DOI: 10.31276/VMOSTJOSSH.66(1).03-15

Technical and scale efficiencies of the salinity-induced rice production system in the western coastal region of the Mekong delta, Vietnam

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Received 28 September 2023; revised 26 November 2023; accepted 1 February 2024

Abstract:

Salinity events make Mekong delta's rice production change significantly. In the salinity-impacted regions, shrimp-rice production is a possibility besides the traditional rice models. This paper aims to assess the economic efficiency of rice-based farms in the Mekong delta in the context of salinity-induced hazards. The random sample is collected from 254 rice-based farms in 28 villages in 24 districts in the western coastal region in the Mekong delta. The method of Data Envelopment Analysis and OLS and Tobit regression estimations are used to measure the economic efficiency and identify the determinants of the technical and scale efficiencies respectively. The findings show that the average overall efficiencies for the technical efficiency and the scale efficiency are 0.642 and 0.848 respectively, implying that substantial inefficiencies occur in farming practices in the Mekong delta. It indicates that there is still potential for improving the economic efficiency of rice-based system. The findings also show that, statistically significantly, the land ownership and the area are the determinants of the economic profit; the irrigation system, saltwater drains, salinity impact, are the determinants of the economic irrigated water use; the land ownership status, the area, and type of seed are the determinants of the technical efficiency; and the gender, age, education level, irrigation system, saltwater drains, area, type of seed, and numbers of fertilizing and weeding are the determinants of the scale efficiency.

Keywords: data envelopment analysis, economic efficiency, rice-based system, scale efficiency, technical efficiency.

Classification number: 2.1

1. Introduction

With a total area of 39,712 km^2, the Mekong delta (MD) has various potentials for agricultural development. It is the key rice production area of Vietnam. The MD rice area has always accounted for more than 50 percent of the total rice area in the country with about 1.781 thousand ha and 21-22 million tons. One of the world's most climatically vulnerable and rapidly changing agricultural production environments [1]. The MD was impacted by climate change coupled with sea level rise and natural hazards [2]. Among impacts of sea-level rise the saltwater intrusion has the greatest economic impact through agriculture, aquaculture, and fresh water availability [3]. In the context of climate-induced risks, the MD is currently coping with the saltwater intrusion and adverse weather changes that cause serious challenges to its rice-based system. During the dry season, the saltwater intrusion comes sooner and leaves lately. The annual loss of saltwater intrusion-induced rice yield is estimated at 2.50 to 4.05 tons per ha [4]. Since 2020 the rice-based system has been changed into diversified cropping pattern with intensive rice and rice-shrimp models. Under the Resolution No. 09/2000/ND-CP the area of rice-shrimp has been developed from 71,000 ha in 2000 to 153,000 ha in 2015 and 200,000 ha in 2020. Kien Giang and Ca Mau provinces located in the western coastal region of the MD are the largest rice-shrimp producers along with Soc Trang, Tra Vinh, and Ben Tre

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provinces in the eastern coastal region. In the Winter-Spring rice model, the yield usually reaches 7-10 tons/ha while it is at 4-7 tons/ha in the rice-shrimp model. Coping with the constraints of irrigated water resource availability and irrigation system investment, the efficiency of rice-shrimp model is still in question.

The concept of efficiency has been widely used in assessing the productivity of the Decision Making Unit (DMU) such as a farm. F. Chemak (2011) [5] used Data Envelopment Analysis (DEA) - a nonparametric method to analyze the technical efficiency (TE), the water use efficiency and the dynamic of the productivity of the irrigated areas in Tunisia. Findings showed that the TE of the farms increased by 17 percent due to an improvement of water use efficiency, up to 22 percent. It revealed a positive impact on the farms' productivity change. N. Anuradha, et al. (2010) [6] estimated the TE in rice production and assessed the farm-specific socio-economic factors on the TE. This study applied a stochastic frontier production function in determining the TE and regression analysis in identifying the socio-economic determinants of the TE. The findings revealed that the farm-specific TEs range from 71,39 percent to 99.82 percent with a mean of 72.78 percent. Besides, factors of operational area, experience, education and distance of plot were the determinants of the TE. N.M. Malana, et al. (2006) [7] used economic efficiency analysis of selected wheat areas in Pakistan and India using the DEA method. Results revealed a ranking of economic efficiency based on four inputs including irrigated water. K.N.R. Kumar (2022) [8] applied DEA and Malmquist Total Factor Productivity (MTFP) Index to ascertain the TE of rice productivity (2021-2022) and its changes over the study period (2019-2020 to 2021- 2022) in India. The results revealed that the overall mean TE score across all the DMUs was 0.860 ranged between 0.592 and 1.000. So, rice farmers could reduce their input usage by 14 percent and still could produce the same amount of rice. Fertilizers, seed, water, and organic manure use can be reduced in rice productivity. MTFP indices (2019-2020 to 2021-2022) revealed that the mean scores of TE change, pure TE change and scale efficiency change are more than one, unlike technological change (0.983). All the DMUs showed impressive progress with reference to TE change (1.112) and it is the sole contributor for TFP change in rice production. The DEA results suggest that farmers should reduce the usage of inputs to boost the TE of rice productivity in India. In Vietnam, H.N. Chuong (2020) [9] used DEA method to measure the efficiency of rice production of Vietnam rural farmers based on the VHLSS database in 2016 with 3,299 observations surveyed in all 6 regions in Vietnam. The results showed that the score of Vietnam's rice production efficiency was poor with a mean TE of 8.95/100. Besides, Tobit regression results revealed that labor and livelihood diversity were determinants of the TE. Moreover, the geographical and socio-economic heterogeneity caused the difference in rice production TE in Vietnam. D.T. Tung (2013) [10] employed the DEA technique to measure changes in TE and SE in rice production in the MD using the sample production datasets from 1998 to 2010. The results showed that the TE changed significantly over this period and increasing return to scale was the dominant trend reflecting the need to increase both production scale and rice area.

