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*Research Article*

# Factors Associated with the Technical Efficiency of Maize Seed Production in the Mid-Hills of Nepal: Empirical Analysis

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Maize is the second most important staple crop in Nepal. Its demand is rapidly increasing due to a growth in the poultry sector. The national maize yield is low, leading to insufficient domestic production and thereby increasing imports. Maize seed is considered as one of the crucial inputs in achieving the targeted yield growth, but usually is in short supply during the cropping season. Farmers are involved in maize seed production, which eases its supply. Thus, understanding the efficiency of maize seed production will have a direct impact on the efficiency of the country's maize production. This paper aimed to assess the technical efficiency (TE) of maize seed production and the major factors affecting TE. Semistructured questionnaire survey was administered in June 2016 to 182 maize seed farmers selected randomly from a total of 260 maize seed growers in Palpa District, a leading maize seed producing district in the mid-hills of Nepal. TE is estimated based on the stochastic frontier production model, and the factors affecting TE are assessed using the Tobit model. TE ranged from 0.25 to 0.92 with an average of 0.71. This revealed the scope of increasing TE by 29%. TE in the study area is largely affected by the age and schooling year of household heads. Similarly, the experience of maize seed production, livestock holding, the share of maize seed area, seed source, and access to extension services affect TE. Hence, a focus on motivating experienced educated maize seed growers to expand the maize seed production area supplemented by a better seed source and extension services would contribute to improving TE.

## 1. Introduction

Agriculture sector contributes about 32.5% to Gross Domestic Product (GDP) and maize alone contributes 6.88% to Agriculture GDP in Nepal [1]. Maize is the second most important staple crop in terms of area and production among the cereal crops in Nepal. The area, production, and yield of maize crop in 2018/19 were 956.45 thousand hectares (ha), 2713.64 thousand tons, and 2.84 tons/ha, respectively [2]. Several plans, policies, and strategies are implemented in the country to improve maize production. However, a substantial improvement in maize yield, thereby its production, is yet to be realized. Maize production and yield are growing at the annual rate of 4.4% and 3.3%, respectively, between 2009/10 and 2018/19 [2]. In contrast, there is a sustained demand for maize. The annual growth rate of maize import in Nepal is 33.3% between 2009 and 2018. Maize import reached its peak in 2017 with an import of 483.64 thousand tons. The import is estimated to reach 500 thousand tons in 2019/20. This shows the growing deficit of maize, thereby increasing the reliance on imports [3].

The low maize yield and production are mainly attributed to a weak management practice, decline in soil productivity due to high use of pesticides, and higher production cost due to hired labor, Farmyard Manure (FYM) cost, and high price of the required inputs. Maize yield is also highly determined by plant density as there is no tillering in maize [4, 5].

Seed is considered as an important inexpensive input, which governs yield [6]. The yield of maize is higher with the adoption of new technology among smallholder farmers [7]. Improved seeds contribute about 20–30% increase in yield [8]. The supply of improved maize seeds, however, is very limited in Nepal [2, 9]. Only around 18% of maize farmers are using improved seeds [10]. Supply of improved seed is also restricted by the very limited supply of breeder and foundation seed for its multiplication, which otherwise could contribute to easy seed supply.

Improved efficiency of maize seed production contributes to overcoming the problems of lower yield through enhanced supply of improved seed. At the same time, it helps to find the possibility of increasing yield by improving efficiency without increasing the resource [7]. It is found relevant to countries like Nepal where there is a narrower scope of increasing production through horizontal expansion. Farmers use more inputs neglecting efficiency due to subsidy on inputs in developing countries [11]. In this context, improvement in technical efficiency (TE) might be an appropriate means to increase the yield. Efforts to improve the existing technologies would be more cost effective than that of discovering new technology for the increment of yield in developing countries [12]. Farmers who are technically efficient will be able to produce maximum output from a given level of input [13]. Hence, this study aims at assessing TE of maize seed production, which is a crucial input to realize the overall improvement in maize yield, thereby production, and determine the important determinants of TE.

