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Status of Seaweed *K. alvarezii* Cultivation Sustainability as a Strategic Direction for Seaweed Management in Baubau City, Southeast Sulawesi

Nurul Annisa[1*], Muhammad Farid Samawi[2*], M. Rijal Idrus[2]

[1] Postgraduate in Environmental Management, Hasanuddin University, Makassar, 90245. Indonesia
[2] Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, 90245 Indonesia

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Corresponding Author:
Nurul Annisa
annisanurul99@gmail.com

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Abstract: This study aims to examine its sustainability status. This study used survey techniques and interviews with seaweed cultivators to collect data. Sustainability data on seaweed cultivation include social, economic, and ecological aspects. The Rapseaweed approach (Rapid Appraisal for Seaweed) has been modified from Rapfish (Rapid Appraisal for Fisheries) to evaluate the sustainability status of seaweed in a multidisciplinary manner. Analysis of the sustainability of *K. alvarezii* seaweed cultivation using the MDS method. The Rapseaweed analysis reveals that the ecological sustainability index value is 57.76, and the availability of seeds is the most sensitive attribute, with a change in root mean square RMS value of 4.59. Seaweed marketing is the most sensitive attribute, with a change in root mean square RMS value of 12.96, and the economic dimension index value is 65.62. The cultivator's habits have the highest index value of 69.75% for the social dimension, with a root mean square RMS change value of 10.47. All dimensions are considered to be "sufficiently sustainable" by these index values. In the three dimensions, each RMS value indicates that there are sensitive attributes whose existence is suppressed or paid attention to. To obtain a strategic direction for the management of seaweed cultivation in Baubau City based on the RMS value, which has been ranked from highest to lowest, a seaweed management strategy for related stakeholders, namely the local government, the industrial sector, and the cultivating community, namely; strengthening coastal communities' capacity to maximize seaweed cultivation activities, ensuring market availability and price stability, and increasing production at seaweed cultivation centre locations.

Keywords: Baubau; *K. alvarezii*; Management; Rapseaweed; Seaweed; Strategic sustainability.

Introduction

Seaweed is one of the natural resources that could be developed in coastal areas. Kappaphycus alvarezii, also known as Euchema cottonii, is a type of seaweed intensively cultivated in coastal areas and has a high economic value. According to the FAO report from 2020, approximately 1.5 million tons of *K. alvarezii* seaweed were grown in 2018, accounting for 4.7% of all seaweed species worldwide. The production of Kappa-carrageenan, which is utilized as a fundamental ingredient in a variety of industrial fields, including the food, pharmaceutical, cosmetic, and textile industries, is the source of *K. alvarezii*'s economic value (Hayashi et al., 2011; Cokrowati et al., 2021). Seaweed has significant ecological benefits for other aquatic organisms and its value as an economic commodity (Rameshkumar et al., 2019). Additionally, seaweed contributes to the stability and longevity of coral reefs by serving as a carbonate provider and primary substrate reinforcement (Khudin, et al., 2019). Macro and micronutrients are required for platensis culture.

The environment's carrying capacity must be considered when cultivating in coastal areas. According to Kamlasi (2008), ecological and economic carrying capacity is the carrying capacity used in the growth of seaweed cultivation. An area's carrying capacity can

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ensure the long-term viability of aquaculture operations. According to WCED 1987, sustainable development is a development that meets current needs without jeopardizing the ability of future generations to do so (Dahuri et al., 2004; Nuryadin, 2015). As a result of a shift in mindset that places economic growth ahead of the environment, sustainable development emerged as an effort to avoid harming the environment. According to Munasinghe, (2002), sustainable development consists of three significant dimensions: the economic, the social (cultural), and the environmental.

One of Baubau City's marine and fisheries sector businesses is cultivating seaweed. Baubau City is one of the locations where seaweed cultivation can be developed, as stipulated by Regional Regulation No. 9 of 2018. Most people in Baubau City, which covers 295,072 km2, earn a living as cultivators (BPS, 2021). Aslan et al. (2020) say Southeast Sulawesi Province is one area that produces a lot of seaweed. The total production of the species Kappaphycus alvarezii, or Euchema cottonii, was reported to be 776,441.61 tons by 2020.

On the coast of Baubau City, seaweed cultivation is still under development. This is done to support regional policies that aim to boost coastal communities' production values and sources of income. Seaweed cultivation activities can degrade the environment, harming the quantity and quality of the seaweed produced. Seaweed cultivation's sustainability may be in jeopardy as a result of this. As a result, this study aims to investigate the viability of the growth of seaweed cultivation by employing the concept of sustainable development, which has three primary dimensions: ecology, social, and economical.

