Research article

Technical Efficiency of Potato Producers in Benguet Province, Philippines

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Abstract The Benguet Province of the Philippines is endowed with distinct agroecological zones favorable for the production of high-value vegetables. Potato is one of the top ten vegetable crops in Benguet Province in terms of production area, volume, and value. However, potato production in the Philippines in general is characterized by low yield, with a yield per hectare of 15.5 tons compared to the world average yield of 20.9 tons in 2018. This study examined the technical efficiency (TE) and inefficiency determinants of potato producers in Benguet Province, Philippines. Data from 101 farmers from the major potato-producing municipalities in Benguet Province was collected in 2019. We employed the Cobb-Douglas stochastic production frontier after the null hypothesis for the translog function was rejected. The production function result revealed that land, hired labor, organic fertilizer (chicken dung) and fungicide had significant effects on potato yield. We also found that the mean technical efficiency of potato farmers is about 0.89, implying that farmers can increase their production by about 11%, with an average yield increase from 15.8 to 17.6 t/ha, using existing resources. The yield gap result further revealed that farmers are producing below the production possibility frontier. However, the observed average yield is about 50% lower than the potential yield (31 t/ha) found by Benguet State University. The inefficiency model result depicted that a larger household size, higher level of education, using the Granola potato variety, receiving training related to vegetable production, and partial irrigation significantly improve technical efficiency, while hand tractor ownership and rainfed cultivation were the major sources of technical inefficiency in potato production. In conclusion, while comprehensive plot-level studies including various parameters remain important to understanding why potato producers' yields are significantly lower than the potential yields, we recommend promoting the Granola variety along with the use of organic fertilizers and the provision of training to enhance the efficiency of producers.

Keywords potato production, technical efficiency, stochastic production function, Philippines

INTRODUCTION

Vegetable production in the Philippines shows an increasing trend in terms of total value of production compared to rice production which was the leading crop until 2020 (Department of Agriculture, 2021). The vegetable production is divided into two main classifications based on location and climatic conditions i.e., highland and lowland. Benguet province in the Cordillera Administrative Region (CAR) is the leading highland vegetable producer area endowed with distinct agroecological zones favorable to producing high-value vegetables. Potato is one of the top ten vegetables in terms of production area, volume, and high value in Benguet. Among the six regions that grow potatoes in the Philippines, CAR contributes 73% and 83% of production area and volume respectively (PSA, 2020). However, potato production is characterized by low yield in the Philippines in general is among the lowest yield per hectare (15.5 tons) compared to the world average yield (20.9 tons) in 2018. According to the JICA 2019 report, there is a reduction in the production of cabbage, cauliflower, carrots, and potatoes in Benguet province. The decrease in the area planted, extreme weather events, pest and disease problems, and low adoption of high-yielding varieties were among the main causes. In this context, only a few studies exist including the status of potato varieties (Kiswa et al., 2020); identification of potato varieties, agronomic characteristics, and potential yields (Gonzales et al., 2016). As far as our knowledge, no studies have been conducted in Benguet to investigate whether the declining production trend is attributed to the technical efficiency of producers. Therefore, this study aims to understand the extent to which potato producers can attain the utmost output from the available combination of inputs.

OBJECTIVES

The objectives of this research are as follows;
1) to estimate the technical efficiency of potato producers, and
2) to identify major sources of technical inefficiency in potato production.

METHODOLOGY

The data used in this study was collected by Benguet State University (BSU) with funding from the Department of Agriculture, Bureau of Agricultural Research (DA-BAR) in 2019, in reference to 2018 production season. Farm-level information including farm profile, facilities, input-output information, perception of recommended practices, and other variables were collected from 700 farmers (7 crops) in eight selected municipalities of Benguet Province, Cordillera Administrative Region, Luzon Island. This study used the potato data collected from 101 farmers in the Atok, Bakun, Buguias, Kibungan, and Mankayan municipalities. Multistage sampling was employed first by selecting the top five municipalities of Benguet with the largest area planted to potatoes. All the villages in the sample municipalities with areas that planted potatoes were then shortlisted from where three villages were randomly drawn.

