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ORIGINAL RESEARCH ARTICLE



Economic analysis of maize production in traditional and mechanized farming systems in Nilkantha Municipality, Dhading, Nepal

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ABSTRACT

The purpose of this study was to evaluate the economic analysis as costs and profitability of maize production in traditional and mechanized farming systems. For this, a purposive random sampling of 101 maize farmers, comprising 30 using traditional methods and 71 employing mechanized systems was selected for structured household surveys. Cobb-Douglas production function, independent sample t-test, chi-square test, and descriptive statistics was performed using MS Excel and STATA software. Farmers under traditional and mechanized systems produced maize on average on 6.18 and 5.46 ropani, respectively. In mechanized systems, the mini tiller was the main tool used for the land preparation, while urea and farmyard manure (FYM) were the main suppliers of nutrients. Weeding was the most expensive operation in maize production. Traditional farming incurred higher costs for land preparation, planting, and plant protection. The net return per ropani was NRs. 1158.98 (8.47\$) for traditional farming and NRs. 1597.44 (11.67\$) for mechanized farming. The benefit-cost ratios were 1.42 for traditional and 1.57 for mechanized systems, respectively. Although the difference in returns per area between the two systems was not statistically significant, but mechanization effectively reduced production costs and enhanced profitability, representing a viable approach to improving maize farmers' financial circumstances. Cobb-Douglas production function analysis revealed a coefficient sum of 0.756 for traditional systems and 1.248 for mechanized systems, indicating decreasing and increasing returns to scale, respectively. Therefore, adoption of mechanization for maize production is recommended for cost minimization and profit maximization in Dhading district of Nepal.

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INTRODUCTION

Maize, often referred to as the “queen of cereals,” is the world's third most important cereal crop after rice and wheat, with an annual output of 3,106,397 metric tonnes and an area of 985,565 hectares. It is the second largest crop in Nepal in terms of production (MoALD, 2023). In Nepal's Terai and hill regions, maize cultivation is a common agricultural practice. Because of the high cost of production, farmers' economic situation remains static despite the trend towards increased maize productivity.

According to Dhakal *et al.* (2022), maize accounts for roughly 25.02% of the nation's total grain production, 6.88% of its AGDP, and 3.15% of its GDP. Food, feed, and industrial applications are only a few of its many uses (Devkota *et al.*, 2015). Nepal has the greatest per capita consumption of maize in South Asia, with 98 gm consumed daily per person (Timsina *et al.*, 2016). Maize is grown in sub-tropical to cool temperate climates (Thapa, 2021). The production of maize in Nepal is as such; hill (72.85%), terai (17.36%) and high hills (9.79%) (Subedi, 2016). In hilly regions, 86% of total production is used for human

consumption whereas in terai, only 20% is used for human consumption (Ransom *et al.*, 2003). The demand for maize is rising but the production within the country is far less than that of total demand. According to FAO (2023), the total import of maize in 2022 was 377449.76 t but the export is only 1t which shows very high scope in increasing domestic maize production and productivity as well as area. Also, the situation calls for increasing the production and yield within country in order to ensure food security. Dhading is a mid-hill district situated in the western part of Bagmati province. It ranges from 300m to 7110m. Maize is the primary crop hence every farmer is involved in its production. It is grown under rainfed conditions both as winter and spring maize. Being one of the high-yielding cereal crops, its production and area under production is increasing. In mid hill region, maize is principal staple food and fodder crop (Devkota *et al.*, 2015). The traditional farming system is the one where farmers don't use agriculture machinery, while mechanized farming system is the one where farmers use agriculture machinery for agriculture operations. Mechanization is the use of tools, implements and machinery in order to improve productivity of farm labor and land, which may either use human, animal, motorized power or combination of these. Hence in practice, it involves use of all power source and mechanical assistance to agriculture. Farm mechanization is characterized by its timely and efficient work. It includes all level of farming and processing technologies from simple and basic hand tools to more sophisticated and motorized equipment (Kandel *et al.*, 2021). Hence, it is major factor enhancing the production and productivity of different crops. It plays significant role in increasing production and productivity in developing countries (Rehman *et al.*, 2016). Agriculture productivity depends mainly on judicious use of farm power (Singh & Sahni, 2019). In spite of increasing trend of mechanization in country, use of farm machinery is limited in hilly region of the country. In the era when nations have transitioned towards automated and precision technologies in agriculture, hill side farming in the country is characterized by immense human and animal drudgery (Devkota *et al.*, 2021). Inefficient selection of machineries, non-availability of standardized products and its seasonal utilization are some of the reasons for lack of adoption of mechanized farming system. In addition, limited number of repair and maintenance facilities has led to poor performance of agricultural equipment.

