Analysis of technical efficiency's lettuce farmers in Dalat City, Vietnam

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ABSTRACT

The study aims to determine the technical efficiency and factors affecting the technical efficiency of lettuce farmers in Dalat City. The study's primary data were collected by surveying structured questionnaires from 100 lettuce farmers in Dalat City. The Cobb-Douglas production, combined with the technical inefficiency according to the one-stage estimation method, was estimated by the program Frontier 4.1. The calculated results illustrate that the average technical efficiency of lettuce farmers is 0.76; with the usage level of available inputs and present techniques, Dalat lettuce production in the rainy season may increase by 24%. Besides, the study has also indicated that factors such as lettuce cultivated area, number of seedlings, and amount of pure potassium fertilizer positively influence lettuce yield. In contrast, the amount of pure nitrogen fertilizer negatively affected lettuce output. However, the education level and experience of household heads in lettuce cultivation positively affected technical efficiency. Therefore, to improve lettuce productivity and technical efficiency in Dalat City, the study suggests that farmers need to increase the amount of potassium fertilizer and reduce nitrogen fertilizer. In addition, state agencies recommend teaching lettuce farmers about the balanced and reasonable application of N, P, and K fertilizers through documents or training courses.

1. Introduction

Crop yield is determined by numerous factors such as technical efficiency, scale efficiency, and technical progress. Technical efficiency is the ability to produce an amount of given output from a minimum amount of input, or the maximum amount of output from an amount of given input, corresponding to a specific technical level (Farrell, 1957). Therefore, factors impacting technical efficiency are not direct inputs to the production process. Recent studies have used the Stochastic Frontier Approach in the technical efficiency analysis of farmers. The results show that farmers' production experience positively affects technical efficiency (Khan et al., 2020; Ngo, Phan, & Dong, 2015; Wahid, Ali, & Hadi, 2017). Similarly, Ngo et al. (2015) and Wahid et al. (2017) also presented that the farmer's education level positively impacts the technical efficiency of tomatoes and cabbage. In addition, the agricultural extension also positively influences technical efficiency through research results on vegetables and cucumbers (Ali, Ashfaq, & Khan, 2016; Julie, Engwali, & Bidogeza, 2017). Meanwhile, Ogunmola, Afolabi, Adesina, and IleChukwu (2021) have opposite results: agricultural extension negatively affects technical efficiency. Furthermore, many studies analyze the technical efficiency of fruit and vegetable farmers, such as

Mari and Lohano (2007); Malinga, Masuku, and Raufu (2015); Masuku, Raufu, and Malinga (2015); Umar, Girei, and Yakubu (2017); Sinaga, Sinaga, and Girsang (2021). However, the studies focus on particular types of vegetables or vegetables in general, but no research on the technical efficiency of lettuce farmers in Vietnam.

Thanks to the potential and advantaged resources of land, water, human, and ecological conditions, Lamdong Province has advantageous conditions to develop large-scale agricultural commodities manufacturing for strong provincial agricultural products, especially temperate and subtropical origins vegetables. With the quality of seeds enhanced solutions, crop productivity increased by 3% on average compared to 2015, in which vegetable yield increased by 1.3%; inefficient farming areas decreased from 31.7% to 18.6% (Lamdong Department of Agriculture and Rural Development, 2021). Over the past years, the vegetable cultivation area of Lamdong has increased continuously, from 42,806 hectares in 2010; to 66,228 hectares in 2020, with more than 2.3 million tons of output (Lamdong Department of Statistics, 2021). In 2020, the vegetable cultivated area in Dalat City was 5,085 hectares, with 48% for leafy vegetables (lettuce, cabbage, spinach, chrysanthemum greens, Chinese cabbage, etc.).

Lettuce is a plant of temperate origin. Therefore, it is suitable for the climate conditions in Dalat City to manufacture products with high productivity, good quality, attractive designs, diversification, and all year round. However, after the Covid-19 epidemic, lettuce cultivation in Dalat is facing a rapid increase in labor costs and input materials (fertilizers, pesticides, etc.). For that reason, lettuce farmers must adjust and coordinate inputs to optimize production, affecting productivity and technical efficiency. The study *"Analysis of technical efficiency's lettuce farmers in Dalat City, Vietnam"* is carried out to determine the farmers' technical efficiency and the factors influencing technical efficiency in Dalat, thereby offering policy implications to improve the technical efficiency in growing lettuce in Dalat.

2. Literature review

Technical efficiency is the ability to produce an amount of given output from a minimum amount of input, or the maximum amount of output from an amount of given input, corresponding to a specific technical level (Farrell, 1957). To analyze technical efficiency generally and in agriculture particularly, Coelli, Rao, O'Donnell, and Battese (2005) have proposed two approaches: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). The SFA separates the inefficient term (u) and random error term (v) from the estimated model and determines the shape of the production function, cost function, profit function, etc. The DEA does not require constraints on the shape of the best-performing frontier, nor the distribution of inefficiencies terms as the parametric approach, except for efficiency indicators in the range (0-1).

