NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Assessment of Technical Efficiency and Its Determinants in Maize (*Zea mays*) Farming System of Chitwan, Nepal

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ABSTRACT

Maize is the second major staple crop of Nepal which is commonly used for human consumption and animal feed. This study analyzed technical efficiency and its determinants in Chitwan's maize farming system. Two villages, Shaktikhor and Fulbari, were purposively selected for this study. In total, 120 maize-growing farmers were selected using simple random sampling, with 60 respondents from each site. Primary data were collected using a set of well-structured pretested questionnaire. The data obtained were analyzed using the stochastic production frontier and Tobit regression. The analysis revealed that the average maize productivity at the site was 1261.21 kg ha^{-1} and was significantly affected by tractor time, farmyard manure, and labor. Technical efficiency was found to vary from 16.7% to 89.7%, with an average of 64.5%. Household head's age, household head's education, access to credit, and extension/training were positive significant determinants of technical efficiency, and every unit increase in each of these variables found to increase technical efficiency by 0.002, 0.001, 0.126, and 0.071 unit, respectively. There is sufficient scope to increase technical efficiency with the same amount of inputs. The local and national governments should emphasize enhancing loans and credit facilities. Furthermore, more educated people should be motivated to be involved in maize farming, and extension or training programs should be boosted to expand maize production efficiency.

Key words: Credit facilities, extension, manure, Stochastic production frontier, Tobit regression,

INTRODUCTION

Nepal, a small country dwelling in the lap of Himalayas, is predominantly an agrarian nation with 51.1% active population relying on agriculture. Agriculture itself contributes 24% of nation's Gross Domestic Product (GDP) (CBS, 2021).

Nepal has a wide variation in climate, ranging from hot tropical Terai to cold alpine in the high Himalayas, engendering favorable conditions for the growth of varieties of crops. Maize (*Zea mays*) is second most important cereal crop in Nepal, occupying 985,653 ha with a production of 106,397 mt (MOALD, 2021/22). It serves as one of the major sources of staple food and animal feed, along with making a significant contribution to Nepalese rural household income. In 2022, Nepal had imported maize worth NPR 16.5 billion (MOF, 2022/23). Maize imports have increased to USD 134.5 thousand in 2022, growing at an average annual rate of 320.78% (Knoema, 2023). Since 2015-2021, the maize area and production have increased, but production has still failed to meet the increasing demand (Dhakal et al., 2022). Chitwan ranks third in Nepal's maize production, producing 105,239 mt, after Ilam and Jhapa. Chitwan has 28,055 hectares of land dedicated to maize farming, yielding 3.75 metric tons per hectare (MOALD, 2021/22). It has diverse agroecological conditions, various farming hurdles, resource constraints, and climatic obstacles, leading to lower productivity. Under such circumstances, enhancing technical efficiency is indispensable for sustainable agriculture and poverty elimination. Technical efficiency, a rooted concept in production economics, refers to the ratio of observed output to the maximum possible output that can be achieved from a constant amount of inputs (Porcelli, 2009). Technical efficiency represents the transformation of input into output without resource wastage to engender a particular amount of output (Charnes et al., 1978). Technical efficiency assessment offers knowledge about production processes, production inefficiencies, and strategies for upgrading resource utilization and production. Agricultural efficiency is influenced by factors such as social capital, access to credit, distance from road, and extension services (Binam et al., 2004). In coupled with these, age of household head, soil quality and sources for investments can also affect the technical efficiency of agricultural production (Nowak et al., 2015). In Nepal, age and education of household head, area of cultivation, livestock holding, and availability of extension services have major influences on technical efficiency of maize (Sapkota & Joshi, 2021). In eastern Terai, technical efficiency is influenced by the age of head of household, land holdings, and number of family members (Adhikari et al., 2018).

This study aims to assess the technical efficiency of the maize farming system in Chitwan using various econometric and empirical methods. By evaluating technical efficiency, this study aims to provide valuable insights for policymakers, extension service providers, and farmers to improve maize productivity and profitability.

MATERIALS AND METHODS

Sampling method and sample size

Chitwan is a major maize-growing district in Nepal. Favorable climatic and weather conditions in the district enable farmers to grow maize throughout the year. Two villages in Chitwan district, Shaktikhor (27.73 °N,84.59 °E) and Fulbari (27.64 °N, 84.37 °E), were purposively selected for the study. Simple random sampling was used to choose maize growing farmers for the study, and a total of 120 respondents were included, 60 of whom came from Saktikhor and 60 from Fulbari.

