Jurnal Manajemen & Agribisnis, Vol. 20 No. 1, March 2023
Permalink/DOI: http://dx.doi.org/10.17358/jma.20.1.56

Available online at
http://journal.ipb.ac.id/index.php/jmagr

SUGARCANE PRODUCTION EFFICIENCY: A CASE STUDY ON PTPN X PARTNER FARMERS

Afifatur Rosidah[*)1], Irham[*)], Masyhuri[*)], Hani Perwitasari[*)]

[*)]Department of Agricultural Socio-economics, Faculty of Agriculture, Universitas Gadjah Mada
Bulaksumur, Caturtunggal, Depok District, Sleman Regency, Special Region of Yogyakarta 55281, Indonesia

Article history:

Received
28 December 2022

Revised
20 January 2023

Accepted
2 March 2023

Available online
31 March 2023

Abstract: The low production and productivity of sugarcane is a problem for the sugar industry in Indonesia, while the demand for sugar increases yearly. One of the efforts to increase sugarcane productivity is improving the efficiency of sugarcane farming. Appropriate farming efficiency and identification of inefficient resources can increase farming productivity. PTPN X, as a company engaged in the sugarcane plantation and sugar industry, obtains most raw materials from partner farmers. This study aimed 1) to determine the technical, allocative, and economic efficiency of sugarcane farming and 2) to analyze the managerial characteristics of farmers that affect the technical inefficiency of sugarcane farming. This study uses the stochastic frontier Cobb-Douglas production function approach and the dual frontier cost function. The results show that the average level of sugarcane farming's technical, allocative, and economic efficiency are 0.762; 1.315; and 0.976, respectively. The average level shows that sugarcane farming has been technical, allocative, and economically efficient. Farmers' managerial characteristic that affects technical inefficiency is the farmer's education level. The study suggests reducing the effect of inefficiency by taking higher education. Farmers with a low technical efficiency value can adopt the use of inputs by farmers with a higher value.

Keywords: technical efficiency, allocative, economic, sugarcane

Abstrak: *Rendahnya produksi dan produktivitas tebu menjadi permasalahan industri gula di Indonesia, sedangkan kebutuhan gula meningkat tiap tahunnya. Salah satu upaya peningkatan produktivitas tebu melalui peningkatan efisiensi usahatani tebu. Penilaian tingkat efisiensi usahatani yang tepat serta identifikasi sumberdaya yang inefisien dapat meningkatkan produktivitas usahatani. PTPN X sebagai perusahaan yang bergerak di bidang perkebunan tebu dan produksi gula memperoleh bahan baku tebu mayoritas dari petani mitra. Tujuan dari penelitian ini adalah 1) untuk mengetahui tingkat efisiensi teknis, alokatif, dan ekonomi usahatani tebu dan 2) untuk menganalisis karakteristik manajerial petani yang memengaruhi inefisiensi teknis usahatani tebu. Penelitian ini menggunakan pendekatan fungsi produksi stochastic frontier Cobb-Douglas dan fungsi biaya dual frontier. Hasil penelitian menunjukkan bahwa rata-rata tingkat efisiensi teknis, alokatif, dan ekonomi usahatani tebu mitra PTPN X adalah 0,762; 1,315; dan 0,976 yang menunjukkan usaha tani telah efisien secara teknis, alokatif dan ekonomi. Karakteristik manajerial petani yang memengaruhi inefisiensi teknis yaitu usia petani dan tingkat pendidikan petani. Studi ini menyarankan untuk mengurangi efek inefisiensi dengan menempuh pendidikan tinggi. Petani dengan nilai efisiensi teknis rendah dapat mengadopsi penggunaan input yang digunakan oleh petani dengan nilai efisiensi yang lebih tinggi.*

Kata kunci: *efisiensi teknis, alokatif, ekonomi, tebu*

[1] Corresponding author:
Email: afifaturrosidah@mail.ugm.ac.id

INTRODUCTION

The low production and productivity of sugarcane is a problem for the sugar industry in Indonesia, while the sugar demand increases yearly. On average, in 2016-2020, Indonesia's sugarcane production decreased by 60,600 tons per year, impacting sugar production which also decreased by 4,243 tons per year (Ditjenbun, 2022). On average, the increase in demand for sugar consumption in 2015-2021 is 70,500 tons per year. There is a deficit based on sugar cane and sugar production. The gap between national sugar demand and production reached 3.78 million tons in 2021, which will be met by imported sugar Indonesia's sugar imports in 2021 amount to 5.46 million tons (Pusdatin, 2022).

Several factors contributed to the decrease in sugarcane production, 1) inefficient production and low productivity (deplantation, 2021). Inefficient production and low productivity because of the higher proportion of ratoon canes than plant canes (Setyawati & Wibowo, 2019); (Fahriyah et al. 2018). The productivity of sugar cane in Indonesia has reached 87.4 tons/ha, which is lower than the potential productivity that can be achieved (Zainuddin & Wibowo, 2018). 2) limited availability of sugar cane land (Zainuddin et al. 2019). Reduced availability of land occurs due to competition with other food commodities in paddy fields and the conversion of agricultural land to the non-agriculture sector (Setyawati & Wibowo, 2019).

Based on the problems, to meet the demand for sugar, the holding PTPN III (persero) aims to achieve self-sufficiency in sugar consumption by increasing production in 2024 (deplantation, 2021). The government has provided investment funds to develop the national sugar industry, both on-farm and off-farm (Sulaiman et al. 2019). The PTPN III holding efforts are strengthening partnerships with farmers and solving problems to achieve efficient sugarcane production (deplantation, 2021). Increasing agricultural productivity can be done by increasing farming efficiency. Assessing the appropriate level of farming efficiency and identifying inefficient resources can increase farming productivity (Zainuddin & Wibowo, 2018). The result of this study can help farmers and PTPN III holding stakeholders to develop innovations and policies.

