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Evaluation of water suitability for sustainable seaweed (*Kappaphycus alvarezii*) cultivation to support science technopark in North Kalimantan

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Abstract. *Tarakan dry seaweed production increased during 2012-2018 to cultivate* Kappaphycus alvarezii *with the longline planting method. This study aims to assess the quality of the waters and their suitability for seaweed cultivation on the coast of Tarakan Island. The environmental parameters of water quality measured were chlorophyll-a, water temperature, salinity, pH, DO, TDS, turbidity, nitrate, phosphate, water depth, current velocity, protection, research location, and distance between settlements. The quality of coastal waters is analyzed descriptively and compared with seawater quality standards for marine biota, while the suitability of the waters is determined based on the results of the calculation of criteria, scoring, and weighting compiled into the water suitability matrix for seaweed cultivation. The results showed that the quality of the coastal waters of Tarakan Island for seaweed cultivation consisted of three class categories, namely marginally suitable (S3) 13.20%, suitable (S2) 86.50%, and very suitable (S1) 0.30%. So it can be concluded that it has water quality and suitability for seaweed cultivation with a potential land area of 33 896.73 ha.*

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INTRODUCTION

North Kalimantan Province (Kaltara) is one of 10 provinces in Indonesia that are designated as seaweed production centers (KKP, 2016). Efforts to develop cultivation areas have been carried out in several coastal areas of North Kalimantan, namely Nunukan, Bulungan, and Tarakan Regencies. The coastal area of Tarakan Island has the potential and suitability of waters to develop seaweed, covering an area of 776 814 ha (BPS, 2018).

The coastal water of Tarakan Island have been potential to be excavated and exploited for their marine biological resources (Firdaus *et al*., 2013). Seaweed cultivation is an essential source of income for coastal households on Tarakan Island. This activity started in 2009 which was initially only as an additional business apart from being a fisherman. Cultivation activities were growing rapidly, and the results were better than fishing (Avianti *et al*., 2015) so that it became the main job. The fishing community has turned into seaweed cultivators because the harvest time is only 45 days, the production cost is low, the technology is simple, and the market opportunity is large. In addition, the investment is cheap; the activities do not recognize gender because children and women can do it (Ferdouse *et al*., 2018).

Generally, Tarakan's dry seaweed production increased from 5 573 782 tons in 2013 to 18 595 762 tons in 2015 then decreased to 13 776 990 tons in 2016 and increased again to 18 482 143 tons in 2017 (BPS, 2018). The cultivated type of seaweed is *Kapphaphycus alvarezii*, previously known as *Euchema cottonii*. Seaweed cultivation activities on the coast of Tarakan Island then developed rapidly as seen from the wider area of the stretch of seaweed hanging ropes starting from the coast up to 5-7 km to the sea (Selamat *et al*., 2015).

Several important factors that support seaweed growth are water quality, land suitability, seeds, and cultivation methods (Rahmayanti *et al*., 2018), while Ramdhan *et al*. (2018) state that environmental quality factors are factors that affect seaweed production are physical conditions, chemical, and biological. Decreasing water quality will have an impact on aquaculture performance. Organic waste from community activities dumped into the waters can cause water pollution (Zahroh *et al*., 2019).

Research related to land suitability for seaweed cultivation in the coastal waters of Tarakan Island is generally carried out partially with limited water quality parameters. Several studies related to water quality and land suitability for seaweed cultivation in coastal waters of Tarakan Island as reported (Avianti *et al*., 2015), land suitability for seaweed cultivation based on Enso and seasonal variability, (Selamat *et al*., 2015) evaluation of space utilization for seaweed cultivation on the Amal coast of Tarakan Island. Taking this into account, this study aims to analyze the water quality and the level of suitability of the coast of Tarakan Island as a seaweed cultivation area for the development of *K. alvarezii* seaweed cultivation in the science technopark priority area of North Kalimantan (STP-Kaltara).

Several studies related to the suitability of waters for seaweed cultivation in Tarakan waters have been carried out by Avianti *et al*. (2015), Selamat *et al*. (2015) but these studies only divide suitability into 3 classes, while this study divides them into 4 classes, another study analyzed the efficiency of seaweed cultivation production in Tarakan (Banyuartiga, 2017).

This research is very important for the attention of Tarakan's science technopark, which is expected to help the development of seaweed from upstream to downstream through research and technological innovation. Also supported by the collaboration of the startup ecosystem through the Penta helix concept, namely Academic, Business, Government, Research, and Communitas.

METHOD

Research Location and Period

This research was conducted in 6 potential sub-areas for seaweed cultivation in the coastal waters of Tarakan Island, North Kalimantan Province (Kaltara). The six locations are the Mambirdan (MB), Tanjung Pasir (TP), Tanjung Batu-Amal Lama (TL), Binalatung (BL), Andulung (AL) and Juata Laut (JL) (Figure 1). In each area, sampling was carried out at 3 points for water quality measurement and seawater sampling (Table 1). The boundaries of the research area from the shore out to the sea are 0.5-1 000 m with a depth of 3 m. The research was conducted in September-November 2018, the transitional season to enter the east season in the Kaltara region.