Empirical Model

Following the neo-classical definition of technical efficiency, a production process is considered technically efficient when it attains the highest achievable output from a given combination of inputs. This study utilized the Stochastic Frontier (SF) approach, which is a parametric method for evaluating farm-level efficiency. The SF model dissects the error term into a two-sided random error that accounts for uncontrollable random effects beyond the firm's control (the decision-making unit), and a one-sided efficiency component. In this research, we adopted the model outlined by Battese and Coelli (1995), and the model specification is provided as follows:

$$Y_i = f(x_i;\beta)\exp(v_i - u_i) \quad (1)$$

where Y is the quantity of output (potato yield) on the ith firm, x is a vector of inputs (production inputs shown in Table 1) used, β is a vector of parameters, $f(x_i;\beta)$ is a suitable production function, v is a random error term assumed to be independently and identically distributed as $N(0,\sigma_u^2)$,

independent of u, which represents technical inefficiency and is identically and independently distributed as truncated normal, with truncation at zero of the normal distribution (Battese and Coelli, 1995). The maximum likelihood estimation of Eq. 1 yields an estimator for β and γ, where $\gamma = \sigma_u^2/\sigma^2$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$. The total variation of output from the frontier, which is attributed to technical inefficiency, is given by γ and has a value between zero and one. Battese and Coelli (1995) proposed a model in which the technical inefficiency effects in a stochastic production frontier are a function of other explanatory variables. In their model, the technical inefficiency effects, u are obtained by truncation (at zero) of the normal distribution with mean, $z_i\delta$ and variance σ_u^2 , such that:

$$u_i = z_i\delta \quad (2)$$

where z_i is a vector of farm-specific explanatory variables (Table 1) and δ is a vector of unknown coefficients of the farm-specific inefficiency variables.

The technical inefficiencies in Eq. 2 can only be estimated if the technical inefficiency effects, u_i are stochastic and have distributional properties (Coelli and Battese, 1995). These conditions lead to conducting different hypothesis tests using the generalized likelihood-ratio statistic, λ, given by Eq. 3.

$$\lambda = -2[\ln\{L(H_0)\} - \ln\{L(H_1)\}] \quad (3)$$

where L (H_0) and L (H_1) denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. In the end, predictions of technical efficiency scores were done as follows in Eq. 4.

$$TE_{ij} = \exp(-u_{ij}) \quad (4)$$

Summary statistics of output, input, and farm-specific explanatory variables are given in Table 1.

RESULTS AND DISCUSSION

Technical Efficiency of Potato Production

To select the accurate functional form for potato producers' technical efficiency estimation, a loglikelihood ratio test was done. The test result revealed that the Cobb-Douglas production functional form is appropriate to estimate potato technical efficiency. Moreover, gamma was computed following the Cobb-Douglas production function to confirm the presence of technical inefficiency in the stochastic frontier model. The result shows that about 25.5% of the total variation in potato production is explained by technical inefficiency. Following the lower value of the gamma, both the unrestricted (stochastic frontier model) and restricted (ordinary least square) estimations were undertaken to confirm whether the presence of technical inefficiency is significant or not. For this purpose, the loglikelihood ratio (LR) test result was generated by applying LR = -2[$L(H_0)$-$L(H_1)$][4]. The LR test result (42.68) was statistically significant at $p < 0.01$, affirming the significance of technical inefficiency in potato production. This substantiates the appropriateness of employing the stochastic frontier model to estimate potato producers' technical efficiency. Additionally, the log-likelihood of the stochastic frontier model was also statistically significant at $p < 0.01$, indicating the overall fitness of the model is robust. This suggests that the model's parameters for the variables differ significantly from zero.

