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Sustainable Fishery Value Chain (SFVC): Study Case in Tilapia Industry

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***Abstract*—This research is built on the concept of sustainable value chains, where a framework for sustainable value chain analysis emerges that covers not only economic aspects but also includes environmental and social impacts in a collaborative model of value chain management. It explores the dimensions on which value chain sustainability should focus. It illustrates how and why it is necessary to take a broader perspective in ensuring the internal economic sustainability of the chain in line with its external socio-environmental consequences. This research aims to analyze the sustainability of the tilapia processing value chain. This research uses the Multi-Dimensional Scaling analysis method supported by Rap-fish software. The Rapfish methodology is a flexible technique that rapidly assesses fisheries status by integrating ecological and human factors according to identified norms. The results of this research show that the sustainability of the tilapia processing value chain is considered entirely sustainable from economic, social, and environmental aspects, with a sufficient sustainability index of 74.40%. The sustainability of the value chain relies on four key actors: tilapia cultivators, collectors, processors, and distributors. The sustainable tilapia processing value chain strategy in North Sumatra can limit floating net cages by considering the environmental carrying capacity and supported by suitable policies and active stakeholder participation in community-based legal institutions. This research found this is a strong sustainability concept if implemented with better governance and policy management in the tilapia industry value chain.**

***Keywords*— Sustainability index; value chain; tilapia processing; value chain; rap-fish.**

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I. INTRODUCTION

Tilapia is now a widely traded aquaculture product, although it is mainly consumed domestically. In 2020, 121 countries reported aquaculture production to the FAO. Of those, 97.52% cultivated tilapia in fresh water, while 9.92% cultivated it in brackish water [1]. Although tilapia originates from Africa, Asia has dominated its production since the fish was introduced to aquaculture. Asia produced 4.2 million tons of farmed tilapia in 2020, which accounted for 68.8% of the world's total [2].

One of the Asian countries that cultivates tilapia is Indonesia. Indonesia is the world's second-largest producer of cultivated tilapia, with 1.35 million tons in 2021 or 22.75% of the world's total tilapia production [3]. Tilapia has become one of the most essential freshwater fish traded domestically and internationally. This can significantly contribute to tilapia production because the quality requirements for aquatic commodities traded on the international market come from cultivating Floating Net Cages in lakes. The amount and value of Indonesian tilapia production over the last 10 years has increased. However, in 2018, the quantity and value of production decreased by 1.23% and 0.49% respectively. Indonesian tilapia cultivation species over the last 10 years have been dominated by Nile tilapia at 98.13% and Mozambique Tilapia at 1.87% (Fig. 1).

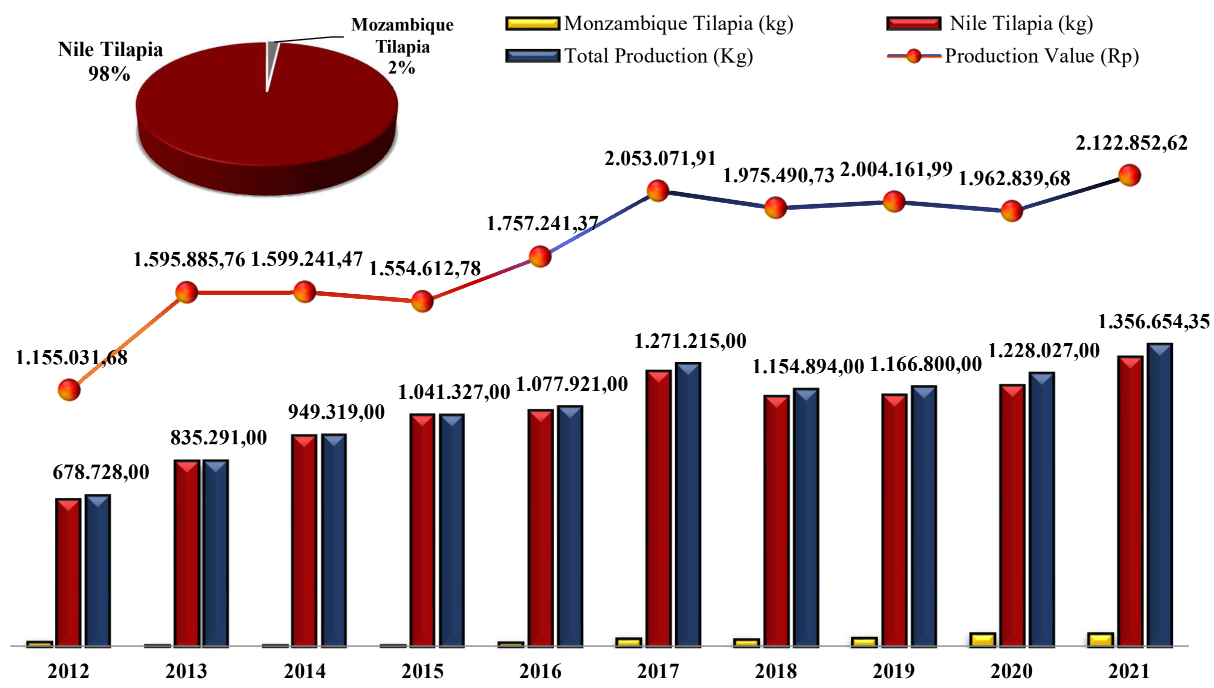

Fig. 1 Species composition and production of tilapia cultivation in Indonesia in 2012-2021, data source: [4]

The agro-industry of tilapia processing should focus on current regional and global business competition, shifting from Comparative to Competitive Advantage [5], [6], [7]. This can impact the sustainability of businesses, particularly those in tilapia processing. Business sustainability can encompass social, economic, and environmental factors [8]–[10], [11].

