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Sustainability Status of Vannamei Shrimp (*Litopenaeus vannamei*) Aquaculture in Millennial Pond Model

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Abstract

Vannamei shrimp (*Litopenaeus vannamei*) aquaculture activities in Jepara Regency are conducted at Brackish Water Aquaculture Centers (Balai Besar Perikanan Budidaya Air Payau/BBPBAP) Jepara with a millennial model. This aquaculture model features a critical point in the middle of the pond, which aims to reduce the risk of failure due to pathogenic virus attacks. However, in running a vannamei shrimp aquaculture, an appropriate strategy is required for business development and sustainability. In this study, a multidimensional scaling (MDS) method was used to analyze the ecological, economic, social, technological, and legal-institutional dimensions. The study was conducted during October-December 2024, in which primary data collection was carried out through interviews with respondents and secondary data from related data references. The results of the study showed that the sustainability values were 88.39 (ecological dimension), 81.05 (economic dimension), 75.25 (social dimension), 99.996 (technological dimension), and 99.996 (legal-institutional dimension). The average value of the sustainability index of vannamei shrimp farming in the millennial pond of BBPBAP Jepara was very sustainable, with a score of 88.94. Based on the leverage analysis, sensitive attributes obtained in this study were ecological domain (1) disease attacks (2) land utilization level (3) land suitability, economic domain (1) price trends, (2) market reach, (3) cultivation profits, social domain (1) education level, (2) community involvement/labor absorption, (3) availability of transportation and communication facilities, technology domain (1) pond construction (2) application of biosecurity and legal domain & (1) institutional training activities and socialization about cultivation businesses (2) availability of cultivator groups.

INTRODUCTION

Shrimp aquaculture is a mainstay and priority for aquaculture development in Indonesia to improve the national economy. Indonesian national data show that from 2000 to 2019, the average volume of shrimp exports was 143.28 thousand tons with a

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value of 1.18 billion USD (Kusuma and Sari, 2021). In 2022, the shrimp production achievement was 1,079 million tons or 18% higher than the previous period (Ariadi *et al*., 2025). Shrimp commodities, as one of the mainstays to achieve the targets set, require to obtain more attention so that they are able to comply with these targets.

Litopenaeus vannamei is one of the shrimp species with high economic value, so market demand is very large. This is because vannamei shrimp have had advantages of being disease resistant, low-cost production, and rapid growth (Li *et al*., 2021). One of the main vannamei shrimp production sites in Indonesia is Jepara Brackish Water Aquaculture Centers with a millennial pond model. The millennial pond is a vannamei shrimp aquaculture model that has one critical point in the middle of the pond, which aims to reduce the risk of failure due to attacks by pathogenic viruses (Sumantri *et al*., 2023). However, in carrying out vannamei shrimp aquaculture activities, there are strengths, opportunities, and various problems that can arise as weaknesses or business threats (Prakoso *et al*., 2016).

The main problem in shrimp production is disease attacks, for instance, AHPND (Acute Hepato Pancreatic Necrosis Disease), a disease characterized by sudden death, pale color, and atrophic-pale hepatopancreas (Zhang *et al*., 2023). AHPND is a deadly bacterial disease primarily affecting *L. vannamei* (Fadel *et al*., 2025). It's triggered by strains of *Vibrio parahaemolyticus* carrying the pirA and pirB toxin genes, hosted on plasmids (Padilah *et al*., 2022). Shrimp mortality caused by AHPND reaches near 100% (Kumar *et al*., 2021). Shrimp harvest failure caused by disease indicates a decline in the quality of the aquaculture environment (Millard *et al*., 2021). Another problem is the increase in production costs, especially shrimp feed, which can reach 60-70% (Bidayani and Valen, 2023). The increase in production costs is not offset by the increase in shrimp prices at the farmer level, so the profits obtained are small. The intensive pond aquaculture processes with high density and large quantities of feed (Rakhmanda *et al*., 2021).