As the analysis, each approach has its advantages and disadvantages. However, the SFA reflects the effects of random external factors (u and v), while the DEA does not. Due to agricultural production being affected by random factors such as weather, pests and diseases, market prices, etc., the SFA is suitable for evaluating agricultural technical efficiency.

According to Coelli et al. (2005), the technical efficiency is estimated through the stochastic frontier analysis with the Formula (1):

$$Y_i = f(x_i, \beta_i)e^{(v_{iTE} - u_{iTE})} \quad (1)$$

Where: Y_i is the production of the i^{th} farmer; x_i is the vector of inputs of the i^{th} farmer; β_i is a vector of the coefficients to be estimated; v_{iTE} represents the effect of random errors assumed to be a normal distribution $(v \sim N(0, \sigma_{vTE}^2))$; u_{iTE} represents a degree of technical inefficiency assumed to be greater than zero and has a half-normal distribution ($u \sim |N(0, \sigma^2_{uTE})|$). u_{iTE}, which is calculated from the difference between the actual yield (Y_i) and theoretical yield value (Y_i*) given by the function Y_i - Y_i*. The larger this value, the lower the technical efficiency.

Maximum Likelihood Estimation (MLE) is widely used to measure production efficiency. When estimating Formula (1) by the MLE method, the estimated value of the variance is as follows:

$$\sigma^2_{TE} = \sigma^2_{vTE} + \sigma^2_{uTE} \text{ và } \gamma_{TE} = \frac{\sigma^2_{uTE}}{\sigma^2_{TE}} \quad (2)$$

The technical efficiency of the *i*th farmer is determined as follows:

$$\text{TE} = \text{E}[e^{(-u_{iTE})}] \quad (3)$$

Due to the SFA method features above, some studies have chosen the SFA method with the MLE to evaluate the technical efficiency in agricultural production (Asfaw, 2021; Julie et al., 2017; Khan et al., 2020; Mulaudzi, Oyekale, & Ndou, 2019; Ogunmodede & Awotide, 2020; Ogunmola et al., 2021; Sinaga et al., 2021; Umar et al., 2017). Commonly independent variables in estimating the stochastic frontier production function are cultivated area, labor, fertilizer, pesticide, and quantity of seed (Julie et al., 2017; Mulaudzi et al., 2019; Ogunmodede & Awotide, 2020; Ogunmola et al., 2021; Sinaga et al., 2021; Umar et al., 2017). In addition, age, farming experience, agricultural extension, and education are commonly used in technical inefficiency analysis (Ali et al., 2016; Malinga et al., 2015; Masuku et al., 2015; Mulaudzi et al., 2019; Wahid et al., 2017). The result of vegetable technical efficiency research is also very variable. The technical efficiency of some vegetable farmers is relatively high, greater than 85% (Julie et al., 2017; Khan et al., 2020; Wahid et al., 2017). Meanwhile, some vegetable farmers have medium technical efficiency, approximately 60% (Dagar et al., 2021; Ngo et al., 2015; Umar et al., 2017). That some farmers' technical efficiency is only 36% can be found in some studies (Yohannis, Tenaye, & Ganewo, 2020).

3. Research methods

3.1. Data

There are some techniques to determine sample size, such as the sampling formula of Slovin (as cited in Tejada & Punzalan, 2012) and Yamane (1967) when the number of whole observations is available. If based on the number of independent variables in a model, Habing (2003) believes that the minimum number of observed samples must be 04 - 05 times higher than the independent variables. Likewise, Hair, Black, Babin, Anderson, and Tatham (2006) suggested that the sample size should be at least 50 or in a 5:1 ratio, which means that the sample size is at least 05 times higher than the independent variables. In reality, the sample collecting can be based on the following statistical principles: (1) Based on the extensive number method, a sample size greater than 40 is considered a large sample for small and medium-sized research; (2) For extensive research, the sample size is 7% of the total (Vo, 2016). Thus, the determination of sample size has many formulas and depends on research conditions. In this study, because the lettuce cultivation areas in Dalat City are mainly concentrated in wards 4, 5, 7, 8, and 9, but there are no exact statistics on the number of lettuce farmers from local agencies, the study focuses on randomly surveying in all 05 wards with 20 farmers/ward. The total sample size of the survey is 100 lettuce farmers. The primary data were collected by random sampling and using a structured questionnaire. The collected data is the situation of lettuce production in the 2021 rainy season in Dalat City.