Hence, this study was performed to bridge the gap by conducting the comparative economic analysis of traditional and mechanized farming system in Nilkantha municipality, Dhading. Specifically, this research aims to assess the cost, returns and benefit cost ratio of each system to determine whether mechanization provides an economically viable pathway for maize farmer in study area.

MATERIALS AND METHODS

Study area

The study was conducted in Dhading district (pin code:45100),

Nepal, which spreads from 27°40' E to 28°17' E and 80°17' W to 84°35' W. The study area was done in Nilkantha Municipality of Dhading district, which was selected as a zone of maize, hence it was purposively selected as a study area. The survey was conducted in wards 3, 7, and 12 of Nilkantha Municipality, Dhading. The site was selected while realizing the potential of maize production, where the maize zone was established under PMAMP (Prime Minister Agriculture Modernization Project). The area was purposively selected due to its highest share of farmers under the mechanized system.

Samples and sampling method

A total number of maize growers was taken as the sampling frame from the inventory list prepared by the Prime Minister Agricultural Modernization Project, Project Implementation Unit, Dhading. Sample size was determined using the Rao soft sample size calculator at a 95% level of confidence and 5% margin of error. 101 farmers were selected from Nilkantha Municipality through a multistage sampling method. Purposive sampling method followed by simple random sampling method was used for the selection of the study area and sample respondents, respectively. Pre-testing of survey instruments was done to determine the effectiveness and ascertain the reliability and validity of the questionnaire. Pre-testing was done in Nilkantha Municipality Ward No. 8 with 10 households. Household survey, key informant interviews were conducted to collect primary data. A semi-structured interview schedule was used to conduct the household survey, which was done from April to June 2024.

Methods and techniques of data analysis

Microsoft Excel and Stata software were used to analyze the data and to draw relevant inferences. Estimates were made for descriptive statistics such as frequency count and percentage. In addition, chi-square, t-test were also conducted. The results obtained from the data were presented through graphs, tables, and different diagrams. Households were categorized into traditional and mechanized. Those using at least one or more agricultural machinery were considered mechanized, and those who don't use any machinery were considered traditional farms. Socioeconomic factors like age, caste, gender, level of education, and cost of inputs were taken as independent variables, and returns were taken as dependent variables. The following calculation was done to compare the economics of traditional and mechanized farming systems.

Cost and benefit analysis

The total cost of production is the sum of all fixed and variable costs. In this case, only variable costs were used, and the calculation was done in the following ways, as done by Sapkota *et al.* (2018).

Total cost = seed cost + cost of land preparation + cost of sowing + cost of fertilizer + cost of weeding + cost of plant protection + cost of harvesting.

Gross revenue

The total returns obtained from grain is gross revenue, which was estimated using the following formula:

$$\text{Gross revenue} = \text{Total production} \times \text{Average selling price}$$

Net return

It is calculated by subtracting the total cost of cultivation from the gross revenue.

$$\text{Net return} = \text{Gross revenue} - \text{Total cost}$$

Benefit-cost ratio

Benefit-Cost ratio, an indicator for the economic performance of any firm, is the ratio of gross revenue and total cost (Poudel et al., 2021). It was calculated using a formula.

$$\text{Benefit-cost ratio} = \text{Gross revenue} / \text{Total cost}$$

Cobb-Douglas production function

Cobb -Douglas production function was used to represent the relation of output to input which in this case was used to estimate the contribution of independent variables in explaining the variation in dependent variable, returns from maize production.

