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# ECONOMIC EFFICIENCY OF VANNAMEI SHRIMP FARMING IN RAWAJITU TIMUR DISTRICT, INDONESIA

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## ABSTRACT

Vannamei shrimp is a highly adaptive species that can be cultivated in ponds with low to high salinity. East Rawajitu District is one of the main centers of Vannamei shrimp farming. By 2024, the area of ponds in this region reached 16,250 hectares, which accounted for about 46% of the total area of Vannamei shrimp ponds in Lampung Province. Vannamei shrimp farmers still face challenges in allocating production factors optimally. The purpose of this study is to analyze further the technical, allocative, and economic aspects of Vannamei shrimp farming. The analysis method used is the Cobb-Douglass stochastic frontier production function and cost. The results of the study are production factors that have a significant effect on the production of Vannamei shrimp at the 99% confidence level (α = 1%) which are fry and feed. In addition, at the 90% confidence level (α = 10%), the variables of kaptan and saponin also showed a significant influence on the production of Vannamei shrimp. Then the results showed that the average technical efficiency was 0.7350, which is classified in the medium category. This indicates that Vannamei shrimp farming in the study area is running efficiently. The allocative efficiency value of 0.7590 is also classified as medium, which shows that in the resource allocation aspect, farmers have done fairly good management. The average economic efficiency is 0.5519, which is classified as low. This indicates that economically, Vannamei shrimp farming in the study location is not fully efficient.

## KEY WORDS

Aquaculture, vannamei shrimp, efficiency, stochastic frontier.

Indonesia has great potential in the fisheries and marine sector with abundant biodiversity. One of the leading commodities in the aquaculture subsector is Vannamei shrimp (Litopenaeus Vannamei), which has become a prima donna in the aquaculture industry in Indonesia (Widodo et al., 2020). According to (Prasetyo et al., 2021), Vannamei shrimp is a highly adaptive species and can be cultivated in ponds with low to high salinity. The main advantages of Vannamei shrimp are rapid growth, good feed conversion rates, and higher resistance to disease than other shrimp species (Setyowati et al., 2019). Lampung Province is one of the largest Vannamei shrimp production centers in Indonesia. Based on data from (Dinas Kelautan & Perikanan Provinsi Lampung, 2024), Vannamei shrimp production in Lampung reaches 120,500 tons per year, with the largest contribution coming from Tulang Bawang Regency, including East Rawajitu District as one of the main cultivation centers.

East Rawajitu District is one of the main centers of Vannamei shrimp farming in Tulang Bawang Regency. In 2024, the area of ponds in this region reached 16,250 hectares, which covers about 46% of the total area of Vannamei shrimp ponds in Lampung Province. Vannamei shrimp production in this sub-district has also increased, with a total yield of 53,844 tons in the same year (BPS Tulang Bawang, 2024). The trend of Vannamei shrimp production growth in East Rawajitu District continues to show an increase from year to year. This progress is driven by the application of increasingly sophisticated aquaculture technology and more efficient pond management. One of the main factors affecting the success of Vannamei shrimp farming is the production factor. In the East Rawajitu District, Vannamei shrimp farmers often face challenges in terms of increasing production costs. Some of the main inputs in Vannamei shrimp farming such as fry, feed, and dolomite lime have experienced significant price increases. Date range to the report (statistik.kkp.go.id, 2024). The price of shrimp feed is one of the largest cost components in this region and can account for more than 50 percent of the total cost of production. Vannamei shrimp farmers still face challenges in allocating production factors optimally. A lack of understanding of the right production factors cause productivity that has not been maximized (Azwar, A.et al., 2019).

The main production factors in Vannamei shrimp farming include fry, feed, labor, use of lime, and differences in the cultivation system applied (Setyowati & Rachmawati, 2020). If the use of these production factors is applied effectively and efficiently, the production results obtained can be optimized, so that production costs can be reduced and farmers' profits increased (Prasetyo et al., 2021). Therefore, an understanding of the allocation of good production factors is a crucial aspect in growing the efficiency and profit of Vannamei shrimp farmers. Based on this description, this study aims to analyze further the technical, allocative, and economic efficiency of Vannamei shrimp farming in East Rawajitu District.