## 2. Materials and Methods

*2.1. The Study Area and Sampling.* Palpa, the leading district in the mid-hills for maize seed production, was selected for this study [14]. The District Agriculture Development Office (DADO) provided the list of maize seed farmers. The list included 260 maize seed farmers producing maize seed through their involvement in maize seed producing cooperatives or farmer groups. The sample size, i.e., 182 constituting 70% of the population, is determined using the Raosoft software at 95% confidence level. A simple random sampling technique was adopted for sample selection. A pretesting was done among 10 respondents to make necessary corrections and modifications in the questionnaire before its administration to actual respondents in June 2016. A Focus Group Discussion (FGD) and Key Informant Interview (KII) were also conducted to collect and verify the responses received from the field surveys.

*2.2. Technical Efficiency Assessment.* The methodology to assess TE is adopted from Coelli et al. [15]. A Cobb–Douglas production function is considered to estimate the stochastic frontier production [16] as follows:

$$\ln\ q_i = x_i b - u_i, \tag{1}$$

where $q_i$ represents the output, $x_{\mathrm{i}}$ is $K*1$ vector which contains the logarithms of inputs, $b$ is a vector of unknown parameters, and $u_i$ is nonnegative random variable which is associated with TE. The stochastic frontier production model can be run independently [17, 18] as

$$\ln\ q_i = x_i b + v_i - u_i. \tag{2}$$

Equation (2) is identical to equation (1) except $v_i$. Here, $v_i$ (symmetric random error) is added to account for statistical noise, which arises from the inadvertent omission of relevant variables. Equation (2) is a stochastic frontier production method. The output values are bounded by the stochastic variable exp $(x_i b + v_i)$. The stochastic frontier production method is widely applied to estimate TE [19]. The following equation shows the stochastic production frontier model:

$$\begin{aligned}\ln Y = a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 \\ + b_5 \ln X_5 + b_6 \ln X_6,\end{aligned} \tag{3}$$

where $Y$ = yield (kilogram (kg)/ha), $X_1$ = seed sown (kg/ha), $X_2$ = FYM used (kg/ha), $X_3$ = chemical fertilizer used (kg/ha), $X_4$ = labor used (man-days/ha), $X_5$ = tractor (hour/ha), $X_6$ = bullock (days/ha), $a$ = intercept, and ln = natural logarithm.

The most common output-oriented measure of TE presented is as follows:

$$\mathrm{TE}_i = \frac{q_i}{\exp\left(x_i'\beta + v_i\right)} = \frac{\exp\left(x_i'\beta + v_i - u_i\right)}{\exp\left(x_i'\beta + v_i\right)} = \exp\left(-u_i\right). \tag{4}$$

Here, TE is the ratio of the observed output to the corresponding stochastic frontier output. It measures the output of the farm relative to the output that can be produced by a fully efficient farm using the same input vector. The estimated TE score is categorized in an interval of 0.1 (10%).

*2.3. Tobit Regression Model Analysis.* TE is a case of a limited dependent variable as its value ranges from 0 to 1. Estimating the model using Ordinary Least Square (OLS) regression produces inconsistent and biased estimates in such cases [20]. The OLS underestimates the true effect of explanatory variables by reducing the slope. Tobit regression employing the maximum likelihood estimation is widely adopted to estimate the factor affecting TE [21, 22]. The equation of the Tobit model used is presented as follows:

$$Y_i^* = X_i b_i + e_i, \tag{5}$$

where $Y_i^*$ is a latent variable, i.e., TE, for the $i^{\mathrm{th}}$ maize seed farmer and the value is censored at 0 and 100 as TE values are transformed to percentage. $X_i$ are the explanatory variables used in the model, $b_i$ are the estimated coefficients, and $e_i$ is the distributed error term which is assumed to be normally distributed with zero mean and constant variance. In this study, the Tobit model is specified as follows:

$$Y = b_0 + \sum_{n=1}^{15} b_n X_n + e, \tag{6}$$

where $Y$ = technical efficiency, $X_1$ = gender of the household head, $X_2$ = age of the household head, $X_3$ = schooling year of the household head, $X_4$ = occupation of the household head, $X_5$ = number of educated members in the household, $X_6$ = family type, $X_7$ = experience in maize seed production, $X_8$ = migration of the household member, $X_9$ = type of seed produced, $X_{10}$ = seed source, $X_{11}$ = access to extension service $X_{12}$ = access to credit, $X_{13}$ = membership in social groups, $X_{14}$ = livestock holding, $X_{15}$ = share of maize seed cultivation area in total cultivated area, $b_0$ = constant, $b_n$ = coefficient of respective variables, and $e$ = error term.

