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Efficiency Analysis of the Progress of Orange Farms in Tuyen Quang Province, Vietnam towards Sustainable Development

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Abstract: Nowadays, Vietnam is known as a developing country with a fast-growing economy. Agriculture is the main traditional sector which plays an important role in Vietnamese economic growth and development. Improving the efficiency of agricultural production towards sustainable development is one of the country's national economic development goals. This study aims to measure the efficiency of the orange farms which have created jobs and improved living standards for people in Tuyen Quang province, Vietnam. A comprehensive literature review, key informant interviews, and a structured questionnaire were applied in this research for data collection. The data envelopment analysis (DEA) model was applied to evaluate the technical, allocative, cost, and scale efficiencies. The main results of this analysis show that the orange farms have high scores for technical and scale efficiencies. On the other hand, the research reveals low levels of cost and allocative efficiencies. This is in line with the fact that though the farms' owners have extensive experience in orange cultivation and receive periodic technical training, they still have low levels of education and a lack of economic management expertise. The study results also propose optimal input allocation for the orange farmers. The research could provide crucial information to farms' owners, the local government, and agricultural planners for formulating effective strategies to improve agricultural sustainability.

Keywords: efficiency; data envelopment analysis (DEA); Vietnam; orange production; farm management

1. Introduction

Located in Southeast Asia, Vietnam is a developing country. Vietnam is considered to be an agricultural-based economy, as agriculture is still a major contributor to the country's GDP. In 2018, agriculture contributed 14.68% of Vietnam's gross domestic product [1]. Sustainable economic development was an important goal for Vietnam's sustainable development during the 2011–2020 period [2]. Accordingly, it is necessary to restructure agriculture and rural areas towards industrialization, promoting the strengths of each region. It is also necessary to produce agricultural products with quality and efficiency, improve income on a hectare of farmland per each day of labor, improve the living standards of farmers, and improve the sustainable development of trade villages.

Along with traditional crops such as rice, maize, industrial crops, and citrus are the key crops in Vietnam. Citrus is believed to have been cultivated more than 4000 years ago [3], originating from Southeast Asia, China, and India [3–5]. Oranges have become one of the most popular fruits in the world in general, and in Vietnam in particular, thanks to their delicious taste and their high levels of folic acid, fiber, and vitamin C [4,6].

During citrus production, the climate is the most powerful natural factor affecting plant growth [7]. Orange trees require high temperatures, sunlight, and adequate rainfall, so commercial oranges come from areas between the 40-degree latitudes north and south of the equator [7]. With its monsoon tropical climate, which occurs from 8°10' North to 23°24' North [8], Vietnam is an ideal area to cultivate oranges and other citrus trees. According to the statistics of the Food and Agricultural Organization of the United Nations, in 2016, 66,974.1 million tons of oranges were produced worldwide, out of which Vietnam contributed 520 million tons [9]. The orange and tangerine growing area of Vietnam in 2016 was 101.3 thousand hectares; in 2017, it increased to 112.5 thousand hectares; in 2018, it went up to 120.8 thousand hectares [10]. Commercial oranges in Vietnam come from some southern provinces and some northern mountainous areas.

Citrus trees, especially orange trees, has become the key fruit tree for many localities. They contribute positively to the creation of employment and income, thus providing an improvement of living standards for farmers. This can be seen in data obtained from Tuyen Quang, where 93 of 107 interviewed farmers said that they decided to plant orange because this crop offers a higher return than other local traditional crops.

Tuyen Quang is a mountainous province, located in the north east, bordering the provinces of Cao Bang, Bac Kan, Thai Nguyen, Vinh Phuc, Phu Tho, Yen Bai, and Ha Giang and is about 165 km from Hanoi, the capital of Vietnam [11]. The main economic activity for the local people of this province is agriculture. In 2018, agriculture, forestry, and fishery accounted for 24.28 percent of Vietnamese gross regional domestic product (GRDP) [12]. Tuyen Quang has a climate and soil suitable for orange trees, which has been identified as important crops that boost commodity production there [13]. In 2018, Tuyen Quang's orange production reached 81,000 tons [12], ranking second in the Tuyen Quang's region; this figure is lower than that for Hoa Binh province (123,000 tons) [14], but higher than for the neighboring provinces Ha Giang (55,000 tons) [15] and Bac Kan (17,000 tons) [16]. Sustainable and effective high-tech application of agriculture is identified as one of the socio-economic development goals of Tuyen Quang province [17]. The Tuyen Quang government has focused on developing the farming model towards promoting commodity production and applying technical advances to production to improve the productivity, quality, efficiency, and competitiveness of key agricultural products [18]. The Tuyen Quang government has developed a mechanism to encourage orange production after recognizing the role of orange trees in the sustainable livelihood of rural people that involves creating sustainable jobs and income for local people, stabilizing living conditions, and improving the living standards of the local people and the local economy, thereby contributing significantly to gross domestic product [13,19,20].