$$Y = aX_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} e^{\mu}$$

This equation was transferred into log-linear form as;

$$\log(Y) = \log(A) + \beta_1 \log(L) + \beta_2 \log(S) + \beta_3 \log(F) + \beta_4 \log(W) + \beta_5 \log(H) + \epsilon \text{ (Traditional Farming)}$$

$$\log(Y) = \log(A) + \beta_1 \log(L) + \beta_2 \log(F) + \beta_3 \log(W) + \beta_4 \log(H) + \beta_5 \log(SC) + \epsilon \text{ (Mechanized Farming) (Prajneshu, 2008):}$$

Where, Y = Per ropani Gross revenue from maize cultivation (NRs. ropani-1); L = Cost of land preparation; S = Sowing; SC= Seed cost; F = Fertilizer cost (FYM+ fertilizer); W= Weeding cost; H = harvesting cost; μ = Random disturbance term or error term; a = Intercept or constant term; e = Base of natural logarithm $\beta_1, \beta_2, \beta_3, \beta_4$ and β_5 = Coefficient of respective variables.

RESULTS AND DISCUSSION

Socio-demographic characteristics of households

In this study, the sociodemographic characteristics of households are given in Table 1. The majority of the household heads in the study area were female (52.48%). The mechanized farm had fewer females (50.70%) than the traditional farm (56.67%). Similarly, Hinduism was the dominant religion in the study area. More than three-fourths of the households were Hindus, which was followed by less than one-fifth Buddhist, and only 3 percent were Christian. The district data (NSO, 2021) also showed similar results for gender, religion, and ethnicity. Under the traditional farming system, more than half of the households were Hindus (53.33%), whereas 88.73% of households in the mechanized farming system were Hindus. The difference between traditional and mechanized farmers was significant at the 1 percent level of significance (p value = 0.000). The dominance of the ethnic group Janajati was seen in both categories, and the difference was found to be significant at the 5% level of significance. The majority of families in the study area were found to be joint. The study revealed that, though not significant, the literacy rate was higher among HH with the traditional farming system. The findings of the study showed that the dominant occupation of the HH head in the study area was agriculture. The household head with a major occupation as agriculture was found to be higher in the traditional farming system.

Table 1. Socio-demographic characteristics of households.

	Variable	Farming system			Chi square value	p-value
		Overall (N=101)	Traditional (n=30)	Mechanized (n=71)		
Gender	Male	48(47.52)	13(43.33)	35(49.30)	0.30	0.583
	Female	53(52.48)	17(56.67)	36(50.70)		
Religion	Hindu	79(78.22)	16(53.33)	63(88.73)	22.25***	0.000
	Buddhist	19(18.81)	14(46.67)	5(7.04)		
	Christian	3(2.97)	0	3(4.23)		
Ethnicity	Brahmin/Chhetri	28(27.72)	4(13.33)	24(33.80)	8.38**	0.015
	Janajati	67(66.34)	26(86.67)	41(57.75)		
	Dalit	6(5.94)	0	6(5.94)		
Family type	Joint	52(51.49)	15(50)	37(52.11)	0.04	0.846
	Nuclear	49(48.51)	15(50)	34(47.89)		
Education	Illiterate	35(34.65)	23(31.51)	12(42.86)	5.19	0.393
	literate	23(22.77)	15(20.55)	8(28.57)		
	primary	16(15.84)	11(15.07)	5(17.86)		
	lower secondary	10(9.90)	9(12.33)	1(3.57)		
	SLC	7(6.93)	6(8.22)	1(3.57)		
Occupation	Higher	10(9.90)	9(12.33)	1(3.57)	3.74	0.443
	Agriculture	89(88.12)	27(90)	62(87.32)		
	Government job	3(2.97)	0	3(4.23)		
	Wages	4(3.96)	1(3.33)	3(4.23)		
	Private sector	4(3.96)	1(3.33)	3(4.23)		
	Others	1(0.99)	1(3.33)	0		

Note: Figures in the parentheses represent percentage; Signs *, **, and *** indicate significant at 10%, 5%, and 1% level, respectively.

