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Profitability of Vannamei Shrimp Farming: Traditional vs. Intensive Systems in Kolaka District in Indonesia

Agus Salim[1], Haji Saediman[2,*], Yusnaini Yusnaini[3] and Muhaimin Hamzah[3]

[1]Department of Agricultural Sciences, Postgraduate Program, Halu Oleo University, Indonesia; [2]Department of Agribusiness, Faculty of Agriculture, Halu Oleo University, Indonesia; [3]Department of Aquaculture, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Indonesia

[*]Corresponding author's e-mail: saediman@yahoo.com

This study compares the profitability of traditional and intensive Vannamei shrimp farming in Kolaka District, Indonesia, focusing on cost structures, net returns, and revenue-to-cost (R/C) ratios. Data was collected from 50 shrimp farmers (40 traditional, 10 intensive) through surveys and observations. The analysis shows that intensive farming generates higher net returns (IDR 81,779,180/ha/year) than traditional farming (IDR 19,848,751/ha/year), due to increased productivity and advanced management. However, traditional farming has a higher R/C ratio (1.50 vs. 1.29), indicating greater cost efficiency. The findings highlight the trade-off between profitability and cost efficiency, with intensive farming offering higher returns but posing greater financial and environmental risks. Recommendations include improving input access, financing, extension services, market integration, and sustainability practices.

Keywords: Farming, profitability, traditional system, intensive system, whiteleg shrimp.

INTRODUCTION

In Indonesia, whiteleg or vannamei shrimp (*Litopenaeus vannamei)* farming has become a cornerstone of the country's aquaculture industry, significantly contributing to domestic consumption and export revenues (Suhana *et al*., 2023). Since its introduction in 2000, vannamei shrimp has rapidly overtaken other species, such as black tiger shrimp (*Penaeus monodon*), due to its higher survival rates, short production cycle, and lower production costs (Kharisma and Manan 2012; Adhawati *et al*., 2020). Indonesia ranks among the top global producers of farmed shrimp, with vannamei accounting for most of the output (Jamilah *et al*., 2019). The government has prioritized the development of vannamei shrimp farming to boost the fisheries sector and has set ambitious targets to increase production to 2 million tons per year by 2024 (Suhana *et al*., 2023). This emphasis on vannamei is part of a broader strategy to strengthen the role of aquaculture in the national economy, which has the potential to generate significant foreign exchange earnings through exports. Vannamei shrimp is one of Indonesia's most valuable export commodities, with major markets including the United States, Japan, and the European Union (Jamilah *et al*., 2019). However, the industry faces challenges such as disease outbreaks and the need for sustainable farming practices, both of which are important to maintaining its competitiveness in the global market.

Traditional shrimp farming has been the predominant method of shrimp cultivation in Indonesia, particularly in rural and coastal regions with limited access to advanced technology and capital. This extensive farming method is characterized by low stocking densities, minimal input usage, and reliance on natural tidal water exchange to maintain pond conditions (Ciptadi *et al*., 2021; Zulkarnain *et al*., 2020). Despite the lower productivity, traditional farming is favored by many smallholder farmers due to its lower operational costs and reduced risk of disease outbreaks (Karim *et al*., 2014; Sivaraman *et al*., 2019). However, traditional farming also faces some challenges. These include vulnerability to fluctuating environmental conditions, such as water quality and temperature changes, which can have negative impact on shrimp health and growth rates (Walker and Mohan, 2009; Sivaraman *et al*., 2019). Additionally, traditional methods often produce lower yields, thus limiting their profitability and sustainability (Karim *et al*., 2014; Nguyen *et al*., 2020).

Intensive shrimp farming in Indonesia represents a more technologically advanced and capital-intensive approach than traditional methods. This system is characterized by high

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stocking densities, controlled environmental conditions, and advanced technologies such as aerators and water quality management tools (Farionita *et al*., 2018; Mira *et al.,* 2022; Ariadi *et al.,* 2019). The primary purpose of intensive farming is to maximize production per unit area, which frequently results in much better yields than traditional farms (Thakur *et al.,* 2018). However, the intensive nature of this farming method also brings several challenges. The high stocking densities raise the risk of disease outbreaks, leading to significant losses if not managed appropriately (Samocha *et al.,* 2002; Shinji *et al*., 2019). Moreover, the environmental impact of intensive shrimp farming is a growing concern, as the discharge of nutrient-rich effluents can lead to water pollution and the degradation of surrounding ecosystems (Paquotte *et al*., 1998; Shinji *et al.,* 2019).

