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The feasibility of seaweed culture in the northern coast of Simeulue Island, Aceh Province, Indonesia

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Abstract. The aim of this study was to select suitable locations for seaweed culture in the northern coast of Simeulue Island, Indonesia. Sea surface temperature, water clarity, water depth, dissolved oxygen, water salinity and pH were examined in the 33 locations to identify the spatial distribution of the characteristic parameters. These parameters were processed and mapped using ArcGIS 10.2 and SeaDAS 7.1. The analysis was divided into two stages: first, all parameters were interpolated with the Kriging method to obtain the characteristics of the water; secondly, the matching method was performed to overlay all of the parameters to locate the water locations suitable for seaweed cultivation. The study covered approximately 12,564.19 hectares of the northern coast of Simeulue Island’s waters. The result showed that a total of 1,877.78 ha (14.95%) are suitable and 10,686.41 ha (85.05%) are not suitable for seaweed culture.
Key Words: mariculture, ArcGIS, bay, small island, SeaDAS, kriging, matching.

Introduction. Aquaculture has been growing significantly in recent years and nowadays nearly half of all seafood comes from aquaculture production (Gormaz et al 2014). One of the most important commodities of aquaculture products is seaweed. According to Graham et al (2007), seaweed is a primary producer in aquatic ecosystems and an important habitat for aquatic invertebrates, fish, mammals and birds. In addition, seaweed is crucial in reducing global warming and climate change because this algae has the ability to absorb carbon dioxide and organic matters and to produce oxygen (Israel et al 2010; Fei 2004). Seaweed absorbs nutrients from the water and performs photosynthesis. For this process, seaweed needs suitable physical and chemical water quality factors related to current, temperature, salinity, nitrate level, and phosphate level as well as exposure to sunlight for growth (Trono 1993). Therefore, study of suitable locations for seaweed cultivation is very crucial and necessary.

Simeulue is one of the smallest islands in the Indian Ocean with an area of 1.838,09 km^2. It is situated approximately 150 km from the island of Sumatra on the west coast of Aceh Province, Indonesia (Badan Pusat Statistik of Simeulue District 2014). Simeulue is strong in marine and coastal resources including seaweed, lobster and grouper. It is supported by the waters’ bathymetry and the distribution of small islands and protected bays such as Sinabang, Dalam, Sibigo, Lewak and Alafan (Dinas Kelautan dan Perikanan Aceh 2013). Therefore, seaweed culture businesses are very prosperous in this region, making them a viable option for improving the welfare of the coastal community in Simeulue Island. However, the island’s potency has not been well utilized or managed due to some constraints including lack of information regarding suitable locations for seaweed culture as well as marketing difficulties. Generally, the wider resource management process, such as spatial zonation and economic development planning should be incorporated in Aceh Province (Garces et al 2010).

Geographic information system (GIS) technology is a promising tool for analyzing the suitability of water for seaweed farming practices. Nath et al (2000) stated that GIS is increasingly becoming an integral component of natural resource management activities worldwide. GIS, remote sensing and mapping have an important role in the development and management of marine aquaculture (Kapetsky & Aguilar-Manjarrez 2007). There are two important reasons why GIS has a significant role in advanced fisheries management. Firstly, a lot of spatial data can be used and displayed together. For example, data on fish habitats may be almost the same as the data required for analysis of the ideal location for cultivation. Secondly, GIS can be used to unify perspectives among different disciplines when making decisions.

Suitability analysis of waters is important for strategic planning for predicting the benefits and constraints that may occur as a result of environmental changes. Therefore, analysis of water suitability is a key factor for success in farming activities and environmental sustainability (Pérez et al 2003). Currently, other information on suitable locations for seaweed farming in Simeulue Island is not available. Thus, the data from this study is crucial in providing comprehensive information on the potential of coastal resources for local farmers and investors. The objective of the present study was therefore to record the coastal area characteristics important for seaweed farming in the north coast of Simeulue Island.

Material and Method

Sampling sites. A total of 33 sampling locations were determined purposefully to meet the minimum requirements for spatial analysis (Table 1). The sampling sites were spread across the northern coast of Simeulue Island (Figure 1) because this region has good geographical conditions including bays with calm waters and a series of small islands.