The complex state of vanamei shrimp cultivation production businesses requires proper management to minimize existing problems. Management of vannamei shrimp aquaculture production businesses can be carried out by developing a management strategy. However, the preparation of a management strategy can be done by knowing the sustainability status of the aquaculture business. The sustainability status of the aquaculture business is assessed by analyzing various aspects that support business sustainability. Based on the existing problems, it is necessary to analyze the ecological, economic, social, technological, and legal-institutional aspects through a multi-dimensional scaling (MDS) method approach (Putra *et al*., 2023). Thus, this study was conducted to analyze the index and status of vannamei shrimp aquaculture sustainability based on ecological, economic, technological, and institutional dimensions. The results of the study are very important to improve the sustainability of the management of vannamei shrimp cultivation in the Millennial Pond of the Jepara Brackish Water Aquaculture Centers.

METHODOLOGY

Ethical Approval

No animals were harmed or improperly treated in this study.

Place and Time

This research was conducted in the millennial shrimp farm of Jepara Brackish Water Aquaculture Centers, East Java, Indonesia (110º 39'11" EL and 6º 33" SL) from October to December 2024 (Figure 1). Millennial ponds are used for research because these ponds are currently in demand by the public, especially the millennial generation. This pond is designed with a technological approach, high efficiency, and environmentally friendly circumstances.

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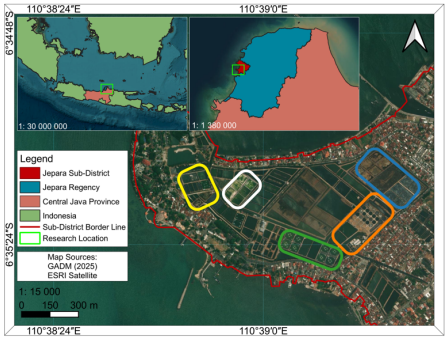

Figure 1. The research location is at Jepara Brackish Water Aquaculture Centers (Bulu Village, Jepara District, Jepara Regency, Central Java Province).

Research Materials

The data required in the study consists of primary and secondary data. Primary data collection was conducted through observation methods, questionnaires, and interviews with research respondents, while secondary data was obtained from references and related data, namely the Central Statistics Agency of Jepara Regency, the Marine, Fisheries and Animal Husbandry Service (of Jepara Regency, and the Regional Planning and Development Agency of Jepara Regency.

Research Design

In this research, a qualitative method was used. This method aims to determine the feasibility of a business based on the sustainability index so that a strategy can be developed for a vanamei shrimp farming business in the Millennial Pond Model of Jepara Brackish Water Aquaculture Centers. Based on Muchtar *et al*. (2023), the qualitative research method aims to analyze and describe phenomena or research objects through social activities, attitudes, and perceptions of people individually or in groups.

Work Procedure

The technique for determining the respondent sample used snowball sampling and purposive sampling (Pasaribu *et al*., 2022). The sampling method for farmer respondents used in this study was snowball sampling. The information of farmer respondents is based on the previous respondent references. Purposive sampling is a sample determination based on certain considerations and adjusting the criteria in the study that respondents understand and are related to the existing and internal conditions of the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers. The number of research respondents can be seen in Table 1.

Table 1. Number of research respondents of the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

Respondent Type	Sample
Head of Jepara Brackish Water Aquaculture Centers	1
Person in charge of Millenial Pond Model	1
Administrator	1
Technical Manager of Millenial Pond Model	1
Technician	1
Operator	11
Laboratory person in charge	2
Backyard seeding around Millenial Pond Model block	15
Total	33

Data Analysis

The data in this study were assessed for sustainability by analyzing several

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dimensions of the sustainability of the vaname shrimp farming business in the Millennial or Millennial Shrimp Farming (MSF) ponds of the Jepara Brackish Water Aquaculture Center. The analysis used for this study was the multi-dimensional scaling (MDS) method with the Rapfish application (Fauzi and Anna, 2002). The assessment (scoring) of each attribute is based on the sustainability criteria of each dimension that describes the condition of the level of sustainability of the research location (Airawati *et al*., 2023).