PTPN X is a PTPN III holding subsidiary engaged in sugarcane plantations in East Java. PTPN X contributes 32% to sugar production in PTPN III holding in 2021. Most of the sugar cane as the raw material for producing sugar in PTPN X comes from partner farmers (PTPN X, 2022). PTPN X can seek to increase sugarcane production and productivity by knowing the current efficiency level and the influence of farmer managerial characteristics on inefficiency. The partner farmers and stakeholders of PTPN X need to know the efficiency level of their sugarcane partner farming to formulate the optimal use of inputs to produce maximum and profitable output.

Technical efficiency measures the ability of a farm to obtain maximum output from a given input (Soekartawi, 2003). Assessments of technical efficiency levels can show increases in sugarcane yields of up to 20% in the Cauvery Delta region and 23% in the Northeast Zone of India through better crop management practices (Murali & Prathap, 2017). Allocative efficiency determines the ability of a farm to use inputs in optimal proportions based on input prices. Both efficiency measures (technical and allocative) can be combined to measure economic efficiency (Farrell, 1957).

The frontier production function measures the actual production against the frontier. The stochastic approach includes a mix of one-sided and two-sided errors. The stochastic approach can account for management factors that affect inefficiency. This approach also recognizes factors outside management's control, such as unfavorable climate and disrupted input supply (Darmawan, 2016). The stochastic frontier production function can facilitate efficiency analysis by modifying the model and changing the initial exponential form to a natural logarithm (Coelli et al. 2005).

Several studies on the efficiency of sugarcane farming were conducted by Murali & Prathap (2017), Zainuddin and Wibowo (2018), Zainuddin et al. (2019), Zaky et al. (2019), Permadhi et al. (2021), and Indriyani (2022). Most of these studies have not considered the potential for sugarcane production, so this research will consider the potential for sugarcane production that partner farmers can obtain. The coverage area in this study (PG Ngadirejo, PG Gempolkrep, and PG Ngadirejo) is wider than the several studies. This research can provide updated information on the efficiency level of PTPN X partner farmers. This study aimed 1) to determine the technical, allocative, and economic efficiency of sugarcane farming, and 2) to analyze the managerial characteristics of farmers that affect the technical inefficiency of sugarcane farming.

METHODS

This study uses the descriptive analytics method. Primary data with a cross-section data type were used. Location determination using a purposive method, considering PTPN X is one of Indonesia's largest state-owned sugar-producing companies. PG Ngadirejo, PG Gempolkrep, and PG Tjoekir represent PTPN X sampling areas. The three PGs have large milling capacities at PTPN X, which are 7.200; 4.150; and 6.250 Ton Cane per Day (TCD). Determination of the sample using the quota sampling method, with the criteria of transacting with PTPN X in 2021. The number of samples in this study was 105 PTPN X partner farmers consisting of 35 farmers in the PG Ngadirejo region, 35 in the PG Gempolkrep region, and 35 in the PG Tjoekir region. Data collection used structured interviews with questionnaires.

The framework of this research explains that the PTPN X partner farmers in producing sugarcane require inputs and costs. Several variables affect sugarcane production and production costs (Figure 1). Sugarcane production and production costs are analyzed with the frontier 4.1c program. The approach uses the Cobb-Douglas stochastic frontier regression with the MLE method. The output is technical, allocative, and economic efficiency. Managerial characteristics that affect technical inefficiency are processed simultaneously with the production function. Based on previous studies by Zainuddin and Wibowo (2018), Zainuddin et al. (2019), Zaky et al. (2019), and Permadhi et al. (2021), the research hypothesis is that the sugar cane farming of PTPN X partner farmers is technically efficient but not allocative and economically efficient.