3.2. Empirical model

3.2.1. Stochastic frontier production and technical inefficiencies function

Technical efficiency is determined through the stochastic frontier production function, which can be estimated by various models such as Cobb-Douglas, Translog, Quadratic, Generalized, and Normalized Quadratic. The two most used models in production economics are the Cobb-Douglas and the Translog, with the following form:

Cobb-Douglas stochastic frontier production function:

$$lnY_i = \beta_0 + \sum_{j=1}^{7} \beta_i \, lnX_{ji} + (v_i - u_i) \quad (4)$$

And the Translog stochastic frontier production function:

$$lnY_i = \beta_0 + \sum_{j=1}^{7} \beta_i \, lnX_{ji} + \frac{1}{2} \sum_{j=1}^{7} \sum_{k=1}^{7} lnX_{ji} lnX_{ki} + (v_i - u_i) \quad (5)$$

Where:

Y_i is the average lettuce yield of the *i*th farmer (ton/1,000m^2);

X_{ji} (j=1, 2, 3, …, 8) and X_{ki} (k = 1, 2, 3, … 8) are the inputs;

X_{1i}, X_{2i}, and X_{3i} are the amounts of pure nitrogen, phosphorus, and potassium fertilizers, respectively, calculated from the used chemical fertilizers (kg/1,000m^2);

X_{4i} is the number of man-days (man-day/1,000m^2);

X_{5i} is the number of lettuce planting density (plants/1,000m^2);

X_{6i} is the number of pesticides used and equivalently converted into solid form at the rate of 1gram = 1ml (gram/1,000m^2);

X_{7i} is the lettuce cultivated area (1,000m^2).

The study used one-stage estimation by Frontier 4.1 software to simultaneously estimate both the production and the technical efficiency functions. However, U_i in formulas (4) and (5) is a technical inefficiency function. This function is used to explain the factors affecting technical inefficiencies. Therefore, the negative sign of the estimated coefficient in the technical inefficiency function will have a positive relationship with the technical efficiency and vice versa.

The technical inefficiency function has the following form:

$$U_i = \alpha_0 + \sum_{k=1}^{4} \alpha_i \, lnZ_{ki} + \xi_i \quad (6)$$

Where:

U_i is the technical inefficiency of the *i*th farmer;

Z_{1i} is the experience of lettuce farmers (year);

Z_{2i} is the education level of the farm owners, calculated by the schooling years (year);

Z_{3i} is a dummy variable representing the use of organic fertilizer (1 for yes, 0 for no);

Z_{4i} is a dummy variable representing *extension courses'* training (1 for participation, 0 for no participation);

ξ_i is the error value representing outside factors.

3.2.2. Likelihood Ratio (LR) test

To use the Cobb-Douglas function in formula (4) or the Translog function in formula (5), the LR test will be used through the value of λ calculated according to the following formula:

$$\lambda = - 2*[L(H0\ ) - L((H1)] \quad (7)$$

Where: L(H0) is the log-likelihood value of the Cobb-Douglas function, and L(H1) is the log-likelihood value of the Translog function (Asfaw, 2021; Pascoe, Hassaszahed, Anderson, & Korsbrekke, 2003). If λ > λ_table (λ_table is the critical $\chi2$ value), hypothesis H0 is rejected, which means that the Translog model is more suitable than the Cobb-Douglas model and vice versa. The critical $\chi2$ value is taken from the Chi-square distribution $\chi2$ with degrees of freedom (df), equaling the number of independent variables of the Translog model minus the number of independent variables of the Cobb-Douglas model.

The variance of random errors is σ_v^2 and the variance of the inefficiency is σ_u^2. The overall variance of the model is $\sigma^2 = (\sigma_u^2 + \sigma_v^2)$. The ratio of gamma variance γ calculated by the formula $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$. Gammar γ lines between 0 and 1 will explain the error term related to inefficiencies in the model (Battese & Coelli, 1992; Pascoe et al., 2003). Frontier 4.1 software can estimate the technical efficiency using the Ordinary Least Squares (OLS) method and the Maximum Likelihood Estimation. Therefore, the gamma coefficient (γ) is used to select the appropriate estimation method with the survey data. Suppose $\gamma = 1$; the technical efficiency is equal to 1, which means that the technical efficiency of the farmer is maximized. In that case, there will be no factors affecting the technical inefficiency ($u_i = 0$), so the OLS estimation method is used. In contrast, if $1 > \gamma > 0$, the technical efficiency is less than 1, which means that the farmer has not reached the optimal efficiency. Some factors cause the level of inefficiency ($u_i > 0$). So that the MLE estimation method will be used to explain the results.

4. Results and discussion

4.1. Results

4.1.1. The lettuce production situation of farmers in Dalat

Table 1 demonstrates the general characteristics of lettuce farmers in Dalat. Survey results of 100 lettuce farmers in Dalat show that the average age of farm owners is middle-aged (43 years old). Similarly, the schooling years are at the upper secondary level (nearly nine years). The labor involved in farmers' agricultural production is almost two people. Farmers will hire seasonal laborers to plant, weeding, or spray chemicals. Farmers have numerous experience years in lettuce cultivation (more than ten years). However, there is a big difference in the experience of lettuce farming. The lettuce cultivated area is small (3,000m^2), the smallest is 1,000m^2, and the largest is up to 10,000m^2. All of the above factors affect the cultivation and yield of lettuce.