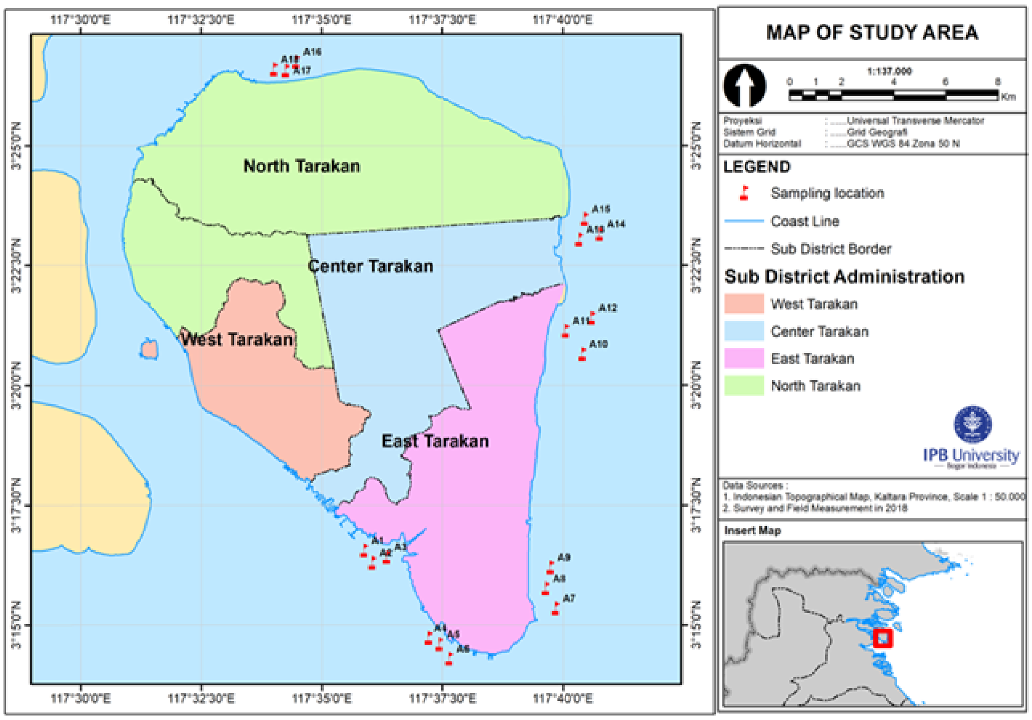

Figure 1 Study area

Table 1 Sampling point at study area

Sub-area Sampling	Sampling Point	Latitude	Longitude
Mamburungan	A1	3°16'33.50"U	117°35'53.22"T
	A2	3°16'18.09"U	117°36'3.34"T
	A3	3°16'24.99"U	117°36'21.45"T
Tanjung Pasir	A4	3°14'43.99"U	117°37'13.10"T
	A5	3°14'36.00"U	117°37'26.94"T
	A6	3°14'17.95"U	117°37'39.19"T
Tanjung Batu-Amal Lama	A7	3°15'20.67"U	117°39'51.23"T
	A8	3°15'45.65"U	117°39'38.98"T
	A9	3°16'12.23"U	117°39'44.84"T
Binalatung	A10	3°20'39.10"U	117°40'24.74"T
	A11	3°21'8.30"U	117°40'3.84"T
	A12	3°21'24.39"U	117°40'36.38"T
Andulung	A13	3°23'2.49"U	117°40'21.00"T
	A14	3°23'9.46"U	117°40'46.74"T
	A15	3°23'28.18"U	117°40'27.97"T
Juata Laut	A16	3°26'45.30"U	117°34'28.78"T
	A17	3°26'34.14"U	117°34'16.00"T
	A18	3°26'35.73"U	117°34'1.09"T

Data Collection

The research was conducted using a survey method to collect data and information at the study site to obtain actual data related to seaweed cultivation activities, such as biophysical and chemical measurements of waters and social community. The data collected in the field are water temperature, salinity, pH, dissolved oxygen (DO), dissolved solids (TDS), turbidity, depth, current velocity, protection, and the distance from the location to the farmer's settlement. A water sampling for examination of chlorophyll-a, nitrate, and phosphate content. These parameters can affect the success of seaweed cultivation (Radiarta and Erlania, 2015) and (Ross *et al*., 2011).

Measurement of water quality using water checker Horiba type U51. The concentration values of chlorophyll-a, nitrate, and phosphate were obtained from the analysis of water samples at the Water Quality Laboratory of the University of Borneo Tarakan. Analysis of chlorophyll-a content based on APHA (2005), phosphate, and nitrate using the procedure (BSN, 2005). The measurement of phosphate concentration was carried out using the ascorbic acid method and measured using a spectrophotometer (BSN, 2005). The chlorophyll-a concentration was calculated using the 90% acetone extraction method (Hutagalung *et al*., 1997) and measured using a spectrophotometer. Mapping of water suitability for seaweed cultivation was carried out using Arc.GIS 10.6 software. The preparation includes a base map, determining boundaries and sampling points, making water suitability matrices, weighting, and spatial analysis (overlay).