In Kolaka District, vannamei shrimp farming has become an essential aquaculture activity, which contributes significantly to the local economy (BPS Sulawesi Tenggara, 2024), with the species emerging as the primary focus of both traditional and intensive farming systems (Isamu *et al*., 2018). As of 2023, most shrimp farms in Kolaka District are operated using traditional methods, with approximately 2,122 farming households engaged in this type of aquaculture. However, there has been a trend towards intensive farming practices, particularly among larger-scale farmers with better access to capital and technology. Intensive shrimp farms have increased from 5 in 2021 to 10 in 2023. This shift is particularly evident in Wundulako, Latambaga, and Samaturu sub-districts, where intensive farms are characterized by higher stocking densities, aerators and other advanced equipment.

The growing importance of vannamei shrimp farming in Kolaka District and the ongoing shift from traditional to intensive farming systems underscores the need for a comprehensive analysis of these two approaches. While intensive farming offers higher productivity and profitability, it also poses significant challenges such as increased operational costs and environmental risks (Zulkarnain *et al*., 2020; Nguyen *et al.,* 2020; Thakur *et al*., 2018). In contrast, despite its lower yields, traditional farming provides a more accessible and sustainable option for smallholder farmers (Isamu *et al*., 2018; Farionita *et al*., 2018; Wijaya *et al.,* 2021; Putri *et al.,* 2020). It is crucial to understand the comparative performance and profitability of these farming systems for informing policy decisions and guiding the future development of the shrimp farming sector in the district. Against this background, the study was conducted to examine the profitability of traditional versus intensive farming practices of vannamei shrimp production in Kolaka District.

MATERIALS AND METHODS

This study was conducted in Kolaka District, Southeast Sulawesi, Indonesia, from December 2023 to June 2024. Kolaka District is a major agricultural area, with its primary commodities including cocoa, clove, rice, beef cattle, seaweed, and shrimp (Saediman, 2015; Geo and Saediman, 2019a; Saediman, *et al.,* 2019a; Isamu *et al.,* 2018). The selection of Kolaka as the study area was based on several factors: (1) It is the leading center for vannamei shrimp production in Southeast Sulawesi, with the majority of farming operation utilizing traditional methods, (2) the presence of intensive farming practices, which are currently concentrated in Wundulako, Latambaga, and Samaturu subdistricts; and (3) the recent trend where several large-scale shrimp farmers have transitioned from traditional to intensive farming methods.

Data was collected through surveys with structured interviews and direct observations. The sample consisted of 50 shrimp farmers — 40 practicing traditional farming (selected by proportional sampling) and 10 engaged in intensive farming (census method). The small sample size for intensive farming reflects the total population of intensive shrimp farmers in the district. By including all intensive farmers, the census method ensures comprehensive data collection and provides an accurate representation of this farming system within the study area.

Several measures were implemented to minimize biases during data collection, including assuring respondents of the confidentiality of their answers and validating self-reported data through direct observations of farming practices. Direct observation of farming practices is crucial to minimizing recall bias as farmers had to rely on their recall of past costs, revenues, and operational details due to their lack of formal recordkeeping.

Data analysis included cost and returns analysis, the revenue-to-cost (R/C) ratio, and descriptive statistics (Surni *et al.,* 2020; Saediman *et al.,* 2019b; Saediman *et al.,* 2015). Revenue was calculated by multiplying unit price by total output, with depreciation assessed using the straight-line method (zero residual value). All costs and returns were calculated per hectare per year. The R/C ratio was used to assess profitability, with a ratio >1 indicating profitability, <1 indicating losses, and 1 indicating breakeven.

RESULTS AND DISCUSSION

***Socioeconomic characteristics of respondents*:** Table 1 presents the respondents' socioeconomic characteristics. The average age of farmers practicing traditional shrimp farming is 48.9 years, slightly younger than their counterparts in the intensive system, who have an average age of 51.8 years. This suggests that farmers engaged in intensive farming may have accumulated more life experience that can potentially influence their ability to adopt and manage more complex farming practices.

