



How Sustainable is the Silk Weaving Agroindustry? Evidence from Wajo Regency, South Sulawesi, Using Multi-Dimensional Scaling

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Abstract: This study evaluates the sustainability level of the silk weaving agroindustry in Wajo Regency, South Sulawesi, using a Multi-Dimensional Scaling (MDS) approach across four dimensions: economic, social, environmental, and resource based. Data were collected from 86 silk weaving agroindustry units through surveys and structured interviews. The results show that the overall sustainability status is classified as moderately sustainable, with sustainability index values of 72% (economic), 68% (resource), 64% (social), and 53% (environmental). The economic dimension demonstrates the strongest performance, reflecting relatively stable profitability and market accessibility, while the environmental dimension exhibits the lowest score, indicating weaknesses in waste management practices, the adoption of environmentally friendly materials, and environmental standards. These findings highlight environmental management as the main leverage point for improving overall sustainability. This study contributes to applied sustainability science by providing a quantitative, multidimensional assessment framework for traditional agroindustries and offers empirical evidence to support sustainability-oriented policy formulation and the strategic development of local silk weaving enterprises.

Keywords: Business sustainability; Multi-dimensional scaling; Silk weaving agroindustry; Sustainability assessment

Introduction

Sustainability has become a central issue in the development of small- and medium-scale agroindustries, particularly those based on local resources and traditional production systems. Business sustainability is closely related to an enterprise's ability to maintain economic viability, ensure the social welfare of its workforce, and minimize negative environmental impacts. In the textile sector, sustainability challenges have become increasingly significant due to high resource intensity, labor dependency, and environmental pressures generated by production activities (Karim et al., 2024; Abuzawida et al., 2023).

Indonesia has a long tradition in the silk weaving industries that not only possesses cultural value but also serve as an important source of livelihood for rural communities (Suryanti et al., 2023; Halide et al., 2023). In South Sulawesi, the silk weaving agroindustry plays a strategic role in supporting local economic development through job creation and income generation (Tenriawaru et al., 2021). Wajo Regency, widely known as the "Silk City," is the main center of silk weaving activities and contributes significantly to national silk production (Andadari et al., 2022; Sulolipu et al., 2022). However, despite its high economic and cultural value, the sustainability of silk weaving enterprises in this region remains vulnerable.

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Various sustainability challenges continue to affect the silk weaving agroindustry. From an economic perspective, business sustainability is constrained by fluctuations in raw material availability and dependence on imported silk yarn, which increase production costs and business uncertainty (Sashikumar, 2015; Sulolipu et al., 2022). From a social perspective, the industry relies heavily on female labor, yet faces issues related to relatively low wages and limited workforce regeneration (Kumar et al., 2023; Ashar et al., 2024a; Sahin, 2025). Meanwhile, from an environmental perspective, inadequate management of production waste and the use of less environmentally friendly materials pose potential risks of environmental pollution (Sutikno et al., 2024; Fatimah et al., 2024). These conditions indicate the need for an integrated assessment of business sustainability.

Therefore, evaluating sustainability performance is essential to understand the current condition of silk weaving enterprises and to determine priority areas for improvement. The Multi-Dimensional Scaling (MDS) approach has been widely applied to assess sustainability levels in various agroindustries, as it enables the simultaneous integration of multiple sustainability dimensions (Sriwana et al., 2021; Widiastuti et al., 2024). This study aims to analyze the sustainability level of silk weaving agroindustry enterprises in Wajo Regency based on economic, social, environmental, and resource dimensions using the MDS approach.

Method

Multi-Dimensional Scaling (MDS) is proposed to conduct a sustainability analysis of the supply chain. MDS was first proposed by Pitcher et al. (2001) to analyze the sustainability status of fisheries. The advantage of using MDS is its ability to analyze sustainability performance, including a simple and comprehensive approach, allowing for non-metric data, and being capable of processing both qualitative and quantitative data, which aligns with a multi-criteria assessment approach (Safriyana, 2024). The following are the MDS stages:

- a) Calculate the MDS ordination using the Euclidean distance (d) according to equation 1.

$$d = \sqrt{(X1 - X2)^2 + (Y1 - Y2)^2} \tag{1}$$

- b) The Euclidean distance value is then approximated using regression (dij) as formulated in Equation 2.

$$d = a + \beta\delta_{ij} + \epsilon \tag{2}$$

- c) After that, the regression process is carried out, which will optimize the squared distance (dij) to the origin (Oijk), which is in three-dimensional space (i, j, k). To determine the accuracy of the analysis, after the ordination is carried out, the Goodness of Fit is determined based on the S Stress value calculated from the S-Stress and R2 values through Equation 3.

$$S = \sqrt{\frac{1}{m} \sum_{k=1}^m \left| \frac{\sum_i \sum_j (d_{ijk}^2 - o_{ijk}^2)^2}{\sum_i \sum_j o_{ijk}^2} \right|} \tag{3}$$

- d) Sensitivity analysis was conducted to assess leverage and uncertainty using the Monte Carlo method. Leverage analysis aims to identify the impact of each indicator on sustainability performance, calculated using the root mean square error.