Method

Location and Time of Research

The research was conducted in Kokalukuna District and Lea-Lea District which are on the coast of Bau Bau City, South East Sulawesi Province throughout September-November 2022. The flow of this research is as Figure 1.

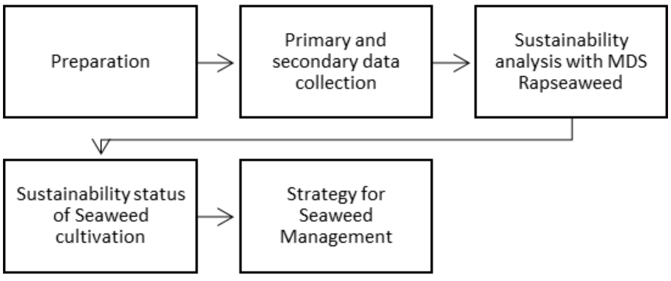

Figure 1. Flow of research

Research design

This study gathered both primary and secondary data. Based on the completed questionnaire, primary data were gathered through field surveys and in-depth interviews (in-depth interviews). Seaweed cultivators, stakeholders in the research area, and the Maritime Affairs and Fisheries Office of Baubau City served as research informants to determine seaweed cultivation activities from an ecological, economic, and social perspective. The City of Baubau's Central Bureau of Statistics and the City of Baubau's Office of Maritime Affairs and Fisheries served as sources for secondary data. To get an accurate picture of the long-term viability of seaweed cultivation in the field, statistical data, annual reports, and other supporting information are collected.

Rapseaweed analysis

The Multidimensional Scaling (MDS) method was used to analyze the activities of cultivating seaweed. Multivariate statistics were used. According to Nuryadin (2015) and Narimawati (2008), multidimensional scaling is a statistical method that measures objects in a multidimensional space based on the respondent's assessment of their similarity. The purpose of this analysis of the sustainability of *K. alvarezii* seaweed cultivation activities is to ascertain whether or not they can be sustained for optimal use.

The Rapseaweed method, adapted from Rapfish (Rapid Appraisal for Fisheries), was used to evaluate the sustainability of seaweed cultivation activities. Rapfish is the most current method for assessing the sustainability of multidisciplinary fisheries developed by the University of British Columbia in Canada. Rapfish uses ordinate techniques and a Multi-Dimensional Scaling (MDS) approach to organizing things in a measurable order of attributes. According to Fauzi & Anna, (2005), MDS is a statistical method that tries to transform multidimensional data into lower dimensions. The following are the stages of evaluating the viability of seaweed or rapseaweed cultivation.

Determination and Assessment of Sustainability Attributes of Seaweed Cultivation

The Rapseaweed method uses a variety of dimensions to select attributes that best represent the opportunities for the sustainability of each dimension that is the focus of the analysis—the ecological, economic, and social dimensions. The literature on seaweed cultivation and other sustainability-related fields compiles the attributes. A field survey was used to obtain more precise and pertinent ecological, economic, and social attributes to strengthen the literature. Table 1 show the characteristics of social, economic, and ecological factors

Table 1. Attributes of Seaweed Cultivation Sustainability

Dimension	Atribute	Score
Ecology	1. Suitability Of Seaweed Cultivation Land 2. Carrying Capacity of Seaweed Aquaculture Waters 3. Pest Attacks 4. Disease Attacks 5. Seed Availability 6. Threats to Waters	0-2
Economics	1. Advantages of Cultivation 2. Cultivation Income 3. Availability of Cost/Capital 4. Seaweed Cultivation Feasibility 5. Seaweed Marketing 6. Contribution of Cultivation Business to Family Income 7. Seaweed Price	0-2
Social	1. Quality of Human Resources 2. Extension 3. Community Knowledge about Seaweed Cultivation 4. Family Participation 5. Cultivator's habits 6. Security Factor 7. Seaweed Institutions	0-2

Assess and score attributes based on available field observations or secondary data. The score can be anywhere from 0 to 2, depending on the situation. The most unfavourable conditions for seaweed cultivation are represented by a value of zero, or "bad," while the most favourable conditions are represented by a value of two, or "good" (Pitcher & Priekshot, 2001; 2003, Susilo).

