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Analysis of technical and financial efficiency of intensive white leg shrimp farming in Tien Giang province, Vietnam

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Abstract— *The objective of this investigation was to evaluate the technical and financial effectiveness of the current intensive culture of white leg shrimp (Litopenaeus vannamei) in Tien Giang province, Vietnam. A survey was conducted from December 2021 to April 2022 to collect data from shrimp farms in the Go Cong Tay district, which is a planned area of this province for brackish shrimp farming. The results showed that, in terms of technique, most farmers have a lot of experience and a high level of application of science and technology. The average size of the culture pond (0.26 ha pond^{-1}), stocking density (78.83 ind. m^{-2}), survival rate (85.28 %), FCR (0.26), and harvested shrimp size (58 ind. kg^{-1}) were similar to other Mekong Delta provinces. There were significant differences in the incomplete water sedimentation and treatment ponds and the major use of groundwater for shrimp farming. In terms of finance, the mean yield was 12,345.97 kg ha^{-1} crop^{-1} and was higher than other provinces in the Mekong Delta. However, the mean profit and the total profitability were 17,575 USD ha^{-1} crop^{-1} and 0.38, respectively, which was lower than the previous year in the Tien Giang province because of the high input costs. The results of this study show the necessary requirements for the sustainable development of the model of intensive shrimp farming in Tien Giang Province, including (1) the complete rebuilding of the system of farming, water sedimentation, and treatment ponds; (2) the efficient solution for using the surface water; and (3) the support of local authorities, aiming to help farmers reduce input costs and increase profits.*

Keywords— ***Financial efficiency, intensive farming, Mekong Delta, technical efficiency, white leg shrimp.***

I. INTRODUCTION

Aquaculture is a high-priority sector for development in Vietnam (Hishamund *et al*., 2009). This country accounted for the world's third-largest exporter of aquaculture products in 2017, with shrimp production reaching about 700 thousand tons in the same year and the value of exports increasing from 3.8 billion USD in 2007 to 8.5 billion USD in 2017 (FAO, 2009; FAO, 2019). In Vietnam, two main farmed shrimp species are black tiger shrimp (*Penaeus monodon*) and white shrimp (*Litopenaeus vannamei*) (Van Duijn *et al*., 2012). Since Decision No. 228/CT-BNN-NTTS on January 25, 2008, was issued by the Vietnam Ministry of Agriculture and Rural Development, allowing the development of white leg shrimp farming nationwide, the white leg shrimp national total farming area and output have continuously increased, and reached 110 thousand ha and 642.5 thousand tons, respectively, in 2021, corresponding to 100.5%and 104.3% compared to 2020, respectively (VASEP, 2022).

The Mekong Delta is one of the crucial regions in the shrimp culture of Vietnam. Tien Giang, a province in the Mekong Delta, also recorded the general shrimp culture development of the nation. In 2021, the province's area and output were 3,230 ha and 18,755 tons, increasing 4% and 6%, respectively, compared to 2020. Intensive shrimp farming has indeed become the main source of income for farmers

and a force of economic development in the Tien Giang province, especially in the eastern districts of this province, such as Tan Phu Dong, Go Cong Dong, Go Cong Tay, and Go Cong. However, this production industry is showing unsustainable development because of a polluted water environment, serious outbreaks of diseases, and high production costs (Tien Giang Fisheries Sub-Department, Vietnam, 2022).

Understanding the characteristics of the current farming system will facilitate the determination of specific aspects for potential improvement. This study aims to survey and evaluate the current situation in order to recommend effective solutions to contribute to the sustainable development of the intensive white-leg shrimp farming industry of Tien Giang province, Vietnam.

II. METHODS

2.1. The Research area and investigated household choices

This study was performed in the Go Cong Tay district, Tien Giang province, Vietnam, which is a planned area of the province for brackish shrimp farming because it is located outside the saline-prevention dike line. We randomly selected the 30 households of intensive white leg shrimp-small scale farming based on the household list of shrimp farming, which was supplied by the District Department of Agriculture and Rural Development to collect investigated information.

