Feasibility study of seaweed farming *Kappaphycus alvarezii* in Sub-District North Pulau Laut and Sub-District East Pulau Laut Kotabaru Regency, South Borneo, Indonesia

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Abstract. *Kappaphycus alvarezii* has the potential to be developed due to the increasing demand for local and international markets. To support the development of *Kappaphycus alvarezii* cultivation, a new feasible cultivation area is needed. This study aims to analyze the feasibility of *Kappaphycus alvarezii* farming in North Pulau Laut District and Pulau Laut Timur District, Kotabaru Regency, South Kalimantan. The analytical method used was a spatial analysis of physical and chemical parameters and strategic environmental conditions analysis. The total area of land suitable for seaweed cultivation in Pulau Laut Utara and Kecamatan Pulau Laut Timur was around 11,499 ha for the feasible category, with the waters carrying capacity of was 9,498 ha for 18,996 units of seaweed cultivation; with this carrying capacity, it can produce 79,783 to 96,880 tons year$^{-1}$ for four times the harvest season or 99,729 to 121,100 tons year$^{-1}$ for 5 times the harvest season. Three main strategies that need to be implemented to achieve the estimated production were improving quantity and quality of seaweed production, utilization of all suitable land for seaweed cultivation basing on the waters carrying capacity, and research development to improve the seaweed quality and products by involving universities, government, and private companies/institutions.

1. Introduction

The seaweed hydrocolloid market continues to grow. This growth was largely driven by new markets in China, Eastern Europe, Brazil, and others [1]. Seaweed is rich in carbohydrates, proteins, and nitrogen compounds, minerals, lipids, vitamins, volatile compounds, and pigments [2-4].

Seaweed has the potential to be developed because it has high domestic and foreign market demand. Market demand is expected to increase following the increasing needs of the food, pharmaceutical, cosmetics, and renewable energy industries [5-7]. 99.73% of Indonesia’s seaweed produced by cultivation [8], so seaweed cultivation is the best alternative in fulfilling market demand [9].
Seaweed cultivation is a popular alternative livelihood in many developing countries in the tropics, such as the Philippines and Indonesia [10, 11]. One species of seaweed that is widely cultivated is *Kappaphycus alvarezii*. *K. alvarezii* cultivation in shallow water continues to increase along with the increased market demand for polysaccharides. Increased market demand stimulates the expansion of the cultivation area [12]. The expansion of seaweed cultivation areas is not always easy because seaweed cultivation sites must have good environmental parameters, such as water temperature, radiation, salinity, water depth, wave action, pH, and oxygen content [13-15].

Seaweed as the priority in the fisheries sector, its production continues to improve by the Indonesian Government [16]. The improving efforts to increase the production of seaweed was the expansion of the cultivation area. One of the waters of Indonesia that has the potential to be developed as a cultivation area is Kotabaru Regency, South Kalimantan Province.

Kotabaru Regency is a coastal area that has a coastline of 825 km, and an area of four nautical waters covering 544 km² or more than 25.52% of the total area of South Kalimantan Province [17]. Seaweed cultivation is a fisheries sector activity that the Government of South Kalimantan wants to develop [17]. Kotabaru is one of the seaweed producing areas in Kotabaru. Seaweed production at Kotabaru Regency reaches 189.26 tons per year [18]. This production could be developed because there are a lot of potential seaweed cultivation areas in Kotabaru Regency that have not been used optimally because of limited data and information about suitable locations for seaweed cultivation. Pulau Laut Utara and Pulau Laut Selatan subdistricts are two of the four subdistricts in Kotabaru Regency that have the potential to be developed as seaweed cultivation development areas. Pulau Laut Utara District began to develop a seaweed cultivation business, which was carried out by around 60 farmers from 6 farming groups [17]. Whereas in Pulau Laut Timur District, the potential of the coastal area has not yet been utilized for the seaweed cultivation development, to date, aquaculture activities were still focused on aquaculture ponds [18].