Data Collection

The majority of the primary data were gathered at the study site, and every ethical guideline was rigorously adhered while creating the questionnaire, conducting the survey, and analyzing the data. A semi-structured questionnaire was created thorough desk reviews, expert opinions, and site visits. Ten percent of the sample size was used for pre-testing before the actual survey. In addition, the questionnaire was improved based on the pre-testing results.

Data analysis

The data gathered from the survey were coded and entered into a computer. Microsoft Excle, STATA, and Statistical Package for Social Science (SPSS) were computer software packages used for data analysis. The local unit of measurement was converted into a scientific unit. The data analysis techniques included both descriptive and analytical methods. Basic descriptive statistics, such as percentage, mean, frequency count, standard deviation, maximum, minimum, etc. of socioeconomic and farm characteristics of the respondents were described. The bulk of the empirical analysis was conducted using STATA. A stochastic frontier function was used to estimate technical efficiency, and the factors influencing technical efficiency were identified using Tobit model.

Technical efficiency analysis

The Cobb-Douglas production function is used to estimate the Stochastic Frontier Production (SFP) model. The SFP analysis was performed as described by Aigner et al. (1977). Cobb-Douglas is preferred over other forms because of its connivance on estimation and interpretation (Coelli et al., 2005). The general form of the Cobb- Doglas production function is

$Yi = f(Xi; \beta) \exp Vi - Ui$

Where Yi is the output and Xi inputs of firm. Vi represent independent and identically distributed random error with normal distribution N (0, $\zeta 2y$) and independent of Ui. Ui represent technical inefficiency effects of half-normal

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e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
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distribution N (μ, ζ2i). Stochastic Frontier Production model is used to estimate input output relationship (Battese, 1992). Stochastic Frontier Production function is represented as-

$$\ln Y = \beta_0+\beta_1 \ln N_1+ \beta_2 \ln N_2+ \beta_3 \ln N_3 + \beta_4 \ln N_4+ \beta_5 \ln N_5 +(V_i-U_i)$$

where,
ln= natural logarithm, Y = Maize yield (kg/ha), N_1 = Area under maize production (ha), N_2 = Tractor time (hr/ha), N_3= Farm Yard Manure (FYM)(kg/ha), N_4 = Seed used (kg/ha), N_5 = Labor (man days/ha), β_0 = Constant term to be estimated, β_1 - β_5 = Coefficient of independent variables, and V_i-U_i = error term

Technical efficiency refers to the capacity of particular farmer relative to a maximum output using given input and technology (Kitila and Alemu, 2014). It is the ratio of current production to corresponding frontier production. General formula for technical efficiency is:

$$\text{T.Ei}= yit/exp(xit,\beta) * expVit) = f \exp(xit,\beta) * expvit * \frac{\exp(-uit)}{expf(xit,\beta)*expvit}$$

$$TE = \frac{Yi}{Yi*} = \exp(-Ui)$$

Where,
Yi= Maize production of ith farm, Yi*= minimum output and represent frontier output, F (Xi) = suitable function of vector Xi of inputs for ith farm, and Vi= symmetric component of error term

Tobit Regression

Socioeconomic and demographic factors affecting technical efficiency of maize production were identified by using Tobit regression. In this model dependent variable technical efficiency score is censored distribution and its value varies from 0 to 1 (Tobin, 1958). Same method was found to be followed by Adhikari et al. (2018) and Ghimire et al. (2023).

$$Ei^* = \beta 0 + \beta_1 M_{1i} + \beta_2 M_{2i} + \beta_3 M_{3i} + \ldots\ldots\ldots\ldots\ldots \beta_n M_{ni} + u_i$$

$$E_i = E_i^* \text{ if } E_{i*} = > 0$$

Where,
E_i = technical efficiency of ith farm, E_{i*} = latent variable, M_i = explanatory variable in model, β_0 = intercept, β_j (j=1,….n) = coefficient of independent variables, i= (1, 2, 3…..n) = numbers of observations, and u_i= error