In terms of education, both groups of farmers show comparable levels, with traditional farmers having an average of 12.0 years of formal education and intensive farmers slightly higher at 12.4 years. This indicates that most farmers in both systems have attained at least secondary education, which may facilitate the adoption of new techniques and improve decision-making in farm management.

The average family size is consistent across both systems, with an average of 4.0 members per household. This suggests that family size does not differ between the two groups and is unlikely to be a distinguishing factor that influences their choice of farming system.

Table 1. Socioeconomic characteristics of respondents (mean).

Characteristics	Traditional	Intensive
Age (years)	48.9	51.8
Education (years)	12.0	12.4
Household size (persons)	4	4
Farming experience (years)	17.7	14.7
Pond size (ha)	1.7	0.6

A notable difference is observed in the pond size managed by the two groups. Traditional farmers operate larger ponds, with an average size of 1.7 hectares, while intensive farmers manage smaller ponds, averaging 0.6 hectares. The smaller pond size in intensive systems is aligned with the need for more precise management and control, given the higher input levels and stocking densities typically associated with these systems.

Farming experience differs between the two groups. Farmers in the traditional system have an average of 17.7 years of experience, compared to 14.7 years for those in the intensive system. The longer farming experience of traditional farmers may reflect the long-standing presence of traditional practices in the region, whereas the slightly lower experience in intensive farming may indicate the more recent adoption of this system in Kolaka District.

Cost structure**:** Cost consists of variable and fixed costs. Variable costs are expenses that fluctuate based on the level of production and operational practices. These include costs for post-larvae, feed, fertilizers, lime, probiotics, pesticides, fuel, electricity, labor, and other miscellaneous expenses. Production cost in vannamei shrimp farming can be seen in Table 2.

As shown in Table 2, in traditional vannamei shrimp farming, the total variable costs amount to IDR 34,293,375 per hectare per year, constituting 86.59% of the total production costs. The primary components of these costs are feed (43.94%), post-larvae (12.17%), and paid labor (10.50%). Fertilizers and lime contribute 8.70% and 1.26%, respectively, while pesticide contributes 1.52%. Miscellaneous costs, including minor repairs and transport, contribute 8.46%.

The intensive shrimp farming system incurs significantly higher variable costs due to the increased use of inputs necessary to support higher stocking densities and advanced management practices. As shown in Table 3, the total variable costs for intensive farming reach IDR 248,369,000 per hectare per year, representing 88.43% of the total costs. Feed is the most substantial expense (52.61% of total variable costs), followed by post-larvae (11.40%) and electricity (7.61%). Additional costs include probiotics (3.82%), pesticides (4.22%), fuel (1.36%), and labor (4.41%). Miscellaneous expenses are relatively low, only contributing 1.05%.

Table 2. Production cost of vannamei shrimp farming in traditional system (Rp/ha/year).

No	Item	Value (IDR)	%
1.	Variable cost	34,293,375	86.59
	Post-larvae	4,821,250	12.17
	Feed	17,406,000	43.94
	Fertilizer	3,447,500	8.70
	Lime	500,250	1.26
	Pesticide	603,875	1.52
	Labor cost	4,162,500	10.50
	Other costs	3,352,000	8.46
2.	Fixed cost	5,311,817	13.41
	Depreciation	5,290,067	13.35
	Tax	21,750	0.05
3.	Total cost	39,605,174	100.0

Notes: US$1 = Rp15,762 (Feb 1, 2024)

Table 3. Production cost of vannamei shrimp farming in intensive system (Rp/ha/year).

No.	Item	Value (IDR)	%
1.	Variable cost	248,369,000	88.43
	Post-larvae	32,030,000	11.40
	Feed	147,780,000	52.61
	Fertilizer	1,960,000	0.69
	Lime	1,436,500	0.51
	Probiotic	10,750,000	3.82
	Pesticide	11,860,000	4.22
	Fuel	3,830,000	1.36
	Electricity	21,392,500	7.61
	Labor cost	12,400,000	4.41
	Other costs	2,970,000	1.05
2.	Fixed cost	32,505,000	11.57
	Depreciation	32,442,650	11.55
	Tax	62,350	0.02
3.	Total cost	280,874,000	100.0

Fixed costs are expenses that remain constant regardless of production levels, including infrastructure, equipment, and taxes. Fixed costs include tax and depreciation of farm tools and equipment, such as sluice gate, water pump, filters, scale, feeding pole, feeding bridge, throwing net, harvesting troll net, guardhouse, plastic net, hoe, scoop, and bucket. Fixed costs in the traditional system amount to IDR 5,311,817 per hectare per year, which accounts for 13.41% of the total costs. These costs primarily include depreciation of infrastructure and equipment (13.35%) and taxes (0.05%).