In Tuyen Quang, oranges have been grown widely in Ham Yen district for more than two decades and become the highest economic value crop of the locality. The cultivation area and orange production rates in Tuyen Quang and Ham Yen are shown in Table 1:

Table 1. Orange cultivated area and production rates in Ham Yen and Tuyen Quang.

Year	Area (ha)			Production (ton)		
	Ham Yen (1)	Tuyen Quang (2)	Proportion (1)/(2)	Ham Yen (1)	Tuyen Quang(2)	Proportion (1)/(2)
2014	4603	5139	89.6%	41,104	43,048	95.5%
2015	6590	7243	91.0%	45,523	47,929	95.0%
2016	6943	7732	89.8%	54,151	56,797	95.3%
2017	7159	8331	85.9%	63,582	67,783	93.8%
2018	7270	8634	84.2%	75,212	81,088	92.8%

Source: [12,21].

Recent annual reports have shown the expansion of the orange farms in Tuyen Quang province [22–26]. The farms have contributed to creating jobs for family labors and hired workers tending and harvesting oranges. In 2018, orange farms created jobs for 568 family labors, 477 permanent hired workers, and 2197 seasonal outsourced workers [26]. The operation of orange farms is significant for creating jobs for local people, especially for untrained workers, while at the same time creating social stability and minimizing the negative impacts of unemployment. Local authorities highly appreciate the efficiency of farms and encourage the development of the farming model as a solution to boost local socio-economic sustainable development. [27]. However, there are currently no studies that scientifically evaluate the efficiency of these farms to provide impact solutions to improve their performances or the value of local orange production. Are orange farms in Tuyen Quang operating effectively? How should we measure their efficiencies? How efficient are they in comparison to similar farms? In order to answer these questions, this study is done to measure the efficiency of orange farms in Tuyen Quang province based on technical efficiency, allocative efficiency, cost efficiency, and scale efficiency.

The study includes five sections: the Introduction—presenting the place of study, the purpose, and the significance of the measurement of the efficiency of the orange farms in Tuyen Quang province; Materials and Methods—describing the study site and sampling, the Data Envelopment Analysis (DEA) approach, and the inputs and output of the local orange farms; Results—providing the results of the study based on the data collected, and suggesting the proposed results from the model; Discussion—explaining the results of analysis from the local situation and comparing them with the others studies, and Conclusion—summarizing the results and recommendations for sustainable orange production.

The study shows that the orange farms in Tuyen Quang province have high technical efficiency but low allocative efficiency and cost efficiency. The farmers can improve the performance of their farms by economizing and efficiently combining their existing resources.

2. Materials and Methods

2.1. Study Site and Sampling

The orange cultivated area and its production yield in Tuyen Quang province are predominately in Ham Yen district [12,21,26]. Therefore, this research chose Ham Yen district, Tuyen Quang province as the study site.

Figure 1 describes the location of the study site. Ham Yen district is located about 40 kilometers from the Tuyen Quang city in the west of Tuyen Quang province. The total natural area of Ham Yen district is of 90,093 ha, of which the land for agricultural production is 11,403 ha, accounting for 13 percent of the total area [30]. Orange tree has been the spearhead tree of the district for more than two decades. The hilly land area is 61,039 ha, and is suitable for fruit trees (citrus, pineapple), industrial crops (citronella, tea), and food crops (corn, cassava) [30].