This article aims to measure the economic efficiency (EE) of the rice-based models in the MD at the salinity-induced prones. There is the statistical testing of economic efficiencies on production and irrigation usage in the study. Either intensive rice model or rice-shrimp model is more economically effective is the key research question in this study. The article consists of three sections. The methodology of the DEA is presented in the first section. The results and discussion of assessment on the EE of rice-shrimp model are shown in the second section. The third section presents the conclusions and policy implications of the study.

2. Methodology

2.1. Conceptual framework

A conceptual framework presented in Fig. 1. was developed to guide data collection and analysis. The first elements of the framework include socio-economic and livelihood factors. The second set of factors includes salinity intrusion situation and human behavior coping with salinity-related risk and hazard. The third set of factors relates to irrigated water use and management. The fourth set of factors links to rice-based production, the farming system, and community- and region-based interventions. These factors are examined to assess the EE of rice-based production models (rice vs rice-shrimp model).

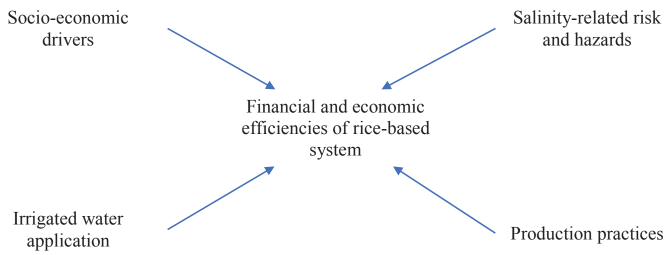

Fig. 1. Conceptual framework of the study.

2.2. Economic efficiency of irrigated water use framework

Theoretically, because of non-priced input data type collected in the survey, the parameter method of stochastic frontier function could not be defined to measure the TE. So, this study uses the non-parametric DEA approach to assess the economic efficiency (EE) of rice-based model with irrigated water use efficiency. Measures of efficiency include the TE and the scale efficiency (SE). The TE refers to functional relation between inputs including irrigated water and output. It is attained when the maximum possible improvement in output is obtained from a set of inputs. The SE measures the potential productivity gain from attaining optimal size of a farm. The EE refers to the maximization of output for a given cost. Methodologically, in the non-parametric procedure, a mathematical programming method of DEA is used to overcome the limitation of parametric Cobb-Douglas production function method. That is, using actual observations, a frontier is defined with reference to all the farms in the sample set. The frontier gives the efficient farms in the set as a benchmark against which to measure other farms' performance. A farm's efficiency is analyzed by comparing its performance with that of other farms located along the frontier. The assumption of a constant return to scale (CRS) works all firms operate optimally [11]. In addition, a variable return to scale (VRS) is proposed by D.E. Banker, et al. (eds.) (2005) [12].

First, the constant returns to scale DEA model for a single output is used to compute output-oriented measures of the TE and the SE is described below.

$$\begin{aligned} &\mathrm{Min}_{\theta,\lambda}\ \theta \\ &\text{Subject to}\quad -y_i + Y\lambda \geq 0 \\ &\qquad\qquad\quad \theta_i x_i - X\lambda \geq 0 \\ &\qquad\qquad\quad \lambda \geq 0 \end{aligned} \tag{1}$$

where θ_i is the proportional increase in output possible for the i-th farm; λ is the weights relative to efficient farms; y_i and x_i are output and input of i-th farm, respectively; Y and X are vectors of output and input, respectively. In other words, equation (1) with the CRS assumption shows that farms are operating at their optimal scale [13].

Second, the variable returns to scale DEA model uses the CRS specification when not all farms are operating at the optimal scale. The CRS linear programming problem is then modified to account for VRS by adding the convexity constraint:

$$\begin{aligned} &\mathrm{Min}_{\theta,\lambda}\ \theta, \\ &\text{Subject to}\quad -y_i + Y\lambda \geq 0 \\ &\qquad\qquad\quad \theta x_i - X\lambda \geq 0 \\ &\qquad\qquad\quad N1'\lambda = 1 \\ &\qquad\qquad\quad \lambda \geq 0 \end{aligned} \tag{2}$$

where N1 is an Nx1 vector of convexity constraints. It provides the TE scores which are greater than or equal to those obtained using the CRS model. A measure of the SE, ranging of (0, 1), which reflects the role of return to scale in the TE is made by comparing the TECRS and TEVRS scores. A difference between the two TE scores indicates that there is the SE that limits achievement of an optimal (constant) scale:

$$SE_i = TE^{VRS}{}_i \,/\, TE^{CRS}{}_i \tag{3}$$

where SE_i = 1 indicates full-scale efficiency and SE_i < 1 indicates scale inefficiency.

This study applies the DEA to measure the TE and the SE of the farms in relation to the optimal situation in irrigated water use in the MD. A second step is to analyze the determinants of efficiency measures. A Tobit model with censored variable of range of 0-1 is estimated as a function of attributes of farms to identify the determinants of inefficiency via the estimation of a second-stage process as follow:

$$\begin{aligned} \theta^{k*} &= \beta 0 + \beta 1Z1 + \beta 2Z2 + \ldots + \beta jZj + e \\ &= Z\beta + e \\ \theta^{k} &= \theta^{k*} \text{ if } 0 < \theta^{k*} < 1 \\ &= 0 \text{ if } \theta^{k*} < 0 \\ &= 1 \text{ if } \theta^{k*} > 1 \end{aligned} \tag{4}$$

where θ^k is the DEA efficiency index for water used as dependent variables (k = 1 for the TE^{VRS} and k = 2 for the SE) and Z is a vector of independent variables related to attributes of farms. The estimation of the Tobit model is based on maximum likelihood procedures [14]. The Tobit estimates require that residuals are normally distributed [15].

