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RESEARCH ARTICLE
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Sustainability Patterns of Coconut Agribusiness Systems in West Java Province, Indonesia

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ABSTRACT

The Sustainable Development Goals emphasize the use of local resources to contribute to economic growth while adhering to the principles of sustainability. This also applies to West Java Province, a region widely recognized for its coconut production. Therefore, this study aims to examine the sustainability of the coconut agribusiness system and to construct a sustainability pattern for coconut agribusiness. The research employs a mixed-method design with a quantitative dominance, involving 368 actors in the coconut agribusiness system in Pangandaran Regency, a central hub of coconut agribusiness in the province. Data were analyzed using the Multi-Dimensional Scaling method, while the sustainability patterns were developed through a systems thinking approach, presented in the form of a causal loop diagram. The findings reveal that the sustainability level of coconut agribusiness in West Java, assessed through five sustainability dimensions, is classified as moderately sustainable, with a sustainability index score of 51.72. The environmental dimension was identified as the most sensitive factor influencing sustainability, with an index score of 54.45. This is consistent with the reality that West Java's environmental conditions are highly favorable for coconut agribusiness activities, both at the on-farm and off-farm stages. Nevertheless, the analysis also indicates that further development of the coconut agribusiness system requires greater attention, particularly in addressing the relatively lower scores in the economic, social, institutional, and technological dimensions. Advancing this sector calls for the implementation of comprehensive sustainability patterns, supported by policy interventions that are inclusive and responsive to the needs of all coconut agribusiness stakeholders.

Keywords: Sustainability Pattern, Agribusiness System, Coconut, Multi-dimensional Scaling, System Thinking

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INTRODUCTION

To support the realization of the 17 Sustainable Development Goals (SDGs), it is essential to harness locally available resources such as coconut as part of Indonesia's broader sustainable development efforts. These efforts must span multiple dimensions and ensure that future generations retain the capacity to fulfill their own needs. Sustainable development, therefore, requires a balanced integration of economic, environmental, and social considerations. This includes sustaining quality of life over time, adopting resource-efficient practices, and ensuring the preservation of natural resources for the benefit of future generations (Khalid, 2002; Kanchan & Kumar, 2015 & Suardi et al., 2022).

First and foremost, the potential for sustainable coconut development must alleviate poverty (SDG 1) and hunger (SDG 2) so that its development can provide decent work and promote sustainable economic growth (SDG 8), by creating jobs, encouraging innovation and supporting entrepreneurship in the sector. As a commitment to responsible production and consumption (SDG 12), utilizing every part of the coconut can minimize waste and create a circular economy (Antonioli et al., 2022; Syahfitri et al., 2023). The potential of coconut, which is an important commodity in an effort to improve the country's

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economy, needs to be maximized in order to increase its usefulness (Allorerung et al., 2005; Arumugam & Hatta, 2022; Kinanda et al., 2022). Statistically, Indonesia, which has 99,083 km of coastline, is still the largest coconut producing country in the world until 2021 and then overtaken by the Philippines and India in 2022 (Ministry of Agriculture of the Republic of Indonesia, 2025). Indonesia's coconut production in 2023 reached 2,890,900 tons produced from 34 regions in Indonesia (Central Bureau of Statistics of Indonesia, 2024). Meanwhile, Indonesia ranks third as an exporter of coconut-derived products, but is still the 54th importer of coconut fruit in 2023 (Ministry of Agriculture of the Republic of Indonesia, 2025). Various Indonesian coconut derivative products have become export goods favored by many countries so that it can be understood that the prospect of coconut agribusiness is not only in the farming sub-system, but also in other sub-systems (International Labour Organization, 2013; Sukmaya, 2017). Recognizing the significant potential for coconut agribusiness development, the Government of the Republic of Indonesia, through the Ministry of Industry and Trade, has formulated a Coconut Downstream Roadmap 2025–2045 to serve as a strategic reference for policy implementation related to the coconut agribusiness sector (Ministry of Industry and Trade of the Republic of Indonesia, 2025). In addition, the Ministry of Agriculture, through the Palm Oil Plantation Fund Management Agency, has introduced a policy on coconut import tariff management, aiming to allocate funds for the rejuvenation of aging and less productive coconut trees (Ministry of Agriculture of the Republic of Indonesia, 2025). These efforts reflect the government's tangible commitment to improving the coconut agribusiness system in Indonesia and are expected to address the various challenges faced by stakeholders across the country.

Coconut production in Indonesia is produced by several center provinces where the largest coconut producing province in Indonesia is Riau Province, followed by North Sulawesi Province to West Java Province which is in tenth place out of 38 provinces in Indonesia. West Java Province's coconut production in 2023 reached 92,178 tons, with a planted area of 145,194 Ha. Despite the increase in production in 2023, the area of coconut planted in West Java Province decreased by 1.25 percent from the previous year. This is certainly a threat to the sustainability of coconut agribusiness in West Java Province (Central Bureau of Statistics of Indonesia, 2024). In fact, coconuts from West Java are known to have advantages both in terms of size and thickness of the pulp inside compared to coconuts produced from other provinces in Indonesia (Fadhilah et al., 2023).