2.2. Data collection

Secondary information sources include annual summary reports of the district's Agriculture Department and Provincial Sub-Department of Fisheries. The primary information was collected from the farmers using a questionnaire, including (1) general household information (name, age, gender, education level, labor force, years of experience); (2) technical aspects (pond area, number of crops per year, feed, farming time, stocking density, breeding size, disease management); (3) production parameters (growth, survival rate, feed conversion ratio); (4) financial information (cost, revenue, product price, selling price, profit, profit margin); and (5) farmer's opinion regarding advantages and disadvantages of this farming model. We also deeply interviewed the leaders of the Department of Agriculture and Rural Development and the Center of Agricultural Extension and Services in Agriculture of Tien Giang province regarding the production situation and related policies for shrimp farming in the province.

2.3. Data analysis: All the data were statistically analyzed, using Excel and SAS software.

III. RESULTS AND DISCUSSION

3.1. The General information

Table 1 shows that the average number of people in the households was 4.93 people, with 1.67 of them working on shrimp farms (accounting for 33.8% of the total number of people in the family) and no recruited workers. Due to the professional nature that requires a lot of health, men were mainly involved in shrimp farming (accounting for 93.33%) and women had less important roles in this profession (6.67%). Most of them had rather low educational levels, consisting of secondary schools (80% in total) and primary schools (13.33%), while a low percentage was in upper-secondary schools (6.67%). These results were similar to those studies by Quyen *et al*. (2017), Long and Hien (2015), and Adesope *et al*. (2012). The average age of the household head was 51.40 years old, which included most of the middle age in the range of 35–55 (66.67%) and the old age of over 55 (33.33%), especially without a youth age of under 35. The average number of years of their shrimp farming experience was rather long, at about 17.07 years. These are also similar characteristics of shrimp farmers in the Mekong Delta (Phuong *et al*., 2020; Quyen *et al*., 2017; Long and Hien, 2015) and in developing countries worldwide (Omobolanle, 2008; Adesope *et al*., 2012; Khan and Akram, 2012; Rehman *et al*., 2013; Bozoglu and Ceyhan, 2007; Okunlola *et al*., 2011; Kitila and Alemu, 2014).

Table. 1: General information about households

Information	Classification	Frequency	Percentage rate (%)	Mean±SD
Age	Young (< 35)	0	0.00	51.40±10.51
	Middle (35–55)	20	66.67	
	Old (> 55)	10	33.33	
Gender	Male	28	93.33	
	Female	2	6.67	

Education	Primary	4	6.67	
	Secondary	24	80.00	
	High school	0	0.00	
	College and above	2	13.33	
Years of experience	<5 years	2	6.67	17.07±8.68
	≥ 5 – < 10 years	6	20.00	
	≥ 10 – < 15 years	4	13.3	
	≥15 years	18	60.00	
No. of people in the family (person household^{-1})	≤ 3	4	13.33	4.93±1.39
	4	6	20.00	
	> 4	20	66.67	
No. of people who worked on the shrimp farms (person household^{-1})	1	20	66.67	1.67±1.11
	2	4	13.33	
	3	2	6.67	
	4	4	13.33	

3.2. Information about the techniques of shrimp farming:

3.2.1. Pond system and crop

On average, each household had an average area of 0.34 ha, and a number of ponds of 1.4 ponds were used for intensive white leg shrimp farming. The average area and depth of farming ponds were 0.26 ha and 1.59 m, respectively (**Table 2**), which was smaller than the report of Quyen *et al*. (2017), where the average farming pond area was 0.39 ha, and quite equivalent to the study by Phung and Lam (2019), which was 0.22 ha. This pond area was suitable for intensive white leg shrimp culture (Hai *et al*., 2017). Besides, a tendency to convert to a smaller farming pond area, about 0.12–0.25 ha, has been expected by the Mekong Delta farmers because it is easier to manage and operate. The results also showed that there was 100% of the shrimp pond edge covered with a tarpaulin, but completely none of the pond bottom tarpaulins (**Table 2**). According to farmers, the current model does not require using tarpaulin for the bottom because the cost of tarpaulin is high and incurs several other costs in care and management. This model is also equivalent to models without a tarpaulin bottom with a density of below 100 ind. m^{-2} in the Mekong Delta (Phung and Lam, 2019).