## 3. Results and Discussion

*3.1. Socioeconomic and Demographic Characteristics of Maize Seed Farmers.* In the context of Nepal, the household head is supposed to be the major decision maker in the family. Age and schooling years of the household head have a significant positive effect on the yield, mainly driven by a better access and rational use of the available resources. With respect to age, the average age of the household head is 56.77 years (Table 1). Similarly, the average schooling year of the household head is 5.51. The experience of growing maize seed production is 6.63 years. The household size ranges from a single member to 16 members with an average of 5.41. The average male and female members in the household are 2.81 and 2.60, respectively.

The number of family members falling under the economically active age group, i.e., age group between 15 and 60 years, suggests the labor available in the household. The average size of economically active members is 3.59. The dependency ratio is 0.62, which indicates that an economically active member must support 0.62 dependent members. The average number of educated members in the household is 4.8. The average landholding of the household is 0.91 ha, which is higher than the national average (0.68 ha). The average area in terms of lowland and upland is 0.17 and 0.43 ha, respectively. Almost one-third of the land possessed are Khoriya, which is a marginal land not considered as a cultivable land. Maize is mainly cultivated in the upland. This shows the land type in the study area favors the cultivation of maize. However, the geography of the area restricts the use of available land for cultivation. Only around 54% of the land is under cultivation. The average area under maize seed cultivation in the study area is 0.32 ha. A standardized unit of livestock, i.e., Livestock Standard Unit (LSU) cattle equivalent, is used to estimate the livestock holding of households. The average livestock holding is 3.05 LSU.

Around 74.2% of the sampled households are male-headed and the rest are headed by females (Table 2). Brahmin/Chhetri (68.7%) is dominating caste groups followed by Janajati (20.9%) and Dalit (10.4%). The major occupation is agriculture (92.3%), followed by government service (4.4%), private services (2.7%), and wages (0.5%). There are 50.5% and 49.5% joint and nuclear family household, respectively. Labor is considered as an active factor of production. The migration of household members to abroad might lead to the decrease in manpower in agricultural activities. About 42.3% of households have at least one member away from their home, migrated abroad. Farm category is broadly divided into two groups based on the farm size. Farmers having more than 0.32 ha, which is equivalent to the average land area under maize seed cultivation, are categorized as large scale, whereas those having less than 0.32 ha are categorized as small scale. There are about 39% households under large scale and 61% households are small-scale farmers.

*3.2. Technical Efficiency Assessment*

*3.2.1. Stochastic Frontier Production Model.* The significant Wald chi-square value indicates the explanatory variables included in the stochastic frontier production model sufficiently describe the variation in the yield of maize seeds (Table 3). A yield of maize seeds increases by 0.38% and 0.29% in response to a percentage increase in the number of labors and amount of seeds, respectively. The increase is statistically significant at one percent level of significance. Similarly, a percentage increase in the quantity of FYM increases maize yield by 0.04%, which is statistically significant at five percent level of significance. Use of chemical fertilizers and tillage by tractors has a positive effect on maize yield, although statistically nonsignificant.

*3.2.2. Technical Efficiency of Maize Seed Production.* The majority of the maize seed farmers (29.1%) are operating at a technical efficiency level of >0.8-0.9 followed by 28.6% at >0.7-0.8 (Figure 1). The statistically significant value of the Pearson chi-square (14.78) at five percent level of significance indicates the significant difference in a distribution of farmers among the eight categories of TE.