One of the areas that has potential in the development of coconut agribusiness in West Java is Pangandaran Regency. Pangandaran Regency, which is located on the coast, is very suitable for coconut growth because it gets maximum sunlight intake and is the center of the coconut processing industry in West Java Province (Abidin et al., 2018; Supomo, 2007). Central Bureau of Statistics, (2024), noted that Pangandaran ranks third in West Java in terms of coconut plantation area, production level and productivity. Then, the coconut commodity plantation area in Pangandaran Regency in 2023 was 25,161 hectares, which was centralized in 5 areas, namely Kalipucang District, Sidamulih District, Parigi District, Cijulang District and Cimerak District. Coconut plantations in Pangandaran Regency are classified as smallholder plantations owned by 65,291 households (Central Bureau of Statistics, 2024). Most of these smallholder coconut plantations are located in the coastal area of Pangandaran Regency.

Although coconut production in Pangandaran Regency has increased in the last three years, changes in the behavior of coconut farmers in Pangandaran Regency that only look at economic aspects without paying attention to conservation aspects could threaten the sustainability and productivity levels of coconut in Pangandaran Regency. Based on the results of field research, coconut farmers in Pangandaran Regency recently saw that the pulai coconut commodity is more promising than the fruit. Therefore, there has been mass and excessive harvesting of janur without considering sustainability aspects over the past few months, which could threaten to reduce the productivity of the coconut fruit produced. Excessive harvesting of janur can cause several problems such as: decreased productivity due to nutrient depletion due to disrupted photosynthesis; decreased soil moisture levels due to reduced shade; disruption of the ecosystem due to disruption of the natural habitat of some animals that use janur as their home; and can threaten the sustainability of the agribusiness system and coconut industry due to decreased productivity (Vieira et al., 2024).

In addition, the downstream processing of coconut-based products in Pangandaran Regency and West Java Province in general still tends to focus primarily on the coconut sugar agroindustry (Abidin et al., 2018). This situation is further exacerbated by the fact that locally grown coconuts produced by farmers in Pangandaran Regency are less competitive compared to coconuts imported from various regions in Sulawesi and Sumatra, which are utilized by coconut processing industries in the area (Wadin et al., 2017). The various challenges observed across each sub-sector of the coconut agribusiness in West Java illustrate the fragmented nature of the current system. This disintegration is particularly evident in the lack of coordination and synergy among the agribusiness subsystems in Pangandaran Regency. In principle, an agribusiness system is an integrative framework comprising several interrelated components: (1) the input supply subsystem (upstream agroindustry), (2) the farming or production subsystem, (3) the post-harvest processing and agro-industrial subsystem (downstream agroindustry), (4) the marketing and trade subsystem and (5) the supporting institutional subsystem (Setiawan, 2012).

Each coconut agribusiness actor currently operates without a clear set of guidelines or references, resulting in decision-making that is often speculative and lacks careful consideration. Such conditions could be avoided if there were a well-defined interconnection among all stakeholders involved in the coconut agribusiness in West

Java Province—what can be referred to as a sustainability pattern of the coconut agribusiness system. This sustainability pattern represents a holistic system that integrates multiple aspects, including environmental, social, and economic factors, and is assessed through five sustainability dimensions: economic, environmental, social, technological, and institutional (Saragih et al., 2020; Setiawan et al., 2023). The development and implementation of such a pattern naturally require the active involvement of multiple parties, particularly the government, which plays a crucial role in formulating policies and strategic frameworks.

According to Sukmaya (2017), the coconut agribusiness system holds considerable potential for holistic development in production centers due to the abundance of raw materials. Moreover, optimizing these resources can significantly enhance the economic conditions of local communities. This, in turn, can foster innovation and help meet global demand for coconut-derived products (Martinez, 2013; Grass Ramírez et al., 2023). Consequently, any development efforts must adopt a systems-based approach, utilizing a helicopter view to examine all subsystems comprehensively and applying a multidimensional perspective (Setiawan et al., 2023). This includes the coconut agribusiness system in Pangandaran Regency. To date, studies on coconut in Indonesia have largely concentrated on a few themes such as value and supply chains, agro-management practices, and innovations and technologies in coconut agribusiness. This study seeks to assess the sustainability level of the coconut agribusiness sector in West Java Province by examining five core dimensions of sustainable agricultural development: economic, social, environmental, technological, and institutional. It specifically focuses on identifying the most influential attributes affecting sustainability. The analysis results will serve as the foundation for designing sustainability patterns for the coconut agribusiness system in West Java Province. This pattern is expected to address issues across each agribusiness subsystem. Ultimately, the findings aim to offer strategic insights to improve both the quantity and quality of coconut production, thereby contributing to the betterment of coconut farmers' livelihoods in Indonesia, particularly in West Java.

MATERIALS & METHODS

Research Design

This study is a positivistic paradigm, quantitative mixed methods design using survey methods conducted to evaluate the sustainability of coconut agribusiness systems in West Java, Indonesia. The analysis was conducted using Multi-Dimensional Scaling (MDS), which was specifically adapted for use in the context of coconut agribusiness through the Rapid Appraisal Coconut Agribusiness (RAPCA) technique. This method is derived from the Rapid Appraisal Technique for Fisheries (RAPFISH) approach, which was adopted from fisheries sustainability studies and has been modified to fit the context of the agribusiness system in this study (Haya et al., 2020; Martias et al., 2023; Yamin et al., 2025).

Research Location

This research is located in Pangandaran Regency as one of the centers of coconut production and coconut processing agro-industry centers in West Java Province (Ministry of Industry of the Republic of Indonesia, 2025). Cimerak District and Padaherang District were chosen as the focus of the research location considering that the two districts are areas with the largest number of coconut agribusiness actors in Pangandaran Regency, both in the on-farm and off-farm subsystems (Central Bureau of Statistics, 2024).