## LITERATURE REVIEW

Farming science is a branch of science that studies how to manage resources effectively and efficiently to achieve optimal profit for farmers or cultivators. According to (Wanda, 2015), farming includes strategies for managing production factors to provide maximum results. This is in line with the opinion of (Setiawan, B., & Prajanti, 2011), which states that farming is a form of organizing resources, labor, and capital to increase the production and income of farmers. Production is defined as the business of allocating the various factors of production to increase the benefits or output (Karmini, 2018). According to (Saeri, 2018), Success in farming and fishing is highly dependent on optimizing productive factors (Daniel, 2002). The production function in farming describes the relationship between the amount of input used and the amount of output produced. (Karmini, 2018) . In agricultural economics, the production function is often used to analyze how changes in inputs such as feed, fingerlings, labor, and pond size can affect the production level of a fishery. Systematically the production function equation can be written as:

$$Y = f(X1, X2, X3, X4, ..., Xn) \quad (1)$$

Productivity in Vannamei shrimp farming is influenced by various factors related to farm management. According to (Sumiratin, 2012), the main factors that contribute to the success of aquaculture include pond size, number of fry, and optimal feeding. In the context of Vannamei shrimp farming, these aspects are crucial in determining yield and production efficiency (Setiawan et al., 2020). In addition, implementing a consistent and sustainable farming system is critical to the success of Vannamei shrimp farming (Fauzan, 2016). The ability of farmers to manage production factors optimally is also a key factor in achieving maximum results (Prasetyo et al., 2021). Farming efficiency is one of the important indicators in assessing the success of an agricultural or fisheries business (Indra, 2011). According to (Tinaprilla et al., 2013), efficiency is measured by comparing actual Productivity to maximum potential productivity. Hidayati (2018) divides performance into three main types: technical, allocative, and economic. Technical efficiency reflects the ability of farmers to optimize the use of inputs to obtain maximum production results (Tinaprilla et al., 2013). Meantime, allocative efficiency relates to the ability of farmers to optimally allocate production factors by market prices and the technology used (Anggraini et al., 2016). Economic efficiency, which is a combination of technical and allocative efficiency, is achieved when the marginal product value of an input is proportional to the cost of that input (Aprilia et al., 2018). In Vannamei shrimp farming, farmers can be technically and economically efficient if they can increase production by utilizing inputs optimally and controlling production costs while selling prices remain profitable (Anggraini, P. D. et al., 2016). With good efficiency, farm productivity, and profitability can be increased sustainably.

The Cobb-Douglas function is a mathematical model that describes the relationship between a dependent variable (Y) and one or more independent variables (X) in production analysis (Mufriantie et al., 2014). This function is widely used to analyze the elasticity of production factors in determining the efficiency and productivity of a business (Gujarati et al.,2009). Mathematically, the Cobb-Douglas function can be written as:

$$Y = AX1(b1)X2(b2) \qquad (2)$$

Where: Y = production; X = factor of production; A, b = estimated parameters.

According to (Anggraini et al., 2016) the Cobb-Douglas production function is often used in economic analysis because it can be easily transformed into linear form, making parameter estimation easier. This model is used to analyze technical efficiency, economic efficiency, and allocative efficiency in farming. In addition, the Cobb-Douglas Frontier function allows the determination of optimal production levels as well as costs in agricultural production systems (Coelli et al. 2005).

Research on farming efficiency using the same method has been conducted by (Ahmad et., 2014; Aigne et., 1997; Gbigbi et al, 2011; Hossain et al. 2019; Jote, A. et al., 2018; Khotimah et al., 2010; Kim, J.Y., 2018; Leovita, 2018; Nguyen et al.,2019). Research conducted by Prasetyo et al. (2021). Research by Nugroho et al. (2021) found that technical efficiency in rice cultivation in Central Java reached 0.74, and allocative and economic efficiency were only 0.52 and 0.39, respectively, indicating that farmers were not fully optimized in allocating production resources. Meanwhile, a study by Sari & Wibowo (2020) revealed that the technical efficiency of chili farming in West Java reached 0.69, However, the economic efficiency was still low (0.41) due to the high cost of production inputs such as fertilizers and pesticides. Another study by Rahman & Suryanto (2022) also found that although Vannamei shrimp farmers in Lampung were technically efficient with an average of 0.76, they still experienced inefficiency in the economic aspect with an economic efficiency of only 0.52. The main factors influencing economic inefficiency are high production costs and lack of access to more efficient farming technologies.

