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Technical Efficiency of Edible Canna Production: A Pathway to Sustainable OCOP Noodles in Vietnam's Northern Mountainous Region

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Learning from Japan's own successful "One Village One Product" (OVOP) movement, Vietnam's One Commune One Product (OCOP) program aims to enhance rural economies by promoting value-added agricultural products, including noodles derived from edible canna (*Canna edulis*). Ensuring the sustainability of such OCOP products relies heavily on the efficiency of raw material production. The primary goal of this research is to evaluate the technical efficiency of edible canna production and identify the key socio-economic factors influencing this efficiency. Ultimately, the study aims to provide evidence-based pathways for enhancing the sustainability of the OCOP noodle value chain. Employing translog stochastic frontier analysis and Tobit models on data collected from surveys with 200 farmers in 2024, the research assesses farm-level efficiency. The findings reveal an average output-oriented TE of 77.45%, indicating a significant potential to increase edible canna yields by 22.55% using current inputs, thereby strengthening the raw material base for noodle production. Key socio-economic factors, including household size, access to extension services, membership in cooperatives, and awareness of the OCOP program, were identified as significant determinants of technical efficiency. These results underscore that improving the TE of edible canna cultivation is crucial not only for optimizing resource use but also for ensuring a stable and efficient supply chain for sustainable OCOP noodles. This study is among the first to empirically measure the direct impact of OCOP program awareness on farm-level technical efficiency, providing a new perspective on the effectiveness of such certification schemes. Policy recommendations emphasize bolstering farmer support through OCOP awareness, enhanced extension services, and cooperative participation, directly contributing to the viability of the OCOP noodle sector and improving rural livelihoods in the region.

Key words: Edible canna (*Canna edulis*), Northern Mountainous Region of Vietnam, OCOP program, Stochastic frontier analysis, Technical efficiency (TE).

INTRODUCTION

In recent years, the One Commune One Product (OCOP) program has emerged as a cornerstone of rural economic development in Vietnam, aiming to promote value-added agricultural products rooted in local knowledge and resources (Vietnam's Prime Minister, 2022b). This initiative is particularly noteworthy as it was developed by learning from Japan's own successful "One Village One Product" (OVOP) movement. The program encourages innovation, entrepreneurship, and standardization to enhance product competitiveness both domestically and internationally. Among the OCOP-certified products, edible canna noodles in the northern mountainous region—locally known as *miến dong*—have garnered increasing attention for their nutritional value, cultural significance, important means of minority people's livelihood, poverty reduction and market potential.

Edible canna (*Canna edulis*) is a tuber crop native to South America but widely cultivated in Southeast Asia for its starch-rich rhizomes. In Vietnam's northern mountainous regions, the starch is traditionally pro-

cessed into translucent, chewy noodles that are highly valued for their gluten-free composition, ease of digestion, and favorable textural qualities—attributes now supported by recent research highlighting canna starch's high resistant starch content and its positive impact on noodle quality (Cao *et al.*, 2025). Despite the growing demand and recognition through OCOP certification, edible canna production remains largely small-scale and labor-intensive, with variability in efficiency across producers. This raises critical questions about the efficiency and sustainability of edible canna farms in the region. This study, therefore, evaluates the technical efficiency (TE) and identifies factors influencing the efficiency of edible canna farms as well as analyzing its role as a pathway towards sustainable OCOP noodle development in Vietnam's Northern Mountainous Region.

Technical efficiency, defined as the ability of a production unit to obtain maximum output from a given set of inputs, serves as a vital metric for evaluating the performance of agricultural and agro-processing sectors (Farrell, 1957; Coelli *et al.*, 2005). In the context of edible canna production, assessing technical efficiency provides insight into how effectively resources such as fertilizers, labor, and fuel are being utilized. Such an assessment is crucial for identifying best practices, reducing input waste, and formulating policy interventions to support rural farmers under the OCOP initiative. Assessing the technical efficiency of OCOP-certified edi-

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ble canna production in the Vietnam's northern mountainous region addresses both academic and practical gaps in the literature. From an academic standpoint, few studies have evaluated technical efficiency of edible canna production under OCOP certification schemes in Vietnam. By using Stochastic Frontier Analysis (SFA) with variables tied to OCOP certification, this research extends its application to niche, culturally rooted food products (Coelli *et al.*, 2005).

