Global J. Environ. Sci. Manage. 10(3): 1-22, Summer 2024, Serial #39

Global Journal of Environmental Science and Management
(GJESM)

Homepage: https://www.gjesm.net/

Podcasts

CASE STUDY

# Sustainability assessment of animal feed production from by-products of Sago palm smallholder industry

**Allaily[1,2,3,*]; A.D. Santoso[2], M.N. Rofiq[2], N.A. Sasongko[2], H. Daulay[4], E.I. Wiloso[2], E. Widjaja[2], B.N. Utomo[5], A.I. Yanuar[2], S. Suryani[2], Y.P. Erlambang[2], U.N.Thiyas[2], D. Iskandar[2,6], A. Anhar[7], M. Rahmawati[8], T. Simamora[2,9], Y. Yusriani[3,10], G. Maghfirah[11], M. Ammar[1]**

[1] *Animal Sciences Department, Agriculture Faculty, Universitas Syiah Kuala, Banda Aceh Indonesia*

[2] *Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia*

[3] *Research Center Aceh Cattle and Local Husbandry Universitas Syiah Kuala Banda Aceh Indonesia*

[4] *Research Center for Behavioral and Circular Economy, National Research and Innovation Agency, Indonesia*

[5] *Research Center for Veterinary Science, National Research and Innovation Agency, Indonesia*

[6] *Directorate Policy Evaluation for Research Technology and Innovation, National Research and Innovation Agency, Indonesia.*

[7] *Department of Forestry Science, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia*

[8] *Department of Agrotechnology, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia.*

[9] *Animal Husbandry Study Program, Faculty of Agriculture, Science and Health, Timor University, Indonesia*

[10] *Research Center for Animal Husbandry, National Research and Innovation Agency of The Republic of Indonesia*

[11] *Environmental Engineering Department, Universitas Serambi Mekkah, Banda Aceh, Indonesia*

## ARTICLE INFO

***Article History:***
Received 25 October 2023
Revised 29 December 2023
Accepted 13 February 2024

***Keywords:***
Animal feed
By-product
Multidimensional scaling (MDS)
Sago palm smallholder industry
Sustainability assessment

## ABSTRACT

**BACKGROUND AND OBJECTIVES:** Sago plant is a valuable source of raw material for the processing industry and every part is very useful for food and shelter. Moreover, by-products of the Sago processing industry are useful as animal feed and liquid waste which has not been widely used. There are limited studies on the use of Sago by-products and sustainability of Sago palm smallholder industry. Therefore, this study aimed to assess sustainability of Sago palm smallholder industry in Simeulue Regency and identify the values of each attribute in the four impacting dimensions.

**METHODS:** This study was carried out through the direct interview method, using a questionnaire containing 35 attributes related to 4 dimensions, namely 8 attributes of economy, 12 environmental, 10 social, and 5 technological. The data were obtained from 5 entrepreneurs of Sago palm smallholder industry in Simeulue Regency, out of a total of 7 active Sago processing factories. Subsequently, the data were analyzed using Multidimensional Scaling method with rapid appraisal software. Sustainability status and leverage attributes were analyzed by Monte Carlo analysis and alternating least-squares algorithm.

**FINDINGS:** The results showed that the general sustainability indicators in Sago palm smallholder industry had an average value of 46.03 percent. This assessment was based on the value for the economic dimension of 45.56 percent, environmental dimension of 27.89 percent, social dimension of 55.65 percent, and technological dimension of 55.03 percent. Furthermore, it was found that techniques in several processing stages or use of liquid waste, cultivation skills, and technology process contributed to sustainable development. This study provided information that production factors needed to be improved for sustainability of Sago palm smallholder industry in terms of economy and environment. However, the use of solid and liquid wastes had not been optimally used.

**CONCLUSION:** In the economic dimension, an improvement in production factors such as the cultivation of Sago plant is important because it only relies on plant that live naturally. Furthermore, it is important to increase the use of Sago pulp as animal feed to improve the substitution of commercial rations usage, and facilitate sustainability value of the economic dimension. Meanwhile, in the environmental dimension, there should be study and socialization on the processing or use of liquid waste. This can help in addressing air and water pollution. In the social and technological dimensions, Sago farmers need to be equipped with cultivation skills to increase the value of this dimension. In conclusion, Sago palm smallholder industry in Simeulue Regency needs to be facilitated from upstream to downstream and sustain plant cultivation, and process Sago commodities using technology while suppressing negative effects on the environment.

DOI: 10.22035/gjesm.2024.03.***



| NUMBER OF REFERENCES | NUMBER OF FIGURES | NUMBER OF TABLES |
|---|---|---|
| 84 | 6 | 3 |

*Corresponding Author:
Email: *allaily@usk.ac.id*
Phone: +8535 907 9042
ORCID: 0000-0001-5216-6713

Note: Discussion period for this manuscript open until October 1, 2024 on GJESM website at the “Show Article”.

## INTRODUCTION

Sago flour is obtained from processing the stems of Sago plant (*Metroxylon sagu Rottb*), and is a major food source with significant impact across various sectors, specifically in Simeulue Regency, Aceh Province, Indonesia. The processing not only yields flour for consumption but also generates by-products suitable for animal feed. However, certain by-products such as solid and liquid wastes can cause environmental problems. Despite the prominence of this plantation in Simeulue Regency, local industry still relies on naturally occurring Sago plant. Various studies in Indonesia showed the importance of Sago as a major food source produced under optimal cultivation, processing, and marketing systems (Sidiq *et al.,* 2021). The inefficiency in the supply chain necessitates solutions grounded in local wisdom and complemented by government policies to ensure sustainability of the industry development (Trisia *et al.,* 2012). In Eastern Indonesia, Sago preservation practices are deeply entrenched in local culture (Kadir *et al.,* 2022), while in the western region, specifically on Meranti Island, Riau Province, efforts toward sustainable production management have been initiated (Murod *et al.,* 2019). There have been limited studies on Sago sustainability in Aceh, the westernmost island of Sumatra. To ensure production sustainability, comprehensive support from upstream to downstream is imperative, including the development of a more organized industry. The relatively low prominence and less favorable pricing based on commodity advantage matrix makes Sago an economical industrial raw material. Aceh, one of the provinces in Indonesia with the largest plantations, has great potential to increase the added value of Sago through more efficient processing. With a plantation area of 6,364 hectares (ha), Aceh occupies a strategic position in Sago production in Indonesia, after Riau, Papua, and Maluku (Directorate General of Estates, 2021). Meanwhile, Indonesia has the largest plantation area, followed by Papua New Guinea, Malaysia, Thailand, the Philippines, and the Pacific islands (Ehara *et al.,* 2018). Traditional processing skills have been cherished as a cultural heritage in Indonesia, passed down through generations. Several plantation commodities have undergone sustainability assessments. Parmawati *et al.* (2023) analyzed sustainability index of a potential coffee plantation in Wagir District, Malang Regency, distributing questionnaires to 20 farmers and conducting interviews with five experts selected through purposive sampling. Parmawati identified four dimensions for sustainability analysis, namely Ecology, Economy, Social Institutions, and Technology. The results showed a sustainability index of 43.42, indicating less sustainability for smallholder coffee plantations in Wagir District. Furthermore, dimension analysis showed four sensitive attributes in ecology, three in economy, five in social institutions, and five in technology. Policymakers are expected to focus on these sensitive attributes to enhance smallholder coffee plantations and industries, as well as the formulation of targeted policies. Sustainability analysis transcends products to include community-based coffee agro-tourism services in East Java, Indonesia (Hidayat *et al.,* 2023). There is a dearth of studies on sustainability of Sago palm smallholder industry in Aceh, specifically in Simeulue Regency, using multidisciplinary scaling (MDS) method. This method allows for a comprehensive evaluation across economic, social, environmental, and technological dimensions (Lloyd *et al.,* 2022). Ingrassia *et al.* (2022) investigated producer and consumer perspectives on motivations, real/perceived difficulties, costs, and positive impacts of voluntary sustainability program certification, as well as intentions to make ethical choices and willingness to spend more money. A census of manufacturers combined with consumer surveys and focus groups was conducted, using MDS to assess producer/consumer opinion polarization regarding voluntary sustainability program certification. Sari *et al.* (2023) adopted MDS to analyze the status of disease control in the peatland built environment in Bangko, Rokan Hilir, Riau, Indonesia. A survey was also conducted to assess the status of disease control through primary data collection with scoring scales, complemented by secondary data. Mucharam *et. al.* (2020) adopted MDS to assess sustainability of rice farming at the provincial level in Indonesia, using 32 sustainability indicators across economic, ecological, social, technological, and institutional dimensions. Moreover, Monte Carlo simulations was used to determine validity and sensitivity analysis, as well as the dominant attributes influencing sustainability. Agovino, *et.al* (2017) investigated "The driving factors of separate waste collection in Italy: a multidimensional analysis at the provincial level." Compared with

Italian provinces in 2011, the analysis consists of two steps. Firstly, characterizing different institutional and socio-economic contexts through multidimensional scaling analysis. Secondly, providing evidence about the existence of subsets among Italian provinces using cluster analysis. The results showed that contexts featuring high institutional quality promoted separate collection processes, whereas tourism-oriented environments characterized by low institutional quality did not positively impact recycling processes. The processing of Sago into flour yields by-products in the form of solid and liquid waste. Solid waste, such as Sago pulp, can be used as quality animal feed after fermentation (Allaily *et al.,* 2023). The use of solid waste as animal feed not only mitigates negative environmental impacts but also serves as a feed source. Previous studies on the use of Sago for ruminant feed have explored fermentation technology using molds, yeasts or bacteria to enhance digestibility by breaking down crude fiber in the form of lignin and cellulose into simpler forms (Susanti *et al.,* 2022). The inclusion of fermented Sago pulp up to 45 percent (%) in the total ration helps maintain the performance of pea goats as small ruminants (Setiawan *et al.*, 2022). The use of fermented Sago pulp for waterfowl such as ducks has also been carried out with less favorable impact on gut physiology (Allaily *et al.* 2023). Similarly, in poultry, specifically native chickens, the use of Sago pulp has not shown improvements in performance (Ralahalu *et al.,* 2021). While several studies focused on the use of Sago pulp as animal feed, sustainability of Sago production as food and by-products in the form of solid and liquid waste from palm smallholder industry in Aceh remained unreported. Sustainability evaluation of Sago production can elucidate the availability of food and feed, as well as contribute valuable insights related to sustainability across various dimensions and attributes. Therefore, this study aimed to provide comprehensive information on sustainability of Sago palm smallholder industry in the western region of Indonesia. It also focused on economic, social, environmental and technological dimensions, and provided valuable contributions to academics, government, study stakeholders. This study hypothesized that providing comprehensive information on sustainability could enhance the development of smallholder Sago industry in the western region of Indonesia. The practical MDS method offered valuable insights to assist decision-makers in the industry, particularly concerning waste management. The primary objectives are as follows: 1) identify sustainability index dimensions, 2) calculate sustainability index across environmental, social, economic, and technological dimensions, and 3) identify critical factors influencing Sago production system. The main objective was to assess sustainability of Sago palm smallholder industry with the largest plantation in Aceh Province, particularly on Simeulue Island, which is one of the primary sources of animal feed. This study was conducted at the Sustainable Food System and Manufacturing unit of the National Research and Innovation Agency, Indonesia, in 2023.

## MATERIALS AND METHODS

*Study area*

This study was conducted from April 2022 to May 2023 in Simeulue, Aceh, as shown in Fig. 1. Focus group discussions (FGDs) were conducted with entrepreneurs from 7 Sago factories in 5 different locations of Teupah Selatan, Simeulue Timur, and Teupah Tengah Districts to obtain data. Simeulue Regency spans an area of 2,310 square kilometers ($km^2$), located between 02° 02′ 03′′- 03° 02′ 04′′ North Latitude and 95° 22′ 15′′ - 96° 42′ 45′′ East Longitude. It is an archipelagic area comprising ± 57 large and small islands. Simeulue Island measures ± 100.2 km long and is between 8 - 28 km wide. In addition, the total land area of the large and small islands is 212,512 ha. Questionnaires were administered to various experts associated with Sago factory workers, solid and wastewater experts, and business actors. The data collection process was facilitated through FGDs conducted at each factory. FGDs aimed to assess the existing conditions of business actors and support for industry resources at the study area, providing material for defining dimensions and sustainability attributes. A total of four dimensions and 35 attributes, including ecology, economic, social, and technology, were identified and subsequently described using a questionnaire with a Likert scale ranging from 0 to 2 for poor, average, and good responses.