In developing seaweed cultivation business, aspects of waters feasibility, waters carrying capacity, and seaweed cultivation development strategies are three things that must be considered. Aspects of water feasibility include environmental parameters, such as salinity, temperature, depth, and substrate [19]. Carrying capacity aspects include the upper limits of aquaculture production and ecological limits, as well as social acceptance of the local community without causing environmental degradation and social structures [20]. Development strategies include steps to achieve long-term shared goals through the processes series, starting from the input process, the analysis process, and the decision-making process. The process begins by identifying all the information needed in the strategy formulation, then proceed with the analysis and formulation of the strategy. The results of the strategy formulation can be used in mapping, developing business systems, empowering, and developing facilities and infrastructure [21]. This feasibility study aims to analyze the land suitability and the carrying capacity of the waters, as well as to develop strategies for seaweed cultivation development of *Kappaphycus alvarezii* in Pulau Laut Utara and Pulau Laut Timur districts, Kotabaru Regency, South Kalimantan.

### 2. Materials and methods

#### 2.1. Location and period

The feasibility study was carried out in the coastal areas of Pulau Laut Utara District and Pulau Laut Selatan District, Kotabaru Regency, South Kalimantan Province (Figure 1), from November 2016 - March 2017.

#### 2.2. Population and sampling technique

The feasibility study uses a survey method. The data used were primary and secondary data. Primary data were obtained from field surveys and measurements of waters physics and chemical parameters, interviews, and questionnaires. Secondary data were obtained from related agencies or institutions, such as the office of Maritime Affairs and Fisheries, Bappeda, and the Department of Industry. Sampling was done by purposive sampling, where the determination of the sampling point was done...
intentionally based on certain considerations [22]. The number of respondents was 34 persons, consisting of 30 seaweed cultivators, one collector, one employee of the Kotabaru Regency Maritime Affairs and Fisheries, one Bappeda Kotabaru Regency, and one Industry and Trade Office interviewed regarding the development of the seaweed cultivation business. Data of the physical and chemical waters parameters were obtained from measurements at 24 sampling points. The sampling point determination was based on the consideration that the sample represents the characteristics of the existing waters. The determination of the sampling point was limited to areas that are still flooded at low tide to a depth of ± 10 meters.

**Figure 1.** Feasibility study site in the coastal areas of Pulau Laut Utara District and Pulau Laut Selatan District, Kotabaru Regency, South Borneo Province, Indonesia.

### 2.3. Data analysis

The suitability analysis of seaweed cultivation land uses the suitability matrix of seaweed cultivation *Kappaphycus alvarezii* (Table 1). Based on the suitability matrix of oceanographic physics-chemical parameters, a quantitative assessment of the level of water suitability was carried out by the method of scoring. Score three was for the parameters that have a dominant influence on cultivated land; score two was for the parameters that have quite a dominant influence, and score one was for the parameters that have no influence. Based on the total score of each parameter, the suitability of seaweed farming land suitability classes was determined using the formula (Prahasta, 2002):

\[
Y = \sum ai \cdot Xn
\]  

(1)

Where Y was the final score, ai = scoring factor, dan Xn = land suitability level score. Land suitability class intervals were obtained based on the equal interval method [23] to divide the interval values into the same size according to the equation:

\[
I = \frac{(\sum ai \cdot Xn)_{\text{max}} - (\sum ai \cdot Xn)_{\text{min}}}{k}
\]  

(2)

Where I was the interval of conformity class, and k was the number of conformity class. Based on the equation, three class intervals of seaweed cultivation suitability obtained were: (1) feasible category (S1) for a score of 71-90 which means that the station has no significant limiting factor; (2) feasible enough (S2) for a score of 51-70 which means the station has a limiting factor that could still be tolerated; and (3) not feasible category (S3) score of 30-50 which means the station has a severely
limiting factor. The last stage was the spatial analysis by overlaying the parameters in the form of polygons. The overlay process was done by combining each layer of each location suitability for seaweed cultivation.