Practically, this study offers actionable insights for local farmers, policy makers aiming to enhance productivity and competitiveness in rural value chains. Identifying the key determinants of technical efficiency – such as extension services access, cooperative membership, and farmers' awareness of OCOP (Vu *et al.*, 2021; Hoi *et al.*, 2022; Nguyen and Nguyen, 2021; Vu *et al.*, 2020; Vu *et al.*, 2019; Tran *et al.*, 2023; Hoang *et al.*, 2018) – can guide targeted interventions to reduce waste, optimize resource allocation, and support sustainable scaling of farmers. Furthermore, by quantifying the efficiency gains attributable to OCOP certification, the research provides evidence on the importance of quality-assurance programs in enhancing farm performance, informing future design and support mechanisms under Vietnam's rural development strategy (Vietnam's Prime Minister, 2022a). The findings can serve as a blueprint for other regions seeking to replicate the OCOP model for local specialties, thereby fostering broader rural industrialization and sustainable development across Vietnam (Hoang *et al.*, 2018). Moreover, the findings are expected to inform local authorities, farmers, producers in their efforts to enhance productivity, quality control, and economic resilience in OCOP-certified value chains.

The paper is organized into five main sections. It begins with an Introduction, which outlines the research context, objectives, and significance of assessing technical efficiency in OCOP-certified edible canna production in the northern mountainous region of Vietnam. The Materials and Methods section details the research design, the use of SFA to estimate technical efficiency and the subsequent Tobit regression to identify its determinants. The Results and Discussion interpret empirical findings in light of theoretical expectations, and the Conclusion summarizes the study's contributions, policy implications, and directions for future research.

STUDY AREAS AND RESEARCH METHODS

Study area

This study was conducted in Bac Kan province. The selection of Bac Kan province was based on three primary criteria: (1) its leadership position in OCOP-certified products, (2) its significant role in national edible canna cultivation, and (3) strong institutional support from the provincial government, making it an exemplary case for studying the OCOP model's impact. As of 2023, Bac Kan ranked among the top five provinces in Vietnam for the number of OCOP-certified enterprises, reflecting strong local engagement with the One Commune One Product initiative (Vietnam's Prime Minister, 2022a,

2022b). The provincial government has actively supported edible canna production through technical training programs and quality-control workshops, making Bac Kan an ideal context to examine how certification efforts translate into production efficiency. The yield of edible canna in Bac Kan in 2022 is reported to reach 73.8 tons/ha, much higher than many provinces like Cao Bang (53.6 tons/ha), underscoring the province's comparative advantage in this crop (People's Committee of Bac Kan Province, 2023). These biophysical strengths allow the study to focus on farmer-level factors – rather than extreme environmental variability – when assessing technical efficiency.

Finally, Bac Kan embodies the dual objectives of rural livelihood enhancement and value-chain development inherent in Vietnam's OCOP strategy. Income from value-added edible canna production has become a key driver of rural diversification in the province, contributing to reducing poverty, creating jobs, and enhancing sustainable development (Hoang *et al.*, 2018). By situating the research in Bac Kan, the study captures both the institutional infrastructure of OCOP support and the real-world outcomes in a province where the model has been most vigorously implemented. This makes Bac Kan an exemplary case for generating insights transferable to other mountainous regions pursuing similar agro-processing and certification initiatives.

This study employed a multi-stage sampling procedure. First, Na Ri district in Bac Kan province was purposively selected due to its high concentration of edible canna cultivation. Second, within the district, six communes (Con Minh, Cu Le, Quang Phong, Dong Xa, Tran Phu, and Van Lang) were chosen based on significant edible canna acreage and yield. Following data collection, the initial dataset was screened; samples with incomplete questionnaires were excluded. This resulted in a final dataset comprising 200 farms used for the analysis.

Methodologies

Stochastic frontier analysis for estimating technical efficiency

Technical efficiency (TE) is measured as the ratio between the observed output to the maximum output, under the assumption of fixed inputs (Farell, 1957; Coelli *et al.*, 2005). Two models of TE are primarily used in the efficiency literature. These are: (i) input-oriented (IO) technical efficiency, (ii) output-oriented (OO) technical efficiency.

Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) developed the stochastic frontier analysis (SFA) to estimate output-oriented TE of firms/producers using parametric econometric techniques. Accordingly, this study estimates technical efficiency of cana edulis production based on output-oriented TE. We assume that a edible canna farm produces a vector of single output denoted as Y , with $Y \in R_+^M$ by using inputs X ($X \in R_+^N$). The stochastic production frontier function of the i -th an edible canna farm is defined as following:

$$Y_i = f(Z_i, X_i, \alpha) \exp(\varepsilon_i) \quad (1)$$

Where: All farms are indexed with a subscript i ; Y_i denotes the fresh edible canna yield level; Z_i and X_i are vectors of inputs (with Z_{i1} is the potassium; Z_{i2} is the phosphorus; Z_{i3} is the nitrogen; Z_{i4} is the fuel cost; X_{i1} is the labor cost, X_{i2} is the bulb cost, X_{i3} is the other cost); α is parameters to be estimated; ε_i is the composed error term, which is equal to $v_i - u_i$. The term v_i is a two-sided ($-\infty < v_i < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g., weather; natural disasters, and luck), measurement errors, and other statistical noise. The term u_i is nonnegative random error term, independently and identically distributed as $N^+(0, \sigma_u^2)$ that represents the technical inefficiency of farm (Coelli *et al.* 2005).