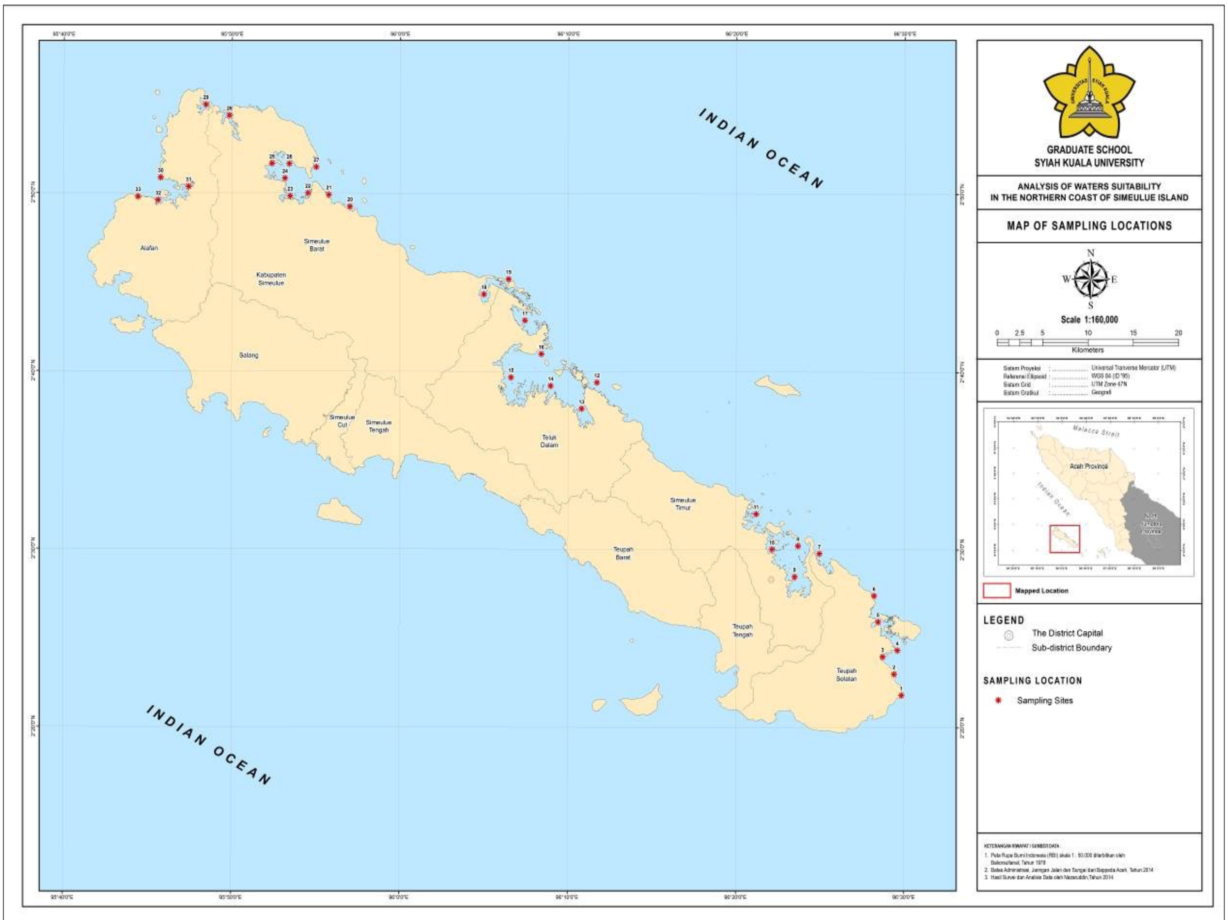

Figure 1. Map of Simeulue Island showing sampling sites (in red circles).

Table 1

The GPS coordinates of sampling sites around the northern coast of Simeulue Island

