Research Article

Technical efficiency of wheat growing farmers of Nepal

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ABSTRACT

Wheat is a major staple food crop of Nepal, so it is necessary to increase its productivity. However, the national average wheat productivity of Nepal is low as compared to other neighboring countries. This study employed a Cobb-Douglas stochastic production frontier model to examine the technical efficiency and its determinants using randomly selected household data from 343 wheat farmers from four districts of Nepal. Maximum likelihood estimation results showed that wheat production responded positively to an increase in the quantity of inorganic fertilizer, whereas it was detrimental to seed rate. Likewise, the study found that farmers were not technically efficient with a mean technical efficiency of 81%. The result showed irrigation, herbicides, sowing time, Farm Yard Manure (FYM), and wheat varieties were statistically significant factors that affect the technical efficiency of wheat farmers. Furthermore, to increase wheat productivity, farmers should use better irrigation, appropriate weed management practices, optimum sowing time, and adoption of recent improved varieties. Findings suggest that the technical efficiency of wheat farmers could be enhanced by practicing optimum use of inputs and improving the inefficiency factors.

Keywords: Efficiency, management, productivity, stochastic

INTRODUCTION

Wheat is the third important crop of Nepal after rice and maize both in area and production. The present wheat area is 703,992 ha with an average productivity of 2.84 Mt/ha (MoALD, 2020). It is grown in Terai, mid-hill, and high-hill of Nepal during the winter season. Among the cereal grain crops, wheat ranks third in hill and mountain and ranks second in the terai region in terms of production and human consumption. Wheat is grown on 25% of the cultivated land in the country and about 60% of wheat produced in the terai (plain) region of Nepal, but the crop productivity has slightly increased over the past three years (MoALD, 2020). The productivity of wheat is far below than of neighboring countries, India (3.37 mt/ha) and China (5.48 mt/ha). There are many factors responsible for low wheat productivity in Nepal like fewer irrigation facilities, lesser availability of fertilizer, pesticides, and insecticides (Pokherel *et al.*, 2007) and Devkota (2013). Nepal has been almost regularly importing wheat, except for few years (ITC, 2016). Wheat's domestic production has remained short for the

domestic demand. To substitute the import; we have to increase wheat productivity by utilizing all possible and optimal ways. The increased production and productivity came from the availability of high yielding wheat varieties as farmers gradually replaced their low yielding traditional varieties with high yielding varieties in Nepal (Prasai & Shrestha, 2015).

The main reason for low productivity is the inability of farmers to fully exploit the available resources (Kavoi *et al.,* 2016). The lack of proper access to quality seeds and fertilizers, timely unavailability of human labor, inadequate irrigation facilities and having no proper access to agricultural machines has been explored as the major problems associated with the wheat production (Subedi *et al*., 2019a).The less productivity of crops implies the need for studies to measure technical efficiency (Ojong & Molua, 2017). Efficiency is an essential factor of productivity growth where resources are scarce and opportunities for new technologies are lacking (Adhikari *et al*., 2018). Improving efficiency in production allows farmers to increase their output without additional inputs and changing production technologies resulting in increased productivity (Bravo-Uretra & Pinheiro, 1997). Measuring efficiency is vital because it can guide resource utilization and may lead to considerable resource savings, which have important implications for policy formulation and farm management (Bravo-Ureta & Riegler, 1991). In Nepal, there is a huge gap between potential yield and the average national productivity of wheat (Timsina *et al*., 2019). Wheat productivity and efficiency may be affected by various farm-specific factors such as seed type, sowing date, seed rate, fertilizer dose, farm size, family size, credit accessible to farmers, technical support, land type, land use pattern, etc. Efficient use of inputs is necessary for the increment of wheat productivity. Several studies have been conducted about wheat productivity and efficiency in developing countries; however, in the case of Nepal study on the technical efficiency of wheat growing farmers is lacking, with most of the research focused on adoption and other issues. Tiruneh and Geta (2016) in Ethiopia found that the mean technical efficiency of wheat farmers was 57% and factors like gender, age, education, livestock holding, membership, farm size were positive towards efficiency. Likewise, Croppenstedt (2005) in Egypt reported that the average level of technical efficiency of wheat farmers was 81% and extension visits and knowledge of irrigation were positive towards efficiency. This study was undertaken to analyze the technical efficiency of wheat farmers across the Terai region of Nepal to find the level of technical efficiency and farm and farmers specific factors associated with technical inefficiency.

