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Short Communication

Sustainability Evaluation of Seaweed Aquabusiness Management in Support of Sustainable Development Goal in Ekas Bay, East Lombok

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Abstract

Indonesia is one of the major countries in the world that produces seaweed. West Nusa Tenggara has become one of the centers of seaweed producers in Indonesia because it has many bays that are used for seaweed cultivation activities. The problem of seaweed aquabusiness is the low productivity of the production unit managed by seaweed farmers. This study aimed to assess the effectiveness and production level of seaweed cultivation technology and the success of seaweed cultivation by seaweed farmers in Ekas Bay based on technological dimensions (17 attributes) and economics (14 attributes). The Rapsewaqua application is used to analyze the sustainability status of seaweed cultivation. Based on the results of the analysis, the index value was 50.08 for the technology dimension and 39.50 for the economic dimension. The result showed that the sustainability of seaweed in Ekas Bay was in the less sustainable category. Spacing between seed clumps, drying area, seedling binding location, and warehouse were the most sensitive attributes on the technological dimension. Market status, market scale, and target market were the most sensitive attributes in the economic dimension. These sensitive attributes need to be improved to support the sustainability of seaweed in Ekas Bay.

1. Introduction

Seaweed plays an ecological role in coastal habitats; it assists in supplying oxygen and absorbing CO_2 to and from the sea, becoming one of the primary producers and competitors in the marine food chain, being used as bio-indicators for heavy metal pollution, and inhibit eutrophication (Chen, 2019). The bioactive compounds in seaweed may be applied in a processed or isolated form in food additives (Radulovich et al., 2015) and pharmaceuticals (Yang et al., 2015). Some species of seaweed may also contain other chemicals and macrochemicals to be used in chemical production (Bikker et al., 2016) or animal feed (Makkar et al., 2016). Seaweeds are also used to produce fertilizer, biofuel, and derivative products (Kim et al., 2017). Seaweed is a source of multipurpose natural resources and providing millions of dollars to the world's economy (Andrade et al., 2020). The important application of seaweed is for production of alginate and carrageenan used in multiple food and non-food products (Van den Burg et al., 2021).

Seaweed cultivation is a type of aquaculture that have the opportunity to be developed in the territorial waters (Tumiwa et al., 2017). Seaweed cultivation can grow close to the sea, using resources from the sea like seawater (Van den Burg et al., 2021). Seaweed cultivation is widely developed around the world (Andrade et al., 2020) and has significantly grown rapidly since the early 20th century due to the continuously rising demand for food and industry (Yang et al., 2015). A rise in demand of seaweed products followed with the rising price of seaweed have continued to increase the number and acreage of seaweed cultivation (Nuryadi et al., 2017). In 2016, the world production of seaweed from aquaculture equaled approximately 30 million tonnes, with a value of US$ 11.6, with the majority produced in China, Indonesia, Philippines and Korea (Van den Burg et al., 2021). Seaweeds are valued as food in many parts of Asia and in western countries (Kim et al., 2017). About 75 - 85% of worldwide seaweed production is used for direct human consumption in Asia (Van den Burg et al., 2021). Seaweed has become one of the main fishery commodities in Indonesia because Indonesia has a tropical climate that is very suitable for the growth of various types of seaweed (Arthatiani et al., 2021), so seaweed farming is very beneficial (Sulystyaningsih et al., 2018). One of the seaweed-producing areas in Indonesia is West Nusa Tenggara (Cokrowati et al., 2019; Muahiddah and Sulystyaningsih, 2021) and the red algae *Kappaphycus* is one of the seaweed type that are widely cultivated there (Kim et al., 2017).

Seaweed aquaculture plays a role in climate change adaptation by damping wave energy, which protects the shores, enhancing pH, and supplying oxygen to the water, thereby locally minimizing the effects of ocean acidification and deoxygenation (Alemañ et al., 2019). The aquaculture industry can help to overcome global challenges such as human health, agriculture, coastal issues management and allow to a sustainable circular bioeconomy and blue growth (Barbier et al., 2020). Seaweed farming raises cash income for individuals, families, and villages, often with minimal impact on the environment (Swanepoel et al., 2020). Therefore, seaweed utilization can be a profitable business and provide better income opportunities for the coastal communities (Limi et al., 2018).

The problem of seaweed aquabusiness is the low productivity of the production unit managed by seaweed farmers. This condition occurs due to the quality of the waters and the oceanographic conditions of the waters as well as the disease and/or the quality of the seaweed seeds themselves. The quality of seaweed is an important indicator affecting the export market. It is influenced by three basic factors such as cultivation, harvesting period, and drying process, but there are other influential factors affecting its quality: the difference in cultivation place, quality seed selection, and supply (Darmawan et al., 2020). Diseases also become a problem in seaweed farming. The most common disease of the *Euchemoid* spp. is called "ice-ice" because of the appearance of white segments on the thalli, causing them to break (Kim et al., 2017). The solidity of laver red rot and 'chytrid' diseases, caused by oomycete pathogens Olpidiopsis porphyae and *Pyhium porphyae* has been increasing as a result of farming intensification. A huge degradation in production has also been seen in many carrageenophytes (*Kappaphycus*) farming countries (Loureiro et al., 2015). The rapid development of mariculture has resulted in an increasing release of nitrogen (N) and phosphorus (P) into the surrounding ecosystems. This organic pollutants may lead to various hazardous effects to local environments, such as eutrophication, anoxia, loss of biodiversity, and coastal-water pollution (Yang et al., 2015). The massive seaweed farming might also encourage turbidity and sedimentation (Van den Burg et al., 2021).