Fixed costs for intensive shrimp farming are considerably higher, totaling IDR 32,505,000 per hectare per year, which constitutes 11.57% of the total costs (Table 3). This includes significant depreciation expenses (11.55%) due to the additional investment in more advanced equipment, such as aerators, generators, Alcon suction pumps, water quality measuring tools, HDPE tarpaulin, and taxes (0.02%).

The total costs of vannamei shrimp farming are the sum of variable and fixed costs, which represent the overall financial requirements of each system. The total cost for traditional shrimp farming is IDR 39,605,174 per hectare per year. This cost structure is dominated by variable costs (86.59%), with fixed costs accounting for only 13.41%. Intensive shrimp farming has a much higher total cost, amounting to IDR 280,874,000 per hectare per year. Variable costs constitute a larger share (88.43%), while fixed costs represent 11.57% of the total costs. This shows the high input and infrastructure requirements of intensive farming practices. The cost structures observed in Kolaka District are similar to those in other major shrimp farming regions in Indonesia, such as East Java and Aceh (Ariadi *et al.*, 2019; Farionita *et al.*, 2018; Mira *et al.*, 2022; Wijaya *et al.*, 2021). In these areas, feed costs are also the largest expense, particularly in intensive systems.

***Net-returns*:** Table 4 presents net returns and the R/C ratio of vannamei shrimp production. The net returns, defined as the difference between total revenue and total cost, show a significant difference between the traditional and intensive farming systems. Traditional farming yields a net return of IDR 19,848,751 per hectare per year, while intensive farming generates a much higher net return of IDR 81,779,180 per hectare per year (Table 4). Higher net returns in intensive farming are driven using advanced inputs and higher stocking densities, which maximize shrimp output and size. The substantial productivity advantage in intensive systems (10,334.35 kg/ha/year) compared to traditional systems (672.98 kg/ha/year) also enhances net returns. Intensive farming leverages efficient management practices and technological advancements to optimize yield.

Table 4. Net Returns and R/C ratio of vannamei shrimp production.

No.	Item	Farming System	
		Traditional	Intensive
1	Total Revenue (IDR/ha/year)	59,453,925	362,653,180
2	Total Cost (IDR/ha/year)	39,605,174	280,874,000
3	Net-Return (IDR/ha/year)	19,848,751	81,779,180
4	R/C ratio	1.50	1.29

The higher net returns observed in intensive vannamei shrimp farming compared to traditional farming can be attributed to several key factors, namely stocking density, feed management, water quality and disease management, and technological innovation. Intensive farming employs significantly higher stocking densities, typically ranging from 65 to 100 shrimp per square meter, compared to 1 to 17 shrimp per square meter in traditional farming. This results in a greater number of shrimps being harvested per cycle. Additionally, intensive systems often complete two to three production cycles per year, compared to two cycles in traditional systems. These factors substantially increase the total output and, consequently, the revenue generated.

Intensive farmers rely on high-quality formulated feeds, which are designed to optimize shrimp growth and improve feed conversion ratios (FCR). The precise control of feeding schedules and quantities minimizes waste and ensures rapid growth, contributing to higher marketable shrimp weights and sizes. These practices directly enhance the revenue per unit of production.

Advanced water quality management systems, such as aerators and water filtration units, are widely used in intensive farming to maintain optimal environmental conditions. This reduces stress on the shrimp, improves survival rates, and minimizes the risk of disease outbreaks. Moreover, the use of probiotics and biosecurity measures further enhances the overall health of the shrimp population, reducing mortality and increasing yields.

Intensive systems incorporate technologies such as water quality monitoring devices and aeration systems, which improve operational efficiency and productivity. These technologies allow farmers to closely monitor some key parameters, such as dissolved oxygen levels, pH, and ammonia concentrations, ensuring optimal growing conditions for the shrimp.