The average TE of maize seed production is 0.71 (71%), and the value ranges from 0.25 to 0.92 (Table 4). The value of TE (71%) indicated that there is still scope for increasing the production by 29% using the existing technologies and available resources in the study area. TE of maize seed production is moderate in Palpa compared to TE reported by other studies around the world [7, 23, 24]. However, TE is relatively less compared to TE of rice/rice seed and hybrid maize growers in Nepal [25–28]. The better allocation of resources helps in increasing yield and thereby production. The farmers should focus on the wise use of existing resources and technology to generate higher maize seed production.

*3.3. Factors Affecting the Technical Efficiency of Maize Seed Production.* It is incomplete to make a conclusion and recommend a better policy based only on TE estimation. Identifying the sources of variation in TE is essential. Tobit model is used to assess the sources of variation in TE and their marginal effect. The explanatory variables included in the model have a good explanatory power with the statistically significant value of the likelihood ratio, i.e., LR $chi^2(15)$ 40.61 (Table 5). All significant variables have positive effects on TE. A year increase in age of the household head will increase TE by 0.2% (significant at five percent level of significance). An increase in age would increase the

Table 1: Socioeconomic and demographic characteristics of the sampled households (continuous variables).

| Variables | Mean (±standard deviation) |
|---|---|
| Age of the household head (year) | 56.77 (±14.30) |
| Schooling year of the household head (year) | 5.51 (±4.69) |
| Experience in maize seed production (year) | 6.63 (±3.91) |
| Household size | 5.41 (±2.72) |
| Male members of household | 2.81 (±1.71) |
| Female members of household | 2.60 (±1.46) |
| Economically active members | 3.59 (±2.21) |
| Dependency ratio | 0.62 (±0.62) |
| Number of educated members in household | 4.80 (±2.49) |
| Total landholding (ha) | 0.91 (±0.79) |
| Lowland (ha) | 0.17 (±0.27) |
| Upland (ha) | 0.43 (±0.30) |
| Khoriya (ha) | 0.31 (±0.49) |
| Land area under cultivation (ha) | 0.49 (±0.36) |
| Land area under maize seed cultivation (ha) | 0.32 (±0.17) |
| Livestock holding (LSU) | 3.05 (±5.63) |

Table 2: Socioeconomic and demographic characteristics of the sampled households (categorical variables).

| Variables | Frequency | Percentage |
|---|---|---|
| Gender of the household head | | |
| Male | 135 | 74.2 |
| Female | 47 | 25.8 |
| Ethnicity | | |
| Brahmin/Chhetri | 125 | 68.7 |
| Janajati | 38 | 20.9 |
| Dalit | 19 | 10.4 |
| Occupation of the household head | | |
| Agriculture | 168 | 92.3 |
| Government service | 8 | 4.4 |
| Wages | 1 | 0.5 |
| Private service | 5 | 2.7 |
| Family type | | |
| Joint | 92 | 50.5 |
| Nuclear | 90 | 49.5 |
| Migration of the household member | | |
| Yes | 77 | 42.3 |
| No | 105 | 57.7 |
| Farm categories | | |
| Large scale | 71 | 39.01 |
| Small scale | 111 | 60.99 |

maturity level. Hence, they can operate better and make wiser allocation of resources, thereby increase the efficiency. As farmers grow old, they collect more experience in farming that makes them more efficient [28, 29]. The elderly farmers have a wealth of experience and therefore they are more technically efficient in production than their younger counterparts.

The schooling year of household head has a positive significant association with TE. A year increase in the schooling year of the household head increases TE by 0.7% which is significant at one percent level of significance. Similar results were reported in several related studies in Nepal and around the world [21, 23, 26, 27, 29–36]. All these studies show that an increase in schooling years of the household head reduces inefficiency. Those who are educated are better placed to receive, analyze, interpret, and show a quick response to the new information. As the household head is the major decision maker in the family, more educated household heads actively adopt new technologies such as improved seed mechanization, soil conservation, and agronomic practices, which could positively influence TE of maize seed production. Farmers with a low level of education are reluctant to adopt improved farming techniques. Such farmers provide poor supervision on their farms and are often very slow in responding to emergencies such as the outbreak of crop diseases or pests [27, 30].