**Table 1. Feasibility matrix of seaweed cultivation Kappaphycus alvarezii [24, 25].**

| No. | Parameters            | Criteria                  | Score (S) | Feasibility Factor (FF) | S x FF |
|-----|-----------------------|---------------------------|-----------|-------------------------|--------|
| 1.  | Shelter               | Sheltered Poorly Sheltered| 3         | Feasible                | 3 x FF |
|     |                       |                            | 2         | Enough feasible         |        |
| 2.  | Current speed (m s⁻¹) | Open 0.2-0.03 or 0.31-0.41| 1         | Not feasible            | 3      |
|     |                       | 0.10-0.19 or 0.10-0.19    | 3         | Feasible                | 9      |
|     |                       | < 0.10 or > 0.41          | 2         | Enough feasible         | 6      |
| 3.  | Total Suspended Solid (mg l⁻¹) | < 25  | Feasible                | 3      |
|     |                       | 25-50                     | 2         | Enough feasible         | 6      |
| 4.  | Salinity (ppt)       | 28-32                     | 3         | Feasible                | 2 x FF |
|     |                       | 25-27 or 33-35            | 2         | Enough feasible         | 4      |
|     |                       | < 25 or > 35              | 1         | Not feasible            | 2      |
| 5.  | Temperature (°C)     | 28-30                     | 3         | Feasible                | 2 x FF |
|     |                       | 26-27 or 31-33            | 2         | Enough feasible         | 4      |
|     |                       | < 26 or > 33              | 1         | Not feasible            | 2      |
| 6.  | Substrate            | Rocky sand                | 3         | Feasible                | 2 x FF |
|     |                       | Muddy Sand                | 2         | Enough feasible         | 4      |
| 7.  | Nitrate (ppm)        | Muddy 0.9-3.5              | 1         | Not feasible            | 2      |
|     |                       | 0.1-0.8 or 3.6-4.4        | 2         | Feasible                | 3 x FF |
|     |                       | < 0.1 or > 4.5            | 1         | Not feasible            | 3      |
| 8.  | Phosphate (ppm)      | 0.015-1.000               | 3         | Feasible                | 3 x FF |
|     |                       | 0.021-0.050               | 2         | Enough feasible         | 6      |
| 9.  | pH                   | < 0.021 or > 1            | 1         | Not feasible            | 3      |
|     |                       | 7.8-5.6                   | 3         | Feasible                | 3 x FF |
|     |                       | 6.5-6.9 or 8.5-9.5        | 2         | Enough feasible         | 6      |
| 10. | Depth (m)            | < 6.5 or > 8.5            | 1         | Not feasible            | 2      |
|     |                       | 0.6-2.1 or 0.3-0.5 or 2.2-10.0 | 3   | Feasible                | 2 x FF |
|     |                       |                            | 2         | Enough feasible         | 4      |
| 11. | Brightness (%)       | < 0.3 or > 1.0            | 1         | Not feasible            | 2      |
|     |                       | > 75                      | 3         | Feasible                | 3 x FF |
|     |                       | 50-75                     | 2         | Enough feasible         | 6      |
| 12. | Dissolved oxygen (mg l⁻¹) | > 50        | 1         | Not feasible            | 3      |
|     |                       | > 6                       | 3         | Feasible                | 2 x FF |
|     |                       | 4-6                       | 2         | Enough feasible         | 4      |
|     |                       | < 4                       | 1         | Not feasible            | 2      |
Waters carrying capacity was the maximum capacity of the land to support cultivation activities continuously without causing a decrease in the quality of the biophysical environment (Rauf, 2008). Waters capacity for seaweed cultivation (WCsc) was calculated by using the equation:

$$WC = \frac{(L_2-L_1)}{L_2} \times 100\% = \frac{(p^2xL_2)-(p^1xL_1)}{(p^2xL_2)} \times 100\%$$ (3)

Where, Lu was large of used unit cultivation area (m²); Lf was large of feasible unit cultivation area (m²); lw was a length of used unit cultivation (m); wu was wide of used unit cultivation (m); lwf was wide of feasible unit cultivation (m), that wu + wide of a boat with the counterweight. Waters Carrying Capacity for seaweed cultivation (WCCsc, in ha⁻¹) was calculated by using the equation:

$$WCCsc = WCsc \times FWLsc$$ (4)

