Selection of sustainable seaweed and grouper aquaculture development strategy: a case of Pulau Panjang, Serang Regency Banten Province

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Abstract. Due to their high-income contribution, seaweed and grouper aquacultures are important activities in Pulau Panjang community. Determining alternative strategies in developing sustainable aquaculture for seaweed and grouper and their priority factors from these aquaculture activities are done using TOPSIS and AHP analysis. It was found that the development strategy that must be taken is the option to maintain aquaculture activities, while, environment factor is the highest priority to maintain seaweed and grouper aquaculture in Pulau Panjang. Then three priorities are obtained from environment factor. The first is to maintain the water quality by the growth requirements of seaweed and grouper by encouraging the formation of “Environmental Community Awareness” that involved the active participation of the community to maintain quality and carrying capacity of the environment. Second is to use of natural or artificial coastal protectors (soft structure). The third priority strategy is integration and real implementation of heavy metal pollution control between government, industry sector and society.

1. Introduction

Seaweed and groupers aquaculture activities are some of the livelihoods options of coastal communities in Pulau Panjang, Serang Regency Banten Province according to [1] activities of fishery aquaculture in Pulau Panjang are in the category of sufficiently sustainable. Therefore, aquaculture activities especially seaweed and grouper are potential sectors to be developed in the region.

Furthermore, the aquaculture activities are providing more certainty for fishermen than capture fisheries activities that are very dependent on the weather and season. This situation justifies that government policy interventions to prioritize improvement production through aquaculture program are considered to be very appropriate [2]. Seaweed and grouper farming activities should be supported by factors that play a role in sustainable growth and management. The influenced factors are the environment, technology, economic and social factors [1]. The management strategy of seaweed farming activities in Pulau Panjang is located in quadrant one which is Strength-Opportunity strategy
(maxi-maxi strategy) [3]. From the results of this study was obtained information that the development of aquaculture in Pulau Panjang was using the strength to take advantage of existing opportunities.

This research aims to provide a more specific alternative strategy to maintain or to optimize or to improve the development of existing seaweed and grouper aquaculture in Pulau Panjang by using TOPSIS approach. Then the AHP approach is used to determine the priority factors of the four factors (environment, technology, economic and social) by using pairwise comparison of each criterion from each factor so that the resulting strategy will be more targeted and obtain effective and efficient results [4].

2. Materials and Methods

2.1. Location and time research
This research was conducted in December 2016 until February 2017 in Pulau Panjang which is administratively located in Banten Bay, Puloampel District Serang Regency, Banten Province and presented in figure 1. The geographical location is at 6°25'18"–6°28'12" South Latitude and 106°22'9"–106°25'36" East Longitude. Primary data were obtained from the questionnaire of 66 respondents. Secondary data were obtained from the Central Bureau of Statistics (BPS), Agency of Marine and Fisheries or Ministry of Maritime Affairs and Fisheries (KKP), Pulau Panjang Sub District and other publications.

![Figure 1. Research location.](image)

2.2. The TOPSIS methods
TOPSIS (Technique for Others Reference by Similarity to Ideal Solution), initially developed by [5], is a concept where the best alternative would be the one that is nearest to the positive-ideal solution and farthest from the negative ideal solution [6].

The TOPSIS approach is used because (1) TOPSIS is rational and easy to understand; (2) easy computing process; (3) This concept allows to search the best alternative for each criterion that is described in simple mathematical form; (4) An important factor weight is incorporated into a comparison process [7].

The positive-ideal solution is composed of all best values attainable from the criteria, whereas the negative ideal solution consists of all worst values attainable from the criteria [8]. TOPSIS steps can be outlined as follows:

- Build a normalized decision matrix. The \( r_{ij} \) element resulted from the normalization of decision matrix R by the Euclidean length of a vector method is:

\[
    r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{ik}^2}}
\]
• Build a weighted normalized decision matrix. With weight \( W = (w_1, w_2, \ldots, w_n) \), then normalization of matrix \( V \) weight is:

\[
V = \begin{bmatrix}
    w_{11}r_{11} & w_{12}r_{12} & \cdots & w_{1n}r_{1n} \\
    w_{21}r_{21} & w_{22}r_{22} & \cdots & w_{2n}r_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    w_{m1}r_{m1} & w_{m2}r_{m2} & \cdots & w_{mn}r_{mn}
\end{bmatrix}
\] (2)