Damelia and Soesilowati (2016) have shortlisted a few issues and challenges in the seaweed farming industry: (1) unavailability of good quality 'seedling', (2) pollution in production areas, (3) occurrence of 'ice-ice' and epiphytes, (4) shortage of raw materials,
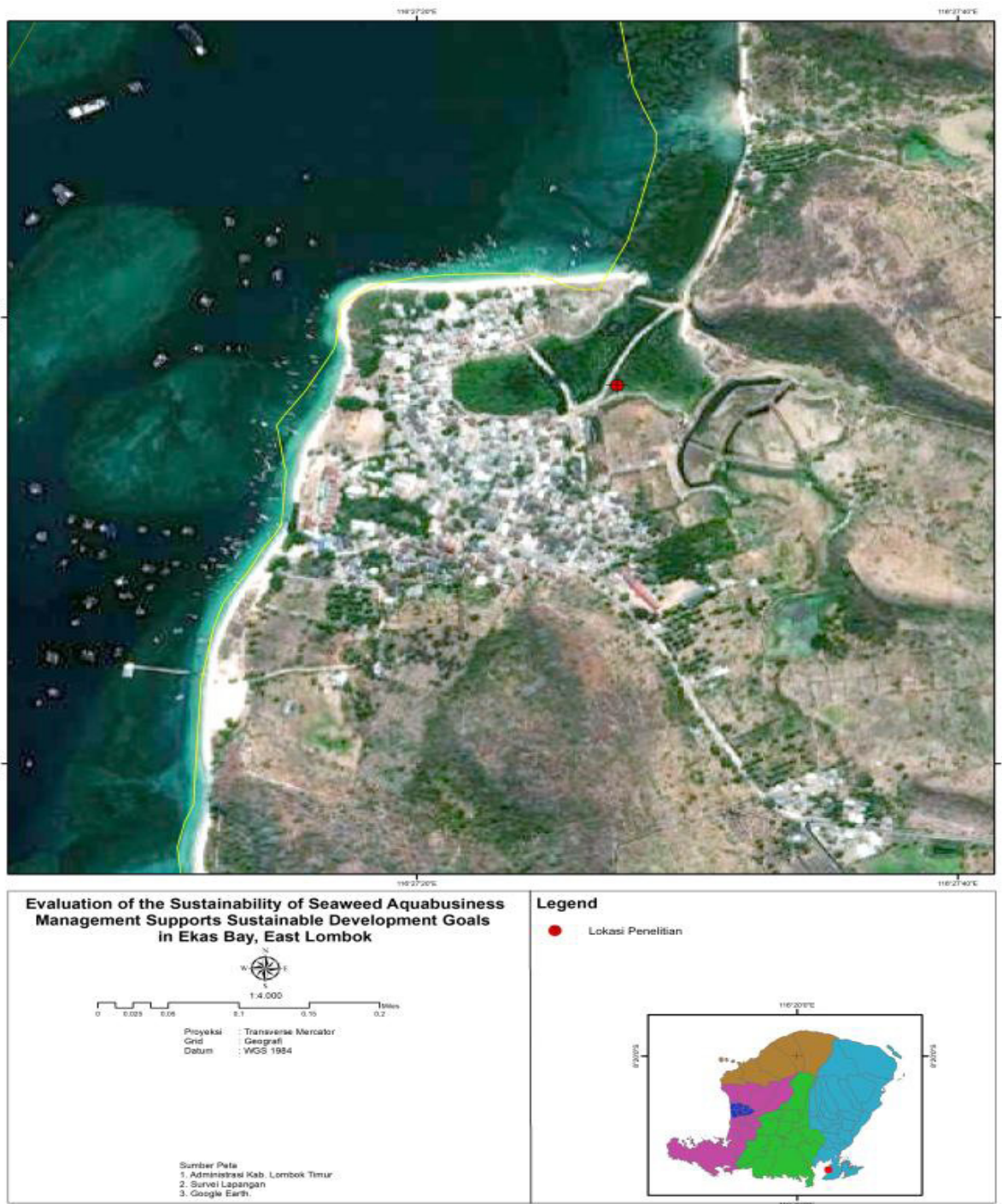
Figure 1. Research site at Ekas Bay, East Lombok, West Nusa Tenggara