Where FWLsc was large of feasible unit cultivation (ha). Large of seaweed cultivation units LUsc was calculated based on the length of used unit cultivation multiplied by the wide of used unit cultivation by using the formula:

$$Usc = lu \times wu$$ (5)

Number of seaweed cultivation units (NUsc) was calculated based on the carrying capacity divided by the area of cultivation units by using the formula [26]:

$$NUsc = \frac{WCCsc}{LUsc}$$ (6)

The development of seaweed cultivation was through five stages. The first stage was the identification of internal and external factors. The second stage, the scoring and rating of each internal and external factor using the Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) matrices [27]. The third stage, combining the total value of the IFE Matrix on the x-axis and the total value on the y-axis to produce an IE matrix that serves to determine the position of seaweed farming [28]. The fourth step, the compilation of Strengths, Weaknesses, Opportunities, and Threats (SWOT) matrices that produced several alternative strategies [29]. And, the fifth stage was decision making using the Quantitative Strategy Planning Matrix (QSPM) analysis tool [30]. This matrix was a tool that allows evaluating alternative strategies objectively, based on internal and external factors that have been identified previously. The QSPM uses input from the input and integration stages to decide which strategy was the best [21].

3. Results
3.1. Physical and chemical parameters
Current speed range at 24 stations was 0.1-0.3 m s⁻¹, with the average 0.18±0.07 m s⁻¹; the total suspended solid range was 3.52 mg l⁻¹, with the average 13.46±10.44 mg l⁻¹; salinity range was 22-33 ppt, with the average 29.25±2.75 ppt; temperature range was 31.0-33.9 °C, with the average 31.92±0.73 °C; nitrate range was 0.1-1.8 ppm, with the average 1.07±0.43 ppm; phosphate range was 0.04-0.70 ppm, with the average 0.20±0.16 ppm; pH range was 7.2-8.7, with the average 7.75±0.24; dept range was 0.33-8.20 m, with the average 2.62±2.45 m; and dissolve oxygen range was 5.4-10.4 ppm, with the average 7.35±1.04 ppm (Table 2).
3.2. Carrying capacity and waters capacity
The total seaweed cultivation area in Pulau Laut Utara and Pulau Laut Timur Districts was 16,444,402 ha, where the feasible area was 11,499,133 ha (66.37%); the quite feasible was 2,747.90 ha (20.27%), and not feasible was 2,197,379 ha (13.36%) (Figure 2). The waters’ total carrying capacity was 9,498 ha for 18,996 units of seaweed culture.

3.3. Seaweed cultivation development strategy
Internal and external factors that exist in Pulau Laut Utara and Pulau Laut Timur consist of 5 strengths, 5 weaknesses, 4 opportunities, and 4 threats. The internal factor score on the IFE matrix was 2.63 (Table 3). While the external factor score on the EFE matrix was 2.56 (Table 4). The mapping of the IFE and EFE matrix scores shows that the position of seaweed cultivation in Pulau Laut Utara and Pulau Laut Timur districts was in Cell V (Figure 3). The top priority strategy based on the highest scaling factor from the QSP matrix analysis was improving the quantity and quality seaweed production (5,519) (Table 5). The SWOT matrix analysis resulted in six alternative strategies (Table 6).

4. Discussion
4.1. Carrying capacity and waters capacity
The seaweed cultivation success mush is designed from the beginning, since the site selection because the quantity and quality of seaweed is highly dependent on the physical and chemical waters factors such as protection, current speed, suspended solids, salinity, temperature, substrate, nitrate, phosphate, pH, depth, brightness, and dissolved oxygen. Therefore, before the seaweed culture development, it is very important to analyze the feasibility of the seaweed cultivation area.