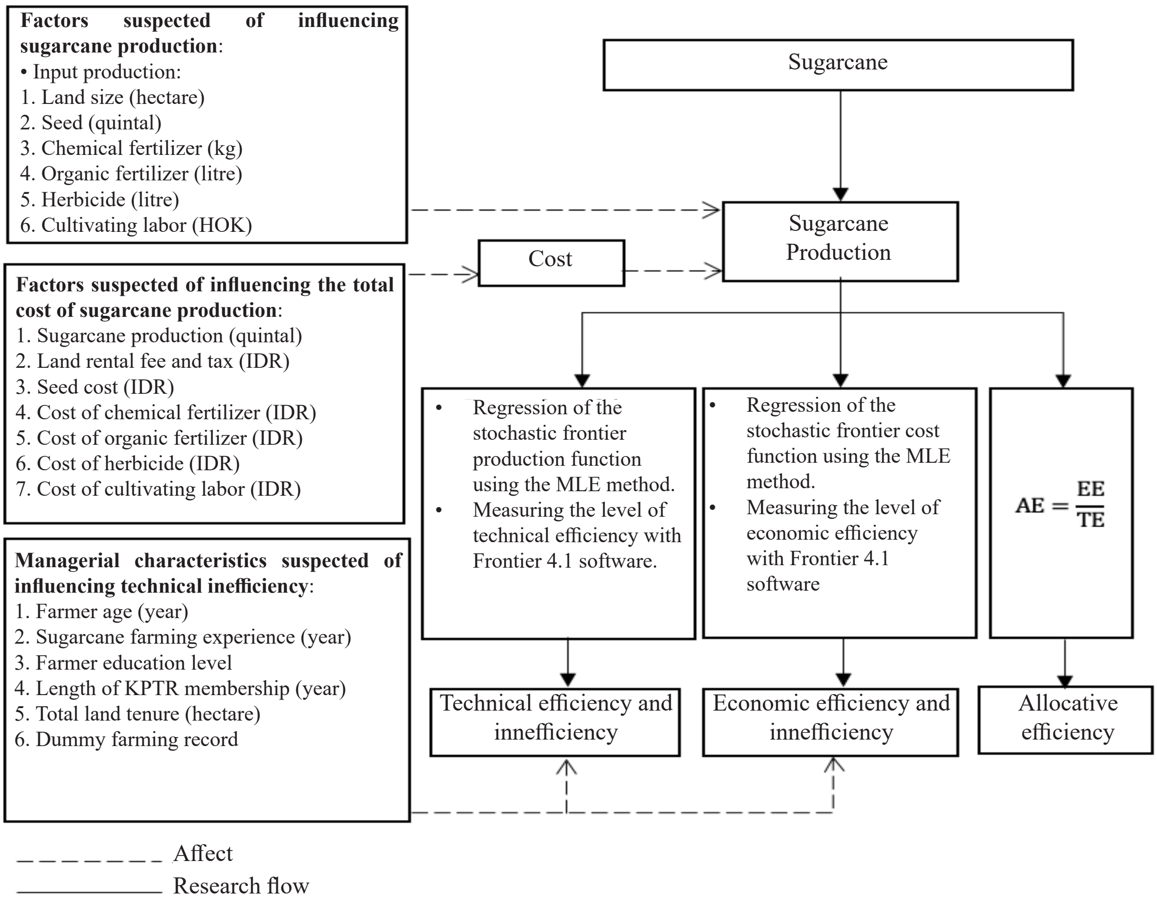

Figure 1. Research hypotheses

Production analysis is needed to analyze the factors that influence sugarcane production and the input elasticity of sugarcane production. Parameter estimation uses the Maximum Likelihood Estimation (MLE) method at 1%, 5%, and 10% errors. The function model of Cobb-Douglas stochastic frontier production in this study is as follows:

$$\ln Y = \alpha_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (v_i - u_i)$$

Where: Y (sugarcane production (quintals)), α_0 (intercept), β_1- β_6 (regression coefficient), X_1 (land size (hectares)), X_2 (seeds (quintals)), X_3 (chemical fertilizer (kg)), X_4 (organic fertilizer (liter)), X_5 (herbicide (liter)), X_6 (cultivating labor (HOK)), v_i (error from external factors that cannot be controlled), and u_i (inefficiency). The formula can measure technical efficiency analysis is (Coelli, 1998):

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(u_i, X_i)}{E(u_i = 0, X_i)} = E\,[expexp\,(\,-\,u_i)/\varepsilon_i$$

Technical efficiency (TE) values range from 0 to 1 (0≤ET≤1).

Estimating technical inefficiency function parameters using the frontier program 4.1 is processed simultaneously with the stochastic frontier production function. Parameter estimation using the MLE method at 1%, 5%, and 10% error rates. The equation model is:

$$u_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + d_1 D_1$$

Where: u_i (technical inefficiency), δ_0 (intercept), δ_1- δ_5 (regression coefficient), d_1(regression coefficient of dummy variable), Z_1(farmer age (years)), Z_2(sugarcane farming experience (years)), Z_3 (education level (years)), Z_4 (total land tenure (hectares)), Z_5(length of KPTR membership (years)), D_1(dummy recording of farming).

Estimates of potential yields of sugarcane production with farmers' technical efficiency values using stochastic. The yield potential of sugarcane uses the equation from Coelli (1998) as follows:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{exp(X_i\beta + v_i - u_i)}{exp(X_i\beta + v_i)}$$

$$\downarrow$$

$$Y_i^* = \frac{Y_i}{ET} = f(X_i;\beta)\,exp\,V_i\,)$$

Where Y_i^* is the frontier or potential output, Y_i is the actual output, and TE_i is the technical efficiency of the i-farm. Koyoe et al. (2022) use this formula to calculate the potential production of shallots in Ethiopia.

Measurement of economic efficiency with a dual cost function model. The dual cost function equation model in this study is:

$$\ln C = \alpha_0 + \theta 0 \ln Y + \theta_1 \ln P_1 + \theta_2 \ln P_2 + \theta_3 \ln P_3 + \theta_4 \ln P_4 + \theta_5 \ln P_5 + \theta_6 \ln P_6 + (v_i - u_i)$$

Where: C (total cost of sugarcane production (Rp)), α_0 (intercept), θ_0 - θ_6 (regression coefficient), Y (sugarcane production (quintals)), P_1 (rent cost and land tax (Rp)), P_2 (seed cost (Rp)), P_3 (cost of chemical fertilizer (Rp)), P_4 (cost of organic fertilizer (Rp)), P_5 (cost of herbicides (Rp)), P_6 (cost of cultivating labor (Rp)), v_i (error term from external factors that cannot be controlled), and u_i (inefficiency). The level of economic efficiency (EE) is obtained by the formula from Farrell (1957) using the frontier 4.1 program as follows:

$$EE = \frac{C^*}{C} = \frac{E(Ci|ui=0,Yi,Pi)}{E(Ci|ui,Yi,Pi)} = E\,[exp\,(u_i)/\varepsilon_i]$$

The frontier program obtains economic efficiency from the inverse of cost efficiency (CE).

$$EE = 1/CE$$

Economic efficiency values range from 0 to 1 (0 ≤ EE ≤ 1). The value of EE getting closer to 1 indicates that farming is more economically efficient. The value of allocative efficiency (AE) can be obtained using the relationship between TE, AE, and EE.

$$AE = EE/TE$$

The value of allocative efficiency is more than equal to 0. Darmawan (2016) explains that a measure of the value of allocative efficiency ≥ 0,70 is efficient.

RESULTS

Respondent Characteristics

Respondents in this study were PTPN X sugarcane partner farmers from the three sugar factory regions (Ngadirejo, Gempolkrep, and Tjoekir). Characteristics of the respondent that were considered necessary in this study included age, sugarcane farming experience, level of formal education, land tenure, membership of the People's Cane Farmers Cooperative (KPTR), and farming records. Age is one of the essential factors related to the physical ability to carry out farming activities. Older farmers are usually very conservative or less responsive to innovation. The Central Bureau of Statistics (BPS) categorizes age into two, productive age (15-64 years) and unproductive age (<15 years and >64 years). 90% of the respondents are of productive age, while 10% are unproductive (Table 1). Most respondents are of productive age, hypothesizing that farmers can produce maximum sugarcane production and productivity because they are supported by stamina, energy, and responsiveness to innovation.