The Analysis of Observed Parameter

The MDS analysis using Rapfish consists of Leverage analysis, Monte Carlo analysis, and Ordinal test. The results of the leverage analysis in the study obtained attributes whose existence has a sensitive effect on increasing or decreasing the sustainability status. The RMS (root mean square) value in the analysis, which is getting bigger, indicates that the role of the attribute is getting higher in the sensitivity of sustainability status (Wulandari *et al*., 2018). Monte Carlo analysis to determine the level of stability of the results in the ordination test in the Rapfish analysis (Fitrianti *et al*., 2014). The ordination test in this study obtained sustainability values, statistics in the form of stress values, and coefficients of determination (R2) from each dimension.

According to Fauzi and Anna (2002), a high stress value (> 25%) indicates that the accuracy (goodness of fit) is not perfect, while a low stress value (<25%) indicates the accuracy in the ordination analysis is categorized as perfect. The determination coefficient value is shown in R2, depicting a high confidence interval value for the results of the ordination analysis if the R2 value obtained is more than 0.90 (90%) (Puspitasari *et al*., 2019). Analysis with the ordination test will produce a sustainability index described on a scale of 0-100. According to Thamrin *et al*. (2007), the determination of the scale of the sustainability index of pond fisheries cultivation businesses, as follows: 75.01 – 100.00 (Good or very sustainable); 50.01 – 75.00 (sufficiently sustainable); 25.01 – 50.00 (Less sustainable), and 00.00 – 25.00 (Poor or unsustainable).

RESULTS AND DISCUSSIONS

Status of the sustainability of ecological dimensions

In this study, an assessment of the sustainability of the ecological dimension was conducted, which aims to determine the balance of natural resources and the environment in running a sustainable vaname shrimp cultivation business. The study of attributes in this dimension, namely disaster potential, land utilization level, land suitability, pollution level, disease attacks, and land carrying capacity. The results of the ordination test in multi-dimensional scaling (MDS) produced an output result, namely a sustainability score of 88.39 in the very sustainable category (Figure 2). Millennial shrimp ponds have various factors that support environmental aspects, like environmentally friendly elements, where pond water is recycled, reducing the need for new water and avoiding direct waste disposal into the environment (Sumantri *et al*., 2023).

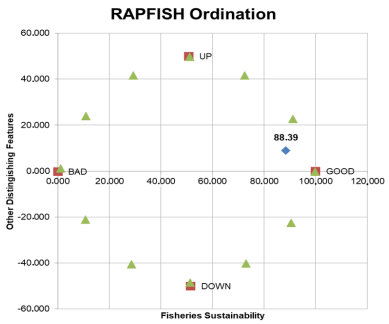

Figure 2. Sustainability index results on the ecological dimension in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

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The results of the leverage analysis on the ecological dimension show that the sensitive attributes that affect the magnitude of the sustainability index value are disease attacks (RMS = 11.610), land utilization rate (RMS = 3.129) and land suitability (RMS = 3.069) in vaname shrimp farming efforts in the Millenial Pond Model at Jepara Brackish Water Aquaculture Centers (Figure 3). According to Rakasiwi and Albastomi (2017), there are problems that often arise in pond shrimp farming efforts that cause failure in pond shrimp farming. One of the main causes is disease attacks, which cause losses for farmers. Until now, there have been no reports of diseases in millennial ponds. However, diseases such as AHPND (Zhang *et al*., 2023) are a scourge for farmers, so many are still worried about it.