Figure 2. The feasibility areas for seaweed cultivation Kappaphycus alvareziin Sub-District North Pulau Laut and Sub-District East Pulau Laut Kotabaru Regency, South Borneo, Indonesia.
This feasibility study indicates that, in general, Pulau Laut Utara District and Pulau Laut Timur District were classified as feasible for seaweed cultivation, because each physical and chemical parameter were largely in the feasible range. The range of suspended solids values was generally at a reasonable value for the coastal area of a large island. This range was almost the same as found in the coastal waters of a large populated island [31]. The dissolved oxygen content was quite high compared to seaweed cultivation in controlled media [32, 33]. The dissolved oxygen content was quite high compared to seaweed cultivation in controlled media. Phosphate concentrations were in the range that was commonly found in coastal waters [34-36]. Current speed was within the range commonly found in *Kappaphycus alvarezii* cultivation area [8]. pH was in a good range for seaweed cultivation [37]. There were some areas that are not feasible due to the limiting factors such as depth, substrate, brightness, and suspended solids. These four parameters can affect the seaweed growth because it was related to the light penetration. Light penetration becomes low when the suspended particles increase in the near shore waters that caused by tides and depth [38].

**Table 2.** Physical and chemical waters parameters in Sub-District Pulau Laut Utara and Pulau Laut Timur Sub-District, Kotabaru Regency, South Borneo, Indonesia.

| Station | Shelter | Current speed (m/s) | TSS (mg/l) | Salinity (%o) | Temperature (°C) | Substrate | Nitrate (ppm) | Phosphate (ppm) | pH | Depth (m) | Brightness (%) | DO (ppm) |
|---------|---------|---------------------|------------|---------------|-----------------|-----------|--------------|----------------|----|----------|----------------|---------|
| 1       | Open    | 0.3                 | 3          | 32            | 32.0            | Rocky sand | 0.8          | 0.32           | 7.60 | 4.20     | 100            | 5.4     |
| 2       | Open    | 0.2                 | 12         | 30            | 31.8            | Muddy Sand | 0.8          | 0.33           | 7.78 | 6.70     | 88             | 6.9     |
| 3       | Open    | 0.1                 | 3          | 28            | 31.9            | Muddy Sand | 1.3          | 0.34           | 7.79 | 7.70     | 50             | 6.9     |
| 4       | Open    | 0.1                 | 14         | 32            | 31.2            | Muddy Sand | 1.2          | 0.32           | 7.80 | 8.20     | 80             | 7.1     |
| 5       | Open    | 0.2                 | 11         | 30            | 31.0            | Muddy Sand | 1.7          | 0.39           | 7.75 | 6.40     | 71             | 6.9     |
| 6       | Sheltered | 0.1              | 12         | 31            | 31.7            | Muddy Sand | 0.8          | 0.70           | 7.81 | 1.40     | 50             | 6.3     |
| 7       | Sheltered | 0.2             | 13         | 27            | 31.9            | Muddy Sand | 1.5          | 0.22           | 7.20 | 0.45     | 67             | 6.6     |
| 8       | Sheltered | 0.1             | 26         | 28            | 32.0            | Muddy Sand | 1.3          | 0.17           | 7.80 | 3.70     | 29             | 6.9     |
| 9       | Sheltered | 0.3             | 12         | 30            | 32.0            | Muddy Sand | 1.8          | < 0.02         | 7.78 | 4.1      | 26             | 7.0     |
| 10      | Sheltered | 0.2            | 14         | 31            | 32.0            | Muddy Sand | 1.4          | 0.07           | 7.74 | 1.35     | 56             | 7.3     |
| 11      | Sheltered | 0.2             | 23         | 32            | 32.4            | Muddy Sand | 0.9          | 0.05           | 7.78 | 0.92     | 56             | 6.9     |
| 12      | Sheltered | 0.1             | 18         | 32            | 32.2            | Muddy      | 1.3          | 0.04           | 7.75 | 0.48     | 27             | 6.8     |
| 13      | Sheltered | 0.2             | 5          | 30            | 32.8            | Muddy      | 1.2          | 0.08           | 7.77 | 0.40     | 100            | 10.4    |
| 14      | Sheltered | 0.2             | 8          | 30            | 32.0            | Muddy      | 1.3          | 0.13           | 7.78 | 0.97     | 77             | 7.5     |
| 15      | Sheltered | 0.1             | 8          | 31            | 32.0            | Muddy      | 0.8          | 0.06           | 7.77 | 1.65     | 43             | 7.4     |
| 16      | Sheltered | 0.2             | 12         | 25            | 32.0            | Muddy      | 0.1          | 0.25           | 8.7  | 1.81     | 63             | 6.8     |
| 17      | Sheltered | 0.1             | 4          | 22            | 33.9            | Muddy      | < 0.1        | 0.38           | 7.63 | 1.18     | 29             | 8.7     |
| 18      | Sheltered | 0.2             | 52         | 27            | 33.6            | Muddy      | 0.4          | 0.09           | 7.80 | 0.59     | 54             | 9.7     |
| 19      | Sheltered | 0.2             | 8          | 28            | 31.4            | Muddy      | 0.8          | 0.06           | 7.67 | 3.92     | 31             | 7.0     |
| 20      | Sheltered | 0.2             | 26         | 28            | 31.4            | Muddy      | 0.7          | 0.08           | 7.68 | 1.72     | 19             | 7.8     |
| 21      | Sheltered | 0.2             | 14         | 30            | 31.7            | Muddy      | 1.2          | < 0.02         | 7.70 | 0.39     | 50             | 7.8     |
| 22      | Poorly Sheltered | 0.4          | 1          | 24            | 31.0            | Muddy      | 0.6          | 0.09           | 7.66 | 0.33     | 73             | 6.9     |
| 23      | Poorly Sheltered | 0.3           | 9          | 31            | 31.1            | Sandy mud | 1.1          | 0.13           | 7.65 | 1.52     | 80             | 7.8     |
| 24      | Poorly Sheltered | 0.1           | 12         | 33            | 31.0            | Muddy      | 1.7          | 0.13           | 7.65 | 2.71     | 50             | 7.5     |
Table 3. Internal strategic factors of seaweed cultivation in Pulau Laut Utara and Pulau Laut Timur Districts (IFE matrix).