The results of the present study showed that the proportion of households with water sedimentation ponds was 66.67%, with an average area and depth of 0.14 ha and 0.16 m, respectively. However, no households were equipped with waste treatment ponds (**Table 2**), so all the waste from shrimp farming was discharged directly into the rivers in the region. This implied an intensive white leg shrimp farming model in the Tien Giang province on a very small scale, and the system of sedimentation ponds and treatment ponds was incomplete compared to the same farming model in other provinces in the Mekong Delta (Hien *et al*., 2021; Phuong *et al*., 2020; Phung and Lam, 2019; Long and Hien, 2015), which made it difficult for farmers to manage the environment and diseases in the farming process. Therefore, it required local authorities to build a standard water supply and drainage system for the area. Besides, it would be better if the shrimp farming households made their plan to use the common land fund to build a settling pond and for alternate uses.

White leg shrimp were farmed in Tien Giang province on average at 2.33 crop year^{-1}, with two crop year^{-1} (66.67%) and three crop year^{-1} (33.33%) farmed. The farming crops usually begin in April, October, and November because of favorable conditions like less rain and high salinity, which are suitable for shrimp growth. According to the experience of most farmers and the recommendations of professionals, the most effective shrimp farming should be two-crop farming. The remaining time is used to improve the pond and isolate the disease sources.

Table. 2: Information about pond system and crops

Parameters	Mean±SD	Maximum	Minimum
Total used area for farming (ha household^{-1})	0.34±0.14	0.6	0.15
No. of farming ponds (pond household^{-1})	1.40±0.74	3	1
The average area of farming pond (ha)	0.26±0.13	0.6	0.15
Water depth of farming pond (m)	1.59±0.21	2	1.2
The average area of sedimentation pond (ha)*	0.14±0.08	0.25	0.04
Water depth of sedimentation pond (m)	0.16±0.24	2	1.2
No. of wastewater treatment ponds (pond household^{-1})	0	0	0
Tarpaulin-covered farming pond edge	30	30	0
Tarpaulin-covered farming pond bottom	0	0	30
No. of crops (crop year^{-1})**	2.33±0.49	3	2

*The percentage of households with sedimentation ponds accounted for 66.67% and those without settling ponds accounted for 33.33%. * *The percentage of households farming two crops accounted for 66.67% and three crops accounted for 33.33 %.

3.2.2. Sources of water, seed, and feed

Sources of water and utilization: The water supply used for shrimp ponds was from drilled wells (100%of households). Before use, the water was supplied to sedimentation ponds to settle the suspended matter and was treated using chemicals for sterilization (66.67% of households). However, if the household does not have a sedimentation pond, the well water was directly supplied to the farming ponds (33.33% of households) (**Table 3**). Several households used salt to enhance the salinity of water used for shrimp farming because well water is usually below 5‰. One of the major impediments to local shrimp farming was a lack of clean water. Moreover, the exploitation and use of groundwater for aquaculture are prohibited by Vietnamese law. However, the management of these activities is still strict now. The necessary solutions are: using available surface water through sedimentation treatment measures; adhering to seasonality to have a good quality water source; not discharging wastewater directly into rivers and canals; strengthening education, and strictly managing the illegal digging of wells by farmers. The shrimp farming model is highly effective and stable when it harmonizes technical, financial, and environmental aspects (Phuong *et al*., 2020).

Seed sources and seed stocking methods: The quality of shrimp seed plays a significant role in the success or failure of the culture. **Table 3** shows that farmers only buy directly from reputable companies without any intermediary agents. Seeds were guaranteed in sufficient quantity and quality. The average stocking density was 78.83 ind. m^{2}; the lowest was 50 ind. m^{-2} and the highest was 100 ind. m^{-2} (**Table 7**); this stocking density was equivalent to the model of intensive shrimp farming without tarpaulin but only half that of the super-intensive farming model with bottom tarpaulin in the Mekong Delta (Hien *et al*., 2021; Phung and Lam, 2019; Quyen *et al*., 2017; Long and Hien, 2015). Interestingly, there are several shrimp seed production companies that also promote 10 to 40% of the seed quantity. This is the cause of increasing stocking density and the actual survival rate. To have a stocking density suitable for the production model, farmers must calculate the amount of shrimp seed to buy and the promotion rate. In Tien Giang, a large percentage of households (86.67%) stocked direct seeds into farmed ponds without nurseries, and 13.33% of households where seeds were nursed in biofloc systems before being stocked into farming ponds (**Table 3**), which was called the 2-stage biofloc-farmed model (Phung and Lam, 2019). This model was reduced to minimize risks in the early 1–2 farming months of the process, so it was deemed effective and was recommended for replication (85 % of opinions).

