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EFFICIENCY OF SOURCES OF IRRIGATION WATER IN OYSTER MUSHROOM PRODUCTION IN QUANG TRI PROVINCE: A COMPARATIVE ANALYSIS

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Abstract: From the cross-sectional data of 94 oyster mushroom farms in Quang Tri province, this study estimates and compares technical, allocative and cost efficiency of the irrigation water from a factory and from wells by using Bootstrap input-oriented Data Envelopment Analysis. The empirical results indicate that oyster mushroom farms are substantially inefficient. The farms that use the irrigation water from a factory are more statistically efficient than those using the water from wells. The mean technical, allocative and cost efficiency of the irrigation water from a factory and from wells is 0.62, 0.58, 0.34 and 0.58, 0.52, 0.26, respectively. Therefore, shifting to use the water from a factory to irrigate oyster mushrooms is one of the proposed recommendations.

Keywords: efficiency, oyster mushroom, bootstrap input-oriented Data Envelopment Analysis

1 Introduction

Mushroom cultivation has now become popular all over the world due to its contribution to livelihoods. It can help to reduce vulnerability to poverty but does not require access to land [1]. Oyster mushroom production started in Quang Tri province a long time ago but has just been developing in a few recent years. It has been considered as a mean of not only taking advantage of by-products of agriculture but also giving job opportunities and increasing the return to the farmers [2]. Producing oyster mushrooms has been known as a simple industry because it does not require large and fertile land as well as high skill workers; it depends mainly on the inputs of seedling and labor [3]. However, in order to get high productivity, besides the requirement for clean agricultural waste materials and temporary clean shelters, the temperature and humidity have to be controlled [1]. That is why irrigation plays an important role during the cultivating period even though it is accounted for a very small proportion (0.5%) of the production cost [3]. Up to now, although there have been many studies on the efficiency of mushroom production [4]–[7], none of them analyze the efficiency on the basis of the irrigation water, especially on the oyster mushroom production [8]. In Quang Tri province, Vietnam, the irrigation water for cultivating oyster mushrooms is mainly from wells and the local water

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supply factory. Ton Nu Hai [3] identifies that this source of irrigation water affects super efficiency [1]of those farms in the study locality. However, she does not show how different it is in technical, allocative and cost efficiency between those using the irrigation water from wells and from the factory. She does either not mention the solution for each group of oyster mushroom farms to be efficient compared with the best practice farms [3]. Therefore, in order to propose persuasive information to the farmers as well as extension officers to apply for upcoming training courses, this paper focuses on the comparative analysis of the efficiency of the oyster mushroom production in Quang Tri province on the basis of the source of irrigation water using Bootstrap Data Envelopment Analysis (DEA).

2 Data and methodology

2.1 Data

This research assesses the cross-sectional data of 94 oyster mushroom farms in Quang Tri province. The oyster mushroom farms in Dong Ha city, Trieu Phong and Cam Lo districts were randomly selected, and the personnels were interviewed using a structured questionnaire. 46 farms use the irrigation water from wells and 48 farms use the irrigation water from the local water supply factory. Moreover, an expert interview was also conducted with the Director of Mushroom Research and Development Station in Quang Tri province to confirm the collected information.

Secondary data for this study were collected from the Bureau of Statistics of the Department of Agriculture and Rural Development and the Department of Science and Technology of Quang Tri province. The information was also collected from books, journals, research reports, and previous studies.

2.2 Methodology

The Data Envelopment Analysis input-oriented model under the constant return to scale (CRS) was used to estimate the efficiency of this study, and it is as follows:

$$Min_{\theta,\lambda}\theta$$

Subject to

$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0$$

The input-oriented DEA model used to define the cost minimization is:

$$Min_{\lambda,xi*} w_i^T x_i^*$$

[1] Super efficiency is the term of efficiency score larger than one. This is because each firm is not permitted to use itself as a peer.