Simeulue Regency has the largest Sago plantations in Aceh Province. The Gross Regional Domestic Product from the agriculture, forestry and fisheries sectors in 2022 totaled US dollars 37,970,466. Despite having the largest area dedicated to cultivation,

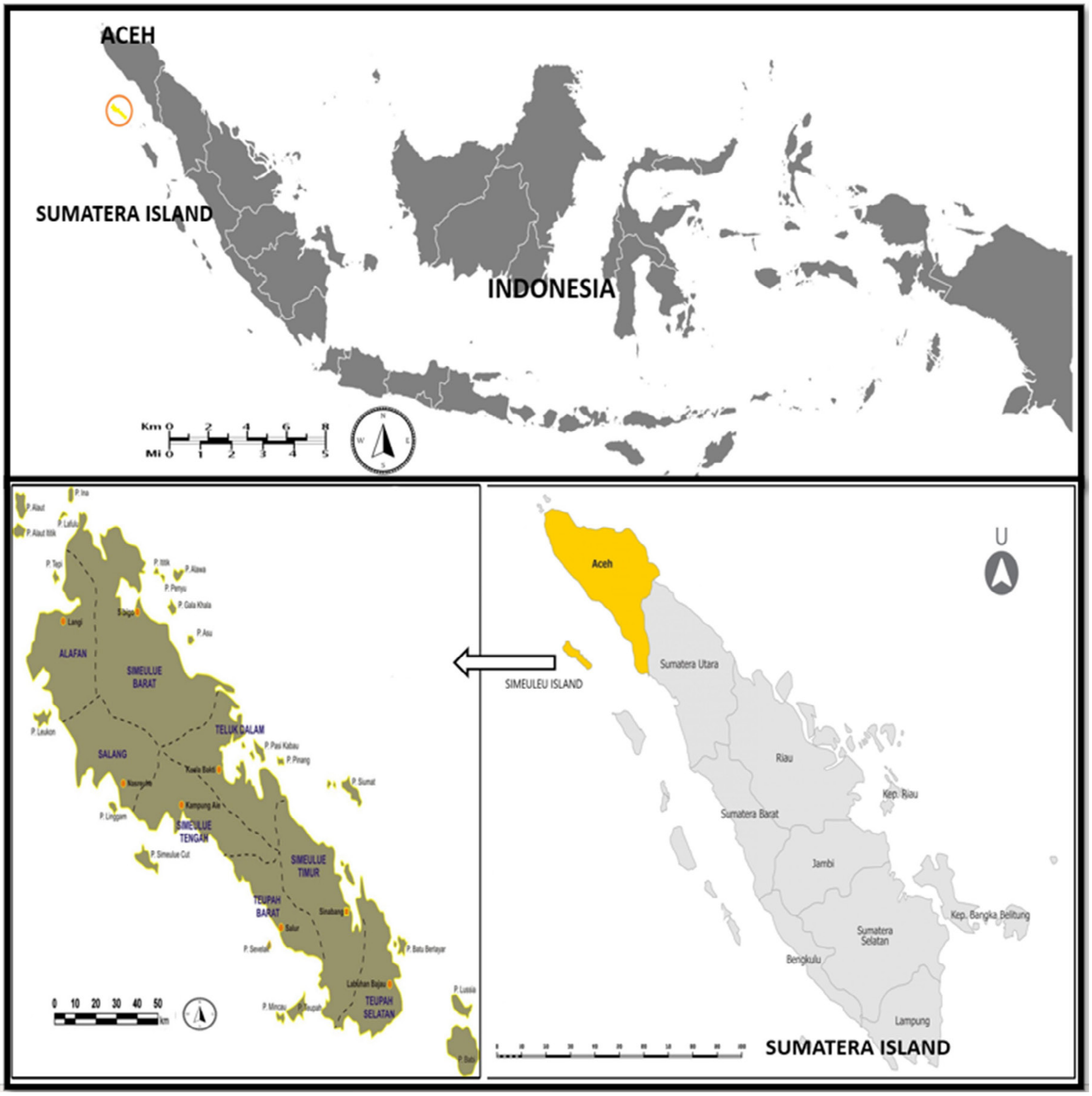


Fig. 1: Geographic location of the study area: Sago entrepreneurs in Indonesia

accounting for 30.48%, Simeulue ranks the second highest producer in Aceh Province (Directorate General of Estates, 2021).

*Data interpretation*

Data were interpreted using MDS Rap-Sago, a derivative of Rapid Appraisal method (Lloyd *et al.,* 2022). This method was adopted to determine sustainability index of Sago production, measured through the following stages (Pitcher and Preikshot, 2001). Analysis of sustainability index is a simple method for determining sustainability status of products or processes in a multidimensional manner. All dimensions were analyzed simultaneously to generate a scale vector. RapFish is based on the ordination method of assigning a value (score) to a measured attribute using MDS of several dimensions. Each dimension has attributes or indicators related

Table 1: Sago plant area and total production in Simeulue Regency (Directorate General of Estates, 2021)

| No. | Items | Simeulue regency |
|---|---|---|
| 1. | Immature Sago plant (ha) | 445 |
| 2. | Mature Sago plantation (ha) | 1,215 |
| 3. | Damaged crop (ha) | 280 |
| 4. | Total Sago plant area (ha) | 1,940 |
| 5. | Sago production (Ton) | 243 |

to sustainability status (Pitcher and Preikshot, 2001). Sustainability level with leverage attributes of Sago production on Simeulu Island was examined through Rap-Sago analysis. Specifically, a) attributes relevant to good intensive Sago production benchmarks were selected to measure sustainability level, b) each attribute was assessed on an ordinal scale for each criterion dimension of sustainability, and c) a level of sustainability and each leverage attribute of Sago production was compiled. Sustainability status was depicted by vertical and horizontal ordinates. The index value of the good value was 100%, and bad extreme was 0%. Sustainability status index of intensive duck-rearing technology had a value scale of 0–100%. A better value of 50% could be considered sustainable, and less than 50% as unsustainable. Meanwhile, sustainability status ordination, which refers to the score of each characteristic, provides a summary of sustainability level for each dimension. Sustainability level of Sago production is represented by the value point on the x-axis, while the variance in scores is presented on the y-axis. The coefficient of determination ($R^2$) was examined by the normalization of stress value (S). The model is considered good when both the $R^2$ and the $S < 0.25\%$ values are close to 1. Additional attributes are also determined by S-stress and ($R^2$), representing the accuracy of the dimensions studied with the real condition simultaneously (Fauzi and Anna, 2005). Leverage analysis is also used to identify characteristics that are sensitive to sustainability. The greatest root mean square (RMS) values represent the most sensitive indicators (Pitcher and Preikshot, 2001). Monte Carlo analysis helps in investigating: a) the relevance of attribute scoring errors; b) the impact of variations in scoring resulting from divergent viewpoints or assessments by study experts; c) the stability of the persistent MDS analysis process; d) data entry errors or the possibility of missing data; and e) the high-stress value of MDS analysis objective. The interpretation study is considered to correlate with actual conditions when the difference between the MDS and Monte Carlo calculation results is less than one (Kavanagh and Pitcher, 2004). According to Borg et al. (2018), the y-axis for up is half the top attribute score of 50, while the y-axis for down is half the minimum attribute score. The maximum value of the x-axis for Good is 100, and the smallest value for Bad is 0. Table 2 shows the prior MDS-based evaluations of agricultural product sustainability.

Interpretations of the concept of sustainable development vary widely, although there is agreement on the need to use sustainability indicators to measure change. Alaoui *et al.* (2022) identified several frameworks available for assessing agricultural sustainability, including Sustainability Assessment of Food and Agriculture Systems (SAFA), Response-Inducing Sustainability Evaluation (RISE), Multiattribute Assessment of Sustainability of Cropping Systems (MASC), Land Degradation Assessment in Drylands (LADA), Sustainability Monitoring and Assessment Routine (SMART) and Public Goods (PG). Mucharam *et al.* (2019) conducted an assessment of sustainability indicators at the provincial level in Indonesia, focusing on rice, using Principal Component Analysis (PCA). Sustainable agriculture was analyzed by Suresh *et al*. (2023) using the Driving Force Pressure State Impact Response (DPSIR) framework. Meanwhile, Bhattacharya *et al*. (2023) conducted a sustainable transportation infrastructure analysis using factor analysis and structural-equation-modeling (SEM). Other methods used to measure sustainability of activity included life cycle assessment, which focused on environmental aspects (Fan *et al.*, 2022). This activity adopted MDS, which, according to Lopes and Machado (2022), is a relevant modeling tool using present-day computational resources.

## RESULTS AND DISCUSSION

All attributes used were spread across four dimensions, totaling 35. Table 3 shows the question content of each attribute.

Table 2: Prior studies used MDS analysis

| No | Topic | Dimensions | Sources |
|---|---|---|---|
| 1 | MDS to visualize and analyze agricultural data | social, environmental, economic | Zhang and Ding, 2023 |
| 2 | Visual analytics of agricultural data by MDS preference plot | environmental, economic, social | Papilo *et al.*, 2022 |
| 3 | Indonesian biodiesel sustainability policy | economic, ecological, social | Dharmawan *et al.*, 2020 |
| 4 | Plant and infrastructure sustainability | environmental, economic, social | Giuntoli *et al.*, 2022 |
| 5 | Sustainable development in agriculture | social, environmental, economic, institutional | Suardi *et al.*, 2022 |
| 6 | Sustainability in the production of microalgal biomass | ecological, social, economic, technological | Santoso *et al.*, 2023 |
| 7 | Sustainability garlic production | environmental, technological, economic, social, and institutional dimensions | Paczka *et al.*, 2021 |
| 8 | Sustainability of chocolate production | ecological, social, economic, institutional dimensions, and technological | Fairuzia *et al.*, 2020 |
| 9 | Compost Production sustainability | environmental, social, economic, institutional dimensions, and technological | Santoso *et al.*, 2023a |
| 10 | Sustainability corn production | environmental, technological, social, economic, and institutional dimensions | Ariningsih *et al.*, 2021 |
| 11 | Chili farming | environmental, economic, social, technological, and institutional dimensions | Mailena *et al.*, 2021 |
| 12 | Sustainability of beef farming | dimensions of the environment, society, economy, technology, and institutions | Kapa *et al.*, 2019 |
| 13 | Dairy cattle production | dimensions of environmental, social, economic, technological, and institutional | Lovarelli *et al.*, 2020 |
| 14 | Sustainability of buffalo farming | environmental, economic, technological, and social dimensions | Deb *et al.*, 2016; Rohaeni *et al.*, 2023 |
| 15 | Shrimp culture | dimensions of environmental, social, economic, technological, and institutional | Sivaraman *et al.*, 2019 |
| 16 | Coffee production | environmental, social, economic, and technical aspects | Yusuf *et al.*, 2022 |
| 17 | Sustainability rice production | institutional, environmental, social, economic, and technical aspects | Rachman *et al.*, 2022 |
| 18 | Red chili production | technical, social, economic, and ecological aspects | Nuraini and Mutolib, 2023 |
| 19 | Black soldier fly production | social, economic enviromental, and technical aspects | Santoso *et al.*, 2023b |
| 20 | Sustainability of integrated farming | institutional, ecological, social, economic, and technical dimension | Widjaja *et al.*, 2023 |