Table 1

General characteristics of lettuce farmers in Dalat

Characteristics	Unit	Mean	Standard deviation	Minimum	Maximum
Age of farm owner	year	43.35	10.79	25.00	67.00
Schooling	year	8.70	2.37	5.00	16.00
Labor	person	2.07	0.64	1.00	4.00
Experience	year	10.28	4.63	3.00	25.00
Cultivated area	1,000m^2	3.05	1.92	1.00	10.00

Table 2 presents the inputs used in lettuce cultivation and illustrates the amount of pure nitrogen and phosphate fertilizers used more than recommended by the Sub-Department of Cultivation and Plant Protection of Lamdong Province by 47% and 72%, respectively. The amount of potassium fertilizer used is less than the recommended 3%.

The average labor used in a lettuce crop is about ten man-days. However, there is considerable variation among farmers. Farmers planting lettuce in a greenhouse, using plastic to cover the beds, and applying automatic irrigation and spraying systems use less labor than farmers who cultivate outdoors without good weed and pest control and with manual farming activities. So labor depends on the complexity of the farming activities (Nguyen, Nguyen, & Pham, 2021). The average number of lettuce/1,000m^2 is nearly 20,000 plants (10,000 - 28,000 plants), mainly depending on the different varieties of lettuce. Lolo is the most commonly grown in Dalat, followed by Coron, and the rest are other varieties. In lettuce cultivation, an essential input is pesticides in various forms, such as solid, liquid, and powder (Nguyen, Nguyen, & Pham, 2022). The equivalent of 1gram = 1ml will be converted for convenience of calculations. Thus, the average amount of pesticides used is about 320 grams/1,000m^2. Some farmers have good pest management, so they use minimal pesticides (70 grams); other farmers with poor pest control use more pesticides (1,200 grams).

The use and combination of inputs in lettuce cultivation affect the yield. The average lettuce output is approximately 1.96 tons/1,000m^2 during the rainy season. However, some farmers still achieve high productivity (3.6 tons), while some only reach 0.7 tons.

Table 2

Outputs and inputs in lettuce cultivation in Dalat

Unit: 1,000m^2

	Unit	Mean	Standard deviation	Minimum	Maximum	Recommendations
Pure nitrogen	kg	13.49	4.95	6.99	30.00	9.20
Pure phosphorus	kg	8.26	3.79	3.20	24.00	4.80
Pure potassium	kg	5.84	2.20	1.00	12.00	6.00
Labour used	man-day	9.94	2.15	4.00	15.00	
Seeding	plant	20,148	3,011	10,000	28,000	
Plant protection products	gram	320.25	237.47	70.00	1,200.00	
Output	ton	1.96	0.58	0.70	3.60	

4.1.2. Likelihood ratio test results

Likelihood ratio test results are used for choosing the Cobb-Douglas or Translog function. The formula (6) shows that λ = -2[L(H0) – L(H1)] = -2(48.89 - 72.58) = 47.92, which is less than the value λ (the critical χ2 value) with (df = 28, α = 0.001) = 56.89. Thus, hypothesis H0 is accepted; that means the Cobb- Douglas production function is suitable for estimation.

The Cobb-Douglas frontier production function (formula 3) and the technical inefficiency function (formula 5) were estimated simultaneously by one-stage estimation and Frontier 4.1

software. The estimated results presented in Table 3 show that the gamma coefficient (γ) is 0.85 (~ 1) at the 1% significance level. Therefore, the model has technical inefficiencies (Battese & Corra, 1977). The efficient production of lettuce farmers is affected by socio-economic factors. So the Maximum Likelihood Estimation method is used.

4.1.3. Cobb-Douglas frontier production function result

The parameters in the model (3) are estimated by the MLE method and presented in Table 3. The calculated results of the parameters are statistically significant and show that technical efficiency influences the lettuce yield of farmers. The gammar coefficient in the formula is 0.85, which illustrates the technical inefficiency of up to 85% of the variation in farmers' lettuce yield in the study area.

The estimation results of the Cobb-Douglas frontier production function demonstrate that variables such as the lettuce cultivated area, number of seedlings, and potassium and nitrogen fertilizers significantly influenced the lettuce yield. This finding is in line with Sinaga et al. (2021). Meanwhile, the variable of phosphate fertilizers, labor, and pesticides had an insignificant effect on the lettuce product.