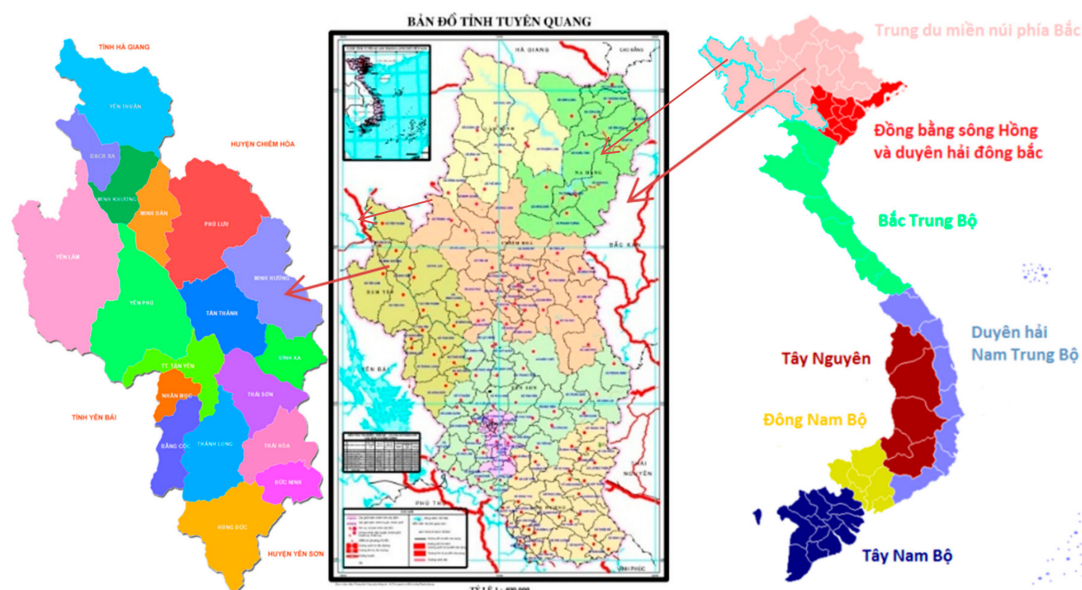


Figure 1. The study site. (Source: [28,29]).

The annual rainfall of the region is 1600–1800 mm and the average number of rainy days is 150 days per year; the water for production and daily life comes from numerous streams and the Lo river [13]. The orange tree requires temperatures of 20 °C to 35 °C, and abundant sunlight for 6 to 7 hours for best performance [31]. Ham Yen has adequate rainfall and a heat regimes that is suitable for the development of fruit trees, especially Sanh orange—a typical local orange that has a strong sweet taste, and is seedy [13].

A farming model in which orange farms are major is encouraged to develop by the local government because of its positive role in local socio-economic development. The orange farms offer jobs for both family labor and outsourced labor [26]. According to the current regulations of the Vietnamese government, to obtain a Farm Certificate, farms need to simultaneously meet two criteria: an annual production value of at least 700 million VND (the Vietnamese currency unit), and a minimum area of 2.1 ha [32].

The experimental unit of the study is the individual farm, which is suitable for small scale research [33]. The larger the number of samples, the higher the accuracy, but due to time and cost limitations, it is necessary to determine the sample size [34]. The minimum number of samples was adopted from the model developed by [35]:

$$n = \frac{z^2 pq}{e^2} \quad (1)$$

where n is the minimum number of samples, z is the distribution value corresponding to the selected reliability, p is the value of estimated percentage of certified farms in the total farms which meet the two criteria for a Farm Certificate, $q = 1 - p$, and e is allowed error.

Using $p = 0.93$ which came from the pilot survey, a 95% confidence interval, and 5% of allowed error, n is calculated by:

$$n = \frac{1.96^2 \times 0.93 \times 0.07}{0.05^2} \approx 100. \quad (2)$$

A total of 107 valid samples were selected from the target population according to the random sample selection method [36]. A structured questionnaire was built after in-depth document reviews and six trial interviews [37]. Official interviews were conducted from April to June 2019. Collected data were processed and analyzed using DEAP 2.1 [38], maxDEA [39], and SPSS 20 [40].

2.2. Efficiency Measurement and Data Envelopment Analysis (DEA)

Technical efficiency relates to a unit's performance ability in the context of its given factors and technology. The theory of technical efficiency was proposed by Koopmans in 1951. As stated by Koopmans, a producer is technically efficient if an increase in an output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output [41]. Agreeing with Koopmans, Greene argued that producers would be described as efficient if they were producing as much as possible with the inputs they used or whether they were producing that output at a cost minimum [42].

Debreu and Farrell are considered to be the founders of efficiency measurement. Farrell proposed the concept of economic efficiency consisting of two components: technical efficiency and price efficiency [43]. Two useful approaches for efficiency measurement are an output-orientated approach and an input-orientated approach [43,44]. Scientists are continuing to perfect the theory of efficiency measurement. Two common methods used to estimate frontier functions are Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) [45].