## METHODS OF RESEARCH

This study was conducted in the Rawajitu Timur Subdistrict, which was purposively selected because the area is one of the main centers of Vannamei shrimp production in Tulang Bawang Regency. Based on data from P3W Lampung, there are approximately 17,139 pond lots in East Rawajitu Sub-district, a strategic area for Vannamei's shrimp farming development. The type of data used in this study is quantitative data obtained from two sources, namely primary data and secondary data. Primary data were collected through direct interviews with respondents, while secondary data were obtained from various previous studies relevant to the research topic. Sampling was performed using the purposive sampling method, which is the deliberate selection of respondents based on certain criteria. The respondents selected in this study were farmers who sustainably cultivate Vannamei shrimp in East Rawajitu District.

The population in this study includes all farmers who cultivate Vannamei shrimp in the main producing areas of East Rawajitu District, Tulang Bawang Regency. Based on available data, the total population of farmers in this area reached 5,692 people. The sample in this study was set at 100 people. The sample was spread across all villages in East Rawajitu Sub-district. The method used in selecting the sample was purposive sampling, where respondents were purposively selected based on certain criteria relevant to the research objectives. The criteria for selecting respondents are farmers who have carried out sustainable Vannamei shrimp farming in East Rawajitu District. The Central Limit Theorem is also used to determine the number of samples in this study, which states that the distribution of sample means will approach the normal distribution when the sample size is large enough, even if the initial population is not normally distributed. Therefore, the 100 farmers were considered to have met the minimum required ($n \geq 30$) to represent the variation in the population of Vannamei shrimp farmers in the study area. The analytical method used was the Stochastic Frontier production function with a Cobb-Douglas production function approach. This method is used to measure the technical efficiency of Vannamei shrimp farming and to identify factors that affect this efficiency. This model allows analysis of technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE), each of which is calculated based on the relationship between actual output and potential output that can be achieved at a certain input level.

## RESULTS AND DISCUSSION

In this analysis, a Cobb-Douglas production function with a stochastic frontier approach was used, estimated with the Maximum Likelihood Estimation (MLE) method. Estimation of production factor parameters will be using this method, intercept value ($\beta_0$), as well as the variance of two error components, namely random error ($v_i$) and inefficiency error ($u_i$). The stochastic frontier production function estimation results presented in Table 1 show that the Likelihood Ratio (LR) value is 22.367, which is higher than the Kodde & Palm value of 5.138. This indicates that the stochastic frontier model used can significantly explain variations in the technical efficiency of farmers in Vannamei shrimp farming. Based on the results of the stochastic frontier analysis, the following function was obtained:

$$LnY = 1.4825 + 0.4527\ LnX1 + 0.3124\ LnX2 + 0.0817\ LnX3 + 0.1268\ LnX4 + 0.1583\ LnX5 – 0.0985\ Ln\ X6\ (vi-ui)$$

Based on the analysis results, a log-likelihood value of -19.022 was obtained in the Maximum Likelihood Estimation (MLE) method. This indicates that the production function model used is the real conditions in the field. The estimated parameters in the Cobb-Douglas-based stochastic frontier production function represent the value of the production elasticity of the limits of the various inputs used in farming. The analysis results for each variable are as follows:

Table 1 – Results of the Stochastic Frontier Production Factor Function of Vannamei Shrimp Farms in East Rawajitu District

| Variables | Parameter | Coefficient | Standard Error | Significant | t-ratio |
|---|---|---|---|---|---|
| Constanta | β0 | 1.4825 | 2.2053 | 0.0000 | 7.2221 |
| Ln Fry | β1 | 0.4527*** | 0.1158 | 0.0001 | 3.9105 |
| Ln Feed | β2 | 0.3124*** | 0.0932 | 0.0008 | 3.3502 |
| Ln Urea Fertilizer | β3 | 0.0817ns | 0.0512 | 0.1104 | 1.5967 |
| Ln. Agricultural lime | β4 | 0.1264** | 0.0586 | 0.0310 | 2.1642 |
| Ln. Saponin | β5 | 0.1583** | 0.0725 | 0.0292 | 2.1821 |
| Ln. Labor Force | β6 | -0.0085 | 0.0557 | 0.0771 | -1.0675 |
| Sigma – square Gama | $s^2$ | 0.6219 | | | |
| Log-likelihood function | c | 0.9863 | | | |
| Generalized Likelihood Ratio (LR) test LR test | LLF | -19.022 | | | |
| | LRtest | 22.367 | | | |