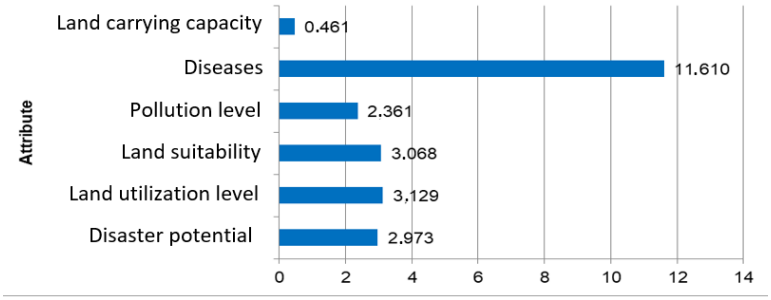

Figure 3. Results of the ecological dimension leverage analysis in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

Sustainability status of the economic dimension

In this study, an assessment of the sustainability of the economic dimension was conducted, which aims to determine the economic increase in running a sustainable vaname shrimp farming business. The study of attributes in this dimension, namely Market reach, Pond productivity, Customer type, Price trends, Business scale, Cultivation profits, and Source of business capital. The results of the ordination test in multi-dimensional scaling (MDS) in the economic dimension produced an output result, namely a sustainability score of 81.05 in the very sustainable category (Figure 4).

Millennial ponds are considered economically sustainable because they are able to generate long-term profits with high efficiency, high productivity, and lower business risks compared to traditional ponds. Millennial ponds use a high stocking density system > 450 fish/m² (Pramudia *et al*., 2022). With good management, the harvest can reach 30-40 tons per hectare per cycle, far above conventional ponds. In addition, the use of technology in millennial ponds such as automatic feeding systems, smart aerators, and water quality sensors reduces waste of feed and labor (Pratiwy *et al*., 2021).

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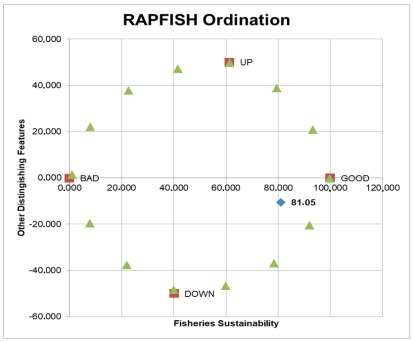

Figure 4. Sustainability index results on the economic dimension in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

The results of the leverage analysis of the economic dimension obtained 2 groups of attributes, namely attributes that have a sensitive effect (3 attributes) and have an insensitive effect (4 attributes) (Figure 5). The results of the leverage analysis on the economic dimension show that the sensitive attributes that affect the value of the sustainability index are price trends (RMS = 10.038), market reach (RMS = 6.448), and cultivation profits (RMS = 3.985) in the vaname shrimp cultivation business in the MSF pond at Jepara Brackish Water Aquaculture Centers. According to Anam *et al*. (2024), the increasing demand, both from the local market and exports, provides great opportunities in the shrimp cultivation business. However, limited market access and fluctuations result in less than optimal selling value and the threat of global price fluctuations, market competition, limited logistics infrastructure, and environmental risks such as shrimp diseases that can reduce cultivation productivity.

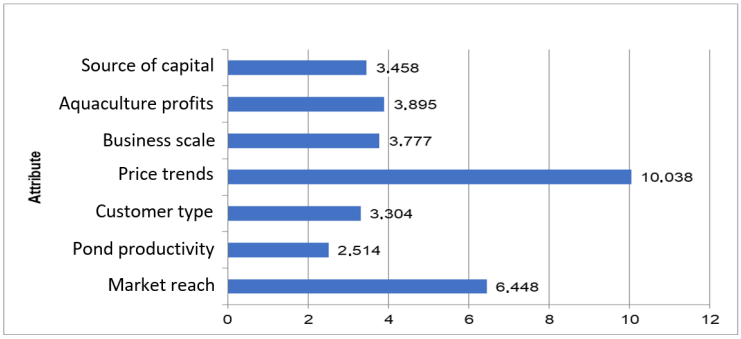

Figure 5. Results of economic dimension leverage analysis in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