METHODOLOGY

This study used the farm level data collected from the household survey with 343 wheat farmers in the Terai region of Nepal and covered four districts: Sunsari district from eastern Terai, Bara from central Terai, Rupandehi from western Terai, and Kailai from far western Terai of the country. These districts are the major wheat-growing district in Nepal. The households' survey conducted using a structured questionnaire during January-April 2019. The survey collected information on household demographics, the quantity of inputs, wheat production technologies, and outputs. Firstly, three pockets in each district were selected based on wheat area, production, productivity, and variety type to create the variation in the sample after that households were selected randomly from the pocket. The primary data were collected through a household survey using a pretested interview schedule. Three FGDs (Focus Group Discussion) were conducted in each pocket. The collected information from four districts was entered in Excel and data analysis was conducted by using software Stata (version 16.1). Both descriptive and econometric methods were used to analyze the data. A stochastic frontier model was used to measure the technical efficiency of wheat farmers.

Empirical Model
This analysis used the Cobb-Douglas form of the stochastic frontier production model proposed by Aigner *et al.* (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 the logarithmic form it is linear and parsimonious (Beattie & Taylor, 1985). Thus, Cobb-Douglas specification provides an adequate representation of agricultural production technology. The empirical Cobb-Douglas frontier production function model with double log form can be expressed as:

$$Ln\ (yield) = ß_0 + ß_1 ln(Fertilizer) + ß_2 ln(seed) + ß_3 ln(Labor) + ß_4 ln(Tillage) + ß_5 ln(Area\ cultivation) + Єi(V_i - U_i)$$

Where, yield is the wheat production per hectare (Kg/ha)
$ß_0$ -$ß_5$ are the parameters to be estimated
$Єi$= Error term, equal to $(V_i - U_i)$
V_i = Two-sided random error component beyond the control of the farmer
U_i = One-sided inefficiency component
The farm-specific technical efficiency (TE_i) of the ith sample farmer estimated by using the expectation of U_i conditional on the random variable $Єi$
$TE_i = Exp\ (-U_i)$
$= Y_i/f(X_i\ ß)exp\ V_i$
$= Y_i/Y^*$
Where Y_i = Observed output
Y^* = Frontier output
If $Y_i=Y^*$
Then, $TE_i = 1$ i.e. 100% efficient
After obtaining technical efficiency, we estimated the socioeconomic determinants of technical inefficiency.
Technical inefficiency determinants are as follows;
$Ln(U_i) = ß_0 + ß_1 ln(V_i) + W_i$
Where, U_i is technical inefficiency, $ß_0$,......... $ß_n$ are the parameters to be estimated
V_i is a vector of a farmer and household socio-economic characters; W_i is a random error.

RESULTS AND DISCUSSION

Summary Statistics
Table 1 presents descriptive statistics of inputs and socioeconomic variables to estimate a stochastic frontier production model using the half-normal method. The average wheat area in the Terai region of Nepal is 0.76 ha, ranging from 0.06 ha to 5.56 ha. The average wheat productivity was 2.77 t/ha, which is slightly lower than the national average of 2.84 t/ha (MoALD, 2020). Wheat production varies from 643 kg to 5100 kg per hectare. On average, wheat farmers applied 268 kg of inorganic fertilizers (Urea, DAP, and Potash), used 170 kg of seed, and 317 hours of labor in one hectare of land. Farmers applied more seed quantity than recommendation dose (120 kg/ha) but there was a variation of seed rate from 100 kg to 375

kg/ha. Farmers used an average of 6.28 hours per ha for tillage operation. Most of the farmers performed tillage operations using a tractor.

The inefficiency model included ten variables namely: age, family size, times of irrigation, herbicide application, study location, FYM application, time of wheat sowing, the variety used, the gender of household head, and agricultural credit. The mean age of the household head was 50 years. The average family size was 7. About 42% of farmers applied more than one time irrigation while more than 50% of farmers used herbicides for weed control in the wheat field. Farmers used postemergence herbicide 2,4-D after 20-35 days of wheat sowing. About 39% of farmers applied FYM on wheat farming. The time of wheat sowing is critical in the wheat crop. About 83% of farmers sow wheat between 14 November and 15 December. Only about 17% of farmers sow wheat before 14 November and after 15 December. About 61% of farmers cultivated recently released wheat varieties (released within 15 years) while about 39% of farmers still adopting old wheat varieties. Farmers used recently released varieties such as Vijaya, Aditya, Tilottama, Gautam, etc. while cultivated old verities were NL-297, UP-262, and RR- 21. Among the surveyed households, just above 90 % of households were headed by the male while only 7% of households were female-headed households. About 28% of farmers received agriculture-related credit.