Compilation of Seaweed Cultivation Sustainability Index

The seaweed cultivation sustainability index scale ranges from 0 to 100 in preparation. A system is considered sustainable if its index is greater than 50, while a system with an index lower than 50 is considered unsustainable. The four categories of sustainability status for seaweed cultivation are listed in Table 2, and they are based on Susilo (2003).

Table 2. Categories Of Sustainability Status for Seaweed Cultivation

Index	Category
25- ≤ 25	Bad
49.9	Less
50-75	Enough
>75	Good

Stages of Ordination

The ordinate stages are analyzed with MDS to determine the position of good (good) and bad (wrong) points. Objects or points in MDS will be mapped into two or three-dimensional space and try to be as close as possible. According to Fauzi & Anna (2005), this ordination process aims to determine the distance in MDS based on Euclidian Distance. The position of bad and good values is depicted horizontally, while vertically, it shows the difference from the assessed mixed attribute scores. Furthermore, Susilo (2003) stated that the position of a point would be tough to imagine given the many dimensions. To make it easier to visualize the point position, MDS analysis uses the Euclidean distance formula in the Rapseaweed application.

Leverage and Monte Carlo Analysis

According to Pitcher & Priekshot (2001) in Kavanagh and Pitcher (2004), leverage analysis is a method used to determine which characteristics are most sensitive, important, or influential in determining the state of a sustainable fishery. After RapSeaweed completes its coordination and obtains a sustainable position in the seaweed cultivation industry under investigation, this procedure occurs. Leverage is used to look at the attributes of each factor or dimension. In this way, if one of the attributes is taken out of the analysis process, changes in ordination will be shown on the horizontal line.

The calculated Root Mean Square (RMS) changes show how each attribute affects how sustainable seaweed cultivation is. The higher the RMS value, the more sensitive the attribute is to supporting seaweed cultivation's sustainability. To ensure that the RMS value is proportional to the number of attributes associated with each of these factors, the RMS calculation is carried out for each ecological, economic, and social dimension.

The statistical simulation technique known as Monte Carlo analysis is used to evaluate the impact of errors on statistical processes. The Rapseaweed MDS ordination point is the subject of this investigation. The goodness of fit in the MDS was determined using the S-Stress value, derived from the S and R2 values, to ensure the accuracy of the analysis. If the R-value is close to 1, the iteration process can be stopped. A low-stress value indicates a good fit, whereas a high S value indicates an unsatisfactory fit. A stress value of less than 0.25 or S 0.25 in RAPFISH indicates a good model (Fauzi & Anna, 2005). This study showed the Monte Carlo results as a scatter plot with 25 replications. According to Kavanagh and Pitcher (2004), Monte Carlo analysis can be used to determine the impact of error-scoring attributes that are the result of a lack of information, a misunderstood understanding of the attributes or the method of scoring them, and the impact of scoring variations that are the result of divergent assessments or opinions by various researchers.

Data analysis

Data analysis using the Rapseaweed application (Rapid Appraisal for Seaweed), modified from Rapfish (Rapid Appraisal for Fisheries).

Result and Discussion

Overview of Seaweed Cultivation Activities in the Coastal City of Baubau

Although only 80.24 ha have been utilized for two sub-districts, Kokalukuna and Lea-Lea Districts, Baubau City is one of the areas in Baubau City with the most incredible maximum area value for the development of seaweed cultivation activities. The results of the potential found in the marine and fisheries sector indicate that these waters are suitable, particularly for seaweed cultivation. Seaweed production in the city of Baubau has increased over the past five years (2017-2021), according to data from the Baubau City Fisheries Service (2022), with a selling price that is relatively high during the good season, reaching IDR 34,000/Kg. As a result, the seaweed cultivation industry benefits from both quantity and quality growth.

Seaweed cultivation activities in Baubau City are located in 2 Districts, namely Kokalukuna and Lea-Lea Districts. Seaweed cultivation methods used in this area are floating rafts and longlines. From the results of observations in the research area, seaweed cultivation activities in the coastal city of Baubau are located on sea transportation routes. This affects the circulation of water currents in the research area so quickly that the cultivated seaweed will be damaged and drift away. As stated by Ikhsan (2013) that seaweed cultivation areas must be protected from waves and currents that are too strong. When this happens, the waves and currents will damage and wash away the plants. Also, in the study area, there are river mouths which are pretty close to seaweed cultivation. This, when viewed from an ecological perspective, will affect the growth and quality of cultivated seaweed. According to Indriyani et al. (2021), Some areas that need to be avoided in seaweed cultivation are areas that are close to river mouths because they have relatively low salinity and will have an unfavourable impact on seaweed maintenance.