DEA is a non-parametric linear programming based technique for measuring the relative efficiency of a set of similar units, which are usually called decision making units (DMUs). The two main advantages of the DEA approach are the avoiding of parametric specifications of technology, and the avoiding of distributional assumptions for the inefficiency term. The first DEA model (commonly known as the CCR-DEA model) was developed by Charnes, Cooper, and Rhodes in 1978 to measure the performance of each DMU compared to the best performance observed in the sample, assuming a constant return to scale and disposability in inputs and outputs [46]. In 1984, following the research of Charnes et al., Banker, Charnes, and Cooper introduced the BCC-DEA model (also known as the VRS-DEA model) to estimate 'pure' technical efficiency under the assumption of variable returns to scale [47]. The conceptual model was presented in Figure 2. The BCC-DEA model was commonly used in the 1990s [45]. The possibility of using DEA to measure efficiency continuously has been of interest to scientists [48–55].

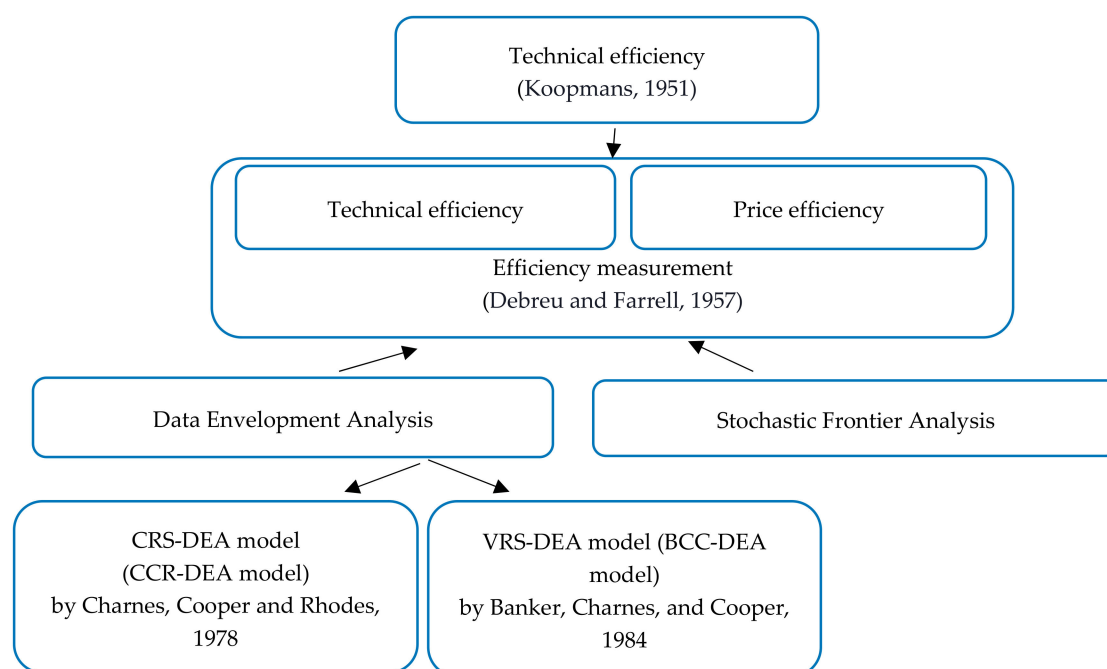


Figure 2. The conceptual model. Source: Authors' summary.

Banking, health care, and agriculture are the three biggest industries that apply the DEA method [56]. Indeed, the measurement of efficiency in agricultural production is a research issue of

major concern to many scientists [57–60]. The terms technical efficiency (TE), allocative efficiency (AE), cost efficiency (CE), and scale efficiency (SE) are widely used to assess agricultural performances.

To evaluate the efficiency of orange farms in Tuyen Quang province, the constant returns to scale DEA model (CRS-DEA model) and the variable return to scale DEA model (VRS-DEA model) were adopted. Outputs and inputs collected from the sample were used to estimate TE, AE, CE, and SE. The DEAP version 2.1, maxDEA was used to estimate the efficiency of orange farms in Tuyen Quang Province.

2.3. Data Envelopment Analysis Model

Efficiency is defined as the ratio of the weighted sum of outputs to the weighted sum of inputs. In this study, the input-oriented models were adopted. Thus, how much firms should reduce their inputs to achieve enough efficiency to provide the same volume of production was determined.