Data Analysis

Data on the quality of the coastal waters of Tarakan Island were analyzed descriptively and compared with the seawater quality standard for marine biota (IP 2004) and the suitability of the waters for seaweed cultivation based on SNI 06-6989.31-2005 (BSN, 2005), SNI 7673.2:2011 (BSN, 2011), SNI 8228.2:2015 (BSN, 2015) and several other works of literature are compiled into a matrix of water suitability for seaweed cultivation (Table 2).

Table 2 Matrix of water suitability for seaweed cultivation

No.	Parameters	Unit	Parameter's value	Parameter state	Score	Reference
Biology						
1	Chlorophyll-a	mg/l	>10	Very suitable	4	Ariyati *et al*. (2007); Avianti *et al*. (2015).
			3.5-10	Suitable	3	
			0.2-<3.5	Marginally suitable	2	
			<0.2	Not suitable	1	
Water Quality						
2	Temperature	°C	28-32	Very suitable	4	BSN (2015); Radiarta *et al*. (2018).
			32-35; 27-28	Suitable	3	
			35-37	Marginally suitable	2	
			<27; >37	Not suitable	1	
3	Salinity	‰	30-34	Very suitable	4	BSN (2015); Radiarta *et al*. (2018).
			28-30	Suitable	3	
			25-28	Marginally suitable	2	
			<25; >34	Not suitable	1	
4	pH		7.5-8.5	Very suitable	4	PI (2004); BSN (2015); Radiarta *et al*. (2018).
			4-7.5; 8.5-10	Suitable	3	
			2-4; 10-11	Marginally suitable	2	
			<2; >11	Not suitable	1	

No.	Parameters	Unit	Parameter's value	Parameter state	Score	Reference
5	DO	mg/l	>6	Very suitable	4	Selamat *et al*. (2015).
			4-6	Appropriate	3	
			2-4	Marginally suitable	2	
			<2	Not suitable	1	
6	TDS	mg/l	<20	Very suitable	4	KLH (2004).
			20-40	Suitable	3	
			40-80	Marginally suitable	2	
			>80	Not suitable	1	
7	Turbidity	NTU	<10	Very suitable	4	Radiarta *et al*. (2018).
			10-20	Suitable	3	
			20-30	Marginally suitable	2	
			>30	Not suitable	1	
8	Nitrate	mg/l	>0.1	Very suitable	4	Ariyati *et al*. (2007); Neksidin *et al*. (2013); Radiarta *et al*. (2018).
			0.01-0.1	Suitable	3	
			0.001-0.01	Marginally suitable	2	
			<0.001	Not suitable	1	
9	Phosphate	mg/l	>0.1	Very suitable	4	SNI (2011); Radiarta *et al*. (2018).
			0.01-0.1	Suitable	3	
			0.001-0.01	Marginally suitable	2	
			<0.001	Not suitable	1	
Physical/geography						
10	Depth	m	3-10	Very suitable	4	Neksidin *et al* (2013); Avianti *et al*. (2015); Radiarta *et al*. (2018).
			10-15	Suitable	3	
			15-20	Marginally suitable	2	
			<3; >20	Not suitable	1	
11	Current velocity	m/s	0.10-0.30	Very suitable	4	Hardjowigeno and Widiatmaka (2007); Ariyati *et al*. (2007); Neksidin *et al*. (2013); Avianti *et al*. (2015), Radiarta *et al*. (2018).
			0.30-0.40	Suitable	3	
			0.40-0.50	Marginally suitable	2	
			<0.10; >0.50	Not suitable	1	
12	Protection		Protected	Very suitable	4	Radiarta *et al*. (2018).
			Quite closed	Suitable	3	
			Temporaly closed	Marginally suitable	2	
			Open area	Not suitable	1	

No.	Parameters	Unit	Parameter's value	Parameter state	Score	Reference
13	Distance to the beach	km	<3	Very suitable	4	Radiarta *et al.* (2018).
			3-4	Suitable	3	
			4-5	Marginally suitable	2	
			>5	Not suitable	1	

Water suitability analysis was carried out to determine the location of the waters suitable for the cultivation of *K. alvarezii* seaweed. Site selection is based on environmental factors as a condition for growing seaweed. The stages of water suitability analysis for *K. alvarezii* seaweed cultivation are as follows:

- Base map preparation
  The preparation of the area suitability map is carried out using a geographic information system (GIS).
- Delineation (determining research boundaries), determining the boundary of the area in question is the furthest distance to the sea that allows for seaweed cultivation activities. The boundary is as far as 0.5-1 000 m from the shoreline with a depth of 3 m, a sampling point is determined from the boundary of the area.
- Compilation of the suitability matrix of seaweed cultivation waters
  Determination of the suitability matrix of seaweed aquaculture based on environmental parameters, including biophysical factors that support seaweed growth. The water suitability matrix for seaweed cultivation is presented in Table 2. The value of the suitability of the area at each data collection location is calculated by the following formula (Avianti *et al.*, 2015):

$$Y = \sum_{i=1}^{n} ai.Xi \tag{1}$$

Where Y is the score from a sampling location, a is the weight coefficient of the parameter, and i is the type of parameter.