The model result revealed potato productivity and the area allocated for potato production had a negative and statistically significant relationship. This implies that an increase in area allocated to potato production results in a decrease in potato productivity. This implies that a large farm size is less productive than a small farm size. On the other hand, hired person day per hectare and potato productivity had a positive and statistically significant relationship. For instance, a 1% increase in hired person day per hectare will increase potato productivity by 0.041%. Similarly, chicken dung

[4] $L(H_0)$ and $L(H_1)$ are the loglikelihoods of the unrestricted and restricted models, respectively.

per hectare had positively and significantly affected potato productivity. This means that potato productivity will be increased by 0.334% for a 1% increase in chicken dung per hectare. Moreover, the number of fungicides had a positive and statistically significant effect on potato productivity at $p<0.05$. This implies that potato producers were effectively using fungicides to protect against harmful fungal diseases that severely affect potato growth and productivity.

Table 1 Descriptive statistics and variables included in the stochastic frontier analysis

Variables	Description	Mean	Standard deviation
Potato yield	Potato yield ton/ha	15.78	12.52
Production inputs			
Land	Potato planted area in hectare (ha)	0.48	0.37
Family labor	Total family and exchange labor in person day/ha	4108.00	8108.00
Hired labor	Total hired labor person day/ha	323.88	617.49
Chemical fertilizer	Total chemical fertilizer in kg/ha	543.18	483.88
Organic fertilizer	Total chicken dung fertilizer in kg/ha	9522.81	7904.91
Insecticides	Total insecticides kg a.i.* /ha	2.33	3.44
Herbicides	Total herbicides kg a.i.* /ha	2.97	3.20
Fungicides	Total fungicides a.i.* /ha	41.84	38.13
Technical inefficiency variables			
Household size	Number of family members	4.68	2.19
Education	Number of years of schooling	9.52	3.36
Training	Dummy (1= if farmers have veg. production training, 0= No)	0.24	0.43
Potato seed variety	Dummy (1= Granola, 0= Igorota (PO_3))	0.60	0.49
Land topography	Dummy (1= hilly/undulating terraced, 0= river/flood plain)	0.82	0.38
Hand tractor ownership	Dummy (1= yes, 0= No)	0.28	0.45
Partially irrigated	Dummy (1= if farmers use partial irrigation, 0= otherwise)	0.38	0.49
Rainfed	Dummy (1= if farmers use fully rainfed, 0= otherwise)	0.63	0.48
Atok Municipality	Dummy (1= if Atok Municipality, 0= otherwise)	0.03	0.17
Bakun Municipality	Dummy (1= if Bakun Municipality, 0= otherwise)	0.10	0.30
Buguias Municipality	Dummy (1= if Bugaias Municipality, 0= otherwise)	0.39	0.49
Kibungan Municipality	Dummy (1= if Kibungan Municipality, 0= otherwise)	0.29	0.45
Mankayan Municipality	Dummy (1= if Mankayan Municipality, 0= otherwise)	0.20	0.40
Number of observations			101.00

Source: Benguate State University (BSU) in collaboration with the Department of Agriculture (DA), 2019
Note: Actual use in liters and kg/ha were converted to kg active ingredient (ai)using ai equivalent from FPA, 2021

On the other hand, herbicide and potato productivity had a negative and statistically significant relationship. This shows that more herbicide users are less likely to be efficient in potato production than their counterparts. The model result further reveals that potato productivity will be decreased by 0.076% for a 1% increase in herbicide. The technical efficiency scores result shows that the score ranges from 0.19 to 0.99 and the average score was 0.89. This shows that potato producers were producing about 11% below the average production capacity. Moreover, the distribution of technical efficiency was categorized into six groups considering statistical procedures. The result shows that about 78.2% of the technical efficiency level was 0.9 and above. Whereas, about 7.9% of the technical efficiency level was 0.8.