Status of the sustainability of the social dimension

In this study, an assessment of the sustainability of the social dimension was conducted, which aims to determine the level of Human Resources (HR) and the work system and environment in running a sustainable vaname shrimp farming business. The study of attributes in this dimension, namely Level of education, Community involvement/labor absorption, Availability of transportation and communication facilities, Potential for conflict between workers, Knowledge of management, and Potential for conflict with the community. The results of the ordination test in multi-dimensional scaling (MDS) in the social dimension produced an output result, namely a sustainability score of 75.25 in the very sustainable category (Figure 6). Millennial ponds are considered socially sustainable because they are able to create a positive impact on society, open up new job opportunities, empower the younger generation, and encourage collaboration in modern fisheries

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communities. Millennial ponds use technologies such as IoT, monitoring applications, and automation, so they are suitable for digitally literate young people (Pramudia *et al*., 2022). In addition, millennial ponds will increase the interest of the millennial generation to enter the fisheries sector, which was previously considered "traditional" (Savianus *et al*., 2023).

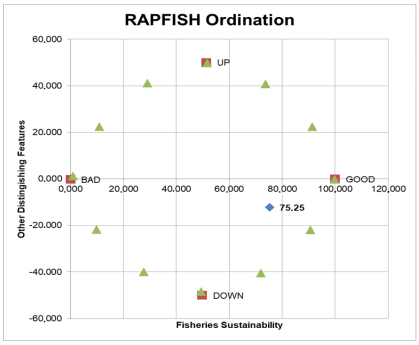

Figure 6. Sustainability index results on the social dimension in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

The results of the leverage analysis of the social dimension obtained 2 groups of attributes, namely attributes that have a sensitive effect (3 attributes) and attributes that have an insensitive effect (3 attributes) (Figure 7). The results of the leverage analysis on the social dimension show that the sensitive attributes that affect the value of the sustainability index are the level of education (RMS = 10.804), community involvement/labor absorption (RMS = 9.471) and the availability of transportation and communication facilities (RMS = 6.008) in the vaname shrimp farming business in the MSF pond at Jepara Brackish Water Aquaculture Centers. According to Suryanty *et al*. (2021) that the level of education influences actions and thought patterns in running a business as well as the level of acceptance of new information and skills. Through the shrimp disease control socialization program activities, it can increase the involvement of farmers or pond farmers and is expected to increase knowledge and provide solutions to reduce the spread of disease in the cultivation environment (Mulyadin *et al*., 2025).

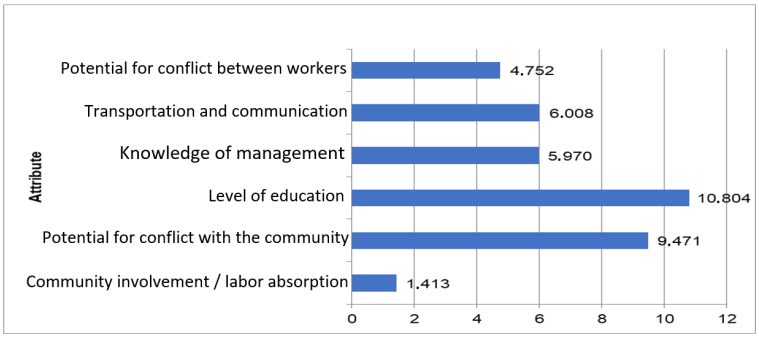

Figure 7. Results of the social dimension leverage analysis in the Millennial Pond Model at JBrackish Water Aquaculture Centers.

Sustainability status of the technology dimension

In this study, an assessment of the sustainability of the technology dimension was conducted, which aims to determine the level of progress and use of technology in running a sustainable vaname shrimp farming business. The study of attributes in this dimension, namely Pond construction, Existence of a cultivation waste processing

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system, Level of understanding of fisheries cultivation technology, Use of technology in fisheries cultivation (water treatment, wheels, and feed), Implementation of Good Aquaculture Practices Standardization/ Certification, and Application of biosecurity. The results of the ordination test in multi-dimensional scaling (MDS) in the technology dimension produced an output result, namely a sustainability score of 99.996 in the very sustainable category (Figure 8). Millennial ponds are considered technologically sustainable because they utilize digital innovation, automation, and advanced monitoring systems to create an efficient, adaptive, and continuously evolving shrimp farming process (Pramudia *et al.*, 2022; Savianus *et al.*, 2023). This makes farming more resilient to future challenges and supports long-term sustainability.