Equation (1) estimated by the maximum likelihood analysis creates consistent estimators for α , λ , and σ . Where $\lambda = \sigma_u / \sigma_v$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

According to Battese and Corra (1977), the ratio variance parameter γ which relates to the variability of u_i to total variability σ^2 can calculate in the following manner:

$$\gamma = \sigma_u^2 / \sigma^2 \quad (2)$$

Such $0 \leq \gamma \leq 1$

If the value of γ is equal to zero, the difference between actual farmer yield and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e. technical inefficiency (Coelli *et al.*, 2005).

The technical inefficiency of individual farm can be estimated by using conditional distribution of u_i given the fitted values of ε_i and respective parameters (Jondrow *et al.*, 1982). If we assume that v_i and u_i are independent of each other, the conditional mean of u_i given ε_i is identified by:

$$E(u_i | \varepsilon_i) = \sigma^* \left[\frac{f^*(\varepsilon_i \lambda / \sigma)}{1 - F^*(\varepsilon_i \lambda / \sigma)} - \frac{\varepsilon_i \lambda}{\sigma} \right] \quad (3)$$

Where: $\sigma^{*2} = \sigma_u^2 \sigma_v^2 / \sigma^2$, f^* is the standard normal density function, and F^* is the distribution function, both functions being estimated at $\varepsilon \lambda / \sigma$.

The output-oriented technical efficiency of the i -th an edible canna farm is determined by the follow function:

$$TE_i = \frac{y_i}{f(X_i, \alpha) \exp(v_i)} = \exp(-E(u_i | \varepsilon_i)) = \exp(-\hat{u}_i) \quad (4)$$

Where: y_i is the observed the fresh edible canna yield level of the i -th edible canna farm, $f(Z_i, X_i, \alpha) \exp(v_i)$ is the maximum feasible of edible canna yield adjusted for statistical noise. TE_i score is between 0 and 1. A farm is fully efficient if TE equals to 1 and fully inefficient if its value is 0.

With the assumption of half-normal model, a simple z -test will be used for examining the existence of techni-

cal inefficiency, the null and alternative hypotheses are: $H_0: \lambda = 0$ (Coelli *et al.*, 2005). The test statistic is:

$$z = \frac{\hat{\lambda}}{se(\hat{\lambda})} \sim N(0, 1) \quad (5)$$

Where: $\hat{\lambda}$ is the maximum likelihood estimator of λ and $se(\hat{\lambda})$ is the estimator for its standard error.

Tobit model for analyzing determinants of technical efficiency

As efficiency scores from stochastic production frontier analysis varied between 0 and 1, the ordinary least square would produce biased and inconsistent estimates (Greene 2003; Bravo-Ureta and Pinherio 1997). Thus, to investigate the relationship among farms' efficiencies and various farmers' socio-economic factors and specific farm characteristics, a two-limit Tobit regression model was applied in this study. The model is estimated as a function of various attributes of the farmers within the sample, indicating which aspects of the farm's human and physical resources might be targeted by public investment to improve efficiency (Wadud and White 2000, Speelman *et al.* 2008). Tobit model can be specified in the following form:

$$TE_i = \omega_0 + \sum_{s=1}^{16} w_{is} K_{is} + e_i \quad (6)$$

Where: TE_i is a scalar of output oriented efficiency scores of the i -th edible canna farm including output and input oriented technical efficiency; K_{is} represents social and economic features of the i -th farmers and edible canna farms including: Age ($s=1$), Gender ($s=2$), Education ($s=3$), Ethnicity ($s=4$), Experience ($s=5$), Household size ($s=6$), extension service access ($s=7$), and cooperative membership ($s=8$), and perception of OCOP ($s=9$).

RESULTS AND DISCUSSIONS

Descriptive statistics

Descriptive statistics are essential before conducting further analyses because they provide a foundational understanding of the data. The following table presents a clear, simple view of our data.

Table 1 shows that Output has moderate average yield but varies widely, possibly due to differences in input usage or efficiency. Labor cost is the dominant expense which accounts for the largest average cost. The high mean and wide spread indicate some farms have significantly lower/higher labor costs.