• Determine positive and negative ideal solutions. The ideal solution is denoted \( A^* \), while the negative ideal solution is denoted \( A^- \):

\[
A^* = \{ (\max v_{ij} | j \in J), (\min v_{ij} | j \in J') \} ; i = 1, 2, 3, \ldots m = \{ v_{j*}, v_{2*}, \ldots v_{n*} \}
\] (3)

\[
A^- = \{ (\min v_{ij} | j \in J), (\max v_{ij} | j \in J') \} ; i = 1, 2, 3, \ldots m = \{ v_{j*}, v_{2*}, \ldots v_{n*} \}
\] (4)

\( J = \{ j = 1, 2, 3, \ldots n \) and \( j \) are benefit criteria \( J' = \{ j = 1, 2, 3, \ldots n \) dan \( j \) are cost criteria \}

• Calculate the separation. \( S_i^* \) is the distance (in Euclidean view) an alternative of the ideal solution defined as:

\[
S_i^* = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_{j*})^2}, \text{ with } l = 1, 2, 3, \ldots m
\] (5)

And farthest away with an ideal-negative solution.

\[
S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_{j^-})^2}, \text{ with } l = 1, 2, 3, \ldots m
\] (6)

• Calculate proximity relative to the ideal solution

\[
C_i^* = \frac{S_i^-}{S_i^* + S_i^-}, \text{ with } 0 < C_i^* < 1 \text{ and } i = 1, 2, 3, \ldots m
\] (7)

• Rank the alternatives. Alternatives can be ranked based on the order \( C_i^* \). Therefore, the best alternative is one of the shortest distance to the positive ideal solution [9].

2.3. The AHP method

Analytical Hierarchy Process (AHP) is a structured technique to organize and analyze complex decisions based on mathematics and psychology [4]. It is used to determine the priority factor of the environment, technology, economic and social factors. AHP steps can be outlined as follow:

- Calculate the normalized matrix
- Calculate the maximum lambda value (\( \lambda_{max} \)) and Consistency Index (CI)
- Calculate Consistency Ratio (CR) that formulated as follows

\[
CR = CI / RI
\] (8)

where CR = Consistency Ratio; CI = Consistency index; RI = Index Random

If the Consistency Ratio (CR) is less than 0.10 then the result can be used to determine priority factor from seaweed and grouper aquaculture activities.

3. Results

3.1. Seaweed farming

Seaweed farming is located in the west of Pulau Panjang. The area of aquaculture is approximately 100 ha, while the seaweed plot has an area of 0.5 ha so there are about 200 plots of the seaweed farming. In Pulau Panjang the type of cultivated seaweed is \( Kappaphycus alvarezii \) (cottonii) as a producer of carrageenan [10]. Seaweed farming system is using long line system by using a rope that stretched from one point to another with a length of 50–100 m. It can be in the form of loose or arranged lines in quadrilateral form with the support of buoys and anchors [11]. Seaweed life cycle is 45 days.

3.2. Grouper aquaculture

Grouper aquaculture in Pulau Panjang is conducted by floating net cage (KJA) technology, which is mounted on floating raft in the coastal area [12]. Size of floating raft is \( 8 \times 8 \) m divided into four plots measuring \( 3.2 \times 3.2 \) m, the raft was floated with a float and tethered with an anchor. While the size of
the cage is $1 \times 1 \times 2 \text{ m}$ for nursery phase and $3 \times 3 \times 3 \text{ m}$ for the enlargement phase [13]. Harvest will be conducted when the weight of fish reaches 500–1,200 gram or depending on market demand. This is a measure of market demand that has high selling value [14]. Currently there are eight KJA for grouper aquaculture [15].

3.3. Result of TOPSIS approach

The expert team determines the criteria of each environmental, technological, economic and social factors for seaweed and grouper aquaculture development in Pulau Panjang. Previous experience, previous observations and research from the expert team were used to determine the criteria. From each factor, there are five selected criteria so that the total criteria used are 20 criteria.

