



## RESEARCH ARTICLE

## ESTIMATION OF TECHNICAL EFFICIENCY IN POTATO PRODUCTION IN SINDHUPALCHOWK DISTRICT, NEPAL: A STOCHASTIC FRONTIER ANALYSIS

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## ABSTRACT

Technical efficiency assessment plays a vital role in determining agricultural productivity, especially in circumstances where resources are scarce. As a major commercial crop in Nepal, potato (*Solanum tuberosum* L.) exhibits inadequate cultivation outcomes because of inefficient use of inputs. The Stochastic Frontier Analysis technique and Cobb-Douglas production function were used to evaluate the technical efficiency of potato farmers in Sindhupalchowk district. Similarly, a Maximum Likelihood Estimation (MLE) method was used to analyze data from 80 randomly chosen farmers for efficiency level identification and determinant identification. Mean technical efficiency levels of potato farmers in Sindhupalchowk district were found to be 74.07%, which shows that additional production output of 25.93% is possible through optimization of current farm input usage. A gamma estimation of 0.969 indicates that 96.9% of output change originates from inefficiencies which surpass random factors. The factors that significantly influence efficiency are education, which shows positive results, as well as training, with highly significant positive effects, whereas subsidy access has positive results at  $p < 0.1$ , however, age results in negative efficiency. The study demonstrates that specific interventions could enhance potato production results. To boost productivity and profitability, the policy should increase farmer training programs, while enhancing the accessibility of subsidies, and strengthening the extension service delivery. The resolution of production bottlenecks creates potential to enhance Nepalese potato cultivation, which supports national food security goals.

## KEYWORDS

Cobb-Douglas production function, Maximum Likelihood Estimation, Potato production, Stochastic Frontier Analysis, Technical efficiency

## 1. INTRODUCTION

Potato (*Solanum tuberosum* L.) cultivation stands as a primary revenue source throughout Nepal due to its AGDP contributions reaching 6.57% and its addition to national GDP totaling 2.17% (MoALD, 2020). The cultivation of potatoes occupies first position among non-cereal crops because farmers maintain 193,997 hectares of land producing about 3.11 million metric tons yearly (MoALD, 2020). The economic value of potatoes suffers from poor production efficiency because farmers continue traditional methods, while lacking modern farming tools and demonstrate inefficient resource usage (Fikadu and Mulatu, 2023). The inefficiencies related to potato cultivation as a main livelihood operation in Sindhupalchowk District create substantial yield gaps (Sapkota and Bajracharya, 2018a).

The total output that a farm generates from existing resources determines its technical efficiency level. Several academic papers reveal that agricultural production inefficiencies come from educational levels as well as training and subsidy access and extension service provision (Danso-Abbeam et al., 2018). The technical efficiency average was assessed at 79% in the mid-western Terai region of Nepal according to who determined that better input management could boost output by 21% (Lamichhane et al., 2019).

The SFA methodology with Cobb-Douglas production elements measures potato production technical efficiency in Sindhupalchowk District. The results from the analysis reveal critical determinants of inefficiency which generate useful evidence for developing policy intervention strategies.

The implementation of strategies to improve these inefficiencies will enhance productivity and enhance farmer profitability to support Nepal's national agricultural development initiatives.

## 2. LITERATURE REVIEW

Various econometric models have been applied to agricultural production efficiency studies which allow both efficiency gaps measurement and determination of efficiency-determining factors. The Nepalese economy heavily depends on potato as a cash crop, but its output faces barriers from outdated practices and limited technology access together with resource mismanagement (Onofri, 2024). The existing issues require analytical evaluation to measure potato farming efficiency and create productivity improvement solutions.

Researchers widely examine technical efficiency, which represents a farm's performance in maximizing outputs from its selected inputs in agricultural studies. Researchers use Stochastic Frontier Analysis (SFA) framework to determine efficiency and evaluate random factors that exceed farmers' control (Aigner et al., 1977). Same methodology leads to a technical efficiency of 68% in Nepalese potato farms according to research results published which signifies more than 30% output enhancement potential coming from improved input utilization (Adhikari et al., 2023). The Kenyan analysis of agricultural productivity demonstrated how the extension services enhancement, together with training and education, contributed to 78.9% average technical efficiency levels (Omache, 2016).

