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Technical Efficiency and Cost Reduction in Pineapple Cultivation: A Study on the Pineapple Growers of North Bengal

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Abstract

North Bengal accounts for approximately 80% of the state's pineapple area and production, accounting for nearly one-fifth of the country's 1.8 million tonnes yield. Despite this spectacular yield, the government does not reap the full benefits of international market conquest and the informal nature of sub-regional trade. Our study estimated the technical efficiencies of pineapple growers in North Bengal and identified some socioeconomic factors that influence them to maximize the benefits of pineapple production. The stochastic frontier production function approach with a cobb-Douglas production function was used to estimate pineapple producers' technical efficiencies, while the inefficiency model was used to determine the socioeconomic factors influencing technical efficiencies. Results showed 65.85% to 96.75% technical efficiency, with a mean of 84.25%, indicating that pineapple output was 15.75% short of the maximum. Production factors such as land, labour, fertilizer, and plant density positively and significantly impact pineapple output variability. The study suggests that improving efficiency necessitates policy intervention, primarily in education, marketing, credit accessibility, and infrastructural development.

***Key words*:** Pineapple, Cultivation, Technical efficiency, Cost reduction, Growers

Pineapple is an important commercial horticulture fruit crop in India. It is abundantly grown in the North-Eastern region (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura), West Bengal, Kerala, Karnataka, Bihar, Goa, and Maharashtra. The total annual global production of pineapple is expected to be 27.92 million tonnes [1]. India is the world's sixth-largest pineapple producer, with an annual output of 1.8 million tonnes [2]. India's position in terms of harvested area of pineapple (1,11,000 ha) is first among the Asian and BRICS countries [3]. According to the Ministry of Agriculture (2021-22), West Bengal is the leading producer of pineapple in India, producing 356.32 metric tonnes (MT), followed by Assam (338.98 MT) and Karnataka (169.54 MT), among others. Although Assam has the most pineapple land, Karnataka and West Bengal have the highest productivity in India [4]. With an average annual production of more than 6.2 lakh metric tonnes, Three North Bengal districts, Darjeeling, Jalpaiguri, and Uttar (North) Dinajpur, contribute approximately 80% of both pineapple area and production in the state [5] accounting for nearly one-fifth of the country's 1.8 million tonnes yield [6]. Despite this dazzling output, the government does not benefit sufficiently as a result of international market conquest and the informal nature of sub-regional trade. The main issues that pineapple growers face is declining income due to high production costs, particularly fertilizer, inefficiency, lack of support, and land for pineapple cultivation. States' productivity is far below potential. The average pineapple productivity is 19 MT/ha per year, with a potential productivity of 50-60 MT/ha per year [7]. This emphasizes the importance of increasing pineapple productivity. To benefit more from pineapple production, and considering the scarcity of resources, globalization of economies marked by competition among nations, a lack of technical support to producers, and this new sector introduced in the producer farming system since the end of the 1990s, it appears necessary to conduct a technical efficiency analysis of pineapple production in West Bengal. Improving the efficiency of input used is one of the strategies that can be used to increase productivity. The study's goal was to estimate pineapple growers' current level of technical efficiency and to identify the factors that contribute to inefficiency. As a result, policy measures to increase technical efficiency and thus productivity must be developed.

MATERIALS AND METHODS

Study area and data collection

The research was carried out in two districts of North Bengal: Darjeeling and North Dinajpur. Primary data were gathered from farmers in the area who specialize in pineapple

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cultivation. To select respondents, a convenient and purposeful sampling technique was used. Darjeeling District had 52 respondents, while North Dinajpur had 50. The study used structured questionnaires as a tool to engage with farmers in the form of interviews, keeping in mind the farmers' literacy gap. Production and input data were gathered to estimate the level of technical efficiency. Farmers' socioeconomic data were also collected in order to identify the factors influencing technical inefficiency.