Sampling Strategy

The selection of the research location was carried out using the Cluster Random Sampling technique, based on the consideration that Pangandaran Regency is among the regions with the highest number of coconut agroindustry producers and the largest production volume in West Java Province (Central Bureau of Statistics, 2024). Subsequently, Cimerak District was selected due to its status as the area with the highest number of off-farm subsystem actors in the regency, while Ciherang District was chosen because it has the largest number of coconut farmers in Pangandaran Regency (Central Bureau of Statistics, 2024). The study population consisted of 8,358 individuals, comprising 5,802 on-farm subsystem actors (Padaherang District: 3,154; Cimerak District: 2,648) and 2,556 off-farm subsystem actors (Cimerak District: 1,877; Padaherang District: 679), as reported by the Department of Agriculture and Plantation of Pangandaran Regency (2023). The sample size was determined using the Krejcie and Morgan formula, with a margin of error set at 5 percent (0.05), resulting in a sample size of 368 respondents. A simple random sampling technique was then applied to allocate the sample proportionally across the districts based on their classification as on-farm and off-farm actors (Creswell & Hirose, 2019). As a result, the sample included 139 on-farm actors and 30 off-farm actors from Padaherang District, and 99 on-farm actors and 100 off-farm actors from Cimerak District. In addition, eight key informants were selected purposively (Creswell & Hirose, 2019), including the Head of the Agriculture Office, the Head of the Industry and Trade Office, the Head of the Cooperatives and MSMEs Office, a representative of Agricultural Extension Officers (PPL), a representative of farmer group leaders, a representative of agricultural input suppliers, a representative of coconut processing agroindustry owners, and a representative of coconut traders in Pangandaran Regency.

Variable and Indicators

This study employs a set of variables categorized under five key dimensions: economic, social, environmental, technological, and institutional. As outlined in Table 1, each dimension is assessed through specific indicators that have been adapted from established literature to align with the characteristics of the coconut agribusiness system (Rasihen et al., 2021).

Table 1: Variable Description

Variable/Dimension	Attributes/ Indicators	Score	Good	Bad	Category
Economic Dimension	productivity	1,2,3,4,5	5	1	1= Very Low
	Income	1,2,3,4,5	5	1	2= Low
	access to product inputs	1,2,3,4,5	5	1	3= Medium
	market access	1,2,3,4,5	5	1	4= Good
					5= Very good
Social Dimension	regeneration of agribusiness actors	1,2,3,4,5	5	1	1= Very Low
	intensity of participating in empowerment activities	1,2,3,4,5	5	1	2= Low
	education level	1,2,3,4,5	5	1	3= Medium
	conflict resolution	1,2,3,4,5	5	1	4= Good
					5= Very good
Environmental Dimension	environmental awareness	1,2,3,4,5	5	1	1= Very Low
	infrastructure access	1,2,3,4,5	5	1	2= Low
	waste management	1,2,3,4,5	5	1	3= Medium
					4= Good
					5= Very good
Technology Dimension	access to production technology	1,2,3,4,5	5	1	1= Very Low
	access to market information	1,2,3,4,5	5	1	2= Low
	use of e-commerce technology	1,2,3,4,5	5	1	3= Medium
					4= Good
					5= Very good
Institutional Dimension	access to agribusiness groups	1,2,3,4,5	5	1	1= Very Low
	access to financial institutions	1,2,3,4,5	5	1	2= Low
	government support	1,2,3,4,5	5	1	3= Medium
	business cooperation	1,2,3,4,5	5	1	4= Good
					5= Very good

Data Collection

Primary data were collected using structured questionnaires that had been tested for validity and reliability and Focus Group Discussions (FGD) to obtain qualitative data to construct patterns of sustainability of coconut agribusiness systems. Secondary data were obtained from government statistics, academic publications, and agency reports. Field research was conducted between May and August 2024, with interviews facilitated by trained enumerators to ensure consistency of data collection.

Analysis Techniques

a. Multi-Dimensional Scaling (MDS): MDS was used to calculate the sustainability index for each dimension on the sustainability of coconut agribusiness systems (Kruskal & Wish, 1978). Scores are normalized on a scale from 0 to 100, with the following categories: 0-25 (Poor), 26-50 (Less Sustainable), 51-75 (Moderately Sustainable), and 76-100 (Highly Sustainable) (Yusuf et al., 2021).

b. Leverage Analysis: To identify the attributes most sensitive to sustainability, leverage analysis was performed. This analysis measures the impact of removing specific attributes on the overall sustainability score, thereby identifying key areas for improvement (Pitcher & Preikshot, 2001a).

c. Monte Carlo Simulation: Monte Carlo simulations were conducted to test the robustness of the MDS results against uncertainty (Metropolis & Ulam, 1949). This approach estimates confidence intervals for sustainability indices and ensures that random errors do not significantly impact the findings.

d. Goodness-of-Fit Test: Goodness-of-fit for the MDS analysis was evaluated using the S-Stress value and R^2. S-Stress values below 0.25 and R^2 values above 0.90 indicate a strong model (Yusuf et al., 2021).

e. System Thinking: The system thinking approach is an approach that recognizes the interdependent and interrelated relationships of the elements in a system. The diagram used in system thinking is called a Causal Loop Diagram (CLD). Each causal relationship is assigned a polarity, positive (+) or negative (-). A positive sign indicates a unidirectional change, while a negative sign indicates an opposite condition (Richardson, 1986; Sterman, 2000). This analysis was conducted to design the sustainability pattern of the coconut agribusiness system.

