Research Article

Technical efficiency of hybrid maize production in eastern terai of Nepal: A stochastic frontier approach

[1]Surya P. Adhikari[*], [1]Krishna P. Timsina, [2]Peter R. Brown, [1]Yuga N. Ghimire and [3]Jeevan Lamichhane

[1]Socioeconomics and Agricultural Research Policy Division (SARPOD), Khumaltar, Lalitpur, Nepal.
[2]Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
[3]Regional Agricultural Research Station, Khajura, Banke, Nepal

*Correspondence: adhikarisurya56@gmail.com; ORCID: https://orcid.org/0000-0002-2712-9387

ABSTRACT

Maize is the second most important crop after rice in terms of area and production in Nepal. This article analyzes the technical efficiency and its determinants of hybrid maize production in eastern Nepal. Using a randomly selected data from 98 farmers (41 from Morang and 57 from Sunsari) in eastern Nepal, the study employed a stochastic frontier production model to find the production elasticity coefficients of inputs, determinants of efficiency and technical efficiency of hybrid maize farmers. The results showed that maize production responds positively to increase in amount of urea, DAP and the area planted, where as it is negative to seed quantity. The study indicate that farmers are not technically efficient with a mean technical efficiency 79 %. Socioeconomic variable age had a negative and significant while the household size had a positive and significant related to maize output. The younger farmers were observed more technically efficient than older farmers. Larger the members in the household higher the maize production. It is recommended that farmers should increase their fertilizer dose and farm size while they should decrease their seed rate for efficient production.

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INTRODUCTION

Maize is the second most important cereal crop in Nepal, after rice and is also staple food for hills people. The demand for maize is increasing in Nepal because of the emerging poultry industry (Dhakal *et al.,* 2015) and (Ghimire *et al.,* 2018), so suitable areas for production and new varieties or improved varieties are required to meet this demand. The area under this crop is approximately 900288 ha, which is about 29% of total cultivated area of 3.09 million ha. The total production of maize in 2017 was 2.30 million tonnes (MoAD, 2017). The national average yield of maize is 2.5 t/ha. However, the average productivity of maize in Nepal is less compared to neighboring countries (FAO, 2008). To increase the maize production and productivity, cultivation of hybrid maize is one of the best alternatives. A current market requirement of maize grains is partly fulfilled by growing hybrids in winter at terai and inner terai (Gurung *et al.,* 2011). Hybrid maize after rice is being popular among the farmers of eastern terai. Technical efficiency is an approach to explore the capacity of farmers to produce optimum quantity of output with the given level of inputs (Farell, 1957). Efficiency is a very important factor of productivity growth in economy where resources are scarce and opportunities for new technologies are lacking. Estimates on the extent of inefficiency also help to decide whether to improve efficiency or to develop new technologies to increase agricultural productivity. Low agricultural productivity and production inefficiency in the smallholder farming are the constraints to increase the production in eastern Nepal. For smallholder hybrid maize farmers, variations in productivity due to differences in efficiency may be affected by various farm specific factors such as seed type, amount of fertilizer dose, farm size, family size, credit accessible to farmers, technical support, education level of household head, land type, land use pattern etc. The main purpose of this study is to analyze technical efficiency of hybrid maize farming in eastern region of Nepal. Maize productivity could be increased by increasing the production efficiency of smallholder farmers. To increase production efficiency of smallholder maize farmers, more efficient use of inputs is necessary. There are many factors that influence farmer's efficiency. Mango *et al.* (2015) in Zimbabwe found that maize production responded positively to increase in chemical fertilizers, seed quantity, the use of labor and area planted. They found mean technical efficiency of around 65%. Similarly, Hanan and Awal (2017) in Ghana found that farm size, labour and access to chemical fertilizers were significant determinant of maize output. Socioeconomic factors that contribute to technical efficiency were sex, credit access, education, resource availability, farm size and years of experience in farming. Binam *et al.* (2004) examined factors influencing the technical efficiency of groundnut and maize farmers in Cameroon. They found mean technical efficiencies of around 73 and 77%, whereas credit accessibility, social capital, distance from the road, and extension services were important factors influencing technical efficiencies. Studies on the technical efficiency are particularly important to eastern Nepal, as they provide vital information for improving the design of agricultural policies. The production inefficiencies are reducing maize productivity; the sources of such inefficiencies are diverse. Many factors contribute to low productivity, which include: farm management, resource use, inadequate knowledge of appropriate technology, in-adequate market price, socio-economic factors. This study therefore aims to assess the technical efficiency of small holder farmers, the determinants of technical efficiency and the production elasticity of inputs in maize production farmers.