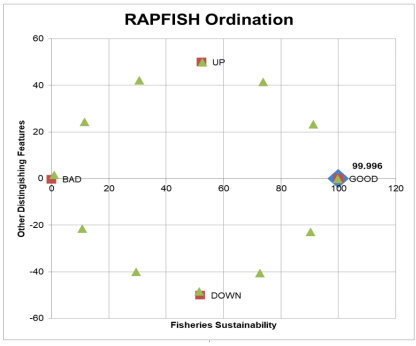

Figure 8. Sustainability index results on the technology dimension in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

The results of the leverage analysis of the technology dimension obtained 2 groups of attributes, namely attributes that have a sensitive effect (2 attributes) and have an insensitive effect (4 attributes) (Figure 9). The results of the leverage analysis on the ecological dimension show that the sensitive attributes that affect the value of the sustainability index are pond construction (RMS = 0.005) and the application of biosecurity (RMS = 0.005) in the vaname shrimp cultivation business in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers. Biosecurity is an integrated principle and action to analyze and manage risks that arise to the health of farmed animals, so that optimal application of biosecurity in cultivation activities can provide a correlation with the increase in the weight and size of harvested shrimp (Patanasatienkul *et al.*, 2023).

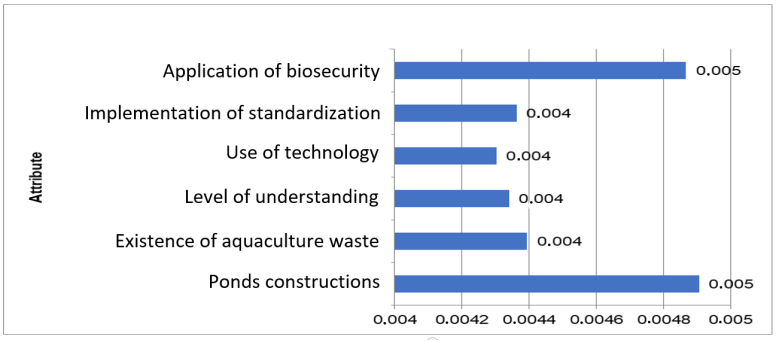

Figure 9. Results of the leverage analysis of the technology dimension in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

Status of sustainability of legal-institutional dimensions

In this study, an assessment of the sustainability of the legal and institutional

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dimensions was conducted with the aim of determining the level of management in business institutions and the effectiveness of policy implementation in running a sustainable vaname shrimp farming business. The study of attributes in this dimension, namely Availability of farmer groups, Availability of formal regulations for farming management, Intensity of legal violations to farming, Regulation of the Minister of Marine Affairs and Fisheries concerning general guidelines for shrimp farming, Regional regulations concerning worker welfare in ponds, and Training and socialization activities regarding shrimp farming businesses.

The results of the ordination test in MDS in the legal and institutional dimensions produced an output result, namely a sustainability score of 99.996 in the very sustainable category (Figure 10). Millennial ponds usually follow sustainable cultivation standards (Good Aquaculture Practices/GAP) set by the Ministry of Marine Affairs and Fisheries (KKP). The use of technology also facilitates reporting and documentation, making it easy to audit by the government or certification bodies. Millennial ponds can operate in the form of institutions such as CVs, thereby strengthening access to funding, training, markets, and legal protection (Pramudia *et al.*, 2024).