The success of the tilapia processing business largely depends on the value chain system created by the business actors. Conducting a fisheries value chain analysis can help organizations identify the key areas to reduce operational costs, optimize efforts, eliminate waste, improve health and safety, and increase profits. By breaking down business processes, organizations can identify the most significant opportunities for improvement and ensure the sustainability of their business activities [12],13],[14]. The first step in analyzing the fisheries value chain is to map the organization's business value chain. This helps identify key activities related to product and service lines, which can help determine performance improvement opportunities. Fisheries value chain mapping involves creating value by analyzing trends and providing solutions to emerging fisheries business problems, using specific knowledge in company processes [13], [15].

Studies on the tilapia value chain have been conducted to investigate the relationships across the various chains and analyze their role in improving overall value chain performance. Previous area studies have examined the tilapia value chain, particularly in developing countries such as Bangladesh, Egypt, Fiji, Ghana, and Samoa. In many developing countries, studies of the tilapia value chain indicate that inter-firm linkages need to be stronger, and coordination and market strategies need to be more effectively aligned, thus impacting business sustainability [16]–[18], [19].

Based on this literature, a gap was found, where up to now, VCA tilapia has primarily focused on economic sustainability. This certainly needs to pay more attention to the social and environmental consequences of corporate behavior and the allocation of resources internal to the company in the chain. These risks result in recommendations that ignore the competitive advantages of improved environmental management social welfare and have adverse external consequences that make the company unsustainable when exposed to government or broader (public) scrutiny [10], [20]–[22], [23].

This paper builds on the concept of sustainable value chains, where a framework for sustainable value chain analysis emerges that does not cover economic aspects alone but also includes environmental and social impacts in a collaborative model of value chain management. It explores the dimensions on which value chain sustainability should focus. It illustrates how and why taking a broader perspective ensures the internal economic sustainability of the chain in line with its external socio-environmental consequences.

This research aims to analyze the sustainability of the tilapia processing value chain. Based on previous literature studies, no one has specifically studied the tilapia processing value chain, which supports business sustainability from economic, social, and environmental aspects.

II. Material and Method

A. Value Chain Sustainability Analysis

Sustainability analysis uses Multi-Dimensional Scaling (MDS) analysis supported by Rapfish software. The Rap-fish methodology (Rapid appraisal for fisheries) is a normative, measurable, and flexible rapid assessment technique that integrates ecological and human dimensions to evaluate the status of fisheries referring to identified norms or goals. This method helps assess sustainability indices and status as well as identify critical indicators of each sustainability dimension through leverage analysis carried out using Multi-Dimensional Scaling (MDS) [10]. The MDS method is used in the rap-fish ordination technique, which involves multiple stages. The preparation stages for this sub-model can be seen in Fig. 2.

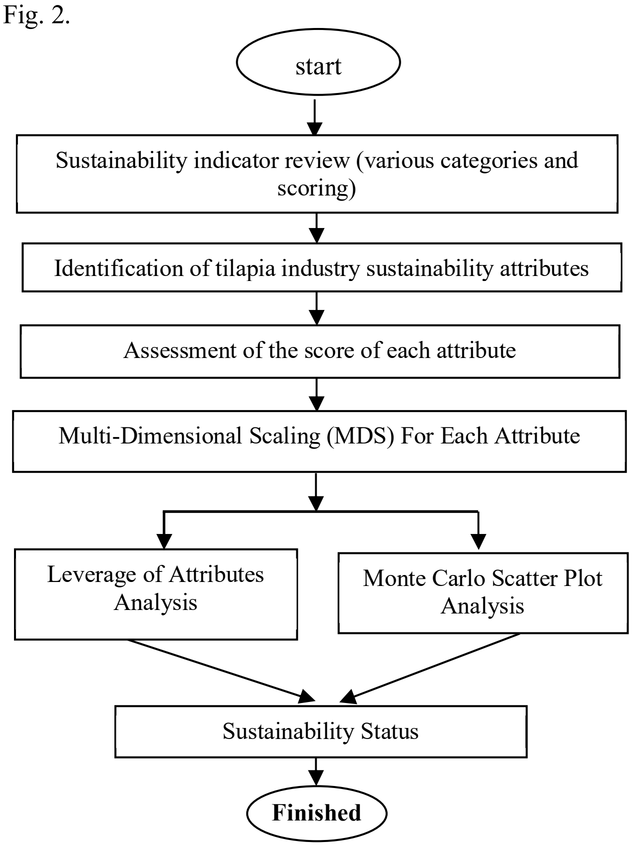

Fig. 2 Stages of preparing a sustainability analysis sub model

The MDS analysis determines the stress value and coefficient of determination (R2) Sensitive indicators are obtained based on the results of leverage analysis, which can be seen in changes in the Root Mean Square (RMS) ordination on the X axis. The more significant the change in RMS, the more sensitive the role of the indicator is in increasing sustainability status. Another analysis carried out on MDS is Monte Carlo analysis. Monte Carlo analysis is an analysis to estimate the influence of random error in the analysis process, which is carried out at a 95% confidence interval [9][24][10]. The sustainability index values for each dimension are classified into four categories, as shown in Table 1.

TABLE I
SUSTAINABILITY INDEX

No.	Sustainable Index Value (%)	Sustainability Category
1.	0,000 – 25.00	Bad: Not sustainable
2.	25.01 – 50.00	Less: Less sustainable
3.	50.01 – 75.00	Fair: Sufficiently sustainable
4.	75.01 – 100.00	Good: Very sustainable

Source: [10]

In MDS, the ordination technique is based on Euclidean distance in a dimensional space, formulated as follows:

$$\boldsymbol{d} = \sqrt{(|\boldsymbol{x_1} - \boldsymbol{x_2}|^2 + |\boldsymbol{y_1} - \boldsymbol{y_2}|^2 + |\boldsymbol{z_1} - \boldsymbol{z_2}|^2 + \ldots\ldots)} \quad (1)$$

This point is then applied by regressing the Euclidean distance (d_{ij}) from point i to point j with the origin point (d_{ij}) with the formulation:

$$d_{ij} = \alpha + \beta d_{ij} + \boldsymbol{\varepsilon} \quad (2)$$

where α is constant, β is coefficient, and ε error.