The experience of working in sugarcane farming in this study is the length of time farmers have run sugarcane farming (years). Experience in farming can influence farmers in carrying out their farming activities. Farmers with more extended farming experience will be more knowledge and skills. 39% of the respondent farmers have more than 20 years of experience in sugarcane farming, 29% of farmers with 11-20 years of experience, and 32% with 1-10 years of experience (Table 1). Farmers with more extended farming experience will be more skilled at producing sugarcane.

Table 1. Farmer respondent characteristics

Farmer's Characteristics	Category	%
Farmer's age (year)	Productive (15-64)	90
	Not productive (<15 and >64)	10
Farmer's experience (year)	1-10	32
	11-20	29
	>20	39
Level of formal education	Elementary school	9
	Junior high school	11
	Senior high school	43
	Undergraduate (S1)	33
	Postgraduate (S2)	4
Total land tenure (hectare)	<1	3
	1-10	45
	11-20	32
	>20	20
KPTR membership	Member	90
	Not member	10
Farming records	Yes	52
	No	48

The education level of the respondent farmers in this study is the length of formal education (years). Farmers with higher levels of education are relatively quicker in adopting innovations (Mandang et al. 2020). The higher the farmer's education tends to be business-oriented in farming (Ahnstrom et al. 2008). The most significant percentage, 43% of respondents, had completed senior high school education, followed by 33% undergraduate (S1), 11% junior high school, 9% elementary school, and 4% postgraduate (S2). Based on the farmers' education level distribution, it can be categorized as high, so the hypothesis is that the management of sugar cane farming is more efficient.

Land tenure in this study is the total area of sugar cane cultivated by farmers, both self-ownership status, lease, and profit sharing. The land tenure can represent the scale of sugarcane farming. The wider the land used, the greater the sugar cane produced and the lower the production costs. 45% of farmers control sugarcane land in 1-10 hectares, 32% in 11-20 hectares, 20% of farmers cover more than 20 hectares, and 3% less than 1 hectare.

The People's Sugar Cane Farmers Cooperative (KPTR) is one of the institutions that carry out activities related to sugarcane agribusiness. KPTR can assist farmers in providing production inputs such as superior seeds, fertilizers, and medicines and distribute subsidized fertilizers. Some KPTRs act as a bridge between farmers and sugar factories (PG) regarding partner contract agreements and providing loans. KPTR is an effort to empower sugar cane farmers through institutional development. The participation of farmers as members of the KPTR can indirectly add to a higher bargaining power than farmers who are not. 90% of the respondent farmers are members of the KPTR, and 10% are not (Table 1).

Farmers, as decision-makers in farming, need to keep records of farming. A farming record is a tool to control the financial management of farming. The farming record in this study does not refer to a particular method of recording farming. 52% of the respondent farmers kept farming records, while 48% did not (Table 1).

Sugarcane Production and Cost Function Using MLE Method

The production function model used in this study is the stochastic frontier Cobb-Douglas production function to analyze the factors influencing sugarcane production. Parameter estimation uses the MLE method with Frontier 4.1 software. It can show the elasticity of the input. Table 2 describes the stochastic frontier regression analysis results of sugarcane farming at PTPN X.

Based on the analysis results (Table 2), the sigma squared value (σ^2) obtained 0.039 significantly. The small value indicates residual variations caused by technical inefficiencies (u_i), and error term (v_i) in the model are normally distributed. The gamma (γ) value of 0.128 significant shows that 12.8% of the variation in the model is due to technical inefficiency (u_i), while another 87.2% is due to error term (v_i). The Likelihood Ratio Test (LR) value of 13.838 exceeds the critical value (X^2_R) (Kodde & Palm, 1986) at (α=10%) is 12.737, which means that the stochastic frontier function can explain technical inefficiency. The log-likelihood function value estimated by the MLE method (21.769) is greater than the OLS method (14.850), indicating that the MLE method is suitable and can represent field conditions. Independent variables significantly influencing sugarcane production are land size, number of seeds, chemical fertilizers, and cultivating labor.

The land size significantly positively affects sugarcane production. The regression coefficient value of the land area variable is 1.078, which means that if the area of land increases by 1%, sugarcane production will increase by 1.078% *(ceteris paribus)*. The greater the land size for farming, the greater the sugarcane production. In line with research conducted by Indriyani (2022); Astuti et al. (2021), an increase in the land area will increase sugarcane production.

The seed variable (quintal) significantly negatively affects sugarcane production. The coefficient regression of seed has a value of -0.368 which means that if there is an increase in the seed of 1%, it will reduce sugarcane production by 0.368% *(ceteris paribus)*. The use of seeds in this study ranged from 4-15 tons per hectare. It did not follow the SOP recommendations for using seeds in the PTPN X area ranging from 8-10 tons per hectare. The inappropriate use of sugarcane seeds in this study will reduce the weight of the sugarcane. The analysis results in this study align with the study conducted by Rizkiyah et al. (2018) that adding seeds will reduce sugarcane production in Malang Regency East Java. The result differs from the studies conducted by Astuti et al. (2021); Zainuddin et al. (2019), that the sugarcane seed variable has no significant effect on production.

Table 2. Regression analysis result of the stochastic frontier production function of smallholder sugarcane farming partners of PTPN X

Variable	Expected sign	Regression coefficient	Standard error	t-ratio
Constant	+/-	7.220	0.588	12.283
Land size (hectares)	+	1.078***	0.120	8.978
Seeds (quintals)	+	-0.368***	0.110	-3.321
Chemical fertilizer (kg)	+	0.200***	0.046	4.388
Organic fertilizer (liters)	+	0.001ns	0.002	0.825
Herbicide (liters)	+	-0.004ns	0.004	-1.041
Cultivating labor (HOK)	+	0.067**	0.034	1.998
Sigma squared (σ^2)		0.039***	0.019	3.066
Gamma (γ)		0.128***	0.153	5.338
LR test of the one-sided error		13.838		
Number of restrictions		(8)		
MLE likelihood function logs		21.769		
Log-likelihood function OLS		14.850		

Information: ***) significant at α=1% **) significant at α = 5%; ns) is not significant; X^2_R significant value at (α=10%) = 12.737 (Kodde and Palm, 1986)

Chemical fertilizer (kg) significantly positively affects sugarcane production. The regression coefficient of the chemical fertilizer variable in this study is valuable at 0.200, which means that if there is an increase in the use of chemical fertilizers by 1%, it will increase sugarcane production by 0.200% *(ceteris paribus)*. Each farmer uses different types and quantities of chemical fertilizers, so this study was categorized as chemical fertilizers. In line with previous studies by Felix et al. (2021), 1% increase in fertilizer use will increase sugarcane production by 0.187% in India. Zainuddin and Wibowo (2018) showed that adding 1% chemical/inorganic fertilizer could increase sugarcane production by 0.056% at PTPN X Kediri Region.