2.3.1. Estimation of Technical Efficiency

We used N decision making units (DMU) ($DMU_i, i = 1, 2, \dots, N$), where each DMU produces S kinds of outputs, y_{ri} ($r = 1, 2, \dots, S$), using M different inputs, x_{ji} ($j = 1, 2, \dots, M$). Technical efficiency was estimated by using the CRS-DEA input-orientated model [61]:

$$\text{Min}_{\theta, \lambda} \theta,$$

subject to:

$$\begin{aligned} -q_i + Q\lambda &\geq 0 \\ \theta x_i - X\lambda &\geq 0 \\ \lambda &\geq 0 \end{aligned} \tag{3}$$

where θ is a scalar, λ is a $N \times 1$ vector of constants, and i denotes the i -th DMU ($i = \overline{1, n}$). The obtained value θ is the efficiency score of DMU_i . The efficiency score was calculated in turn for each DMU.

2.3.2. Calculation of Scale Efficiency

Technical efficiency can be calculated by using both a CRS model and a VRS DEA model. The one obtained from the CRS DEA model was decomposed into two components: VRS TE and scale efficiency [61]. The difference between CRS TE and VRS TE for a particular DMU is scale efficiency. The scale efficiency measure can be roughly interpreted as the ratio of the average product of a firm operating at the point P_v to the average product of the operation at a point of (technically) optimal scale (point R). The scale efficiency calculation is modeled on Figure 3.

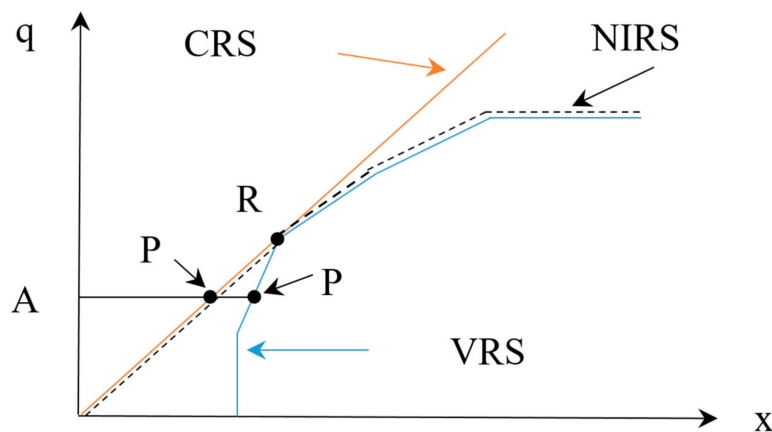


Figure 3. Calculation of scale efficiency in Data Envelopment Analysis (DEA). (Source: [61]).

VRS TE was determined by substituting the convexity constraint: $I1'\lambda = 1$ in DEA-model (3):

$$\text{Min}_{\theta, \lambda} \theta,$$

subject to:

$$\begin{aligned} -q_i + Q\lambda &\geq 0 \\ \theta x_i - X\lambda &\geq 0 \\ I1'\lambda &= 1 \\ \lambda &\geq 0 \end{aligned} \quad (4)$$

where $I1$ is an $I \times 1$ vector of ones. This approach formed a convex hull of intersecting planes that envelope the data points more tightly than the CRS conical hull and thus provides technical efficiency scores that are greater than or equal to those obtained using the CRS model [61].

One shortcoming of this measure of scale efficiency is that the value does not indicate whether the firm is operating in an area of increasing or decreasing returns to scale. This latter issue can be determined by running an additional DEA problem with non-increasing returns to scale (NIRS) imposed. This was done by altering the DEA model (4) through substituting the $I1'\lambda = 1$ with $I1'\lambda \leq 1$, to provide: $\text{Min}_{\theta, \lambda} \theta$, subject to:

$$\begin{aligned} -q_i + Q\lambda &\geq 0 \\ \theta x_i - X\lambda &\geq 0 \\ I1'\lambda &\leq 1 \\ \lambda &\geq . \end{aligned} \quad (5)$$

2.3.3. Calculation of Cost Efficiency and Allocative Efficiency

Using VRS-DEA input-orientated model that was determined in linear programming (4), we then ran the following cost minimization DEA [62]:

$$\text{Min}_{\lambda, x_i^*} w_i' x_i^*,$$

subject to:

$$\begin{aligned} -q_i + Q\lambda &\geq 0 \\ x_i^* - X\lambda &\geq 0 \\ I1'\lambda &= 1 \\ \lambda &\geq 0 \end{aligned} \quad (6)$$

where w_i is a $N \times 1$ vector of input prices for the i -th DMU and x_i^* is the cost-minimizing vector of input quantities for the i -th DMU, given the input prices w_i and the output level q_i .