While bulb cost has moderate mean with moderate variability, other cost and fuel cost show high variability across observations, which means they differ greatly by case and might affect profitability. Nutrient inputs (Nitrogen, Phosphorus, Potassium) vary considerably, suggesting different fertilization practices. In particular, potassium has moderate use, relatively consistent across samples while phosphorus has high variability in application amounts. It is also noticeable of wide range and notable variability in nitrogen use.

Table 1: Descriptive Statistics of variables

Variable	Mean	Max	Min	Std. dev.
Fresh edible canna yield (quintal/ha)	819.5	1850.0	325.0	246.2
Potassium (kg/ha)	416.1	875.0	200.0	138.8
Phosphorus (kg/ha)	513.0	1254.0	100.0	203.8
Nitrogen (kg/ha)	345.7	1000.0	100.0	156.7
Fuel cost (thousand dong/ha)	4,081.0	16,666.7	526.3	2,831.9
Labor cost (thousand dong/ha)	109,657.9	137,500.0	11,880.0	17,307.7
Bulb cost (thousand dong/ha)	6,396.4	11,428.6	1,600.0	1,844.7
Other cost (thousand dong/ha)	21,714.3	76,000.0	5,500.0	15,067.5

Source: Estimation of the authors

Edible Canna production function specification

Before estimating stochastic production frontier model, it is very essential to test multicollinearity and heteroskedasticity which cause the estimation in the model biased using Variance Inflation Factor (VIF) and Breusch–Pagan/Cook–Weisberg (Wooldridge, 2012). The results show that there has no multicollinearity¹ and heteroskedasticity² in the model. Furthermore, we specified the production functional form. The Cobb–Douglas function (null hypothesis: H_0) against the translog function (alternative hypothesis: H_1) was tested using the log likelihood test (Coelli *et al.* 2005). The likelihood ratio test statistic was equal to 47.52 which is greater than $\chi^2_{(28, 0.05)} \approx 41.337$, thus Cobb–Douglas function form was rejected at 5 % level. With it, the translog production model with seven significant inputs was used in this study. The estimates of translog production function ordinary least square (OLS) and maximum likelihood estimation (MLE) are presented in Table 2.

The R^2 is equal to 0.432, showing that around 43.2 percent of the variation of output is explained by inputs in the model. The presence of technical inefficiency effect in edible canna production was tested using z test. Using the results reported in Table 2 and function (5), we obtain $z_{statistic} = \frac{\hat{\lambda}}{se(\hat{\lambda})} = \frac{2.874}{0.071} = 40.48$. This test statistic exceeds the critical value $z_{0.99} = 2.576$, thus the null hypothesis that inefficiency effects were absent in the production model was rejected at 1 % level of significance, suggesting that the edible canna farms in the study site were technically inefficient. The results also pointed that 89.8 % of the variance of output was explained by technical efficiency effects ($\gamma=0.898$).

Prior to estimate efficiency, the return to scale of existing edible canna production technology was considered. Table 3 reports the output elasticity per individual input.

The variable with the highest elasticity was Bulb cost (4.843), followed by Labor cost (2.371), Phosphorus (2.203), Potassium (1.213), Other cost (0.187), and Nitrogen (−0.534). The sum of output elasticity (1.614) is greater than 1, indicating that Vietnamese edible canna production is under increasing returns to scale. This means that equiproportional increase all inputs in edible canna production leads to a greater than proportionate increase in output.

Technical efficiency of edible canna production

We estimated output-oriented TE of edible canna farms by equation (4). The estimation results are summarized in Table 4.

The average output-oriented TE of edible canna production was 77.45%, with the variation from 35.35% to 95.85%. This result suggests that the possibility of increasing edible canna yield level, with given inputs is 22.55%. 90% of farms have TE score greater than 60%, indicating that most of edible canna farmers in the study site achieve high output-oriented technical efficiency.

Factors affecting technical efficiency of edible canna production

The Tobit model was applied to determine the factors affecting TE of edible canna production instead of the OLS estimate producing biased results, often toward to zero (Bravo–Ureta & Pinheiro, 1997). As shown in the equation (6), TE was used as dependent variable and the socio-economic characteristics of the farmers were used as independent variables.