(5) lack of capital to venture into the industry, (6) prolonged processing time in borrowing from financing institutions, (7) poor crop management, and (8) lack of funding. Lunkapis and Danny (2016) concerned about some issues of seaweed plantation such as plantation plots/output, new technology, market issues, and understanding local condition. Another factor that causes the low productivity of seaweed production units is the choice of technology. There are various cultivation me- thods, such as the fixed, off-bottom line method, the floating raft method and basket method. The steps in the farming include site selection, selection of cultivation methodology, farm maintenance, and harvesting and drying (Kim *et al.*, 2017). The current onshore and off- shore cultivation systems are not yet environmentally sustainable, and they are economically unstable, be- cause the production fluctuates very rapidly, due to the impact of abiotic and biotic factors (García-Poza *et al.*,

2020). The people in Ekas Bay who carry out seaweed cultivation activities have not implemented proper cultivation standards or proper and correct methods of seaweed cultivation. They have not been able to provide superior seeds and cultivation methods, as well as cultivation technology and post-harvest handling. Eggertsen and Halling (2021) suggested that the low-technique farming methods and low investment cost have caused the low productivity of seaweed production.

The sustainability of seaweed cultivation is affected by multidimensional factors such as the quality of the aquatic environment, cultivation technology, economic contribution to farmers, social conditions of the community, and government institutional support (Laapo et al., 2021). However, the farmers at Ekas Bay have not implemented proper cultivation standards for seaweed cultivation. They have not been able to provide superior seeds and cultivation methods, as well as cultivation technology and post-harvest handling. The problems faced by seaweed farmers in Ekas Bay need to be solved in order to increase the productivity of seaweed cultivation. This study aims to assess/evaluate the effectiveness and production level of seaweed cultivation technology and the success of seaweed cultivation by seaweed farmers in Ekas Bay based on two dimensions, i.e. economic and technological. Each dimension has attributes related to sustainability of seaweed farming in Ekas Bay.

2. Materials and Methods

2.1 Location and Time of Research

This research was conducted in Ekas Bay, Lombok East, Province of NTB (Figure 1), from March to November 2021.

2.2 Data Collection

Data were collected using a survey method with observation and interview techniques. Interviews were conducted to collect data relating to aspects of the economic and technological dimensions. Forty seaweed farmers were interviewed through questionnaires. The type of data collected to answer the research objectives is based on dimensions that are proxied into several factors that affect the sustainability of seaweed cultivation.

2.3 Method

The research object is seaweed cultivators and fishery product collectors. The research approach is ho-

listic and the research method is a dependent descriptive survey. Data collection techniques consist of sampling, dialogue, observation, and documentation.

2.4 Data Analysis

Quantitative data analysis used the Rapid Appraisal for Seaweed Aquabusiness (Rapsewaqua) application for model testing, sustainability analysis, and sensitivity analysis. In this study, a study of two dimensions will be carried out, namely the technological dimension (17 attributes) (Table 1) and the economic dimension (14 attributes) (Table 2). The results of the analysis are used to determine the value of sustainable management and the sensitive attributes of each dimension in formulating a seaweed aquabusiness management strategy.

Determination of the value of the sustainability index is based on the assessment criteria scores: unsustainable criteria (bad) if the index value lies between 0 – 25%, less sustainable if the index value lies between 26 – 50%, quite sustainable if the value the index lies between 51 – 75%, and good if the index value is between 76 – 100% (Table 3) (Irfan et al., 2020).

Leverage analysis and Monte Carlo analysis are used to see which attributes are most sensitive to their sustainability status. Monte Carlo analysis is used to analyze the error value in the estimated ordination of seaweed cultivation and leverage analysis is used for the most influential attributes. Stress value is the standard deviation value, it is accepted if the value < 25 (Irfan et al., 2020).

3. Results and Discussion

3.1 Results

3.1.1 Technological dimension

Based on the results of the analysis, the index value of the sustainability level of seaweed cultivation is 50.08 (Figure 2). The value lies between 26 and 50, which indicates less sustainable index. This value indicates that the technological conditions in these water areas do not support the management of seaweed cultivation. This condition needs serious attention in management to improve sustainability status.

Based on the results of the analysis of leverage on 17 attributes of the technological dimension for seaweed cultivation, four attributes obtained are sensitive

Table 1. Management attributes for technological dimension

No.	Attribute	Bad	Good	Index Value
1	Water depth	0	2	0 = < 5.0 m; 1 = 5.0 m; 2 = >5.0 m
2	Harvest age	0	2	0 = 35 – 40 days; 1 = >40 – <45 days; 2 = 45 – 60 days
3	Length of ris rope	0	2	0 = < 25 m; 1 = 25 – 50 m; 2 = >50 – 100 m
4	Float of fastening ris	0	2	0 = < 600 ml; 1 = 600 ml; 2 = >600 ml
5	Anchor material	0	3	0 = sand sack; 1 = iron; 2 = stone; 3 = beton
6	Anchor weight	0	2	0 = <50 kg/pcs; 1 = 50 kg/pcs; 2 = >50 kg/pcs
7	Dot rope	0	1	0 = < 1.0 & > 1.5 mm; 1 = 1.0 – 1.5 mm
8	Material of dot rope	0	2	0 = except PE & Rafia; 1 = PE; 2 = Rafia
9	Diameter of main rope	0	2	0 = < 10 mm; 1 = 10 mm; 2 = >10 mm
10	Space between seed clumps	0	2	0 = < 20 & > 30 cm; 1 = 20 – 25 cm; 2 = 25 – 30 cm
11	Weight of seed clumps	0	2	0 = < 40 g/clump; 1 = 40 – 50 g/clump; 2 = >50 – 100 g/clump
12	Seedling binding sites	0	2	0 = sea; 1 = boat; 2 = land
13	Type of seed binding	0	1	0 = not a ribbon knot; 1 = a ribbon knot
14	Space between main rope	0	2	0 = < 1.0 m; 1 = 1.0 m; 2 = >1.0 m
15	Cleaning frequency	0	2	0 = 1 time/season; 1 = 2 times/season; 2 = 3 times/season
16	Drying place	0	3	0 = not available; 1 = sand; 2 = terpal; 3 = para-para
17	Warehouse	0	2	0 = not available; 1 = warehouse without receipt system; 2 = warehouse with receipt system