Another factor is labor efficiency and expertise. While labor costs are higher in intensive systems due to the need for skilled workers to manage advanced equipment and operations, the overall labor efficiency is improved. Skilled labor ensures better implementation of management practices, thus reducing losses and increasing overall productivity.

The net return for the traditional vannamei shrimp farming system in the study area is IDR 19,848,751 per hectare per year. This figure is significantly lower than net returns reported in several other regions in Indonesia. For example, Farionita *et al.* (2018) reported higher net returns in Situbondo, East Java, while Mira *et al.* (2022) documented similar findings in Aceh Tamiang District, Aceh Province. Additionally, Wijaya *et al.* (2021) reported higher profitability in Aceh Besar District, Aceh Province, and Husada *et al.* (2021) reported greater returns in Sidoarjo, East Java Province. Sulnidar *et al.* (2022) also observed higher net returns in Parigi Moutong, Central Sulawesi Province. These comparisons suggest that the economic performance of traditional shrimp farming in the study area is less competitive, potentially due to differences in management practices, input use, productivity levels, and market access.

The net return for the intensive vannamei shrimp farming system in the study area is IDR 81,779,180 per hectare per year. This net return is considerably lower than that reported in several other regions in Indonesia. For instance, Ariadi *et al*. (2019) documented higher net returns in Probolinggo, East Java, while Farionita *et al*. (2018) reported similar findings in Situbondo, East Java. Mira *et al*. (2022) also highlighted greater net returns in Aceh Tamiang District, Aceh Province. These discrepancies suggest potential variations in cost structures, productivity levels, market access, and management practices, which may influence the profitability of intensive shrimp farming across regions.

***R/C Ratio*:** The revenue-to-cost (R/C) ratio, which measures the efficiency of farming systems, highlights interesting contrasts between the traditional and intensive systems. The R/C ratio for traditional farming is 1.50, meaning that the system generates 1.5 units of revenue for every unit of cost. Conversely, the R/C ratio for intensive farming is slightly lower at 1.29, showing that every unit of cost yields 1.29 units of revenue.

The higher R/C ratio in traditional farming suggests greater cost efficiency. With lower total costs and moderate revenue, traditional systems effectively generate profits relative to their expenditure. This efficiency can be attributed to lower input utilization, reliance on natural resources, and reduced infrastructure costs. On the other hand, the lower R/C ratio in intensive farming suggests that the substantial operational costs reduce cost efficiency. Intensive systems rely heavily on high-quality inputs and advanced technology which significantly increase costs. Despite increased revenue, these costs dilute the proportional returns, resulting in a lower R/C ratio than traditional systems.

While intensive farming generates higher absolute net returns, the lower R/C ratio highlights the trade-off between increased revenue and the higher costs required to achieve it. This trade-off indicates that intensive farming prioritizes maximizing output over cost efficiency,

The differences in net returns and R/C ratios between traditional and intensive farming systems highlight the trade-offs in choosing each system. For the traditional system, the higher R/C ratio and lower costs make it a more accessible and financially stable option for small-scale farmers. However, the lower net returns highlight the importance for strategic interventions to increase profitability, such as enhanced market access, better management practices, and low-cost innovations. For intensive systems, the significantly higher net returns in intensive farming demonstrate its potential for higher profitability, particularly for farmers with access to sufficient capital, technology, and market opportunities. However, the lower R/C ratio implies that cost optimization strategies, such as improved feed management, energy efficiency, and disease control, are necessary to enhance cost efficiency and long-term sustainability.

However, compared to several other regions in Indonesia, the R/C ratio of 1.50 for the traditional vannamei shrimp farming system in the study area is lower than in several other regions in Indonesia. For instance, Wijaya *et al.* (2021) reported an R/C ratio of 1.60 in Aceh Besar District, Aceh Province. Mira *et al.* (2022) found a significantly higher R/C ratio of 3.17 in Aceh Tamiang District, Aceh Province. Similarly, Farionita *et al.* (2018) reported an R/C ratio of 2.18 in Situbondo, East Java, while an even higher ratio of 4.30 was observed in Torue Subdistrict, Parigi Moutong District, Central Sulawesi Province (Sulnidar *et al.*, 2022). These differences suggest variations in cost efficiency and revenue generation across regions, likely influenced by factors such as farming practices, input costs, market access, and environmental conditions.

