Technical efficiency of rice production in Terai district of Nepal

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ABSTRACT

This paper aimed to estimate the technical efficiency of rice production, also identifying the factors affecting technical efficiency. Jhapa, the Terai district of Nepal, having the highest rice production in the country, was purposely selected for the study. The primary information was collected from 100 rice growing farmers, randomly selected from the sampling frame, using the pre-tested semi-structured interview schedule. Also, two Key Informant Surveys were done. Besides, the secondary information was collected by reviewing the related literatures. Descriptive statistics, stochastic frontier model with Cobb-Douglas production function, and tobit model were used for data analysis. The stochastic production frontier model revealed that with the increase in seed, chemical fertilizer, human labor, and tractor power by 1 percent, the rice yield increases by 0.25 (P<0.05), 0.15 (P<0.01), 0.13 (P<0.05) and 0.21 (P<0.01) percent respectively. The average technical efficiency of the rice growing farmers in the study area was estimated 92%; in addition, majority of the farmers (62%) were operating at an efficiency level of 0.91- 0.95 followed by 32% at 0.86- 0.90. The tobit regression model revealed that farming experience (P<0.01), membership of the organization (P<0.01), and major occupation being agriculture (P<0.05) have statistically significant and positive on technical efficiency; while, schooling years (P<0.05) and number of economically active family members (P<0.05) have statistically significant but negative effect. There is still scope to increase the rice yield through efficient use of available resources with existing technologies.

Keywords: Rice, technical efficiency, Terai, tobit regression

INTRODUCTION

Rice (*Oryza sativa* L.) is the member of the Poaceae family. Out of twenty three species of rice, only two species of rice have been known for their commercial value. These two species are *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice) among which *Oryza sativa* is the most important commercial species of rice (CDD, 2015). Rice is the major staple food crop of Nepal. It ranks first among the cereal crops of Nepal having the highest area (1,491,744 ha), production (5,610,011 mt) and productivity (3.76 t/ ha) (MoALD, 2020). Moreover, Fageria (2007) reported that it is the foremost staple food for more than 50% of the world's population. There is the highest contribution of agriculture and forestry sector (28%) to the national Gross Domestic Product (GDP) of Nepal; moreover, rice is the major agricultural crop having significant contribution to the Agriculture Gross Domestic Product (AGDP).

Rice is found to be grown in the three distinct major agro-ecological zones, which are: Terai and inner Terai (60-900 masl), Mid hills (900-1,500 masl) and Mountains/High hills (1,500 - 3,050 masl). Also, it has been reported that more than two third of the total rice production of Nepal is produced in the Terai. Moreover, Jhapa is the Terai district of Nepal having highest rice production in the country (MoALD, 2020). In addition, it is the first 'rice superzone' district of Nepal declared by Prime Minister Agriculture Modernization Project (PM-AMP); nearly 1000 hectares of land are required for a super zone (MoAD, 2016). The area, production and productivity of rice in Jhapa district has been reported 85,879 ha, 365,845 t and 4.26 t/ha respectively (MoALD, 2020).

The technical efficiency of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditional on the level of inputs used by the farm.Therefore, technical efficiency is defined as the amount by which the level of production for the farm is less than the frontier output (Kibaara, 2005). The productivity of rice could be increased through the efficient use of inputs such as: improved seed, fertilizer, human labor and farm machineries. The yield difference between improved and local varieties of rice was found to be significant at 5% level of significance in the study conducted in eastern the Terai of Nepal (Timsina et al., 2012a). Moreover, Timsina et al. (2012b) conducted a study in eastern Terai of Nepal and reported that out of 38 rice varieties released and registered for Terai and inner Terai of Nepal, about 12 varieties existed in the study area; moreover, in totality, about 67% varieties were released after 1990s.