Table 2. Management attributes for economic dimension

No.	Attribute	Bad	Good	Index Value
1	Production unit ownership	0	3	0 = Rent; 1 = Pawn; 2 = KSO; 3 = Owner
2	Fund source	0	3	0 = Loan; 1 = Family; 2 = Together; 3 = personal
3	Business scale	0	3	0 = Micro; 1 = Small; 2 = Middle; 3 = Large
4	Business license	0	4	0 = None; 1 = UD/Personal; 2 = Union; 3 = CV/Komandite; 4 = PT/Persero
5	Price trend	0	4	0 = Sharply decreased; 1 = Decreased; 2 = Constant; 3 = Increased; 4 = Sharply increased
6	Consumer type	0	4	0 = Household; 1 = Peddler; 2 = Collector; 3 = Inter seluler trader ; 4 = exporter
7	Market status	0	2	0 = Online market; 1 = Online & offline market; 2 = Offline market
8	Market target	0	3	0 = Local; 1 = District; 2 = Province; 3 = Expor
9	Market system	0	2	0 = Oligopsoni; 1 = Sale; 2 = Oligopoly
10	Market type	0	1	0 = Public market; 1 = Exclusive market
11	Market scale	0	3	0 = Traditional; 1 = Modern; 2 = Supermarket; 3 = Hygiene market
12	R/C ratio	0	2	0 = R/C <1.0; 1 = R/C = 1.0; 2 = R/C >1.0
13	Farmer income	0	2	0 = <UMR; 1 = UMR; 2 = >UMR
14	Business profit transfer	0	2	0 = Bigger out; 1 = Balanced; 2 = Bigger in

to the level of sustainability of the technological dimension, namely 1) distance between seed clumps (RMS – 3.51); 2) drying area (RMS – 3.22); 3) seedling binding sites (RMS – 3.16); 4) warehouse (RMS – 3.13) (Figure 3).

Table 3. Category status of the seaweed aquaculture sustainable management

Index	Category
0 – 25	Bad
26 – 50	Less
51 – 75	Enough
76 - 100	Good

3.1.2 Economic dimension

Based on the results of the analysis, the index value of the sustainability level of seaweed cultivation is 39.50 (Figure 4). The value lies between 26 and 50, which indicates less sustainable index. This value indicates that the economic conditions in these water areas do not support the management of seaweed cultivation. This condition needs serious attention in management to improve sustainability status.

Based on the results of the analysis of leverage on 14 attributes of the economic dimension for seaweed cultivation, 3 (three) attributes obtained are sensitive to the level of sustainability of the economic dimension, namely 1) market status (RMS – 6.11); 2) market scale (RMS – 5.83); 3) market target (RMS – 5.22) (Figure 5).

3.2 Discussion

Changes to this leverage factor will easily affect the value of the sustainability index in each dimension. Therefore, leverage analysis is used as one of the important inputs in carrying out strategic steps toward the sustainability of the seaweed cultivation business.

Based on the technological dimension, distancing between seed clumps is the main factor in supporting the continuity of seaweed cultivation. Planting distances that are too far will result in waste in land use. However, if the spacing is too close, it will inhibit the growth of seaweed because there is competition for nutrients. Spacing between seed clumps affects water flow; optimized water flow will help avoid accumulation of dirt around the thallus. This in turn provides the much needed aeration for photosynthesis process. It

also helps preventing large fluctuation of water salinity and temperature, ultimately supporting the growth of the seaweed. Research by Wijayanto et al. (2020) stated that planting additional seaweed biomass by shortening plant spacing (from 30 cm to 25 cm) has also been shown to increase profits and RC ratio. Planting additional seaweed biomass has a significant contribution in the success of the seaweed cultivation business. With the cost of seeds reaching more than 90% of the total cost per cycle, seaweed farmers anticipate using part of their crops as seeds.