Factors Affecting Technical Inefficiency in Potato Production

The results in Table 2 demonstrated that various factors influenced the technical efficiency of potato production. Household size had a negative effect on the technical inefficiency of potato production, indicating that an increase in household size is associated with reduced technical inefficiency. Agricultural production, especially potato farming, is known for its labor-intensive nature. Therefore, a larger household size facilitates the demanding tasks of farm plot preparation, sowing, follow-up, and harvest. Furthermore, a larger household size plays a crucial role in lowering the costs of hiring labor and reducing the time required to find labor during peak production seasons.

Table 2 Parameter estimates of the stochastic frontier and inefficiency model

Variables	Coefficient	Std. Error	T-value	P-value
Log (Planted area)	-0.275***	0.091	-3.040	0.002
Log (Family labor)	-0.045	0.035	-1.270	0.205
Log (Hired labor)	0.042*	0.022	1.920	0.055
Log (Chemical fertilizer)	-0.018	0.030	-0.600	0.549
Log (Organic fertilizer)	0.334***	0.066	5.070	0.000
Log (Insecticide)	0.023	0.033	0.690	0.493
Log (Fungicide)	0.135**	0.062	2.180	0.029
Log (Herbicide)	-0.076***	0.034	-2.270	0.023
Constant	6.092	0.562	10.840	0.000
Technical inefficiency				
Household size	-0.739**	0.333	-2.220	0.026
Educational level	-0.429**	0.175	-2.450	0.014
Training	-1.648**	0.828	-1.990	0.047
Potato seed variety	-1.078*	0.604	-1.780	0.074
Land topography	-1.230**	0.607	-2.030	0.043
Hand tractor ownership	3.117**	1.259	2.480	0.013
Partially irrigated	-1.274**	0.553	-2.300	0.021
Rainfed	2.845**	1.355	2.100	0.036
Bakun	0.755	4.156	0.180	0.856
Buguias	0.559	4.099	0.140	0.892
Kibungan	-2.198	4.308	-0.510	0.610
Mankayan	3.226	4.006	0.810	0.421
Constant	3.942	4.581	0.860	0.389
σ_u	0.268**	0.120	2.230	0.026
σ_v	0.458***	0.035	13.180	0.000
λ	0.584***	0.126	4.640	0.000
γ				0.255
$\sigma^2 = \sigma_\mu^2 + \sigma_v^2$				0.281
Mean technical efficiency				0.898
Loglikelihood				-64.59***
-2[L(H_0)-L(H_1)				42.68***
Number of observations				101

*Source: Benguate State University (BSU) in collaboration with the Department of Agriculture (DA), 2019. *, **, *** indicate significant at 10%, 5% and 1% level respectively.*

Similarly, there is a negative and statistically significant relationship between educational level and technical inefficiency. As the educational level of the household head increases, the technical inefficiency of potato production decreases. This implies that less educated farmers exhibit greater inefficiency compared to those with higher educational attainment. This might be due to the proficiency of literate household heads in crop production and management, understanding the dynamics of production trends, and implementing yield-enhancing strategies that surpass that of less educated farmers. Likewise, a negative and statistically significant relationship occurred between training access and technical inefficiency.

Granola potato seed had a negative and statistically significant effect on the technical inefficiency of potato production. This shows that Igortoa seed users are more inefficient than Granola seed users. Moreover, the mean comparison result confirms that the mean productivity of Granola seed (16.8 tons/ha) is higher than Igorota seed (14.2 tons/ha). The cross-tabulation result depicted that about 53.16% and 46.84% of Granola and Igorota seed users' technical efficiency distribution is 0.9 and above, respectively. This shows that Granola seed users are more efficient than Igorota seed users. Therefore, the model result is congruent with the cross-tabulation and mean comparison results. Additionally, land topography had negative and statistically significant effects on the technical inefficiency of potato production. This implies that river/floodplain land topography increases potato production inefficiency more than hilly/undulating terraced land topography. This might be due to river/floodplain land topography being more susceptible to soil erosion that results in poor soil fertility. Then, poor soil fertility directly affects potato growth and productivity.