Analytical methods

An individual farmer's Technical Efficiency (TE) is defined as "the ratio of the observed output to the corresponding frontier output, conditioned on the level of inputs used by the pineapple grower." The amount by which the farm's level of production is less than the frontier output is thus defined as technical inefficiency. This research focuses on a stochastic frontier approach (SFA) with maximum likelihood [8]. A production function is used to assess technical efficiency. The model is:

$$Y_i = f(Xi\beta) + (V_i - U_i), \text{ where, } i = 1, 2, 3, \ldots\ldots\ldots\ldots, n$$

Y_i = Production, f (Xiβ) = Suitable Production Function (Either Cobb-Douglas or translog), X_i = i^{th} farm's input quantities, β= Parameter to be estimated, $(V_i – U_i)$ = Composed Error, V_i = Error of random factors, it's variance distribution is normal i.e., N (0, $\sigma^2{}_v$) U_i = Positive random variable which leads to i^{th} farm technical inefficiency and independently distributed as N (0, $\sigma^2 U$).

The error term in the stochastic frontier model is divided into two parts. The stochastic frontier production function model allows for the specification of two equations. One equation specifies the main factors of production, while the other specifies the variables that are assumed to cause inefficiency. Technical inefficiency effects, according to Battese and Coelli [9], are defined as:

$$U_i = Z_i\delta_i + W_i, \text{ where } i = 1, 2, 3, \ldots\ldots\ldots\ldots\ldots, n,$$

Z_i = Factors responsible for inefficiency, δ_i = unknown parameter vector to be estimated, W_i = Unobservable random variables with identical distributions obtained by truncating the normal distribution with mean zero and unknown variance, such that Ui is positive.

A two-stage process was used to estimate TE in this case. The first step was to calculate efficiency using a frontier production function. The second step was to identify the socioeconomic factors that influence levels of technical inefficiency. From estimated stochastic production frontiers, the software predicts individual growers' technical efficiencies. The technical efficiency measures in relation to the production frontier are as follows:

$$TE = Y_i / Y_i^*, \text{ where, } Y_i = f(Xi\beta) + (V_i - U_i), \text{ and } Y_i^* = f(Xi\beta),$$

the Maximum predicted value of the firm.

Technical efficiency of the i^{th} farm (TE_i) = Exp ($-U_i$). TE_i will be assigned a value between zero and one in the case of a production frontier. As a result, technical inefficiency = 1 – TE_i. Hence, the technical inefficiency will lie between 0 to 1.

The likelihood-ratio test is used to determine the model's significance. The likelihood function is expressed in terms of the total variance of the composite error $\sigma_s^2 = \sigma_v^2 + \sigma_u^2$, and the variance of U_i is $\gamma = \sigma_u^2 / \sigma_s^2$ So that $0 \le \gamma \le 1$ representing relative variance explained by technical inefficiency. If γ is close to zero, the difference between a farmer's yield and the efficient yield is caused primarily by statistical error. If γ is close to one, the difference is due to the farmer's inefficient use of technology.

Empirical stochastic frontier production functions can be expressed in a number of ways, including the Cobb-Douglas frontier production function and the Translog production function, which are defined as follows:

$$\text{Translog Function - } \ln y_i = \alpha_0 + \Sigma_{i=1}^{n} \alpha_k \ln x_{ki} + \Sigma_{i=1}^{n} \Sigma_{j=1}^{n} \alpha_{kj} \ln x_{ki} \ln x_{ji} + \varepsilon$$

&

$$\text{Cobb-Douglas – } \ln y_i = \alpha_0 + \Sigma_{i=1}^{n} \alpha_k \ln x_{ki} + \varepsilon, \text{ where, } \varepsilon = (V_i - U_i)$$

In the above productions, the study used six independent variables namely, Land (X_{1i}), Labour (X_{2i}), Agrochemical(X_{3i}), Fertilizer (X_{4i}), Plant Density (X_{5i}), Irrigation (X_{6i}).

A stochastic production function can be estimated using the maximum likelihood method or a variant of the Corrected Ordinary Least Squares method [10].