Multi-Dimensional Scaling (MDS), developed by the Fisheries Center at the University of British Columbia, was utilized to analyze the sustainability of the coconut agribusiness in West Java Province. Quantitative descriptive analysis was also employed to interpret the results of the study. The economic, social, environmental, technological, and institutional dimensions were adapted with sustainability indicators relevant to the coconut agribusiness system in West Java using the RAP-CA (Rapid Appraisal Coconut Agribusiness) technique. This method is a modification of the Rapid Appraisal Technique for Fisheries (RAPFISH) framework (Pitcher & Preikshot, 2001b; Kavanagh & Pitcher, 2004). The modification involved developing or adjusting the indicators within each dimension to align with the specific system, topic, and scope of the research related to the coconut agribusiness system.

The sustainability assessment using the RAPCA approach begins with the process of reviewing, identifying, and defining the relevant indicators. Following this, each indicator is scored according to the criteria established within the RAPFISH methodology. Data analysis, which includes Multidimensional Scaling (MDS), leverage analysis, and Monte Carlo simulation, is conducted using Rapfish version 3.1, which can be obtained from the official RAPFISH website (www.rapfish.org). This software functions as an add-in to Microsoft Excel and facilitates data processing. The scoring data for the indicators are organized in a Rap Scores matrix within an Excel worksheet, which serves as the input for the analysis

carried out by the software.

The output of this analysis is a coconut agribusiness sustainability index based on the five dimensions analyzed, which is then described in the form of a score on a scale of 0-100 and depicted in a kite diagram. The sustainability index is then used as a reference to determine the level of sustainability within predetermined categories (Table 2).

Table 2: Sustainability Level Categories Based on the Results of the Rap-Coconut Agribusiness Index

Index Values	Category
0 – 25	Poor (Unsustainable)
25,01 – 50	Poor (Less Sustainable)
50,01 – 75	Fair (Moderately Sustainable)
75,01 – 100	Good (Very Sustainable)

Source: Saragih et al. (2020).

The MDS analysis also yields the S-Stress value (Standardized Residual Sum of Squares) and the coefficient of determination (R^2), both of which serve as indicators of model fit. These metrics help determine whether the current set of attributes adequately represents each analyzed dimension or whether further attributes are needed. A lower S-Stress value signifies a better model fit, whereas a higher value suggests poor fit (Zou, 2023). Generally, an MDS model is considered acceptable if the S-Stress is below 0.25 and the R^2 approaches 1.00 (or 100%), indicating that the attributes account for nearly all variance in the model.

Leverage analysis is employed to identify how each attribute influences the overall sustainability score, thereby highlighting which attributes are most sensitive (Groen et al., 2017; Mawarsari & Noor, 2020). Following this, Monte Carlo simulation is utilized to assess the extent to which random variability may affect the outcomes across all dimensions (Hu, 2024). This method estimates uncertainty at a 95% confidence level, effectively quantifying the potential error in the analysis (Cunha et al., 2014; Sanz-Alonso & Al-Ghattas, 2024). The results of the Monte Carlo simulation are then compared to those of the MDS analysis; the closer the two values, the lower the error margin in the MDS results.

RESULTS

The agribusiness sector is one of the factors in supporting global economic development. The sustainability of the agribusiness sector is one of the prerequisites for economic sustainability, poverty alleviation and efforts to ensure global food security (World Bank, 2019; FAO, 2020; & OECD, 2021). This certainly includes the sustainability of coconut agribusiness in West Java Province. This study evaluated the sustainability of coconut agribusiness in West Java Province using the RAP-Coconut Agribusiness (RAPCA) approach, which integrates five key dimensions: economic, social, environmental, technological, and institutional. The analysis employed several statistical measures, including Monte Carlo simulation, S-Stress, and R^2 values, to assess model reliability. According to the RAPABS analysis, the model's fit was determined by the S-Stress and R^2 indicators, which signify the robustness of the analysis (Zhen & Routray, 2003).

Table 3 shows that the S-Stress values range from 0.18 to 0.20, while the coefficient of determination (R^2) values range from 0.91 to 0.93. This indicates that the suitability criteria in the RAPCA analysis have been satisfactorily met. A high R^2 value signifies that the selected attributes effectively account for and contribute to the sustainability of the system under investigation. Moreover, the acceptable S-Stress range implies that the attribute configuration reliably represents the original data set. This confirms that the analyzed indicators are statistically valid and can be confidently interpreted. Consequently, the indicators used are deemed compatible with the model applied in this study. In other words, a value approaching 100 percent reflects that the model is capable of accurately explaining the observed data (Yusuf et al., 2021).

Table 3: Results (Goodness of fit) from RAPCA Analysis and Sustainability Status of Coconut Agribusiness

Criteria	MDS	Monte Carlo	Selisih	S-Stress	R^2
Multidimensi	51.72	50.99	0.73	0.18	0.93
Economy	50.40	50.06	0.34	0.18	0.92
Social	48.80	47.42	1.38	0.19	0.92
Environment	54.45	52.40	2.05	0.20	0.91
Technology	53.61	52.78	0.83	0.20	0.91
Institutional	53.03	52.45	0.58	0.19	0.92

Based on the results of the multidimensional RAPCA analysis presented in Table 3 and analyzed using the Multidimensional Scaling (MDS) method in Fig. 1, the coconut agribusiness sustainability index in West Java Province was calculated at 51.72. This score falls within the range of 51 to 75, classifying it as 'moderately sustainable.' The analysis yielded an S-Stress value of 0.18 and an R^2 value of 0.93, indicating a reliable model fit. The index reflects the integrated assessment across five key dimensions: economic, social, environmental, technological, and institutional.