Status of Seaweed Cultivation Sustainability

1. Ecological Dimensions

The analysis findings indicate that, with a water area of 3649 ha, the aquatic land in the coastal city of Baubau is suitable for seaweed cultivation. Although only 80.24 ha have been utilized for two sub-districts, Kokalukuna and Lea-Lea Districts, this value represents the maximum area value for the development of seaweed cultivation activities in Baubau City. Seaweed cultivation activities still have the potential to continue to be developed since the activities taking place in the coastal area of the city of Baubau have not harmed changes in water quality, as determined by the results of the suitability of these waters. However, continue to be mindful of other limiting factors in the waters, such as the infrastructure and other social activities. This must be done to safeguard the long-term viability of seaweed cultivation in the area and prevent the impact of sensitive activities that have the potential to spark conflict. Suppose seaweed cultivation in the city of Baubau uses a maximum water area of 3649 ha and 8309 people per capita. In that case, the carrying capacity of the waters for seaweed cultivation in Baubau reaches 30,099 tons per year. Yonviter (2007) asserts that a region with a high carrying capacity can accommodate fewer people than its carrying capacity. This is because the existing ecosystem cannot meet all human needs, and the fundamental calculation of carrying capacity is constrained in its ability to account for natural resources and the environment.

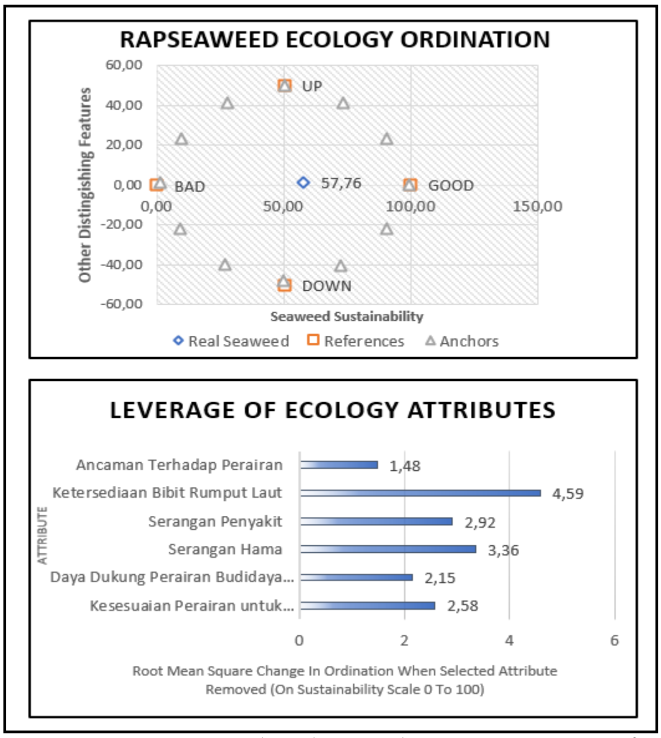

Figure 1. Rapseaweed Ecology Ordination & Leverage of Ecology Attributes

According to interviews with seaweed farmers, the availability of high-quality seaweed seeds from nurseries could have been more consistent with the availability of seaweed seeds. Seaweed farmers acquire seeds by saving some of their seaweed for later use. Seaweed produced as a result of this may be of lower quality. Variations in aquatic environmental factors make seaweed cultivation susceptible to disease and pest attacks. Seaweed farmers in the research area frequently encounter ice-ice and cat hair diseases. Farmers typically overcome this problem by cutting off the diseased seaweed's stems or thallus to prevent its spread to the entire plant. Rabbitfish frequently consume seaweed during pest attacks in the study area, as do most plants that adhere to seaweed and prevent its growth. Seaweed can also get ice-ice disease if moss is on it because there will be more ecological pressure on the seaweed, and bacteria will be more likely to attack it (Indriyani et al., 2021). Cultivators typically carry out cultivation controls daily to combat these pest attacks. The presence of river estuaries adjacent to the seaweed cultivation area and the fact that the seaweed cultivation area is a sea transportation route pose threats to the coastal seaweed cultivation area of Baubau City.

Rapseaweed's ecological dimension analysis finds "entirely sustainability status" with an index value of 56.45 out of six attributes, and the leverage analysis reveals three of its most sensitive attributes: seed supply, disease, and pest control. These two analyses are shown in Figure 1.