Heteroscedasticity is an OLS requirement violation in which the error variance is not constant. The estimated coefficients are not biased but inefficient and the variance is either too large or too small resulting in errors due to heteroscedasticity. OLS is not the best linear unbiased estimator [11]. As a result, maximum likelihood estimates of the parameters were used to estimate the production function in this study. The multiple linear regression model for inefficiency associated with farmer-specific factors can be expressed using the following:

$$INEF_i = \beta_0 + \beta_1 GEN + \beta_2 AGE + \beta_3 LSIZE + \beta_4 EXP + \beta_5 EDU + \beta_6 OCCUP + \beta_7 CI$$

Where, $INEF_i$ = inefficiency of the ith farmer, GEN= Gender of the farmer, LSIZE= Land Area, EXP= Experience of the pineapple cultivation, OCCUP= either full-time cultivator or part-time, CI= Problems Index of the pineapple growers.

The top 5 major problems faced by pineapple growers were taken. Individual growers' marks out of ten for each problem separately were used to determine the severity of the problems they were experiencing. By turning them into an index, these issues were added to the inefficiency model [8]. Each grower's index was determined separately using CI = [ΣX_i /N]/5 formula. (X_i= Marks given to the i^{th} problem, N=1,…..,N)

Table 1 Maximum likelihood estimates (MLE) for the Translog function's parameters

Variables	Coefficients	t-ratio	Variables	Coefficients	t-ratio
Intercept	7.532	16.38	Labour*Labour	-0.234	-2.64**
Land (Bigha)	1.181	8.83**	Agrochem*Agrochem	0.042	o.342
Labour (Days)	1.123	2.76**	Fertilizer*fertilizer	0.345	0.543
Agrochem (Lit)	0.031	0.47	Plants*Plants	-0.434	-0.967
Fertilizer (Kgs)	-0.433	-1.34	Irrigation*Irrigation	0.0706	1.914
Plants (Density)	0.835	2.13	Total Variance	0.1456	2.934
Irrigation (Day)	0.534	0.45	Variance Ratio	0.912	47.678
Land*land	0.643	4.32**			

Log-likelihood Function – 54.37 LR Test – 27.64

**Significant at 5% level

RESULTS AND DISCUSSION

Translog and Cobb-Douglas forms were both used to develop the production relationship. In order to determine whether the Cobb-Douglas form or the translog function is more appropriate for the data, Gunaratne and Thiruchcelvam [12] used the significance of the translog function's cross terms. In the translog form, only a small number of cross terms and variables were significant. The Cobb-Douglas functional form was chosen as the means of gauging technical efficacy. But by limiting the production elasticities to be constant and the input substitution elasticities to be unity, it imposes limitations on the farm's technological capabilities [13]. The estimated parameter coefficients are shown in (Table 1).

Table 2 OLS and MLE for the pineapple production's stochastic frontier (Cobb- Douglas model) parameters

Variables	Ordinary Least Square (OLS)		Maximum Likelihood Estimates (MLE)	
	Coefficients	t-ratio	Coefficients	t-ratio
Intercept	3.886	4.343	3.234	3.843
Land	0.432	1.987**	1.236	10.432**
Labour	0.324	2.689**	0.567	3.986**
Agrochem	0.043	1.321	0.0321	1.234
Fertilizer	0.234	2.734**	0.435	2.934**
Plant Density	0.553	5.678**	0.824	16.27**
Irrigation	0.017	0.684	0.056	1.062

Total Variance – 0.072, Variance Ratio – 0.91, Log-likelihood Function – 42.67, LR test – 13.67

** Significant at 5% level

Data depicted in (Table 2) shows the results of the ML estimates. LR test indicates the goodness of fit of the model. The variance ratio's estimated value was 0.91. This suggests that the was nearly equal to one and that technical inefficiency is primarily to blame for the difference between the farmer's yield and the efficient yield. This indicates that the stochastic frontier model's technical inefficiency effects were significant. The estimated production function model's variables all had positive coefficients. The positive coefficient suggests that any rise in the variable's value would result in an increase in production. With the exception of agrochemicals and irrigation, all of the positive factors with estimated ML coefficients were found to have a significant impact on pineapple production. This indicates that raising the input level will also raise the output level. Land and plant density has the highest input elasticity coefficient.