Likewise, the R/C ratio of 1.29 for the intensive vannamei shrimp farming system in the study area is lower compared to other regions in Indonesia, indicating relatively reduced cost efficiency. For instance, Mira *et al*. (2022) reported a higher R/C ratio of 1.76 in Aceh Tamiang District, Aceh Province, while Farionita *et al.* (2018) observed an even greater ratio of 2.20 in Situbondo, East Java. This disparity suggests that intensive shrimp farming in the study area incurs higher costs relative to revenue generated, possibly due to factors such as higher input prices, limited access to cost-effective technologies, and suboptimal management practices.

***Sensitivity analysis*:** The sensitivity analysis reveals how changes in production costs and output prices influence the net returns and R/C ratios of vannamei shrimp farming under both traditional and intensive systems. Three scenarios were considered: a 10% increase in production costs, a 10% decrease in output prices, and a simultaneous 10% increase in production costs coupled with a 10% decrease in output prices (Saediman *et al.*, 2014).

Table 5 presents the results of sensivity analysis of vannamei shrimp farming. A 10% increase in production costs resulted in a notable reduction in net returns and R/C ratios for both farming systems. In the traditional system, net returns declined from IDR 19,848,751 to IDR 15,884,234, while the R/C ratio decreased from 1.50 to 1.37. Similarly, in the intensive system, net returns dropped from IDR 81,779,180 to IDR 53,691,780, while the R/C ratio declined from 1.29 to 1.17.

This reduction can be attributed primarily to the increase in the price of feed, which constitutes the largest proportion of production costs in both systems. Feed prices frequently fluctuate due to market conditions, making them a critical cost component. The results underscore the economic vulnerability of shrimp farming, especially the intensive system, to increases in input costs, emphasizing the need for price stabilization mechanisms or subsidies for essential inputs.

Table 5. Sensitivity analysis of net returns and R/C ratios of vannamei shrimp farming under traditional and intensive systems.

Sensitivity Scenario	Traditional Systems		Intensive Systems	
	Net Returns (IDR/ha/year)	R/C Ratio	Net Returns (IDR/ha/year)	R/C Ratio
10% Increase in Production Cost	15,884,234	1.37	53,691,780	1.17
10% Decrease in Output Price	13,903,359	1.35	45,513,862	1.16
Simultaneous 10% Increase in Production Cost and 10% Decrease in Output Price	9,942,842	1.23	17,426,462	1.06

When output prices decreased by 10%, both systems experienced significant declines in profitability. Net returns in the traditional system dropped to IDR 13,903,359, reducing the R/C ratio from 1.50 to 1.35. In the intensive system, net returns fell to IDR 45,513,862, with the R/C ratio decreasing to 1.16.

These findings highlight the sensitivity of vannamei shrimp farming to market price volatility. Since output prices are largely determined by supply-demand dynamics and global market conditions, farmers relying on local markets may face reduced profitability when prices fall. Intensive farmers, with higher production volumes and greater exposure to market fluctuations, are particularly vulnerable in such scenarios.

The combined effect of a 10% increase in production costs and a 10% decrease in output prices had the most severe impact. In the traditional system, net returns plunged to IDR 9,942,842, and the R/C ratio decreased from 1.50 to 1.23. Similarly, in the intensive system, net returns were reduced drastically to IDR 17,426,462, while the R/C ratio dropped to 1.06, approaching the breakeven point.

The sensitivity analysis demonstrates that while both traditional and intensive vannamei shrimp farming systems are sensitive to changes in production costs and output prices, they remain economically feasible under all three tested scenarios. Despite reductions in net returns and R/C ratios, neither system experienced a negative net return nor an R/C ratio below 1, indicating continued profitability even under adverse conditions.

The results highlight the resilience of traditional farming, which maintained higher cost efficiency due to its lower input reliance and simpler operational structure. Meanwhile, intensive farming, despite being more vulnerable to cost fluctuations and market volatility, continued to yield positive returns due to its higher production volumes.

While the sensitivity analysis has focused on internal factors such as production costs and output prices, it is important to recognize that external factors can also significantly influence the profitability and sustainability of vannamei shrimp farming. Variables such as climate variability, disease outbreaks, and market fluctuations extend beyond the farmers' direct control but play a critical role in determining financial outcomes. Integrating these factors into future profitability assessments would provide a more comprehensive understanding of the economic dynamics of shrimp farming.