The output variable produced is a single value in the range of 0 - 100 that represents the sustainability index of the textile fiber supply chain. The range of values for the textile fiber supply chain sustainability index is presented in Table 1.

Table 1. The Values and Categories for Sustainability (Kavanagh & Pitcher, 2004)

Sustainability value	Category
0 - 24.99	Unsustainable
25 - 49.99	Less sustainable
50 - 74.99	Moderately sustainable
75 - 100	Sustainable

Data Collection

Respondents for measuring the sustainability level and multidimensional aggregate index of the silk woven fabric agro-industry supply chain were recruited from 86 agroindustry units, consisting of three medium scale agro-industries and 83 small-scale agro-industries, selected using a proportional sampling approach.

This study was conducted from April to June 2025 in Wajo Regency, South Sulawesi. This location was purposively selected (Mukhlis et al., 2019; Mukhlis et al., 2024; Asgaf et al., 2025), because it is known as one of the main centers of the silk textile agro-industry in Indonesia, contributing approximately 70% to total national silk production (Muin & Isnain, 2019; Halide et al., 2025).

Table 2. Sustainability Attributes

Dimension	Code	Attribute
Economic (E)	E1	Production loss
	E2	Supply chain agility
	E3	Net profit
	E4	Profit margin
	E5	Return on investment (ROI)
	E6	Market accessibility
	E7	Lead time flexibility
	E8	On-time delivery

Dimension	Code	Attribute
Social (S)	E9	After-sales service
	S1	Institutional support
	S2	Supply chain infrastructure
	S3	Corporate social responsibility (CSR)
	S4	Workforce skill improvement
	S5	Occupational health and safety
	S6	Social and cultural norms
	S7	Wages
	S8	Percentage of local labor involvement
Environmental (N)	N1	Noise level
	N2	ISO 14001 certification
	N3	Environmentally friendly raw materials
	N4	Environmentally friendly packaging
	N5	Environmental performance evaluation
	N6	Inventory of hazardous-free materials
	N7	Hazardous waste
Resource (R)	R1	Resource accessibility
	R2	Workforce competence
	R3	Raw material quality
	R4	Raw material availability
	R5	Availability of traditional and modern looms
	R6	Availability of traditional and modern motifs
	R7	Intensity of non-machine loom (ATBM) maintenance

Result and Discussion

The assessment of the sustainability of the agro-industry supply chain for woven fabric in Wajo Regency was conducted based on four main dimensions: economic, social, environmental, and resource aspects. The analysis was carried out using the Multi-Dimensional Scaling (MDS) method, adapted from the Rapfish approach, to evaluate the sustainability index value, stress value, and the determination coefficient (R²). The results of this analysis are presented in Table 3.

Table 3. Sustainability Index Value, Stress Value, and R Square Value

Dimension	MDS	Stress	R ²	Category
Economic	72	0.21	0.96	Moderately sustainable
Social	64	0.12	0.98	Moderately sustainable
Environment	53	0.17	0.97	Moderately sustainable
Resource	68	0.23	0.95	Moderately sustainable

Table 3 shows that in each dimension, the categorization of “moderately sustainable” follows the sustainability classification proposed by Kavanagh et al. (2004), where an index value between 50 - 74.99 indicates near sustainability. Thus, dimensions scoring within this range, including economic (72%), social (64%), environmental (53%), and resource (68%), are considered moderately sustainable.

Figure 1 illustrates the flyover diagram that illustrates the comparative sustainability performance across the four assessed dimensions. The visualization highlights the dominance of economic indicators and the relative weakness of environmental performance.

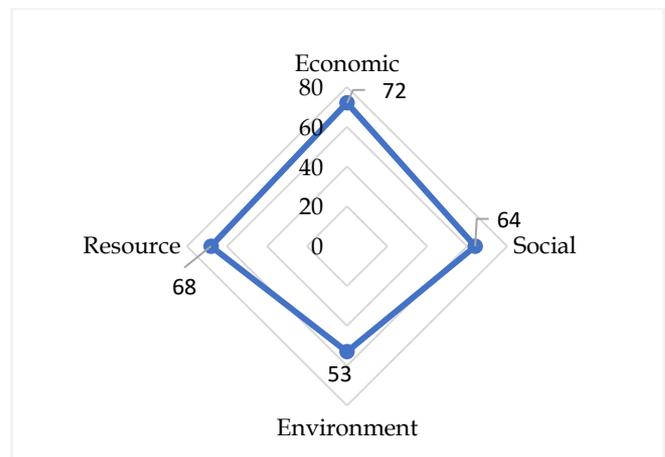


Figure 1. Flyover diagram

The sustainability value in the economic dimension is 72%, the highest compared to other aspects, indicating that the financial and business efficiency aspects within the silk woven fabric supply chain in Wajo Regency are relatively good. This is influenced by high performance in indicators such as net profit (E3), profit margin (E4), return on investment (E5), and after-sales service (E9), which reflect the ability of business actors to generate sustainable profits. A well-executed market strategy, encompassing distributors, customers, and exhibitions, is also supported by the completeness of service implementation and delivery (Halide et al., 2023).