It is anticipated that by the year 2025, the world's farmers should produce about 60% more rice than at present to meet the food demands of the projected world population at that time (Fageria, 2007). Lots of attempts and new ideas are emerging to increase the productivity of rice (Uprety, 2006). Improving the technical efficiency might be the appropriate means to increase the yield. Due to inadequate knowledge on optimum use of resources, most of the farmers are using the inputs in an unscientific manner which has resulted to low yield and efficiency. Ahmad et al. (2006) reported that in general, the agricultural input resources are being inefficiently utilized, especially in the under-developed countries. Also, it has been reported that improved efficiency results to increased output and yield without additional inputs and production technologies (Bravo-Uretra and Pinheiro 1997).

The farmers could produce maximum output from the given level of input resources, if their farming practice is technically efficient (Chiona, 2011). It is therefore appropriate option for developing countries like Nepal, to increase the yield of major staple food crop- rice, by improving the technical efficiency through efficient use of available resources. Bajracharya et al. (2017) conducted a study on technical efficiency of certified maize seed in Palpa district of Nepal. Moreover, Adhikari et al. (2018) also conducted a research to estimate the technical efficiency of hybrid maize production in eastern Terai of Nepal. However, an assessment on technical efficiency of rice production is lacking. This paper aims to estimate the technical efficiency of rice growing farmers and identify the factors affecting it. This shows the way to increase the yield by possible improvement in efficiency without increasing the resource. Moreover, this study also explores the areas where the major interventions are needed to be done to improve the efficiency and increase the yield.

METHODOLOGY

Study area

Jhapa district was purposely selected for this study. Jhapa is the Terai district of Nepal having the highest rice production in the country. Moreover, it is the first rice super zone district declared by PM-AMP, MoALD. The study sites selected for the study purpose in Jhapa were: Gauradaha municipality, Gaurigunj rural municipality, Birtamod municipality, Arjundhara municipality and Kanchankawal rural municipality.These sites were selected on the basis of consultation with the agricultural officials of rice super zone, Agriculture Knowledge Centre and the local government.

Sampling procedure and data collection

The sampling frame of the rice growing farmers in the study area was obtained in coordination with rice super zone office, Jhapa. Then, the simple random method of sampling was applied to select the sample from the sampling frame. The primary information was collected using the pre-tested interview schedule; also, two Key Informant Surveys were done. Moreover, related literatures were reviewed to collect the secondary information. All total, 100 samples were taken from the study sites for the purpose of the study.

Methods and techniques of data analysis

The collected data were coded and entered into the computer for further analysis. Data entry was done in MS-Excel and analysis was done using the packages, STATA and Statistical Package for Social Science (SPSS). The following analyses were done.

Statistical description of the socio-economic and demographic characteristics
The statistical description of the continuous variables used in the tobit model was done by estimating the mean and standard deviation while for dummy variables; the frequency and percentage were calculated.

Econometric model
The estimation of technical efficiency was done using the econometric modeling according to the stochastic frontier methodology of Aigner et al. (1977). The stochastic frontier method is a parametric approach that estimates technical efficiency within a stochastic production

function model (Chakraborty et al. 2002; Coelli et al. 2005). The technical efficiency was predicted by using the stochastic frontier model with Cobb-Douglas production function.

Cobb-Douglas frontier production function model

The Cobb–Douglas production function has been widely used in many empirical studies, particularly in developing countries for the analysis of farm efficiency (Bravo-Ureta and Pinheiro 1997; Bajracharya, 2017; Adhikari, 2018). In this study, we used the Cobb-Douglas frontier production function model described below.

$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + u$

Where,

Y = Yield (Kg/ha)

X_1 = Quantity of seed used (Kg/ha)

X_2 = Quantity of chemical fertilizers used (Kg/ha)

X_3 = Human labor used (man-days/ ha)

X_4 = Tractor power used (hours/ ha)

u = Random disturbance term or error term

a = Intercept or constant term

e = Base of natural logarithm

$\ln$ = Natural logarithm

b_1, b_2, b_3 and b_4 = Coefficients of respective variables.