So, a normality test with the conditional moment test for normality in censored data is used in the study.

Study location: As shown in Fig. 2, in the period 2005-2019 there is an abnormal weather pattern happening in the coastal areas of the MD. Annual temperature and sunshine hours tend to increase, while annual rainfall and humidity tend to decrease except in Kien Giang province. Moreover, the fluctuation of monthly climate means over the years shows that the MD currently follows a heterogeneous climate pattern. According to V.T. Danh, et al. (2019) [16], the combination of these climate factors triggers the adverse impact on the sustainability of the rice model in the MD.

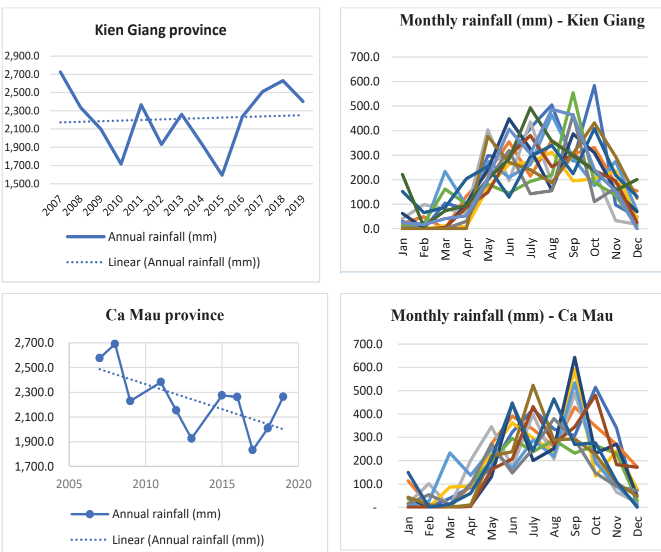

Fig. 2. Province-level weather patterns in the period 2005-2019. Source: General Statistics Office (2020).

2.3. The pattern of rice-based system

In the period 2015-2019, the rice-based system in the western region of the MD changed in terms of a reduction in intensive rice areas and an increase in rice-shrimp areas. However, the pattern of change is quite different. In Ca Mau province, a part of rice-based areas is replaced with extensive- or semi-intensive aquaculture models consisting of monodon and vannamei models. As a result, both rice and rice-shrimp areas decrease at the annual rate of 8.7 percent and 3.2 percent respectively. Meanwhile, in Kien Giang province, the decreased rice areas were set aside for rice-shrimp areas. So, the rice area in this five-year period reduced at the annual rate of 6.2 percent while the rice-shrimp area increased at the annual rate of 25.2 percent. Table 1 shows the changes of rice and rice-shrimp areas in Ca Mau and Kien Giang areas.

Table 1. Rice-based area in western coastal provinces in the MD, period of 2015-2019 (unit: ha).

Province	2015	2016	2017	2018	2019	Change (%)
Ca Mau						
Rice	126,587	112,243	113,148	117,390	115,585	-8.69
Rice-shrimp	278,745	276,433	271,535	268,062	269,869	-3.18
Kien Giang						
Rice	769,464	766,033	735,266	728,415	722,014	-6.17
Rice-shrimp	98,753	104,935	117,336	122,701	126,822	28.42
Total						
Rice	896,051	878,276	848,414	845,805	837,599	-14.86
Rice-shrimp	377,498	381,368	388,871	390,763	396,691	25.24

Source: General Statistics Office (2020).

Regarding the impact of the salinity intrusion in the study location, it also shows that nearly 26 percent of farmers in the survey have to cope with issues of agricultural hazards. Those who are impacted by diseases, extreme weather and salinity intrusion are 52.6 percent, 28.1 percent, 17.5 percent respectively. This, of course, affects the rice yield for the risk-induced farms.

2.4. Sampling procedure

This study employs a random sample of 224 rice-shrimp households in Ca Mau and Kien Giang provinces. The study sites are in salinity-prone western coastal areas. Household selection is conducted in three stages. Firstly, based on a salinity-intrusion map (SIWRR, 2019) [17], of 24 districts, 9 salinity-prone districts are selected with the recommendation by local authorities. Secondly, a population-weighted random sample of 23 communes is drawn from a total of 245 communes. As a result, there are 28 villages selected for the face-to-face interviews. Finally, eight households are selected within each village. Where a list of all village farmers is available, eight households are randomly chosen; if it is not available, the village head is invited to provide a list of twenty households, in which five households are well-off, ten households are at a medium, and five households are less well-off. The chosen farmers are rice farmers and rice-shrimp farmers. The target farmers are selected with three years or more in rice-based production. The interview is then implemented using a well-designed questionnaire. As a result, eight households will be randomly selected from the list of twenty households applying a function of RAND() in EXCEL among 224 rice-based farmers with a total of 254 plots of rice land selected for interviewing, there are 32 and 138 rice farms in Ca Mau and Kien Giang, respectively; and 41 and 43 rice-shrimp farms in Ca Mau and Kien Giang, respectively. A face-to-face interview is implemented using the Census and Survey Processing System (cspro) package written for the well-designed questionnaire.

3. Results and discussion

3.1. Characteristics of sample

In the sample, the average household head is 45 years of age and has been cultivating rice for at least 7 years. Of the respondents, 89 percent are men. Of the heads of households, 10 percent have an education of high school or above, and 86 percent of households who participate in the survey are of Kinh ethnicity. There are 85 percent of farmers are landlords. The average rice area is 2.74 ha per household with the average pieces of rice land per household at 1.13. On irrigation investment, the proportion of investment in irrigation water and saltwater drains are 60 percent and 32 percent, respectively. There are 84 percent, 72 percent, and 41 percent of farmers use marketed seed, certificated seed and salt-tolerant seed respectively. The average rice yield in the 2019 Winter-Spring crop is at 6.05 tons per ha. Statistically significant, the results of t-test show that there are differences in rice yields in the rice model and the rice-shrimp model in Ca Mau versus Kien Giang (p=0.0030) and (p=0.0240). Finally, numbers of fertilizing, spraying pesticides, and weeding are 4, 4, and 1 times respectively. The results of t-test also show that many differences in economic variables depend on different contexts of such an agricultural system (Appendix 2). Table 2 presents descriptive summaries of sampled household characteristics.