The resource dimension sustainability index of 68% indicates conditions that are adequate for further development. Good performance is observed in the quality of raw materials (R3), raw material availability (R4), and motif diversity (R6). This factor is supported by the skillfulness in traditional knowledge passed down through generations, as well as the availability of both traditional and modern tools (R5). However, the regulation of young workers' skills remains limited, and the intensity of non-machine tools processing (ATBM) (R7) is not yet optimal, which has the potential to reduce the supporting capacity of energy resources in the future (Suryanti et al., 2023).

The social dimension plays a role with a score of 64%, which is considered quite adequate but still faces challenges in the aspects of employment stability and worker protection. Several indicators, such as wages (S7), occupational health and safety (S5), and workforce skill improvement (S4), still show performance that needs to be improved. The participation of local workers is quite high, and cultural norms remain strong, but

corporate social responsibility (CSR) programs (S3) are still limited and not yet well-structured (Yani et al., 2022; Ashar, Nurmalina, & Muflikh, 2024).

The sustainability index in the environmental dimension is 53%, which indicates that environmentally friendly practices need to be a top priority. The low performance is evident in indicators such as ISO 14001 environmental certification (N2), environmental performance evaluation (N5), the use of hazardous chemicals (N6), and the management of hazardous waste (N7). The continued dominance of synthetic dyes results in colored wastewater that has the potential to pollute the environment, while the adoption rate of waste management technology and environmental certification remains very low. This condition aligns with previous research showing that synthetic dyes are difficult to decompose and significantly impact water pollution and ecosystem toxicity (Huang et al., 2024). Additionally, the low adoption of environmental standards like ISO 14001 is reported as a major barrier to realizing a sustainable textile supply chain (Zimon et al., 2020). Other studies also indicate that conventional textile dyeing processes are water-intensive, produce high emissions, and hinder the widespread adoption of environmentally friendly technologies (Lara et al., 2022).

This validation is further used to assess the reliability of the model employed. The validation is conducted based on two main parameters, namely the S-Stress value and the determination coefficient (R^2). According to Saragih et al. (2020), an S-Stress value below 0.25 and an R^2 approaching 1 indicate that the model has a good level of accuracy and goodness of fit. Additionally, validation is supported by Monte Carlo simulation, which is used to estimate the influence of uncertainty and errors in the model. The simulation was conducted at a 95% confidence level, with an error tolerance limit of less than 5% (Kavanagh & Pitcher, 2004). The results show that all validation criteria are met: S-Stress value < 0.25 , R^2 approaching 1, and Monte Carlo simulation error $< 5\%$. Therefore, the MDS model used to evaluate the sustainability of the supply chain for woven cloth agroindustry in Wajo Regency can be considered valid, reliable, and suitable for representing the actual conditions on the ground.

Conclusion

Based on the results of the Multi-Dimensional Scaling (MDS) analysis, the sustainability level of silk weaving agroindustry enterprises in Wajo Regency is classified as moderately sustainable across all assessed dimensions. The economic dimension demonstrates the strongest performance, indicating that silk weaving businesses are able to maintain economic viability and

generate stable income. The resource dimension also shows relatively favorable conditions, supported by the availability of raw materials, production tools, and traditional weaving skills. The social dimension reflects adequate contributions to employment and community empowerment, particularly for women, although issues related to wages and workforce regeneration remain challenges. In contrast, the environmental dimension records the lowest sustainability index, highlighting insufficient waste management practices and limited adoption of environmentally friendly materials and standards. These findings indicate that environmental aspects should become a priority for improving the overall sustainability of silk weaving enterprises. Therefore, integrated efforts involving business actors and policymakers are required to strengthen environmental management, enhance social welfare, and support long-term economic resilience. The results of this study provide important insights for designing sustainability-oriented development strategies for traditional agroindustries.

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Author Contributions

S; conceptualization, methodology design, formal analysis, and drafting of the original manuscript, as well as supervising the entire process. SM; contributes significantly to data curation, investigation, visualization, and manuscript review and editing. AK; provides resources, assists in software implementation, and conducts data collection. FR; supports project administration and assists in manuscript review. AP; provides general guidance and also helps in manuscript review.

Conflict of Interest

The writer states that they have no conflicts of interest.

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