Estimation of technical efficiency (TE)

The methodology for assessment of technical efficiency was used taking the reference of book by Coelli et al. (2005). Moreover, Aigner and Chu (1968) used the Cobb-Douglas production frontier to estimate the stochastic production frontier of the form:

$\ln q_i = x_i b - u_i$ ……. (1)

Where,

q_i represents the output; x_i is $K*1$ vector which contains logarithms of inputs; b is a vector of unknown parameters and u_i is non-negative random variable which is associated with technical inefficiency. Also, Aigner et al. (1977) proposed the stochastic frontier production function model independently, which was,

$\ln q_i = x_i b + v_i - u_i$ …………. (2)

This equation 2 is identical to the equation 1 except v_i. Here v_i (symmetric random error) was added to account for statistical noise. The model defined in equation 2 is called as a stochastic frontier production method. In addition, Battese (1992) and Rahman (2003) applied the stochastic production frontier method to estimate the technical efficiency. The half-normal distribution is assumed for the asymmetric technical inefficiency parameter in this study. The farm specific technical efficiency (TE_i) of the ith sample farmer was estimated by using the formula;

$$TE_i = \frac{q_i}{\exp(X_i'\beta + v_i)} = \frac{\exp(X_i'\beta + v_i - u_i)}{\exp(X_i'\beta + v_i)} = \exp(-u_i)$$

The ratio of observed output to the corresponding stochastic frontier output. The measure of technical efficiency takes a value between zero and one. It measures the output of the firm relative to output that could be produced by a fully efficient firm using the same input vector.

$Y = f(X_i; b_i) + 1$

The error term is composite (Chavas et al., 2005; Rahman, 2003; Sharma & Leung, 2000; Bravo-Ureta & Pinheiro 1993; Ali & Flinn, 1989).

Thus,

L= v – u

Where v is a two-sided ($-\infty < v < \infty$) normally distributed random error [$V \approx N (0, sd^2_v$] that captures the stochastic effects outside the farmer's control (e.g., weather, natural disasters and luck), measurement errors, and other statistical noise. The term u is a one-sided ($u \geq 0$) efficiency component that captures the technical inefficiency of the farmer. It measures the shortfall in output from its maximum value given by the stochastic frontier. The study assumed u has an exponential distribution [$U \approx N (0, sd^2_u$)]. The two components v and u are also assumed to be independent of each other. Technical efficiency levels were predicted from the stochastic frontier production function estimation. The technical efficiency score was obtained and categorized in an interval of 5.

Tobit regression model

The tobit regression was used to determine the socio-economic and demographic characteristic factors affecting the technical efficiency. The technical efficiency was a continuous variable which value could range from 0 to 1. The past researches showed that the tobit model has been widely used to determine the factor affecting technical efficiency (Nyagaka, Obare & Nguyo, 2010). The equation of the tobit regression model used is described below;

$Y_i^* = X_i b_i + e_i$

Where, Y_i^* is latent variable for the ith rice growing farmers and the values was censored at 0 and 100. X_i were the explanatory variables used in models, b_i were the estimated coefficient and e_i was the distributed error term which was assumed to be normally distributed at zero mean and constant variance.

The Tobit model used in this study was;

$Y = b_0 + \sum_{n=1}^{9} b_n X_n + e_i$

Where,

X_1 = Age (Age of the household head; in years)

X_2 = Schooling_yrs (Schooling of the household head; in years)

X_3 = Membership (Membership of any organization; Yes=1, otherwise 0)

X_4 = Farm_exp (Experience on rice production; in years)

X_5 = Seed source (Seed source if cooperatives/government farms = 1, otherwise 0)

X_6 = Fm_15_59 (Economically active family members; in number)

X_7 = Subsidy (Subsidy in rice farming; Yes=1, otherwise 0)

X_8 = Maj_occup (Major occupation of the farm household; Agriculture = 1 otherwise 0)

X_9 = Ln_rice_land (Area of rice cultivated land in hectare; in natural log)

b_0 = Constant

e_i = Error term

Y = Technical efficiency scores (in %)

The maximum likelihood estimation was used for tobit regression analysis.