Table 3

Estimation results of Cobb-Douglas production and technical inefficiency function

Variables	**Variable names**	**Parameters**	**Standard-error**	**T-ratio**
Production function				
	Constant	-0.598	1.056	-0.566ns
lnX_1	N fertilizer	-0.104	0.057	-1.833*
lnX_2	P fertilizer	0.036	-0.047	0.762^{ns}
lnX_3	K fertilizer	0.072	0.042	1.723*
lnX_4	Labour	-0.066	0.075	-0.885ns
lnX_5	Seed	0.179	0.101	1.777*
lnX_6	Pesticide	-0.031	0.038	-0.815^{ns}
lnX_7	Land	0.144	0.029	4.839***
Inefficiency effects				
	Constant	1.062	0.115	7.338***
Z_1	Experience of farmers	-0.024	0.009	-2.685**
Z_2	Education	-0.077	0.019	-4.094***
Z_3	Organic fertilizers dummy	0.047	0.062	0.770^{ns}
Z_4	Extention dummy	-0.076	0.061	1.239^{ns}
Sigma-squared		0.035	0.009	4.020***
Gamma		0.848	0.100	8.454***
Log likelihood function		48.890		
Mean efficiency		0.766	0.145	
* , ** , *** significance at the 10%, 5% and 1% level, respectively.				

4.1.4. Factors affecting technical inefficiencies

Table 3 shows the results of estimating the factors affecting the technical inefficiencies, which present the significant impact trend of each variable in enhancing the technical efficiency of lettuce farmers in Dalat. In the technical inefficiency model, the estimated coefficients' negative sign (-) shows a negative relationship with the level of technical inefficiency and a positive (+) relationship with technical efficiency. The estimated results indicate that the level of production experience and education level's lettuce farmers negatively affect technical inefficiency at a 1% significance level and positively affect technical efficiency (Khan et al., 2020; Masuku et al., 2015; Ogunmola et al., 2021). Meanwhile, the agricultural extension and use of organic fertilizers variables have an insignificant impact on technical inefficiency.

4.1.5. Technical efficiency level allocation

The MLE calculated results are presented in Figure 1. In the 2021 rainy season, the technical efficiency of Dalat lettuce farmers has a significant variation, from 0.37 to 0.97, with an average of approximately 0.76. The ratio proves a technical inefficiency in lettuce cultivation in Dalat. This consequence is lower than the technical efficiency of vegetable farms in previous studies (Julie et al., 2017; Khan et al., 2020; Wahid et al., 2017).

Figure 1 presents the distribution of technical efficiency levels of lettuce growers in Dalat. Although the average technical efficiency of the surveyed farmers was 0.76, none achieved the maximum level of technical efficiency (1.0). Meanwhile, 5% of farmers have technical efficiency below 0.50, even with only 0.37. Moreover, farmers have a technical efficiency level of 0.50 - 0.60, about 9%. The technical efficiency from 0.60 - 0.90 is the highest for 62% of surveyed farmers. Similarly, 14% of the farmers can achieve technical efficiency above 0.90.

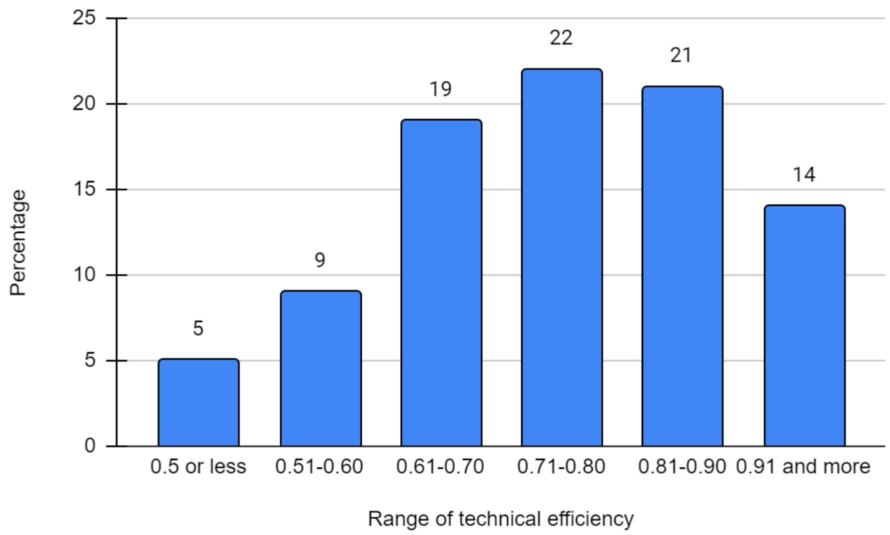

Figure 1. Percentage distribution of technical efficiency level of lettuce farmers in Dalat

4.2. Discussion

4.2.1. Cobb-Douglas frontier production function

In the production function, the lettuce cultivated area positively affects yield at a 1% significant level. The estimated coefficient shows that if the cultivated area increases by 1%, the yield will increase by 0.14%, assuming other factors remain constant. Other studies on the technical efficiency of vegetable farms confirmed the yield increase in scale in this study (Bozoglu

& Ceyhan, 2007; Julie et al., 2017; Mulaudzi et al., 2019; Ngo et al., 2015; Ogunmodede & Awotide, 2020; Ogunmola et al., 2021; Tiedemann & Lohmann, 2013; Yohannis et al., 2020). Because of the farmer on a large scale, farming becomes more specialized with better technical processes for higher production results. Besides that, large-scale farmers will focus more on management and care to get a higher yield than lettuce farmers on a small scale. The results imply that expanding the scale of lettuce production by increasing the cultivated area or establishing a large-scale concentrated production region can significantly enhance the yield.