Table 1. Description of variables used in Tobit model

Name of variables	Type of variables	Description	Expected sign
Technical Efficiency(E_i)	Dependent	Technical efficiency of individual maize growing farmers.	
Age of household head (M_1)	Continuous	Age of maize growing household head in years.	+/-
Gender of household head (M_2)	Dummy	1 if household head is male and otherwise, 0.	-
Education of household head (M_3)	Continuous	Years of schooling of household head.	+
Marital status of respondent (M_4)	Dummy	1 if married and 0, otherwise	+
Location of farmer (M_5)	Dummy	1 if location is Shaktikhor and 0 for Fulbari	+/-
Involvement in organization (M_6)	Dummy	1 if farmer is involved in certain organization and 0, otherwise	+
Access to credit (M_7)	Dummy	1 if famer has access to credit and 0, otherwise.	+
Extension and training (M_8)	Dummy	1 if farmer has involved extension and training program related to maize farming and 0, otherwise.	+

RESULTS AND DISCUSSION

Socio- economic characteristics

The data obtained from the research revealed that majority of the households in the study were male headed. Only 9.2% of households were found to be head by females. Household heads are the major decision-makers in every operation of the house. The average age of household head was found to be 46.92 years. Households in Fulbari were found to be headed by older people than those in Shaktikhor. The education status of the household head was found to be low on the site, with an average of 3.80 years. Economically active members can contribute significantly to farming practices and lead to greater output, both in the form of yield and revenue. Economically active members were found to be 630. The economically active members were higher in Fulbari than in Shaktikhor.

Most respondents involved in the survey were married (97.5%). The results revealed that farmers' involvement in organizations and access to formal or informal credit were quite impressive. A total of 73.3% of farmers were involved in the organization, and 80.8% had access to credit facilities. The values of both

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variables were found to be superior in Fulbari than in Shaktokhor. Extension or training facilities were disappointing, with only 21.7% farmers gaining training or extension facilities. Detailed information is presented in Tables 2 and 3.

Table 2. Description of continuous variables

Variables	Mean	Shaktikhor	Fulbari
Age of household head(yrs)	46.92	41.08	52.75
Education of household head	3.80	1.20	6.41
Economically active members (15-59 years)	630	215	415

Table 3. Description of dummy variables

Variables		Shaktikhor (n=60)	Fulbari (n=60)	Total (N=120)
Gender of household head	Female	4 (6.7)	7 (11.7)	11 (9.2)
	Male	56 (93.3)	53 (88.3)	109 (90.8)
Marital status of respondent	Unmarried	3 (5)	0 (0.0)	3 (2.5)
	Married	57 (95.0)	60 (100.0)	117 (97.5)
Involvement in organization	No	31 (51.7)	1 (1.7)	32 (26.7)
	Yes	29 (48.3)	59 (98.3)	88 (73.3)
Access to formal or informal credit	No	17 (28.3)	6 (10.0)	23 (19.2)
	Yes	43 (71.7)	54 (90.0)	97 (80.8)
Participation in extension/training	No	54 (90.0)	40 (66.7)	94 (78.3)
	Yes	6 (10.0)	20 (33.3)	26 (21.7)

Inputs

The study was conducted on small landholder farmers at the study site. Thus, mean maize growing area of site was 0.23 ha with highest value 0.83 hector to lowest 0.03 hector. Farm yard manure (FYM) was the predominant manure used to improve soil quality. The average FYM used per hector was discovered to be 7109.36 kg/ha. 2.16 hour per hectare was the mean time used by the tractor for overall activities in maize production. The average seed requirement was 20.25 kg/ha. The average number of man-days required for maize production, from land preparation to harvesting was 46.31 in average. Its value varied from 13.13 to 103 man days.

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Table 4. Descriptive statistics of inputs used in maize production in study area

Variables	Mean	Standard deviation	Minimum	Maximum
Total land (ha)	0.23	0.15	0.03	0.83
FYM (kg/ha)	7109.36	3285.52	1575	25200
Tractor(h/ha)	2.16	2.23	0.63	10
Seed (kg/ha)	20.25	11.69	10	75
Labor(mandays/ha)	46.31	16.42	13.13	103

Production and productivity

The study asserted that the production and productivity of the study site were lower than the national average for the surveyed year. The average production was 282.67 kg with a higher production in Fulbari. The minimum production was 15 kg, whereas the highest amount produced by the farmers at the survey site was 1800 kg. The finding on productivity was also in line with the findings on production. This value was higher in Fulbari. Mean productivity was 1261.12 kg/ha varying from 281.25 kg/ha to 3750 kg/ ha. This indicated that the majority of farmers in the study site were smallholders and productivity was notably lower than the national average which is 3.11 mt/ha (MOALD, 2021/22). This indicates that farmers in the study site had a significant probability of enhancing their production with the proper inclusion of techniques and technologies and upgrading their skills.