Feed sources and feeding methods: Industrial pellet feed was used in 100% of the farms and diets according to the growth stages of shrimp. Feeding machines were also used in most households (86.67%), and the remaining ones did not use this equipment because they have small farming areas (Table 3). Using feeding machines has reduced labor and improved the feed efficiency for shrimp. All households set up feeding machines with the same capacity, which means that the feeding machines have not been used optimally. As a result, farmers must be instructed on how to choose the number and capacity of feeding machines for suitable farming scales for each household.

Table. 3: Sources of water, seed, feed and utilization

Content	Classification	Frequency	Percentage (%)
Water source	River	0	0
	Drilling well	30	100
Source of seed	Production in the province	0	0
	production outside the province	30	100
Quality of seed	Qualified	30	100
	Unqualified	0	0
Seed stocking method	Direct breeding stocking	26	86.67
	Nursery postlarvar for fingerlings	4	13.33
Source of feed	Industrial pellet feed	30	100
	Homemade feed	0	0
Feeding method	Feeding machine	26	86.67
	Without feeding machine	4	13.33

3.2.3. Equipment and chemicals

The percentage of farming households equipped with the paddle wheel and the bottom aerator was 100% and 4.66% , respectively, and in most cases, the number and the set location of the equipment depend on the farmer's experience and investment ability. Farmers must be instructed on how to properly arrange and install equipment in order to manage the water environment and reduce the cost of use in order to increase the equipment's efficiency. According to Boyd (1990), on average, 4–8 paddle wheels with a capacity of 2.5 KW, or two air compressors (3 HP) can be installed for one hectare of ponds. In addition, 86.66% of the households have been using feeding machines, and the remaining ones did not use this equipment because they have small farming areas. The results show that there were 100% of shrimp farming households equipped with backup generators, water pumps, and water environmental test kits (**Table 4**).

All households used chemicals in the pond renovation. The choice of chemicals used has been mainly based on the experience and knowledge of farmers. **Table 4** shows that the percentage of households that used unslaked lime and probiotics was 100, and permanganate potassium and chlorine were 60% and 20%, respectively. Meanwhile, the percentage of farmers using chlorine and other chemicals in other provinces in the Mekong Delta was much higher, at 54.52% and 45.48%, respectively (Phuong and Lam, 2019).

Table. 4: Equipment and chemicals have been used for shrimp farming in households

Equipment	Frequency	Percentage (%)
Paddle wheel	30	100
Aerator	14	46.66
Generator	30	100
Water pump	30	100
Feeding machine	26	86.66
Water environment test kit	30	100
Chemicals		
Unslaked lime	30	100
Potassium permanganate	18	60
Chlorine	6	20
Using probiotics	30	100
None	0	0

3.2.4. Renovation techniques and management of ponds

Before each farming crop, 100% of households performed pond renovation using the wet method and coloring pond water (**Table 5**), unlike other provinces in the Mekong Delta that all follow the dry method (Phung and Lam, 2019). According to Hai *et al*. (2017), it didn't matter whether it was dry or wet as long as the correct technique was followed. In the survey area, 100% of the households only supplemented well water without changing the water during farming crops, periodically fertilized lime, and removed waste deposited at the bottom. Besides, those who used probiotics and permanganate potassium were 73.33% and 60%, respectively (**Table 4**). Most farmers pay attention to and effectively manage environmental factors such as water temperature, pH, alkalinity, dissolved oxygen, etc. However, a huge difficulty is that 100% of farmers did not change the water (**Table 5**), resulting in low clarity (20–30 cm), while in the provinces in the Mekong Delta, the percentage of households that change the water regularly after two months of farming accounts for 72.50% (Phung and Lam, 2019).