| Strengths                                                                 | Scaling Factor (a) | Rating (b) | Score (a x b) |
|--------------------------------------------------------------------------|--------------------|------------|---------------|
| 1. Large area suitable for seaweed cultivation                           | 0.129              | 4          | 0.52          |
| 2. Local government support for seaweed cultivation development          | 0.079              | 4          | 0.32          |
| 3. Easy accessibility to seaweed cultivation sites                       | 0.084              | 3          | 0.28          |
| 4. Simple cultivation techniques and short production periods            | 0.095              | 3          | 0.32          |
| 5. Manpower/labor available                                             | 0.102              | 4          | 0.41          |

Strengths
1. Suboptimal production and low quality                                 | 0.136              | 1          | 0.18          |
2. Low community interest                                                 | 0.071              | 1          | 0.09          |
3. Limited capital                                                        | 0.096              | 1          | 0.10          |
4. Skills lack in seaweed cultivation                                     | 0.089              | 2          | 0.18          |
5. Limited seedlings availability                                          | 0.118              | 2          | 0.24          |

Total
1,000                                                                    |                      | 2,63       |

Table 4. External strategic factors of seaweed cultivation in Pulau Laut Utara and Pulau Laut Timur Districts (EFE matrix).

| Opportunities                                                                 | Scaling (a) | Rating (b) | Score (a x b) |
|-----------------------------------------------------------------------------|-------------|------------|---------------|
| 1. Continues increase of seaweed market demand                              | 0.100       | 4          | 0.04          |
| 2. Seaweed industry development                                             | 0.128       | 3          | 0.43          |
| 3. Increasing employment                                                    | 0.193       | 4          | 0.77          |
| 4. Increased business partnerships                                           | 0.064       | 3          | 0.21          |

Threat
1. Seaweed price fluctuations                                               | 0.179       | 2          | 0.30          |
2. Seaweed pests and diseases                                               | 0.114       | 1          | 0.11          |
3. Season                                                                    | 0.114       | 1          | 0.15          |
4. Land use conflict                                                        | 0.107       | 2          | 0.18          |

Total
1,000                                                                    |                      | 2,56       |

Figure 3. Matrix IFE and EFE.
Table 5. Matrix of quantitative strategy planning (QSP).