Table 1: Descriptive statistics of wheat farmers in Terai region of Nepal (N=343)

Variables		Mean	Std. Dev.	Min	Max
Total wheat productivity (kg/ha)		2774	744,35	643	5100
Total wheat area (Hectare)		0.76	0.88	0.066	5.56
Total labour (hours/ha)		317.32	182.46	52.5	879.75
Seed quantity (kg/ha)		170.43	43.31	100	375
Tillage hour (hour/ha)		6.28	2.96	1.62	15
Total inorganic fertilizer (kg/ha)		268.33	91.28	90	600
Age of the household head (Years)		50	12.64	20	90
Family size (Number)		7.37	3.76	2	31
Irrigation used (Yes= More than one times irrigation & No= only one time irrigation)		41.69	0.49	0	1
Herbicide used (Yes %)		51.31	0.50	0	1
District dummy % (Yes= Farm located in eastern & central part& No= farm located in western and far western region)		55.1	0.49	0	1
FYM Application (Yes %)		39.4	0.48	0	1
Wheat sowing time (Yes= 14 Nov. to 15 Dec. & No= Before 14 Nov. & After 15 Dec.)		83.38	0.48	0	1
Variety dummy (Yes= Recently released varieties i.e. released within 15 years & No= Old varieties i.e. released before 15 years)		61.22	0.48	0	1
Gender dummy (Yes = Male headed household& No= Female headed household)		92.42	0.26	0	1
Agri. Credit dummy (Yes = If farmers received credit & No= Not received)		28.0	0.45	0	1

Source: Field Survey, 2019

Empirical results

Table 2 shows the maximum likelihood estimates of the stochastic frontier analysis and the determination of technical efficiency. We applied a one-stage stochastic production function. A cobb-Douglas production function was estimated using half-normal stochastic production methods. All input variables and dependent variables are log-transformed, the coefficient represents elasticity. The hypothesis of no technical inefficiency is rejected because the likelihood ratio of 23.27 is higher than the critical value of 5.14 indicating the existence of technical inefficiency on the sampled farms.

The result showed that the output of wheat was affected by the amount of seed and chemical fertilizers. The coefficient of seed rate was negative and significant at 5% level of significance. The result implies that with a 1% increase in seed quantity, wheat production decreased by about 0.15%. So, there should give knowledge about seed rate to wheat farmers. It may also imply that farmers use poor quality seed which resulted in the germination of more than the recommended number of plants with low vigor, which ultimately results in low production. Similar findings have been observed by Hussain *et al*. (2012) in Pakistan. The use of inorganic fertilizer was positively significant at the 1% level of significance. The findings indicated that a 1% increase in inorganic fertilizer dose increased the value of wheat production by 0.21%. Wilson *et al*. (2001), Croppenstedt (2005) and Kaur *et al*. (2010) reported fertilizer application was positively significant towards the wheat output. Hussain (2014) also found chemical fertilizer application contributed positively to the technical efficiency of wheat farmers.

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

Variable	Coefficient	Standard error	p-value
Log wheat area (ha)	-0.025	0.017	0.155
Log seed (Kg/ha)	-0.151**	0.058	0.010
Log labor (hours/ha)	0.031	0.022	0.147
Log Tillage hours (hours/ha)	0.002	0.030	0.948
Log total inorganic fertilizer (Kg/ha)	0.212***	0.038	0.000
Constant	7.52***	0.386	0.000
Inefficiency component			
Log Age of HH (Years)	0.367	0.481	0.444
Log Family size (No.)	-0.119	0.254	0.641
Irrigation time (Yes=Used more than one times)	-1.174***	0.389	0.003
Herbicide application (1=Yes)	-0.702**	0.294	0.017
District (Yes= Farm located in eastern & central part)	0.562*	0.339	0.097
FYM Application (1=Yes)	-0.556**	0.266	0.036
Sowing time	-0.612*	0.330	0.064
Variety dummy	-0.677**	0.278	0.015
Gender dummy	0.562	0.527	0.417
Agri. Credit (1=Yes)	-0.199	0.271	0.462
Constant	-2.63	1.922	0.172
V sigma	-3.326***	0.196	0.000
Other statistics			
Log-likelihood	-11.14		
Prob> chi^2	0.0000***		
Number of observations	343		
Wald Chi^2 (6)	36.27		

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

In the inefficiency model, a negative coefficient means an increase in efficiency or a positive effect on productivity, whereas a positive coefficient means an increase in inefficiency or negative relation with productivity. The estimates of the inefficiency model showed irrigation

time, herbicides and FYM application, wheat sowing time and wheat variety were statistically significant. Times of irrigation have a negative relationship with technical inefficiency, which implies that farmers who applied more than one number of irrigations were more technically efficient than farmers who used only one irrigation in wheat farming. Irrigation assists plants to absorb nutrients available in the soil which increased production (Abbas, 2012). Likewise, Fatima (2010) revealed that several irrigations applied to the wheat crop had a positive impact on wheat production. Furthermore, Hussain *et al*. (2012) in Pakistan found that irrigation application had a positive effect on wheat productivity.