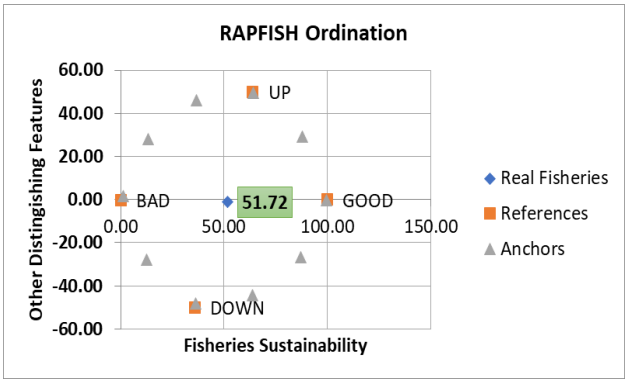


Fig. 1: Sustainability Index of Coconut Agribusiness in West Java Province.

The sustainability index for each dimension is illustrated using the radar diagram (Fig. 2). In this visualization, a point located further from the center (zero) indicates a higher level of sustainability, whereas points nearer to the center suggest lower sustainability levels. Commonly referred to as a radar or spider chart, this diagram effectively displays the relative performance of each dimension. As shown in Fig. 2, the social dimension registers the lowest sustainability index, followed by the

economic and institutional dimensions. In contrast, the technological and environmental dimensions exhibit the highest index values. The radar chart offers an integrated view of the sustainability status of coconut agribusiness in West Java Province, encompassing five key dimensions: economic, social, environmental, technological and institutional. A more detailed breakdown of the sustainability scores for each dimension is provided in Fig. 3.

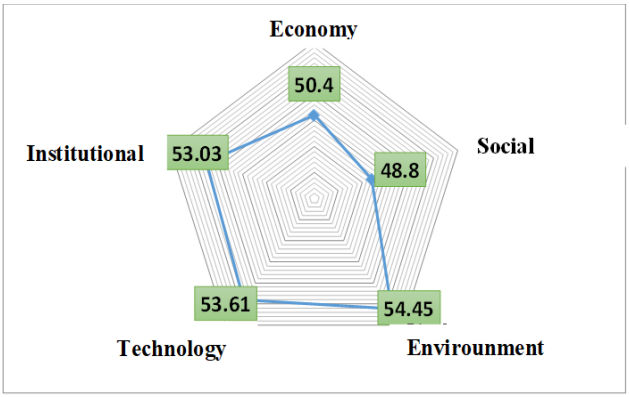


Fig. 2: Kite Diagram of Coconut Agribusiness Sustainability Index in West Java Province.

The sustainability of each dimension in this study is evaluated through a range of specific attributes. In addition, (Fig. 4) presents the results of the sensitivity analysis, highlighting the most influential attributes across the five dimensions used to assess the sustainability of coconut agribusiness in West Java Province.

DISCUSSION

Economic Dimension

The economic aspect plays a pivotal role in assessing the sustainability of coconut agribusiness in West Java Province. The economic dimension has a sustainability value of 50.40, thereby falling into the moderately sustainable category. Based on the RAPCA analysis, five key attributes are used to evaluate this dimension: (a) productivity, (b) income, (c) access to production inputs, and (d) market access. The sensitivity analysis, conducted through the leverage method in Rapfish software, reveals that among these attributes, two stand out as the most influential in determining sustainability. As illustrated in Fig. 4, access to production inputs (RMS = 5.52) and productivity (RMS = 5.18) demonstrate the highest sensitivity levels. According to Pawiengla et al. (2020), a higher leverage value indicates a stronger influence of the attribute on sustainability outcomes. These findings highlight the importance of prioritizing improvements in access to inputs and productivity to enhance the economic sustainability of coconut agribusiness in the region.

Based on the results of the analysis, 44 percent of respondents considered that the economic dimension was in the good enough category and the rest were scattered in other answers. However, 40 percent of respondents have chosen the good and very good answer categories when accumulated. The reality in the field shows that so far the productivity of businesses carried out by coconut agribusiness actors in West Java Province is still fluctuating, depending on capital and the availability of raw materials or production inputs. Various problems occur in each agribusiness actor in each sub-system. Production input providers often complain about business capital, cultivation actors have complaints about the availability of production inputs and their prices such as fertilizers and coconut tree seeds, production processing actors experience problems in the provision of production inputs because the number is still limited and not all cultivators sell their products in the same area, besides marketing actors also complain about product availability and price fluctuations due to fluctuating product availability.

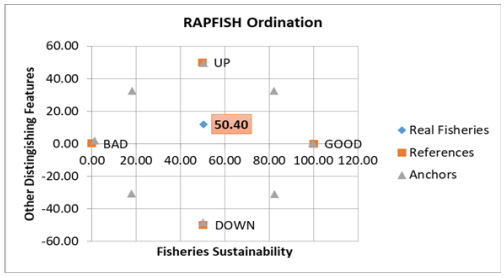
Social Dimension

The social dimension plays a crucial role in the successful development of coconut agribusiness in Pangandaran Regency. It serves as a foundational pillar for sustainable development, significantly influencing rural advancement and the reduction of poverty, as highlighted by Zhang et al. (2022). Utilizing RAPFISH software, the sustainability analysis focusing on social factors yielded an index score of 48.80 across all evaluated attributes. This score places the social sustainability of coconut agribusiness in West Java Province within the category of unsustainability, consistent with the classification range of 50 to 75 reported by Saragih et al. (2020). This research examines four key attributes to assess sustainability in the region's coconut agribusiness sector: (a) the regeneration of agribusiness actors, (b) the degree of participation in empowerment programs, (c) education levels, and (d) mechanisms for conflict resolution.