The sign of the variables in the Tobit model is very important in explaining the observed level of technical efficiency of the farmers. A positive sign on the coefficient implies that variables had an effect in increasing technical efficiency, while a negative coefficient signifies the effect of reducing technical efficiency. The results shows that variables such as: Household size; extension services access, cooperative member, and OCOP awareness have positive impacts on technical efficiency

¹ Mean value of VIF is equal to 1.32

² Prob > chi-square = 0.6080, indicating that the null hypothesis of constant variance is accepted

Table 2: Translog production function estimation

Variables	OLS		MLE	
	Coefficient	Std.error	Coefficient	Std.error
<i>Potassium</i>	5.063	5.027	8.623*	4.499
<i>Phosphorus</i>	1.645	5.767	-1.872	5.574
<i>Nitrogen</i>	-7.352	4.752	-8.510**	3.831
<i>Fuel cost</i>	0.283	2.997	-2.049	2.524
<i>Labor cost</i>	-7.113	7.169	-7.986	6.380
<i>Bulb cost</i>	2.575	5.590	4.264	4.956
<i>Other cost</i>	-0.009	4.292	-1.199	4.009
<i>Potassium. Potassium</i>	0.207	0.398	0.234	0.297
<i>Phosphorus. Phosphorus</i>	0.122	0.217	0.12	0.175
<i>Nitrogen. Nitrogen</i>	-0.006	0.237	-0.076	0.210
<i>Fuel cost. Fuel cost</i>	-0.064	0.084	-0.041	0.066
<i>Labor cost. Labor cost</i>	0.438	0.567	0.376	0.529
<i>Bulb cost. Bulb cost</i>	-0.209	0.321	-0.356	0.268
<i>Other cost. Other cost</i>	-0.116	0.151	-0.110	0.114
<i>Potassium. Phosphorus</i>	-0.164	0.246	0.135	0.188
<i>Potassium. Nitrogen</i>	-0.070	0.217	-0.165	0.197
<i>Potassium. Fuel cost</i>	-0.165	0.125	-0.181*	0.101
<i>Potassium. Labor cost</i>	-0.180	0.411	-0.495	0.358
<i>Potassium. Bulb cost</i>	-0.271	0.191	-0.305*	0.169
<i>Potassium. Other cost</i>	0.096	0.138	0.130	0.116
<i>Phosphorus. Nitrogen</i>	0.063	0.162	0.029	0.143
<i>Phosphorus. Fuel cost</i>	0.066	0.109	0.074	0.102
<i>Phosphorus. Labor cost</i>	-0.433	0.431	-0.256	0.424
<i>Phosphorus. Bulb cost</i>	0.417*	0.213	0.404	0.185
<i>Phosphorus. Other cost</i>	-0.090	0.115	-0.092	0.098
<i>Nitrogen. Fuel cost</i>	0.125	0.106	0.107	0.090
<i>Nitrogen. Labor cost</i>	0.600*	0.343	0.698**	0.301
<i>Nitrogen. Bulb cost</i>	-0.035	0.205	0.002	0.167
<i>Nitrogen. Other cost</i>	-0.020	0.144	0.079	0.115
<i>Fuel cost. Labor cost</i>	-0.017	0.228	0.159	0.201
<i>Fuel cost. Bulb cost</i>	-0.099	0.107	-0.087	0.086
<i>Fuel cost. Other cost</i>	0.126	0.082	0.141*	0.073
<i>Labor cost. Bulb cost</i>	0.110	0.385	0.056	0.338
<i>Labor cost. Other cost</i>	0.141	0.305	0.222	0.296
<i>Bulb cost. Other cost</i>	-0.158	0.15	-0.145	0.129
Constant	20.778**	9.126	8.623**	7.671
R^2	0.432			
σ_v			0.115	0.030
σ_u			0.331	0.044
σ^2			0.122	0.023
$\lambda = \sigma_u / \sigma_v$			2.874	0.071
$\gamma = \sigma_u^2 / \sigma^2$			0.898	

Note. *, ** indicate statistical significance of 10%, 5%

Source: Estimation of the authors

Table 3: Output elasticity per specific input

Input	Postassium	Phosphorus	Nitrogen	Fuel cost	Labor cost	Bulb cost	Other cost
Elasticity	1.213	2.203	-0.534	1.013	2.371	4.843	0.187
Sum				1.164			

Source: Estimation of the authors

Table 4: Output – oriented technical efficiency distribution

TE levels	Output orientation		
	No of farm	Percent %	Cumulative %
≤60%	20	10.00	10.00
60% – 70%	42	21.00	31.00
70% – 80%	35	17.50	48.50
80% – 90%	62	31.00	79.50
≥90%	41	20.50	100.00
Mean		77.45	
Median		80.42	
Min		35.35	
Max		95.85	