Given the energy- and input-intensive nature of intensive farming, climate-related disruptions such as temperature fluctuations, irregular rainfall, and extreme weather events could negatively impact pond water quality, shrimp health, and overall production yields. Similarly, disease outbreaks, exacerbated by higher stocking densities, pose a persistent risk that could lead to substantial financial losses if proper biosecurity measures are not in place.

Market fluctuations also represent a significant external factor, affecting both systems but particularly intensive farming due to its reliance on large-scale production and market access. Global shrimp prices, influenced by international trade policies, competition from other producing countries, and shifting consumer preferences, directly impact revenue potential.

Considering these external factors highlights the need for comprehensive risk management strategies, including climate adaptation measures, improved biosecurity protocols, and enhanced market diversification. Incorporating these considerations into farm management and policy frameworks would strengthen the resilience of vannamei shrimp farming in the face of both internal and external uncertainties.

***Environmental impact and sustainability*:** The environmental impact of intensive farming poses greater challenges compared to traditional farming due to differences in input use, management practices, and operational intensity. Key environmental issues include water pollution, greenhouse gas (GHG) emissions, disease outbreaks and chemical usage, as well as long-term soil and water degradation.

Intensive farming generates substantial levels of effluent because of the extensive use of formulated feeds, fertilizers, and chemical treatments. The discharge of untreated effluent into the environment can lead to significant water pollution which negatively affects the quality of nearby rivers, streams, and coastal ecosystems. Additionally, the energy-intensive nature of intensive farming, characterized by heavy reliance on diesel-powered pumps, aerators, and other machinery, contributes to increased GHG emissions.

Higher stocking densities in intensive systems also increase the risk of disease outbreaks, necessitating the use of antibiotics and other chemical treatments. If improperly managed, these chemicals can contaminate water bodies and contribute to the development of antibiotic-resistant bacteria. Moreover, the accumulation of organic matter, chemical residues, and soil salinization in and around shrimp ponds degrades soil and water quality which reduces the land's suitability for other agricultural uses.

Given these challenges, intensive farming systems require skilled farmers with technical expertise to implement effective effluent management, biosecurity protocols, and sustainable farming practices. Enhancing farmer capacity and promoting environmentally responsible strategies are essential for ensuring the profitability and sustainability of intensive shrimp farming operations.

***Barriers to transition and opportunities for improvement*:** Despite the much greater returns associated with intensive vannamei shrimp farming, the study revealed that most farmers involved in traditional farming in the study area prefer to remain in the traditional system. This preference is primarily determined by several factors. First, the lack of financial resources poses a major impediment to moving to intensive farming. Intensive systems require substantial financial investment for infrastructure, high-quality inputs, and advanced technologies, which many traditional farmers need help to afford. Second, there is a fear of harvest failure among traditional farmers. Intensive farming is associated with higher risks, such as disease outbreaks and water quality issues, which can lead to significant financial losses. Traditional farming, while less profitable, is perceived as more stable and less risky due to its reliance on natural conditions and lower operational intensity. Third, limited farming skills and technical knowledge also discourage traditional farmers from adopting intensive practices. Intensive farming necessitates a deeper understanding of advanced management practices such as water quality monitoring, disease prevention, and feed optimization, including technical skills to address potential environmental impact, which many traditional farmers feel they need help to handle.

Nonetheless, few farmers have moved from traditional to intensive farming. These farmers typically have adequate financial resources for the required infrastructure and inputs. Furthermore, they frequently possess or have gained the necessary skills and technical knowledge to manage the complexities of intensive farming. This transition is particularly noticeable among more progressive farmers willing to take risks to achieve higher returns. These individuals also benefit from access to information and technology as well as financial support, which address some of the challenges associated with intensive farming. The decision to shift to particular farming systems, such as intensive shrimp farming, is often influenced by higher expected returns, the level of risk, the required skills and technical knowledge, and the availability of financial resources (Geo and Saediman, 2019b; Saediman *et al*., 2021). The hesitation of most traditional farmers to adopt intensive practices emphasizes the importance of overcoming the barriers to transition. Access to affordable financing, targeted capacity-building initiatives, and risk mitigation measures, such as crop insurance, may encourage more farmers to pursue intensive farming. At the same time, assisting traditional farmers to increase their productivity and profitability through low-cost innovations and improved access to extension services is critical to sustaining their livelihoods. This dual approach would ensure that both traditional and intensive systems can coexist while also contributing to the overall development of the shrimp farming sector in the study area.