The second factor that affects the sustainability of seaweed cultivation is the drying area. Seaweeds are sold in different forms, such as raw products (dried or salted), condiments, and mashed algae. However, these seaweed products have a perishable nature similar to other seafood (Sánchez-García et al., 2021). The majority of farmers still prefer using low technologies and cheaper conventional methods of drying the harvested seaweeds (i.e. hanging, platform, shade drying, 'sauna-like method,' etc.). However, these methods pose serious problems for carrageenophyte quality (Ali et al., 2017). Therefore, the drying process is very important to maintain the quality of seaweed products. Drying facilities are very important to consider. The availability of standardized drying facilities will ensure that the quality of dried seaweed products remains good, clean, and the water content is up to standard. The application of the cultivation method will produce good quality seaweed products according to market standards. However, Zamroni et al. (2018) stated that post-harvest handling, such as low availability of drying facilities, was due to the lack of financial capacity to invest in equipment that supports the seaweed drying process.

Seaweed warehouses also greatly affect the sustainability of seaweed cultivation. Warehouses for dried seaweed need to be dry, have good air circulation, and the floor is covered with boards as a base to avoid direct contact with the floor; keeping the seaweed dry. Purnomo et al. (2020) said that storing in the on-farm warehouses is a critical post-harvest handling stage in seaweed farming. The decrease in quality of seaweed is attributed to poor existing facilities, such as warehouses not equipped with light and rain protection, which makes the average humidity high.

Drying area and warehouse in post-harvest handling are very important to support the quality of seaweed. Purnomo et al. (2020) revealed that there are three factors in the post-harvest handling stage were identified as affecting the quality of Indonesian sea
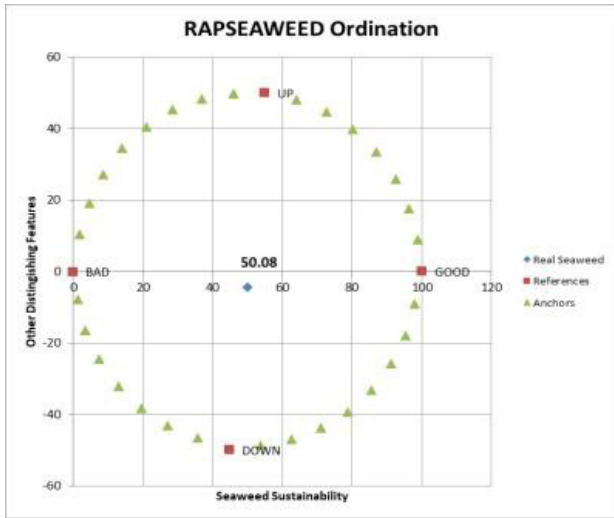
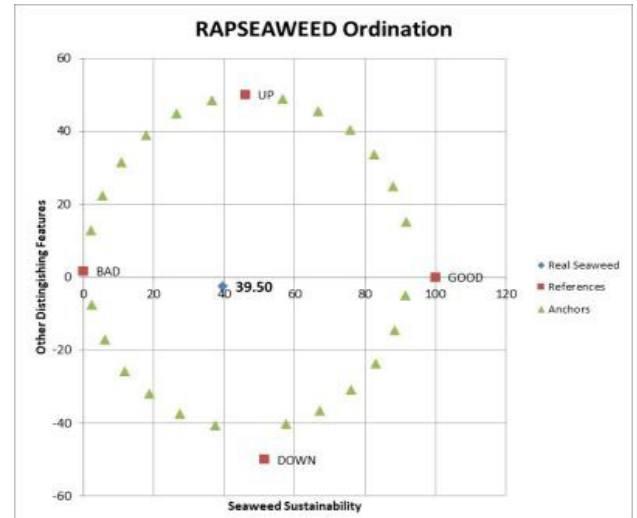**Figure 2.** Index value and sustainability status of technological dimension

Figure 4. Index value and sustainability status of economic dimension
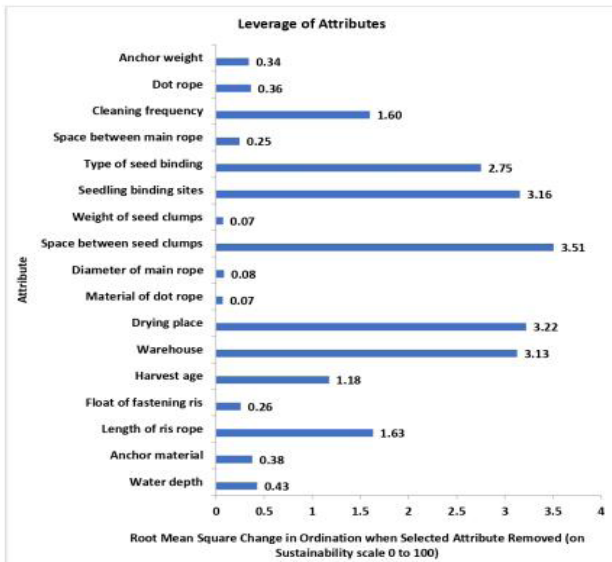

Figure 3. Changing value of RMS for all technological attribute

Figure 5. Changing value of RMS for all economic attribute

weed, namely the drying, cleaning and storing methods. Ali *et al.* (2017) explained that the quantity and quality of carrageenan derived from seaweed depends on the post-handling treatment and management from the harvested seaweeds.