*Multidimensional sustainability of Sago industry*

Multidimensional scaling results showed that Sago industry in Simeulue Regency was less sustainable, with sustainability index of about 46.03%. This was supported by Murod *et al.* (2019), where management index score ranged between 32.35–46.85 in Meranti Regency, Riau. Fig. 2 presents two dimensions with less sustainability, namely environment and economic, with sustainability index of 27.89% and 45.56%, respectively. Meanwhile, social and

Table 3: Dimensions and attributes used in this study

| No | Dimensions | | | | | | |
|---|---|---|---|---|---|---|---|
| | Economy | | Environment | | Social | | Technology |
| 1 | The productivity level in the cultivation of Sago | 1 | Optimizing the use of environmentally friendly materials in the production of Sago flour | 1 | The educational background, level of industry managers, or entrepreneurs engaged in Sago industry | 1 | The level of ease of adoption of Sago production system for the surrounding community |
| 2 | The industry management level of Sago production | 2 | Enhancing the resourcefulness of non-biodegradable materials in the production of Sago flour | 2 | The participation of family members in Sago industry | 2 | The level of specialization/expertise/skills required for managers of Sago palm smallholder industry |
| 3 | Potential for scaling up business operations/improved chances of achieving business objectives | 3 | Optimization of water use in the process of Sago production | 3 | The degree of drive or motivation in the business context, particularly in Sago industry | 3 | Availability of Sago production facilities and infrastructure |
| 4 | Enhancing the well-being of managers and workers through active participation | 4 | Maximizing the effectiveness of electricity and fuel usage in Sago production process | 4 | The tendency for public dissatisfaction or unrest arising from Sago industrial process | 4 | Potential for increasing technology/cultivation methods/planting Sago |
| 5 | Optimizing the production process of raw materials | 5 | The possibility of atmospheric contamination | 5 | The tendency for additional job displacement resulting from Sago industry | 5 | The level of technical/method sensitivity to the quality and quantity of Sago production and Sago dregs |
| 6 | Contribution to the rise in substitution of animal feed ingredients (derived from Sago waste materials) | 6 | The possibility of contamination or pollution of water sources | 6 | The extent of knowledge among managers or workers regarding Sago tree cultivation, environmental conservation, or restoration practices | | |
| 7 | The ease of acquiring raw materials for Sago production varies | 7 | The use of solid waste produced from Sago manufacturing process | 7 | The tendency for work-related accidents occurring in Sago industry | | |
| 8 | The rate at which the market absorbs Sago production | 8 | The use of liquid waste resulting from Sago production | 8 | The possibility of generating employment opportunities for local residents | | |
| | | 9 | The use of gas waste produced during the manufacturing process of Sago | 9 | The skills of entrepreneurs/managers in cultivating Sago plant | | |
| | | 10 | The extent of exploitation of natural resources, such as Sago trees, and the use of land for cultivating these trees | 10 | The cultivated Sago is grown naturally | | |
| | | 11 | Possible harm to biodiversity attributed to the existence or cultivation of Sago palms | | | | |
| | | 12 | The potential for disease spread associated with the presence or operations of Sago industry | | | | |

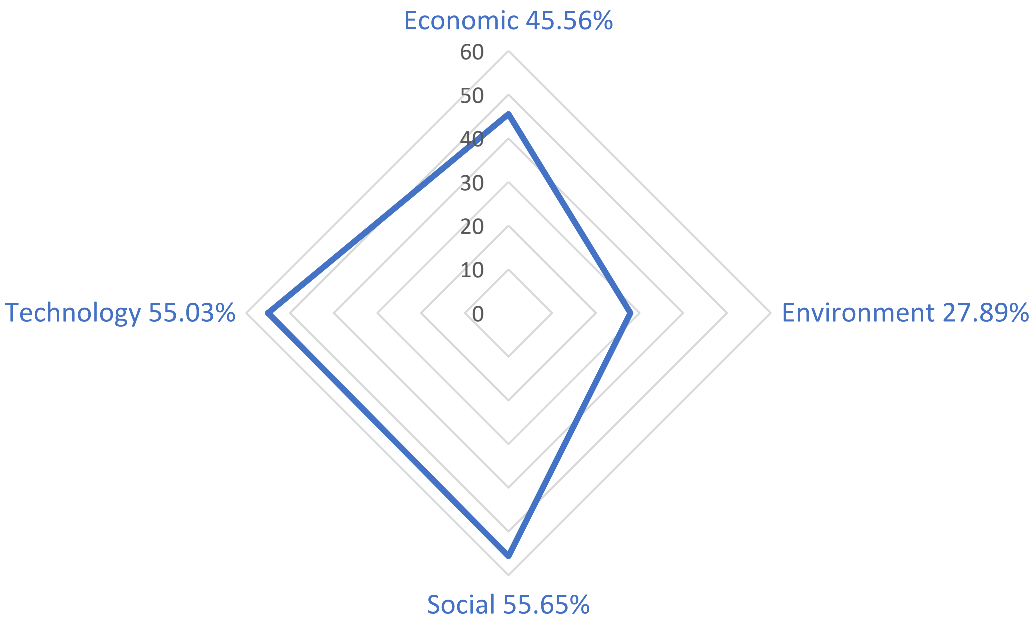


Fig. 2: Multidimensional sustainability of Sago industry in Simeulue Regency

technology dimensions were relatively sustainable, with sustainability index of 55.65% and 55.03%, respectively. This study provided the necessity to improve production factors for sustainability of the local Sago industry in Simeulue Regency across all dimensions, particularly economic and environmental. It is necessary to foster integration activities between Sago industry and livestock by using industrial waste (solid waste), for animal feed to enhance sustainability value, specifically in environmental, social (*Garrett et al.,* 2017), and economic aspects. The development of animal feed innovations based on Sago small industry can promote sustainable agriculture and support Global Sustainable Development Goals (SDG) by reducing food waste and responsibly using resources. Feeding strategies that minimize environmental impact and use waste through circular systems for animal feed production are crucial for enhancing sustainability of animal feed production. The application of technology is also crucial for transforming food waste into safe, nutritious feed products, thereby adding value and achieving sustainability (Wani *et al*., 2023). A sustainable feed production system should be efficient, generate economic resources for farmers, and adopt conservation strategies (Cakmaci *et al*., 2023). Regarding Sago Industry, according to Wulan (2018), the low yield category had 14.88% due to higher solid waste (854,89 kg/ton of Sago stems) and liquid waste (29,464.2 liters/ton/year), indicating the potential for further use of solid waste. Therefore, advocated for promoting waste use and explaining the value-add potential of Sago processing to stakeholders to garner interest and participation. Widjaja *et al*. (2023) reported on integration activities between organic fertilizer production, chicken feed, and laying hen farming by using palm oil mill by-products and chicken manure waste for organic fertilizer, resulting in a multidimensional sustainability index ranging from 74.29% to 93.79%.

*Economic dimension*

In economic dimension, the highest value of 4.08 was generated concerning the contribution to the increase in substitution of animal feed ingredients (from Sago waste products). The potential of Sago pulp as an alternative feed ingredient to substitute main rations, specifically for poultry, has been extensively reported in various studies. For instance, the use of fermented Sago pulp at 5% in the ration maintained the performance of native chickens to conform with the performance of 100%

commercial rations (Ralahalu, *et al.,* 2021). However, the application of solid waste from Sago palm smallholder industry in Simeulue Regency remained very low. The global livestock sector is characterized by diverse dynamics. In developing economies, livestock sector is rapidly evolving in response to increasing demand for livestock products driven by population growth, higher prosperity, and urbanization. Meanwhile, in developed economies, demand for animal products is stagnating, with many production systems enhancing efficiency and environmental sustainability. Production is proposed to be increasingly influenced by globalization of trade in feed commodities and livestock products, competition for natural resources leading to volatility, and the necessity to operate in a carbon-constrained economy. Moreover, livestock production can be increasingly shaped by consumer and societal concerns, as well as legislative measures. There is considerable uncertainty regarding how these factors will unfold in different regions of the world in the coming decades. Animal feed and nutrition play a crucial role in the livestock production chain, bridging crop cultivation, animal protein production, and processing. Rising demands and constrained supplies create challenging environments where animal feed operators and farmers need to continuously balance activities, considering animal performance as well as customer, consumer, and societal demands. Since animal feed contributes up to 80% of the total costs in meat production, and profits in the chain are typically under pressure, the enhancement of feed and feeding programs has garnered and will continue to receive significant attention to optimize productivity and efficiency.

An investigation was conducted on the use of Sago pulp, comprising 30% mixed raw materials such as bran, corn flour, coconut meal, and fish meal in the form of pellet feed. This can significantly increase wafer performance and the dry matter content from 90.67% to 91.80% (Mucra *et al.,* 2020). Furthermore, the application at up to 30% in the starter phase of indigenous chickens can improve performance (Rianza *et al.,* 2019). In superior native chickens, Sago pulp can replace conventional feed ingredients with the lowest feed conversion ratio (3:1) (Zurriyati, 2023). Despite the potential for optimizing profits through maximum production, the cultivation level of the plantations as raw material for Sago production is currently nonexistent (Wahyuni, 2013). Without any cultivation efforts, factories are compelled to relocate when Sago source is depleted or distant, resulting in expensive transportation costs. Consequently, factories are established closer to abundant sources for entrepreneurs to consistently harvest. According to Fig. 3, Simeulue Regency needs to organize a planting process for sustainability of the local industry. This ranks as the second-highest attribute to be considered for enhancing the potential of the economic dimension. Following closely in economic importance is market absorption. Sago products have diverse applications in various countries, namely liquid sugar, flavoring (monosodium glutamate), noodles, caramel, Sago pearls, crackers, and adhesives. Sago starch also serves as an acetone-butanol-ethanol substrate (Amni *et al.,* 2019). Despite the potential to contribute to global food security, studies on Sago palms have been limited. The plant can thrive in areas where other food plants cannot, such as wetlands and peatlands. Besides producing edible starch, various parts of the plant can be used for animal feeds, Sago worm production, roofing materials, weaving mats and baskets. This diversification can improve rural economy by generating employment opportunities and increasing family income (Konuma and Ehara, 2018). However, the development of downstream products from Sago palm, such as bark and pulp waste, is still relatively limited and suboptimal. Sago bark remains underutilized, and most pulp waste is discarded into rivers (Rasyid *et al*., 2020), despite the significant economic potential of the main product and the use. With Sago starch having unique properties suitable for specific application, it remains relatively unknown on the international market compared to corn or cassava flour. Most leading starch producers cater to domestic demands, and there is a lack of awareness among buyers regarding the unique properties. Therefore, further investigation and development or modification of existing products are necessary to enhance awareness and market penetration before addressing other factors such as cost, quantity, and supply sustainability (Jong and Ehara, 2018). By-products of Sago can be used to produce animal products with economic and commercial value. This can help reduce production costs, enhance sustainable agricultural practices, mitigate environmental impact, and promote circular economy principles (Chisoro *et al*., 2023). Economically, incorporating Sago dregs