Similarly, an increase in a year of experience in maize seed production will increase TE by 0.49%, which is significant at five percent level of significance. Farmers having more years of experience are better placed to acquire the knowledge and skills necessary for choosing appropriate new farm technologies over time. They can manage the field effectively and allocate the resources wisely. Experience in farming tends to increase farmers' capacity to do better. Hence, they influence TE positively and significantly [27, 36, 37]. With respect to seed source, use of the seed sourced from the National Maize Research Program (NMRP), which is the organization responsible for production of quality maize seeds and their distribution to the farmers for further multiplication, will increase the TE by 4.76% compared to those who used the seed sourced from other sources. This relationship is statistically significant at five percent level of significance.

Similarly, it is evident that the farmers who have access to extension service have higher TE by 6.62% compared to those who are not having access to extension services. The relationship is statistically significant at five percent level of significance. The informal sources of teaching and learning process through access to extension services helped farmers in updating their farming ways, hence positively influencing TE. Those farmers having access to the extension service receive better knowledge about the use of resources (inputs), technical knowledge about

Table 3: Stochastic frontier production of maize seed production.

| Variables | Coefficients | Standard error | $z$ | $P$ value |
|---|---|---|---|---|
| Log seed sown (kg/ha) | 0.29*** | 0.11 | 2.69 | 0.007 |
| Log FYM used (kg/ha) | 0.04** | 0.02 | 2.40 | 0.016 |
| Log chemical fertilizer used (kg/ha) | 0.01 | 0.01 | 1.45 | 0.146 |
| Log labor used (man-days/ha) | 0.38*** | 0.08 | 4.93 | ≤0.001 |
| Log tractor (hour/ha) | 0.01 | 0.01 | 0.95 | 0.341 |
| Log bullock (days/ha) | −0.01 | 0.01 | −0.92 | 0.357 |
| Constant | 4.41*** | 0.41 | 10.77 | ≤0.001 |
| Sigma v | 0.27 | 0.04 | | |
| Sigma u | 0.48 | 0.07 | | |
| Sigma$^2$ | 0.31 | 0.06 | | |
| Lambda | 1.78 | 0.10 | | |
| Observations | 182 | | | |
| Wald chi$^2$ (6) | 76.50 | | | |
| Prob > chi$^2$ | ≤0.001 | | | |
| Log likelihood | −87.46 | | | |

*Note*. ***and ** indicate significance at 1% and 5% levels, respectively.

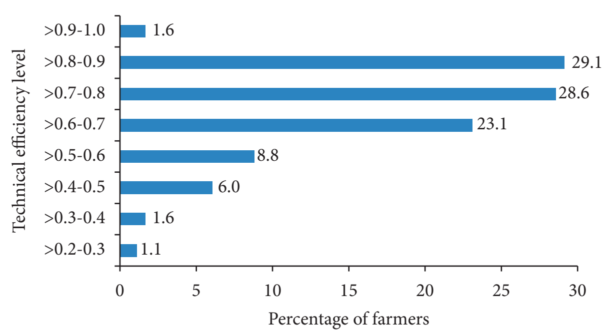


Figure 1: Farmers operating at different technical efficiency levels.

Table 4: Overall technical efficiency of maize seed production.

| Variable | Observation | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Technical efficiency | 182 | 0.71 | 0.13 | 0.25 | 0.92 |

Table 5: Factors affecting technical efficiency using the Tobit model.