Econometric models

A proper model is crucial for attaining scientific results from any analysis. A good model should be free of multicollinearity, heteroscedasticity, and omitted variables. Thus, to avoid these three factors, different model specification tests were conducted. Variance inflation factor (VIF) was calculated for multicollinearity, the Breush-Pagan/Cook-Weisberg test for heteroscedasticity, and the Ramsey reset test was performed for omitted variables. The VIF analysis disclosed a mean value of 1.60 with the highest value of 1.79, which was lower than 5, suggesting that there was no multicollinearity in the model. Furthermore, the Breush-Pagan/Cook-Weisberg test showed a Chi^2 value of 0.01 and Pro> chi^2 of 0.9061 (P>0.05), suggesting no heteroscedasticity in the model. In combination, the Ramsey reset test was done and Prob>F was 0.1817 (P>0.05), indicating the absence of omitted variables in the model.

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Table 5. Descriptive statistics of production and productivity

Production(kg)	Average	SD	Min	Max
Shaktikhor	210.08	192.16	15	1200
Fulbari	355.25	297.59	40	1800
Total	282.67		15	1800
Productivity(kg/ha)				
Shaktikhor	1086.47	547.07	300	3000
Fulbari	1435.77	746.62	281.25	3750
Total	1261.12		281.25	3750

Table 6. Stochastic production frontier of maize production

Variables	Coefficient	Standard Error	P > z	Test of Multicollinearity	
				VIF	1/VIF
Log Area per hector	0.104	0.092	0.262	1.78	0.561
Log tractor time(hour/ha)	0.095**	0.045	0.034	1.76	0.567
Log FYM (kg/ha)	0.290**	0.115	0.012	1.13	0.884
Log Seed (kg/ha)	0.101	0.133	0.939	1.52	0.658
Log labor(man days/ha)	0.554**	0.173	0.001	1.79	0.558
Constant	3.003	1.306	0.021		
Sigma_v		0.327	0.063		
Sigma_u		0.638	0.113		
Sigma 2		0.5133	0.117		
Lambda		1.952	0.165		

** represents significant at 5% level of significance

Summary Statistics	
Log likelihood	-86.138
Number of observations	120
Wald chi2 (5)	22.10, Prob> chi 2 = 0.0005
Likelihood-ratio test of sigma u =0: chibar2 (01)	4.47 prob>= chibar2 = 0.017

Test of Statistics

Variance Influence Factor (VIF)	Mean VIF(1.6) Maximum VIF(1.79)
Breush-Pagan/Cook-Weisberg test	Chi2 (1) = 0.01 Pro> chi2 = 0.9061 (Constant variance)
Ramsey reset test	F(3,110) = 1.65 Prob>F = 0.1817 (model has no omitted variables)

Stochastic Production Frontier

Stochastic frontier analysis revealed that area, quantity of farm yard manure (FYM), quantity of seed, tractor time, and labor had a positive relationship with the quantity of maize produced. Among others, tractor time, FYM, and labor were found to have a significant effect on maize production. These three variables were found to be significant at the 5% level. An increase in tractor time by 1% found to increase maize production by 0.095%. This is in line with the findings of Subedi et al. (2020) and Khan et al. (2020), who found a positive and significant relationship between the tractor time and the amount of crop produced. Similarly, a 1% increase in the amount of FYM resulted in a 0.29% increase in production. Similar results were reported by Bajracharya and Sapkota (2017) and Sapkota and Joshi (2021), where a 1% increase in FYM increased maize production by 3.8 and 4%, respectively. A percent increase in the number of man-days of labor seems to increase maize production by 0.554%. This can be supported by research conducted in Ghana by Bempomaa and Acquah (2014) and another study conducted in Switzerland by Dlamini et al. (2012).