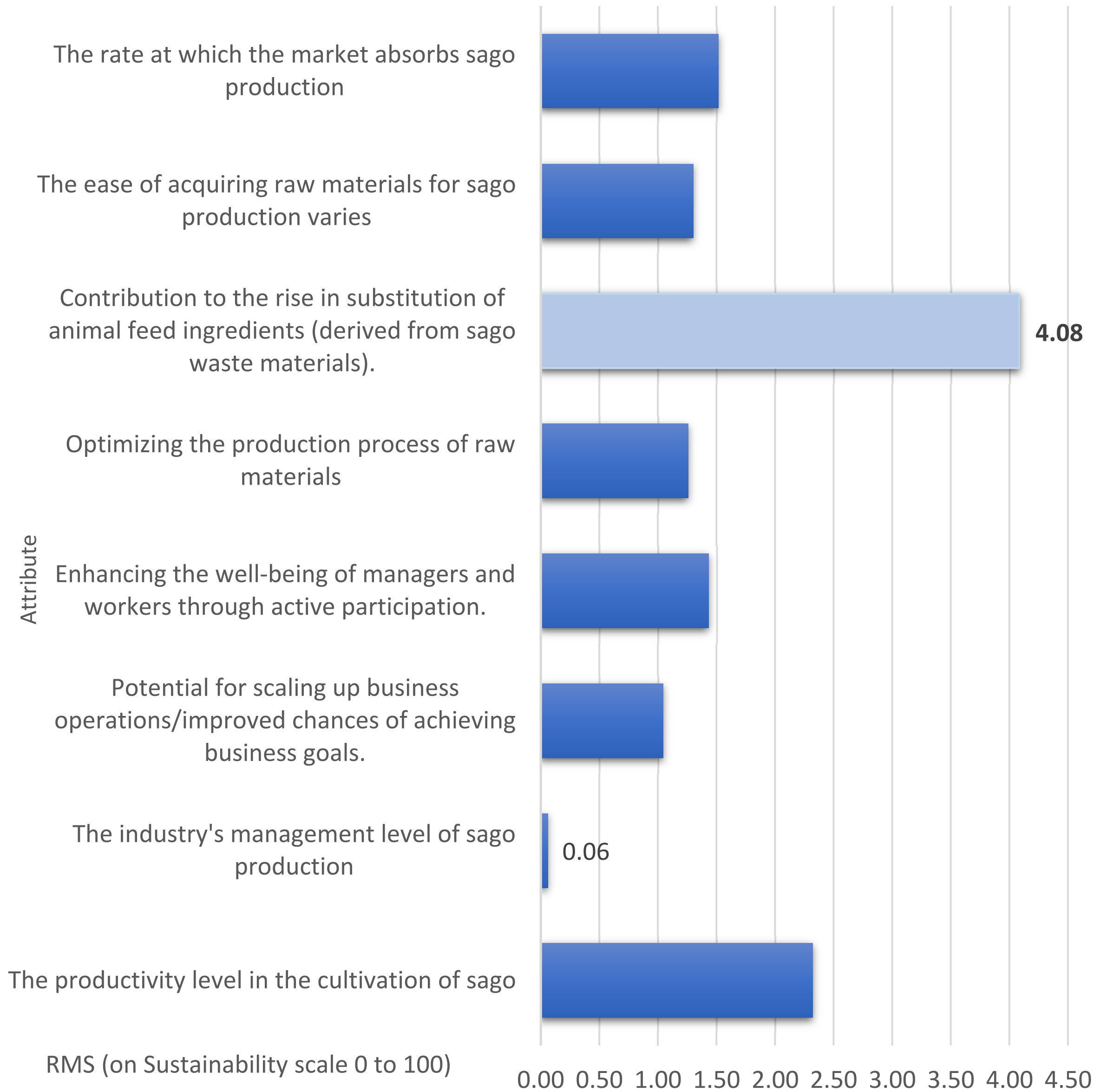


Fig. 3: Leverage attribute for economic dimension

into animal feed offers breeders cheap formulation options and easier access to livestock feed with lower transportation costs. This not only benefits breeders but also provides an additional revenue stream for small-scale processing industry through the sale of dregs, thereby contributing to sustainability of the industry. Studies reported that neutral detergent fiber (NDF) content of Sago ranged from 18.87% to 26.75%, compared to 36.53% for maize. However, the texture of Sago fiber is harder than corn. High fiber content can increase intestinal viscosity, pathogenic microbial populations, as well as reduce pancreatic enzyme activity and nutrient digestibility. There are limited studies on the improvement of nutritional value of diets containing Sago through the addition of different types of feed additives such as synbiotics, prebiotics, and probiotics. The results of Economic Dimension analysis showed that the value of Sago production was highly dependent on availability of raw materials. Since there is no cultivation process on Simeulue Island, improving this attribute can enhance Economic Dimension value. Using Sago dregs is a lucrative industry that significantly benefits breeders. In addition to producing food, Sago also provides dregs suitable for animal feed, particularly for cows. Simeuleu Regency, being a livestock center, different feeds are necessary to meet the demands of beef cattle. Farmers can use dregs as an alternate feed to enhance the growth of cattle while minimizing costs. The economic dimension analysis of this study was in line with the previous explanation. Generally, sustainability index for the economic dimension was 45.56%. The most significant contribution to farmers was the use of Sago waste as animal feed (91%), compared to the absorption of product (30%). Therefore, improving farmer welfare (32%) and business development potential (23%) through this was relatively low. The productivity level of plantations had quite good leverage at 51%, while the efficiency of raw material production at 28% was not matched by production management, leveraging at only 1%. Recommendations for enhancing economic dimension include: 1) increasing knowledge of Sago starch production and marketing management through training programs for farmers; 2) educating international Sago starch market through research and development publications.

*Environment dimension*

Analysis of the environmental dimension of sustainability comprised eleven attributes. The results showed that sustainability index value of environmental dimension was 27.89%, falling in the less sustainable range of 25.01%–50%. Moreover, the leverage analysis of environment dimension showed that the attribute with the most dominant influence on sustainability index value was the potential for air pollution (Fig. 4). In Sago processing industry, wastewater was typically directed to storage ponds without treatment, leading to the sedimentation of water, the emission of acidic odors, and air pollution around the industry. Currently, Sago starch industry is faced with waste management challenges, resulting in environmental pollution and health hazards (Amin *et al*., 2019). Several industries still dispose waste directly into rivers (Saleh *et al.*, 2020). The volume of waste disposal into rivers is substantial due to high water requirement of industry (28,612 liters/ton of Sago starch) (Wulan, 2018) for the extraction of Sago flour from fiber, necessitating proximity to water sources (Rasyid *et al*. 2020), and leading to potential water and air pollution (Periyasamy and Sagar, 2021). Sari *et al*. (2020) reported that river water contaminated with Sago waste exceeded recommended threshold parameters. Considering this situation, preventive measures are necessary. To reduce environmental pollution, it is crucial to design low-cost wastewater treatment systems (Periyasamy and Sagar, 2021), with government supervision and control playing a significant role (Saleh *et al*., 2020). The conversion of Sago wastes into useful products presents a promising method to mitigate environmental pollution (Amin *et al*., 2019). Various products are derived from the use of industry waste (Amin *et al*., 2019). Solid waste emitting odors in some areas has elicited protests from residents, with liquid waste, turning black and emitting a sour smell. By using these by-products as feed ingredients, smallholder industries can reduce environmental footprint, contribute to resource efficiency, and minimize waste. Livestock plays a crucial role in using food waste and by-products by converting low-value materials into high-quality products, a practice also observed in Canada (Ominski *et al*., 2021). Another significant leverage point impacting the environmental dimension is the efficient use of electricity and fuel during production process. Efficient fuel use is particularly crucial because, according to Wulan (2018), fuel consumption in Sago industry is considerable. Increased fuel consumption during Sago harvesting and starch processing in factories contributes to GHG emissions. To address these issues, an energy-independent Sago starch production process using by-products and liquid waste is a potential solution. For instance, processing 1,000 tons of Sago per day with an optimal yield of 14% has the potential to generate approximately 90,562 Kilowatt-hours (kWh) of energy. This energy output can satisfy the processing energy requirements, totaling 26,070 kWh, enabling the transition of Sago starch production into a closed production system (Bantacut and Indriyani, 2022). Studies on waste sugarcane for biomass energy in supplying

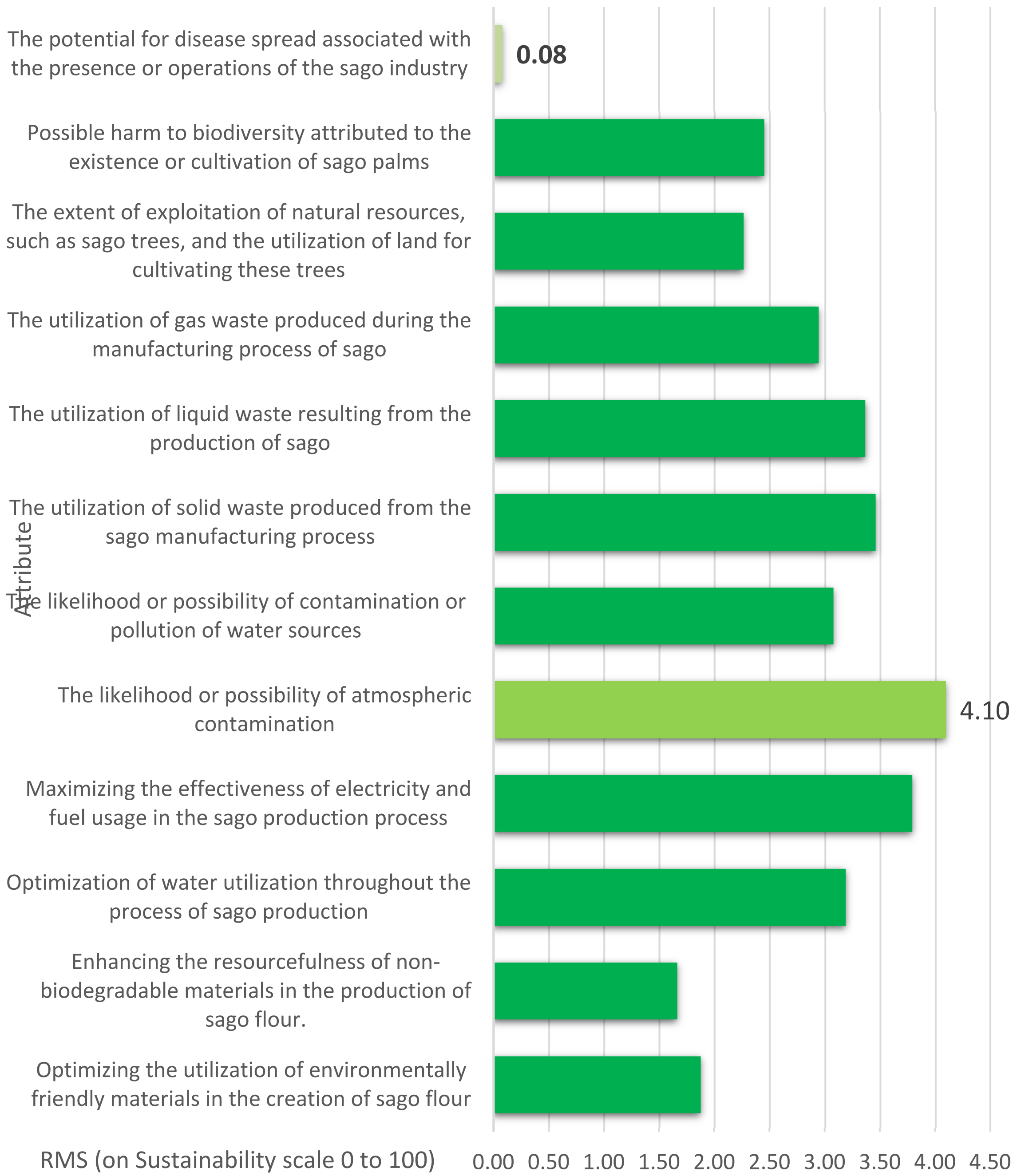


Fig. 4: Leverage attribute for environment dimension

electrical energy have shown promising results, with sugarcane waste (averagely 1,035 tons/day) meeting all electrical energy requirements for the operation of Madukismo sugar factory (Syahputra *et al.*, 2020). Therefore, the use of industrial waste as an energy source offers a solution for future energy efficiency.