This equation is regressed using the ALSCAL method. The ALSCAL method optimizes the squared distance (squared distance = d_{ij}) of squared data (origin = O_{ijk}), which in three dimensions (i, j, k) is written in a formula called S-Stress as follows:

$$S = \sqrt{\frac{1}{m}\sum_{k=1}^{m}\left[\frac{\Sigma_i \Sigma_j \left(d_{ijk}^2 - o_{ijk}^2\right)^2}{\Sigma_i \Sigma_k o_{ijk}^4}\right]} \quad (3)$$

where S is stress, d_{ijk} is squared distance, and o_{ijk} *is* original point

The S-Stress value measures the point at which the original data can be influenced. A stress value of less than 0.25 indicates good analysis. The R^2 value should be close to 1 (100%), meaning the currently selected attributes can account for close to 100% of the existing model [24], [25] [10].

III. Results and Discussion

A. Value Chain Analysis of Sustainable Tilapia Processing

Based on surveys and interviews conducted with 45 respondents in the field, it was found that the processing industry can be classified into two categories: primary activities and supporting activities. The main activities encompass four key areas: supply of production inputs, tilapia production, tilapia processing, and marketing and distribution to final consumers. On the other hand, supporting activities comprise four areas: human resource management, technology development, infrastructure, and procurement [5]. The actors involved in the sustainable tilapia processing value chain can be seen in Fig. 3.

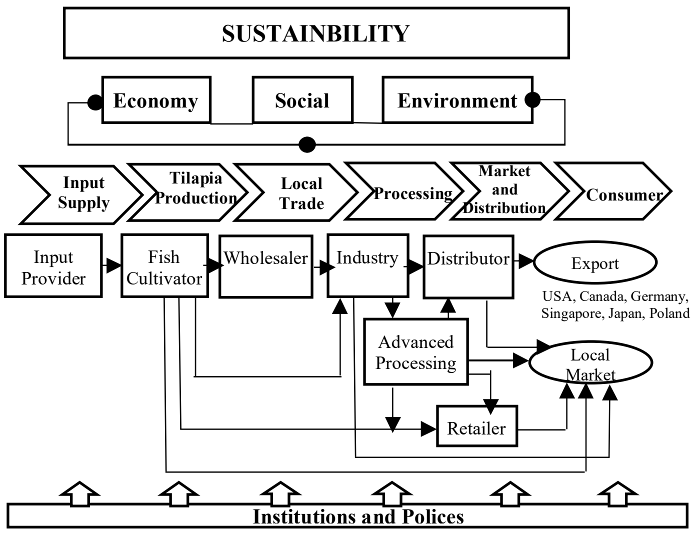

Fig. 3 Tilapia industry value chain network [5]

B. Analysis of the Sustainability of the Tilapia Fish Processing Value Chain

1) Sustainability Measurement: The sustainability indicators were determined through field surveys and in-depth interviews with four expert sources. An extensive literature review supported the results. The research identified 36 indicators across three dimensions, namely 14 economic, 14 social, and 8 environmental. These indicators provide a comprehensive reflection of the sustainability performance of the tilapia processing industry. Table 2 presents a summary of the expert assessment results.

2) Sustainability Analysis of Economic, Social and Ecological Dimensions: The graph of the sustainability of the value chain of the tilapia processing industry in economic, social, and ecological dimensions is symbolized in several shapes; namely, the blue-green rhombus shape is the index quantity; The red and yellow rectangular shapes are reference anchors, which refer to the formula, which shows that on the x-axis Good has a maximum value of 100 and Bad has a minimum value of 0. At the same time, the y-axis for Up is half the maximum attribute score (50), and down is half the minimum attribute score (-50), and the blue triangle shapes are anchors that indicate boundaries.

Analysis of Rap-Oreochromis niloticus shows the sustainability index's value in economic, social, and environmental dimensions. The results of the analysis of the sustainability index of the tilapia processing value chain in the economic dimension show that there is a diversity of economic dimensions that is entirely sustainable, namely 81.55 percent. If you look at the position of the value 81.55%, it is above 0 on the x and y axes. Statistically, this indicates an increase in sustainability status, and the resulting sustainability index value is categorized as moderate or entirely sustainable. This means that the tilapia processing industry activities in the value chain obtain results that are economically viable over a relatively long period and are economically sustainable (see Fig. 4).