Conversely, hand tractor ownership had a positive and statistically significant effect on the technical inefficiency of potato production. This shows that hand tractor users are more inefficient

than non-users. The mean potato productivity comparison result also reveals that the mean potato productivity of hand tractor owners and non-owners was 14.3 tons/ha and 16.4 tons/ha, respectively. This result is unexpected and might be hand tractor owners renting out their tractors for better returns instead of using them for potato cultivation, or the tractor type may not be suitable for potato production. However, this requires further validation.

Whereas potato production through partial irrigation had a negative and statistically significant relationship with technical inefficiency. In contrast, rainfed production and technical inefficiency had a positive and statistically significant association. This illustrates that rainfed producers are more inefficient than fully irrigated production users. This further shows that rainfed potato production might be prone to water shortage due to drought and erratic rainfall as potato production needs more water compared to other cereal crops.

CONCLUSION

This study found that the observed average potato yield (15.8 t/ha) in Benguet province is about 50% below the potential yield found by the BSU-Northern Philippine Root Crops Research and Training Center. About 60% of producers used the Granola variety obtaining 16.8 t/ha on average and the remaining used the Igorota variety (14.2 t/ha). Besides, the estimated mean technical efficiency of potato producers was 0.89. The model result depicted that yield and technical inefficiency of potato production are determined by land size, hired labor, amount of organic fertilizer (chicken dung), agro-chemicals, household size, education level, training access, Granola variety, topography, irrigation use, and hand tractor ownership respectively. Therefore, we conclude that concerned stakeholders such as the Department of Agriculture, universities, and research institutes, among others should conduct a measured plot level study including various parameters to understand why potato producers' yield is much lower than the potential yields of the two dominantly grown varieties (Igorota variety (25-35 t/ha) and Granola (21-30 t/ha)) despite farmers' relatively efficient potato production. Furthermore, the promotion of the Granola variety, coupled with the application of organic fertilizers and the provision of training related to potato production, is essential for enhancing the efficiency of potato producers and, consequently, boosting productivity in Benguet province.

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REFERENCES

Battese, G.E. and Coelli, T. J. 1995. A model of technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics, 20, 325-332, Retrieved from DOI https://doi.org/10.1007 /BF01205442

Department of Agriculture-Brue of Agricultural Research. 2021. Philippines vegetable industry roadmap (2021-2025). Diliman, Quezon City, Philippines, Retrieved from URL https://www.pcaf.da.gov.ph/wp-content/uploads/2022/06/Philippine-Vegetable-Industry-Roadmap-2021-2025.pdf

Gonzales, I.C., Kiswa, C.G. and Bautista, A.B. 2016. Sustainable potato production in the Philippine Cordillera Region. International Journal of Engineering and Applied Sciences (IJEAS), 3 (6), 29-37, Retrieved from https://www.ijeas.org/download_data/IJEAS0306034.pdf

JICA. 2019. Survey on issue analysis of food value chain in the Philippines. Final Report, Retrieved from URL https://openjicareport.jica.go.jp/pdf/1000041342.pdf

Kiswa, C.G., Dao-ines, G.K. and Gayao, B.T. 2020. Status of introduced potato varieties in Benguet and Mountain Province, Philippines. Mountain Journal of Science and Interdisciplinary Research, 80 (1), 20-27, Retrieved from URL http://journals.bsu.edu.ph/index.php/BRJ/article/view/261/334

Philippine Statistics Authority (PSA). 2017. Consumption of Selected Agricultural Commodities in the Philippines, Volume 2. Philippine Statistics Authority, Retrieved from URL https://library.psa.gov.ph/cgi-bin/koha/opac-retrieve-file.pl?id=8c52290a940f90af6a411407883d8f3c