*Social dimension*

Analysis of sustainability of social dimension was conducted on 9 attributes. MDS Rap-Sago-industry analysis showed that sustainability index value of the dimension was 55.65%, falling in the range of 50.01% - 75%, indicating a fairly sustainable state. This suggested that the social contribution to sustainability of Sago industry production process in Simeulue was quite good. The results were supported by Yusuf *et al*. (2019) regarding Sago industry activities in South Sorong. Leverage analysis of social dimension showed that the attribute of dominant influence on sustainability index value was the knowledge level of manager/worker in Sago tree cultivation or environmental conservation and restoration (Fig. 4). The highest leverage point in social dimension correlated with the leverage point in technology dimension, where the level of knowledge, skill, or expertise of managers/workers played a crucial role in industry activities. This condition, according to Partini *et al*. (2023), can lead to low Sago productivity. Human resources skills were also identified by Yusuf *et al*. (2019) as a leverage point in social dimension of the continuation of industry activities in South Sorong, in addition to partnerships and Sago farmer income. Rizky *et al*. (2023) showed a positive and significant influence between knowledge and business success. Therefore, coaching, education (Sari *et al*., 2020), and training were essential. According to Heylen *et al*. (2020), training provides significant and measurable benefits for welfare and economic growth without causing significant negative environmental impacts. This method can address other leverage points (attributes), such as the potential for job losses in Sago industry and the potential for public unrest due to industrial processes. The analysis of attribute leverage results for social dimension (Fig. 5) showed that out of the nine analyzed attributes, three sensitive attributes significantly influenced sustainability of the activity, namely: 1) The level of knowledge of managers/workers in Sago palm cultivation or environmental conservation and restoration, 2) The potential for other job losses in Sago industry, and 3) The potential for community unrest due to Sago industry processes.

The highest leverage point in social dimension was quite similar to the leverage point in technology dimension, where knowledge, skills, or abilities of managers/workers played a crucial role in industry activities. Skilled human resources serve as leverage points in social dimension for sustainability of industry activities in South Sorong, alongside cooperation and income for farmers (Yusuf, 2019). Rizky *et al.* (2023) found a positive and significant influence of knowledge in entrepreneurial industry on business success. Through continuous training, significant and measurable benefits can be provided for well-being and economic growth without significant negative impacts on the environment (Heylen *et al.,* 2020). This also addresses other attributes, namely the potential for job losses and the potential for community unrest due to industry processes.

*Technology dimension*

The results of sustainability analysis, using five attributes, showed that the status of technology dimension was fairly sustainable with sustainability index value of 55.03%. This was supported by Yusuf *et al*. (2019) regarding Sago industry activities in South Sorong. Irianto *et al*. (2023) also reported a smaller sustainability index for technology dimension in organic paddy farming, namely 49.49%. The application of technology in Sago industry process in Simeulue Regency still required improvement. According to Girsang (2018), a sustainable Sago industry requires adaptive technology to increase added value and efficiency. This notion was supported by Timisela *et al*. (2021), which identified technology as the biggest contributing factor to the development of Sago agroindustry, followed by capital, human resources, production, and marketing. In line with Yusuf and Romli (2020), technology is the most crucial factor in maximizing Sago starch production efficiency by applying cleaner production methods. Ishak *et al.* (2021) reported that technology was a significant challenge in increasing Sago production in Sarawak. Moreover, it was not only essential for increasing production but also for improving the quality of Sago flour (Talakua and Rukoyah, 2023). The analysis of leverage attribute for technology dimension showed that one attribute dominated compared to the other four, namely the level of specialization/expertise/ skills needed for managers in Sago industry (Fig. 6). Saediman *et al*. (2021) identified skills and expertise as crucial elements in industry management. The lack of technical skills was also identified as one of the challenges to the implementation of Sago production differentiation technology, aimed at meeting market

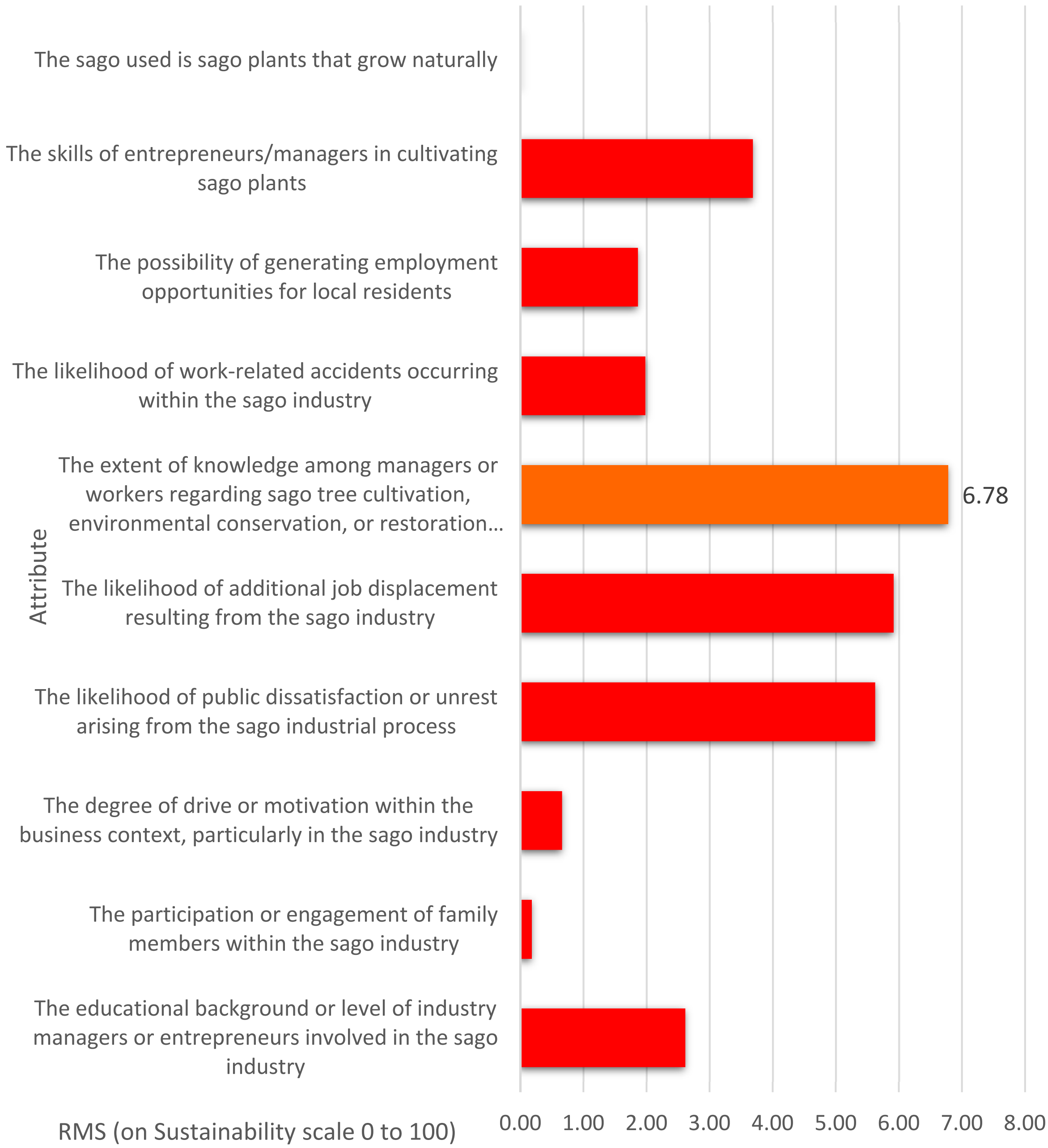


Fig. 5: Leverage attribute for social dimension

needs. The implementation of technology was essential as it helped improve the efficiency of Sago production and reduce negative environmental impacts. A more efficient and environmentally friendly Sago treatment technology can also be developed. Therefore, human resource development needs attention, specifically in mastering technology related to Sago industry. Technology transfer, according to Suwanan *et al*. (2021), is closely related to the implementation of extension services.

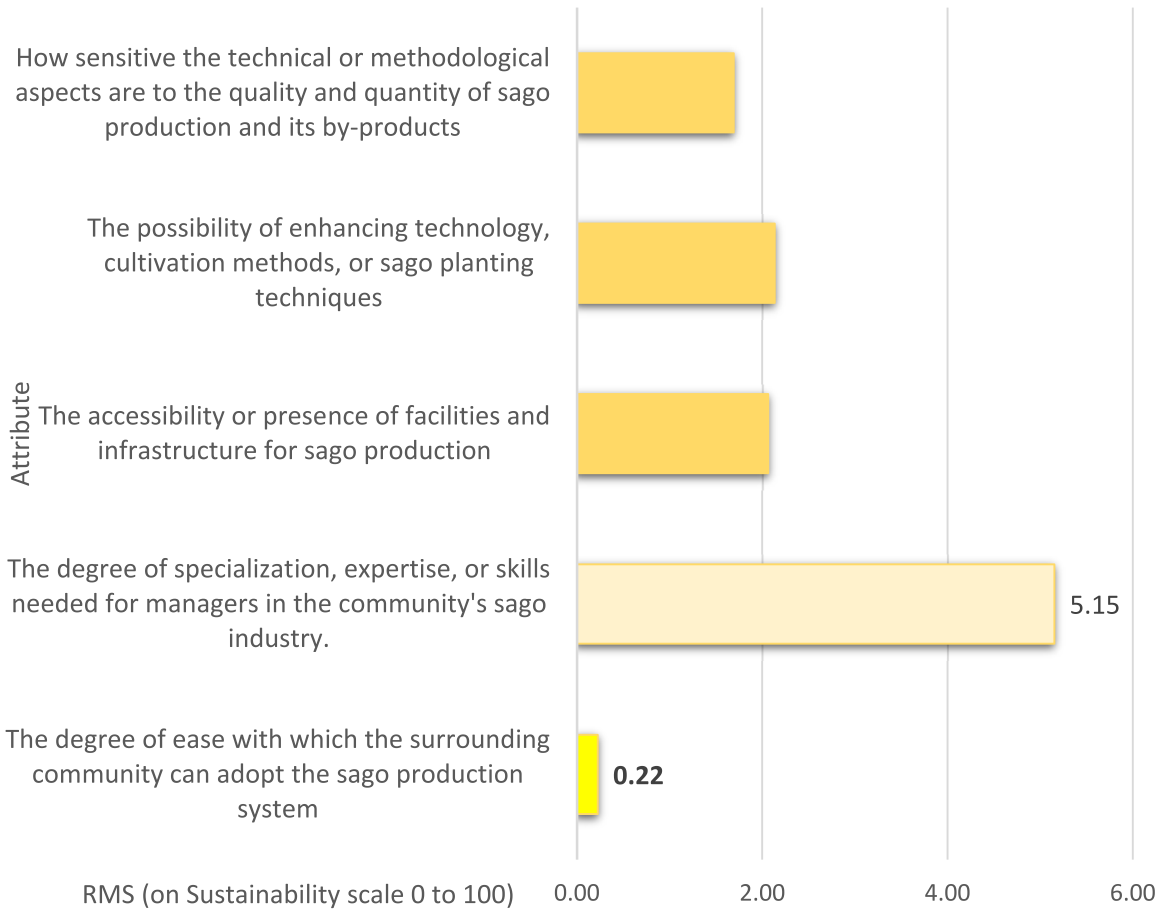


Fig. 6: Leverage attribute for technology dimension

Dalampira *et al*. (2022) stated that extension workers acted as trainers, innovators, educators, mentors, organizers, technicians, consultants, and advocates in technology transfer, a continuous process with follow-up activities (Rani *et al*., 2021).

The analysis of leverage attribute for technology dimension indicated that one attribute dominated the other four. This included the level of specialization/ skills/expertise required for managing community-based Sago industry (Fig. 6). Therefore, human resource development should be considered, particularly in mastering technology related to Sago industry, as well as the role of extension services. Technology transfer in Indonesian agriculture, according to Suwanan *et al*. (2021), is closely related to the provision of extension services.