Sampling sites no.	Coordinate		Sampling sites no.	Coordinate	
	Latitude	Longitude		Latitude	Longitude
1	2°21' 49.479" N	96°29' 51.415" E	18	2°44' 20.878" N	96°5' 0.198" E
2	2°23' 1.008" N	96°29' 24.927" E	19	2°45' 11.851" N	96°6' 27.462" E
3	2°23' 59.283" N	96°28' 44.433" E	20	2°49' 15.899" N	95°57' 1.213" E
4	2°24' 21.032" N	96°29' 37.243" E	21	2°49' 55.905" N	95°55' 45.719" E
5	2°25' 57.050" N	96°28' 27.871" E	22	2°50' 0.570" N	95°54' 31.117" E
6	2°27' 24.525" N	96°28' 13.536" E	23	2°49' 50.821" N	95°53' 27.687" E
7	2°29' 46.705" N	96°24' 58.291" E	24	2°50' 50.841" N	95°53' 9.393" E
8	2°30' 12.470" N	96°23' 42.032" E	25	2°51' 40.063" N	95°52' 23.095" E
9	2°28' 28.891" N	96°23' 29.800" E	26	2°51' 39.588" N	95°53' 24.877" E
10	2°30' 1.055" N	96°22' 8.764" E	27	2°51' 28.308" N	95°55' 0.906" E
11	2°32' 0.233" N	96°21' 12.316" E	28	2°54' 21.991" N	95°49' 51.091" E
12	2°39' 24.154" N	96°11' 43.596" E	29	2°54' 58.671" N	95°48' 26.668" E
13	2°37' 55.551" N	96°10' 48.912" E	30	2°50' 52.328" N	95°45' 46.042" E
14	2°39' 12.702" N	96°8' 58.309" E	31	2°50' 21.883" N	95°47' 25.877" E
15	2°39' 40.929" N	96°6' 36.716" E	32	2°49' 36.498" N	95°45' 36.946" E
16	2°40' 59.843" N	96°8' 25.195" E	33	2°49' 48.115" N	95°44' 25.316" E
17	2°42' 52.581" N	96°7' 26.169" E			

Sampling procedure. Water clarity, sea surface temperature, water depth, dissolved oxygen, salinity and pH were obtained by measurements taken at the locations (*in situ*). The data on the depth of the sea water was combined with a bathymetry map from DISHIDROS-Indonesian Navy and the sea surface temperature data was generated from Aqua MODIS satellite data.

Conversion and interpolation of data. Field measurement data in tabular form was converted into spatial data and then into shape file format with ArcGIS software. The Kriging method was used to interpolate the data. Kriging is a stochastic estimation method; it is a similar to Inverse Distance Weighted (IDW) which uses a linear combination of weight and samples to estimate the value of the data.

Overlaying and reclassification. The matching method was utilized to overlay the data. The matching method is a model of matching characteristics and qualities of water with aquatic abilities grade criteria. Results are obtained from the level of conformity waters suitability with the parameters are shown in Table 2. Reclassification is a function of spatial analysis used to classify the data to create new spatial data based on suitability criteria or attributes. The level of conformity is divided into two classes: S (suitable) and N (not suitable). A summary of the procedure is presented in Figure 2.

Suitability criteria. The classification of the suitability of the waters for seaweed cultivation was based on the work of Foscarini & Prakash (1990) and Cornelia et al (2005), as summarized in Table 2.

Table 2

Suitability criteria of seaweed cultivation

Parameter	Suitability criteria	
	Good	Bad
Depth (m)*	1	< 1; > 1
Temperature (°C)*	25 - 30	< 25; > 30
Salinity (ppt)*	≥ 28	< 28
Water clarity (%)**	> 75	< 75
pH**	7.51-8.3	< 7.5; > 8.3
DO (ppm)**	> 6	< 6

Source: * Foscarini & Prakash (1990), ** Cornelia et al (2005).