High production costs and low product prices at harvest are still a problem for farmers. One way to overcome this is to implement a warehouse receipt system. The application of this system can help farmers maintain the quality of seaweed in the event of delays in product marketing due to bad weather or market prices that tend to fall. Edi *et al.* (2019) said that Implementation
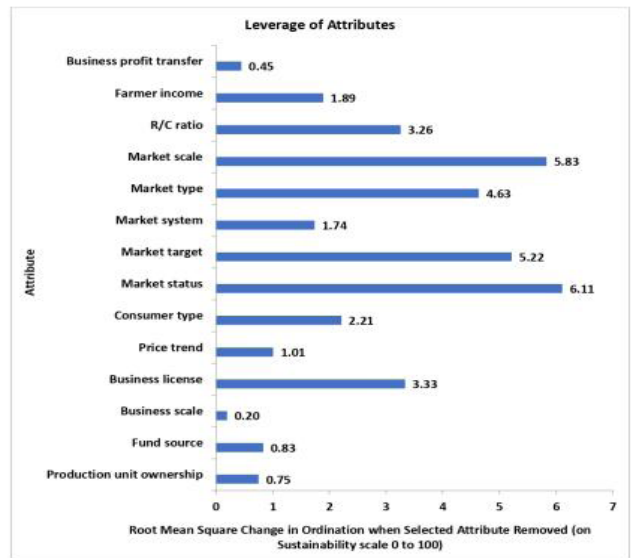
of warehouse receipt system (WRS) can be increased by expanding WRS information and communication to seaweed farmers, financial institutions, local government, industry and traders. A business model of seaweed WRS scheme that can integrate stakeholders is needed. So, the warehouse receipt system procedure can act as an alternative financing for seaweed farming operations.

Market status affects the sustainability of seaweed cultivation. Market status includes virtual markets, real markets, and a combination of the two. Along with the rapid advancement of technology, it has encouraged the creation of a virtual market that facilitates the

buying and selling process that can be done anywhere and anytime. Selling online provides several advantages, namely small capital, can be done anytime and anywhere, and easy to reach a wide target market. By increasing the ability to use technology, it will support the increase in scale and target market. However, this must be accompanied by an increase in product quality in order to attract buyers. Product quality improvement can be done by product diversification. As suggested by Suryawati and Ma'ruf (2018), processed seaweed such as carrageenan is much higher in quality than dried seaweed.

Institutionalism in the field of seaweed cultivation is very important because it can facilitate farmer to obtain information in marketing seaweed products. Seaweed cultivation can run well if there is a clear market availability. The marketing aspect is important because it will affect the price formation of a commodity. It is undeniable that the price of Indonesian seaweed is highly affected by the dynamics of the global market Purnomo et al. (2020). The marketing of seaweed products is still riddled with various problems, such as weak bargaining position of farmers, so that the price of seaweed is decided more by traders without involving farmers as the producers (Tumiwa et al., 2017).

The level of farmer's income is influenced by the selling price and the amount of production (Marhawati et al., 2020). If the seaweed selling price from farmers is too low, the profit margin becomes very small. In order to minimize expenditure, the farmers implement only a minimum treatment in the cultivation, harvesting and post-harvest handling, and these practices automatically affect the quality Purnomo et al. (2020). The seaweed farmers carry out the seaweed farming as bountiful as possible to obtain a high production number and to obtain a reasonable price. Thereby, they could earn sufficient income to meet their families' needs and for the additional capital by adding the number of stretch lines (Limi et al., 2018).

Traders are important in the seaweed industry but their profitability varies because some are local-level traders who sell to larger traders or processors and the others operate regionally to repack seaweed and resell it to exporters or processors (Nuryartono et al., 2021). The selling price of seaweed accepted by farmers depends on the price decided by the traders at the farmer level. Farmers do not have access to information on the market price of seaweed (Edi et al., 2019). As the commodities traded in international markets, the prices in farm-level depend on the volatility (Limi et al., 2018).

Technological and economic aspects in the sea weed cultivation process need to be increased so tha seaweed production does not decrease, which wil affect the welfare of seaweed farmer's lives (Rimme et al., 2021). One approach that can be used is th Kaizen approach that is used to compose strategie to improve production and product quality, decreas operational costs and waste, and improve jo security (Purnomo et al., 2021). Arranging trainin and assistance are also needed for practicing th latest technological innovations (Tahang et al., 2019).

4. Conclusion

The results of the Rapsewaqua analysis showed that the index value of the technological and economic dimensions of seaweed cultivation in Ekas Bay lied between 26 and 50 which indicated less sustainable index. There are several attributes that affect the sustainability of seaweed cultivation in Ekas Bay, namely the distance between seed clumps, drying places, seedling binding locations, and warehouses (technology dimension), market status, market scale, and target market (economic dimension). The sustainability status of seaweed cultivation in Ekas Bay will increase if efforts are made to improve these attributes. Seaweed farmer also need assistance in practicing the latest technological innovations.

Authors' Contributions

Author's Contribution All authors have contributed to the final manuscript. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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References

Alemañ, A. E., Robledo, D., & Hayashi, L. (2019). Development of seaweed cultivation in Latin America: current trends and future prospects. *Phycologia*, 58(5):462-471.