Meanwhile, the TOPSIS calculation based on the distance of each strategy option to the shortest distance from the positive ideal solution and the furthest distance from the negative ideal solution as well as the value of relative proximity to the ideal solution (Ci) is shown in table 1.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline
Strategy & Environment & Technology & Economic & Social & S+ & S- & Ci & Rank \\
\hline
Maintain & 0.2095 & 0.2882 & 0.1895 & 0.0677 & 0.1185 & 0.2393 & 0.6687 & 1 \\
Increase & 0.1048 & 0.0913 & 0.1327 & 0.1524 & 0.1847 & 0.1048 & 0.3621 & 2 \\
Optimizing & 0.0873 & 0.0456 & 0.0948 & 0.1863 & 0.2393 & 0.1185 & 0.3312 & 3 \\
\hline
\end{tabular}
\caption{Distance of strategic options to ideal positive solutions (S+) and ideal negative solutions (S-) as well as the value of relative proximity to the ideal solution (Ci).}
\end{table}

3.4. Result of AHP method

Of the four supported factors, each factor is compared pairwise between factors to obtain priority factor in maintaining existing seaweed and grouper aquaculture. The result of pairwise comparison between environmental, technological, economic and social factors is shown in table 2.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
 & Environment & Technology & Economic & Social & Weight & Rank \\
\hline
Environment & 1 & 1.9792 & 1.1465 & 1.376 & 0.3214 & 1 \\
Technology & 0.5053 & 1 & 1.5886 & 1.1993 & 0.2446 & 3 \\
Economic & 0.8722 & 0.6295 & 1 & 1.9834 & 0.2538 & 2 \\
Social & 0.7268 & 0.8338 & 0.5041 & 1 & 0.1802 & 4 \\
\hline
\end{tabular}
\caption{The result of pairwise comparison between environmental, technological, economic and social factors.}
\end{table}

\[ CR = 0.0884 \]

Analysis of hierarchical structure of priority strategies to maintain seaweed and grouper aquaculture in Pulau Panjang is conducted by using AHP approach presented in figure 2.
Figure 2. Hierarchy of priority strategies to maintain seaweed and grouper aquaculture in Pulau Panjang.

The alternative strategies to maintain seaweed and grouper aquaculture in Pulau Panjang by considering the priority factor of environmental is presented in table 3.

Table 3. Alternative strategy with environmental factors as a priority factor.

| Alternative | Descriptions |
|-------------|--------------|
| A1          | Maintaining the water quality by the growth requirements of seaweed and grouper by encouraging the formation of “Environmental Community Awareness” where there is an active participation of the community to maintain the quality and carrying capacity of the environment. Seaweed and grouper have certain water quality threshold to be able to live and grow continuously. |
| A2          | Integration and real implementation of heavy metal pollution control between government, industry sector and society. Pulau Panjang waters allegedly affected by heavy metal pollution from factories in the Bojonegara area which is characterized by high values of Pb and Cd. |
| A3          | Preparation and implementation of planting season calendar of seaweed and seed grouper seedlings calendar. Seaweed disease attacks mostly occur during the rainy season and pests occur in certain predictable months so that these predictions can be used as a reference for planting seaweed and spreading grouper seeds to obtain maximum yield. |
| A4          | Using natural or artificial coastal protector (soft structure). Water protection is essential to maintain the stability of oceanographic factors (currents, waves, winds) so that seaweed and grouper can be well developed. Planting mangroves as a natural coastal protector can also be useful as an eco-tourism location in Pulau Panjang. |
A5 Provision of facilities and infrastructure of TPS (Temporary Disposal Site) and cubluk or septic tank for Pulau Panjang community

The availability of TPS and cubluk or septic tank is crucial to process the domestic waste of Pulau Panjang community before being discharged into the waters.

Meanwhile, the weight and rank of priority strategies to maintain seaweed and grouper aquaculture can be seen in table 4.