## CONCLUSION

In conclusion, sustainability value of Sago palm smallholder industry in Simeulue Regency, viewed through Economic Dimension, firstly, required improvements in production factors. This was specifically crucial for the cultivation of Sago plant, relying solely on naturally growing Sago resources. Secondly, there was a need to increase the use of Sago pulp as animal feed to enhance the substitution of commercial rations and improve sustainability value of economic dimension. In environmental dimension, studies and socialization efforts were crucial regarding the processing or use of liquid waste. This method could help mitigate pollution to soil, water, and air. Furthermore, farmers should be equipped with cultivation skills to enhance the value of social and technological dimensions. Sago palm smallholder industry required support from upstream to downstream to organize cultivation, process commodities using technology, and reduce negative environmental impacts. Based on the main objective of calculating Sago industrial sustainability index, a quantitative conclusion was formulated on the value of sustainability index. The results showed a less-than-optimal sustainability of smallholder Sago industry and waste use for animal feed in Simeulue Regency, as indicated by sustainability index of approximately 46.03%. Environmental dimension specifically showed sustainability index of 27.89%. In contrast, economic, social, and technological dimensions showed moderately sustainable statuses with sustainability index ranging from 45.56% to 55.65%. This suggested that while there were areas of moderate sustainability, urgent attention was required to address environmental concerns. In the complex landscape of sustainability, a total of 35 leverage attributes crucial for influencing sustainability of the community Sago industry management and waste use for animal feed was identified. The attributes included factors such as the contribution to increasing the substitution of animal feed ingredients from Sago waste products, the potential for air pollution, the knowledge level of Sago tree management among worker managers, as well as the requisite specialization, expertise, and skills for managers in palm smallholder industry. Recognizing these as highly sensitive factors, strategic management and improvement of the attributes were necessary for enhancing sustainability. Moreover, the attributes could serve as basis for developing targeted policies aimed at sustaining Sago palm smallholder industry. This study offered valuable insights into the current state of sustainability in Sago industry and waste use for animal feed. By identifying the crucial role of environmental dimension and addressing key leverage attributes, policymakers and industry stakeholders could collaboratively work toward implementing targeted strategies to improve sustainability and ensure the longevity of Sago palm smallholder industry in the area. This study also provided a roadmap for informed decision-making, demonstrating the interconnectedness of economic, social, environmental, and technological factors in achieving a more sustainable Sago industry.

## AUTHOR CONTRIBUTIONS

Allaily conducted a thorough literature review, designed the study, supervised the experiments, and drafted the manuscript; A.D. Santoso drafted the manuscript and supervised the experiments; M.N. Rofiq designed the study; N.A. Sasongko played a key role in conceptualizing the study and interpreting the data; H. Daulay contributed to the preparation of the manuscript; E.I. Wiloso critically analyzed the crucial substantive value of the manuscript; E. Widjaja critically analyzed the crucial substantive value of the manuscript; B. N. Utomo prepared and supervised the manuscript; A.I. Yanuar contributed to data processing and statistical analyses; Y.P. Erlambang provided bibliographic material and operational support; A. Anhar provided operational support; M. Rahmawati drafted the manuscript ; D. Iskandar drafted the manuscript; T. Simamora drafted the manuscript; M. Ammar supported data collection; Y. Yusriani contributed to manuscript drafting; G. Maghfirah drafted the manuscript; Suryani produced maps and figures; and U.N. Thiyas facilitated linking the literature review and data recognition.

## ACKNOWLEDGMENTS

The authors are grateful to the Field Team R. Rafiqi, the managers of 7 Sago factories in 5 districts in Simeulue Regency for granting permission to conduct this study, the Head of Simeulue Agriculture and Plantation Livestock Office, the Head of the Research Centre for Sustainable Production Systems and Life Cycle Assessment, National Research and Innovation Agency, and the Management Talent for the Post Doctoral Programme. This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. In addition, ethical issues, including plagiarism, informed consent, misconduct, data fabrication and falsification, double publication and submission, and redundancy, were observed by the authors.

## OPEN ACCESS

## PUBLISHER'S NOTE



## ABBREVIATIONS

| | |
|---|---|
| *%* | Percent |
| *DPSIR* | Driving Force Pressure State Impact Response |
| *FGD* | Focus group discussions |
| *GHG* | Greenhouse Gas |
| *ha* | Hectare |
| *kg* | Kilogram |
| *km²* | square kilometer |
| *kWh* | Kilowatt-hour |
| *LADA* | Land degradation assessment in drylands |
| *MASC* | Multiattribute assessment of sustainability of cropping systems |
| *MDS* | Multidimensional scaling |
| *NDF* | neutral detergent fiber |
| *PCA* | Principal Component Analysis |
| *PG* | Public goods |
| *Rapfish* | Rapid appraisal for fisheries, an analytical method to assess the sustainability of fisheries based on a multidisciplinary approach |
| *RISE* | Response-inducing sustainability evaluation |
| *RMS* | Root Mean Square |
| $R^2$ | coefficient of determination |
| *S* | Stress |
| *SAFA* | Sustainability assessment of food and agriculture systems |
| *SDG* | Sustainable development goals |
| *SEM* | Structural-equation-modeling |
| *SMART* | Sustainability monitoring and assessment routine |
| *x-axis* | Horizontal number line |
| *y-axis* | Vertical number line |

## REFERENCES

Agovino, M.; Ferrara, M.; Garofalo, A. (2017) The driving factors of separate waste collection in Italy: A multidimensional analysis at provincial level. Environment, Development and Sustainability. 19(6): 2297 – 2316 (**20 pages**).

Alaoui, A.; Barao, L.; Ferreira, C.S.S.; Hessel, R., (2022). An overview of sustainability assessment frameworks in agriculture. Land. 11(537): 1-26 **(26 pages).**

Allaily, A.; Samadi,S.; Daud, M.; Aprilia, T.; Dwina, E.N.; Zulfan, Z.; Yaman, M.A.; Rofiq, M.N. (2023). Utilization of fermented Sago pulp and effect on the performance of broiler ducks. Pol. J. Environ. Stud. 33(2): 1001-1006 (**6 pages**).

Allaily, A.; Samadi; Fitriani, A. (2023). Quality of fermented solid Sago waste for animal feed using EM4 on pH, LAB population, and total bacteria. Jurnal Peternakan Indonesia. 25(2): 150-155 (**6 pages).**

Amin, N.; Sabli, N.; Izhar, S.; Yoshida, H., (2019). Sago wastes and its applications. Pertanika J. Sci. Technol. 27(4): 1841-1862 **(22 pages).**

Amni, C.; Ismet; Aprilia, S.; Mariana., (2019). Study on biodegradable plastic from Sago with the addition of glycerol and serbitol. IOP Conference Series: Earth Environ. Sci., 365: 012052. **(6 pages).**

Ariningsih, E.; Rachman, B.; Sudaryanto, T.; Ariani, M.; Septanti, K.S.; Adawiyah, C.R., (2021). Strategies for sustainable corn production: A case of South Lampung District, Lampung Province, Indonesia. IOP Conference Series: Earth Environ. Sci., 892: 012075 **(8 pages).**

Bantacut, T.; Indriyani, F., (2022). Energy sufficiency of biomass and wastewater in closed process of Sago starch production. Industria: J. Teknologi dan Manajemen Agroindustri. 11(1): 10-18 **(9 pages).**

Bhattacharya, K.; Sarkar, D.; Chatutvedi, S., (2023). Application of factor analysis and structural equation modelling for evaluation of key performance indicators affecting the development of sustainable transportation model. SSRN Product and Services, 1-37 **(37 pages).**

Borg, I.; Patrick, J.F.; Groenen; Mair, P., (2018). Applied Multidimensional Scaling and Unfolding. Springer Cham.

Cakmakci, R.; Salik, M.A.; Cakmakci, S. (2023). Assessment and principles of environmentally sustainable food and agriculture systems. Agriculture. 13, 1073: 1-27 **(27 pages).**

Chisoro, P.; Jaja, I. F.; Assan, N. (2023). Incorporation of local novel feed resources in livestock feed for sustainable food security and circular economy in Africa. Frontier in Sustainability. 4: 1251179 (**17 pages**).

Dalampira, E.S.; Tsoukalidis, I.; Lazaridou, D.; Nikouli, S.; Livadiotis, A.; Michailidis, A., (2022). Investigating technology transfer gaps through farmers field school. European J. Interdiscip. Stud., 14(2): 193-206 **(14 pages).**

Deb, G.K.; Nahar, T.N.; Duran, P.G.; Presicce, G.A., (2016). Safe and sustainable traditional production: The water buffalo in Asia. Front. Environ. Sci., 4(38): 1-7 **(7 pages).**

Dharmawan, A.H.; Fauzi, A.; Putri, E.I.; Pacheco, P.; Dermawan, A.; Nuva, N., Amalia, R.; Sudaryanti, D.A., (2020). Bioenergy policy: The biodiesel sustainability dilemma in Indonesia. Int. J. Sustainable Dev. Plann., 15(4): 537-546 **(10 pages).**

Directorate General of Estates, (2021). Statistical of National Leading Estate Crops Commodity 2020-2022. Ministry of Agriculture.

Ehara, H.; Toyoda, Y.; Johnson, D.V., (2018). Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. Springer Singapore.

Fairuzia, N.; Krisnamurthi, B.; Rifin, A., (2020). Analysis of sustainability status of cocoa plantation smallholders. IOP Conference Series: Earth Environ. Sci., 486: 012001 **(8 pages).**

Fan, J.; Liu, C.; Xie, J.; Han, L.; Zhang, C.; Guo, D.; Niu, J.; Jin, H.; McConkey, B.G., (2022). Life cycle assessment on agricultural production: A mini review on methodology, application, and challenges. Int. J. Environ. Res. Public Health. 19: 9817 **(16 pages).**

Fauzi, A.; Anna, Z., (2005). Modeling of Fisheries and Marine Resources. Gramedia. Jakarta.

Garrett, R.D.; Gardner, T.A.; Morello, T.F.; Marchand, S.; Barlow, J.; Blas, D.E.; Ferreira, J.; Lees, A.C.; Parry, L., (2017). Explaining the persistence of low income and environmentally degrading land uses in the Brazilian Amazon. Ecol. Soc., 22(3): 27 **(24 pages).**

Girsang, W., (2018). Feasibility of Small-Scale Sago Industries in the Maluku Islands, Indonesia. Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. Springer Singapore. 109-121 **(13 pages).**

Giuntoli, J.; Barredo, J.I; Avitabile, V.; Camia, A.; Cazzaniga, N.E.; Grassi, G.; Jasinevičius, G.; Jonsson, R.; Marelli, L.; Robert, N.; Agostini, A.; Mubareka, S., (2020). The quest for sustainable forest bioenergy: win-win solutions for climate and biodiversity. Renewable Sustainable Energy Rev., 159: 112180 **(20 pages).**

Heylen, C.; Meunier, F.; Peeters, A.; Ek, S.; Neang, M.; Hean, S.; Peanh, S., (2020). Multidimensional benefits of sustainable agriculture practices of Cambodian smalllholder farmers. Sustainable Agric. Res., 9(1): 10 – 25 **(16 pages).**

Hidayat, F.R.; Hakim, L.; Parmawati, R. (2023). Analysis of community-based Coffee agro-tourism sustainability in East Java, Indonesia. Habitat. 34(1): 1-12 (**12 pages).**

Ingrassia, M.; Chironi, S.; Grasso, G.; Gristina, L.; Francesca, N.; Bacarella, S.; Columba, P.; Altamore, L. (2022) Is environmental sustainability also "Economically efficient"? The case of the "SOStain" certification for Sicilian Sparkling Wines. Sustainability. 14 7359: 1-26 (**26 pages**).

Irianto, H.; Riptanti, E.W.; Widiyanti, E.; Khairiyakh, R.U., (2023). Sustainability strategy for organic paddy farming business toward global market: Network process analysis approach. Universal J. Agric. Res., 11(1): 56-71 **(16 pages).**

Ishak, S.Z.A.; Yaakub, A.N.; Daud, A.I.A.; Hussin, S.H.; Yusof, A., (2020). Constraints affecting the increase of Sago production: A case of Melanau rural youth's participation in Sago industry in Sarawak, Malaysia. Int. J. Academic Res. Bus. Soc. Sci., 11(14): 51-70 **(20 pages).**

Jong F.S., Ehara, H., (2018). Sago Palm: An Overview of Sago Industry Development, 1980–2015. Sago Palm: multiple contributions to food security and sustainable livelihoods. Springer Singapore. 75-89 **(15 pages).**

Kadir, A.; Suharno; Reawaruw, Y.; Komari; Mahuze, A. (2022) Ethnobotanical knowledge of Marind-Anim Tribe in utilizing Sago (Metroxylon sagu) in Merauke, Papua, Indonesia. Biodiversitas. 239910: 264-272 (**9 pages**).