Ali, M. K. M., Fudholi, A., Sulaiman, J., Muthuvalu, M. S., Ruslan, M. H., Yasir, S. M., & Hurtado, A. Q. (2017). Post-harvest handling of eucheumatoid seaweeds. In A. Q. Hurtado, A. T. Critchley, I. C. Neish (Ed.), Tropical seaweed farming trends, problems and opportunities. (pp. 131-145). Denmark: Springer, Cham.

Andrade, H. M. M. Q., Rosa, L. P., de Souza, F. E. S., da Silva, N. F., Cabral, M. C., & Teixeira, D. I. A. (2020). Seaweed production potential in the Brazilian Northeast: A study on the eastern coast of the State of Rio Grande do Norte, RN, Brazil. *Sustainability*, 12(3):1-20.

Arthatiani, F. Y., Wardono, B., Luhur, E. S., & Apriliani, T. (2021). Analisis situasional kinerja ekspor rumput laut Indonesia pada masa pandemi Covid-19. *Jurnal Kebijakan Sosial Ekonomi Kelautan dan Perikanan*, 11(1):1-12.

Barbier, M., Araújo, R., Rebours, C., Jacquemin, B., Holdt, S. L., & Charrier, B. (2020). Development and objectives of the PHYCOMORPH European Guidelines for the Sustainable Aquaculture of Seaweeds (PEGASUS). *Botanica Marina*, 63(1):5-16.

Bikker, P., van Krimpen, M. M., van Wikselaar, P., Houweling-Tan, B., Scaccia, N., van Hal, J. W., Huijgen, W. J. J., Cone, J. W., & López-Contreras, A. M. (2016). Biorefinery of the green seaweed *Ulva lactuca* to produce animal feed, chemicals and biofuels. *Journal of Applied Phycology*, 28(6):3511-3525.

Chen, H. (2019). Bayesian inference of environmental effects on seaweed production in Japan via a production-environmental suitability model. *Botanical Studies*, 60(2):1-10.

Cokrowati, N., Diniarti, N., Setyowati, D. N., Waspodo, S., & Marzuki, M. (2019). Eksplorasi dan penangkaran bibit rumput laut (*Eucheuma cottonii*) di perairan Teluk Ekas Lombok Timur. *Jurnal Biologi Tropis*, 19(1):51-53.

Damelia, D., & Soesilowati, E. (2016). The strategy to improve the competitiveness of Indonesian seaweeds in global market. *Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi Dan Pembangunan*, 17(2):193-204.

Darmawan, A., Hambali, M., & Salam, A. R. (2020). Evaluation on moisture content of *Eucheuma cottonii* seaweed variety using statistical quality control approach. *Industria: Jurnal Teknologi Dan Manajemen Agroindustri*, 9(2):99-108.

Edi, S., Siregar, H., Mohammad, L., & Imam, A. (2019). Situational analysis of seaweed warehouse receipt system scheme in Indonesia. *International Journal Sciences: Basic and Applied Research*, 48:108-118.

Eggertsen, M., & Halling, C. (2021). Knowledge gaps and management recommendations for future paths of sustainable seaweed farming in the Western Indian Ocean. *Ambio*, 50(1):60-73.

García-Poza, S., Leandro, A., Cotas, C., Cotas, J., Marques, J. C., Pereira, L., & Gonçalves, A. M. M. (2020). The evolution road of seaweed aquaculture: Cultivation technologies and the industry 4.0. *International Journal of Environmental Research and Public Health*, 17(18):1-42.

Irfan, M., Abdullah, N., Yuliana, Samadan, G. M., & Subur, R. (2020). Sustainability status of seaweed *Kappaphycus alvarezii* cultivation in Posi-Posi waters, South Kayoa subdistrict, Regency of South Halmahera, Province of North Mollucas, Indonesia. *International Journal of Advanced Science and Technology*, 29(8):806-817.

Kim, J. K., Yarish, C., Hwang, E. K., Park, M., & Kim, Y. (2017). Seaweed aquaculture: cultivation technologies, challenges and its ecosystem services. *Algae*, 32(1):1-13.

Laapo, A., Howara, D., Kassa, S., Sultan, H., & Rahim, A. (2021). A multidimensional approach to assessing the leverage factors of the sustainability of seaweed farming in coastal area of Parigi Moutong District, Indonesia. *Journal of Aqua-*

culture and Fish Health, 10(3):271-281.

Limi, M. A., Sara, L., La Ola, T., Yunus, L., Suriana, Taridala, S. A. A., Batoa, H., Hamzah, A., Fyka, S. A., & Prapitasari, M. (2018). The production and income from seaweed farming after the sedimentation in Kendari Bay. *AACL Bioflux*, 11(6):1927-1936.

Loureiro, R., Gachon, C. M. M., & Rebours, C. (2015). Seaweed cultivation: Potential and challenges of crop domestication at an unprecedented pace. *New Phytologist*, 206(2):489-492.

Lunkapis, G. J., & Danny, H. W. (2016). Preliminary impact assessment of seaweed cultivation by the coastal communities in Sabah, Malaysia. *Transactions on Science and Technology*, 3(2-2):413-420.