Research on Nepalese potato production efficiency remains minimal while

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agricultural productivity studies show that inefficiencies result from combinations of age, educational level, subsidy access and training opportunities (Thapa and Dhakal, 2024). The study conducted in Ethiopia revealed that potato production efficiency rated between 46% to be 46%, and about 17,782.43 kg of potato output per hectare was lost due to inefficiency factors, implying there is a room for improvement in technical efficiency by 54% with the present technology (Wassihun et al., 2019). The Nepalese agriculture sector faces efficiency limitations because of minimal mechanization usage, together with small land parcels, and inadequate agricultural extension services (Paudel, 2016).

The use of Cobb-Douglas Production Function provides an appropriate framework for analyzing the effect of major inputs, such as land, labor, seed, fertilizers, and farmyard manure, on productivity. Empirical observations indicated that fertilizer application and farmyard manure use increased potato yields, whereas inefficient labor allocation and lack of seed selection caused production loss (Dahal and Rijal, 2019). Furthermore, subsidy programs are said to enhance technical efficiency but depend on their effective implementation and accessibility (Thapa et al., 2023).

This study then intends to apply Stochastic Frontier Analysis with a Cobb-Douglas production function for the efficient assessment of potato farmers in Sindhupalchowk district, Nepal. The findings will help realize evidence-based policy recommendations for improved resource-use efficiency and productivity in the Nepal potato sector since the study will identify the main inefficiency determinants.

### 3. MATERIALS AND METHODS

#### 3.1 Study Site

The research took place in Sindhupalchowk district, which stands as a leading potato cultivation area for national production in Nepal. The geographic region of Sindhupalchowk district offers perfect potato farming conditions because of its landscape differences along with the suitable climate. The district faces production inefficiencies because farmers have different management practices while lacking modern inputs and dealing with labor shortages. The research studied the technical efficiency of farmers in potato cultivation within Lisankhu Pakhar Rural Municipality as potato farming is an essential livelihood practice in that area.

#### 3.2 Data Collection Methods

The study implemented a cross-sectional survey to gain data from 80 randomly chosen potato farmers by using structured questionnaire methods. The questionnaire collected extensive data about farming materials, including fields, workers, seeds, fertilizers, and manure from farmyards as well as production quantities together with farmer social and economic features. Information collection involved personal interviews together with key informant sessions and household questionnaires to maintain data reliability. The research team used pre-testing activities with a small group of farmers to test the questionnaire and enhance its reliability.

The analysis incorporated both primary data collection and secondary data obtained from government reports and agricultural extension offices and previous research studies to understand potato production trends and efficiency levels in Nepal.

#### 3.3 Data analysis

The analysis was conducted using RStudio, applying the environmental Stochastic Frontier Analysis (SFA) framework using the Cobb-Douglas production function to estimate technical efficiency. The Maximum Likelihood Estimation (MLE) method was used to derive efficiency scores and establish their determinants of inefficiency. The total error term in the model consists of a random error ( $V_i$ ), representing uncontrollable external shocks, and an inefficiency term ( $U_i$ ), capturing deviations from the production frontier. The gamma ( $\gamma$ ) value was estimated to determine the proportion of output variation attributable to inefficiency. The socio-economic determinants of efficiency include age, education, training, and access to subsidies, analyzed to see their influence on technical efficiency. Descriptive statistics also summarize the distribution of efficiency scores across farmers. The results from the analysis provide the empirical basis for policy recommendations to enhance productivity and resource efficiency in the potato sector of Nepal.

## 4. RESULT AND DISCUSSION

#### 3.1 Estimation of Technical Efficiency

Stochastic Frontier Analysis (SFA) results demonstrate that potato farmers in Sindhupalchowk display diverse efficiency ratings. The assessment of technical efficiency indicated an average of 74.07% which

demonstrates a potential 25.93% output increase through optimizing current operation while using existing inputs. A wide spectrum of efficiency results between 42.42% and 96.95% implies that potato farmers in Sindhupalchowk have different capacities to achieve production optimization. A large portion (26.25%) of farmers achieved high efficiency, while more than a tenth (13.75%) demonstrated low efficiency, less than 60%, which indicates poor resource management and insufficient farm management techniques. Similarly, A gamma value of 0.969 indicates that 96.9% of output variation is due to inefficiency rather than random factors.

Results indicate that output variations stem from inefficiencies to 96.9%. This finding matches previous research by which demonstrates inefficiencies as the primary performance factor in smallholder farming systems (Dhillon and Moncur, 2023). The results can be confirmed through and who also point out inefficiencies to be the main factor limiting agricultural productivity (Mandal et al., 2023; Endalew et al., 2023).