The total Cost Efficiency (CE) of the i -th DMU was calculated as:

$$CE = \frac{w_i' x_i^*}{w_i' x_i}. \quad (7)$$

The allocative efficiency was then calculated residually as:

$$AE = \frac{CE}{TE}. \quad (8)$$

2.3.4. The Output and the Inputs

The Output

The output of an orange farm is only orange fruit. Oranges ripen fully from October to February of the year after they grow. All of the farms studied here sell fresh oranges and do not sell other

products made from oranges. Diversification of output is desirable for many farm owners, but the current local production technology is not sufficient to enable this.

In this study, the output was determined as the amount of oranges harvested, in tons. The output of each farm was collected through interviews of farm owners. The 2018-2019 crop was assessed to be a seasonal crop [26]. The orange production of farms in the sample is scattered from 25 tons to 290 tons, while the average yield of these farms is 109 tons per farm.

The Inputs

Orange production inputs include:

Land: Land for production was recorded as all of orchards used for growing oranges. In Vietnam, all of the land is owned by the people, under the ownership and uniform management of the state, and the state grants land-use rights to people to use under the Land Law [63]. In the study site, all of the farms were allocated productive land, without having to rent land, so the cost of land did not exist. Since each farm may have more than one orange orchard, the area of land produced in hectares is the total area of all orange orchards.

Labor: All of the farms studied use family labor in orange production. Orange farmworkers come from two sources: Family labor and outsourced labor. Family labor is the portion of this labor that is not paid for. The calculation of the number of working hours used for production activities is very complicated; the unit used in the study for this input was the number of people. The number of family members involved in orange production was collected through direct interviews with farm owners. In the 107 farms observed, 305 working-age family members work at these farms as their main job. Outsourced labor includes permanent labors and seasonal workers. Outsourced permanent laborers are those who are usually hired by couples to work permanently on the farm all year round; the cost of hiring outsourced labor varies from 35 to 45 million VND for two people per year [26]. Seasonal workers are hired to spray, clean orchards, and harvest or transport oranges from the mountains to the selling points. For the 2018–2019 crop, each farm paid an average of 115 million VND to pay for outsourced workers, including 77.5 million VND for seasonal workers. Because the farm owners are unable to account for the number of outsourced workers involved harvesting and transporting oranges, and information is available on the amount paid to outsourced workers, in this study, this input is called outsourced labor costs, which is measured in thousands of VND.

Crop production costs: Crop production costs of orange farms are the sum of numerous types of costs used in production, including fertilizer costs, pesticide costs, fuel costs, and so on. The two main costs in orange production are fertilizer costs and pesticide costs; the average value of these two types of costs at the surveyed farms is 76.2 million VND/farm/crop and 77.3 million VND/farm/crop, respectively.

Other expenditure: Because the farms in the study site do not have high-value agricultural machines that meet the fixed asset standards, depreciation does not exist. This cost includes interest costs and tool costs.

The inputs and output of orange farms are summarized in Table 2:

Table 2. Basic statistics for the data used.

Items	Min	Max	Mean
Output:			
Production (ton)	25	290	108.95
Inputs:			
Land (ha)	2.2	20.0	5.59
Family laborer (person)	0	7	2.85
Outsourced labor cost (1000 VND)	30,000	401,000	115,102.80
Crop production cost (1000 VND)	56,500	444,000	158,686.92
Other expenditures (1000 VND)	1000	134,000	12,752.16

Source: Data surveyed (2019).

3. Results

There are many computer programs used to estimate technical efficiency, allocative efficiency, cost efficiency, and scale efficiency: DEAP [38], MaxDEA [39], rDEA in R [64], and so on. This study used DEAP 2.1 and MaxDEA for calculations and used program SPSS for analysis.

3.1. Technical Efficiency, Allocative Efficiency, and Cost Efficiency

3.1.1. Technical Efficiency

We used the constant return to scale technique to estimate technical efficiency. The results from DEAP 2.1 were continuously analyzed by the program SPSS 20, as shown in Table 3.

Table 3. Summary of technical efficiency estimates from the CRS-DEA input-orientated model.

Statistic	Technical Efficiency	Statistic	Technical Efficiency
Mean	0.82341	Kurtosis	0.893
Minimum	0.205	Std. Error	0.463
Maximum	1.000	Skewness	−0.955
Standard deviation	0.163910	Std. Error	0.234

Sources: Data surveyed, 2019.

The average technical efficiency for the sample was about 82 percent, with a minimum of about 21 percent and a maximum of about 100 percent (Table 3). This implies that the farm owners that were interviewed can save an average of 18 percent of their mix of input while obtaining the same output by adopting the technology and the techniques used by the best practice orange farms.