Effect of training and subsidy on the adoption of farming systems

Among the farmers, 23.33% of traditional farmers received training, but only 11.27% of mechanized farmers received training related to maize farming. Pokhrel *et al.* (2018) also mentioned that the majority of farmers didn't receive any training on maize production. 28.17% of mechanized farmers received a subsidy for maize cultivation, but those receiving a subsidy in the traditional farming system were null. The difference between the two farming systems was statistically significant at the 1% level of significance.

Varieties cultivated

The data on maize varieties cultivated by farmers in the study area are shown in Figure 1. The most cultivated variety in the study area was CP-808, followed by the local variety of the area. Rampur hybrid-10 (RH-10) and Rampur composite are also cultivated by some farmers, whereas preference for the Arun-2 variety is found to be low. Lamichhane *et al.* (2015) also mentioned the use of local varieties by most of the farmers in their findings.

Labor use pattern

In the study area, the average number of laborers used per ropani for maize cultivation was found to be 4.71, which is similar to the findings of Paudyal *et al.* (2001). In the traditional farming system, the average total number of laborers used for maize cultivation was higher (6.14) than in the mechanized farming system (4.1) because machinery substitutes for the labor required (Aurangzeb *et al.*, 2007). The mean difference of 2.04 was found to be significant at the 1% level of significance with t-value and p-value 2.9714, 0.0037, respectively.

Machinery used in land preparation

Figure 2 shows the data on types of machinery used by farmers for land preparation. Mini tiller is the most adopted machine for land preparation in the study area, which is used by 72.28% of farmers. Higher adoption of Mini tiller in study area for land preparation is due to the subsidy provided by PMAMP and Agriculture Development Office in the district for purchasing machinery 25.74% of farmers still use animal plough for the land preparation for maize cultivation which is followed by hand hoe which has 1.99% share which shows the status of farm mechanization in the country (Shrestha, 2012).

Frequency distribution of sowing techniques

Figure 3 shows the different sowing methods adopted by farmers in the study area. Among the four methods of sowing, broadcasting is the widely adopted method of sowing in the study area, followed by sowing behind the plough. Out of 101 farmers, 7 farmers used a push row seeder and 4 used a jab-planter for sowing. The lower adoption of sowing machines is due to their recent introduction in the study area.

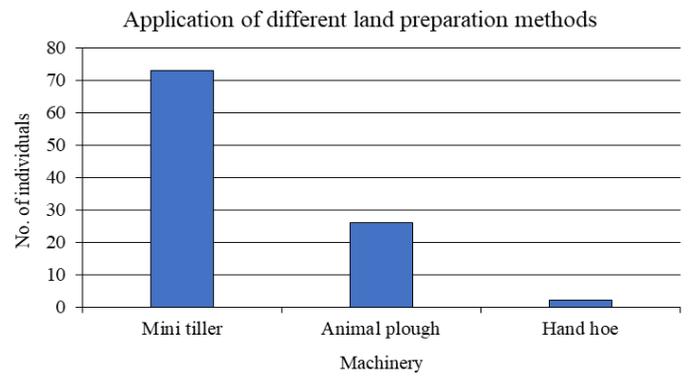


Figure 1. Land preparation methods for maize cultivation used in the study area.

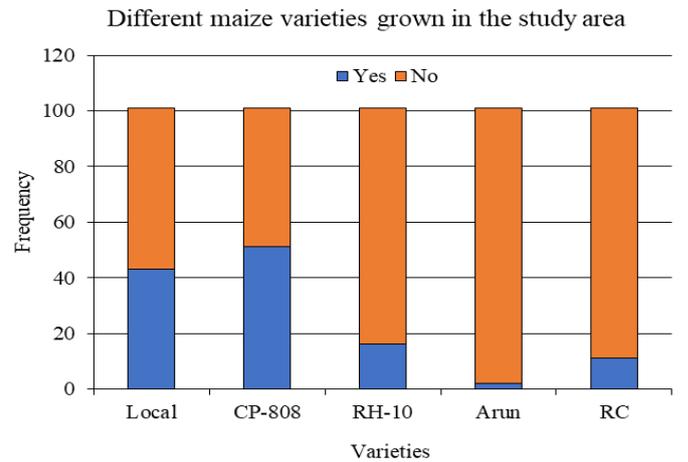


Figure 2. Different varieties of maize grown in the study area.