METHODOLOGY

The data for this study were obtained from a survey of hybrid maize farmers in eastern terai region of Nepal. Morang and Sunsari districts were purposively selected because these districts are the major hybrid maize production district in the eastern Gangetic plain of Nepal. The District Agriculture Development Office launched maize mission programs in these two districts. Random sampling was used to select the wards in the two districts and the households to be interviewed with the consultation of District Agriculture Development Offices. 41 households from Morang and 57 households from Sunsari were selected randomly from the list of hybrid maize growers in the selected villages. A total of 98 households were surveyed from March to April, 2017 for the study. The data collection involved a household survey, using a structured questionnaire. In the survey, collected information on household socio-economic characteristics, crop production, hybrid maize input cost and return, training received and problems on hybrid maize farming. Collected information was entered in Excel and data analysis was conducted by using computer software Stata (version 15.0). Both descriptive and econometric methods were used to analyze the data. A stochastic frontier model (see below) was used to measure the technical efficiency of hybrid maize farmers.

Empirical Model
This paper uses the method of estimating a stochastic frontier production function proposed by Aigner *et al.* (1977), and Meeusen and van Den Broeck (1977). Kumbhakar *et al.* (1991) extended the stochastic frontier methodology by openly introducing the determinants of technical efficiency into the model. The stochastic frontier production function differs from the traditional production function in that it consists of two error terms. The first error term accounts for technical efficiency and the second for factors such as measurement error in the output variable, the weather, and the combined effects of unobserved inputs. It is a homogeneous function that provides a scale factor enabling one to measure the return to scale and to interpret the elasticity coefficients with relative ease. It is also relatively easy to estimate because in logarithmic form it is linear and parsimonious (Beattie & Taylor, 1985). Thus, Cobb-Douglas specification provides an adequate representation of the agricultural production technology. The empirical Cobb-Douglas frontier production function model with double log form can be expressed as:

$Ln (yield) = \beta_0 + \beta_1 ln(Urea) + \beta_2 ln(DAP) + \beta_3 ln(seedqt) + \beta_4 ln(Labor) + \beta_5 ln(Tillage) + \beta_6 ln(Area cultivation) + \epsilon_i (V_i - U_i)$ Where, Ln is the natural logarithm, yield is the maize production per hectare (Kg/ha), $\beta_0 - \beta_6$ are the parameters to be estimated, Urea is the amount of Nitrogenous fertilizer applied per hectare (Kg/ha), DAP is the amount of phosphatic fertilizer applied per hectare (Kg/ha), seedqt is the maize seed rate per hectare (kg/ha), labor is the total number of labor required per hour, tillage constitutes number of tillage hours required for one hectare of land, area cultivation is the area under maize cultivation (ha), ϵ_i is the error term, equal to $(V_i - U_i)$, V_i is a two sided random error component beyond the control of the farmer and U_i is a one-sided inefficiency component.

The farm specific technical efficiency (TE_i) of the ith sample farmer will be estimated by using the expectation of U_i conditional on the random variable ϵ_i

$TE_i = Exp (-U_i)$

$= Y_i / f(X_i \beta) exp V_i$

$= Y_i / Y^*$ Where, Y_i = Observed output, Y^* = Frontier output

If $Y_i = Y^*$ Then, $TE_i = 1$ i.e. 100% efficient

After obtaining the technical efficiency, we will estimate socioeconomic determinants of technical inefficiency.