The results also illustrate that increasing the number of lettuce seedlings will expand the yield at a 10% significant level, which demonstrates the results of previous research conducted by Mulaudzi et al. (2019); Yohannis et al. (2020); Ogunmodede and Awotide (2020); Ogunmola et al. (2021) and Sinaga et al. (2021). Specifically, when the number of lettuce seedlings increases by 1%, the yield will rise by 0.18%, assuming other factors remain constant. Thus, the current average lettuce planting density of about 20.15 thousand plants/1,000m^2 can be considered unsuitable for maximum yield. Farmers should consider increasing planting density to improve lettuce yield in consultation with technical staff.

Fertilizer is one of the essential inputs in increasing crop production. A balanced and reasonable fertilizer application of Nitrogen (N), Phosphorus (P), and potassium (K) are necessary. The results indicate that the coefficient of pure potassium (0.072) positively affects lettuce yield at the 10% significance level. These results confirmed previous research on the effect of fertilizers on vegetable yield (Masuku et al., 2015; Umar et al., 2017; Mulaudzi et al., 2019; Yohannis et al., 2020; Sinaga et al., 2021) but conflict with Ogunmodede and Awotide (2020). The survey showed that lettuce farmers only used 5.84kg of potassium fertilizer, 6.0kg less than the recommended, which implies that farmers can still use more potassium fertilizers in lettuce cultivation to achieve higher yields. Meanwhile, the estimated coefficient of pure nitrogen fertilizer (-0.104) negatively impacts lettuce yield at a 10% significance level. That is inconsistent with the effect of nitrogen fertilizer on tomato yield in Balochistan (Khan et al., 2020). Table 2 demonstrates the amount of nitrogen fertilizer used in lettuce cultivation. The nitrogen fertilizer farmers use in lettuce grown is 13.49kg, 47% higher than the recommended level.

The actual production indicates that nitrogen fertilizer is a critical factor in the production of vegetables in general. Nitrogen is used more than phosphorus and potassium fertilizers by farmers (Ta, 2005). The unbalanced use of macronutrients nitrogen, phosphorus, and potassium, especially the excessive quantity of nitrogen fertilizer, will adversely affect the growth of lettuce and reduce yield. Thus, farmers need to consider reducing the amount of nitrogen fertilizer and applying more balanced and reasonable nitrogen, phosphorus, and potassium fertilizers.

4.2.2. Technical inefficiencies function

Research result indicates that the education level variable significantly and positively affects lettuce's technical efficiency. The higher the number of schooling years, the higher the technical efficiency. Dalat is the leading locality in high-tech agricultural applications. Farmers with higher education levels may access new techniques and production technologies to improve crop productivity. This result is similar to previous studies (Bozoglu & Ceyhan, 2007; Ngo et al., 2015; Masuku et al., 2015; Nguyen, 2017; Khan et al., 2020; Ogunmola et al., 2021) but conflicts with Julie et al. (2017), the higher the educational level's farm in Cameroon, the lower the vegetable technical efficiency.

The experience's lettuce planting positively and significantly influences technical efficiency. That means the more experienced years, the higher the technical efficiency in lettuce production. The results show that the average lettuce farming experience of the surveyed farmers is ten years, while some have only three years of experience. Farmers with numerous experiences get new knowledge and techniques in farming to improve lettuce production. The finding confirmed the results of the previous studies conducted by Bozoglu and Ceyhan (2007); Ngo et al. (2015); Masuku et al. (2015); Wahid et al. (2017); Khan et al. (2020); Ogunmola et al. (2021). Nevertheless, some researchers have indicated conflicting results that farmers with more farming experience are slower to access new science and technology and often apply their traditional experience and knowledge in production more than strictly follow the recommended technical procedures (Le & Pham, 2019; Ngo & Nguyen, 2019; Umar et al., 2017). These traditional experiences and knowledge may be outdated or no longer suitable.

4.2.3. Technical efficiencies allocation

The survey shows that lettuce productivity can increase by 24% to reach the maximum yield with the recent level of inputs and techniques. That implied that lettuce farmers in Dalat could reduce their inputs by about 24% without reducing their production by improving technical efficiency. Enhanced technical efficiency will reduce production costs and increase profit margins in vegetable farming (Bozoglu & Ceyhan, 2007).