- Weighting and grading

Parameter weighting is carried out because each parameter has a different role in supporting seaweed cultivation activities. Parameters that have a large role get greater weight than parameters that do not have an enormous impact. The total of all parameter weights is 100%. The weighting of each limiting factor/variable is determined based on the dominance of that variable over an allotment of the feasibility of aquaculture land (Utojo *et al.*, 2007). Giving value to each criterion is called weighting, while assigning a value to sub-criteria (class) is called a score. The results of scoring and weighting are evaluated to obtain a suitability class that describes the level of suitability of the waters for seaweed cultivation. The suitability class of the limiting cultivation parameters is determined based on the growth response of the cultured organisms (Ariyati *et al.*, 2007). The level of suitability of the waters for seaweed cultivation activities is divided into four categories (Hardjowigeno and Widiatmaka, 2007), namely:

1. Class S1 (Very suitable): in this class, the land does not have a large limit for the management of the given land or only has a barrier that does not significantly affect the activity or production of results.
2. Class S2 (Suitable): in this class, the land has a rather large limiting factor in maintaining the management level that must be applied.
3. Class S3 (Marginally suitable): in this class, the land has a greater barrier to maintaining the management level that must be applied.
4. N (Not suitable): in this class, the land has a permanent barrier that prevents any possibility of sustainable land use in the long term.

- Determination of categories with each criterion following the approach applied by Prahasta (2002). The value of interval the formula determines me for each class of regional suitability level:

$$I = \frac{Y_{mak} - Y_{min}}{k} \quad (2)$$

$$I = ((\Sigma ai. Xn) - (\Sigma ai. Xn) \min) / k \quad (3)$$

Where:
I = Interval of land suitability class
Ai = Score parameter to i,; i = 1,2,3 ... etc
Xn= Weight to n
K = Number of land suitability classes used
Y_{max} and Y_{min} are the maximum suitability and minimum suitability values. This study has 4 location suitability classes so that the value of k= 4.

RESULTS AND DISCUSSION

Water Quality

The results of the analysis of water quality on the coast of Tarakan Island showed that the concentration of chlorophyll-a during the study was very fluctuating in the range of 0.13-4.56 mg/L with an average of 1.83 mg/L (Table 3). The highest chlorophyll-a concentration was found at sampling point A18 in the Juata Laut sub-area and the lowest at sampling point A7. Previously (Avianti *et al*., 2015) obtained high chlorophyll-a values in the Juata Laut sub-area with a range of 6.5 mg/L-6.7 mg/L. Thus, the value of chlorophyll-a is obtained lower. Based on this value, the average value of chlorophyll-a in the coastal waters of Tarakan Island is <4 mg/L. Although the level of chlorophyll-a in this study area is <4 mg/l, this is not very influential because the level of chlorophyll-a in the waters is not a limiting factor in seaweed cultivation, but high levels of chlorophyll-a will increase the growth of seaweed.

The temperature in the coastal waters of Tarakan Island is generally high for seaweed cultivation, with a range of 30.27-32.21^{o}C. The optimal temperature for this activity is 26-32^{o}C (BSN, 2005), so the temperature in the coastal waters of Tarakan Island still meets the requirements for seaweed growth. High water temperatures cause the thallus to be yellowish and pale, even unhealthy (Burdames and Ngangi, 2014). The success of seaweed cultivation is influenced by the determination of a suitable location for seaweed cultivation activities. Errors in determining the location greatly affect the yield and quality of seaweed. The results of measuring water quality in the coastal waters of Tarakan during the study in 6 sub-areas spread over 18 sampling points can be seen in Table 3.

The salinity range of the coastal waters of Tarakan Island shows a fairly large variable value (22.60-29.40). Low salinity values are found in the Juata Laut sub-area, where this area is directly opposite the mouth of the Sesayap river. In general, the salinity range in the coastal waters of Tarakan Island is still supportive of seaweed cultivation activities. The suitable salinity range for seaweed cultivation is 28-34 (BSN, 2005).

The degree of acidity (pH) has an important role in aquatic environmental conditions. Changes in pH affect organisms' chemical and biological processes in the waters. The pH value in the coastal waters of Tarakan Island ranges from 7.76-7.98. This shows that all of the study sub-areas in the coastal waters of Tarakan Island have a very suitable pH for seaweed cultivation. Optimal seaweed growth requires a pH value range of 7.5-8.5 (PI, 2004; BSN, 2015; Radiarta *et al*., 2018). This value also shows that the coastal waters of Tarakan Island are very suitable for marine life (PI, 2004).