The cultivating labor variable (HOK) has a significant positive effect at 5%. The value of the regression coefficient of the cultivating labor variable is 0.067, which means an increase in cultivating labor by 1%, will increase sugarcane production by 0.067% *(ceteris paribus)*. The correct number of cultivators for sugar cane farming can provide optimal results. The increase in cultivating labor in this study will impact increasing sugarcane production. The analysis results in this study align with the study conducted by Astuti et al. (2021), which states that adding labor workers can increase sugarcane production by 0.588% in smallholder sugarcane farming in North Lampung Regency. Zainuddin and Wibowo (2018) state that a 1% increase in labor will increase sugarcane production by 30.5% and 0.009%. Murali and Prathap (2017) and Purnamasari et al. (2018) also stated the same.

The stochastic frontier cost function model analyses the factors affecting sugarcane production's total cost. Parameter estimation uses the maximum likelihood estimation (MLE) method with Frontier 4.1 software. Table 3 describes the regression analysis results of the stochastic frontier cost function. The sigma squared (σ^2) value is obtained, which is low at 0,012, significantly indicating residual variation caused by inefficiency (u_i) and error term (v_i) are normally distributed. The gamma (ɣ) value is 0.022, which is insignificant, so the proportion of error caused by inefficiency to the deviation caused by the error term in the model cannot be known. The Likelihood Ratio Test (LR) value of 6.566 is less than the critical value χ^2_R with the *number of restrictions* (8) (Kodde and Palm, 1986) at α 10% is 12.737, which means that the stochastic frontier cost function cannot explain the cost inefficiency in the model.

Table 3. Regression analysis result of the stochastic frontier cost function of smallholder sugarcane farming partners of PTPN X

Variable	Expected sign	Regression coefficient	Standard error	t-ratio
Constant	+/-	3.077	0.261	11.766
Sugarcane production (quintals)	+	0.155***	0.031	5.006
The land rental fee and tax (Rp)	+	0.163***	0.006	25.019
Cost of Seed (Rp)	+	0.286***	0.033	8.555
Cost of chemical fertilizer (Rp)	+	0.223**	0.015	15.097
Cost of organic fertilizer (Rp)	+	0.002**	0.000	2.412
Cost of herbicide (Rp)	+	0.002**	0.001	2.262
Cost of cultivating labor (Rp)	+	0.167***	0.018	9.075
Sigma squared (σ2)		0.012***	0.001	10.682
Gamma (ɣ)		0.022ns	0.041	0.532
LR test of the one-sided error		6.566		
Number of restrictions		(8)		
MLE likelihood function logs		83.195		
Log-likelihood function OLS		79.991		

Information: ***) significant at α=1% **) significant at α = 5%; ns) is not significant; χ^2_R significant value at (α=10%) = 12,737 (Kodde and Palm, 1986)

The value of the log-likelihood function estimated by the MLE method (83.195) is greater than the value of the log-likelihood function estimated by the OLS method (79.991), which means that the production function by the MLE method is good and can represent field conditions (Coelli et al. 2005). The independent variables that significantly affect the total sugarcane production cost are sugarcane production, land rental, and tax, cost of seed, cost of chemical fertilizer, cost of organic fertilizer, cost of herbicide, and cost of cultivating labor.

The sugarcane production variable (quintal) has a significantly positive effect at the 99% level. The regression coefficient value is 0.181, meaning that an increase in production of 1% will affect the total cost of sugarcane production by 0.181% *(ceteris paribus)*. Higher sugarcane production is associated with input use, so the effect on input costs incurred is also more.

The land rent and tax (Rp) variable has a significant positive effect. The regression coefficient of the variable cost of land rent and tax is 0.163, which means that an increase in the cost of rent and land tax by 1% will increase the total cost by 0.163% *(ceteris paribus).* The land costs incurred by the respondent farmers are related to the ownership status of the land. The land cost under the lease will be greater than owning land because renting land is expensive. The cost incurred by farmers when using their land is the land tax, which nominal value is much lower than the rental fee.

The cost of seed variable (Rp) has a significant positive. The regression coefficient of the variable seed costs is 0.286, which indicates that if there is an increase in the cost of seeds by 1%, the total cost will increase by 0.286% *(ceteris paribus).* The price of seeds per quintal used by the respondent farmers is relatively the same, so the cost incurred by farmers in this study is only related to the number of seeds used. Based on the results of the regression of the stochastic frontier production function discussed before, the addition of seeds will result in a decrease in sugarcane production. Excessive sugarcane seeds not following the SOP results in higher costs and decreased production.

The regression coefficient of chemical fertilizer value is equal to 0.223 significant positive, which means that every 1% increase in the price of chemical fertilizers will increase the total cost by 0.223% *(ceteris paribus).* The high or low costs incurred by farmers to buy chemical fertilizers are influenced by the number of chemical fertilizers, fluctuations in market prices, and the type of fertilizer. In 2021 there was quite a high increase in the price of chemical fertilizers, both subsidized and non-subsidized (CNBC Indonesia, 2021); (CNN Indonesia, 2021), so there were farmers who bought fertilizer at high prices at that time. Some farmers buy fertilizer at standard prices without being affected by the increase in fertilizer prices in 2021 because these farmers bought fertilizer before the price increase occurred.