TABLE II
RESPONDENT ASSESSMENT RESULTS FOR ECONOMIC, SOCIAL, AND ENVIRONMENTAL ASPECT CRITERIA

No.	Attributes/Indicators of the Economic Dimension	Expert Rating				Median	Mean	Mode
		P1	P2	P3	P4			
1.	input supply and product quality	1	1	0	2	1	1	2
2.	Access to capital and finance	1	1	0	0	0.5	0.5	2
3.	Plan for costs, benefits, and risks	2	1	1	1	1	1.25	2
4.	Absorption of local labor	0	0	0	0	0	0	1
5.	Increased production performance	0	1	1	0	0.5	0.5	2
6.	Method and Amount of production	1	1	1	1	1	1	2
7.	Revenue/profit	2	2	2	1	2	1.75	3
8.	Improving quality and innovation performance to increase added value	2	2	2	2	2	2	1
9.	Price fluctuation (daily, seasonal)/price stability	2	2	2	2	2	2	2
10.	Increasing integrated, productive, and partnership market access	2	2	2	2	2	2	2
11.	Market demand	1	2	2	0	1.5	1.25	2
12.	Good and flexible payment transaction system	0	0	2	3	1	1.25	0
13.	Tourism potential	2	3	3	3	3	2.75	3
14.	Technology transfer and prosperity of small and medium enterprises	2	1	3	3	2,5	2.25	3
No	**Social Dimension Attributes/Indicators**	**Expert Assessment**				**Median**	**Mean**	**Mode**
		P1	**P2**	**P3**	**P4**			
1.	Availability of land, opportunity to own, security of ownership of kja	0	0	1	2	0.5	0.75	0
2.	Socialization and creation of sustainable organizational culture	0	0	0	1	0	0.25	0
3.	Supervision and quality control by existing laboratories (food safety)	1	1	0	0	0.5	0.5	1
4.	CSR Investment	1	0	0	3	0.5	1	2
5.	The convenience of markets and transportation networks	3	2	0	3	2,5	2	3
6.	Level of education	1	1	0	1	1	0.75	1
7.	Employee training and preparation that focuses on safety and health	2	0	3	2	2	1.75	2
8.	Ability to adapt to change	1	0	0	0	0	0.25	1
9.	Provide new information and insights	0	0	0	1	0	0.25	1
10.	Labor Availability and Skills	0	1	0	1	0.5	0.5	1
11.	Technical Innovation and Transformation Dynamics	1	0	1	0	0.5	0.5	1
12.	Strengthen the legal environment, involved institutions, and effective government policies	0	0	2	0	0	0.5	2
13.	Guarantee social justice/equal distribution of economic benefits	1	0	2	2	1.5	1.25	2
14.	Obligation to provide employee wages	1	0	0	2	0.5	0.75	0
No	**Environmental Dimension Attributes/Indicators**	**Expert Rating**				**Median**	**Mean**	**Mode**
		P1	**P2**	**P3**	**P4**			
1.	Water quality and availability	0	1	1	1	1	0.75	1
2.	The length of a species' life cycle	2	2	2	1	2	1.75	2
3.	The design and construction of KJA is environmentally friendly	2	1	0	0	0.5	0.75	0
4.	Feed management and fish density	1	1	1	1	1	1	1
5.	Fish health management and effective fish management	1	2	1	1	1	1.25	2
6.	Disposal/waste	2	2	1	0	1.5	1.25	2
7.	Global climate change	0	0	0	0	0	0	0
8.	Environmental Pollution (air and water)	1	1	2	2	1.5	1.5	1

The sustainability index analysis of the tilapia processing value chain in the social dimension (as shown in Fig. 5) reveals that the diversity in the social dimension is reasonably sustainable at 67.97%. However, it is essential to note that the position of the value 67.97% is below 0 on the x and y axes, indicating a statistical decline even though the status is entirely sustainable. This highlights the need to improve the social system and cooperative relationships to support the long-term and sustainable development of the fishing industry.

The results of the analysis of the sustainability index of the tilapia processing value chain in the ecological dimension (see Fig. 6) show that there is a reasonably sustainable diversity in the ecological dimension, namely 57.82 percent. If you look, the position of the value 57.82 percent is below 0 on the x and y axes. Statistically, this indicates a decline even though the status is entirely sustainable. This means that the quality of the environment, tilapia resources, and the natural processes therein are still sustainable enough to support every economic activity carried out in the aquaculture sector. The dimensional index value in the future can be increased by maintaining and conserving tilapia, especially activities that affect water quality [15], [18], [26], [27]. Floating net cage business actors have also become increasingly aware that protecting the aquatic environment of Lake Toba has become necessary. Not only is it for the benefit of nature conservation as a tourist destination, but the quality of polluted waters can directly impact the continuity of the Floating Net Cage business itself. One of the efforts is implementing suitable fish cultivation methods by government regulations, including environmentally friendly fish food. The feed criteria include floating feed type, low phosphorus content, feed nutritional content that can be easily/efficiently digested by fish, thereby reducing FCR (feed conversion) rates, measured and environmentally friendly feeding methods, and using quality and consistent raw materials [8], [17], [28].

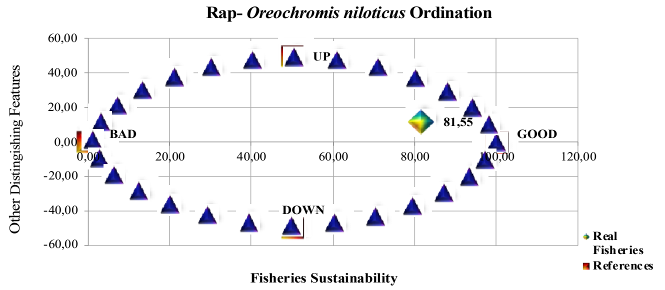

Fig. 4 Rap - Oreochromis niloticus ordination, which shows the value of the economic dimension sustainability index

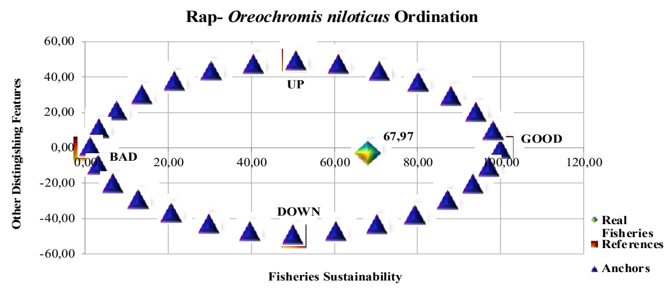

Fig. 5 Rap - Oreochromis niloticus ordination, which shows the social dimension sustainability index value