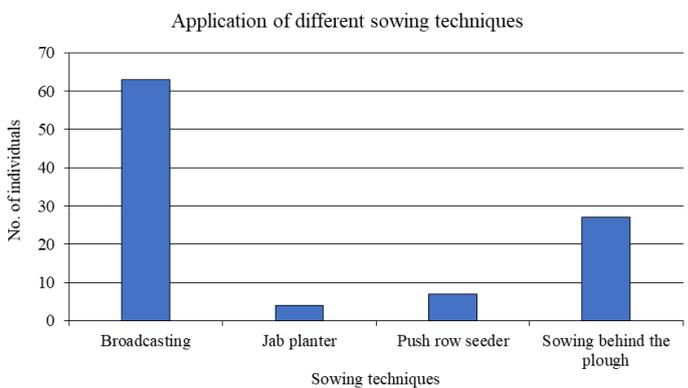


Figure 3. Estimated cost of maize production.

Comparison of the cost of different practices of crop production

Table 2 shows the independent sample t-test, which was conducted to find out whether the difference in means of cost between traditional and mechanized farms during different farm practices is significant or not. The total cost of cultivation was higher in the traditional farming system due to higher use of labor. The seed cost is significantly higher in the mechanized farming system at the 10% level of significance. This finding contradicts the findings of Manjulatha *et al.* (2021) and Aurangzeb *et al.* (2007). The cost of land preparation is lower in a mechanized system because of the fast and efficient operation of machinery used during land preparation, and a bullock farm utilizes more human labor than a tiller farm (Pradhan *et al.*, 2016). The mean difference of Rs. 311.42 between the two farming

systems is significant at the 1% level of significance. The study revealed that sowing cost was higher in the traditional system owing to the higher labor used in the traditional farming system. Manjulatha et al. (2021) also mentioned that sowing in a traditional system incurs higher costs than in a mechanized farming system. Similarly, though statistically non-significant, cost of fertilizer application and weeding is found to be higher in mechanized farming system. This finding is in line with the findings of Aurangzeb et al. (2007) which mentioned lower use of fertilizer in traditional farming. The study showed that the plant protection cost to higher in the traditional farming system, which is significant at the 10% level of significance. Also, harvesting cost was found to be higher in the mechanized farming system.

Yield, returns, and benefit-cost analysis

The results of returns and yield of maize production in traditional and mechanized farming systems are presented in Table 3. The average gross return per ropani in the study site was Rs. 5009.16 (\$36.57). In the traditional farming system, average gross return per ropani was Rs. 4875.24 (\$35.59) with a standard deviation of 1716.97 (\$12.53). Similarly, in a mechanized farming system, the average gross return is Rs. 5065.75 (\$36.98) with a standard deviation of 5106.75(\$37.28). The mean difference of -190.51 is found to be non-significant. The average net return per ropani of maize production is Rs. 1467.20 (\$10.71) in the study area. The average net return of the mechanized farming system is higher (Rs. 1597.44 or \$11.66) than that of the traditional farming sys-