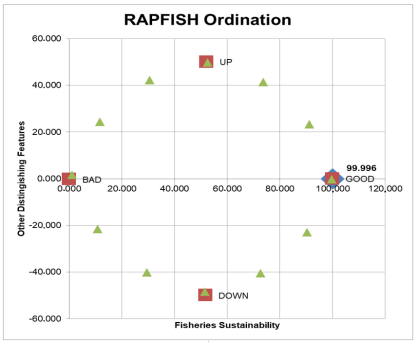

Figure 10. Results of the sustainability index on the legal-institutional dimension in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

The results of the leverage analysis of the legal-institutional dimension obtained 2 groups of attributes, namely attributes that have a sensitive effect (2 attributes) and attributes that have an insensitive effect (4 attributes) (Figure 11). The results of the leverage analysis on the legal and institutional dimensions show that the sensitive attributes that affect the value of the sustainability index are training and socialization activities on shrimp farming (RMS = 0.005) and availability of farmer groups (RMS = 0.005) in vaname shrimp farming activities in MSF ponds at Jepara Brackish Water Aquaculture Centers. The method of socialization program activities is carried out in three stages, namely presentation of material, discussion and survey, and sampling. This socialization activity provides the most benefits to participants to be able to apply the material in cultivation activities (Mulyadin *et al.*, 2025).

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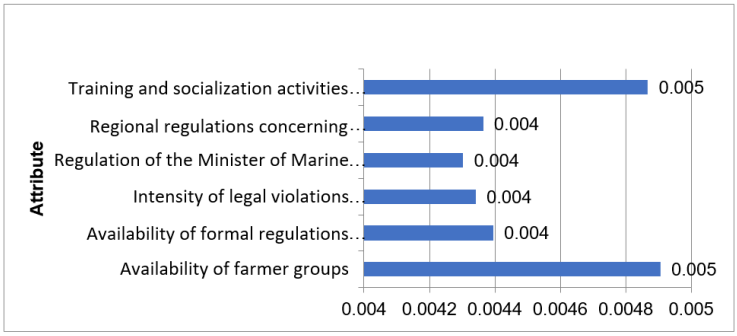

Figure 11. Results of the legal-institutional dimension leverage analysis in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

Multidimensional sustainability status

In the multidimensional scaling analysis, an ordination test was conducted on each dimension of sustainability, namely the ecological, economic, social, technological, and legal and institutional dimensions. The results of the ordination test in this study obtained statistical values in the form of stress values and determination coefficients (R2) from each dimension (Table 2). The results of the ordination test in this study obtained statistical values in the form of stress values and determination coefficients (R2) from each dimension. The stress value was obtained in the ecological dimension, which was 14.3%, the economic dimension, which was 14.%, the social dimension, which was 14.7%, the technological dimension, and the legal and institutional dimensions obtained stress values, which were 14.2%.

The determination coefficient value obtained in this test was the economic dimension, which was 94.6%, the social dimension, which was 93.8%, the ecological dimension, the technological dimension, and the legal and institutional dimensions obtained values of 94.1%. Based on the results of the ordination test, the stress value in the MDS analysis in the study was less than 25% and the determination coefficient was more than 90% indicating perfect analysis accuracy conditions. The stress value describes the accuracy of the configuration in the MDS analysis of the original data.

Table 2. The results of statistical values in the MDS ordination analysis on the sustainability of vaname shrimp aquaculture efforts in the Millennial Pond Model at Jepara Brackish Water Aquaculture Centers.

No.	Dimention	Stress		R^2	
		Statistic value	Percentage	Statistic value	Percentage
1	Ecology	0.143	14.3	0.941	94.1
2	Economy	0.14	14	0.946	94.6
3	Social	0.147	14.7	0.938	93.8
4	Technology	0.142	14.2	0.941	94.1
5	Law and Institutions	0.142	14.2	0.941	94.1

The analysis in this study on the sustainability of the vaname shrimp farming business in the Millennial Pond Model of Jepara Brackish Water Aquaculture Centers produces a sustainability index value. At the end of this study, the results of the RAPFISH analysis by analyzing each dimension of sustainability so that overall it can be seen that the vaname shrimp farming business in the Jepara Brackish Water Aquaculture Centers Millennial Pond is very sustainable, with a score of 88.94. According to Arofi *et al*. (2015), the sustainability status with a value range of 75-100 is included in the very sustainable category. The results of the analysis are interpreted through a flyover diagram to be able to describe the sustainability conditions of the vaname

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shrimp farming business in the Jepara Brackish Water Aquaculture Centers Millennial Pond.