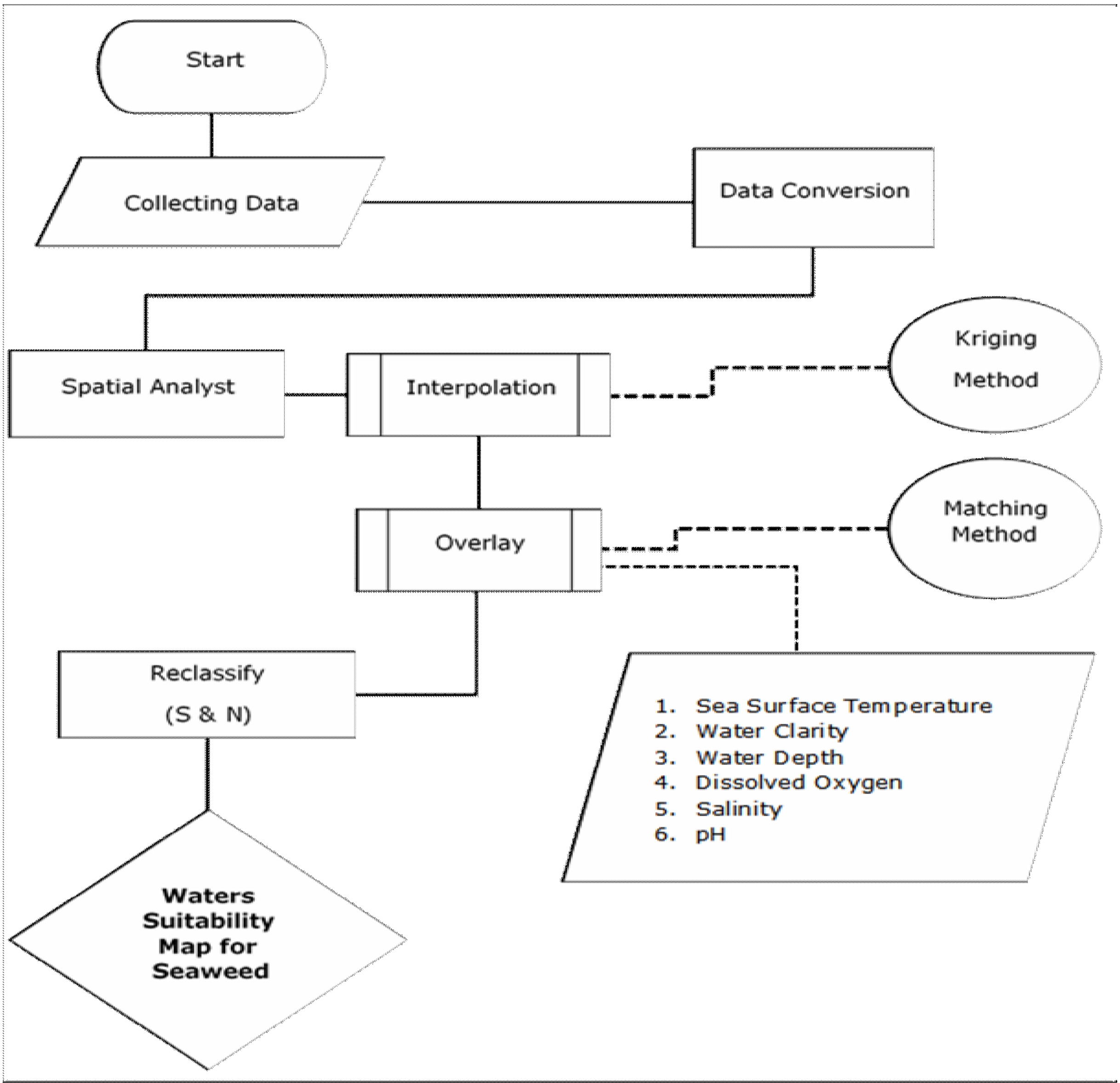

Figure 2. The stages of research feasibility for seaweed culture.

Results and Discussion. The physical parameters observed were as follows: (1) sea surface temperature ranged from 29.1 to 35.0°C with an average of 31.0°C; (2) water depth ranged from 1 to 25 meters with the average of 7.1 meters; (3) water clarity ranged from 48% to 100% with an average of 83.1%. The measurements of chemical water quality parameters were: (1) dissolved oxygen ranging from 3.08 to 7.58 (ppm) with an average of 5.1 ppm; (2) salinity ranging from 25 ppt to 40 ppt with an average of 32.3 ppt; and (3) pH ranging from 7 to 9 with an average of 8.1. These observed measurements demonstrate the variations of water characteristics among the different locations.

Variation in the observed parameters may have occurred because of the physical conditions of the coastal area of Simeulue Island. As shown, the sea surface temperatures of the different locations varied. This is strongly influenced by the time and duration of sun exposure in the area, mixing with freshwater from the land and the currents. For example, the depth of the water can be influenced by the relief of the seabed; the relief can be formed by sea erosion and sedimentation over a long period of time (Niedoroda 2005). The clarity of the water is influenced by dissolved particles, silt, organic and inorganic materials and other microscopic organisms (Wilson 2013). The concentration of dissolved oxygen is strongly influenced by diffusion and aeration, photosynthesis, respiration and decomposition. Dissolved oxygen levels strongly correlate with temperature, salinity and pressure changes (Kemker 2013).