Table 2. Sample's characteristics.

Item	Unit	N	Minimum	Maximum	Mean	Standard deviation
Head's age	Year	254	22	73	49.23	11.58
Head's gender	1: Male 0: Female	254	0	1	.89	0.31
Head's education level	1: high school or above 0: otherwise	254	0	1	0.10	0.30
Ethnic	Kinh: 1 Other: 0	254	0	1	0.86	0.35
Number of years of living in the area	Years	254	7	73	44.26	15.15
Landowner status	Landlord: 1 Leaser: 0	254	0	1	0.85	0.36
Having a salinity protection gate	Yes: 1 No: 0	254	0	1	0.32	0.62
Source of production water	Irrigation: 1 Other: 0	254	0	1	0.60	0.490
Agriculture model	Rice: 1 Rice-shrimp: 0	254	0	1	0.67	0.47
Salinity impact	Yes: 1 No: 0	254	0	1	0.10	0.30
Rice area	Ha	254	0.26	38.00	2.74	3.10
Rice yield	(ton/ha)	254	0.80	10.45	6.05	2.07
Marketed seed	Yes: 1 No: 0	254	0	1	0.84	0.37
Certificated seed	Yes: 1 No: 0	254	0	1	0.72	0.45
Salt-tolerant seed	Yes: 1 No: 085	254	0	1	0.41	0.49
Number of fertilizing	Time	254	0	8	3.34	1.10
Number of pesticiding	Time	254	0	12	3.30	2.38
Number of weeding	Time	254	0	2	0.89	0.33

Source: Survey (2019).

3.2. Irrigated water use

The result of statistical summary in Table 3 shows that the mean of irrigated water cost is at 260,000 VND per ha. There is more than three-fourths of the farms having the irrigated water cost below one million VND per ha. However, there were differences in irrigated water cost in rice production under different scenarios (Appendix 2). Statistically significant, there is no difference in irrigated water cost per ha between rice model and rice-shrimp model ($p<0.5770$).

Table 3. Distribution of irrigated water cost (thousand VND/ha).

Irrigated water cost	N	%
Below 1,000	193	76.0
1,000-2,000	38	15.0
Above 2,000	23	9.1
Total	254	100.0

Source: Authors' calculation.

3.3. Economic analysis of rice production

3.3.1. Economic efficiency

Table 4 presents the production outputs of the rice and rice-shrimp models. First, results reveal that the rice revenues or rice sales in rice model and rice-shrimp model are 39.7 million VND and 22.4 million VND per ha respectively. Statistically significant, the result of the t-test shows that there is a difference in the revenue means in the two systems ($p<0.0000$). Second, the financial costs of rice production per ha are 13.5 million VND and 10.0 million VND for the rice model and rice-shrimp model respectively. Statistically significant, the result of the t-test shows that there is a difference in the financial production cost means in the two systems ($p<0.0000$). Third, the economic costs of rice production per ha are 14.3 million

Table 4. Statistical summary of financial and economic inputs and outputs.

Index	Unit	Total		Rice model		Rice-shrimp model		t-value
		FE#	*EE##*	*FE#*	*EE##*	*FE#*	*EE##*	
Revenue	Thousand VND/ha	33,971	33,971	39,695	39,695	22,387	22,387	13.3166***
Land preparation cost	Thousand VND/ha	1,299	1,299	1,483	1,483	926	926	5.5835***
Seed cost	Thousand VND/ha	123	123	143	143	83	83	9.2750***
Pesticides cost	Thousand VND/ha	2,588	2,588	3,569	3,569	604	604	9.5112***
Fertilizer cost	Thousand VND/ha	3,644	3,644	4,281	4,281	2,353	2,353	8.2193***
Irrigation cost	Thousand VND/ha	260	260	272	272	235	235	0.7833
Rent-labor cost	Thousand VND/ha	1,704	1,704	741	741	3,652	3,652	-12.6649***
Own-labor cost	Thousand VND/ha	-	1,233	-	813	-	2,083	-6.2451***
Harvesting cost	Thousand VND/ha	3,233	3,233	2,391	2,391	4,937	4,937	-15.7477***
Financial cost	Thousand VND/ha	12,288	-	13,478	-	9,880	-	7.6982***
Economic cost	Thousand VND/ha	-	13,520	-	14,290	-	11,963	4.9466***
Financial profit	Thousand VND/ha	21,684	-	26,218	-	12,507	-	10.4727***
Economic profit	Thousand VND/ha	-	20,191	-	25,133	-	10,190	11.2790***
Financial return-to-sale	%	57.37	-	62.60	-	46.77	-	4.6826***
Economic return-to-sale	%	-	50.95	-	59.50	-	33.64	6.5991***

Note: *** statistically significant level at 1%; #, ## are financial efficiency and economic efficiency respectively numbers in t-value column show the mean differences of rice model vs rice-shrimp model descriptions of variables are presented in Appendix 1.
Source: Authors' calculation.