RESULTS

Description of the socio-economic and demographic variables

The statistical analysis of the socio-economic and demographic variables was done by using descriptive statistics; measures of central tendency such as mean and standard deviation was used for continuous variables while measures of dispersion such as percentage, frequency

was used for the categorical variables. The average age, schooling and farming experience of the respondent were found to be 48.7, 8.5 and 13.2 years respectively; the family size and number of economically active family members were estimated 5 and 3 respectively. Moreover, average rice cultivated area and rice productivity of the respondents in the study area were calculated 1.6 ha and 4500 kg/ha respectively (Table 1).

Table 1. Scio-economic and demographic characteristics of the respondents (N=100)

Continuous variables	Mean	Standard deviation
Age of the household head (in years)	48.7	11.02
Schooling years of the household head (in years)	8.5	4.01
Family size (in number)	5.1	1.80
Economically active family members (in number)	3.3	1.55
Farming experience (in years)	13.2	8.03
Area of rice cultivated land (in ha)	1.6	2.62
Rice productivity (kg/ha)	4500	1192.84
Dummy variables	**Frequency**	**Percentage**
Membership of any organization (Yes=1)	71	71
Seed source if cooperatives/government farms (Yes=1)	47	47
Subsidy in rice farming (Yes=1)	39	39
Major occupation of the farm household, if agriculture (Yes=1)	68	68

Source: Field survey, 2020

Stochastic production frontier model

The wald chi-square value was found to be highly significant which indicated that the model has good explanatory power at the 1% level. This means that the explanatory variables included in the model were enough to describe the variation in the dependent variable. Moreover, the model revealed that with the increase in seed, chemical fertilizer, human labor and tractor power by 1 percent, the rice yield increases by 0.25 (P<0.05), 0.15 (P<0.01), 0.13 (P<0.05) and 0.21 (P<0.01) percent respectively. Also, the sum of the estimated coefficients of all the inputs of rice production was calculated 0.74 which indicated that the production function exhibited a decreasing return to scale; implies that if all the inputs specified in the function are increased by 1%, the output from rice production will increase by 0.74% (Table 2).

Table 2. Stochastic production frontier of rice production

Variables	Coefficients	Standard error	z	P>z
Log seed (kg/ha)	.2549**	.1011	2.52	0.012
Log chemical fertilizer (kg/ha)	.1541***	.0405	3.80	0.000
Log human labor (man-days/ha)	.1342**	.0558	2.40	0.016
Log tractor power (hours/ha)	.2055***	.0729	2.82	0.005
Constant	5.8091***	.4041	14.38	0.000
sigma_v	.1915	.0135		
sigma_u	.0020	.2124		
sigma2	.0367	.0052		
Lambda	.0106	.2136		
Summary statistics				
Number of observations	100			
Wald chi^2(4)	75.68			
Prob>chi^2	0.0000			
Log likelihood	23.3474			

Note: ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level
Source: Field survey, 2020

Estimation of technical efficiency

The prediction of the technical efficiency of rice production revealed that majority of the farmers (62%) were operating at efficiency level of 0.91- 0.95 followed by 32% at 0.86- 0.90 (Table 3). The average technical efficiency of rice production was estimated 0.92 (92%); the minimum and maximum values were 0.86 and 0.95 respectively (Table 4). The average value of technical efficiency (92%) indicated that technically, the rice production in the study area is highly efficient; however, there is still scope to increase it by nearly 8% through proper allocation of available resources and technology.

Table 3. Overall technical efficiency of rice production

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Technical efficiency	100	0.917	0.027	0.863	0.954

Source: Field survey, 2020

Table 4. Percentage of farmers operating at different technical efficiency level

Technical efficiency level	Percentage of farmers
0.86- 0.90	38
0.91- 0.95	62

Source: Field survey, 2020

Factors affecting the technical efficiency

The tobit model was used to identify the determinant factors affecting the technical efficiency. For this, the predicted technical efficiency score (in percent) of the rice growing farmers was used as dependent variable and their major socio-economic and farm characteristics were used as the explanatory variables. The value of likelihood ratio (81.91) was statistically significant at 1% level which indicated that the model has good explanatory power. The value of pseudo R^2 was estimated 0.17, which showed that the 17% of the variation in technical efficiency is explained by the explanatory variables included in the model. The interpretation is shown in table 5.