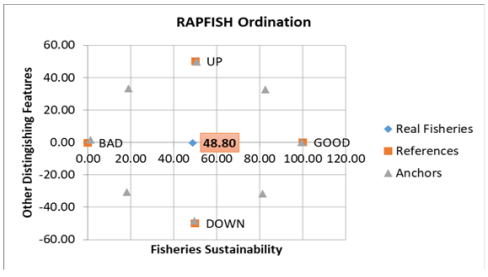
The sensitivity analysis (leverage) performed on the four social dimension attributes reveals that two attributes exhibit the highest leverage values, as illustrated in Fig. 4. Specifically, the attributes exerting the greatest influence on the sustainability status of the social dimension are the intensity of involvement in empowerment activities, with an RMS value of 2.39, followed closely by the education attribute, which has an RMS value of 2.31. This can be seen from the reality in the field where the reality in the field shows that coconut agribusiness actors in Pangandaran Regency have participated in various empowerment activities related to their business, both related to business management and related to increasing their business productivity.

Environmental Dimension

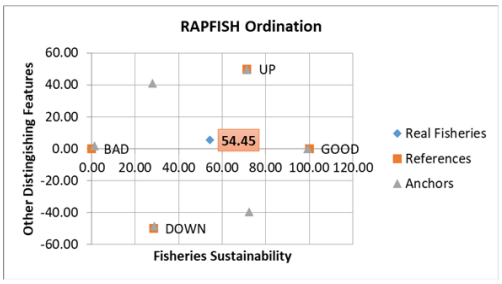
Sustainable natural resource management must maintain its original function while meeting the criteria of eco-efficiency, which is economically and environmentally efficient. (Muscalu et al., 2016; Hook & Marcantonio, 2022 & Prakash et al., 2023). The sustainability of coconut agribusiness within the environmental dimension was evaluated through three key attributes, which were examined using RAPCA analysis: (a) environmental awareness, (b) accessibility to infrastructure, and (c) waste management practices. The analysis results of the environmental sustainability dimension using the RAPFISH software across all attributes revealed a sustainability index



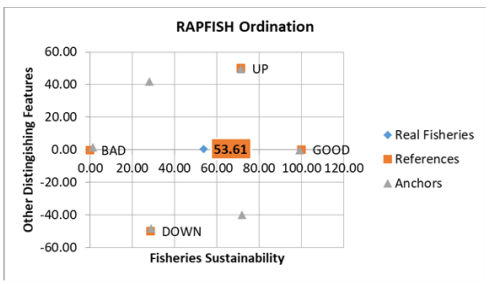
Economic Dimension Sustainability Status



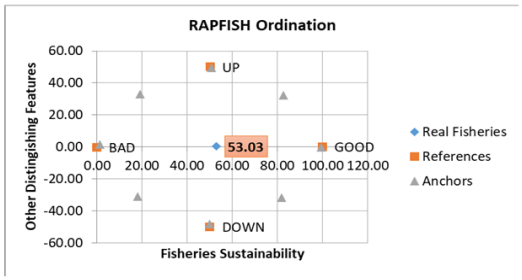
Social Dimension Sustainability Status



Environmental Dimension Sustainability Status

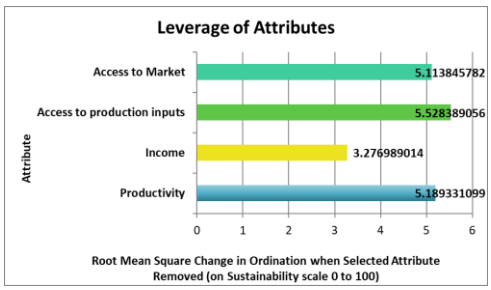


Technology Dimension Sustainability Status

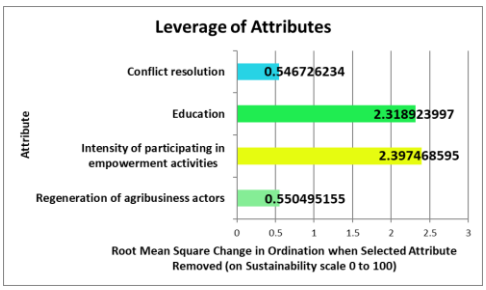


Intitutional Dimension Sustainability Status

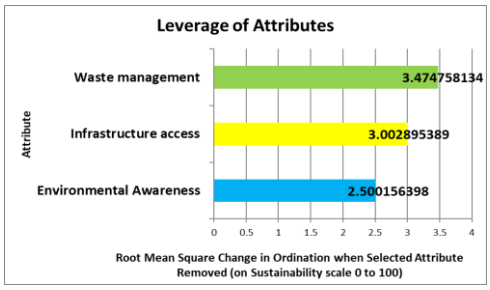
Fig. 3: Sustainability Status of Each Dimension.