The regression coefficient value of the organic fertilizer variable is 0.002, which has a significant positive meaning that every 1% increase in the cost of organic fertilizer will increase the total production cost by 0.002%. The coefficient value is small, so the effect of the increase in organic fertilizer costs is small on the total sugarcane production costs incurred by farmers. Only some partner farmers in this study use organic fertilizers for sugarcane cultivation.

The herbicide cost variable (Rp) has a regression coefficient value of 0.002, which means that every 1% increase in herbicide costs will increase the total production cost by 0.002% *(ceteris paribus).* The small coefficient is because some respondent farmers use herbicides to destroy the weeds around the cultivated sugarcane. However, some farmers do not use herbicides because the grass that grows will be used as animal feed by local breeders. Based on this, there is a difference in the cost of buying herbicides by farmers. Both methods can eradicate the grass that grows around the sugarcane plants, but farmers whose local breeders assist in weeding the grass will benefit more because they do not incur the cost of buying herbicides. The average price of herbicides the farmers use per hectare is IDR 705,182.

The cost of cultivating labor (Rp) has a significant positive effect on the total cost. The variable regression coefficient of cultivating labor costs is 0.167, which means that an increase in labor costs of 1% will increase the total cost of production by 0.167% *(ceteris paribus).* The labor cost for cultivating varies depending on the type of work, the amount of labor employed, and the wage standards of local farm workers.

Technical, Allocative, and Economic Efficiency

The technical efficiency of sugarcane farming is the ability of a farm to obtain maximum output from inputs. The level of technical efficiency of sugarcane production in this study was analyzed using frontier 4.1 software. The results of the analysis of the level of technical, allocative, and economic efficiency of sugarcane partner farmers of PTPN X are presented in Table 4.

The average value of technical efficiency was 0.762, with the highest value being 0.958 and the lowest value being 0.478. Based on the average technical efficiency value of 0.926, greater than 0.70, sugarcane partner farmers in this study have been technically efficient. Based on the average value of technical efficiency, sugarcane farming at PTPN X has realized 76.2% of the potential value of sugarcane production on existing resources and technology. Increasing output by around 23.8% is still possible by providing inputs at a specific size. 14% of the total respondent farmers got technical efficiency values in the range of (0.90-0.99), 30% (0.80-0.89), 22% (0.70-0.79), and 24% (0.60-0.69). Based on the distribution of technical efficiency in Table 4, 66% of farmers have a technical efficiency value of more than 0.70, and the other 34% have less than 0.70.

Table 4. Distribution of technical, allocative, and economic efficiency of smallholder sugarcane farming partners of PTPN X

Range	Efficiency (%)		
	Technical	Allocative	Economic
≥ 1.00	0	99	1
0.90 – 0.99	14	1	98
0.80 – 0.89	30	0	1
0.70 – 0.79	22	0	0
0.60 – 0.69	24	0	0
0.50 – 0.69	8	0	0
≤ 0.49	2	0	0
Amount	100	100	100
Average	0.762	1.315	0.976
Maximum	0.958	2.082	1.000
Minimum	0.478	0.961	0.885

The average value of technical efficiency obtained in this study is smaller than the efficiency value obtained by Astuti et al. (2021) at 96% on the first cane, Yusuf et al. (2020) at 0.962 for the plant cane and 0.946 for the ratoon cane in state-owned cane in East Java. Zainuddin et al. (2019) at 93%, Zainuddin and Wibowo (2018) of 0.77 at PTPN X Kediri region, Purnamasari et al. (2018) at 0.887 in Mojokerto, East Java. Murali and Prathap (2017) obtained an average value of technical efficiency of sugarcane farming in Tamil Nadu, India of 82%. Although the mean technical efficiency in this study has a smaller value than in the previous study, the sugarcane partner farmers of PTPN X were efficient. However, the technical efficiency score was close to the benchmark (0.70). It means that the partner farmers can obtain maximum output from user inputs. The cause of the low value is the use of organic fertilizer input, which is very large, but the effect of organic fertilizer is relatively low in sugarcane production.

The allocative efficiency of sugarcane farming illustrates its ability to use inputs at an optimal proportion based on the price. The average value of allocative efficiency of smallholder sugarcane farming partners of PTPN X is 1.315, with the lowest score being 0,961 and the highest being 2.082. Based on table 4.99% of total farmers get allocative efficiency values ≥ 1.00, while the value of the other 1% of farmers is in the range of 0.90 – 0.99. The values of allocative efficiency are greater than 0,70 (efficient), which means the partner farmers of PTPN X can use inputs in optimal proportions based on the price. The average allocative efficiency value is higher than Zainuddin & Wibowo (2018), which is 0.60. If the average value of allocative efficiency is to achieve the highest, it must save 36.84% (1-(1.315/2.082)). If the lowest allocative efficiency value is to achieve the highest, it must save 53.84% (1-(0.961/2.082)).

Economic efficiency is a combination of technical and allocative efficiency. The economic efficiency of sugarcane farming shows that the farming has produced maximum output using inputs and low prices. The average value of economic efficiency is 0.976, with the highest economic efficiency being 1.000, while the lowest is 0.885. 1% of farmers get economic efficiency values ≥ 1.00. 98% of farmer's values in the range of 0.90-0.99, and 1% in the range of 0.80-0.89. Based on the average value and distribution of economic efficiency values greater than 0.70, farming at PTPN X can be categorized as economically efficient. It means the partner farmers of PTPN X have produced maximum output using inputs and low prices. The average value of economic efficiency is greater than Zainuddin & Wibowo's (2018) study, which is 0.45. If the average farm can obtain the maximum economic efficiency value in this region, then the farm can realize savings of 2.4% (1-(0.976/1.000)). If the farm with the lowest value can obtain the maximum economic efficiency value in this region, then the farm has saved costs of 11.5% (1-(0.885/1.000)).