Table. 5: Renovation techniques and management of ponds

Content	Classification	Frequency	Percentage (%)
Pond **r**enovation method	Wet method	30	100
	Dry method	0	0
Bottom slugs dredging	Applied	30	100
	Not applied	0	0
Coloring water pond	Applied	0	0
	Not applied	30	100
Environment parameters test	Applied	30	100
	Not applied	0	0
Water exchange	Unapplied	30	100
	Applied	0	0

Disease control: The disease was most visible in the first 30 farming days (53.33% of respondents); after 30-60 farming days (46.67% of respondents). After 60 days until harvest, there was no disease in farmed shrimp (**Table 6**). The pathogens are very diverse, and the disease frequency was also very different for farms. The statistical results show that White Feces Syndrome had the highest rate (51.61%), followed by Acute Hepatic Necrosis Syndrome/Early Mortality Syndrome (25.81%), Yellowhead virus (12.90%), Necrotizing hepatopancreatic bacterium (6.45%), and Viral syndrome White spot syndrome virus (3.23%) (**Table 6**).

Table. 6: Diseases management

Content	Classification	Frequency	Percentage (%)
Stages of disease appearance	During the first 30 farming days	16	53.33
	After 30–60 farming days	14	46.67
	After 60 farming days	0	0
Pathogens	Yellowhead virus	16	12.90
	Necrotizing hepatopancreatic bacterium (NHPD)	8	6.45
	White spot syndrome virus (WSSV)	4	3.23
	White feces syndrome (WFD)	32	51.61
	Acute hepatopancreas/early mortality syndrome	16	25.81
Treatment methods	Using minerals and vitamins	22	73.33

	Using antibiotics	30	100
Treatment effectiveness	Success	4	13.33
	Unsuccessful	26	86.67

3.3. Parameters of harvesting and finance

Table 7 shows that the average survival rate, harvesting shrimp size, and FCR were 85.28%, 58 ind. kg^{-1}, and 1.24, respectively, which were similar to other provinces in the Mekong Delta, Vietnam. In 2021–2022, the input costs (seed, feed, drug, chemical, etc.) increased to lead the product price up to 3.65 USD kg^{-1} was higher than in previous years, while the average sales price of 5.05 USD kg^{-1} was unchanged. This was the reason for the average profit of 17,575.40 USD $ha^{-1}crop^{-1}$ and the total profitability of 0.38, which were lower than in previous years (Phuong *et al*., 2020; Quyen *et al*., 2017; Long and Hien, 2015). Market prices often govern shrimp harvesting time. Most farmers knew how to choose the right time to harvest shrimp to reduce the molting shrimp rate. Although intensive shrimp farming is profitable, its attractiveness has been very low due to its relatively high-risk level, large capital requirement, and negative impacts of wastewater discharge into the environment from farming (Long, 2017).

Table. 7: Parameters of harvesting and finance

	Mean±SD	Maximum	Minimum
Harvesting parameters			
Culturing duration (day $crop^{-1}$)	90	100	80
Stocking density (ind. m^{-2})	78.83±18.75	100	50
Seed size	PL_{10} - PL_{12}	30	100
Harvesting size (ind. kg^{-1})	58.00±16.27	35	100
Survival rate (%)	85.28±6.52	100	75
Feed conversion ratio	1.24±0.05	1.3	1.2
Yield (tons ha^{-1} $crop^{-1}$)	12,345.97±3,863.58	18,000	4,000
Financial parameters			
Product price (USD kg^{-1})	3.65 ± 0.32	4.34	3.04
Sales price (USD kg^{-1})	5.05±0.67	6.07	4.03
Total cost (USD ha^{-1} $crop^{-1}$)	44,923.94±13,541.72	62,472.89	13,882.86
Turnover (USD ha^{-1} $crop^{-1}$)	62,499.34±19,697.61	84,338.39	16,832.97
Profit (USD ha^{-1} $crop^{-1}$)	17,575.40±7,878.60	26,030.37	2,950.11
Total profitability	0.38±0.14	0.56	0.12