2. Economics Dimensions

Seaweed marketing is one of the essential aspects of operating a growing business. Cultivators gain money and profits from the outcomes of this marketing. Farmers in the study area advertise their seaweed by exclusively selling it to collectors.

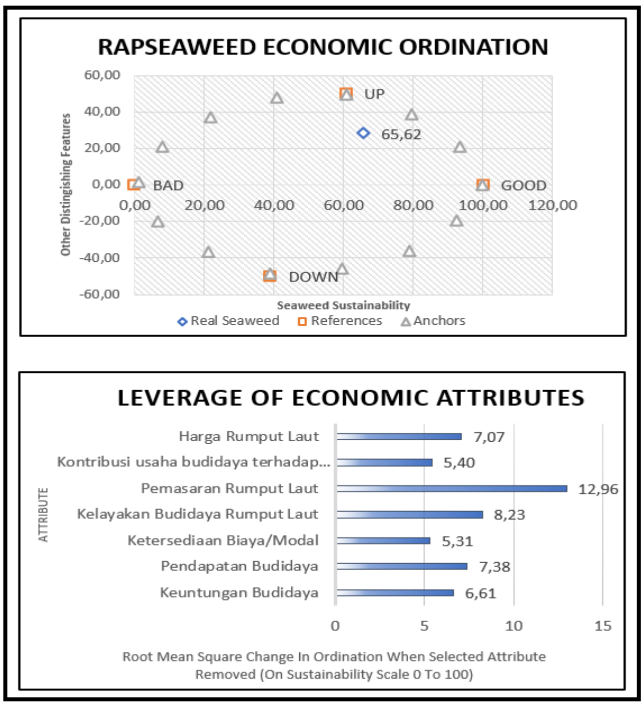

Figure 2. Rapseaweed Economic Ordination & Leverage of Economic Attributes

Farmers can recognize opportunities and select the more profitable traders because their connection with collectors needs to be entwined. The quantity and quality of seaweed produced impact sales and the revenue value is calculated by multiplying the seaweed produced by the current seaweed price. The income value per output at the study site ranged from Rp 3,000,000 to Rp 5,000,000. The average harvest yields between IDR 6,000,000 and IDR 8,000,000 in profit for each production. In the research area, dried seaweed costs between Rp 26,000 and 34,000 per kilogram. The ability to develop seaweed agriculture can be inferred from the Net B/C Ratio value, which was calculated to obtain a value larger than 1. The outcomes of the economic dimension are shown in Figure (2). The three most sensitive attributes from the outcomes of the leverage analysis, namely seaweed marketing, seaweed cultivation feasibility, and cultivation revenue, provide the rapseaweed analysis with a sustainability index value of 65.62 (entirely sustainable).

Social Dimensions

The study area's coastal inhabitants primarily engage in the farming and fishing of seaweed, with a limited number of traders and public workers. According to the findings of interviews conducted in the study region, "cultivators' habits" were a significant aspect of managing seaweed farming. The cultivator's practice of applying soapy water and fertilizers to the seaweed produces good results and gives the seaweed a lustrous appearance. These practices have been handed down through the generations. This cannot be justified indefinitely because it violates the SNI's guidelines for managing seaweed for culture. If left unchecked, it will eventually affect the quality of seaweed farming waters. This is also related to the expertise of farmers in running grass-growing operations.