Kapa, M.M.J.; Hasnudi; Henuk, Y.L., (2019). Measuring technology sustainability status of local beef cattle under extensive rearing systems in the dryland area, Indonesia. IOP Conference Series: Earth Environ. Sci., 260: 012018 **(5 pages)**.

Kavanagh, P.; Pitcher, T.J., (2004). Implementing microsoft excel software for rapfish: A technique for the rapid appraisal of fisheries status. Fish Centre, University of British Colombia, 12(2): 1–75 **(75 pages).**

Konuma, H.; Ehara, H., (2018). Sago palm: Status and outlook of global food security and the role of underutilized food resources: Sago Palm. Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. Springer Singapore. 3-16 **(14 pages).**

Lloyd, C.; Ananthan, P.S.; Ramasubramanian, V.; Sugunan, V.V.; Panikkar, P.; Landge, A.T., (2022). Rapid reservoir fisheries appraisal (r-RAPFISH): Indicator based framework for sustainable fish production in Indian reservoirs. J. Cleaner Prod., 379 : 134435 **(17 pages).**

Lopes, A. M.; Machado, J. A. T. (2022). Multidimensional scaling and visualization of patterns in global large-scale accidents. Chaos, Solitons Fractals. 157: 111951 **(14 pages).**

Lovarelli, D.; Bacenetti, J.; Guarino, M., (2020). A review on dairy cattle farming: Is precision livestock farming the compromise for an environmental, economic and social sustainable production?. J. Cleaner Prod., 262: 121409 **(13 pages).**

Mailena, L.; Sirnawati, E.; Widjaja, E.; Ibrahim, T.; Nurfaida., (2021). Sustainability assessment of chili farming in the highlands of Pacet Sub District, Regency of Cianjur, West Java. IOP Conference Series: Earth Environ. Sci., 807: 032049 **(10 pages).**

Mucharam, I.; Rustiadi, E.; Fauzi, A.; Harianto., (2019) Development of sustainable agricultural indicators at provincial levels in Indonesia: A case study of rice. IOP Conference Series: Earth Environ. Sci., 399: 012054 **(9 Pages).**

Mucharam, I.; Rustiadi, E.; Fauzi, A.; Harianto**.** (2020) Assessment of rice farming sustainability: Evidence from Indonesia provincial data, International Journal of Sustainable Development and Planning, 15(8): 1323 – 1332 (**10 pages).**

Mucra, D.A.; Adelina, T.; Harahap, A.E.; Mirdhayati, I.; Perianita, L.; Halimatussa'diyah., (2020). Kualitas nutrisi dan fraksi serat wafer ransum komplit subtitusi dedak jagung dengan level persentase ampas sagu yang berbeda. J. Peternakan. 17(1): 49 – 53 **(5 pages)**.

Murod, M.; Kusmana, C.; Bintoro, M.H.; Widiatmaka; Hilmi, E., (2019). Strategy of Sago management sustainability to support food security in Regency of Meranti Islands, Riau Province, Indonesia. Adv. Agric. Botanics. 11(1): 1-20 **(20 pages).**

Nuraini, C.; Mutolib, A., (2023). The sustainability analysis of red chili farming in Taraju District, Tasikmalaya Regency. IOP Conference Series: Earth Environ. Sci., 1133 **(8 pages).**

Ominski, K.; McAllister, T.; Stanford, K.; Mengistu, G.; Gunte, K.E.; Omonijo, F.; Cordeiro, M.; Legesse, G.; Wittenberg, K. (2021). Utilization of by-products and food waste in livestock production systems: A Canadian perspective. Anim. Front., 11(2): 55-63 (**9 pages)**.

Paczka, G.; Mazur-Pączka, A.; Garczyńska, M.; Kostecka, J.; Butt, K.R., (2021). Garlic (Allium sativum L.) Cultivation using vermicompost-amended soil as an aspect of sustainable plant production. Sustainability. 13(24): 13557 **(11 pages).**

Papilo, P.; Marimin, M.; Hambali, E.; Machfud, M.; Yani, M.; Asrol, M.; Mahmud, J., (2022). Palm oil-based bioenergy sustainability and policy in Indonesia and Malaysia: A systematic review and future agendas. Heliyon. 8(10): 10919 **(17 pages).**

Parmawati, R.; Risvita, W.; Hakim, L.; Rahmawati, N.O.; Gunawan, F. K.; Ashari, F.M.; Haqqi, S.S., (2023) Sustainability index of Robusta Coffee plantation (Cases study: Wagir District smallholder Coffee plantation in Malang, Indonesia**.** *International Journal of Design and Nature and Ecodynamics*. 18(2): 279–288 (**10 pages).**

Partini, P.; Noer, M.; Suliansyah, I.; Devianto, D., (2023). Review literatur: Dinamika pengembangan perkebunan sagu berkelanjutan berbasis kearifan lokal. J. Agribisains. 9(1): 28-37 **(10 pages).**

Periyasamy, P.; Sagar, R., (2021). Assessment of environmental damage and policy actions by using contingent valuation method: An empirical analysis of Sago industrial pollution in Tamil Nadu, India. J. Environ. Law Policy. 1: 86-104 **(19 pages).**

Pitcher, T.J.; Preikshot, D., (2001). RAPFISH: A rapid appraisal technique to evaluate the sustainability status of fisheries. Fish. Res., 49(3): 255-270 **(16 pages).**

Rachman, B.; Ariningsih, E.; Sudaryanto, T.; Ariani, M.; Septanti, K.S.; Adawiyah, C.R.; Ashari; Agustian, A.; Saliem, H.P.; Tarigan, H.; Syahyuti; Yuniarti, E., (2022). Sustainability status, sensitive and key factors for increasing rice production: A case study in West Java, Indonesia. PLoS One. 17(12): 1-19 **(19 pages).**

Ralahalu, T.N.; Latupeirissa. CH.C.E.; Hehanussa, S.CH.H.; Fredriksz, S., (2021). Performance of native chicken fed on ration containing fermented Sago waste. IOP Conference Series: Earth Environ. Sci., 883**:** 012084 **(8 pages).**

Rani, S. S.; Rao, B.M.; Ramarao, P., (2021). Technology transfer processes from Indian public funded research and development institutions to industries. Int. J. Manage., 12(2): 21 – 39 **(19 pages).**

Rasyid, T.H.; Kusumawaty, Y.; Hadi, S. (2020), The utilization of Sago waste: prospect and challenges, IOP Conference Series: Earth Environ. Sci., 415: 012023 **(8 pages).**

Rianza, R.; Rusmana, D.; Tanwiriah, W., (2019). The use of fermented Sago pulp as feed for super-native chicken for 1-5 weeks. Jurnal Ilmu Ternak Universitas Padjadjaran. 19(1): 36 – 44 **(9 pages).**

Rizky, F.A; Santosa, E.; Nursina., (2023). Pengaruh pengetahuan kewirausahaan, kualitas produk, dan keterampilan wirausaha terhadap keberhasilan pedagang cabai PD Jaya Pasar Induk Kramatjati Jakarta Timur. J. Ikrath-Ekonomika. 6(2) 182 – 190 **(9 pages).**

Rohaeni, E.S.; Santoso, A.D.; Ariningsih, E.; Widaningsih, N.; Hutahaean, L.; Priyanto, D.; Ilham, N.; Suharyon, S.; Herdis, H.; Widiawati, Y.; Hadiatry, M.C.; Ermuna, S.S.; Mardiharini, M.; Sugandi, D.; Bakrie, B.; Wasito, W., (2023). Analysing the sustainability of swamp buffalo (Bubalus bubalis carabauesis) farming as a protein source and germplasm. Open Agric., 8(1): 20220224 **(23 pages).**

Saediman, H.; Helviani, H.; Said, L.R.; Sarinah, S.; Taridala, S.A.A.; Alwi, L.O.; Rianse, I.S., (2021). Market structure of Sago starch in Southeast Sulawesi, Indonesia. Wseas Trans. Bus. Econ., 18: 628-635 **(8 pages).**

Saleh, H.; Surya, B.; Hamsina., (2020). Implementation of Sustainable Development Goals to Makassar Zero Waste and Energy Source. Int. J. Energy Econ. Policy. 10(4): 530-538 **(9 pages).**

Santoso, A.D.; Hariyanti, J.; Pinardi, D.; Kusretuwardani; Widyastuti, N.; Djarot, I.N.; Handayani, T.; Sitomurni, I.; Apriyanto, H., (2023). Sustainability index analysis of microalgae cultivation from biorefinery palm oil mill effluent. Global J. Environ. Sci. Manage., 9(3): 559-576 **(18 pages).**

Santoso, A.D.; Arianti, F.D.; Rohaeni, E.S.; Haryanto, B.; Pertiwi, M.; Panggabean, L.P.; Prabowo, A.; Sundari, S.; Wijayanti, S.P.; Djarot, I.N.; Kurniawati, F.; Sahwan, F.L.; Prasetyo, T.; Barkah, A.; Adibroto, T.A.; Ridlo, R.; Febijanto, I.; Wasil, A.A.; Lusiana, S.; Rosmeika, R., Heryanto, R. B., (2023a). Sustainability index analysis of organic fertilizer production from paunch manure and rice straw waste. Global J. Environ. Sci. Manage., 9(SI): 193-218 **(26 pages).**

Santoso, A.D.; Handayani, T.; Nugroho, R.A.; Yanuar, A.I.; Nadirah, N.; Widjaja, E.; Rohaeni, E.S.; Oktaufik, M.A.M.; Ayuningtyas, U.; Erlambang, Y.P.; Herdioso, R.; Rofiq, M.N.; Hutapea, R.; Sihombing, A.L.; Rustianto, B.; Susila, I.M.A.D.; Irawan, D.; Iskandar, D.; Indrijarso, S.; Widiarta, G.D., (2023b). Sustainability index analysis of the black soldier flies *(Hermetia illucens)* cultivation from food waste substrate. Global J. Environ. Sci. Manage., 9(4): 851-870 **(20 pages).**

Sari, D.A.A.; Suryanto; Sudarwanto, A.S.; Nugraha, S.; Utomowati, R., (2020). Reduce marine debris policy in Indonesia. IOP Conference Series: Earth Environ. Sci., 724: 012118 **(6 pages).**

Sari, C.P.; Sukendi, S.; Siregar, Y. I.; Afandi, D. (2023) Ecological and socio-economic sustainability of built environment of Peatlands using rap-disease control with Multi-Dimensional Scaling. International Journal of Sustainable Development and Planning, 18(12): 4041–4047 **(7 pages)**.

Setiawan, D.; Jayanegara, A.; Nahrowi; Kumalasari, N.R. (2022). Performance and nutrient digestibility of kacang goats fed with fermented Sago waste. IOP Conf. Series: Earth and Environmental Science 977 (012136) (**6 pages).**

Sidiq, F.F.; Coles, D.; Hubbard, C.; Clark, B.; Frewer, L.J., (2021). Sago and the indigenous peoples of Papua, Indonesia: A review. Journal of Agriculture and Applied Biology, 2(2):138-149 (**12 pages**).