tem (Rs. 1158.98 or \$8.46). The mean difference of -438.46 between the two systems is non-significant. Similarly, the average yield of maize in the study area was 1.22 Qt per ropani. The average yield in the traditional arming system was 1.2 Qt per ropani with a standard deviation of 0.57, which is less than a mechanized farming system of 1.23 Qt/ropani with 1.70 standard deviation. The difference of -0.3 between the two systems was found to be non-significant. Gross return, net return, and yield in a mechanized farming system are higher, which is due to the use of farm machines in various production activities (Kandel et al., 2021). The average production in the household in the study area was 7.095 Qt. In the household of a traditional farmer, the average production was 6.95 Qt, which is less than that of a household in the mechanized farmer (7.16 Qt). The standard deviation of the mean of production in traditional and mechanized households is 7.02 and 14.19, respectively. The mean difference of production between the two farming systems is non-significant. The BC ratio has been calculated as the ratio of total returns to the total cost. The overall BC ratio of maize production in the study area is 1.53, which means in the expenditure of every Rs 1, Rs. 0.53 is obtained as net return, indicating that maize production in Dhading is economically feasible. The BC ratio of the mechanized farming system is higher (1.57) than that of the traditional farming system (1.42). Likewise, Manjulatha et al. (2021) have also stated a higher BC ratio of the mechanized farming system in his findings.

Table 2. Estimated cost of maize production.

Variable	Farming system					
	Overall (N=101)	Traditional (n=30)	Mechanized (n=71)	Mean difference	t-value	p-value
Seed cost	433.06	334.13(209.35)	478.47(389.08)	-144.34	-1.84*	0.069
Land preparation	1096.75	1315.67(566.86)	1004.25(509.46)	311.42	2.71***	0.008
Sowing	69	170.91(264.29)	25.95(33.83)	144.96	4.56***	0.000
Fertilizer application	820.53	768.31(584.91)	842.59(576.54)	-74.28	-0.59	0.557
Weeding	1174.68	1163.02(533.42)	1179.31(927.07)	-16.29	-0.09	0.932
Plant protection	105.97	150.76(84.17)	93.17(69.47)	57.59	1.71*	0.010
Harvesting	479.91	416.91(156.58)	508.15(340.31)	-91.24	-1.30	0.196
Total cost	4179.9	4319.70(1185.80)	4131(1417.59)	188.7	0.82	0.417

Note: Figures in parentheses represent standard deviation; Sign *, ** and *** indicate significant at 10%, 5% and 1% level respectively

Table 3. Yield, returns, and BC ratio of maize production.

Variable	Farming system					
	Overall (N=101)	Traditional (n=30)	Mechanized (n=71)	Mean difference	t-value	p-value
Gross return (Rs./ropani)	5009.16	4875.24 (1716.97)	5065.75 (5106.75)	-190.51	-0.2	0.843
Net return (Rs./ropani)	1467.20	1158.98 (1851.90)	1597.44 (4989.67)	-438.46	-0.47	0.642
Yield (Qt/ropani)	1.22	1.2(0.57)	1.23(1.70)	-0.03	-0.12	0.901
Production in HH (Qt)	7.095	6.95(7.02)	7.16(14.19)	-0.21	-0.09	0.922
BC ratio	1.53	1.42(0.59)	1.57(1.1)	-0.15	-0.72	0.476

Note: Figures in parentheses indicate standard deviation.

Cobb-Douglas production function for the traditional farming system

The R-squared value of 0.733 in the traditional farming system indicates that 73.3% of the variation in returns from maize production is due to the inputs used in the model. It was found that land preparation has a statistically significant impact on total returns (Table 4). A 100% increase in the cost of land preparation is associated with a 29.8% rise in total returns, showing a significant impact at the 1% level of significance. In contrast, the costs of sowing, weeding, fertilization, and harvesting do not have a statistically significant impact on total returns. The cost of sowing has a minimal effect, with a 100% increase leading to only a 2.8% rise in total returns. Similarly, a 100% increase in the cost of fertilization will reduce total returns by 4.1%. Additionally, a 100% increase in weeding costs results in a 13.3% increase in total returns, and the harvesting cost will also cause a 13.3% increase in total returns, but with no statistical significance. The return to scale of this model is 0.756, which is less than 1, indicating decreasing returns to scale (Table 4). The results of our study are in line with Prajneshu (2008) who reported that set of Cobb-Douglas production functions is usually fitted by first linearizing the models through logarithmic transformation and then applying method of least squares.