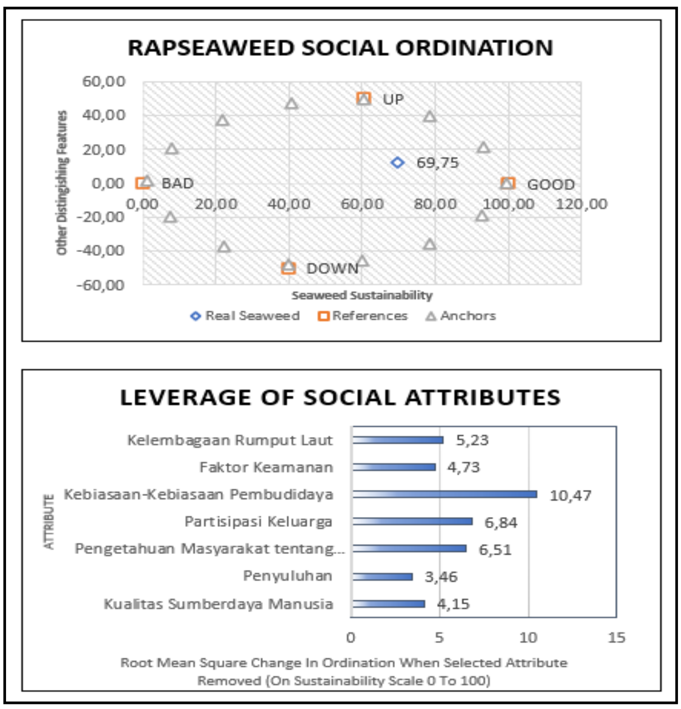

Figure 3. Rapseaweed Social Ordination & Leverage of Social Attributes

Poor human resources are produced due to the study field's low educational level. The fact that males in the family, like fathers and sons, do work at sea, such as land preparation, maintenance, and harvesting. At the same time, women, like mothers and daughters, are more engaged in work on the land, such as manufacturing rope, tying seeds, and drying seaweed. This shows that family participation in seaweed cultivation activities is relatively high. The social dimension of the Rapseaweed analysis results in a sustainability index value of 69.75 (entirely sustainable). The three most sensitive attributes are farming practices, knowledge level, and family involvement in seaweed agriculture. Figure 3 displays the analysis's findings.

3. Monte Carlo

The ecological dimension in the Rapseaweed analysis has a score of 57.76, the economic dimension of 65.62, and the social dimension of 69.75. The Monte Carlo analysis findings reveal that the points in the scatter plot (Figure 4) are in a clustering position, indicating that the ordination points used to assess the sustainability status of seaweed cultivation are stable and may be used to overcome errors or disturbances.

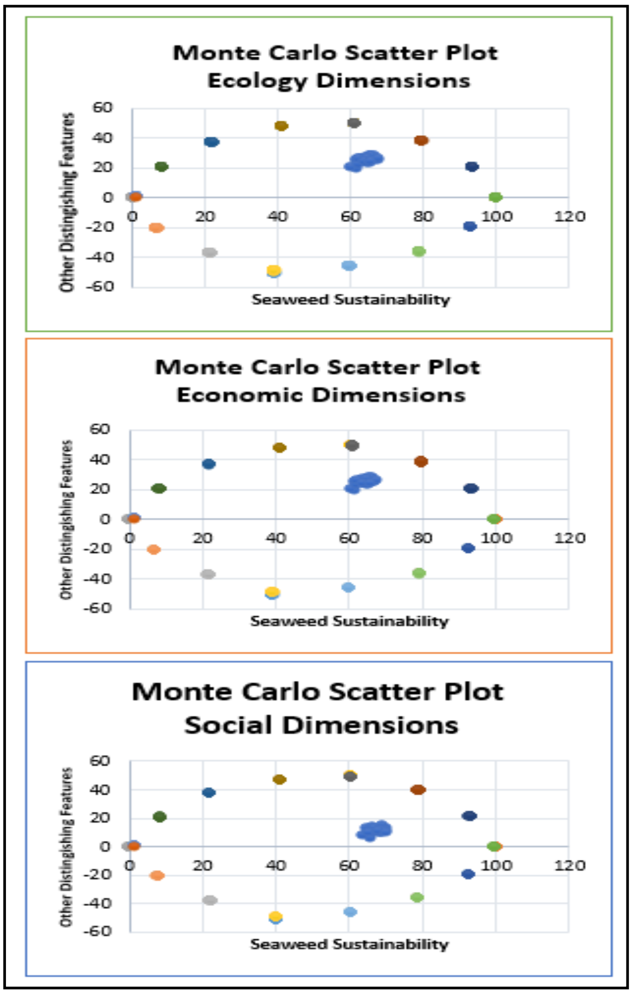

Figure 4. Monte Carlo Scatter Plot of Three Dimensions

Points that are dispersed or separated from other points in the scatter plot, according to Kavanagh and Pitcher (2004), signify mistakes or disturbances in the results of ordination. This demonstrates that the final Rapseaweed analysis may be used to evaluate the sustainability index of seaweed farming activities.

Conclusion

The primary management strategy directions for seaweed cultivation can be prepared, which can serve as the basis for decision-making for stakeholders, namely the local government and seaweed entrepreneurs or related fields. This preparation of strategic directions for the management of seaweed cultivation in Baubau City is based on the order of priority of dominant/sensitive attributes resulting from the leverage analysis affecting sustainability. The three strategic goals for managing sustainable seaweed farming are: Increasing production at seaweed cultivation centres with guaranteed fulfilment of seaweed seeds. Meeting market availability guarantees and maintaining stable seaweed prices. Building the capacity of coastal communities to maximize seaweed farming efforts.

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