3.4. Advantages and disadvantages of intensive white leg shrimp farming in Tien Giang province

When farmers were asked about the sources of scientific and technical information being used, 100% of the opinions were from relatives and technical staff of business establishments, 66.66% from radio and television, and 46.67% from newspapers. However, there weren't any sources received from the state extension. The role of the district Agricultural Service Center in extension is ineffective these days because of difficulties such as the separation and union of functions, the lack of staff specialized in fisheries, and the limited funds for the extension. Meanwhile, there is a very strong development of business establishments for food, chemicals, and aquatic drugs that possess technical staff to support farmers. Several establishments accompany farmers by supporting food, drugs, chemical costs, etc., at the beginning but pay after harvest with a high-interest rate, of about 10% per month. It is necessary to strengthen local extension and encourage sustainable association between farmers and agents by negotiating a reasonable interest rate.

During the shrimp farming period, 100% of farmers said they were facing many shortcomings in terms of unfavorable water environments, difficult-to-control

diseases, increasing production costs, an 86.67% lack of production capital, and 53.33% unpredictable prices. These are also common challenges in Mekong Delta intensive white leg shrimp farming (Quyen et al., 2017; Long and Hien, 2015; Phung and Lam, 2019). It is necessary to coordinate between sectors in the province and district and to get the cooperation and consensus of farmers to solve these problems. These actions are urgent and long-term at the same time.

Regarding increasing the level of intensive farming soon, up to 86.66% of farmers reported that it was hard to successfully implement in the current conditions because the technique is difficult to apply. Besides, 100% of farmers believed that the cost was high, resulting in a lack of investment capital. There were 93.33%of the opinions were that farmers would keep the current model because the demand for the world's white leg shrimp market was still open, and 6.67% thought they would shift the production scale to super-intensive 2-stage shrimp farming.

Table. 8: Advantages and disadvantages associated with shrimp farming

Information	Classification	Frequency	Percentage rate (%)
Technical information sources	Fishery extension programs	0	0
	Professional documents	14	46.67
	Television, radio	20	66.66
	Relatives	30	100
	Staff of aquaculture services	30	100
Disadvantages of the present farming model	Poor quality water environment	30	100
	Disease increases	30	100
	Lack of production capital	26	86.67
	High input costs	30	100
	Unstable selling price	16	53.33
Difficulties in approaching new technical advances	Inappropriate/applied-difficult technique	26	86.66
	High investment capital demand	30	100
Transforming the production scale for the next time	Agree	2	6.67
	Disagree	28	93.33

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

The model of intensive white leg shrimp farming in Tien Giang was small-scale with incomplete sedimentation and treatment pond systems. Farmers had a lot of experience and technical knowledge, as well as obstacles to the polluted water environment, diseases, and increasing production costs, which were the same as in all other provinces in the Mekong Delta. The difference was that farmers did not use surface water to culture shrimp but used illegal well water, thereby affecting the sustainability of the model. Although productivity increased, production costs increased rapidly, and selling prices did not increase, making total profitability lower than before. This made the attractiveness of the intensive white leg shrimp farming model very low. Most farmers did not want to increase investment and expand production scale.

4.2. Recommendations

There are many issues that need to be addressed for the sustainable development of white leg shrimp farming in Tien Giang, including:

Enhancing extension activities: strengthening expertise knowledge training activities; carrying out demonstration plots related to technical factors such as the proper arrangement of water sedimentation and treatment ponds, addle-wheels, and feeding machines; and rational use of drugs, chemicals, and biological products in shrimp farming; guiding farmers in effectively using surface water and limiting the exploitation of underground water sources; arranging seed nursery places in shrimp ponds and determining suitable stocking density for the intensive farming model without tarpaulin.

The local government should have policies to support loans with low-interest rates for farmers; effectively manage the price and quality of input materials; develop policies to encourage investment in research to create Vietnamese-

branded products with good quality and reasonable prices; and invest in completing water supply and drainage systems to meet the requirements of the intensive white leg shrimp farming areas in the coming years.

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