Salinity is greatly influenced by rainfall and evaporating (Pilson 2013). Concentration of pH in a body of water is influenced by many factors, both natural factors and those influenced by human intervention. pH changes generally occur naturally as a result of interaction with the surrounding environment such as rocks containing carbonate material. In addition, pH can also fluctuate due to rainfall (especially due to acid rain), waste (domestic or mining) and the concentration of CO_2 in the water (Kemker 2013). Each parameter that affects suitability was measured once in each sample location. In general, the values of the measurement results of each location were outside the suitability criteria as shown in Table 2.

Table 3 shows the values of water clarity, dissolved oxygen, salinity, sea surface temperature, pH and water depth. These parameters are very important hints for the study of seaweed culture. The requirement for a good water depth should be at least one meter at the lowest spring tide. Cornelia et al (2005) proposed other depth classifications for suitable areas for seaweed cultivation. According to their study there are four classifications for depth, i.e. S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable) and N (not suitable). However, in this report it was not stated when the depths were measured. Moreover, according to Foscarini & Prakash (1990) the depth should be measured at the lowest spring tide. Hence, we used their classifications in this study.

Table 3

The value of each field parameter

Sampling sites	*Parameter*					
	Water clarity (%)	*Dissolved oxygen (ppm)*	*Salinity (ppt)*	*Sea surface temperature (°C)*	*pH*	*Water depth (m)*
1	100	3.22	31	33	8	8
2	100	3.48	25	32.7	8	5
3	100	3.08	31	31	8	6
4	100	3.12	33	32.4	8	2
5	100	4.44	34	33.5	8	7
6	100	4.7	32	31	8	4
7	100	3.7	32	31	8	4
8	88	4.09	34.5	31.5	8	8
9	58	5.32	32	31.8	8	12
10	83	5.6	33	32.1	8	12
11	100	6.82	33	33	8	2
12	53	6.05	32	30.8	9	15
13	80	6.65	33	30	8	1
14	95	7.58	33	29.7	8	1
15	75	7.03	32	30	8	1.5
16	100	3.78	34	31.2	8	2
17	60	3.66	30	31.3	8	5
18	100	3.26	30	31.1	7	1.5
19	67	4.53	39	29.5	8	15
20	83	4.3	32.5	33	8	18
21	60	4.67	33	29.1	8	20
22	100	7.5	33	29.4	7.5	1.5
23	80	6.8	29	30	8.5	1
24	80	7.4	30	29	8	1
25	85	7.05	29	30.3	8	1
26	75	4.13	28	29.5	8	1.5
27	48	4.67	40	29.1	8	25
28	58	6.0	37	30.7	9	12
29	85	6.0	33	30	8	1
30	100	4.5	32	34.5	8.5	10
31	60	4.0	33	35	8.5	10
32	100	5.5	32	32	8.5	10
33	70	4.1	32	35	8.5	10

Simeulue Island is situated in the Indian Ocean, where the tides are very low and the currents are mainly caused by monsoons (Rizal et al 2012). However, in the area near the Malacca Strait, the Aceh waters are greatly influenced by the tides (Rizal & Sündermann 1994; Rizal 2000, 2002; Rizal et al 2013) and also by the monsoons (Rizal et al 2010, 2012; Haoliang et al 2014).

Based on analysis of suitability, a total of 1,877.78 ha (14.95%) are suitable and about 10,686.41 ha (85.05%) are not suitable for seaweed cultivation. Of the 33 locations, three locations are suitable for seaweed cultivation. Among the five bays examined in this study (Sinabang Bay, Dalam Bay, Sibigo Bay, Lewak Bay and Alafan Bay), only a small part of Dalam, Sibigo and Lewak Bays were categorized as suitable locations for seaweed cultivation. The total area of Dalam Bay is 5,438 ha but only 940.2 ha (17.28%) is categorized as suitable for seaweed cultivation. Sibigo Bay counts for 1,527 ha of the total area but only 811.61 ha (53.15%) is categorized as very suitable, followed by Lewak Bay which occupies an area of 675 ha with only 125.97 ha (18.66%) considered very suitable for seaweed cultivation (Table 3). The suitability of areas were presented in Figure 3.

Among the recorded parameters, two parameters appeared to be major limiting factors for seaweed cultivation, namely the depth and DO. Only some locations in the bays have the depth required for seaweed, as well as the distribution of DO that has a value below the required range (Table 2).