| Variables | Coefficient | Standard error | $t$ value | $P$ value |
|---|---|---|---|---|
| Gender of the household head (male = 1, otherwise 0) | −0.83 | 2.26 | −0.37 | 0.713 |
| Age of the household head (year) | 0.20** | 0.08 | 2.42 | 0.017 |
| Schooling year of the household head | 0.70*** | 0.24 | 2.94 | 0.004 |
| Occupation of the household head (agriculture = 1, otherwise 0) | 1.09 | 3.48 | 0.31 | 0.754 |
| Family type (joint = 1, otherwise 0) | 0.45 | 2.21 | 0.21 | 0.838 |
| Number of educated members in household | 0.50 | 0.42 | 1.17 | 0.244 |
| Experience in maize seed production | 0.49** | 0.25 | 1.97 | 0.050 |
| Migration of the household member (yes = 1, otherwise 0) | −2.54 | 1.94 | −1.31 | 0.193 |
| Type of seed produced (foundation seed = 1, otherwise 0) | 2.52 | 3.15 | 0.80 | 0.425 |
| Seed source (NMRP = 1, otherwise 0) | 4.76** | 2.18 | 2.19 | 0.030 |
| Access to extension service (yes = 1, otherwise 0) | 6.62** | 3.10 | 2.14 | 0.034 |
| Access to credit (easy = 1, otherwise 0) | 2.67 | 2.42 | 1.11 | 0.270 |
| Membership in social groups (cooperative = 1, otherwise 0) | −3.09 | 2.16 | −1.43 | 0.155 |
| Livestock holding (yes = 1, otherwise 0) | 9.01** | 3.70 | 2.43 | 0.016 |
| Share of a maize seed cultivation area in total cultivated area (%) | 0.26** | 0.11 | 2.39 | 0.018 |
| Constant | 27.93*** | 9.32 | 3.00 | 0.003 |
| Number of observations | 182 | | | |
| LR chi$^2$(15) | 40.61 | | | |
| Prob > chi$^2$ | ≤0.001 | | | |
| Pseudo $R^2$ | 0.028 | | | |
| Log likelihood | −704.998 | | | |
| Correctly predicted | 70.97 | | | |

*Note.* ***and ** indicate significance at 1% and 5% levels, respectively.

maize seed production, and information about the market, which lead to better TE [33, 36]. Easy access to credit has a positive effect (2.67%) on TE, although statistically nonsignificant. A credit helps the farmers to purchase the required inputs and gather the required resources to prepare their land on time before planting. A credit access to farmers might act as an instrumental motivation to produce more efficiently [34].

Livestock is often integrated with farming and is an important source of soil nutrients in the mid-hills of Nepal. The farmers who hold livestock have a higher TE by 9.01% compared to those who do not. This suggests that the traditional practice of integrating farms with livestock can ensure better TE in maize seed production. An increase in the share of maize seed cultivation, which also serves as a proxy for the land area under maize seed cultivation, by 1%, will increase TE by 0.26%. Such positive relationships between production area and TE, mainly resulting from the economy of scale, were also reported by other studies [13, 23, 25, 29, 38].

## 4. Conclusions

Improved seeds support the yield increase and thereby the production of maize. Farmers involved in maize seed production in Palpa have better access to extension services. They have received a training and collected better experience in maize seed production, hence having a moderate TE (71%). There is a scope of improving the efficiency by 29% using the existing resources and technologies. Most of the farmers (29.1%) are operating at higher TE level (>0.8-0.9 level). Tobit model analysis revealed that TE has a positive significant association with the age of the household head, schooling year of the household head, experience in maize seed production, seed source, access to extension services, livestock holding, and the share of maize seed cultivation area to the total cultivated area. A wise use of existing resources and improvement of existing technologies will be more cost-effective rather than urging for new technology. The better allocation and wise use of existing resources (inputs) and technologies should be prioritized to maximize maize seed production. Hence, intervention programs should focus on improving the efficiency of existing resources through better access to extension services, motivating more educated households to involve in maize seed production, and encouraging farmers to bring more areas under maize seed production. Thus, farmers with better TE will be able to use the inputs more efficiently and maximize the production; thereby, the maize seed production will be a profitable enterprise contributing to the improvement of the economic condition and livelihood of farmers.

## Data Availability

The data used for analysis in this paper can be made available to the interested readers by the corresponding author upon request.

## Disclosure

The first author received partial research support from the Directorate of Research and Extension (DoREx), Agriculture and Forestry University (AFU), Nepal, to collect data for this study.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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