Source: Estimation of the authors

Table 5: Determinants of technical efficiency in Tobit model

Explanation	TE Coef.
Age of House hold (years)	-0.0004
Gender of House hold (1=male, 0=female)	-0.0289
Education level of House hold (years)	0.0012
Ethnicity of House hold (1=Kinh, 0= otherwise)	-0.0129
Experience in edible canna farming (years)	-0.0003
Household size	0.0119**
Extension services access (1= farmer access to extension service, 0=otherwise)	0.0745***
Cooperative member (1= farmer join cooperative, 0=otherwise)	0.0811***
OCOP awareness (1= farmer aware of OCOP program, 0=otherwise)	0.0648***
Constant	0.6433***

Note. *** and ** indicate statistical significance of the 0.01 and 0.05 level, respectively

Source: Estimation of the authors

We employed the translog stochastic frontier analysis for cross-sectional data sets of 200 edible canna farmers in 2024 to estimate technical efficiency of edible canna production in the Northern mountainous region of Vietnam. We also characterized edible canna farmers in to social and economic classes and evaluate their impact on technical efficiency. The results showed that the farmers' socio-economic characteristics such as: household size, extension services access, members of cooperatives, and awareness of OCOP programme have significant influence on technical efficiency of edible canna production in the region.

It is clearly shown from Table 5 that Household size variable had a positive effect to output-oriented technical efficiency. Households with more people can produce more output with given inputs. This result supplements the finding of Tran *et al.* (2024) that household size, along with plot size, had a positive and statistically significant effect on output oriented technical efficiency among Vietnamese agricultural households (Tran *et al.*, 2024), or the study by Hoi *et al.* (2022) in which Household size was found to have a positive but statistically insignificant impact on technical efficiency (Vu *et al.*, 2019)

Extension services access variable had positive significant effects on technical efficiency at the level of 1 percent, implying that accessing extension services can help edible canna farmers not only increase output but also save inputs use. By accessing extension services, these farmers can receive guidance on best practices, efficient input use, and sustainable farming techniques, potentially leading to increased yields and cost savings. We also found that agricultural extension services could help improving technical efficiency. This result is consistent with literature (Hoang *et al.*, 2018). Specifically, Vu, Peng, and Chung (2020) found that farms with better access to extension services exhibited higher levels of technical efficiency, suggesting that such institutional support is essential for improving resource allocation and narrowing the efficiency gap among producers.

Agricultural extension policy was designed in Vietnam to develop agriculture production in a sustainable way. Edible canna production is one of the important sectors implementing this policy. Extension service includes several features such as: training courses or technical instruction on edible canna cultivation (land preparation, planting etc.), training on modern techniques of application of fertilizer and pesticide, training on harvesting and conservation, provision of information on edible canna market and sale skills. Extension service is important tool in educating farmers and it could bring positive behavioral changes among farmers. Thus, it is essential for Vietnamese edible canna farmers to have easy access to extension services in order to optimize on-farm technical efficiency, given the limited resources available.

Cooperative member variable also had a statistically positive effect on output-oriented technical efficiency. The effect is positive and significant at the 1% level,

indicating that farmers being members of cooperatives had more potential to expand output and to reduce inputs, compared with those who did not participate in any cooperative. Though this research is the first Vietnam-specific research on edible canna production that examines the effect of cooperative membership on output-oriented technical efficiency, this result is consistent with similar research. The study by Qu *et al.* (2020) assessed Chinese apple farmers using stochastic frontier analysis and propensity score matching (PSM). They found that membership in agricultural cooperatives was associated with higher output-oriented technical efficiency, particularly for non-marketing cooperatives (Qu *et al.*, 2020). Therefore, the promotion of cooperative membership is very important to produce edible canna efficiently and sustainably.

OCOP awareness variable had a significant positive impact on output-oriented technical efficiency. To the best of our knowledge, there are no studies that specifically measure or validate an effect of OCOP awareness on output-oriented technical efficiency in any agro-production setting. In this research, the positive sign of OCOP awareness suggests that for farmers who are aware of OCOP programme, their productive efficiency will be increased through reduction of inputs. With higher income, farmers can have more chance to improve knowledge of modern cultivation techniques or buy good machines, which lead to inputs saving in production process. Bui *et al.* (2018) analyzed upland and lowland rice farmers in Vietnam using Stochastic Frontier Analysis to assess technical efficiency. They found that higher-income farmers – who often had more assets and diverse income sources – were better situated to adopt sustainable practices (like certified seed, reduced chemical use, and mechanization) promoted through extension services. These practices led to more efficient use of seeds, fertilizers, and labor inputs, enhancing output with fewer resources (Bui *et al.*, 2018).

CONCLUSIONS

In Vietnam's Northern Mountainous Region, the development of sustainable OCOP (One Commune One Product) noodles – particularly those made from edible canna – offers a promising pathway for enhancing rural livelihoods and promoting local agro-based industries. However, the long-term success and sustainability of these value-added products depend critically on the efficiency of raw material production at the farm level.