*Source: Primary Data (processed) 2025.*

The Stochastic Frontier Analysis results production model revealed that the variable fry had a significant effect on Vannamei shrimp production, with a confidence level of 99%. The coefficient of fry is positive, 0.4527, indicating that any increase in the number of fry by 1% will encourage an increase in Vannamei shrimp production by 0.4527%. Compared to other production variables, fry showed the highest level of responsiveness to changes in production. This is in line with research conducted by (Asmarantika, et al., 2017; Khotim, et al., 2010; Leovita, 2018; Ohajianya, et al., 2014; Ratih, et al., 2011), research in Nigeria, found that fry is one of the main production factors in Vannamei shrimp farming. The elasticity coefficient of fry in their production model was 0.43, which is similar to the result of this study (0.4527).

The results of the analysis of the Stochastic Frontier production model showed that the feed variable has a significant influence on the production of Vannamei shrimp, with a confidence level of 99% ($p < 0.01$). The coefficient of feed is positive, which is 0.3124, which indicates that increasing the amount fed by 1% will encourage an increase in Vannamei shrimp production by 0.3124%, assuming other factors remain (ceteris paribus). This is in line with the findings of various studies by (Anand, S., 2020; Juárez-Hernández, B., 2021; Kim, J.Y., 2018; Tran, H.T., 2020; Xu, W., 2019) explain that feed is one of the main production factors in Vannamei shrimp farming because it plays a role in growth, survival rate, and feed efficiency (Feed Conversion Ratio / FCR).

The estimation results of the Stochastic Frontier production model show that the urea fertilizer variable has no significant effect on Vannamei shrimp production at the 90% confidence level (p> 0.10). The variable coefficient value of the amount of urea fertilizer is 0.0817, which indicates that any increase or reduction in the use of urea fertilizer has no significant impact on the production of Vannamei shrimp. Because Vannamei shrimp rely more on protein-rich artificial feed for growth. The main function of urea fertilizer in ponds is to stimulate the growth of plankton as natural food, but if the use of artificial feed is sufficient, the role of urea becomes less important. In addition, excessive use of urea fertilizer can trigger an increase in ammonia levels, which is potentially detrimental to shrimp health. In this study, the average use of urea fertilizer in the study area was 11.45 kg per production cycle with an average land area of 0.23 hectares. The results of this study are in line with research (Huda et al., 2018) in his research on the efficient use of production inputs in Vannamei shrimp farming Find that using no significant effect on the productivity of intensive ponds because the main nutrients in the pond system are sufficient through regular feeding.

The variable agricultural lime has a significant effect on Vannamei shrimp production at the 99% confidence level (p < 0.01). The coefficient value of Agriculture lime is positive at 0.1264, which means that every additional 1% use of kaptan will increase the production of Vannamei shrimp by 0.1264%. This is because agricultural lime plays a role in stabilizing the pH of pond water, increasing the availability of nutrients for plankton as a natural food source, and reducing the toxicity of harmful substances such as ammonia and sulfide in water (Boyd, 2018). In addition, Using the agricultural lim can also improve the structure of the pond bottom soil, thus creating optimal environmental conditions for the growth of Vannamei shrimp (Furtado et al., 2015). Research conducted by (Gao et al., 2016) states that the optimal application of kaptan before stocking fry can increase feed utilization efficiency and Raise shrimp survival ratio. Therefore, applying agricultural lime according to the recommendations (500 - 1,000 kg/ha) is very important to increase the productivity and efficiency of Vannamei shrimp ponds.