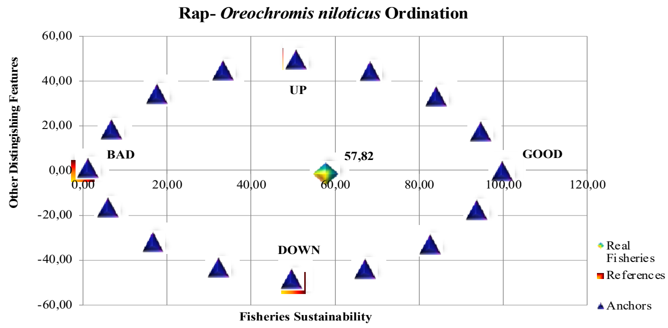

Fig. 6 Rap - Oreochromis niloticus ordination, which shows the value of the sustainability index of the ecological dimension

3) Leverage Analysis on Economic, Social and Ecological Dimensions: The following analysis process in assessing the sustainability of the tilapia processing value chain in economic, social, and environmental dimensions is leverage analysis. The findings of the leverage analysis on economic, social, and environmental dimensions are displayed in Fig. 7, Fig. 8, and Fig. 9.

Visually, the leverage factor depicted in an elongated bar is the attribute being assessed. The results of the leverage analysis, as shown in Figure 7, show that three leverage factors influence the value of the sustainability index's economic dimension: increased production performance, good and flexible payment transactions, and absorption of local labor. These three lever factors significantly influence sustainability status, with Root Mean Square (RMS) figures of 2.56 percent, 1.96 percent, and 1.47 percent, respectively. This states that if there is intervention in improving production performance, good and flexible payment transactions, and absorbing local labor, it will affect the value of the sustainability index.

Improving production performance is the primary factor that has the most significant impact on the economic dimension. Production performance can be enhanced in the tilapia processing industry by delegating responsibilities and authority to individuals or work groups, who are expected to achieve the set goals by following applicable values and norms [18], [29], [30].

The second lever factor influencing the economic dimension is the absorption of local labor, where several things, including minimum wage, unemployment, population, and poverty, influence this factor. Indirectly, these factors will influence the expansion and development of investment, which is useful in absorbing more workers in tilapia processing industry companies in North Sumatra. So, the tilapia processing industry needs to consider the influence of local workers so as not to compete with foreign companies. This is in line with previous research, which states that the influence of foreign investment and exports positively affects labor absorption in North Sumatra [31].

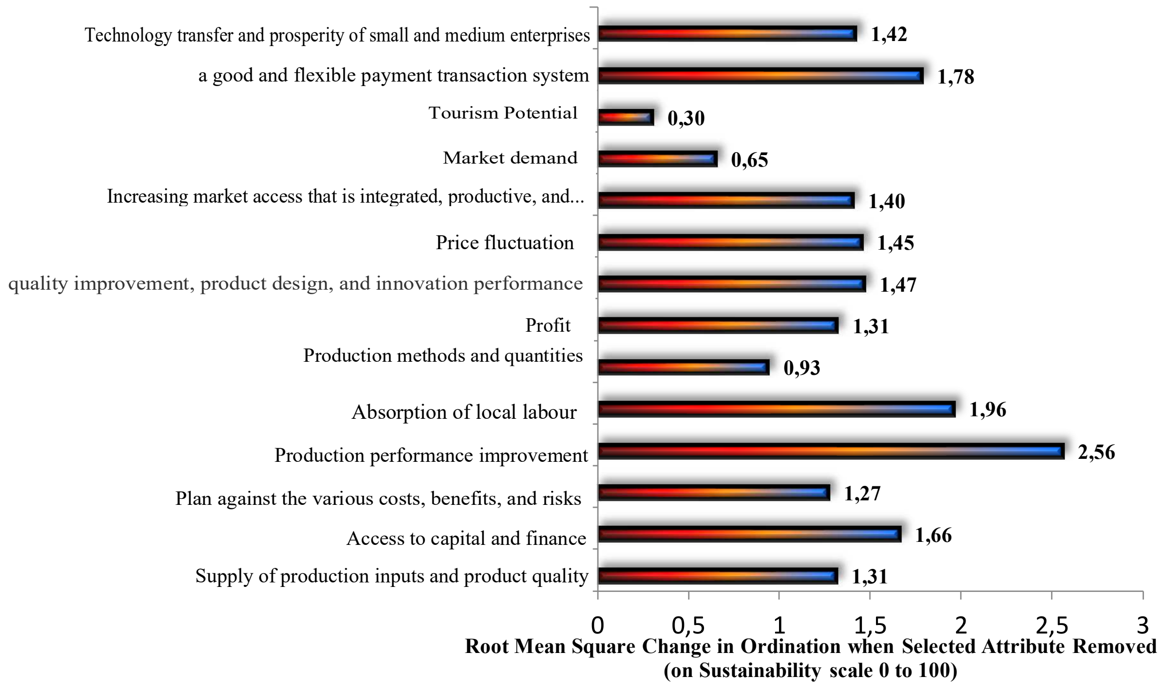

Fig. 7 Leverage of attributes economic dimensions

The third leverage factor is good and flexible payment transactions. This is because the actors involved in the value chain currently still use traditional payment systems, and only a few uses modern payment systems. Hence, the payment system is still simple, affecting the production performance and sustainability of the tilapia industry value chain. This is supported by previous research, which states that to improve the value chain and ensure sustainability, it is necessary to encourage key actors to have well-defined payment transactions with customers and adopt flexible payment methods [16], [17].

The leverage analysis of the ecological dimension can be seen in Figure 8. The results of the leverage analysis, as shown in the figure, show that the leverage factors/attributes that influence the value of the sustainability index for the ecological dimension are global climate change and environmental pollution. This leverage factor has a major influence on sustainability status, with Root Mean Square (RMS) figures of 2.858 percent and 2.259 percent. This states that if there is intervention in the pressure factors of global climate change and environmental pollution, it will affect the sustainability index value of the tilapia processing business in North Sumatra in the future.