**Table 1: Summary of Technical Efficiency Estimates**

Efficiency Statistics	Value (%)
Mean Technical Efficiency	74.07
Minimum Efficiency Score	42.42
Maximum Efficiency Score	96.95
Farmers with Efficiency > 80%	26.25
Farmers with Efficiency < 60%	13.75

Research findings showed that all of the fertilizer ( $p < 0.05$ ), labor ( $p < 0.01$ ), and farm yard manure ( $p < 0.01$ ) had significantly contributed to input use efficiency in potato farming. Fertilizer is effective in enhancing soil fertility and thus yields (Shah & Wu, 2019), while skilled labor contributes a strong influence on efficient optimizing input productivity (Ogunyiola et al., 2025). Similarly, farmyard manure improves soil structure and long-term productivity (Bhattacharya et al., 2007).

**Table 2: Maximum Likelihood Estimates of the Stochastic Frontier Model.**

Variable	Coefficient	Standard Error	P-value
Fertilizer (kg)	0.05	0.021	0.032**
Labor (man-days)	0.14	0.037	0.004***
Farmyard Manure (t/ha)	0.09	0.029	0.006***
Seed (kg)	0.02	0.015	0.181
Farm Size (ha)	-0.01	0.024	0.673

Note: \*, \*\*, \*\*\* represent significance at the 10%, 5%, and 1% levels, respectively.

These results highlight the effect of efficiently distributing fertilizers, training laborers, and motivating advanced practices in organic soil management. Precision farming and specific advisory services can equally contribute to further enhancing productivity.

#### 4.2 Determinants of Technical Efficiency

Maximum Likelihood Estimation (MLE) results demonstrate that education level, training participation, and subsidy availability enhance technical efficiency, yet worker age decreases efficiency levels. Higher levels of education led farmers to achieve better efficiency according to the negative and statistically significant coefficient ( $p < 0.01$ ). Studies conducted showed that education serves as an essential condition which enhances resource management quality and strategic decision-making abilities (Paltasingh and Goyari, 2018; Jafari et al., 2024).

The study demonstrated that training participation strongly enhanced ( $p < 0.01$ ) efficiency levels just as whose research demonstrated that technical training results improved input management practices among farmers (Alemu, 2017). The moderate significance of subsidy coefficient ( $p < 0.1$ ) demonstrates the positive relationship between financial assistance to farmers and efficiency outcomes while program implementation quality stands as a determining factor in this connection.

The research revealed age as a negative significant factor ( $p < 0.05$ ) which showed older farmers operated with less efficiency because they tended to resist modern agricultural methods. The book chapter by support the results as younger farmers showed better efficiency levels because they adapt faster (Srinivasan and White, 2024).

**Table 3: Determinants of Technical Inefficiency**

Variable	Coefficient	Standard Error	p-value	Effect on Efficiency
Education (years)	-0.07	0.022	0.002***	Positive
Training (access)	-0.15	0.041	0.001***	Positive
Subsidy Access	-0.08	0.037	0.094*	Moderately Positive
Age (years)	0.05	0.018	0.037**	Negative

Note: \*, \*\*, \*\*\* represent significance at the 10%, 5%, and 1% levels, respectively.

Technological improvement in potato farming requires enhanced training accessibility as well as improved subsidy delivery with stronger youth participation in agricultural development.

## 5. CONCLUSION AND RECOMMENDATIONS

The research demonstrates that potato producers in Sindhupalchowk operate with a mean efficiency rate of 74.07%. Information reveals that by improving resource-use effectiveness, potato harvests can rise by 25.93% keeping all current input quantities steady. Most variations in output stem from inefficiencies because the gamma value reaches 0.969 in this analysis. The efficiency levels of potato growers in Sindhupalchowk are influenced by education level and training experience and the availability of subsidies, which increase productivity, yet age acts as a negative factor because younger farmers tend to adopt contemporary agricultural approaches better. Such results stress the requirement for specific interventions that aim to boost production efficiency.

Priority should be given to increasing farmer training programs as a means to improve technical efficiency because producers need a better understanding of input management and disease control alongside advanced cultivation techniques. The efficiency of subsidy programs will increase when appropriate accessibility combines with need-based assessments to let farmers obtain superior inputs and modern technologies. Agricultural efficiency grows when young participants join agricultural activities through business-oriented programs that integrate contemporary farming systems. Farmers need enhanced extension services together with improved market access to receive production-related information to make better decisions. These measures would lead to increased productivity together with enhanced profitability and sustained long-term potato farming in Nepal.

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