The estimation results of the Stochastic Frontier production model show that the saponin variable has a significant effect on Vannamei shrimp production at the 99% confidence level (p < 0.01). The positive coefficient of sapponin of 0.1583 indicates that any increase in the use of sapponin by 1% will increase Vannamei shrimp production by 0.1583%. This finding suggests that saponin plays a major role in increasing pond productivity, especially in controlling nuisance organisms such as predators and wild fish that can inhibit shrimp growth. In addition, the use of saponin in appropriate doses can contribute to improving the quality of the aquaculture environment, thus positively impacting shrimp growth. This finding is in line with previous research which states that saponin has a toxic effect on wild fish and organisms that are competitors in the pond ecosystem, so it can reduce the level of competition and increase the growth of Vannamei shrimp optimally (Kumar et al., 2018). In addition, research by Zhao et al. (2020) also showed that Using saponin in aquaculture can improve feed conversion efficiency and suppress disease infection due to certain pathogens, which in turn results in to increased yields.

The estimation results of the Stochastic Frontier production model show that the labor variable has no significant effect on Vannamei shrimp production in East Rawajitu District at the 90% confidence level (p> 0.10), with a coefficient value of -0.0085. This means that the addition or reduction of labor does not have a significant impact on increasing Vannamei shrimp production. This is most likely due to the efficiency of labor that has been achieved, where the average number of workers used by farmers in the study site ranged from 2 to 3 people per pond, which is considered sufficient to handle all stages of cultivation. In line with research (Guntoro et al., 2017), labor in Vannamei shrimp farming tends to have no significant effect on production when it is at an optimal level, where productivity is more influenced by factors of technology and farm management than the amount of labor. Similarly, research (Sari et al., 2020) showed that labor efficiency in aquaculture is more determined by skills and experience than the number of workers. The results of technical efficiency research can be presented in Table 2:

Table 2 – Distribution of Technical Efficiency Values

| Efficient distribution | Number (Person) | Percentage (%) |
|---|---|---|
| < 0,40 | 0 | 0,00 |
| 0,40 - 0,59 | 12 | 12,00 |
| 0,60 - 0,69 | 18 | 18,00 |
| 0,70 - 0,79 | 45 | 45,00 |
| 0,80 - 0,89 | 18 | 18,00 |
| 0,90 - 0,99 | 7 | 7,00 |
| Total | 100 | 100 |
| Minimum | 0,4810 | |
| Average | 0,7350 | |
| Maximum | 0,9880 | |

*Source: Primary Data (processed) 2025.*

Based on Table 2, it is known that the level of technical efficiency of Vannamei shrimp farmers in East Rawajitu District is in the range of 0.40 to 0.99, with an average of 0.73. This average technical efficiency can be categorized as efficient because it is above the efficiency limit of 0.70 as stated by (Coelli et al., 1998). According to (Kusnadi et al., 2015), a farm can be said to have achieved technical efficiency if the efficiency value is more than 0.70. The results of technical efficiency analysis using the stochastic frontier production model in this study indicate that farmers have optimized using production factors, so it can be said that Vannamei shrimp farming in the study area has been technically efficient. The average technical efficiency obtained was 0.73, with the highest value of 0.98 and the lowest of 0.48. The results of the research described above are in line with research that has been done (Adeyonu et al., 2019) revealed that the average technical efficiency in shrimp farming under the assumption of Constant Return to Scale (CRS) is 0.685, while under the assumption of Variable Return to Scale (VRS) is 0.783. Research by (Kumar et al.,2018) stated that the average technical efficiency of Vannamei shrimp farming reached 0.74, which is influenced by land area, education level of farmers, access to business credit, and involvement in fisheries extension programs.

Allocative efficiency in this study is analyzed based on the allocation of production input use by considering the prevailing input prices at the farm level. Allocative efficiency describes the extent to which farmers can allocate their production resources optimally in accordance with the cost structure and market prices. The results of the calculation of allocative efficiency in more detail can be presented in Table 3:

Table 3 – Distribution of allocative efficiency values

| Efficient distribution | Number (Person) | Percentage (%) |
|---|---|---|
| < 0,40 | 9 | 9,00 |
| 0,40 - 0,59 | 21 | 21,00 |
| 0,60 - 0,69 | 15 | 15,00 |
| 0,70 - 0,79 | 16 | 16,00 |
| 0,80 - 0,89 | 9 | 9,00 |
| 0,90 - 1.00 | 30 | 30,00 |
| Total | 100 | 100 |
| Minimum | 0.2464 | |
| Average | 0.7590 | |
| Maximum | 1.7526 | |

*Source: Primary Data (processed) 2025.*

Based on Table 3, the average value of allocative efficiency in Vannamei shrimp farming in the study area was recorded at 0.7590. This value indicates that farmers have generally been able to allocate production inputs well enough to achieve cost efficiency.