VND and 12.0 million VND for the rice model and rice-shrimp model respectively. Statistically significant, the result of the t-test shows that there is a difference in the economic production cost means in the two systems (p<0.0000). Fourth, the financial profits per ha are 26.2 million VND and 12.5 million VND for the rice model and rice-shrimp model respectively. Statistically significant, the result of the t-test shows that there is a difference in the financial profit means in the two systems (p<0.0000). Fifth, the economic profits per ha are at million 25.1 VND and 10.2 VND for the rice model and rice-shrimp model respectively. Statistically significant, the result of the t-test shows that there is a difference in the economic profit means in the two systems (p<0.0000). Sixth, the financial rates of return are 62.6 percent and 46.8 percent for the rice model and rice-shrimp model respectively. Statistically significant, the result of the t-test shows that there is difference in the financial rate of return means in the two systems (p<0.0000). Finally, the economic rates of return are 59.5 percent and 33.6 percent for the rice model and rice-shrimp model respectively. Statistically significant, the results of the t-test show that there is a difference in the economic rate of return means in the two rice-based production systems (p<0.0000).

To measure the EE of rice-based system, a DEA function of economic profit with its arguments of irrigated water cost, fertilizer cost, pesticide cost, labor cost, and seed cost is applied in this study. Table 5 presents the summary of TE and the SE of the rice model, rice-shrimp model, and rice-based system as a whole. Results show that the overall means of the TE and the SE are 0.642 and 0.848 respectively. They tell that the TE of rice-based farms is low while the SE is relatively high. The results also indicate that the distribution of the SE is widely scattered at the range of 0.400 to 1.000. The highest proportion of farms with the SE of 0.901 to 1.000 is 48.4 percent. In general, the proportion of farms with the SE above 0.500 is 97.7 percent. For the TE, there is a dispersed distribution pattern in the range of 0.100 to 1.000 in which a wide distribution of the range 0.300 to 0.800 is 63.8 percent and the range of 0.900 to 1.000 is 22.8 percent. It proves that many rice-based farms in the MD are producing at low-efficiency levels. Lastly, in term of the EE of economic return-to-scale, there are 78 percent and 11.8 percent of the farms having the decreasing return to scale (DRS) and the constant return to scale (CRS) respectively while the proportion of farms having increasing return to scale (IRS) is 10.2 percent. Results show that there is still potential for improving the EE of rice-based system in the MD.

In the rice model, the SE is relatively high. The distribution of the SE is at the range of 0.600 to 1.000 with more than 67 percent of farms attaining the efficiency level of above 0.800. The fact that the average score of the TE is 0.605 implies the TE of farms is still low and needs to be improved. There is only nearly one-fourth of farms attaining the high TE of 0.800-1.000. In term of the EE of economic return to scale, there are 79.4 percent and 16.5 percent of farms having the DRS and CRS respectively while the proportion of farms having IRS is 4.1 percent. In the rice-shrimp model, the average scores of the TE and the SE are 0.665 and 0.509 respectively implying that inefficiencies happened. The distribution of the SE is widely dispersed at the range of 0.100-1.000. The highest proportion of farms with the SEs at the range of 0.100-0.200 and 0.900-1.000 are 18.3 and 17.2 percent respectively. There are 49 percent of farms attaining the low TE (below 0.500) while there are 22.1 percent of them getting the high TE (0.800-1.000). In term of the EE of economic return to scale, there are 86.9 percent and 2.4 percent of farms having the DRS and CRS respectively while there are 10.7 percent of farms having IRS. Comparing the two models it is concluded that the rice-shrimp farms have more TE than rice farms but reversely in the case of the SE.

Table 5. Summary of the technical efficiency, scale efficiency, and economic efficiency.

Index	TE^{CRS}		TE^{VRS}		SE	
	N	*%*	*N*	*%*	*N*	*%*
OVERALL RICE-BASED SYSTEM						
EFFICIENCY						
Mean	0.538		0.642		0.848	
Min	0.109		0.115		0.145	
Max	1.000		1.000		1.000	
S.d.	0.232		0.250		0.152	
Range of efficiency	254	100.0	254	100.0	254	100.0
<0.100	0	0	0	0	0	0
0.101-0.200	12	4.7	9	3.5	1	0.39
0.201-0.300	19	7.5	8	3.1	1	0.39
0.301-0.400	43	16.9	34	13.4	-	-
0.401-0.500	57	22.4	33	13.0	4	1.57
0.501-0.600	41	16.1	36	14.2	13	5.12
0.601-0.700	26	10.2	32	12.6	21	8.27
0.701-0.800	13	5.1	27	10.6	42	16.54
0.801-0.900	11	4.3	17	6.7	49	19.29
0.901-1.000	32	12.6	58	22.8	123	48.43
Total	254	100.0	254	100.0	254	100.0
RETURN TO SCALE	N	%				
Constant return-to-scale	30	11.8				
Decreasing return-to-scale	198	78.0				
Increasing return-to-scale	26	10.2				
Total	254	100.0				
RICE MODEL						
EFFICIENCY						
Mean	0.494		0.605		0.830	
Min	0.005		0.006		0.125	
Max	1.000		1.000		1.000	
S.d.	0.264		0.285		0.167	
Range of efficiency	170	100.0	170	100.0	170	100.0
<0.100	8	4.7	7	4.1	0	0
0.101-0.200	9	5.3	5	2.9	1	0.6
0.201-0.300	14	8.2	10	5.9	1	0.6
0.301-0.400	42	24.7	21	12.4	2	1.2
0.401-0.500	29	17.1	26	15.3	5	2.9
0.501 - 0.600	21	12.3	19	11.2	4	2.4
0.601 - 0.700	14	8.2	21	12.4	22	12.9
0.701 - 0.800	5	2.9	12	7.1	21	12.4
0.801 - 0.900	3	1.8	7	4.1	38	22.4
0.901 - 1.000	25	14.7	42	24.7	76	44.7
RETURN TO SCALE						
Constant return-to-scale	28	16.5				
Decreasing return-to-scale	135	79.4				
Increasing return-to-scale	7	4.1				
Total	170	100.0				
RICE-SHRIMP MODEL						
EFFICIENCY	84	100.0	84	100.0	84	100.0
Mean	0.361		0.665		0.509	
Min	0.022		0.122		0.127	
Max	1.000		1.000		1.000	
S.d.	0.279		0.245		0.256	
Range of efficiency	84	100.0	84	100.0	84	100.0
<0.100	8	9.5	0	0	0	0
0.101-0.200	9	10.3	16	18.8	15	18.3
0.201-0.300	8	10.1	9	10.8	10	11.4
0.301-0.400	7	8.5	8	9.9	8	9.6
0.401-0.500	8	9.2	8	9.5	9	10.3
0.501-0.600	10	11.4	9	10.6	4	5.1
0.601-0.700	6	7.4	8	9.1	12	14.7
0.701-0.800	4	4.7	8	9.2	8	9.0
0.801-0.900	10	11.7	6	6.6	4	4.4
0.901-1.000	14	17.2	13	15.5	14	17.2
RETURN TO SCALE						
Constant return-to-scale	2	2.4				
Decreasing return-to-scale	73	86.9				
Increasing return-to-scale	9	10.7				
Total	84	100.0				