The oxygen (DO) solubility in the six research sub-areas ranged from 5.48-8.39 mg/L. The highest oxygen solubility was found in the Juata Laut sub-area at sampling point A16 compared to other sub-areas. This shows that it generally supports the life of marine biota and meets the quality standard >5 mg/L (PI, 2004). Dissolved oxygen is a basic requirement for the life of plants and aquatic animals. Dissolved oxygen levels in the waters are an important factor in seaweed growth (Nur *et al*., 2016). The main source of oxygen in seawater is from the air through diffusion and photosynthesis of phytoplankton and other aquatic plants during the day.

Dissolved oxygen levels in waters vary depending on temperature, salinity, water turbulence, and atmospheric pressure.

Table 3 Results of water quality measurements at the research site

Sub-area sampling	Sampling point	Parameters												
		Biological	Water quality								Physical/geographic			Social
		Chlorophyll-a (mg/mL)	Temperature (°C)	Salinity (‰)	pH	DO (mg/L)	TDS (g/L)	Turbidity (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Depth (m)	Current velocity (m/s)	Protection	Distance to the beach (km)
MB	A1	2.05	30.33	28.90	7.98	5.94	27.25	24.30	0.12	0.15	6.87	0.50	protected	0.55
	A2	1.46	30.33	29.40	7.98	5.48	27.70	19.75	0.08	0.17	11.46	0.50	protected	0.55
	A3	2.56	30.27	29.25	7.79	7.93	27.55	58.25	0.08	0.14	1.88	0.50	protected	0.55
TP	A4	1.45	30.41	29.20	7.90	8.07	27.55	31.70	0.09	0.14	12.62	0.50	protected	0.50
	A5	1.48	30.40	28.65	7.94	7.20	27.10	31.85	0.11	0.13	9.80	0.50	protected	0.50
	A6	1.71	30.55	28.70	7.98	6.16	27.15	34.50	0.07	0.13	20.47	0.50	protected	0.50
TL	A7	0.13	31.10	28.20	7.93	7.41	26.70	38.80	0.03	0.16	3.99	0.48	open area	1.66
	A8	1.91	30.92	28.40	7.97	7.33	26.85	46.95	0.09	0.17	2.10	0.48	open area	1.66
	A9	1.41	30.82	28.00	7.98	7.45	26.55	46.70	0.11	0.16	1.05	0.48	open area	1.66
BL	A10	0.54	31.74	27.20	7.96	7.46	25.85	73.90	0.11	0.17	1.41	0.48	open area	1.52
	A11	3.19	32.21	26.25	7.85	7.29	25.05	108.50	0.12	0.16	0.31	0.48	open area	1.52
	A12	1.08	31.96	25.75	7.88	7.38	24.60	107.25	0.16	0.14	1.85	0.48	open area	1.52
AL	A13	3.24	31.60	24.75	7.78	7.39	23.70	270.00	0.13	0.11	1.27	0.50	open area	1.69
	A14	1.93	31.42	24.40	7.78	7.32	23.45	308.00	0.09	0.14	2.59	0.50	open area	1.69
	A15	2.93	31.76	24.35	7.78	7.42	23.35	355.50	0.14	0.16	2.15	0.50	open area	1.69
JL	A16	0.28	31.23	22.60	7.76	8.39	21.85	78.40	0.11	0.19	10.29	0.48	protected	1.75
	A17	1.04	31.19	22.70	7.76	7.40	21.95	66.90	0.10	0.18	9.02	0.48	protected	1.75
	A18	4.56	31.24	22.75	7.79	6.83	22.00	86.40	0.07	0.16	8.86	0.48	protected	1.75

Notes: MB: Mamburungan, TP: Tanjung Pasir, TL: Tanjung Batu Amal Lama, BL: Binalatung, AL; Andulung, JL: Juwata Laut

Total dissolved solids (TDS) were obtained from 21.85-27.70 mg/L and still meets the seawater quality standard for marine biota according to PI (2004), namely the standard quality value for coral and seagrass life is <20 mg/L. The supply of suspended solids in the coastal waters of Tarakan Island comes from river estuaries spread from the west to the north of Tarakan Island.

The value of turbidity in the study location of the coastal waters of Tarakan Island fluctuates greatly (19.75-355.50 NTU). The highest level of turbidity was found in the Andulung sub-area (sampling points A13, A14, and A15) due to the slightly muddy bottom texture of the waters and the presence of rivers. According to (Avianti *et al*., 2015), shallow water bottoms, solid currents, and muddy sandy bottoms cause particles to rise to the waters' surface. Increasing turbidity reduces the brightness of the waters, while brightness is one of the important factors in seaweed cultivation (Neksidin *et al*., 2013). According to (Radiarta *et al*., 2018), turbidity levels still suitable for seaweed growth range from 10-20 NTU, if turbidity >30 NTU is not suitable for seaweed growth.