Managerial Characteristics Affecting the Technical Inefficiency of Sugarcane Farming

Table 5 describes the managerial characteristics that affect technical inefficiency. A variable that has a significant effect on inefficiency is the education level of the farmer. The coefficient of the farmer's education level is -0.028, which indicates that the higher the farmer's education level, the lower the technical inefficiency of the sugarcane farming of PTPN X's partner farmers. The education level of the respondent farmers in this study can be categorized as high, 42.8% of farmers have a senior high school education, and 37.1% of farmers have higher education from undergraduate to postgraduate levels. The higher the farmer's education, the easier for farmers to adopt innovations, seek information and apply their knowledge in sugarcane farming. In line with the study conducted by Murali & Prathap (2017), the higher education level of farmers can reduce the inefficiency of sugarcane farming in India. Zainuddin et al. (2019) also stated that farmers' education level could reduce the inefficiency of sugarcane farming at PTPN X.

Potential Production of Sugarcane Based on Technical Efficiency Value

Based on the potential production yield formula, a comparative calculation of sugarcane production due to technical inefficiencies is obtained in Table 6. The average actual sugarcane output is 1.075 quintals per hectare. The average technical efficiency value is 0.762. A potential output of 1.410 quintals per hectare is obtained. It shows that the average sugarcane production of PTPN X partner farmers is less than their yield potential. There are opportunities to increase sugarcane productivity by minimizing the effects of inefficiencies at the existing resource and technology levels. The difference between the average actual production and the average potential production is 336 quintals. The large difference between actual and potential output is an opportunity for farmers to increase their productivity.

Potential productivity can be obtained by reducing the effect of inefficiency and doing better cultivation. In addition to reducing inefficiency, there are more recent sugarcane cultivation methods to increase sugarcane productivity. The ring pit method of sugarcane farming in India significantly saves irrigation water and increases yield. Using hole diggers developed in the ring pit method can increase profits (Singh et al. 2016). Mishra (2019) revealed that the use of the bud chip method was able to increase sugarcane productivity by 37.3% higher than the use of conventional methods. Zainuddin & Wibowo (2018) stated that the bud chip method is more technically efficient than conventional methods. Some of these methods can be adopted to increase the productivity of sugarcane intensification.

Table 5. Results of analysis of managerial characteristics that influence the technical inefficiency of smallholder sugarcane farming partners of PTPN X

Variable	Expected sign	Regression coefficient	Standard error	t-ratio
Constant	+/-	1.040	0.327	3.181
Farmer's age	-	0.010^{ns}	0.006	1.645
Farmer's experience	-	-0.004^{ns}	0.007	-0.507
Level of education	-	-0.028^{*}	0.015	-1.878
Total land tenure	-	-0.000^{ns}	0.000	-0.684
Length of KPTR membership	-	-0.002^{ns}	0.006	-0.266
Farming records	-	-0.020^{ns}	0.074	-0.271

Information: *) significant at α = 5%; ^{ns}) is not significant

Table 6. The difference in sugarcane productivity is due to technical inefficiencies

Variable	Min	Max	Mean
Actual yield (quintals/hectare)	433.3	1857.1	1074.5
TE estimates	0.478	0.958	0.762
Potential/frontier yield (quintals/hectare)	906	1939	1410
Yield gap/loss (quintals/hectare)	473	81	336

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The land area variable is the most responsive, so extensification is a fast way to increase sugarcane production. The number of seeds negatively impacts sugarcane production, so reducing the number of seeds will increase production. The addition of chemical fertilizers and the amount of labor will increase sugarcane production. The cost of rent/land tax, the cost of seeds, the cost of chemical fertilizers, the cost of organic fertilizer, the cost of working labor, and production affect the total sugarcane production. The addition of these input costs will increase the total cost of production. The technical, allocative, and economic efficiency levels of PTPN X's sugarcane farming partners are 0,926, 1,035, and 0,969, indicating that farming has been efficient. Farmers' managerial characteristic that influences technical inefficiency is the farmer's education level. This study's results differ from previous studies, which stated that sugarcane farming was technically efficient but not allocative and economically efficient.

Recommendations

Increasing the sugarcane production of PTPN X partner farmers can be conducted by increasing the area of arable land, increasing the use of chemical fertilizers, cultivating labor, and reducing the use of sugarcane seeds. The effect of technical inefficiency has a low effect, but increasing the efficiency of sugarcane farming can be done by reducing the effect of inefficiency, namely by attending training or taking higher education. Farmers with a low technical efficiency value can adopt the use of inputs (seeds, chemical fertilizers, organic fertilizers, herbicides, and cultivating labor) by farmers with a higher technical efficiency value.

FUNDING STATEMENT: This research did not receive any specific grant from funding agencies in the public, commercial, or not - for - profit sectors.

CONFLICTS OF INTEREST: The authors declare no conflict of interest.

REFERENCES

Ahnstrom JH, Bergea JHL, Francis CA, Skelton P, Hallgren L. 2008. Environmental knowledge, attitude, and awareness of farmers in Chencha Woreda, Gamo Gofa Zone, South Ethiopia. *International Journal of Scientific and Research Publications* 7(1):69–76.

Astuti TN, Prasmatiwi FE, Murniati K. 2021. Efisiensi teknis usahatani tebu rakyat dengan pendekatan stochastic frontier di kabupaten lampung utara. *Jornal of Food System and Agribusiness* 5(2): 156–165. https://doi.org/10.25181/jofsa.v5i2.1952

CNBC Indonesia. 2021. Harga pupuk subsidi 2021 naik, pemerintah hemat Rp 2,7 T. https://www.cnbcindonesia.com/news/20210118125827-4-216854/harga-pupuk-subsidi-2021-naik-pemerintah-hemat-rp-27-t [15 Des 2022].

CNN Indonesia. 2021. Harga pupuk non subsidi naik. https://www.cnnindonesia.com/ekonomi/20211101063020-92-714781/harga-pupuk-non-subsidi-naik [15 Des 2022].