Nearly 24% of the lettuce yield is lost due to the underutilization of inputs and inefficiencies. These inefficiencies are related to the farmers' characteristics and farming techniques. In addition, lettuce production in the Dalat rainy season is also affected by external factors such as hoarfrost, hail, diseases, etc., which are out of farmers' control. These factors also contribute to reducing the technical efficiency of farmers' lettuce.

5. Conclusion

The Cobb-Douglas production function combined with the technical inefficiency function according to the one-stage estimation method was used for analysis by the program Frontier 4.1. The estimated results illustrate that the average technical efficiency of farmers is 0.76 (from 0.37 to 0.97), implying that with the level of available inputs and recent techniques, lettuce production in the 2021 rainy season in Dalat may increase by 24%. Besides, this study has also indicated that factors such as lettuce cultivation area, number of seedlings, and amount of pure potassium fertilizer positively influence lettuce yield. In contrast, the quantity of pure nitrogen fertilizer negatively affected lettuce output. That shows that farmers are using nitrogen fertilizers over the recommended threshold. In addition, factors causing technical inefficiencies in lettuce production are demonstrated in this study, such as the positive effect of the farmer owners' education level and experience in lettuce cultivation.

Therefore, to improve productivity and lettuce technical efficiency in Dalat, the study suggests that farmers need to increase the amount of potassium fertilizer and reduce the amount of nitrogen fertilizer. Besides, farmers consider expanding the farming scale with improved techniques and efficient use of inputs under the guidance of technical staff. In addition, state agencies could support lettuce farmers in the balanced and reasonable application of N, P, and K fertilizers through documents or training courses.

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References

Ali, Q., Ashfaq, M., & Khan, M. T. I. (2016). Analysis of off-season cucumber production efficiency in Punjab: A DEA approach. *Journal of Experimental Biology and Agricultural Sciences*, *4*(6), 653-661.

Asfaw, D. M. (2021). Analysis of technical efficiency of smallholder tomato producers in Asaita district, Afar National Regional State, Ethiopia. *PloS One*, *16*(9), 1-16. doi:10.1371/journal.pone.0257366

Battese, G. E., & Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis, 3*(1), 153-169.

Battese, G. E., & Corra, G. S. (1977). Estimation of a production frontier model: With application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*, *21*(3), 169-179.

Bozoglu, M., & Ceyhan, V. (2007). Measuring the technical efficiency and exploring the inefficiency determinants of vegetable farms in Samsun Province, Turkey. *Agricultural Systems, 94*(3), 649-656. doi:10.1016/j.agsy.2007.01.007

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. New York, NY: Springer Science & Business Media.

Dagar, V., Khan, M. K., Alvarado, R., Usman, M., Zakari, A., Rehman, A., ... Tillaguango, B. (2021). Variations in technical efficiency of farmers with distinct land size across agro-climatic zones: Evidence from India. *Journal of Cleaner Production*, *315*(2021), 11-17. doi:10.1016/j.jclepro.2021.128109

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General), 120*(3), 253-281.

Habing, B. (2003). *Exploratory factor analysis*. Columbia, SC: University of South Carolina.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. (2006). *Multivariate data analysis* (6th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Julie, T. N., Engwali, F. D., & Bidogeza, J. C. (2017). Technical efficiency of diversification versus specialization of vegetable-based farms in the West region of Cameroon. *American Journal of Agriculture and Forestry*, *5*(4), 112-120. doi:10.11648/j.ajaf.20170504.15

Khan, K., Wotto, M., Liaqat, S., Khan, G., Rasheed, B., Rafiq, S., & Xiangyu, G. (2020). An assessment of technical efficiency of tomato farms in district Lasbela, Balochistan. *Journal of Innovative Sciences*, *6*(1), 60-65. doi:10.17582/journal.jis/2020/6.1.60.65

Lamdong Department of Agriculture and Rural Development. (2021). *Report on the current status of agro-forestry development in Lamdong Province*. Dalat, Vietnam: Lamdong Department of Agriculture and Rural Development.

Lamdong Department of Statistics. (2021). *Lamdong statistical yearbook 2020*. Hanoi, Vietnam: Statistical Publishing House.

Le, D. V., & Pham, T. L. (2019). Technical efficiency of hybrid maize production in the Mekong Delta. *Ho Chi Minh City Open University Journal of Science*, *14*(1), 16-30. doi:10.46223/HCMCOUJS. soci.vi.14.1.458.2019

Malinga, N. G., Masuku, M. B., & Raufu, M. O. (2015). Comparative analysis of technical efficiencies of smallholder vegetable farmers with and without credit access in Swazil and the case of the Hhohho region. *International Journal of Sustainable Agricultural Research*, *2*(4), 133-145. doi:10.18488/journal.70/2015.2.4/70.4.133.145

Mari, F. M., & Lohano, H. D. (2007). Measuring production function and technical efficiency of onion, tomato, and chillies farms in Sindh, Pakistan. *The Pakistan Development Review*, *46*(4), 1053-1064.