Nitrate is one of the important nutrients for seaweed growth. The measured nitrate level was 0.03-0.16 mg/L, and the highest nitrate level was found at the A12 sampling point in the Binalatung sub-area. Previous research (Selamat *et al*., 2015) found nitrate content in the range of 0.07-0.22 mg/L. Good nitrate levels for seaweed growth are 0.1-0.7 mg/L (Avianti *et al*., 2015). Based on this, the coastal waters of Tarakan Island support seaweed growth because the average nitrate content is in the range of 0.10 mg/L.

Phosphate is one of the nutrients needed by seaweed. Phosphate values at the study site were not much different from other research sub-areas, ranging from 0.11-0.19 mg/L. This shows that the coastal waters of Tarakan Island have phosphate levels that are very suitable for seaweed cultivation. According to (Radiarta *et al*., 2016), the most appropriate level for seaweed cultivation is >0.1 mg/L. The highest phosphate value from all research sites was found in the Juata Laut sub-area sampling point A16. The high value of phosphate in the sub-area is thought to have come from the Sesayap river flow, whose estuary is directly opposite the Juata Laut sub-area. It is suspected that phosphate was carried out with the river flow to increase its levels in the area. The phosphate value in the coastal waters of Tarakan Island is by (BSN, 2011), which is >0.1 mg/L. The high content of organic matter can be caused by the large amount of material carried by the river flow in the area, which also comes from household waste (Zahroh *et al*., 2019).

The current velocity in the research sub-area is 0.48-0.50 m/s with an average of 0.49 m/s. Locations for seaweed cultivation should be protected from strong water movements and waves to avoid damage and drift of seaweed. The sub-area which is located on the east coast of Tarakan Island, is generally open water but the measurement results from other parameters are still supported so that cultivation activities in the area continue.

The depth of the waters on the coast is relatively shallow between 2-5 m, except on the south coast, where it has a depth of more than 15 m, such as at the sampling point of the Mambirdan and Tanjung Batu sub-areas. The distance of the outermost sampling point is not too far, ranging from 0.55-1.75 km from the shoreline. This is good in terms of controlling and harvesting seaweed. The appropriate depth is 3-10 m, with the furthest distance from the settlement to the cultivation area being <3 km (Radiarta *et al*., 2018). In general, the quality of the coastal waters of Tarakan Island meets the criteria for suitability for seaweed cultivation, except for water quality parameters (turbidity). In addition, based on physical/geographical parameters (protection), several locations of the research sub-areas are in open areas which causes these areas to have a low weight in determining the suitability class, such as in the Tanjung Batu-Amal Lama, Binalatung, and Andulung sub-areas.

Suitability of Seaweed Cultivation Waters

One of the efforts to achieve sustainable development is to evaluate the carrying capacity of the environment, namely by assessing the suitability between land capability and actual land use and its allocation (Widiatmaka *et al*., 2015). Determining the suitability class of waters for seaweed cultivation in the coastal waters of Tarakan Island is based on comparing the results of field measurements related to biological, water quality, and physical (geographic) parameters against several requirements/criteria as listed in Table 2. The results are then weighted, which is arranged in a matrix to determine the suitability class. Each parameter that is considered the most important in determining land suitability has a suitability value from each zone (Jailani *et al*., 2015). Each score obtained varies according to the level of influence of each parameter on the results of the suitability of waters for seaweed cultivation. The weighting results were analyzed in a matrix to produce several categories of suitability classes (Table 4).

Table 4 Results of the suitability criteria for *K. alvarezii* seaweed culture waters

Class	Criteria	Water suitability value
S1	Very suitable	61.76-76.00
S2	Suitable	47.51-61.75
S3	Marginally suitable	33.26-47.50
N	Not suitable	19.00-33.25

The results of the analysis of the suitability of the waters for the cultivation of *K. alvarezii* seaweed on the coast of Tarakan Island indicate that the level of suitability class produced is from marginal to very suitable (Table 5). Sub-areas with categories that are very suitable for *K. alvarezii* seaweed cultivation are at sampling points A1 (Mamburungan) and A5 (Tanjung Pasir). The sub-areas of Mamburungan and Tanjung Pasir are areas that are very supportive for seaweed cultivation activities based on the results of spatial analysis, because they are included in the category of very suitable suitability (S1) and suitable (S2). However, if viewed from the coastal zone and small island zone plan (RZWP3K) the two sub-areas are Zone C areas (mangrove forest and fishery rehabilitation plans), so it is not recommended for cultivation activities because they are contrary to the marine spatial plan (RTRL) (PI, 2019). In this area, there are mangrove ecosystems and seagrass beds, so that it is a strategic area for the carrying capacity of the environment. In addition, the Tanjung Pasir sub-area is an industrial area as well as a defense and security area (PI, 2018). Thus, although the sub-areas of Mamburungan and Tanjung Pasir are areas that are very suitable for the cultivation of *K. alvarezii* seaweed on Tarakan Island, these areas have limiting factors because they are conservation, industrial, defense and security areas.