The use of herbicides had a negative effect on technical inefficiency. Farmers who applied herbicides were more efficient than non-user farmers. Herbicide promotes efficient fertilizer use, which leads to an increase in production. Adhikari *et al*. (2020) found that herbicide user farmers obtained more wheat output as compared to non-users. Another significant variable was the district. Farmers from the eastern and central region were less efficient than western and far western region farmers. FYM application had a negative coefficient of -0.523. This means that using FYM increases the chance of the farmer to increase technical efficiency.

Sowing time is critical in wheat production. Farmers who sowed wheat between 15 November and 14 December were more efficient than farmers who sowed before 15 November and after 14 December. It is positively significant towards technical efficiency at 10% level of significance. Husain (2014) also mentioned late sowing of wheat crop lower the technical efficiency. Lastly, farmers who cultivated recently released improved varieties such as Vijay, Tilottama, and Gautam were more technically efficient than farmers who adopted old varieties like NL-297, UP-262 and RR-21. Availability of quality wheat varieties in time is found to be major constraint in wheat production in Nepal (Subedi *et al*. 2019b; Timsina *et al.*, 2018).

Level of Technical Efficiency of Wheat Farmers
The technical efficiency of the wheat farmers was between a minimum of 31% and a maximum of 95% with a mean of 81%. The average technical efficiency score suggests that a 19% increase of wheat yield could be attained by improving technical management at the prevailing inputs level. Improved efficiency would reduce production cost and increase wheat production. Percentage frequency distribution of technical efficiency is shown in Table 3.

Table 3 : Distribution of technical efficiency of wheat farmers in the Terai region of Nepal

Efficiency level	Frequency	Percent (%)
Less than 0.5	10	3.43
0.51-0.6	13	3.79
0.61-0.7	17	4.96
0.71-0.8	75	21.87
0.81-0.9	159	46.36
0.91-1.0	69	20.12
Total	343	100
Mean	0.81	
Standard deviation	0.11	
Minimum	0.31	
Maximum	0.95	

The result showed that about 12% of the sample farms had technical efficiency of less than 70%, whereas about 22% of farms had a technical efficiency between 70% and 80%. A large

number of farms (46%) had technical efficiency between 80% and 90%. Lastly, about 20% of the households were more than 90% of technical efficiency.

This result showed that technical efficiency is highly skewed. Variation in technical efficiency indicates that most of the farmers were not using input efficiently in wheat production because they are affected by the inefficiency determinants. Kamruzzaman and Islam (2008) in Bangladesh also found the average technical efficiency of wheat farmers were 70%. Likewise, the study conducted in Kenya also found a variation in technical efficiency of wheat farmers from 48% to 95% with a mean of 87% (Njeru, 2010).

CONCLUSION

This study measured the level of technical efficiency of wheat growing farmers of Nepal and also identified the inefficiency factors. The result showed the presence of technical inefficiency in the model. Variation in technical efficiency indicated that most of the wheat-growing farmers were not using the inputs efficiently in the production process because they were affected by the inefficiency factors. There is a still chance to maximize the technical efficiency of wheat farmers by 19% through the rational use of available resources. The result showed that among the input variables, seed had negative and inorganic fertilizer had a positive significant effect on technical efficiency of wheat growers. This showed farmers need to reduce the seed rate but need to increase the quantity of inorganic fertilizers to get higher yield. The estimated inefficiency model showed that the farmers who had applied irrigation for more than one time were more efficient than only one-time applying farmers. Likewise, herbicide and FYM users were more efficient than non-users. Farmers who had sowed wheat between 15 November to 15 December were more efficient than early and late sowing farmers. Moreover, farmers who had adopted recently released improved wheat varieties had a higher level of technical efficiency than those who cultivated old varieties. This study suggested to follow the recommend dose of inputs in the wheat field. In nutsheel, farmers and concerned stakeholders should focus on better irrigation facilities, proper weed management practices, optimum sowing time, and adoption of recent improved varieties to increase technical efficiency of wheat growers.

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Authors' contributions
S.P. Adhikari designed and drafted the paper. Y.N. Ghimire, K.P. Timsina, S. Subedi, and M. Kharel were responsible for the edition and revision of the paper.

Conflict of Interest
The authors declare that there are no conflicts of interest in this paper.

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