Subject to

$$-y_i + Y\lambda \geq 0,$$
$$x_i^* - X\lambda \geq 0,$$
$$\lambda \geq 0$$

where θ is the technical efficiency score. λ is the $N \times 1$ vector of weights (constants), which defines the linear combination of the peers of the i-th farm. Y is the vector of output quantities and X is the vector of observed inputs. $-y_i$ is the vector of output of the i-th farm compared with the output vector of the theoretically efficient farm ($Y \cdot \lambda$). $X \cdot \lambda$ is the minimum input of the theoretically efficient farm, given the actual level of output produced by the i-th farm. x_i is the actual level of inputs of i-th farm. If θ is equal to 1, the farm is technically efficient because the level of input of that farm is as small as the quantity of input utilized by the theoretically efficient farm in producing the same level of output. On the contrary, if θ is less than 1, the farm is technically inefficient. That farm can still further reduce the level of used input to as low as $X \cdot \lambda$ in producing the same level of output.

w_i is the vector of input prices for the i-th farm, x^* is the cost-minimizing vector of input quantities for the i-th farm, given the input prices w_i and output level y_i. The cost efficiency is the ratio of the minimum cost over the observed cost for the i-th farm.

$$CE = \frac{w_i^T x_i^*}{w_i^T x_i}$$

And the allocative efficiency can be calculated as

$$AE = \frac{CE}{TE}$$

Moreover, to correct the bias –a major disadvantage of DEA method due to deterministic nature [10], [9] – and estimate its confident interval, the data envelopment approach with the smoothed bootstrap procedure was applied in this study. And the nonparametric two-sample Wilcoxon test was also used to confirm the difference in the mean values of the two groups.

3 Results and discussion

On the basis of the source of water the farmers use to irrigate oyster mushroom, the total observation was divided into two groups, one uses the water from wells (denoted as "irrigation-water-from-wells") and the other uses water supplied by the local factory (denoted as "irrigation-water-from-the-factory"). The summary of descriptive statistics of inputs and output of these two groups is shown in Table 1.

There is a large difference in inputs and output of the oyster mushroom production between irrigation-water-from-wells and irrigation-water-from-the-factory groups. Generally, the former group uses more inputs but produces less output than the latter. On average, a farm of the irrigation-water-from-wells group uses 3,3521 seedling bags and spends 857 hours on watering, harvesting to produce only 1,560 kg of oyster mushroom. Meanwhile, a farm that uses irrigation water from the factory has only 2,791 seedling bags and 530 hours on the same purpose and produces 1,700 kg of output. The p-value of the Wilcox test also shows that the differences in labor used and the oyster mushroom production of the two groups are statistically significant.

Table 1. Inputs and output of oyster mushroom production per farm in Quang Tri province

	Units	Irrigation water from well						Irrigation water from factory						P-value of Wilcox test
		Min	1st Qu.	Median	Mean	3rd Qu.	Max	Min	1st Qu.	Median	Mean	3rd Qu.	Max	
Inputs														
Seedling	Bag	400.0	837.5	1150.0	3,352.1	2200.0	25,000.0	500.0	725.0	1,200.0	2,791.0	3,000.0	18,000.0	0.9547
Labor	Hours	72.7	615.0	683.3	857.0	862.5	4,218.0	138.8	257.4	400.0	530.2	637.5	1,800.0	6.575e-05***
Output														
Production	Kg	196.0	620.0	890.0	1,559.0	1,450.0	9,000.0	270.0	530.0	830.0	1,700.0	2,620.0	6,600.0	0.08352*

Source: Field survey and author's calculation

With the information above, the technical, allocative and cost efficiency and their confident interval were estimated, corrected employing Bootstrap input-oriented Data Envelopment Analysis under the constant return to scale. The descriptive analysis is shown in Table 2.

Table 2. Bias-corrected technical efficiency of oyster mushroom farms in Quang Tri province

		Irrigation water from wells	Irrigation water from a factory	p-value of Wilcox test
Min		0.05	0.14	
1st Qu.		0.49	0.52	
Median		0.65	0.63	
Mean		0.58	0.62	0.09548*
3rd Qu.		0.73	0.73	
Max		0.98	0.92	
Confident interval	Lower	0.57	0.58	
	Upper	0.62	0.69	

Source: Field survey and author's calculation

The bias-corrected technical efficiency of oyster mushroom farms that use the irrigation water from the factory is statistically significantly larger than that of farms that use the irrigation water from wells. We are 95% confident that the mean technical efficiency of the irrigation-water-from-wells group is between 0.57 and 0.62 (with the mean value of 0.58) and from the irrigation-water-from-the-factory group is between 0.58 and 0.69 (with the mean value of 0.62). This means that all oyster mushroom farms are technically inefficient. The irrigation-water-from-wells farms waste more inputs than the irrigation-water-from-the-factory farms in producing the current level of output. The former use 42% higher inputs than the best practice farms, while it is only 38% for the latter.