Table 5 Suitability class of seaweed cultured waters *K. Alvarezii*

Sub-area sampling	Sampling point	Water suitability value	Water suitability class			
			S1 (61.76-76.00)	S2 (47.51-61.75)	S3 (33.26-47.50)	N (19.00-33.25)
MB	A1	62.00	Very suitable			
	A2	60.00		Suitable		
	A3	54.00		Suitable		
TP	A4	60.00		Suitable		
	A5	62.00	Very suitable			
	A6	54.00		Suitable		
TL	A7	53.00		Suitable		
	A8	48.00		Suitable		
	A9	50.00		Suitable		
BL	A10	49.00		Suitable		
	A11	48.00		Suitable		
	A12	49.00		Suitable		
AL	A13	48.00		Suitable		
	A14	46.00			Marginally suitable	
	A15	48.00		Suitable		
JL	A16	58.00		Suitable		
	A17	58.00		Suitable		
	A18	59.00				

Notes: MB: mamburungan; TP: tanjung pasir; TL: tanjung batu amal lama; BL: binalatung; AL; andulung; JL: juwata laut.

The increasing use of coastal resources can trigger regional economic growth. On the other hand, however, it raises the issue of social complexity that can overlap between sectors, so there is a need for synergy in the use of coastal resources to maintain the carrying capacity of the environment (Husain *et al.*, 2019). There are often conflicts of interest internally between seaweed farming communities and with other space users, even at the government level.

In general, the coastal area of Tarakan Island shows the appropriate class category (S2) for seaweed cultivation. This is due to several biophysical and chemical parameters suitable for seaweed growth, such as nitrate, phosphate, area depth, turbidity, and current velocity. The seaweed growth rate is influenced by many factors such as salinity, water temperature, pH, radiation, water oxygen content, sedimentation rate, nutrition, seed size and genetic material, epiphytes, fish, and disease infection (Ateweberhan *et al.*, 2014).

The coastal waters of Tarakan Island with a marginally appropriate class level as a *K. alvarezii* cultivation area are located in the Andulung sub-area, sampling point A14. Factors that cause this area to be included in the appropriate marginal criteria because water quality factors such as nitrate and chlorophyll-a levels are less supportive for seaweed growth. Nitrate content in waters is one of the main factors that must be considered in seaweed cultivation (Akib *et al.*, 2015). According to (Radiarta and Erlania, 2015), nitrate and phosphate are the most important nutrients for seaweed growth and are limiting factors in seaweed cultivation. Meanwhile, chlorophyll-a is not the main parameter for seaweed growth but is still a consideration as a substance for the formation of seaweed pigments.

The results of the water suitability analysis show that the coastal waters of Tarakan Island with class criteria are very suitable (S1) for seaweed cultivation covering an area of 101.49 ha (0.39 %), which is a zone that is highly recommended for seaweed cultivation (Figure 2 and Table 6). This zone is located in the southern part of Tarakan Island. However, the area with the appropriate class potential (S2) for seaweed cultivation *K. alvarezii* covers the widest area of 29 320.20 ha (86.50%). This zone is mainly located in the eastern part of Tarakan Island (Tanjung Batu-Amal and Binalatung). According to (Selamat *et al*., 2015), the east coast of Tarakan Island has suitable potential for seaweed cultivation activities of around 8 796 ha or 41% that has not been utilized.