In essence, farmers need to focus on increasing tractor time, FYM, and man-days to increase maize productivity. The lambda value of the model was 1.95 (>1), which indicated that the model was well fitted (Ghimire et al., 2023). The model was found to be significant at the 1% level of significance, indicating that the included independent variables can properly explain the variation in the dependent variable.

Technical efficiency

Technical efficiency calculated from stochastic frontier analysis showed that technical efficiency at study sites were found to fluctuate from 16.7% to 89.7%.Average efficiency was found to be 64.5%, and most repeated value of efficiency among farmers was 48.2%. This indicates that if proper techniques and technologies are followed than in average 35.4% more output can be gained by the use of same amount of inputs. 58.33% of farmers in the area of study found to have efficiency between 70 to 79%. 47(39.17%) sampled farmers had efficiency below mean level, whereas 73(60.83%) farmers were working above mean level.

Table 7. Technical efficiency and mean productivity of study area

Efficiency	percent	Mean
0.3-0.39	0.83	75
0.4-0.49	0	0
0.5-0.59	7.5	48.33
0.6-0.69	17.5	182.38
0.7-0.79	58.33	319.71
0.8-0.89	15	388.89
0.9-0.99	0.83	2000
Total	**100**	**297.67**

Mean +- SD	0.645 +- 0.157
Mode	0.482
Minimum	0.167
Maximum	0.897

A study conducted in mid hill of Nepal discovered mean 71% of technical efficiency of maize production (Sapkota and Joshi, 2021), whereas in Switzerland, its value was found to be 80% (Dlamini et al., 2012).Meanwhile technical efficiency of 79% was found in eastern terai of Nepal (Adhikari et al., 2018). A study conducted in hills of Nepal in 2004 reported lower efficiency than this study, which was 58% for local maize and 63% for improved varieties (Paudyal and Ransom, 2004). Mean productivity for different efficiency level 0.1 -0.19, 0.2-0.29, 0.3-0.39, 0.4-0.49, 0.5-0.59, 0.6-0.69, 0.7-0.79 and 0.8-0.89 are 281.25, 337.5, 445.71, 656.67, 822, 1148.23, 1517.64 and 2332.77 kg per hector, respectively.

Determinants of technical efficiency – Tobit analysis

Based on different literature review, eight different socioeconomic variables were selected for the Tobit analysis. The research finding showed that the technical efficiency of maize at the area of study was significantly affected by the age of the household head, education of the household head, marital status, access to credit, and extension or training. All variables except marital status had positive influence on technical efficiency of maize production. Gender of household head, location of farmer, and involvement in the organization were non-significant variables in the model, whereas involvement in the organization was found to be negatively related to the technical efficiency of maize. This indicates that the government and other sectors should emphasize these variables in order to make maize production efficient in Chitwan.

a) Age of the household head

Respondents' age had a positive and significant impact on the efficiency of maize farms. If the age of the household head rises by a year, the technical efficiency of the maize farm will expand by 0.002 units. As age increases, farming experiences will also increase, which will aid in conducting farm activities efficiently, leading to an increase in technical efficiency. This might be a reason for the positive relationship between the age of the household head and technical efficiency of maize production. This finding was inconsistent with the results of different studies conducted worldwide. Belete (2020) reported a negative relationship between age and technical inefficiency of maize production. Research proclaimed that a year increase in the age of head of household the technical inefficiency of the farmers get deducted by 0.02 units. Moreover, even in Nepal, a positive and significant relationship between age and the efficiency of maize production had been reported (Sapkota and Joshi, 2021). In agriculture sites, every increase in year makes farmers well experienced in farming activities along with galvanizing their marketing and socialization skills, which might lead to enhanced production.

Table 8. Determinant of technical efficiency of maize production

Variable	Coefficient	Standard Error	P(z)	dy/dx
Age of household heads	0.002*	0.001	0.093	0.002*
Gender of household heads	0.018	0.048	0.706	0.018
Education of household heads	0.010***	0.004	0.007	0.010***
Marital status	-0.220**	0.086	0.011	-0.220**
Location	0.047	0.041	0.256	0.047
Access to credit	0.126***	0.038	0.001	0.126***
Involvement in organization	-0.053	0.040	0.178	-0.053
Extension or training	0.071**	0.032	0.029	0.071**
Constant	0.610	0.107		
Summary Statistics				
Numbers of observations	120			
LR chi2 (8)	30.96			
Prob > chi2	0.000			
Log likelihood	64.960			
Pseudo R2	-0.313			

*, ** and *** represent 1%, 5% and 10% level of significance respectively.