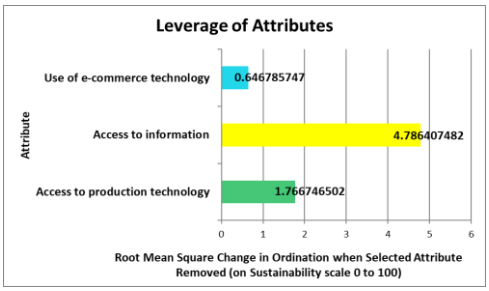
Result of Economic Dimension Leverage Attributes



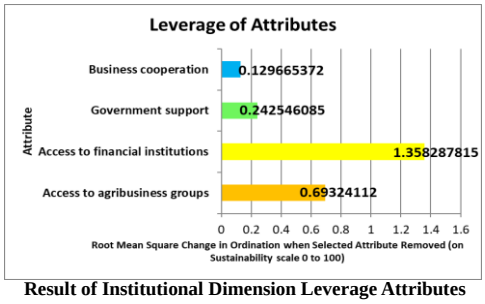
Result of Social Dimension Leverage Attributes



Result of Environmental Dimension Leverage Attributes



Result of Technology Dimension Leverage Attributes



Result of Institutional Dimension Leverage Attributes

Fig. 4: Results of Each Dimension Based on Leverage Value.

score of 54.45. This score places the environmental dimension within the "moderately sustainable" category, as it falls within the 50 to 75 range (Saragih et al., 2020).

The leverage analysis results reveal that the sustainability factors most significantly impacting the environmental dimension are waste management, which has an RMS value of 3.47, followed by infrastructure access, with an RMS value of 3.00. Coconut is a type of commodity that has a high usefulness so that all parts can be reused and not become waste. Therefore, the majority of coconut agribusinesses do not produce wasted waste so that they can be reprocessed into other types of products.

Technology Dimension

The sustainability of the technology aspect within coconut agribusiness in West Java Province is evaluated through the extent of technology adoption and usage. Technology plays a crucial role in promoting sustainable development in coconut agribusiness by enhancing operational efficiency and facilitating business processes. To assess this sustainability dimension, three key indicators are examined: (a) availability of production technology, (b) access to market information, and (c) implementation of e-commerce platforms. The analysis results of the technological dimension of sustainability using RAPFISH software indicate that the sustainability index score for this dimension is 53.61. This score falls within the range of 50 to 75, which classifies it as moderately sustainable, in accordance with the categorization outlined by Saragih et al. (2020).

Based on the leverage analysis, it is known that there are two attributes that most sensitively affect the sustainability of the technology dimension as presented in (Fig. 4), namely access to market information and access to production technology. In reality, coconut agribusiness actors are very active in seeking various market information by socializing through social media. Agribusiness actors have social media groups that are used to exchange information with each other. In addition, the majority of agribusiness actors already have machine technology to assist in the implementation of their business production.

Institutional Dimension

The sustainability of coconut agribusiness in Pangandaran Regency, within the institutional dimension, is evaluated based on four key attributes: a) accessibility to agribusiness groups, b) accessibility to financial institutions, c) support from government agencies, and d) business partnerships. The analysis results of the institutional sustainability dimension using the RAPFISH software indicate that the sustainability index score for this dimension is 53.03. Based on the classification range of 50–75 (Saragih et al., 2020), this score places the institutional dimension in the moderately sustainable category.

Among the four attributes examined, access to financial institutions emerges as the most critical factor, evidenced by an RMS value of 1.35. This finding indicates that enhancing the sustainability of the institutional dimension requires careful attention and prioritization of this particular attribute. So far, access to financial institutions has been carried out by several coconut agribusiness actors in Pangandaran Regency through the People's Business Credit (KUR) scheme. Coconut agribusiness actors feel that the existence of financial institutions that provide capital loans is a solution to the business capital problems they experience.

Sustainability Pattern of Coconut Agribusiness System in West Java Province

The results of the sustainability analysis show that the development of coconut agribusiness system in West Java Province has great potential related to natural resources, human resouces, land, climate, high demand, high supply, institutional, product inputs, processing industry, infrastructure (Fig. 5). However, in its development there are still various problems that have been revealed based on the analysis of the five dimensions of sustainability, namely related to system integration, price, capital, market, technology, impatience, supply chain, cooperation, empowerment, policy, input prices, local breeders, credit access, regeneration, waste, pests, promotion (Fig. 5). Therefore, it is necessary to develop a pattern of sustainable development of the coconut agribusiness system to ensure the achievement of each of the development goals that have been proclaimed.

The idea of developing the sustainability of the coconut agribusiness system in West Java Province is inseparable from the five dimensions considered in looking at its sustainability. To achieve economic, environmental, social, technological and institutional sustainability, there needs to be continuity between economic systems, social systems and ecological systems that are intertwined in every coconut agribusiness activity (B1, R1). The primary key to ensuring connectivity among the three components of the system lies in strengthening the social system connectivity of coconut agribusiness actors. Enhancing social capital particularly in terms of trust and shared norms will lead to improved interactions among stakeholders within each subsystem and across the broader coconut agribusiness system. This, in turn, will foster a more extensive transfer of knowledge, innovation, and technology (Setiawan et al., 2025).

Holistic collaborative efforts need to be made in the aspects of technology dissemination, climate change mitigation, strengthening social capital and education and empowerment of actors involved in it. This can be done by increasing the knowledge and skills of coconut agribusiness system actors as a counterweight to progress in other aspects (R2). An improvement in the social system is likely to lead to enhanced interactions and knowledge transfer, which in turn contributes to the adoption of innovation (Ali et al., 2023). Once this condition is achieved, it is expected to positively influence both ecological and economic systems, particularly by raising awareness of the importance of sustainable production environments. This increased awareness may subsequently result in higher productivity and long-term business profitability.