It was observed that only 16 percent of the farms have a technical efficiency level that is less than 0.7, 55 percent of the farms have a technical efficiency level that was between 0.8 and 1.0, 29 percent of the farms were fully technically efficient (Figure 4).

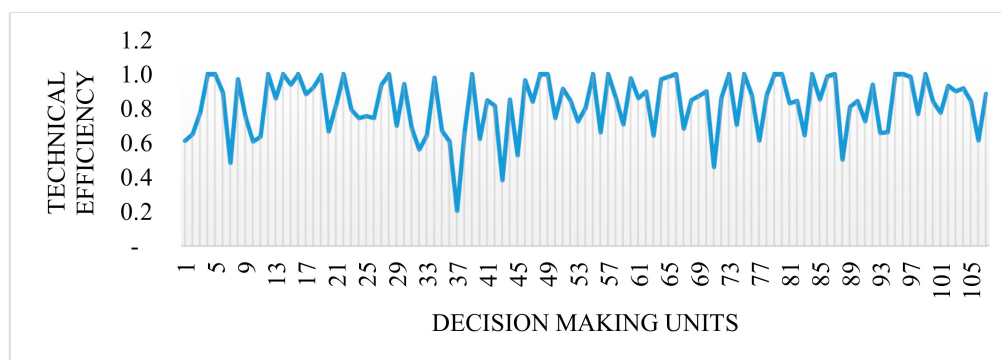


Figure 4. Estimated technical efficiency of the studied orange farms. Source: Data surveyed, 2019.

3.1.2. Allocative efficiency and Cost efficiency

The study used the VRS-DEA input-orientated model to estimate allocative efficiency and cost efficiency. The collected data was analyzed using DEAP 2.1 and SPSS 20. The results are in Table 4.

The cost efficiency is lower than the technical efficiency, while the average cost efficiency of farms in the sample is 0.686, showing that the owners can save up to 31.4% of their average total costs, while still being able to achieve the current output. The low allocative efficiency score is the consequence of low-cost efficiency.

Table 4. Allocative efficiency and Cost efficiency of orange farms.

Items	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error	Statistic	Std. Error
Allocative efficiency	0.448	1.000	0.78145	0.116528	−0.276	0.234	0.147	0.463
Cost efficiency	0.239	1.000	0.68614	0.162884	0.039	0.234	−0.367	0.463

Source: Data surveyed, 2019.

3.2. Scale Efficiency

The results of the scale efficiency estimation are indicated in Table 5. They imply that only 23 farms achieved full efficiency, equivalent to 21.5% of the total number of farms.

Table 5. Statistical results for the orange farms in Ham Yen District.

Statistic	CRS-TE	VRS-TE	SCALE
Mean	0.82341	0.87580	0.93965
Standard deviation	0.16391	0.14564	0.09987
Maximum	1.000	1.000	1.000
Minimum	0.205	0.423	0.268
Efficient farms	22	40	23
IRS orange farms			70
DRS orange farms			14

(IRS: Increasing Returns to Scale; DRS: Decreasing Returns to Scale). Source: Surveyed data, 2019.

The production efficiency of orange farms in Ham Yen district can be improved based on these results. The overall technical efficiency (CRS-TE) was divided into two parts: "Pure" technical efficiency from variable returns to scale (VRS-TE) and scale efficiency (SCALE, SE). Hence, the obtained CRS-TE is 0.823 while VRS-TE is 0.876 and scale efficiency is 0.94. Scale inefficiency (0.06) can occur due to operations being below the optimal scale of farms. We found that 65.4% of surveyed farms operated at increased returns to scale and 13.1% of farms operated at decreased returns to scale.

3.3. Average Input Values Proposed

Bases on the data surveyed, the VRS-DEA input-orientated model also proposes the cost-minimizing input quantities for the samples. The proposed values were estimated for each farm. The average values are shown in Table 6:

Table 6. Average input values observed and proposed from the VRS-DEA input-orientated model.

Inputs	Average Value Observed	Average Value Proposed
Land (ha)	5.59	4.43
Family laborer (person)	2.85	2.40
Outsourced labor cost (1000 VND)	115,102.80	93 978.38
Crop production cost (1000 VND)	158,686.92	132 098.18
Other expenditures (1000 VND)	12,752.16	6 310.11

Source: Data surveyed, 2019.

According to the proposed results, the interviewed farmers can economize 21 percent of the land used, 16 percent of family labor, 18 percent of outsourced labor costs, 17 percent of crop production costs, and 51 percent of other expenditure. The farm owners could use the proposed values as a suggestion to improve their farms' activities.