This study provides essential insights by evaluating the technical efficiency (TE) of edible canna cultivation using translog stochastic frontier analysis and Tobit regression, based on primary data collected from 200 farmers in 2024. The results indicate an average output-oriented TE of 77.45%, suggesting that yields could be improved by 22.55% without increasing input use – an efficiency gain with direct implications for strengthening the edible canna supply chain. Importantly, socio-economic factors such as household size, access to agricul-

tural extension services, cooperative membership, and awareness of the OCOP program were found to significantly influence TE. These findings underscore the critical role of improving farm-level efficiency not only for resource optimization but also for ensuring a stable, high-quality, and cost-effective input base for OCOP noodle production.

This study makes a distinct academic contribution by bridging a gap in the literature concerning the efficiency of niche, OCOP-certified agricultural products in Southeast Asia. While previous studies have focused on staple crops, our research provides a rare empirical analysis of edible canna, a culturally important but under-researched commodity. The innovative aspect is the quantitative link established between OCOP program awareness and technical efficiency, offering novel evidence that institutional branding and support programs can translate into measurable performance improvements at the farm level. The findings of this study can be applied by provincial Departments of Agriculture and Rural Development in Bac Kan province and other provinces in Northern Mountainous Region, to design more effective farmer support programs. For instance, the quantified positive impact of cooperative membership provides a clear rationale for policymakers to allocate resources towards establishing and strengthening agricultural cooperatives in the region.

In the context of the Northern Mountainous Region – where limited infrastructure, smallholder farming, and income disparities prevail – this research highlights that enhancing technical efficiency is a strategic lever for supporting inclusive, resilient, and sustainable development of OCOP noodles. Strengthening farmer support systems through targeted extension, cooperative engagement, and OCOP awareness-building will be vital to realizing the full potential of the OCOP program in this region. Specific suggestions are as follows:

First, to improve resource use efficiency in edible canna production, the government should focus on enhancing agricultural extension services. This includes expanding the reach of extension officers, especially in underserved areas, and providing targeted training on sustainable farming techniques and efficient resource management. Leveraging digital tools such as mobile applications and radio programs can also help disseminate timely and relevant information to farmers.

Supporting and promoting farmer cooperatives is another key strategy. The government can assist in forming cooperatives, offer incentives for effective group performance, and provide leadership training in areas such as business management and marketing. Cooperatives can play a crucial role in reducing production costs and improving access to markets and inputs.

Third, raising awareness and encouraging participation in the One Commune One Product (OCOP) programme is equally important. This can be done through local campaigns, demonstration farms, and offering incentives for farmers who engage with the programme. Additionally, helping farmers with product branding and marketing under the OCOP initiative can open up new

opportunities and add value to their produce.

Further, improving farmers' access to affordable credit and quality inputs will empower them to adopt resource-efficient technologies and practices. Subsidized loans and support for acquiring improved seeds or irrigation systems can significantly enhance productivity.

Lastly, the government should invest in localized research and rural infrastructure, such as roads and storage facilities, to reduce post-harvest losses and streamline the supply chain. Continuous monitoring and evaluation of these interventions will ensure policies remain effective and adaptive to farmers' needs.

Future research could expand upon these findings in several directions. A longitudinal study tracking the same farms over several years would provide insights into how technical efficiency evolves over time. Comparative studies across different OCOP products or other mountainous regions could help generalize the findings. Furthermore, future research could incorporate variables related to climate change resilience and specific market access channels to provide a more comprehensive understanding of sustainable agricultural development. Another perspective is to investigate how farm mechanization or improved processing technology influences technical efficiency in edible canna production. Exploring these avenues will deepen insight into the mechanisms driving sustainable agricultural productivity.

AUTHOR CONTRIBUTIONS

Do Thi Thuy LINH designed research questionnaire, collected data, and wrote a part of the manuscript. Nguyen Bich HONG advised the research methodology, analyzed data, managed the whole writing process, wrote and revised the manuscript. Yoshifumi TAKAHASHI supervised the research, commented and edited on the manuscript. All authors read and approved the final manuscript.