The results of the sustainability analysis in the flyover diagram illustrate the relative position of the sustainability index value based on each dimension of sustainability. In the flyover diagram, it can be seen that sustainability based on the technological aspect and the legal & institutional aspect has the highest value compared to other dimensions, as indicated by the lines of the larger planes that lead to the outer corner (sustainability angle). However, business sustainability in the social aspect tends to lead to the inner corner (unsustainable angle). This condition illustrates that the social aspect of the business is vulnerable to influencing the unsustainability of the business. Research related to the Millennial Shrimp Farming System in Indonesia was first reported in 2022, and the results showed that this system is a feasible and profitable business with a low level of sensitivity to feed price fluctuations and uncertain operational income (Pramudia *et al*., 2022; 2024). The use of the latest technology attracts the interest of the younger generation to develop fisheries businesses with more efficient and environmentally friendly methods (Pratiwy *et al*., 2021; Savianus *et al*., 2023).

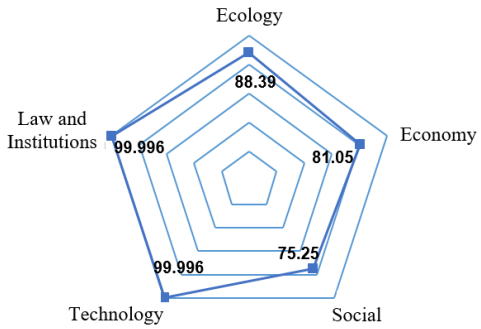

Figure 12. Flyover diagram of the sustainability status of vaname shrimp aquaculture business in the Millennial Ponds Model of Jepara Brackish Water Aquaculture Centers.

The results of the analysis that has been carried out can produce recommendations for improvement plans as an effort for management strategies and improving vaname shrimp farming efforts in the Millennial Pond Model of Jepara Brackish Water Aquaculture Centers. Determination of recommendations is based on leverage analysis, so that sensitive attributes are obtained that can increase the sustainability index value and maintain business conditions in the very sustainable category. The implementation of the business management action plan is carried out in stages (short, medium and long term) with priority implementation on attributes that are categorized as highly sensitive, namely in the ecological domain: disease attacks, land utilization level, land suitability; economic domain: price trends, market reach, cultivation profits; social domain: education level, community involvement/labor absorption, availability of transportation and communication facilities; technology domain: pond construction, application of biosecurity; and legal & institutional domain: training and socialization activities on cultivation efforts, and availability of cultivator groups.

This recommendation needs to be done because research related to the millennial pond model has not been widely reported. The first report related to the millennial pond was only reported in 2022. With decent and profitable business results, plus the use of more efficient technology, it is hoped that it can increase public interest in shrimp farming and increase Indonesian fisheries production (Pramudia *et al*., 2022; 2024).

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CONCLUSION

The average value of the sustainability index based on the ecological, economic, social, technological, and legal & institutional domains in the vaname shrimp farming business at the Millennial Pond Model of Jepara Brackish Water Aquaculture Centers is 88.94. This value illustrates that the vaname shrimp farming business is in a very sustainable condition. Efforts to increase the sustainability index value and maintain the sustainability of the vaname shrimp farming business at the Millennial Pond Model of Jepara Brackish Water Aquaculture Centers, so that it can run optimally through a management strategy. Preparation and implementation of a priority strategic action plan for managing the vaname shrimp farming business at the Millennial Pond Model of Jepara Brackish Water Aquaculture Centers based on short-term, medium-term, and long-term priorities by improving several aspects of attributes in each dimension of sustainability. Determination of attributes based on leverage analysis so that sensitive attributes are obtained in each domain.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest among all authors upon writing and publishing the manuscript.

AUTHOR CONTRIBUTION

Conceptualization: SBP and PWP; data collection: AG; data analysis, investigation, methodology, validation, and data curation: AG, SBP, and PWP; writing—original draft, review, and editing: AG, SBP, and PWP.

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