Coelli TJ, Rao DSP, Battese GE. 1998. *Introduction to Efficiency and Productivity Analysis.* Boston:Kluwer Academic Publisher. https://doi.org/10.1007/978-1-4615-5493-6

Coelli TJ, Rao DSP, O'Donnell CJ, Batesse GE. [2005]. *An Introduction to Efficiency and Productivity Analysis. Second edition*. Springer Science-i-Business Media, Inc. New York.

Darmawan DP. 2016. *Pengukuran Efisiensi Produktif Menggunakan Pendekatan Stochastic Frontier.* Yogyakarta: Elmatera.

deplantation 2021 Sep. Strategi Holding PTPN

III (Persero) Mewujudkan Kemandirian Gula Nasional 2024. https://deplantation.com/berita/2021/09/strategi-holding-ptpn-iii-persero-mewujudkan-kemandirian-gula-nasional-2024/. [1 Agustus 2022].

Ditjenbun. 2022. *Statistik Perkebunan Unggulan Nasional 2020-2022*. Jakarta: Kementerian Pertanian.

Fahriyah, Hanani N, Koestiono D, Syafrial. 2018. Analisis efisiensi teknis usahatani tebu lahan sawah dan lahan kering dengan pendekatan data envelopment analysis (DEA). *Jurnal Ekonomi Pertanian dan Agribisnis* 2(1):77–82. https://doi.org/10.21776/ub.jepa.2018.002.01.8

Farrel MJ. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society* 120 (3): 253–290. https://doi.org/10.2307/2343100

Felix KT, Kumar PN, Arivarasan S. 2021. Technical-and-allocative inefficiency index of indian sugarcane farms- a primal system approach. *Environmental and Sustainability Indicators*. 11(2021):1–9. https://doi.org/10.1016/j.indic.2021.100133

Indriyani I. 2022. Analisis Efisiensi Penggunaan Faktor Usahatani Tebu (Saccharum officinarum). *Jurnal Ilmiah Mahasiswa Pertaian (JIMTANI)*. 2(2).

Kodde DA, Palm FC. 1986. Wald criteria for jointly testing equality and inequality restrictions. *Econometric* 54: 1243–1248. https://doi.org/10.2307/1912331

Koyoe TD, Koye AD, Amsalu ZA. 2022. Analysis of Technical Efficiency of Irrigated Onion (Allium cepa L.) Production in North Gondar Zone of Amhara Regional State, Ethiopia. *PLoS ONE* 17(10):1–12. https://doi.org/10.1371/journal.pone.0275177

Mishra K. 2019. Evaluation of bud chip method for enhancing yield and economics of sugarcane. *International Journal of Chemical Studies* 7(3): 1726–1729.

Murali P, Prathap D. Puthira. 2017. Technical efficiency of sugarcane farms: an econometric analysis. *Sugar Tech* 19(2): 109–116. https://doi.org/10.1007/s12355-016-0456-8

Permadhi D, Dianpratiwi T. 2021. Efisiensi usahatani tebu rakyat lahan sawah kategori tanaman pc (plant cane) (studi kasus: wilayah kerja PG Gempolkrep, PTPN X). *Jurnal Ekonomi Pertanian dan Agribisnis (JEPA)* 5(2): 361-376. https://doi.org/10.21776/ub.jepa.2021.005.02.08

PT Perkebunan Nusantara X. 2022. Profil dan Produksi Gula PTPN X. http://ptpn10.co.id [5 Agustus 2022].

Purnamasari I, Hanani AN, Suhartini. 2018. Technical Efficiency Analysis of Sugarcane Farming in East Java Indonesia. *Agricultural Socio-Economics Journal* 18(1): 23–29. https://doi.org/10.21776/ub.agrise.2018.018.1.4

Rizkiyah N, Koestiono D, Setiawan B, Hanani N. 2018. Studi Efisiensi Teknis Usahatani Tebu Tanam Awal dan Tebu Keprasan di Kabupaten Malang. *Seminar Nasional Dalam Rangka Dies Natalis UNS Ke-42*. 2(1).

Setyawati IK, Wibowo R. 2019. Efisiensi Teknis Produksi Usahatani Tebu Plant Cane dan Tebu Ratoon Cane. *JSEP (Journal of Social and Agricultural Economics)* 12(1): 80–88.

Sulaiman AA, Sulaeman Y, Mustikasari N, Nursyamsi D, Syakir AM. 2019. Increasing Sugar Production in Indonesia through Land Sustainability Analysis and Sugar Mill Restructuring. *Land* 8(4): 1–17.

Singh AK, Sharma MP, Gupta R. 2016. Development of Tractor-Operated Double Bottom Pit Digger for Mechanizing Ring Pit Method of Sugarcane Planting. *Sugar Tech* 19: 10–516.

Soekartawi. 2003. *Teori Ekonomi Produksi dengan Pokok Bahasan Analisis Fungsi Cobb-Douglas*. Jakarta: PT Raja Grafindo Persada.

Yusuf MT, Jamhari, Irham. 2020. Technical Efficiency of State-Owned Sugarcane Production in East Java. *Agro Ekonomi* 31(1): 1–15.

Zainuddin A, Wibowo R. 2018. Analisis potensi produksi tebu dengan pendekatan fungsi produksi frontir di PT Perkebunan Nusantara X. *Artikel Pangan* 27(1).

Zainuddin A, Wibowo R, Setyawati IK. 2019. Evaluation of bud chip method to increase sugarcane productivity (case study of PT Perkebunan Nusantara X). *Jurnal Manajemen dan Agribisnis* 16(3):201–212.

Zaky Y, Pambudy R, Harianto, 2019. Analisis efisiensi usahatani tebu petani mitra dan non mitra di Kabupaten Blora Jawa Tengah. *Forum Agribisnis* 9(1): 85-106.

Mandang, Miranda, Sondakh MFL, Laoh OEH. 2020. Karakteristik petani berlahan sempit di Kecamatan Tompaso. *Agri-SosioEkonomi Unsrat* 16(1): 105–114.