The social dimension leverage analysis can be seen in Figure 9. As shown in the figure, the leverage analysis findings show that the leverage attributes that influence the value of the social dimension sustainability index are strengthening the legal environment, institutions involved, and effective government policies, providing new information and insights. This leverage factor greatly influences sustainability status, with Root Mean Square (RMS) figures of 4.265 percent and 4.214 percent. This states that institutions are involved if there is intervention in a strengthened legal environment, and effective government policies provide new information and insights. Providing new information and insights can influence the sustainability index value of tilapia processing businesses [32].

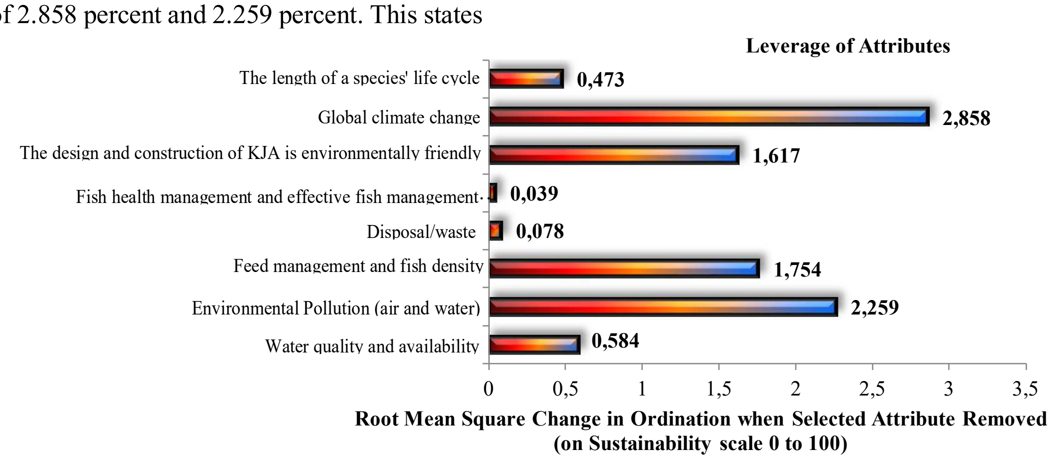

Fig. 8 Leverage of attributes environmental dimensions

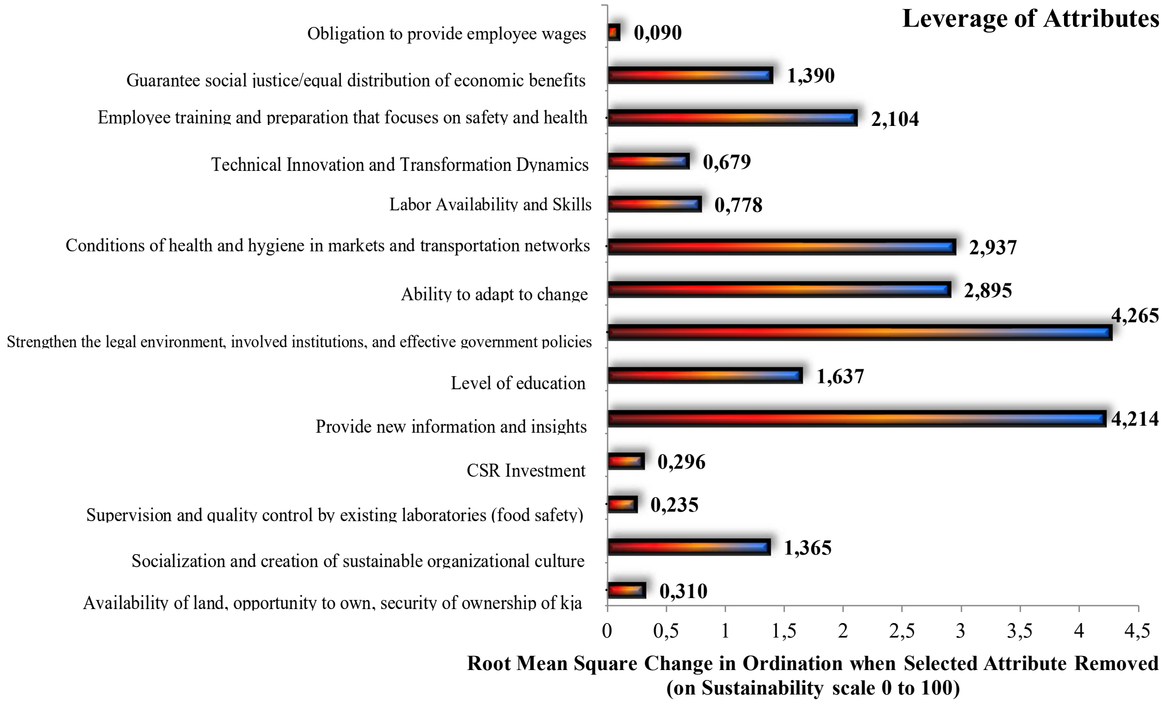

Fig. 9 Leverage of attribute s social dimension

4) Monte Carlo Analysis: Key indicators (existing conditions) from each dimension need to be intervened to sustain each dimension. The next stage is to carry out validation using Monte Carlo analysis. Monte Carlo analysis was used to test the confidence level in the total and dimensional index values.

Monte Carlo analysis is constructive in the analysis of Rap-Oreochromis niloticus to see the influence of errors in scoring each attribute in dimensions caused by procedural errors or understanding of the attribute, variations in scoring due to differences in opinions or assessments by different researchers, stability of the MDS analysis process, missing data, and assessed as having "stress" that is too high. Thus, the final results of the Rap-Oreochromis niloticus analysis in the form of a sustainability index for the tilapia processing value chain at the research location have a high confidence level.