Technical inefficiency determinants are as follows;

$Ln(U_i) = \beta_0 + \beta_1 ln(V_i) + W_i$, Where, U_i is technical inefficiency, $\beta_0, \ldots \ldots \beta_n$ are the parameters to be estimated. V_i is a vector of farmer and household socio-economic characters; W_i is a random error.

RESULTS AND DISCUSSION

Summary Statistics

Average maize output by the hybrid maize producers is 6899 kg/ha. On average, maize farmers applied 25.59 kg of seed, 195.91 kg of urea and 158.1 kg of DAP per hectare and allocated 0.63 ha of land to hybrid maize (Table 1). Farmers used an average of 711 hours labor to produce the maize, but there was a wide variation, from 208 to 1312 hours. Most of the farmers performed tillage operation by tractor. Farmers used average of 7 hours for tillage operation to produce maize in one hectare. The average total land area of farmers in eastern Nepal was 0.98 ha. To find factors related with inefficiency, socioeconomic variables were incorporated into the stochastic frontier model. The average age of the household head was 47 years whereas average education was 6 years and average household size was 5 to 6. In terms of training only 21% farmers received training whereas about 27% farmers were involved in agriculture related organization.

Estimation results

Table 2 shows the maximum likelihood estimates of the estimated stochastic frontier production function and the determinants of technical efficiency. Among the productive factors, coefficients of total maize area is positively significant at 5%, dose of urea and dose of DAP fertilizers are positively significant at 1%. Seed rate per hectare is negatively significant at 10% level. The coefficient for area under maize cultivation is 0.062 which indicates that 1% increase in area under maize increases the maize production by 6.2%. This result is similar to Amaza and Olayemi (2002) and Mango et al. (2015). The coefficient of Urea (Nitrogenous) and DAP (Phosphatic) fertilizers are 0.11 and 0.23 respectively indicating maize output is elastic to changes in the application of fertilizers. A 1 % increase in dose of urea and DAP would lead to 11% and 23% increase in maize output respectively. To increase maize productivity farmers should use higher dose of urea and DAP fertilizers. The increasing effect of nitrogen on maize production is in line with the findings of Alene and Hassan (2003) and Rahman and Umar (2009) in which application of fertilizer increases production significantly. This finding is consistent also with Mango *et al.* (2015).

Seed rate had an elasticity of -0.32, which is negative, and implies that a 1 % increase in seed rate, would lead to a 32% decrease in maize output. This is because of that high seed rates would result in higher maize plant density, which in turn results in high competition among the plants for the same small amount of nutrients and water at their localized area.

Table 1. Descriptive statistics of maize farmers in eastern Nepal (N=98)

Variable	Mean	Std. Dev.	Min	Max
Total maize area (Hectare)	0.63	0.46	0.06	2
Age of the household head (Years)	47.44	12.05	24	80
Education of household head (Years)	6.32	3.55	0	14
Family size (Number)	5.81	1.65	3	12
Production (kg/ha)#	6899	2864.81	2600	13200
Seed quantity (kg/ha)#	25.59	4.19	15	45
Tillage hour (hour/ha)#	7.22	1.45	4.24	12.94
Total urea (kg/ha)	198.12	111.11	25	550
Total DAP (kg/ha)	159.39	97.36	30	500
Total Labor (hour/ha)	711.35	170.06	208	1312
Total land (Hectare)	0.98	0.72	0.06	3.53
Training (Yes %)	19	.39	0	1
Membership (Yes %)	27	.443	0	1

Table 2. Input elasticity and socio-economic determinants of inefficiency

Variable	Coefficient	Standard error	p-value
Log maize area (ha)	0.062*	0.034	0.071
Log seed (kg/ha)	-0.321*	0.180	0.074
Log labor (hours/ha)	0.008	0.100	0.939
Log tillage (hours/ha)	0.025	0.124	0.843
Log total Urea (kg/ha)	0.110**	0.040	0.006
Log total DAP (kg/ha)	0.232***	0.049	0.000
_cons	8.110***	0.807	0.000
Lnsig2v	-3.591	0.278	0.000
Inefficiency Component			
Age of HH (Years)	0.040*	0.022	0.073
Education of HH (Years)	-0.071	0.072	0.325
Family members (No.)	-0.352**	0.171	0.039
Total landholding (ha)	-0.036**	0.015	0.022
Training received (1=Yes)	-5.276	7.045	0.454
Membership (1=Yes)	0.270	0.519	0.602
Constant	-0.822	1.518	0.588
Other statistics			
Log likelihood	1.15807		
Prob> chi^2	0.0000***		
Number of observations	98		
Wald chi^2 (6)	93.3		