Table 5. Factors affecting the technical efficiency of rice production

Variables	Coefficients	Standard error	t-value	p-value
Age	-.0096	.0204	-0.47	0.638
Schooling_yrs	-.1510**	.0605	-2.49	0.014
Membership	2.0272***	.4154	4.88	0.000
Farrming_exp	.1946***	.0323	6.02	0.000
Seed source	.0056	.4676	0.01	0.990
Fm_15_59	-.2743**	.1059	-2.59	0.011
Subsidy	.1400	.4275	0.33	0.744
Major_occup	1.4002**	.4274	3.28	0.001
Ln_rice_land	-.2916	.2406	-1.21	0.229
Constant	90.8769***	1.4837	61.25	0.000
Summary statistics				
Number of observations	100			
LR chi^2(9)	81.91			
Prob>chi^2	0.0000			
Pseudo R^2	0.1704			
Log likelihood	-199.4499			

Note: ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level
Source: Field survey, 2020

The model revealed that with the one year increase in schooling years, the technical efficiency decreases by 0.15% (P<0.05); while with the unit year increase in farming experience, the technical efficiency increases by 0.19% (P<0.01). Moreover, the technical efficiency of the farmers having membership of the organization was found to be 2% more (P<0.01) than that of those who don't have. In addition, with the unit increase in number of economically active family members in the family, the technical efficiency decreases by 0.27% (P<0.05). Furthermore, the technical efficiency was found to be 1.4% more (P<0.05) for the farmers whose major occupation is agriculture, as compared to those whose major occupation is otherwise (Table 5).

DISCUSSION

Stochastic frontier model
The stochastic frontier model has revealed positive and statistically significant relationship between the inputs (seed, chemical fertilizer, human labor and tractor power) used in rice production and the yield. Bajracharya and Sapkota (2017) also reported significantly positive influence of seed, labor and tractor power on yield of maize. In addition, Lamichhane et al. (2019) also reported positive and significant relationship between quantity of seed, fertilizer, and labor use and the yield. Moreover, Dube et al. (2018) reported that quantity of seed and labor were found to have positive and significant effect on yield. Also, Dessale (2019) reported that the maximum likelihood parameter estimates showed that wheat output was positively and significantly influenced by fertilizer and labor.

Technical efficiency of rice production
The average technical efficiency of the farmers in the study area was estimated 92%; in addition, majority of the farmers (62%) were operating at efficiency level of 0.91- 0.95 which showed that the resources are allocated efficiently in rice production. As Jhapa is the rice super zone district and the highest rice producing district of Nepal (MOAD, 2020), the higher technical efficiency of the majority farmers revealed from this study is not surprising. Also, in overall, there is still scope to increase 8% efficiency with the rationale allocation of available resources; the adjustment in resource use should be made taking account of the estimated coefficients of the inputs revealed from the Cobb-Douglas frontier production function. In a synonymous manner, Wabomba (2015) also found that more than one third (40.5%) of the farmers had technical efficiency measure of 90% and above in soyabean production in Kenya. Moreover, it has been reported that the estimated mean technical efficiency of the farmers in wheat production in Ethopia was about 82% (Dessale, 2019). In contrary to this, Oluwatayo, Sekumade and Adesoji (2008) reported the average technical efficiency of maize farmers to be 68% in rural Nigeria. Also, the average technical efficiency of maize and beans in Nicaragua was found 69.8% and 74.2% respectively estimated by using the translog stochastic frontier model (Abdulai and Eberlin, 2001).

Factors affecting the technical efficiency
The tobit regression model revealed that schooling years and number of economically active family members have negative and significant effect on technical efficiency; while, farming experience, membership of the organization and major occupation being agriculture have positive and significant effect.