Based on the results of the Monte Carlo simulation for the economic dimension, which ran 25 repetitions with 95 percent confidence, it presented an average value of 81.55 percent (Fig. 10), and when compared with the MDS coordination value, namely 81.89 percent, it does not appear to differ much. The difference between the MDS sustainability index and Monte Carlo analysis is relatively small (less than 5%) for each indicator, with an average value of 0.337%. This shows that Rap-Oreochromis niloticus has a fairly appropriate range of indicator values used, and the incidence of errors in preparing scores for each attribute in the ordination analysis is relatively small, so it can be concluded that there is accuracy in the MDS ordination analysis in assessing an object [25], [33][10].

Meanwhile, the Monte Carlo simulation results for the social and ecological dimensions that ran 25 repetitions with 95 percent confidence presented average values of 67.89 percent and 58.04 percent (Fig. 11 and Fig. 12). The difference between the MDS sustainability index and Monte Carlo analysis is relatively small (less than 5%) for each indicator, with an average value of 0.11 percent and 0.22 percent. This shows that Rap-Oreochromis niloticus has a fairly appropriate range of indicator values used, and the incidence of errors in preparing scores for each attribute in the ordination analysis is relatively small, so it can be concluded that there is accuracy in the MDS ordination analysis in assessing an object.

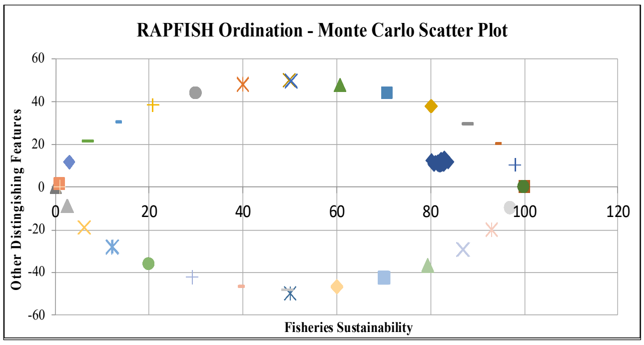

Fig. 10 Rap - Oreochromis niloticus ordination - monte carlo scatter plot economy dimension

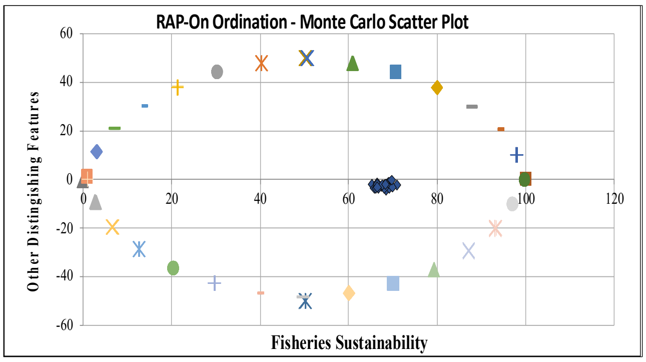

Fig. 11 Rap - Oreochromis niloticus ordination - monte carlo scatter plot social dimension

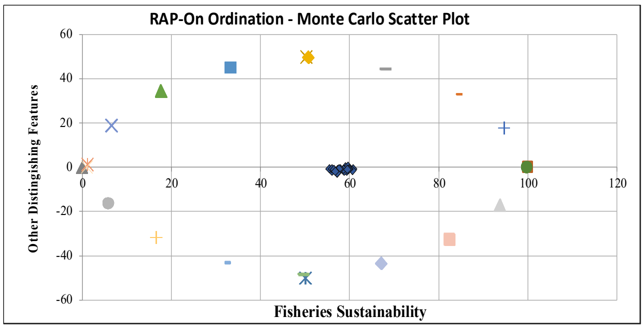

Fig. 12 Rap - Oreochromis niloticus ordination - monte carlo scatter plot environmental dimensions

The results of the sustainability index validation can be analyzed by comparing the sustainability index (MDS) and Monte Carlo. Table 3 shows that the difference value of the sustainability index between MDS and Monte Carlo produces a difference of less than 5% (95% confidence level), which is considered valid (no errors in the MDS analysis). This means that the sustainability of the management studied has a high level of confidence. At the same time, the Rap-Oreochromis niloticus analysis method can be used as an evaluation tool to assess the sustainability of the tilapia processing industry quickly [24], [2]. The slight differences in sustainability index values between the results of the MDS method analysis and Monte Carlo analysis also indicate the following:

- The error in scoring each attribute is relatively small
- Variations in scoring due to differences in opinion are relatively small
- The analysis process carried out repeatedly is stable
- Errors in entering missing data can be avoided

TABLE III
RESULTS OF MONTE CARLO ANALYSIS FOR MULTI-DIMENSIONS

Dimensions of Sustainability	Index value (MDS) (%)	Monte Carlo Value (%)	Error (%)	Description
Economy	81.55	81.89	0.34	Valid
Social	67.97	67.89	0.11	Valid
Environment	57.82	58.04	0.22	Valid
Multi-dimensional index	**69.11**	**69.27**	**0.22**	**Valid**

5) *Multidimensional Sustainability Analysis:* An analysis of the sustainability of the tilapia processing industry was conducted using the multi-dimensional scaling (MDS) method, which involved studying 36 attributes across three dimensions - ecological, economic, and social. The attributes were divided into 8 ecological, 14 economic, and 14 social indicators. Rap-Oreochromis niloticus was used as a case study, and the accuracy of the indicators was measured using the stress value and coefficient of determination (R2). The results showed that each indicator was highly accurate, with a stress value of less than 0.25 and a determination value close to 1,0, indicating the reliability of the sustainability index value obtained [24]. Table 4 displays the stress value and coefficient of determination results for the sustainability dimensions in economic, social, and ecological aspects. The analysis of Rap-Oreochromis niloticus demonstrates that the attributes evaluated for the sustainability status of the tilapia processing value chain are precise. The stress values range from 0,134 to 0,151, with a relatively high degree of coefficient of determination (R^2) of 0,944 to 0,953 for all assessed dimensions, indicating that the attributes used to assess the sustainability status of each dimension are valid. The researcher must reevaluate the research attributes if the stress and R2 values are invalid. [24], [10].