| No. | Alternative strategies                                                                 | Score | Priority |
|-----|----------------------------------------------------------------------------------------|-------|----------|
| 1.  | Improving quantity and quality seaweed production                                        | 5.519 | I        |
| 2.  | Utilization all suitable land for seaweed cultivation basing on the waters carrying capacity | 5.029 | II       |
| 3.  | Research development to improve the seaweed quality and products by involving universities, government, and private companies/institutions | 4.800 | III      |
| 4.  | Human resources development by counseling, coaching and assistance to improve skills and appropriate technology use | 4.239 | IV       |
| 5.  | The government facilitates cooperation between farmers and seaweed entrepreneurs with financial or economic institutions and the private sector to improve capital and marketing capacities | 4.126 | V        |
| 6.  | Establish policies and regulations for seaweed cultivation zoning                          | 2.818 | VI       |

In this feasibility study, carrying capacity means the physical carrying capacity. Physical carrying capacity is the total area of various activities that can be supported by an area or feasible area (McKinsey et al. 2006). Physical carrying capacity evaluation takes into consideration the status of land use, which includes the socio-economic dimension such as the port area, transportation, fishing area, and marine tourism areas and others so that seaweed cultivation will not interfere with other activities. With reference to the current seaweed cultivation at the feasibility study location, where each aquaculture business unit has 150-200 rope stretches, and each stretch produces 7-8.5 kg of dried, it will produce 1,050-1,275 kg of dried seaweed for each business unit for each harvest. Assuming that this seaweed cultivation is constant, it could produce 79,783 to 96,880 tons per year for four harvest times or 99,729 to 121,100 tons per year for 5 times.

4.2. Seaweed cultivation development strategy

Strengths are resources or business capacity that can be used effectively in achieving the goals, while weaknesses are the limitations, tolerance, or defects of the business that can hinder the achievement of its goals. Opportunity is a supportive situation in business, which is illustrated by the tendency that allows an organization to increase its bargaining position through supply activities. While the threat is a situation that does not support or hinder business activities [39].

This Feasibility Study indicated that the main strengths of the seaweed cultivation business in Pulau Laut Utara and Kecamatan Pulau Laut Timur were the large feasible area for seaweed cultivation, while the main weakness was little community interest to develop seaweed cultivation. Internally, the business position is quite strong, so theoretically, the seaweed cultivation business has a high ability to take advantage of its strengths and overcome its internal weaknesses [21].

The biggest opportunity in the development of seaweed cultivation in Pulau Laut Utara and Kecamatan Pulau Laut Timur was employment, while the main threats were pests and diseases. Externally, the seaweed business position was strong enough to take advantage of opportunities and anticipate threats [21]. The IFE and EFE matrix values indicate that the business position was in cell V which means it was in the growth stability quadrant. Cell V was a growth strategy through horizontal integration which means to achieve the growth it is necessary to expand the business by penetrating markets or increasing access to wider markets, building cultivation businesses in other locations, improving technology and production facilities, increasing product quality, and product development in terms of quality and processing [40].

There are three best priority strategies that can be carried out for the seaweed cultivation in Pulau Laut Utara District and Pulau Laut Timur District. The first was processing quantity and quality seaweed production. This top-priority strategy will work well if there is support from the second priority strategy, namely the utilization of all feasible seaweed cultivation areas basing on the waters.
carrying capacity. In addition, to support the first priority strategy to improve the quality of seaweed production, the third strategy is needed, namely research development to improve the products and quality by involving universities, government, and private companies or institutions. The three strategies are interrelated to one another so that their implementation must be done together.

5. Conclusion
The total area of land suitable for seaweed cultivation in Pulau Laut Utara and Pulau Laut Timur is around 11,499 ha for the feasible category, with the waters carrying capacity of is 9,498 ha for 18,996 units of seaweed cultivation; with this carrying capacity, it can produce 79,783 to 96,880 tons year\(^{-1}\) for four times the harvest season or 99,729 to 121,100 tons year\(^{-1}\) for 5 times the harvest season. The three main strategies that need to be implemented to achieve the estimated production were improving quantity and quality of seaweed production, utilization of all suitable land for seaweed cultivation basing on the waters carrying capacity, and research development to improve the seaweed quality and products by involving universities, government, and private companies/institutions.

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