is reflected in the term $a + b_4$ and $a + b_5$, respectively. The corresponding increase in profits per acre was in the order of ₹7618.19 and ₹7657.19. The value of intercept indicates that the LMF could save ₹1069.81 through mechanization. In other words, it indicates due to less degree of mechanization, the loss of profit was ₹1069.81.

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The estimated profit per acre on farms with different degrees of mechanization at the mean level of independent variables was estimated and presented in Table 8. The profit realized per acre on HMF was 26% higher compared to LMF indicating the economic advantage of mechanization in maize cultivation.

Table 8. Estimated profit across different degrees of mechanization in maize cultivation

	Mean expenditure on				
Degrees of mechanization	Machine labour (X_1)	Human labour (X_2)	Bullock labour (X_3)	Profit function	Estimated profit (Rs.)
HMF	4505.62	3630.87	3791.34	$Y = 7618.19 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3$	31106.2
MMF	1350	3438	4050	$Y = 7657.19 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3$	29513
LMF	1300	1952	3246.15	$Y = -1069.81 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3$	24644.49

3.9. Estimated profit functions

$Y = -1069.81 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3 + 8688 D_1 + 8727 D_2$ ..... (1)
(-0.14) (3.71) (0.31) (2.73) (1.89) (4.26)

Profit function of LMF

$Y = -1069.81 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3$ ..... (2)

Profit function of HMF

$Y = -1069.81 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3 + 8688 D_1$.

On assigning value '1' for D_1 in the profit function, the function reduces to

$Y = 7618.19 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3$ ..... (3)

Profit function of MMF

$Y = -1069.81 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3 + 8727 D_2$

On assigning value '1' for D_2 in the profit function, the function reduces to

$Y = 7657.19 + 4.45 X_1 + 0.38 X_2 + 2.25 X_3$ ..... (4)

3.10. Cost efficiency in maize cultivation across different degrees and sources of mechanization

Cost efficiency is the sole measure of overall economic efficiency of decision making units since it considers both allocative and technical efficiency. The mean scores of technical efficiency, allocative efficiency and cost efficiency of 47 sample farmers were found to be 0.85, 0.72 and 0.61, respectively. The mean score of cost efficiency indicates 67% of economic efficiency. The cost inefficiency was mainly due to allocative inefficiency rather than technical inefficiency. Allocative inefficiency is due to misallocation of scarce capital on human labour and bullock labour which is relatively costlier than machine labour. The frequency distribution of cost efficiency in maize cultivation across degrees of mechanization is presented in Table 9.

The perusal of Table 9 indicates that Cent percent of the HMF were found to be economically efficient with cost efficiency score of more than 0.8. The cost efficiency score ranged between 0.5-0.7 for majority of MMF. Around 85% of less mechanized farms were found to have cost efficiency score less than 0.6. This finding reiterates the existence of economic efficiency on those farms which had high degree of Mechanization.

Table 9. Frequency distribution of cost efficiency in maize cultivation across degrees of mechanization

Cost Efficiency	HMF (n=4)	MMF (n=16)	LMF (n=27)
0.3-0.4			1(3.70)
0.4-0.5			4(14.81)
0.5-0.6		7(43.75)	18(66.66)
0.6-0.7		5(31.25)	3(11.11)
0.7-0.8		2(12.50)	1(3.70)
0.8-0.9	1(25)	2(12.50)	
0.9-1.0	3(75)		

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4. Conclusion

The impact of different degrees of mechanization in maize cultivation was assessed considering 47 sample farmers. The sample farms were post stratified based on the extent of mechanization as HMF, MMF and LMF. About 58% of the sample farms were regarded as LMF. The economics indicated that mechanization results in cost saving and increased profit of 20.21% and 32.14% on HMF compared to LMF. Mechanization could reduce dependence on human labour to an extent of 64.28% and 18.50% in case of HMF and MMF compared to LMF. In order to enable wide coverage of farmers under mechanization, government should increase accessibility through establishment of CHSCs at village level. The energy use efficiency and energy productivity was found to relatively higher in case of HMF compared to MMF and LMF. The cost of various energy sources revealed mechanical energy (₹2.93) as the cheapest source compared to human (₹19.13) and animal energy (₹20.14). The DEA results indicated that HMF are most cost efficient compared to MMF and LMF. The dummy variable analysis revealed that every additional rupee spent on machine labour increases net returns by ₹4.45 while it was meagre in case of human labour at ₹0.38. The study brought out the positive impact of mechanization and hence, farmers should be encouraged to adopt mechanization to make production more cost effective.

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