TABLE IV
RAPFISH VALUE, STRESS, AND COEFFICIENTS

Dimensions	Value						Information	Sustainability Status
	Weight	Stress	R^2	Index value (%)	Monte Carlo (%)	Difference/ Error (%)		
Economy	0.646	0.139	0.951	81.55	81,89	0.34	Valid	Sustainable
Social	0.123	0.134	0.953	67.97	67,89	0.11	Valid	Sufficiently Sustainable
Environment	0.231	0.151	0.944	57.82	58.04	0.22	Valid	Quite Sustainable
Multidimensional (Aggregation)	**1,000**	**0.141**	**0.949**	**74.40**	**74.66**	**0.26**	**Valid**	Quite Sustainable

Multidimensional Sustainability is an assessment of the sustainability status of fisheries management that cannot be done by looking at the average of the three dimensions used as indicators but must be done using a paired comparison test [10]. Pairwise comparisons must be made because each dimension assessed has a different weight. Based on the assessment that has been carried out, a weighted score is obtained, and the results of the pairwise comparison produce a weighting index value of 57,92 (see Table 4). This means that the tilapia processing industry activities at the research location are sustainable because the sustainable status value category is in the range 51–75. This happens because the availability of input supplies of raw materials seen from the lake's condition where Floating Net Cage tilapia is cultivated, as well as the tools and machines used in processing tilapia, still support the industry's sustainability. The potential for developing the tilapia industry in North Sumatra is still quite good, so its use is very profitable for actors involved in the sustainable tilapia chain. The tilapia fish processing business is very dependent on the ecology of the waters of Lake Toba, where ecology still plays a vital role in the availability and sustainability of the ecosystem that lives in it.

By understanding the interactions facilitated by value chain governance arrangements, we can determine their potential to drive changes in consumption and production practices that ultimately lead to sustainable fisheries [22]. Human institutions and social actors interact in complex governance processes to influence the sustainability of the tilapia industry [10], [18]. The overall results of a multidisciplinary analysis can be demonstrated using kite diagrams comparing different locations, periods (including future projections), and management scenarios, making policy trade-offs explicit. This enhancement is now available in the R programming language, and users can run Rapfish analysis by downloading the software. The research results show that the tilapia processing value chain in North Sumatra is included in the moderately sustainable category. This is shown in every sustainable dimension that has been analyzed, especially the ecological, economic, and social dimensions. The sustainable tilapia processing value chain strategy in North Sumatra can limit floating net cages by considering the environmental carrying capacity and is supported by good policies and active stakeholder participation in community-based legal institutions. Weak sustainability utility is limited to sustainability comparisons between fisheries. On the contrary, it was found that it is a strong sustainability concept if applied by implementing better governance and policy management in the tilapia industry value chain.

Based on Table 20, the economic dimension is ranked the most sustainable because it has increased by 0,34%. In comparison, the social and ecological dimensions have decreased by 0,11% and 0.22%, even though the tilapia processing industry is in the quite sustainable category. However, let us consider the sustainability thresholds we set for each dimension. The economic, social, and environmental dimensions are in a fairly good situation. Meanwhile, the multidimensional sustainability index is 74,40%, which shows that the value chain of the tilapia processing industry is quite sustainable. An illustration of these three dimensions can be seen in the kite diagram in Fig. 13. This image shows that the economic dimension dominates the kite diagram of the 3 (three) economic, social, and ecological dimensions in the value chain of the tilapia processing industry.

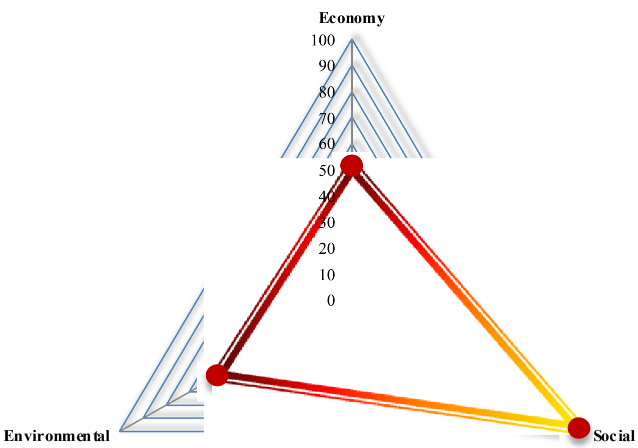

Fig. 13 Multi-dimensional kite diagram

IV. Conclusion

The sustainability of the tilapia processing value chain shows that the tilapia processing industry is currently considered quite sustainable, with a sustainability index of 74,40%. The sustainable tilapia processing value chain strategy in North Sumatra can limit floating net cages by considering the environmental carrying capacity and is supported by good policies and active stakeholder participation in community-based legal institutions. This research found this is a strong sustainability concept if implemented with better governance and policy management in the tilapia industry value chain.

This research aims to elucidate the sustainability model within the value chain of the tilapia processing industry in North Sumatra. The objective is to help all involved actors achieve ecological, economic, and social sustainability throughout the value chain. The study indicates that implementing Sustainable Value Chain Management in the tilapia processing industry will be more effective by focusing on the designed sustainability model.

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