Sivaraman, I.; Krishnan, M.; Radhakrishnan, K., (2019). Better management practices for sustainable small-scale shrimp farming. J. Cleaner Prod., 214: 559-572 **(14 pages).**

Suardi, T.F.; Sulistyowati, L.; Noor, T.I.; Setiawan, I., (2022). Analysis of the sustainability level of smallholder oil palm agribusiness in

Labuhanbatu Regency, North Sumatra. Agriculture., 12(9): 1469 **(16 pages).**

Suresh, K.; Tang, T.; Vliet, M.V.; Bierkens, M.F.P.; Strokal, M.; Domenigg, F.S.; Wada, Y., (2023). Recent advancement in water quality indicators for eutrophication in global freshwater lakes. Environ. Res. Lett., 18(6): 063004 **(34 pages).**

Susanti, T.L.; Safitri, R.; Padmadijaya, A. H. (2022). Utilization of Sago dregs as ruminant feed by using the fermentation method: Literature review. Bioteknologi & Biosians Indonesia. 9(2): 268-282 (**15 pages).**

Suwanan, A.F.; Rori, A.M.; Kurniawan, D.T., (2021). The critical review of agriculture technological transfer in the era of decentralization. E3S Web of Conferences. 306: 03021 **(7 pages).**

Syahputra, R.; Pambudi, O. I.; Mujaahid, F.; Soesanti, I., (2020). A study of sugarcane waste for biomass energy in the supply of electrical energy. J. Elect. Technol., 4(1): 28 – 38 **(11 pages).**

Talakua, J.; Rukoyah., (2023). Sago forest ecotourism potential in Negeri Rutong South Leitimur District. J. Humanit. Social Stud., 1(03): 785 – 797 **(13 pages).**

Timisela, N.R.; Siahaya, W.A.; Hehanussa, M.M.; Polnaya, F.J., (2022). Condition of plantation and development strategy of Sago garden. Int. J. Sustainable Dev. Plann., 17(2): 421 – 432 **(12 pages).**

Trisia, M.A.; Tachikawa, M.; Ehara, H. (2021). The role of the Sago supply chain for rural development in Indonesia: A Review and Perspective. Reviews in Agricultural Sclence,9: 143-156 (**14 pages**).

Wahyuni, S., (2013).Teori konsumsi dan produksi dalam perspektif ekonomi islam. Jurnal Akuntabel. 10(1): 74 – 79 **(6 pages).**

Wani, Najaf Ali, and Umakanta Mishra. "A sustainable municipal solid waste supply chain management with biodiesel energy production using microwave technology." *Environment, Development and Sustainability* (2023): 1-38 **(38 pages).**

Widjaja, E., Utomo, B.N.; Santoso, A.D.; Erlambang, Y.P; Surono; Firmansyah, M.A.; Handoko, S.; Erythrina, E.; Rofiq, M.N.; Iskandar, D.; Sasongko, N.A.; Rochmadi, T.; Abbas, N.; Hanif, M.; Garno, Y.S.; Arianti, F.D.; Suretno, N.D.; Askinatin, M.; Hastuti, C.O.I.; Fahrodji, F., (2023). Sustainability index analysis for environmentally low-input integrated farming. Global J. Environ. Sci. Manage. 10(2):1-20 **(20 pages).**

Wulan, S. (2018). Sago as an environmentally sustainable food resource in the climate change era. J. Environ. Sci. Sustainable Dev., 1(1): 53 – 73 **(11 pages).**

Yusuf, E.S.; Ariningsih, E.; Ashari; Gunawan, E.; Purba, H.J.; Suhartini, S.H.; Tarigan, H.; Syahyuti; Hestina, J.; Saputra, Y.H.; Wulandari, S.; Ilham, N.; Ariani, M., (2022). Sustainability of arabica coffee business in West Java, Indonesia: A multidimensional scaling approach. Open Agric., 7: 820–836 **(17 pages).**

Yusuf, M.A.; Romli, M., (2020). Study on cleaner production strategy in the medium scale Sago starch industry: A case study in Cimahpar, North Bogor Sub-District. Musamus AE Featuring Journal. 2(2): 82 – 91 **(10 pages).**

Yusuf, M.S., (2019). Sustainability of Sago agro-industry using rapid appraisal: Case study in Sago industri X in South Sorong, Papua. Europian International Conference on Industrial Engineering and Operations Management. 3: 1436- 1445 **(10 pages).**

Zanten, H. H. E. V.; Ittersum, M. K. V.' Boer, I. J. M. D. (2019) The role of farm animals in a circular food system. Global Food Security. 21: 18-22 (**5 pages).**

Zhang, Y.; Ding, C., (2023). Using MDS preference plot as visual analytics of data: A machine learning approach. Methodol. Innovations. 16(1): 205979912211445 **(11 pages).**

Zurriyati, Y.; Ahmad, S.N.; Yusriani, Y., (2023). The utilization of Sago dregs to increase body weight gain and feed conversion rate of Balitbangtan superior native chicken. Animal Prod., 25(2): 92-98 **(7 pages).**

**AUTHOR (S) BIOSKETCHES**

**Allaily,** Ph.D., Lecturer, [1] Animal Sciences Department of Agricultural Faculty, Universitas Syiah Kuala, Banda Aceh Indonesia; [2]Post Doctoral Researcher, Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia. [3]Researcher member in Research Center Aceh Cattle and Local Husbandry Universitas Syiah Kuala Banda Aceh Indonesia.

- Email: *allaily@usk.ac.id*
- ORCID: 0000-0001-5216-6713
- Web of Science Researcher ID: JQV-9813-2023
- Scopus Author ID: 57215089702
- Homepage: https://fsd.usk.ac.id/allaily/

**Santoso, A.D.,** Ph.D., Senior Researcher, Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia.

- Email: *arif.dwi.santoso@brin.go.id*
- ORCID: 0000-0003-3595-9265
- Web of Science Researcher ID: HJY-1972-2023
- Scopus Author ID: 56516534000
- Homepage: https://brin.go.id/

**Rofiq, M.N.,** Ph.D**.,** Researcher, Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia.

- Email: *mnas001@brin.go.id*
- ORCID: 0000-0002-4632-9376
- Web of Science Researcher ID: AAZ-6409-2020
- Scopus Author ID: 57221967761
- Homepage: https://brin.go.id/

**AUTHOR (S) BIOSKETCHES**

**Sasongko, N.A.,** Ph.D., Researcher and Director at Research Center for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia
- Email: *nugroho.adi.sasongko@brin.go.id*
- ORCID: 0000-0002-6546-1348
- Web of Science Researcher ID: IUM-2301-2023
- Scopus Author ID: 56709544200
- Homepage: https://www.linkedin.com/in/nugroho-adi-sasongko-94558ab9/

**Daulay, H.,** Dr., Senior Researcher at Research Center for Behavioral and Circular Economy, National Research and Innovation Agency, Indonesia
- Email: *hotm001@brin.go.id*
- ORCID: 0000-0001-9664-5548
- Web of Science Researcher ID: HJP-7060-2023
- Scopus Author ID: ID: 6506164078
- Homepage: https://brin.go.id/

**Wiloso, E.I.,** Ph.D., Associate Proofessor, Research Center for Sustainable Production System and Life Cycle Assessment, BRIN, Tangerang, Indonesia
- Email: *edi.iswanto.wiloso@brin.go.id*
- ORCID: 0000-0002-9308-3030
- Web of Science ResearcherID: G-5542-2015
- Scopus Author ID: 55274147100
- Homepage: https://brin.go.id/

**Widjaja, E.,** Ph.D., Researcher at Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency (BRIN), Indonesia.
- Email: *ermi005@brin.go.id*
- ORCID: 0009-0007-2993-0577
- Web of Science Researcher ID: EED-5296-2022
- Scopus Author ID: 57217826643
- Homepage: https://brin.go.id/

**Utomo, B.N.,** Ph.D., Researcher at Research Center for Veterinary Science, National Research and Innovation Agency (BRIN), Indonesia
- Email: *bamb063@brin.go.id*
- ORCID: 0000-0003-3472-515X
- Web of Science Researcher ID: JFJ-3890-2023
- Scopus Author ID: 57211914562
- Homepage: https://brin.go.id/

**Yanuar, A.I.,** M.Eng. Reseacher at Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia.
- Email: *ahma028@brin.go.id*
- ORCID: 0000-0003-4322-1383
- Web of Science Researcher ID: HOH-0253-2023
- Scopus Author ID: 57990829300
- Homepage: https://brin.go.id/

**Suryani, S.** Si., Researcher, Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia
- Email : *sury021@brin.go.id*
- ORCID : 0009-0005-6072-8911
- Web of Science Researcher ID: JXN-4818-2024
- Scopus Author ID: NA
- Homepage: https://brin.go.id/

**Erlambang, Y.P.,** B.Eng., Researcher at Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia.
- Email: *yaumilerlambang@gmail.com*
- ORCID: 0009-0008-5342-0099
- Web of Science Researcher ID: HRC-5569-2023
- Scopus Author ID: 57990917300
- Homepage: https://brin.go.id/

**Thiyas, U.N.,** S.Si., Researcher at Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency (BRIN) , Indonesia.
- Email:*ulfa002@brin.go.id*
- ORCID: 0009-0003-8517-9838
- Web of Science Researcher ID: JXN-6131-2024
- Scopus Author ID: NA
- Homepage: http://brin.go.id/

**AUTHOR (S) BIOSKETCHES**

**Iskandar, D.,** Ph.D, [2)]Senior Researcher at Research Centre for Sustainable Production System and Life Cycle Assessment, [5)]Directorate Policy Evaluation for Research Technology and Innovation, National Research and Innovation Agency, Indonesia.
- Email: *dudi002@brin.go.id*
- ORCID: 0000-0001-9092-0619
- Web of Science Researcher ID: HRA-9766-2023
- Scopus Author ID: 58578191500
- Homepage: https://brin.go.id/

**Ashabul, A.** Ph.D., Professor, Department of Forestry Science, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia
- Email: *ashabul.anhar@usk.ac.id*
- ORCID: 0000-0002-8948-3058
- Web of Science Researcher ID: AAW-1610-2021
- Scopus Author ID: 55184033500
- Homepage: https://fsd.usk.ac.id/ashabul.anhar/

**Rahmawati, M.** M.Sc., Department of Agrotechnology, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia.
- Email: *marai_rahmawati@usk.ac.id*
- ORCID: 0009-0001-0397-4666
- Web of Science Researcher ID: NA
- Scopus Author ID: 58209128900
- Homepage: https://fsd.usk.ac.id/marai.rahmawati/

**Simamora, T.,** Ph.D., [2)]Post Doctoral at Research Centre for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Indonesia. [9)]Animal Husbandry Study Program, Faculty of Agriculture, Science and Health, Timor University.
- Email: *turesimamora@unimor.ac.id*
- ORCID: 0000-0001-8331-5590
- Web of Science Researcher ID: JGL-8414-2023
- Scopus Author ID: 58209128900
- Homepage: https://www.unimor.ac.id/

**Yusriani, Y.,** Ph.D., Research Center for Animal Husbandry, Research Organization for Agriculture and Food, National Research, and Innovation Agency of The Republic of Indonesia (BRIN), Cibinong Sciences Center, Bogor, Indonesia
- Email: *yenn011@brin.go.id*
- ORCID: 0000-0002-6570-2527
- Web of Science Researcher ID: NA
- Scopus Author ID: 57215095896
- Homepage: https://brin.go.id

**Magfirah, G.,** M.Si., Environmental Engineering Department, Universitas Serambi Mekkah, Banda Aceh, Indonesia
- Email : *geubrinamaghfirah@serambimekkah.ac.id*
- ORCHID: 0009-0005-0877-1269
- Web of Science Researcher ID: NA
- Scopus Author ID: NA
- Homepage: https://serambimekkah.ac.id

**Ammar, M.,** M.Si., Lecturer in Animal Sciences Agriculture Faculty Universitas Syiah Kuala, Banda Aceh Indonesia
- Email: *ammar@usk.ac.id*
- ORCHID: 0009-0003-7505-6906
- Scopus Author ID: 57225946099
- Web of science ID: JXM-5139-2024
- Homepage: peternakan@usk.ac.id



**HOW TO CITE THIS ARTICLE**

*Allaily; Santoso, A.D.; Rofiq, M.N.; Sasongko, N.A.; Daulay, H.; Wiloso, E.I.; Widjaja, E.; Yanuar, A.I.; Suryani; Erlambang, Y.P.; Thiyas, U.N.; Iskandar, D.; Utomo, B.N.; Anhar, A.; Rahmawati, M.; Simamora, T.; Yusriani, Y.; Maghfirah, G.; Ammar, M., (2024). Sustainaibility assessment of animal feed production from by-products of smallholder Sago industry. Global J. Environ. Sci. Manage., 10(3): 1-22.*

**DOI:** 10.22035/gjesm.2024.03.***

**URL:** ***