Table 4. The rank of priority strategies to maintain seaweed and grouper aquaculture.

| Matriks | A1 | A2 | A3 | A4 | A5 | Weight | Rank |
|---------|----|----|----|----|----|--------|------|
| A1      | 1  | 2.1077 | 3.4463 | 1.6158 | 0.8444 | 0.3009 | 1 |
| A2      | 0.4745 | 1   | 2.3072 | 1.1734 | 1.6454 | 0.2076 | 3 |
| A3      | 0.2902 | 0.4334 | 1   | 0.6077 | 0.6132 | 0.0962 | 5 |
| A4      | 0.6188 | 0.8521 | 1.6454 | 1   | 3.1770 | 0.2313 | 2 |
| A5      | 1.1841 | 0.6077 | 1.6305 | 0.3147 | 1   | 0.1640 | 4 |

CR = 0.0813

4. Discussion

4.1. Strategy options for seaweed and grouper aquaculture development

From table 1 can be seen that the strategy option to maintain the existing seaweed and grouper aquaculture in Pulau Panjang has the biggest proximity (Ci) value of 0.6687. From the table it can be seen that the maintain option also has the shortest distance from the positive ideal solution (S+) with a value of 0.1185 and the furthest distance from the negative ideal solution (S-) with a value of 0.2393. So, the best strategic option to be implemented in Pulau Panjang is to maintain the existing seaweed and grouper aquaculture development. This result appropriate with interview result with respondent that the best option is to maintain the existing development of aquaculture based on their economic and social condition as well as environment and technology condition.

4.2. Identification of priority factors to maintain seaweed and grouper aquaculture in Pulau Panjang

Table 2 shows that environmental factor is a priority factor to maintain seaweed and grouper aquaculture activities with a weight value of 0.3214. Seaweed and grouper aquaculture activities need appropriate environmental and natural conditions to be able to live and grow well and continuously. The appropriate environmental condition is the initial factor of how seaweed and grouper aquaculture activities can run as expected. These conditions according to [1] and [16] can be regarded as a key factor in aquaculture activities. Therefore the selection of priority strategies to maintain seaweed and grouper aquaculture in Pulau Panjang is prepared by notice all criteria of environmental factors as a priority factor.

4.3. Recommendation of priority strategies

Table 4 shows that A1 priority strategy is the priority strategy with a weight of 0.3009. The priority strategy is to maintain water quality under the growth requirements of seaweed and grouper by encouraging the formation of “Environmental Community Awareness” where there is active participation of the community to maintain the quality and carrying capacity of the environment. Water quality must be maintained to the appropriate threshold for seaweed and grouper growth. Environment carrying capacity can be interpreted as the level of sustainable use of natural resources or ecosystems without causing damage to resources and environment [2].

Therefore, a social approach is needed to encourage the active involvement of the community in maintaining the water quality and environment, especially those directly related to the of seaweed and groupers aquaculture. The changes in water and environmental quality can have an impact on the
production decrease of seaweed and grouper. This will certainly also affect the average income of seaweed and grouper farmers in Pulau Panjang in the future. Active involvement of the community can be formed by approaching influential figures in Pulau Panjang to be able to mobilize and increase public awareness of the importance of maintaining the environment carrying capacity in Pulau Panjang.

The second priority strategy is the A4 strategy, which is the application of natural or artificial coastal protector with a weight of 0.2313. Water protection to maintain the stability of oceanographic factors such as currents, waves and winds is essential for the continuity of seaweed and grouper aquaculture in Pulau Panjang. The ideal current velocity for the living conditions of seaweed and grouper is between 20–40 cm·sec⁻¹ [17]. Mangrove can serve as a natural coastal shield where mangroves can serve as greenbelt to withstand waves naturally, play an important role as fauna habitat, protect the shoreline, spawning and nursery ground for some species of fish and crustaceans, natural wastewater treatment facilities and prevent pollution in coastal areas [18]. Mangrove also can support tourism potential where mangrove can become one of ecotourism area in Pulau Panjang.