***Policy implications*:** The findings of this study highlight critical challenges and opportunities for improving the profitability and sustainability of vannamei shrimp farming in Kolaka District. To address these issues, the following policy implications and recommendations are proposed:

(1) Provision of Credit Facilities: Limited access to capital is a major barrier to transitioning from traditional to intensive farming. Establishing low-interest credit schemes or microfinance programs tailored to shrimp farmers can help address this constraint, enabling investment in infrastructure, advanced technologies, and higher-quality inputs.

(2) Extension Services and Capacity Building: The study reveals that knowledge and skill gaps are a critical barrier to adopting intensive farming practices. Strengthening extension services to provide technical training on feed management, water quality monitoring, disease prevention, and sustainable farming practices is essential. These programs should be designed to cater to both traditional and intensive farmers, with a focus on improving productivity and reducing operational risks.

(3) Environmental Sustainability Measures: Intensive farming systems pose greater environmental challenges, such as effluent discharge, greenhouse gas emissions, and soil degradation. To mitigate these impacts, policymakers should incentivize sustainable practices, including effluent treatment systems, renewable energy technologies, and integrated aquaculture systems. Promoting biofloc technology and polyculture systems could enhance resource efficiency and reduce ecological harm.

(4) Market Access and Development: Enhancing market access is crucial for both traditional and intensive farmers to achieve better profitability. Investments in transportation infrastructure, cold storage facilities, and market linkages can help farmers reach high-value markets.

(5) Risk Mitigation Mechanisms: Fear of harvest failure due to disease outbreaks and market fluctuations deters many

farmers from adopting intensive farming practices. Introducing crop insurance schemes to cover losses from environmental and market risks can enhance farmers' confidence and willingness to invest in higher-risk systems.

(6) Support for Research and Development: Continued investment in R&D is vital for addressing systemic challenges in shrimp farming. Areas of focus should include cost-effective feed formulations, improved disease management strategies, and innovations that enhance productivity while minimizing environmental impacts. Collaborative efforts between government, academia, and the private sector can accelerate technological advancements.

(7) Incentivizing Recordkeeping: The lack of formal recordkeeping among farmers limits data accuracy and hinders financial planning. Policies that incentivize recordkeeping, such as linking it to access to credit, could encourage farmers to adopt better practices. Introducing simple, user-friendly tools could further facilitate this process.

***Conclusion*:** This study highlights the significant differences in profitability and cost efficiency between traditional and intensive vannamei shrimp farming systems in Kolaka District, Indonesia. Intensive farming generates higher net returns (IDR 81,779,180/ha/year) than traditional farming (IDR 19,848,751/ha/year), driven by advanced management practices and higher stocking densities. However, the R/C ratio for traditional farming (1.50) surpasses that of intensive farming (1.29), indicating greater cost efficiency in the traditional system despite its lower absolute returns.

Notably, the net returns and R/C ratios for both systems are lower compared to those reported in several other regions in Indonesia. This reflects the challenges faced by vannamei shrimp farming in the study area, including higher input costs, limited access to advanced technologies, and suboptimal management practices. However, this also highlights significant opportunities for improvement, suggesting untapped potential to enhance efficiency, profitability, and sustainability in the local shrimp farming sector.

The sensitivity analysis reveals that both farming systems remain feasible under scenarios of increased production costs, reduced output prices, and combined cost-price shocks. However, intensive farming is more vulnerable to market fluctuations and input price volatility due to its high operational intensity. External factors such as climate variability, disease outbreaks, and market instability could also influence the profitability and sustainability of shrimp farming. Addressing these internal and external factors is crucial to ensure long-term sector resilience.

Several policy measures are recommended to address these issues. Key strategies include improving access to high-quality inputs, providing affordable credit facilities, enhancing market linkages, and promoting capacity-building programs to improve farmers' technical skills. Adopting cost-efficient technologies is critical for intensive farming to balance productivity with environmental stewardship. Meanwhile, introducing low-cost innovations and facilitating access to premium markets can increase profitability and competitiveness in traditional farming systems. Future research should explore the socio-economic and environmental impacts of these systems and identify strategies for scaling up sustainable practices.

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