Source: Authors' calculation.

Overall, in the salinity-induced areas the TE of both intensive rice and shrimp-rice models are low. Besides, a large proportion of rice-based farms in the MD are producing at the low efficiency. It implies that there is chance of improvement on the EE of rice-based system in the salinity-induced areas at the MD. The study also shows that the intensive rice model has the higher SE than the rice-shrimp model. In the context of agricultural policy analysis, the fact that the SE of the intensive rice model is higher than the SE of the rice-shrimp model presents a necessity of increase in scale of cultivated rice area in the salinity-induced regions.

3.3.2. Determinants of economic efficiency

Table 6 presents the results of OLS and Tobit estimations on the economic efficiencies. First, the results in Model 1 show that, statistically significant, the gender, ethnicity, education level, type of rice-base system, irrigation system, and number of fertilizing are the determinants of the economic profit. These factors have positive effects on the economic profit excepting the irrigation system. In terms of the on-farm earnings, it raises questions about the role of irrigation system investment in the MD. Furthermore, the positive effect of number of fertilizing implies that the rice-based farms are still dependent of modern inputs in the rice production practice. Besides, there is a difference in economic profit among provinces. That is, rice-based farms in Kien Giang have a higher economic profit than rice-based farms in Ca Mau. Second, the results in Model 2 show that, statistically significant, the age, irrigation system, saltwater drains, salinity impact, are the determinants of the efficiency of irrigated water use. These factors have positive effects on the efficiency of irrigated water use excepting the irrigation system. Third, the results in Model 3 show that, statistically significant, the gender, ethnicity, area, type of rice-base system, type of seed, number of pesticides, and salinity impact are the determinants of the TE. The factors of the gender, ethnicity, area, and

Table 6. Results of regression estimations on the economic efficiency of the rice-based system.

Variable	Model 1[a/]	Model 2[a/]	Model 3[b/]	Model 4[b/]
(Constant)	-77,639.91** (-2.0982)	-0.221* (-1.9367)	0.5493*** (3.8700)	1.0175*** (12.6200)
Gender	34,662.16** (2.5820)	0.119 (2.3715)	0.1069** (2.0900)	0.0136 (0.4700)
Age	-316.47 (-0.6324)	0.003* (1.8329)	0.0029 (1.5100)	0.0002 (0.1600)
LivYear	207.21 (0.5767)	0.001 (0.0864)	-0.0009 (-0.6700)	-0.0008 (-0.9500)
Ethnic	52,145.28*** (4.0546)	0.016 (0.3453)	0.1067** (2.0600)	-0-0308 (-1.0800)
D_Primary	-6,599.40 (-0.5586)	-0.042 (-0.9542)	0.0047 (0.9800)	0.0058 (0.2200)
D_Secondary	-12,414.24 (-0.9808)	-0.028 (-0.5999)	0.0019 (0.0400)	-0.0320 (-1.1700)
D_HighSchool	3,800.72 (0.2160)	-0.014 (-0.2119)	-0.0325 (-0.4900)	-0.0538 (-1.4200)
D_AboveHighSchool	53,301.77* (1.7786)	0.023 (0.2118)	0.2210 (1.6200)	0.0920 (1.3500)
LandOwnership	-1,908.85 (-0.1714)	-0.053 (-1.2850)	0.0593 (1.3900)	-0.0018 (-0.0700)
Irrigationsystem	-47,885.92** (-2.2291)	-0.181** (-2.2560)	-0.0440 (-0.5300)	0.0266 (0.5700)
SalProteGate	38,498.03*** (3.2245)	0.137*** (3.1177)	-0.1179 (-0.3900)	0.0231 (0.8900)
Salinity_Impact	-13,058.88 (-0.9081)	0.253*** (4.6977)	-0.1207** (-2.2200)	-0.0406 (-1.3000)
Area	-	-	0.0650*** (6.9300)	-0.0249*** (-8.0300)
AgriModel	32,753.21*** (2.9456)	0.034 (0.9796)	0.1447*** (3.4000)	0.0539** (2.2100)
Marketed_Seed	-6,206.11 (-0.4046)	-	-0.2879*** (-4.7600)	-0-04.19 (-1.2500)
Certificated_Seed	-14,966.62 (-1.1766)	-	0.0023 (0.0500)	0.0149 (0.3800)
SaltTolerant_Seed	520.40 (0.0632)	-	0.0349 (1.0600)	0.0278 (1.5400)
NumberFert	18,153.39*** (3.9500)	-	-0.0197 (-1.0600)	-0.0143 (-1.3600)
NumberPes	-1,841.04 (-0.8690)	-	-0.0351*** (-4.3200)	-0.0107** (-2.3200)
NumberWeeding	-10,303.58 (-0.7972)	-	-0.0707 (-1.4100)	-0.0134 (-0.4700)
D_KienGiang	19,766.37* (1.8170)	-0.062 (-1.5860)	0.0369 (0.8700)	-0.0041 (-0.1700)
R^2	0.390	0.120		
F-value	7.4461 (0.000)	2.5254 (0.002)		
LR chi square			142.31 (0.0000)	106.00 (0.0000)
Psedo R^2			0.6954	-0.8346