Table 3 Level of technical efficiency in pineapple growers

TE Level	0.61-0.70	0.71-0.80	0.81-0.90	0.91-1.00	Total	Maximum	0.9675
Frequency	5	14	36	47	102	Minimum	0.6585
Percentage	4	13.72	35.29	46.07	100	Mean	0.8425

The frequency distribution of pineapple growers in the study area was displayed in (Table 3) based on their technical production efficiencies. The results showed that the estimated technical efficiencies of the pineapple growers ranged between 0.6585 and 0.9675, with a mean technical efficiency of 0.8425. Inferred from this was that, on average, farmers can produce 84.25% of their maximum yield using a particular combination of production inputs. Thus, without incurring any additional costs, pineapple production efficiency could be increased by 15%. Technically efficient farmer enjoys the comparative cost advantage against inefficient one. To make pineapple cultivation commercially viable, production costs should be reduced by increasing efficiency.

The implications of the findings are that an average Pineapple farmer in the study area could save 12.91%, i.e., 1-(0.8425/0.9675)*100, to achieve the technical efficiency level of his most efficient counterpart, whereas the most technically inefficient Pineapple farmer in the study area could save 31.93%, i.e., 1-(0.6585/0.9675)*100.

The inefficiency measures that emerged here were linked to grower-specific factors that were investigated using a multiple linear regression model. Table 4 shows the regression outcome. The positive and significant coefficient of occupation indicates that growers who only engage in pineapple farming are more efficient than those who work part-time. The positive and significant constraint index coefficient suggests that inefficiency increases with the severity of the grower's problems. The negative and significant coefficients of education and experience indicate that any increase in the variable will impact the inefficiency negatively (efficiency will increase). The coefficients of gender, age, and land size do not significantly impact the efficiency level of pineapple growers in North Bengal.

Table 4 Parameter estimates of the inefficiency model (Multiple Regression Output)

Variable	Coefficients	Prob.
Intercept	0.6183	0.123
Gender	0.1123	0.234
Age	0.034	0.321
Land Size	-0.212	0.184
Experience	-0.834	0.032**
Education	-1.043	0.046**
Occupation	1.156	0.037**
Constraint Index	0.967	0.047**

**Significant at 5% level

Pineapple farmers have reported massive losses as a result of a lack of food storage and government procurement facilities [14]. Pineapple price variation was low, but the pineapple pricing system had not yet been developed. The lack of processing facilities limits the expansion of pineapple acreage. Farmers with limited resources are discouraged from expanding their crop area due to a lack of infrastructure facilities [15-16]. The main issues that growers faced were high input costs, a lack of training facilities, storage facilities, financial constraints, lack of infrastructure, and marketing facilities. Most growers do not devote much time to cultivation due to the unavailability of finance, price fluctuations, marketing difficulties, and high production costs. They continue to cultivate in order to generate additional income with their vacant land with minimal resource use, as it is profitable even at this level. As a result, they did not give much thought to the efficient use of resources for cultivation.

CONCLUSION

Using a stochastic frontier production function (Cobb-Douglas) approach, the research examined the technical efficiency of pineapple production in North Bengal. The results indicate that the factors associated with the production i.e., land, labour, fertilizer, and plant density have a positive and significant impact on pineapple output variability. The cost of production should be reduced by increasing efficiency in order to make pineapple cultivation commercially viable in the study area. The inefficiency model indicates that experience, education level, occupation, and constraint index have significant effects on technical inefficiency. Inefficiency increases with the severity of problems and decreases with the increase in the education level and experience of the growers. The growers who only engage in pineapple farming are more efficient than those who work as part-timers. The results also show that the average technical efficiency of pineapple growers in North Bengal is 84.25% per cent and it suggests that pineapple production could be increased by more than 15% without the use of any additional inputs. Improving efficiency necessitates policy intervention, primarily in education, credit accessibility, and marketing. Promoting education among these economically disadvantaged growers will enable them to make better decisions, embrace technological advances, and comprehend the complexities of business. Thus, inefficiency can be reduced in four ways. The first method is to solve the problems, such as improving marketing facilities, infrastructure, and storage facilities, as well as implementing the guaranteed price scheme, which will encourage growers. The second method is to encourage collective farming among small pineapple growers. The third method is to improve growers' knowledge by organizing educational seminars and an extension system. The fourth option is to develop a specific methodology to improve cultivation efficiency beyond the first season. If it can be implemented, this may be a better solution.

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