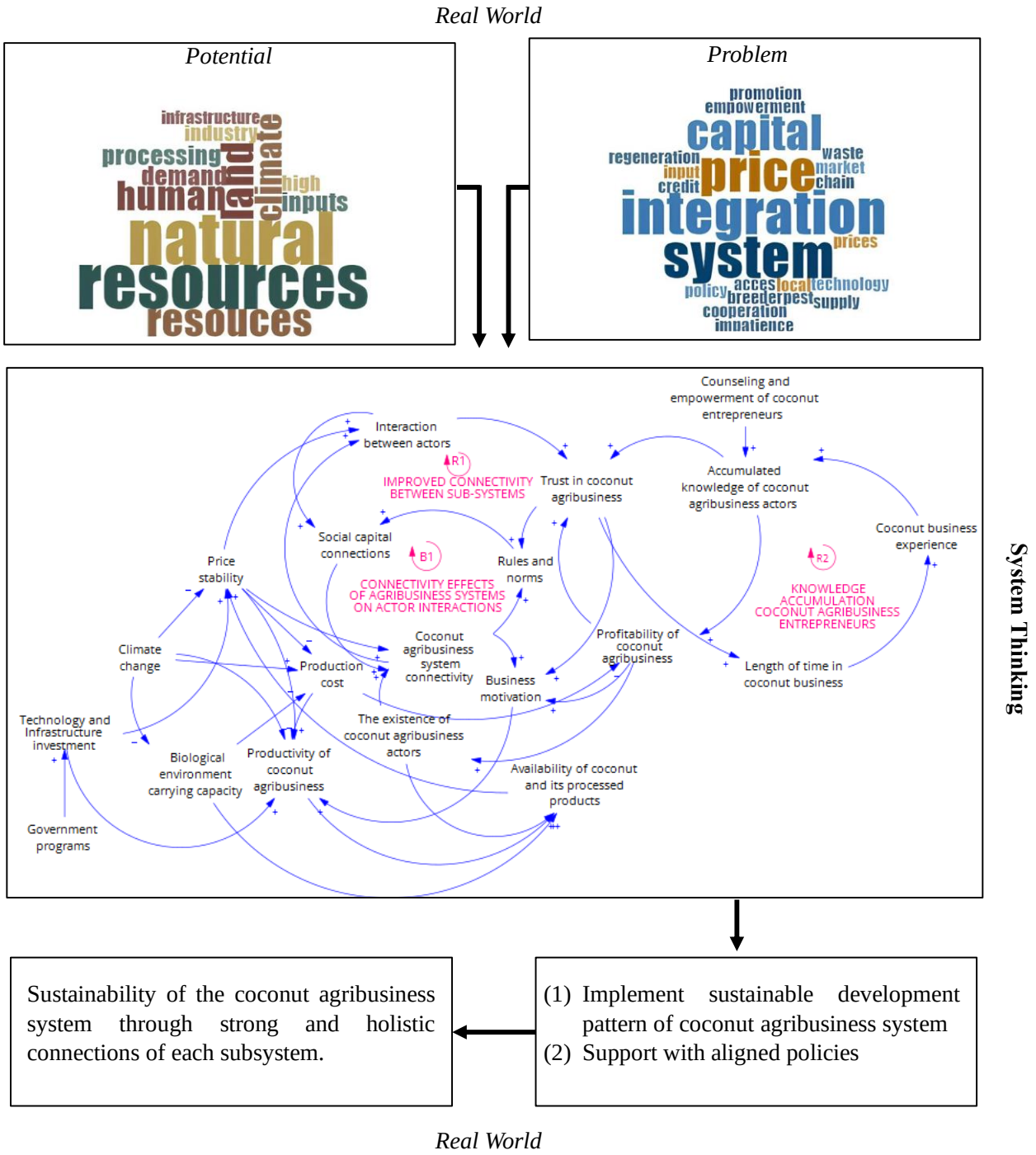


Fig. 5: Sustainability Pattern of Coconut Agribusiness System in West Java Province.

In addition, the sustainability of the coconut agribusiness system is also largely determined by the economic decisions taken by coconut agribusiness actors as a feedback or response to the economic system, ecological system and social system that runs, because in the end, it is almost impossible to separate economic aspects from social and environmental aspects (Heryanto & Nugraha, 2018). Implementation of the pattern that has been designed is expected to have an impact on improving the connection of a sustainable coconut agribusiness system in West Java Province which of course must be supported by various policies that favor each actor contained in the system. As highlighted in the studies conducted by Arulraj et al., (2018); Dissanayaka et al., (2023), an established coconut agribusiness system must be supported by favorable policies and strong decision-making capacities from all actors involved across its various sub-systems. This approach has been effectively implemented in countries such as Thailand, Sri Lanka, and India. Achieving similar outcomes in West Java Province requires collaborative efforts and strong commitment from multiple actors, including pentahelix stakeholders and all participants engaged in the coconut agribusiness ecosystem.

Conclusion

The sustainability of coconut agribusiness in West Java

Province, evaluated through five key dimensions economic, social, environmental, technological, and institutional falls within the category of moderate sustainability. Among these dimensions, the environmental aspect exerts the strongest impact on the overall sustainability status, followed in descending order by technological, institutional, economic, and social dimensions, with the latter showing the least influence. Within the environmental dimension, waste management emerges as the most critical factor, reflecting partial adoption of green, blue, and circular economy principles by coconut agribusiness stakeholders in the region. In terms of technology, access to market information concerning commodity prices and market trends represents the most influential attribute. For the institutional dimension, the pivotal attribute is accessibility to financial institutions, while access to production inputs holds the greatest significance in the economic dimension. Lastly, participation intensity in empowerment programs is identified as the key sensitive attribute in the social dimension. Given these findings, addressing the various dimensions and their sensitive attributes is essential for enhancing the sustainability of coconut agribusiness in West Java. Improvements should be operationalized through a comprehensive agribusiness system framework, supported by policies that accommodate the needs of all actors involved in the sector.

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