4. Discussion

The analysis showed that orange farms in Tuyen Quang province had relatively high and uniform technical efficiency, which was explained by many factors, including the long-term production experience of farm owners as well as the impact of technical assistance policies and the construction of commercial orange production areas.

However, low scores for cost efficiency and allocative efficiency were found for the orange farms there. These outcomes are consistent with the fact that the majority of farm owners has not been trained in cost management and accounting skills, and most of them have low educational levels. The survey reveals the average education level of the 107 farmers interviewed is 8.76 years, and only one of these farmers were educated in business management. This type of result is commonly found in many developing countries. The average education of farmers in Punjab, Pakistan was found to be almost the same, at 8.75 years [65]; the average education of smallholder pearl millet farmers in Kano state, Nigeria was a little higher at 10.3 years [66]; the education levels of smallholder farmers in Zambia was even lower, at 7.54 years [67]. Both Vietnamese national and local governments are trying to find solutions to improve the production scale, increase efficiency, and enhance the value chain of agricultural products in general and oranges in particular to upgrade the country's agricultural sector. Training courses and vocational training programs for rural workers are not outside of the above objectives.

The average technical efficiency for our sample was about 82 percent. In comparison, the technical efficiency of wheat farms in Punjab, Pakistan was much lower, at 57 percent [65], the efficiency of smallholder pearl millet farmers in Kano state, Nigeria was almost the same, at 81 percent [66], and the efficiency of fish farms in Ghana was lower, at about 74 percent [68]. These results showed that orange farms in Tuyen Quang seemed to be technically uniform. This provides an advantage for building solutions to improve production efficiency.

The average scale efficiency of the orange farms in Tuyen Quang province is about 94 percent. By comparison, the average scale efficiency of wheat farms in Punjab, Pakistan is 90 percent [65], while the equivalent figure for smallholder pearl millet farmers in Kano state, Nigeria is 87 percent [66], both of which are lower than that for the orange farms in Tuyen Quang.

The proposed values from the VRS-DEA input-orientated model can underpin suggestions for farm owners to improve their operations. By better combining their available resources, farmers can reduce those resources while achieving the same production level or can keep existing inputs while achieving a higher output. This not only has economic implications, but also has important ones for environmental and social sustainability.

The average value of pesticide cost per hectare of the orange farms in Tuyen Quang Province in 2018 was under 16 million VND/ha/year (95% confidence interval). Comparing to the pesticide costs of a similar study in Yen Bai province of 24 million VND/ha/year [69], the costs in Tuyen Quang were lower. This could mean that orange farms in Tuyen Quang use fewer pesticides. However, the Tuyen Quang farmers still can reduce this cost further to minimize negative impacts on the ecosystem.

5. Conclusions

In this study, the data envelopment analysis approach was applied to investigate the TE, SE, AE, and CE of the orange farms in Tuyen Quang province, Vietnam. Using comprehensive data collected through a structured questionnaire for the 2018/2019 crop, 107 randomly selected orange farms' owners, a measure of TE, SE, AE, and CE were estimated. The results show that CRS-TE and VRS-TE were estimated to be 82 percent and 88 percent, respectively; SE, AE, and CE were estimated to be 94 percent, 78 percent, and 67 percent, respectively. In addition, the average income from orange production for a family laborer was about 11.75 million VND per month, which is more four times higher than the minimum wage of a laborer in the region (which is 2.76 million VND per month) [70].

According to the results, it can be concluded that the production of oranges provides high income for their growers; farms owners also have a high orange production levels thanks to their farming

experience and regular training courses. At the same time, it is recommended that further efficiency improvements can be obtained by training the orange farm owners on ideal inputs combinations which can ensure maximum efficiency during orange production. Further, pest resistance and the proliferation of resistant orange species can be promoted by constantly using the same pesticide [7]. Hence, it is necessary to control the pesticides utilized. Integrated pest management should be applied to achieve sustainable development [71].

In addition, the establishment of a stable consumer market and diversification of orange products should also be considered and implemented by the Vietnamese government to encourage the further development of orange farms, create more jobs, improve living standards for local people, augment gross regional domestic product (GRDP), and optimize other economic-social indexes.

Nevertheless, these estimates are only the results of quantitative analysis; the estimates do not count qualitative factors and natural factors such as garden slopes, disease, rainfall, and so on. Future research is needed to further explore orange production to improve the performance of orange farms in Tuyen Quang province and continue their trend toward sustainable development.

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