Note: [a/]Models 1 and 2 are estimated in OLS with the dependent variables of the economic profit and the ratio of irrigated water cost to economic profit respectively; [b/]Models 3 and 4 are estimated in Tobit truncated regression with the dependent variables of the variable return to technical efficiency and the scale efficiency respectively; *, **, *** statistically significant level at 10%, 5%, 1%, respectively. Numbers in parenthesis () show t-values. Descriptive of variable is presented in Appendix 1.

Source: Authors' calculation.

type of rice-base system have the positive effect on the TE. Meanwhile, the factors of the type of seed, number of pesticides, and salinity impact have negative effects on the TE. It provides the evidence that applying the marketed seed and much pesticides would reduce the TE of the farms. Finally, the results in Model 4 show that, statistically significant, the type of rice-base system, area, and number of pesticides are the determinants of the SE. The factors of area, and number of pesticides have the negative effects on the SE. Result also indicates that the rice farms are higher economically efficient than the rice-shrimp farms.

4. Conclusions and policy implications

The study uses the DEA approach to assess the EE of rice-based system in the western coastal region of the MD. The rice model has higher financial/economic profits and financial/economic rates of return than the rice-shrimp model. Specifically, the financial profits per ha are 26.2 and 12.5 million VND for the rice model and rice-shrimp model respectively; and the economic profits per ha are 25.1 and 10.2 million VND for the rice model and rice-shrimp model respectively. Furthermore, the financial rates of return are 62.6 and 46.8 percent for the rice model and rice-shrimp model respectively; and the economic rates of return are 59.5 and 33.6 percent for the rice model and rice-shrimp model respectively. Second, the average overall technical efficiencies for the TE and the SE are 0.665 and 0.509 respectively implying that substantial inefficiencies occurred in farming operations of the sample farm households. Results also reveal that the distribution of the SE is widely scattered at the range of 0.100-1.000. The highest proportion of farmers with the SE of 0.100-0.200 and 0.900-1.000 are 18.3 and 17.2 percent respectively. The results indicate that there are 49 percent of farmers who attain the low TE (below 0.500) while there are 22.1 percent of them who attain the high TE (0.800-1.000). In term of the EE of economic return-to-scale, there are 86.9 percent and 2.4 percent of farmers having the DRS and CRS respectively while the proportion of farmers having IRS is 10.7 percent. Furthermore, it is found that the rice-shrimp farms have more TE than rice farms. However, the rice farms have more SE than rice-shrimp farms. Results showed that there was still potential for improving the EE of rice-based system. Third, results show that, statistically significant, the land ownership and the rice area are the determinants of the economic profit; the irrigation system, saltwater drains, salinity impact are the determinants of the economic irrigated water use; the land ownership status, the area, and type of seed are the determinants of the TE; and the gender, age, education level, irrigation system, saltwater drains, area, type of seed, and practices of fertilizing and weeding are the determinants of the SE. Nevertheless, the effect of irrigation system on economic profit is not as the expectation. Besides, the positive effect of number of fertilizing proves that the rice-based farms are still dependent of modern input uses. Results also indicate that the rice farms are higher economically efficient than the rice-shrimp farms. Finally, results also reveal that rice-based farms in Kien Giang attain a higher economic profit, TE and SE than farms in Ca Mau.

For policy implications on rice-based farming system in the MD's coastal area, the intensive rice production models is more economically efficient than other farming models like rice-shrimp model. There is still a room for improvement on TE, SE, and EE for all rice-based models. Comparing to intensive rice model vis-à-vis rice-shrimp model, the scale of area is an important factor causing higher TE and ES of rice farmers. This has a significant policy implication in the practice of rice industry development in the MD. A land accumulation policy is needed in order to improve the TE and EE of rice production system in the MD. This recommendation on land accumulation policy should be tested for other rice production regions so that it can be a proof for agricultural land use policy reform in Vietnam.

APPENDICES

Appendix 1. Description of variables used in the study.