The third priority strategy is A2 strategy which is integration and real implementation of heavy metal pollution control between government, industry sector and society with weight of 0.2076. Based on data on the number and type of industry located around Pulau Panjang according to [19] it can be predicted that these industries have hazardous wastes for the environment if not well managed such as heavy metal waste in steel industry, shipbuilding, sulphonation, organic waste from refined sugar manufacturing industries, heat waste resulting from the construction and operation of steam power plants and the disposal of natural gas pipelines as well as turbidity of waters from sand mining activities. From the results of the activities of these industries, [1] found that Pulau Panjang waters allegedly affected by heavy metal pollution from the factory in Bojonegara area is marked by the high value of Pb (0.207–0.214 mg·L⁻¹) and Cd (0.01–0.2 mg·L⁻¹). So that, the implementation of heavy metal pollution control especially for the affected locations in the waters of Pulau Panjang is needed immediately.

5. Conclusion
From the result of alternative determination strategy of seaweed and grouper aquaculture development in Pulau Panjang by using TOPSIS approach, the strategy is obtained to maintain the development of existing seaweed and grouper aquaculture.

Meanwhile, from the results of the pairwise comparison of environmental, technological, economic and social factors, it is seen that environmental factors are a priority factor in maintaining seaweed and grouper aquaculture activities in Pulau Panjang with a weighted value of 0.3214. Appropriate environmental conditions is the initial factor of how seaweed and grouper aquaculture activities can run as expected.

From the weight and rank of priority strategies in maintaining the activities of seaweed and grouper cultivation on Pulau Panjang, there are three main priority strategies. The priority strategy is to maintain water quality under the growth requirements of seaweed and grouper by encouraging the formation of “Environmental Community Awareness” where there is active participation of the community to maintain the quality and carrying capacity of the environment. The second priority strategy is the application of natural or artificial coastal protector. The third priority strategy is integration and real implementation of heavy metal pollution control between government, industry sector and society.

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References
[1] Soejarwo P A 2016 Thesis Program Magister Teknik Lingkungan ITB Bandung
[2] Marzuki M 2014 Dissertation Program Pascasarjana IPB Bogor
[3] Soejarwo P A and Fitriyanny W P 2016 Jurnal Kebijakan Sosial Ekonomi Kelautan dan Perikanan 6(2) 123–34
[4] Saaty T L 2008 Journal Services Science 1 83–98
[5] Hwang C L and Yoon N 1981 Multiple Attributes Decision Making Methods and Application (Berlin: Springer-Verlag)
[6] Hsu P F and Hsu M G 2008 J. Quality & Quantity 42(2) 181–201
[7] Wang T C and Chang T H 2007 J. Expert Syst. Appl. 33 870–80
[8] Wang Y J 2007 J. Expert Syst. Appl. 34 1837–45
[9] Morteza Z, Reza M F, Seddiq M M, Sharareh P and Jamal G 2016 Journal Ocean and Coastal Management 130 179–87
[10] Astutty S and Diana S 2004 Journal Agriculture 14 166–70
[11] BSN 2010 SNI 7579.2–2010 Standar Nasional Indonesia Badan Standardisasi Nasional Jakarta
[12] Sunyoto P 1994 Pembesaran Kerapu dengan Karamba Jaring Apung (Jakarta: Penebar)
[13] BSN 2006 SNI 01–7222–2006 Standar Nasional Indonesia Badan Standardisasi Nasional Jakarta
[14] WWF 2015 World Wide Fund Indonesia (Jakarta: WWF)
[15] Dinas Kelautan dan Perikanan Provinsi Banten 2015 DKP Dalam Angka 2014 (Banten: DKP Provinsi Banten)
[16] Susilo S B 2003 Dissertation Program Pascasarjana IPB Bogor
[17] KKP 2014 Kajian Dampak Penambangan Pasir Laut Pantai Utara Banten untuk Reklamasi Teluk Jakarta Terhadap Sumberdaya Laut dan Pesisir (Jakarta: Badan Penelitian dan Pengembangan Kelautan dan Perikanan)
[18] Biswas S R, Mallik A, Choudhury J and Nishat A 2008 Journal Wetlands Ecology and Management 17 365–83
[19] http://bplhd.co.id 2013 Accessed in 16 June 2016