In contrast to these findings, Adhikari et al. (2018) observed that compared to older maize farmers, younger farmers were more technically efficient.

b) Education of household head.

Education of the household head was found to be positively and significantly related to technical efficiency of maize production at 1% level of significance. Technical efficiency will increase by 0.01 units with every year of increase in the level of education of the household head. Education is a major source of knowledge in all sectors. Educated people have more knowledge and information related to production, improved technologies and techniques, and plans and policies of the country. Furthermore, they are innovative and have an enhanced capacity to deal with people. All these qualifications might led to a surge in the efficiency of maize farms. Addai and Owusu (2014) and Asante et al. (2013) also found similar findings. Research in Ghana and Ghimire et al. (2023) also reported an advantageous link between education and the technical efficiency of farms. In contrast to this findings, Abdulai et al. (2018) reported an inverse relationship between education and the technical efficiency of maize production. Educated persons are supposed to have better accumulation of farming knowledge, better exposure to technologies, and better decision-making capacities, leading to more production per hectare. In contrast, uneducated farmers are reluctant to adopt new technologies and take proper decisions during disease outbreaks and natural calamities, subsequently leading to lower efficiency (Khanal and Maharjan, 2013).

c) Marital status

The study disclosed that if a farmer is married, the farmer had a negative and significant impact on the technical efficiency of maize production. If the farmer is married, technical efficiency will lower by 0.22 units. The reason for this might be an increase in the responsibilities of married farmers compared to unmarried ones. A married person may have to spend more time on household chores, which may reduce the chances of gathering farm-related information, ultimately leading to lower farm efficiency.

d) Access to credit

As expected, access to credit had a positive and significant impact on the technical efficiency of maize farming. Compared to farmers without access to credit, farmers with credit will have possibility to enhance their technical efficiency by 0.126 units. This might be because most of the inputs used are associated with money, and if the farmers have access to credit, their possibilities to use improved technologies, tools, and equipment will extend,

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which will ultimately aid in increasing farm efficiency. In maize production, technical inefficiency was 0.012% lower for farmers with credit availability than for those without (Belete, 2020). Similar findings were reported by Kibaara (2005) and Beyan et al. (2013).

e) Extension or training

In line with previous expectations, extension and training had a positive influence on technical efficiency. Involvement in extension or training was found to be significant at 1% level. With involved in extension and training, the technical efficiency of maize production will increase by 0.071 units. Farmers gaining extension or training facilities will gain information about cultivation practices, new and effective technologies, input supplies, and market status, which might aid in uplifting the technical efficiency of farms. This was in line with the findings of Sapkota and Joshi (2021) and Abdulai et al. (2018). Extension and training engender informal farming-related education for farmers. It increases farmers' qualifications for the proper selection of seeds, cultivation techniques, better dealing with diseases, weeds, risks and uncertainties, and marketing obstacles, ultimately ameliorating maize production and productivity. Gautam (2000) also reported that an effective agricultural extension service is crucial to enhance the productivity of stable crops and thus eradicate poverty.

CONCLUSION

This study elucidated that maize production at the study site was not efficient, with the majority of farmers cultivating below-average efficiency. There is room for increasing technical efficiency of maize production using the same amount of inputs. Maize production was significantly influenced by tractor time, FYM and Labor. This implies that to produce more, tractors, FYM, and labor need to be used. Age of the household head, education of the household head, marital status, access to credit, and extension or training were determinants of technical efficiency of maize production at the site. This suggests that encouraging more educated people in maize farming would boost the efficiency of maize production. Access to credit had a significantly positive impact. Thus, priorities must be prioritized to enhance banking and financing facilities at the site with an effective interest rate for farmers. Furthermore, extension and training activities need to be increased by focusing on technology dissemination, cultivation techniques, weed and pest management, and cost management. This will aid in surging maize production and productivity in Chitwan, leading to efficient production and prosperous farmers.

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ACKNOWLEDGEMENTS

The author expresses her gratitude to all respondent farmers and other supporting participants for granting their time and sharing their information for this research.

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