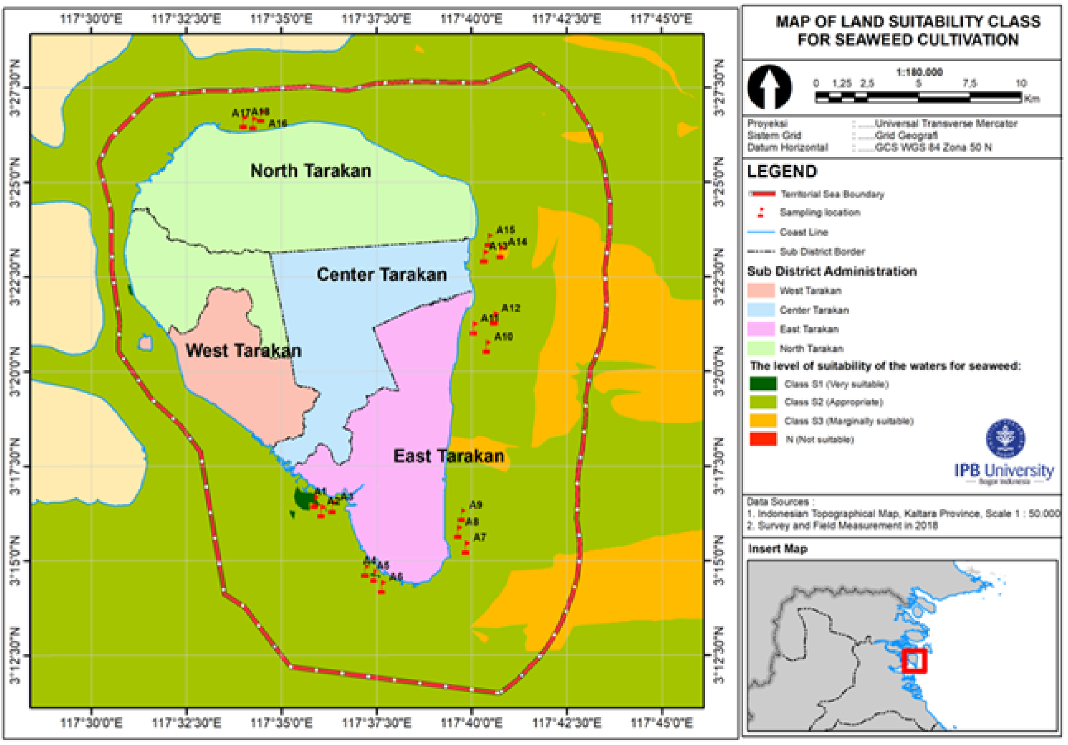

Figure 2 Map of land suitability class for seaweed cultivation

Table 6 The area of the suitability of seaweed aquaculture

Water Suitability Class	Surface Area	
	Large (ha)	Percent (%)
S1 (Very suitable)	101.49	0.30
S2 (Suitable)	29 320.20	86.50
S3 (Marginal suitable)	4 475.04	13.20
Total	33 896.73	100.00

So far, seaweed cultivation activities on Tarakan Island have been concentrated on the east coast. Although most of the east coast of Tarakan Island is an area with suitable class potential (S2), there is a zone with a marginally suitable category (S3) covering an area of 4.47504 ha. This suitable marginal zone can still support seaweed cultivation. Conformity analysis using spatial analysis can identify potential locations (Sahabo and Mohammed, 2016). Based on the research results, the area can be used as a top priority area under the guidance of the Kaltara science techno-park (STP-Kaltara) for the development of special seaweed of the *K. alvarezii* species. This is a challenge for the local government of North Kalimantan Province.

One of the important points in the national medium-term development plan (RPJMN) for 2015-2019 is developing science technoparks (STP) to grow the economy in an area. The development of science and technoparks is planned to spread throughout Indonesia and cover all sectors of economic development. The construction of the North Kalimantan science technopark (STP-Kaltara) began in 2015, and the area is located in the coastal area of Tarakan Island. This STP area is expected to increase seaweed cultivation activities from upstream to downstream, as one of the leading commodities for coastal communities in North Kalimantan besides shrimp, milkfish, and crabs.

An area can be designated as a place for science and technology development activities, business incubation, business support facilities, and production functions due to collaboration between the government, educational institutions, and industry (business) in a technopark (Mustafa *et al*., 2020). The STP Kaltara area in Tarakan City is the closest area to seaweed cultivation activities so it plays a very important role in supporting the development of seaweed aquaculture from upstream to downstream. STP Kaltara collaborates with central and local governments, universities, business people, and the community, and marketing can be done by the media and is expected to support the development of Tarakan seaweed. Indirectly STP-Kaltara has been running with the Pentahelix concept in supporting sustainable development in the region. The existence of STP Kaltara is also a forum for research institutions, including universities, industry, and the government, so that they can support innovation in the fields of science and technology to produce products from superior regional commodities such as seaweed which is one source of regional economic potential. The Penta helix can be used as an initial framework to grow new industries, innovations, and knowledge-based startups (Sudiana *et al*., 2020b). It was born from a research result and synergized with product innovation to grow the economy (Sudiana *et al*., 2020a).

Through STP Kaltara, a business incubator will be created to support entrepreneurs in preparing findings in the form of products that can be sold as raw materials, especially in the food industry. According to (Ferrara, 2020), algae is very suitable for consumption by everyone because it contains active biological compounds that can be applied to the food industry and the pharmaceutical industry as a source of food ingredients, hydrocolloids, supplements, and biotechnology products. Algae can also be consumed as soups and vegetables because it has low calories and various nutrients. The form of STP Kaltara's support to develop regional superior commodity-based cultivation areas can be implemented through 1) various research programs and research results through research institutions at the University of Borneo Tarakan as well as from other research institutions in the Kaltara region, 2) downstream environmentally friendly technological innovations in activities upstream to downstream, 3) building an innovation cluster and startup innovation based on seaweed raw materials, developing the seaweed industry, establishing partnerships, quality assurance and implementing a coastal community cultivation business in the form of an integrated area and according to the RZWP3K. Everything can be studied at STP Kaltara as a form of support to realize Kaltara as one of the centers of seaweed production in Indonesia.

CONCLUSION

The results of the water suitability analysis concluded that the coast of Tarakan island has a potential quality for seaweed cultivation activities and based on its class is very suitable 101.49 ha, suitable 29 320.20 ha, and suitable marginal 4475.04 ha with a total area of 33 896.73 ha.

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