Farmers with the highest level of allocative efficiency reached 1.7526, while the lowest amounted to 0.2464, indicating variations in the ability of farmers to allocate resources optimally. The distribution of allocative efficiency shows that 16% of farmers have efficiency values in the range of 0.70-0.80, while another 16% are in the range of 0.80-0.899, and 30% of farmers have achieved high-efficiency levels in the range of 0.90-1.00. High allocative efficiency indicates that farmers have considered the balance between the price of inputs, the amount of inputs used, and the production yield obtained.

This is in line with research by (Rahman et al.,2019) showing that farmers who can adjust the amount and type of feed based on shrimp growth rate and water quality tend to achieve higher allocative efficiency. Meanwhile, research by (Nguyen et al., 2020) revealed that excessive or non-standard feed use leads to allocative inefficiency, leading to increased production costs without a comparable increase in yield. The average level of allocative efficiency in Vannamei shrimp farming in different regions varies depending on the scale of production, access to technology, and skill level of farmers. Studies by (Yusuf et al., 2019) found that medium to large-scale farmers have higher levels of allocative efficiency than small-scale farmers, as they are better able to access production resources more efficiently and utilize better market information.

Economic efficiency is the result of a combination of technical efficiency and allocative efficiency, which reflects the extent to which farmers can minimize production costs while still maximizing the output produced in this case can be presented the results of the distribution of economic efficiency values in Table 4:

Table 4 – Distribution of Economic Efficiency Values

| Efficient distribution | Number (Person) | Percentage (%) |
|---|---|---|
| < 0,40 | 25 | 25,00 |
| 0,40 - 0,59 | 40 | 40,00 |
| 0,60 - 0,69 | 10 | 10,00 |
| 0,70 - 0,79 | 11 | 11,00 |
| 0,80 - 0,89 | 6 | 6,00 |
| 0,90 - 0,99 | 8 | 7,00 |
| Jumlah | 100 | 100 |
| Minimum | 0.1540 | |
| Average | 0.5519 | |
| Maximum | 0.9788 | |

*Source: Primary Data (processed) 2025.*

Based on the estimation results in Table 4, it is found that the average value of economic efficiency in Vannamei shrimp farming is 0.5519, with a range of values between 0.1540 and 0.999. This value indicates that overall, Vannamei shrimp farming in the study area still has not achieved optimal economic efficiency. This is due to the allocation of production inputs that are not fully efficient, especially the use and cost of production inputs. The farmer with the highest level of economic efficiency reached 0.9788, while the farmer with the lowest economic efficiency was only 0.1540. This low level of economic efficiency is generally due to several factors, such as the high cost of production inputs, especially fry, and feed, which have the largest contribution to the operational cost structure of the farm. In addition, limited access to technology and markets is also a factor that hinders to help improve economic efficiency. These results are in line with research (Gbigbi, 2011) which shows that economic efficiency in the agricultural sector has a range of 0.13 to 0.99, with an average of 0.61, which also indicates that the Agricultural Industry in general has not achieved optimal economic efficiency. (Ohajianya et al., 2014) You can also find that high input prices and imbalances in resource allocation are the main causes of low economic efficiency in the fisheries and aquaculture sectors.

## CONCLUSION

The research findings show that individual factors, production factors that have a significant effect on Vannamei shrimp production at the 99% confidence level (α = 1%) are fry and feed. These two variables contribute greatly to the increase in Vannamei shrimp production so the optimization in the selection of quality fry and appropriate feeding is Very critical to increase productivity. In addition, at the 90% confidence level (α = 10%), the variables of kaptan and saponin also showed a significant effect on Vannamei shrimp production. The results showed that the average technical efficiency is 0.7350, which is classified in the medium category. This indicates that Vannamei shrimp farming in the study location is running efficiently. Allocative efficiency: the value of allocative efficiency of 0.7590 is also classified as medium, which indicates that with the aspect of resource allocation, farmers have done fairly good management. The average economic efficiency is 0.5519, which is classified as low. This indicates that economically, Vannamei shrimp farming in the study location is not fully efficient.

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