With a tighter confident interval, which is between 0.50 and 0.56 for the irrigation-water from-wells group and between 0.58 and 0.60 for the irrigation-water-from-the-factory group, the data reveal that the latter group is more allocative-efficient than the former. The mean bias-corrected allocative efficiency of those two groups is 0.52 and 0.58, respectively. This implies that these farms use an inappropriate input mix at the given input prices.

Table 3. Bias-corrected allocative efficiency of oyster mushroom farms in Quang Tri province

		Irrigation water from wells	**Irrigation water from a factory**	***p*-value of Wilcox test**
Min		0.30	0.30	
1st Qu.		0.37	0.37	
Median		0.43	0.43	
Mean		0.52	0.58	0.0366**
3rd Qu.		0.53	0.79	
Max		1.00	1.00	
Confident interval	Lower	0.50	0.58	
	Upper	0.56	0.60	

Source: Field survey and author's calculation

Moreover, the data in Table 2 and 3 also indicate that the allocative inefficiency is the primary cause of cost inefficiency of oyster mushroom farms in this study area, which is shown in Table 4.

Table 4. Bias-corrected cost efficiency of oyster mushroom farms in Quang Tri province

		Irrigation water from wells	**Irrigation water from a factory**	***p*-value of Wilcox test**
Min		0.05	0.11	
1st Qu.		0.20	0.22	
Median		0.26	0.26	
Mean		0.26	0.34	0.01561**
3rd Qu.		0.33	0.43	
Max		0.48	0.76	
Confident interval	Lower	0.24	0.30	
	Upper	0.30	0.40	

Source: Field survey and author's calculation

It is 95% confident that the cost efficiency of oyster mushroom farms that use irrigation water from wells and from the factory is from 0.24 to 0.30 and from 0.30 to 0.40, respectively. The former group is more cost-inefficient than the latter. The mean of bias-corrected cost efficiency of 0.26 and 0.34 shows that there is a substantial cost inefficiency in the oyster mushroom production in the study area due to the overuse of inputs. On average, the farms that use irrigation water from the factory spend 66% higher production cost than the best practice farms, while it is 74% for the irrigation-from-wells group.

The data analysis from the three tables of technical, allocative and cost efficiency shows that oyster mushroom farms that irrigate with the water from the factory are more efficient than those using the water from wells. A possible explanation is that the water from the factory is always treated and filtered; meanwhile, the water from wells is completely natural, untreated and unfiltered. It is not sure whether water from wells can qualify the growth of oyster mushroom in a good condition when all relevant technical documents notice that the mushrooms require clean water for irrigation.

This information might be useful for not only farmers themselves but also local extension officers in confirming the important role of irrigation water in cultivating oyster mushrooms in Quang Tri province. In order to improve efficiency, oyster mushroom farms should use the water from the factory for irrigation if they could access to this water source. Those who could not access this source of water can also use the current irrigation water from wells. However, according to the guides of extension officers, the water from wells should be kept and deposited for several hours before irrigating oyster mushrooms.

4 Conclusion

This study employs the Bootstrap input-oriented Data Envelopment Analysis to measure the technical, allocative and cost efficiency of oyster mushroom farms in Quang Tri province. The analysis results show that farms using irrigation the water from the local water supply factory are more technically, allocative- and cost-efficient than those using the irrigation water from wells. Their mean technical, allocative- and cost-efficiency is 0.62 and 0.58, 0.58 and 0.52, and 0.34 and 0.26, respectively. The allocative inefficiency is the primary source of cost inefficiency of those oyster mushroom farms in the study area. The farms should use fewer inputs in producing the current level of output and use the water from the factory to irrigate mushrooms.

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