Note: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$

Thus the amount of nutrients and water needed by the individual maize crops is reduced which results reduction in the expected yield of maize Kuwornu *et al.* (2013). The inefficiency factors shown in Table 2 relate to the farmers' socio-economic characters. The variables include the age of the household head, family size, farm size, education of household head, dummy variables training received related to maize farming and membership of the organization. The coefficient of age of the household head has a positive effect on

technical inefficiency and significant at 10 % showing that younger farmers are more technically efficient. This shows that young farmers are more aware of hybrid maize production and they have the knowledge of proper dose of fertilizer application and other farm management skills. The coefficient of family size is found to be negative and statistically significant at 5%. This implies that larger households are more efficient. It is because of more members in the family have more resources and they have time to involve in the field for intercultural operation and other farm management activities.

Farm size was also an important determinant of the technical efficiency of hybrid maize farmers. The coefficient is negative and statistically significant at 5%, and indicates that farmers with larger agricultural land tend to be more efficient. This could be because larger farmers have more resources and they have more capacity to purchase more fertilizers and seeds. This finding is similar to Wadud and White (2000).

Level of Technical Efficiency of Maize farmers
The results obtained from the econometric estimation indicate that technical efficiency indices ranges from < 50% to 99% in the sample farmers with an average of 79%. This implies the possibility of increase the technical efficiency level of the farmers in eastern Nepal by 21%. A majority (72%) of the farmers had technical efficiency levels greater than 0.70. Hybrid maize farmers can increase their productivity by raising the technical efficiency through increasing Nitrogenous and Phosphatic fertilizers. Adedapo (2008) found that mean technical efficiency of maize farmers in Nigeria was 76.3%.

Table 3. Frequency of technical efficiency distribution

Efficiency level	Frequency	Percent (%)
Less than 0.5	3	3.1
0.51-0.6	10	10.2
0.61-0.7	14	14.3
0.71-0.8	15	15.3
0.81-0.9	23	23.5
0.91-1.0	33	33.7
Total	**98**	**100**
Mean	0.79	
Standard deviation	0.16	
Minimum	0.39	
Maximum	0.99	

Source: Field survey, 2017

CONCLUSION AND RECOMMENDATIONS

This study was conducted to estimate the technical efficiency and also determine the socio-economic and farm specific factors that influence technical efficiency in hybrid maize production among the farmers in eastern Nepal. The study shows that DAP and Urea fertilizers, seed and area under maize area are the major factors associated with changes in maize production. The dose of Urea and DAP on maize output is positive and coefficient is statistically significant at 1%. Farmers should increase the amount of chemical fertilizers to increase their production. The quantity of seed is negative and significant at 10 %, which shows that farmers should apply proper dose of seed with proper intercultural operations to

produce higher maize production. The result shows that area under maize cultivation is significantly positive. The significant determinants of technical inefficiency variables include age, family size and total land holdings. Family size and total landholding size are negatively associated with technical inefficiency, while age of the household head had a positive association with technical inefficiency.

The technical efficiency of hybrid maize farmers could be increased by 21 % an average through better use of available resources as fertilizers, seed and land. This could be achieved through improving efficiency factors, increased involvement of young farmers for better use of resources, larger household sizes and should focus on larger area of maize farming through commercialization.

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Authors Contribution
Surya Prasad Adhikari designed and collected the data and drafted paper. Krishna Prasad Timsina, Peter R. Brown edited and revised the paper. Yuga Nath Ghimire and Jeevan Lamichhane provided feedback to improve the paper.

Conflicts of Interest
The authors declare that there is no conflicts of interest.

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