Variable	Unit	Description
Revenue	Thousand VND	Rice revenue
Seed	Thousand VND	Cost of seed
LandPreparation	Thousand VND	Cost of land preparation: in the 1st stage of land preparation
Pesticides_1	Thousand VND	Cost of pesticides: in the 1st stage of land preparation
Rentlabor_1	Thousand VND	Cost of rent labor: in the 1st stage of land preparation
OwnLabor_1	Thousand VND	Cost of family labor: in the 1st stage of land preparation
Fertilizer_2	Thousand VND	Cost of fertilizers: in the 2st stage of rice production
Pesticides_2	Thousand VND	Cost of pesticides: in the 2st stage of rice production
WaterIrriCost	Thousand VND	Cost of irrigated water cost: in the 2st stage of rice production
Rentlabor_2	Thousand VND	Cost of rent labor: in the 2st stage of rice production
OwnLabor_2	Thousand VND	Cost of family labor: in the 2st stage of rice production
ProdCost_2	Thousand VND	Cost of rice production: in the and 2rd stage of rice production
TotalProdCost_1_2	Thousand VND	Total cost of rice production: in the 1st and 2rd stage of rice production
MachineCost_3	Thousand VND	Cost of machine for harvesting: in the 3st stage of harvesting
TransportCost_3	Thousand VND	Cost of transport for harvesting: in the 3st stage of harvesting
DryingCost_3	Thousand VND	Cost of drying for harvesting: in the 3st stage of harvesting
Rentlabor_3	Thousand VND	Cost of rent labor: in the 3st stage of harvesting
OwnLabor_3	Thousand VND	Cost of family labor: in the 3st stage of harvesting
HarvestCost	Thousand VND	Total cost of harvesting: in the 3st stage of harvesting
FinProfit	Thousand VND/household	Financial profit
EconProfit	Thousand VND/household	Economic profit
FinCost	Thousand VND/household	Financial cost
OwnLabor	Thousand VND/household	Cost of family labor
EconCost	Thousand VND/household	Economic cost
FinROS	%	Financial return on sales
EconROS	%	Economic return on sales
Area	ha	Rice area
AgriModel	Dummy (1: rice; 0: rice-shrimp)	Agricultural Model
LandOwner	Dummy (1: owned; 0: leased or rent)	Land owner
Irrigationsystem	Dummy (1: irrigated; 0: non-irrigated)	Irrigation system
MarketedSeed	Dummy (1: marketed; 0: in-house)	Marketed seed
CertificatedSeed	Dummy (1: certificated; 0: non-certificated)	Certificated seed
SaltTolerantSeed	Dummy (1: tolerant; 0: non-tolerant)	Salt-tolerant seed
Yield	ton/ha	Rice yield
Seed_Kg	kg	Quantity of seed
Seed_ha	kg/ha	Quantity of seed
NumberFert	Number	Number of fertilizing
NumberPes	Number	Number of pesticiding
NumberWeeding	Number	Number of weeding
IrriCost	.000 VND	Irrigated water cost
SalProteGate	Dummy (1: having a gate; 0: no gate)	Salinity protection gate
Salinity_Impact	Dummy (1: impacted; 0: not impacted)	Salinity impact
Gender	Dummy (1: male; 0: female)	Head's gender
Age	Years	Head's age
LivingYear	Years	Number of year to live in the location

Appendix 2. Results of t-tests of critical variables by categories.

Indicator	Agricultural model (1: rice; 0: rice-shrimp)	Irrigation system (1: yes; 0: no)	Seed status 1 (1: bought; 0: in-house)	Seed status 2 (1: certificated; 0: non-certificated)	Seed status 3 (1: salt-tolerant; 0: non-salt tolerant)	Land ownership (1: owned; 0: rent or leased)	Salinity protection system (1: yes; 0: no)	Salinity impact (1: yes; 0: no)
Financial profit/ha (,000 VND)	-10.7433	-7.7732	0.5657	-1.1803	1.0825	0.0362	-7.4764	8.4380
	0.0000	0.0000	0.5718	0.2382	0.2793	0.9711	0.0000	0.0000
Economic profit/ha (,000 VND)	-2.4572	-2.9352	-0.6548	-0.8172	1.0823	0.8876	0.1532	2.3554
	0.0142	0.0034	0.5127	0.4140	0.2794	0.3750	0.8783	0.0187
Scale efficiency	-1.6675	-0.6447	0.1384	0.4252	-1.1441	-0.9606	-2.5455	2.1089
	0.0958	0.5193	0.8900	0.6708	0.2529	0.3370	0.0112	0.0353
Rice yield (ton/ha)	-13.0300	-7.8371	-1.5699	-3.2236	1.0219	-0.4864	-7.1352	7.7372
	0.0000	0.0000	0.1168	0.0013	0.3071	0.6268	0.0000	0.0000
Seed (kg/ha)	-15.4614	-3.5411	3.4886	4.4431	1.7177	1.9079	-4.8956	0.8210
	0.0000	0.0004	0.0005	0.0000	0.0862	0.0567	0.0000	0.4119
Number of fertilizing	-10.9297	-7.3029	1.5917	2.7919	3.2221	2.8878	-7.5803	2.3619
	0.0000	0.0000	0.1118	0.0054	0.0013	0.0040	0.0000	0.0184
Number of pesticiding	-9.2883	-5.3482	-0.8518	-2.5127	3.4555	0.4964	-4.4047	2.0798
	0.0000	0.0000	0.3946	0.0122	0.0006	0.6197	0.0000	0.0379
Number of weeding	-5.5963	-1.9686	2.1179	2.8424	0.2580	0.7968	-2.7731	1.3303
	0.0000	0.0493	0.0345	0.0046	0.7965	0.4258	0.0057	0.1838
Irrigation cost (,000 VND)	-1.7537	-6.2149	-1.1733	0.0146	0.9073	1.8217	-7.4111	0.1501
	0.0799	0.0000	0.2410	0.9883	0.3645	0.0689	0.0000	0.8807
Area (ha)	1.8570	-0.3467	-1.4209	-0.8622	0.8381	1.3181	5.0832	0.0068
	0.0637	0.7289	0.1557	0.3888	0.4022	0.1878	0.0000	0.9946
Financial Return on Sales (%)	-5.6892	-4.0651	2.8110	0.3525	0.7482	-0.0355	-4.2425	8.5855
	0.0000	0.0001	0.0051	0.7245	0.4545	0.9717	0.0000	0.0000
Economic Return on Sales (%)	-7.5200	-3.1414	2.2096	-0.5492	1.2562	0.1141	-3.3141	8.1871
	0.0000	0.0017	0.0274	0.5830	0.2094	0.9092	0.0010	0.0000

First subrows show t-values and second subrows show p values.

CRediT author statement

Vo Thanh Danh: Methodology, Data collection and analysis, Writing and final reviewing; Thomas Muenzel: Reviewing and Editing.

ACKNOWLEDGEMENTS

The authors would like to thank the International Center for Tropical Agriculture and the Virginia Tech University of USA for sharing surveyed data followed by the contract number C-049-18 under which the article is written.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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