Makkar, H. P. S., Tran, G., Heuzé, V., Giger-Reverdin, S., Lessire, M., Lebas, F., & Ankers, P. (2016). Seaweeds for livestock diets: A review. *Animal Feed Science and Technology*, 212:1-17.

Marhawati, Rakib, M., Syam, A., & Ma'ruf, M. I. (2020). Analysis of the feasibility of seaweed farming in Pangkep district. *ICSAT Proceeding*, 8:1486-1492.

Muahiddah, N., & Sulystyaningsih, N. D. (2021). Analisis hasil ekstraksi *Sargassum* sp. dari Teluk Ekas, pemicu peningkatan produksi rumput laut, Lombok Timur Nusa Tenggara Barat. *Jurnal Agroqua*, 19(1):131-142.

Nuryadi, A. M., Sara, L., Rianda, L., Bafadal, A., Muthalib, A. A., Hartati, Nur, M., & Rosmalah, S. (2017). Agrobusiness of seaweeds in south Konawe (Indonesia). *AACL Bioflux*, 10(3):499-506.

Nuryartono, N., Waldron, S., Tarman, K., Siregar, U. J., Pasaribu, S. H., Langford, A., Farid, M., & Sulfahri. (2021). An analysis of the South Sulawesi seaweed industry. The Australia-Indonesia Centre.

Purnomo, A. H., Kusumawati, R., Pratitis, A., Alimin, I., Wibowo, S., Rimmer, M., & Paul, N. (2021). Improving margins of the Indonesian seaweed supply chain upstream players: The application of the Kaizen approach. *E3S Web of Conferences*, 226:1-11.

Purnomo, A. H., Subaryono, Utomo, B. S. B., & Paul, N. (2020). Institutional arrangement for quality improvement of the Indonesian Gracilaria seaweed. *AACL Bioflux*, 13(5):2798-2806.

Radulovich, R., Umanzor, S., Cabrera, R., & Mata, R. (2015). Tropical seaweeds for human food, their cultivation and its effect on biodiversity enrichment. *Aquaculture*, 436:40-46.

Rimmer, M. A., Larson, S., Lapong, I., Purnomo, A. H., Pong-masak, P. R., Swanepoel, L., & Paul, N. A. (2021). Seaweed aquaculture in Indonesia contributes to social and economic aspects of livelihoods and community wellbeing. *Sustainability*, 13(19):1-22.

Sánchez-García, F., Hernández, I., Palacios, V. M., & Roldán, A. M. (2021). Freshness quality and shelf life evaluation of the seaweed *Ulva rigida* through physical, chemical, microbiological, and sensory methods. *Foods*, 10(181):1-15.

Sulystyaningsih, N. D., Nikmatullah, A., & Setyowati, D. N. (2018). Analysis of using bondre system to cultivate three kinds of seaweed through different seed weights in the early summer at Ekas Bay, Jerowaru, East Lombok. *International Journal of Scientific and Research Publications*, 8(11):378-385.

Suryawati, S. H., & Ma'ruf, W. F. (2018). Analisis dimensi ekonomi kesiapan daerah dalam program pembangunan pabrik rumput laut. *Buletin IImiah Marina*, 4(1):1-6.

Swanepoel, L., Tioti, T., Eria, T., Tamuera, K., Tiitii, U., Larson, S., & Paul, N. (2020). Supporting women's participation in developing a seaweed supply chain in Kiribati for health and nutrition. *Foods*, 9(4):1-13.

Tahang, H., Latama, G., & Kasri. (2019). Development strategy and increased production of seaweed in Takalar District. IOP Conference Series: *Earth and Environmental Science*, 370:012058.

Tumiwa, B. B., Renjaan, M. R., Somnaikubun, G. B. A., Betauubun, K. D., & Hungan, M. (2017). Analysis of seaweed marketing in Warbal Village, Southeast Maluku Regency, Indonesia. IOP Conference Series: *Earth and Environmental Science*, 89:012018.

Van den Burg, S. W. K., Dagevos, H., & Helmes, R. J.

K. (2021). Towards sustainable European seaweed value chains: A triple P perspective. *ICES Journal of Marine Science*, 78(1):443-450.

Wijayanto, D., Bambang, A. N., Nugroho, R. A., & Kurohman, F. (2020). The impact of planting distance on productivity and profit of *Eucheuma cottonii* seaweed cultivation in Karimunjawa Islands, Indonesia. *AACL Bioflux*, 13(4):2170-2179.

Yang, Y., Chai, Z., Wang, Q., Chen, W., He, Z., & Jiang, S. (2015). Cultivation of seaweed Gracilaria in Chinese coastal waters and its contribution to environmental improvements. *Algal Research*, 9:236-244.

Zamroni, A., Nurlaili, N., & Witomo, C. M. (2018). Peluang penerapan konsep Blue Economy pada usaha perikanan di Kabupaten Lombok Timur. *Buletin Ilmiah Marina Sosial Ekonomi Kelautan Dan Perikanan*, 4(2):39-44.