With the higher level of formal education, the household head might be engaged in service and other educational activities due to which he/she would have neglected or given less time to the agricultural production. Also, might have got less time to consult with the agricultural technician regarding adoption of improved varieties and technologies which ultimately results low yield. Subedi et al. (2017) reported that the probability of adoption of improved varieties by the farmer increases with the increased consultation with the agricultural technician. Also, the negative influence of formal education towards adopting genetically modified crops has been reported (Uematsu and Mishra, 2010). The findings of this study are in contrary to the findings of Assadullah and Rahman (2009) and Ajewole and Folayan (2008).

The population belonging to the age group 15-59 years is considered as the economically active population by the Government of Nepal (CBS, 2012). It has been revealed that the negative relationship exists between the technical efficiency and number of economically active population. Subedi et al. (2020) also reported the negative relationship between number of economically active population and the total quantity of wheat produced. This might be due to the reason that the members of this age group might have been engaged either in service, business or employed elsewhere other than agricultural production.
Moreover, it has been revealed that the farming experience has positive relation with technical efficiency. With the increased farming experience, farmers acquire knowledge and skills necessary for choosing appropriate new farm technologies and have idea on efficient use of resources. The finding was in line with the findings of Olarinde (2011) and Gul et al. (2009); however, contrary to the findings of Ajewole and Folayan (2008).

Also, the membership of organization was found to have positive and significant effect to technical efficiency. Being the member of the organization such as cooperatives, farmers' group, farmers got opportunity to interact with each other in different meetings and trainings and learn about the improved agricultural technologies. This motivates them towards adoption of such technologies which ultimately contributes to higher yield and make them technically efficient.

In line of this, Uaiene *et al.* (2009) reported that the individual decisions are affected by social network effects, and that in the context of agricultural Innovations, farmers interact, share and learn from each other. Also, Subedi et al. (2019) had also reported that the farmers who have membership of any organization had 15% more probability for adoption of improved varieties as compared to those who haven't.

Furthermore, it has been revealed from this study that the farm households having agriculture as their major occupation have higher technical efficiency as compared to the counterparts. The investment of time, money and effort in rice production will be with great care if the major occupation is agriculture; also, the farmer will be more responsive towards adoption of improved agricultural technologies. Ultimately, this results to increased yield and high technical efficiency.

Subedi and Dhakal (2015) also reported that the probability of adoption of improved agricultural technologies is significantly more for the farm households whose major occupation is agriculture as compared to those whose major occupation is otherwise. Also, Mottaleb (2018) reported that the farm households having agriculture as their major

occupation are dependent on agriculture for their livelihoods, thus are more eager to adopt improved agricultural technologies agricultural machinery than others.

CONCLUSION

The average technical efficiency of rice production predicted from stochastic frontier model was more than ninety percent; majority of the rice growing farmers were operating at this efficiency level. This showed the efficient allocation of input resources in rice production in the study area; however, there is still scope to improve the technical efficiency. Moreover, the study revealed that the technical efficiency could be improved by improving the knowledge and skills of the farmers through informal education such as trainings and seminars rather than formal; motivating the farmers of economically active age group is the most. Also, the farmers should be encouraged to be the member of agricultural organization such as cooperatives, farmers' group; membership of experienced farmers in such organization will have positive multiplier effect to technical efficiency. The government should encourage the farm households to adopt agriculture as their major occupation through different supportive policies of grants, subsidies and technical assistance. In the developing countries like Nepal, the efficient allocation of input resources and wise use of existing technologies could increase the yield to certain level, eventhough new technologies are not introduced.

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Author's Contribution

S. Subedi designed the research plan. S.Subedi, M. Kharel and S.P. Adhikari collected the data; B.K. Sapkota designed a data entry template in MS excel and entered the data. S. Subedi analyzed the data and prepared the manuscript. Y.N Ghimire and Jiban Shrestha provided comments and feedback to finalize this manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

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