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REFERENCES

- Aigner, D., C. A. K. Lovell and P. Schmidt 1977 Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, **6**(1): 21–37
- Battese, G. E. and G. S. Corra 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
- Bravo-Ureta, B. E. and A. E. Pinheiro 1997 Technical, economic, and allocative efficiency in peasant farming: Evidence from the Dominican Republic. *The Developing Economies*, **35**(1): 48–67
- Bui, T. L., H. C. Tran, H. Azadi and P. Lebaillly 2018 Improving the technical efficiency of Sengcu rice producers through better financial management and sustainable farming practices in

- mountainous areas of Vietnam. *Sustainability*, **10**(7): 2279
- Cao, M., C. Liu, Z. Zhou, W. Li and J. Li 2025 Effect of Canna edulis starch addition on the properties of flour, rheology of dough and quality of semi-dry noodles. *Journal of the Science of Food and Agriculture*, **105**(6): 3474–3482
- Coelli, T., D. S. P. Rao, C. J. O'Donnell and G. E. Battese 2005 *An introduction to efficiency and productivity analysis* (2nd ed.). Springer.
- Farrell, M. J. 1957 The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General)*, **120**(3): 253–290
- Greene, W. H. 2003 Simulated likelihood estimation of the normal-gamma stochastic frontier function. *Journal of Productivity Analysis*, **19**(2–3): 179–190
- Hoang, T. L., N. L. Ta, D. H. Nguyen, T. M. H. Ho and P. Lebailly 2018 One Village One Product (OVOP) – A Rural Development Strategy and the Early Adaption in Vietnam, the Case of Quang Ninh Province. *Sustainability*, **10**(12): 4485
- Hoi, V. X., N. D. Quyen, D. T. T. Xuan, B. N. Tan, N. T. P. Thao, L. T. Phiet, N. Dat, T. T. Ha and L. D. Niem 2022 Training, technology upgrading, and total factor productivity improvement of farms: A case of cassava (*Manihot esculenta* Crantz) production in Dak Lak province, Vietnam. *Cogent Economics and Finance*, **10**(1)
- Jondrow, J., C. K. Lovell, I. S. Materov and P. Schmidt 1982 On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics*, **19**(2): 233 – 238
- Meeusen, W. and J. Van Den Broeck 1977 Efficiency estimation from Cobb–Douglas production functions with composed error. *International Economic Review*: 435–444
- Nguyen, N. T.T. and T. Nguyen 2021 Impact of government intervention to maize efficiency at farmers' level across time: a robust evidence in Northern Vietnam. *Environment, Development and Sustainability*, **23**(3)
- People's Committee of Bac Kan Province 2023 Report No: 138 /BC–SNN on Production plan and linkage for consumption of edible canna in Bac Kan province.
- Qu, R., Y. Wu, J. Chen, G. D. Jones, W. Li, S. Jin, Q. Chang, Y. Cao, G. Yang, Z. Li and L. J. Frewer 2020 Effects of agricultural cooperative society on farmers' technical efficiency: Evidence from stochastic frontier analysis. *Sustainability*, **12**(19): 8194
- Speelman, S., M. D'Haese, J. Buysse and L. D'Haese 2008 A measure for the efficiency of water use and its determinants, a case study of small-scale irrigation schemes in North–West Province, South Africa. *Agricultural Systems*, **98**(1): 31–39
- Tran, D. T., T. T. Nguyen, V.A. Dao, A. T. Nguyen, T. T. L. Nguyen, A. A. Shah and T. L. H. Nguyen 2024 Technical efficiency and returns to scale in Vietnam's agriculture: Stochastic output distance function approach. *Hong Kong Journal of Social Sciences*, **63**
- Tran, G. T. H., T. Nanseki, Y. Chomei and L. T. Nguyen 2023 The impact of cooperative participation on income: The case of vegetable production in Vietnam. *Journal of Agribusiness in Developing and Emerging Economies*, **13**(1): 106–118
- Vietnam's Prime Minister. 2022a. Decision No. 263/QĐ–TTg on Approving the national target program on building new rural areas for the 2021–2025 period.
- Vietnam's Prime Minister. 2022b. Decision No. 919/QĐ–TTg on Approving the One Commune One Product Program for the 2021 – 2025 period
- Vu, T. H., K. C. Peng and R. H. Chung 2019 Evaluation of environmental efficiency of edible canna production in Vietnam. *Agriculture*, **9**(11): 242
- Vu, T. H., K. C. Peng and R. H. Chung 2020 Efficiency measurement of edible canna production in Vietnam. *AIMS Agriculture and Food*, **5**(3): 466–479
- Vu, T. H., K. C. Peng, R. H. Chung and H. T. Dao 2021 Energy efficiency measurement of arrowroot production in Vietnam. *AIMS Energy*, **9**(2): 326–341
- Wadud, A. and B. White 2000 Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods. *Applied economics*, **32**(13): 1665–1673
- Wooldridge, J. M. 1960 *Introductory econometrics: a modern approach*. Mason, Ohio: South–Western Cengage Learning.