Cobb-Douglas production function of maize production for the mechanized farming system

The R-squared value of this model is 0.7415, indicating that 74.15% of the variation in total returns is explained by the explanatory variable of the mechanized farming system (Table 5). The table shows that land preparation, weeding, and harvesting have a statistically significant impact on total returns from maize production. When the land preparation cost is increased by 100%, total returns will significantly increase by 22.5% at the 5% level of significance. Similarly, weeding cost has a large impact on total returns, with a 49.1% increase in total returns when weeding cost is increased by 100% at the 1% level of significance. Additionally, an increase in harvesting cost by 100% will lead to a significant 37% increase in total returns at the 1% level of significance. In contrast, fertilization and seed costs do not have a statistically significant impact on total returns. When the fertilization cost is increased by 100%, there is a 17.3% increase in total returns, and a 100% increase in seed cost will result in only a 1.1% decrease in total returns, with no statistical significance. The return to scale for this model is 1.248, which indicates increasing returns to scale, meaning proportionately greater output when inputs increase (Table 5). Prajneshu (2008) reported that set of Cobb-Douglas production functions is usually fitted by first linearizing the models and it showed increasing return to scale in mechanized system but decreasing return to scale in traditional farming system.

Table 4. Cobb-Douglas production function for the traditional farming system.

Explanatory variables (NRs. in log)	Dependent variable (Rs. In log): Returns from maize production		
	Coefficient	t-value	p-value
Land preparation	0.298	1.84*	0.083
Sowing	0.028	0.27	0.792
Fertilization	-0.041	-0.26	0.798
Weeding	0.133	0.51	0.618
Harvesting	0.338	1.25	0.229
Constant	3.847	2.87**	0.011
R square	0.7336		
R square adjusted	0.6553		
F-value	9.63		
Return to scale	0.756		

Note: * indicates significant at 10% level, ** indicates significant at 5% levels.

Table 5. Cobb-Douglas production function for mechanized farming system.

Explanatory variables (NRs. in log)	Dependent variable (Rs. In log): Returns from maize production		
	Coefficient	t-value	p-value
Land preparation	0.225	2.08**	0.044
Fertilization	0.173	1.59	0.119
Weeding	0.491	3.59***	0.001
Harvesting	0.370	2.93***	0.006
Seed cost	-0.011	-0.20	0.846
Constant	-0.226	-0.23	0.820
R square	0.7415		
R-squared adjusted	0.7107		
F-value	24.10		
Return to scale	1.248		

Note: ** indicates significant at the 5% level, *** indicates significant at the 1% level.

Conclusion

The comparative economic analysis of traditional and mechanized farming system revealed that labor is major input in maize production with significantly lower labor requirement for mechanized farming system than the traditional farming system. This is due to high efficiency and labor replacement by farm machines. Additionally, the studied showed that mechanization significantly lowered cost for land preparation, sowing and plant protection. The total variable cost per ropani in mechanized system is found to be lower than in traditional system, indicating mechanization is beneficial. Although, there is no significant difference between gross and net returns, BC ratio of mechanized farm is higher indicating greater economic viability. The Cobb-Douglas production function analysis showed increasing return to scale in mechanized system but decreasing return to scale in traditional farming system. The main limitations of conventional methods were high production costs and labor shortages while mechanized systems were constrained by high initial investment, restricted access to credit, and a lack of skilled worker. Therefore, the study revealed that mechanization is advantageous for cost reduction and profit maximization. Hence, adoption of mechanization is recommended for cost minimization and profit maximization in Dhading district of Nepal.

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DECLARATIONS

Author contribution statement

Conceptualization: S.S. and P.S.; Methodology: S.S.; Software and validation: S.S. and P.S.; Formal analysis and investigation: S.S., R.B., and N.K.; Resources: B.C.; Data curation: S.S., N.K. and R.B.; Writing—original draft preparation: S.S.; Writing—review and editing: S.S.; Visualization: B.C. and D.P.; Supervision: D.P.; Project administration: P.S. and N.K. All authors have read and agreed to the published version of the manuscript.

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