Masuku, M. B., Raufu, M. O., & Malinga, N. G. (2015). The impact of credit on technical efficiency among vegetable farmers in Swaziland. *Sustainable Agriculture Research*, *4*(1), 114-126. doi:10.5539/sar.v4n1p114

Mulaudzi, V. S., Oyekale, A. S., & Ndou, P. (2019). Technical efficiency of African indigenous vegetable production in Vhembe District of Limpopo Province, South Africa. *Open Agriculture*, *4*(1), 778-786. doi:10.1515/opag-2019-0077

Ngo, H. M., Phan, T. X., & Dong, M. T. (2015). Analysis of technical efficiency of organic vegetable production: A case study in Thanh Xuan commune, Soc Son District, Hanoi City. *Journal of Science and Development*, *13*(6), 1043-1050.

Ngo, T. A., & Nguyen, D. H. (2019). Factors affecting the technical efficiency of Jasmine rice householders in Chau Thanh district, An Giang Province. *Scientific Journal of Can Tho University*, *55*(2019), 108-114. doi:10.22144/ctu.jsi.2019.086

Nguyen, D. H. (2017). Technical efficiency of dragon fruit farming householders in Chau Thanh District, An Giang Province. *Vietnam Journal of Agricultural Sciences*, *15*(4), 537-544.

Nguyen, T. T., Nguyen, S. P., & Pham, T. L. (2021). Estimating the market power of traders in the Arabica coffee value chain in Lamdong, Vietnam. *International Journal of Economics and Financial Research*, *7*(3), 102-108. doi:10.32861/ijefr.73.102.108

Nguyen, T. T., Nguyen, S. P., & Pham, T. L. (2022). Analysis of farmers' market power in the value chain of Arabica coffee in Lamdong Province, Vietnam. *Ho Chi Minh City Open University Journal of Science-Economics and Business Administration*, *12*(1), 139-147. doi:10.46223/HCMCOUJS.econ.en.12.1.1917.2022

Ogunmodede, A. M., & Awotide, D. O. (2020). Profitability and technical efficiency of leafy vegetable production: A stochastic frontier production function analysis. *International Journal of Vegetable Science*, *26*(6), 608-614. doi:10.1080/19315260.2019.1711283

Ogunmola, O. O., Afolabi, C. O., Adesina, C. A., & IleChukwu, K. A. (2021). A comparative analysis of the profitability and technical efficiency of vegetable production under two farming systems in Nigeria. *Journal of Agricultural Sciences, Belgrade*, *66*(1), 87-104. doi:10.2298/JAS2101087O

Pascoe, S., Hassaszahed, P., Anderson, J., & Korsbrekke, K. (2003). Economic versus physical input measures in the analysis of technical efficiency in fisheries. *Applied Economics*, *35*(15), 1699-1710. doi:10.1080/0003684032000134574

Sinaga, A. H., Sinaga, R., & Girsang, R. (2021). Analysis of lettuce (Lactuva Sativa L) farming efficiency, Jaranguda village, Merdeka district, Karo regency. *Journal of Environmental and Agricultural Studies*, *2*(2), 118-124. doi:10.32996/jeas

Ta, C. T. (2005). *Vegetable cultivation module*. Hanoi, Vietnam: Hanoi Publishing House.

Tejada, J. J., & Punzalan, J. R. B. (2012). On the misuse of Slovin's formula. *The Philippine Statistician*, *61*(1), 129-136.

Tenaye, A. (2020). Technical efficiency of smallholder agriculture in developing countries: The case of Ethiopia. *Economies*, *8*(2), 1-27. doi:10.3390/economies8020034

Tiedemann, T., & Lohmann, L. U. (2013). Production risk and technical efficiency in organic and conventional agriculture–the case of arable farms in Germany. *Journal of Agricultural Economics*, *64*(1), 73-96. doi:10.1111/j.1477-9552.2012.00364.x

Umar, H. S., Girei, A. A., & Yakubu, D. (2017). Comparison of Cobb-Douglas and Translog frontier models in the analysis of technical efficiency in dry-season tomato production. *Agrosearch*, *17*(2), 67-77. doi:10.4314/agrosh.v17i2.6

Vo, L. T. T. (2016). *Textbook of scientific research methods and writing a research proposal*. Can Tho, Vietnam: Can Tho University.

Wahid, U., Ali, S., & Hadi, N. A. (2017). On the estimation of technical efficiency of tomato growers in Malakand, Pakistan. *Sarhad Journal of Agriculture*, *33*(3), 357-365. doi:10.17582/journal.sja/2017/33.3.357.365

Yamane, T. (1967). *Statistics: An introductory analysis*. New York, NY: Harper & Row.

Yohannis, T., Tenaye, A., & Ganewo, Z. (2020). Technical efficiency of agricultural production in Ethiopia. *Journal of Natural Sciences Research*, *10*(5), 46-54. doi:10.7176/JNSR/10-5-05