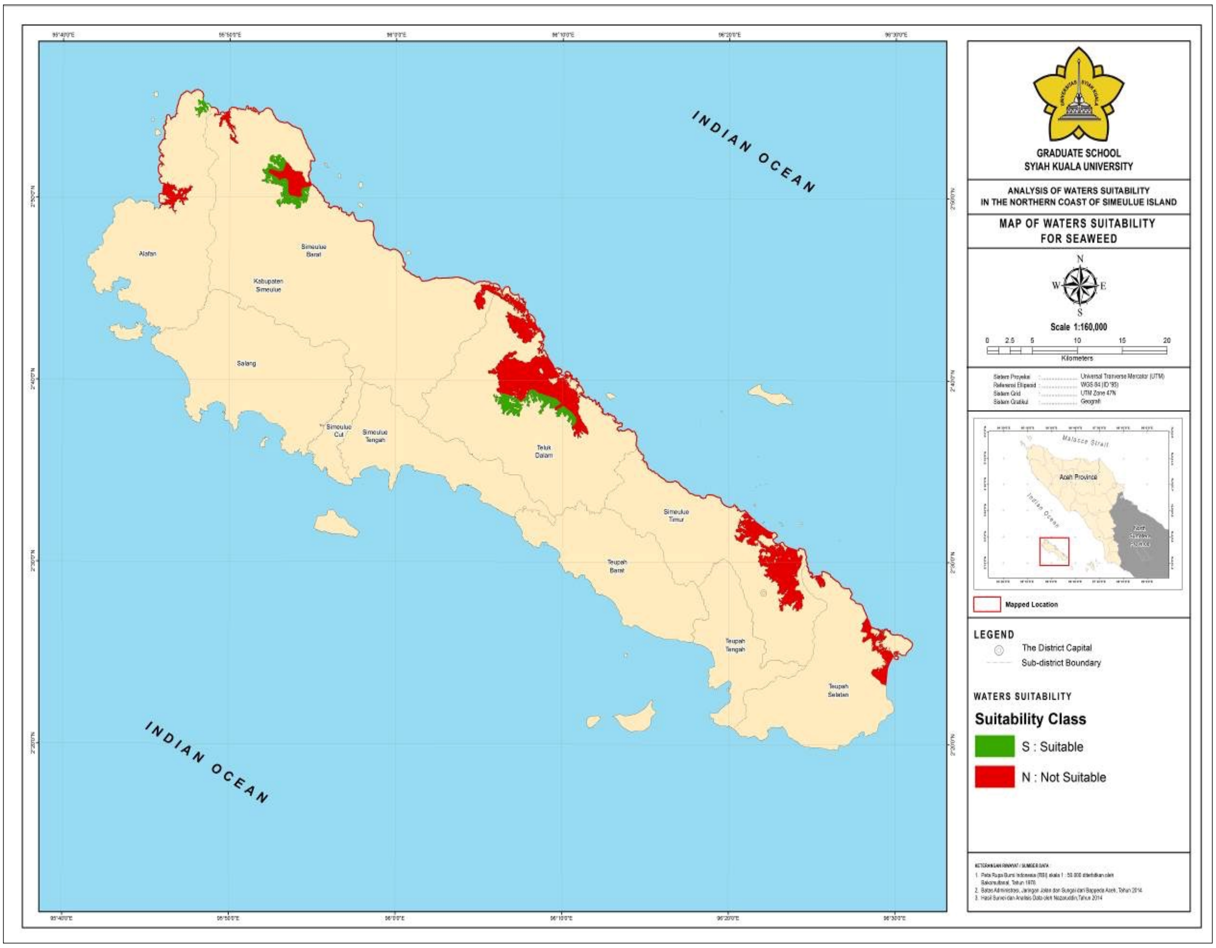

Figure 3. Map of Simeulue Island showing the feasible locations for seaweed cultivation.

Conclusions. The study shows that approximately 1,877.78 ha or 14.95% of the total area observed of northern coast of Simeulue Island is suitable for seaweed cultivation. The rest of the observed area is not suitable for seaweed cultivation. In the area of marine aquaculture development should consider the carrying capacity of the area where the carrying capacity of the area for cultivation depends on the condition of natural resources, farming systems, commodity cultivation and cultivation technology level used. Since the Simeulue island is surrounded by the Indian Ocean, it is necessary also conducted a study on the suitability of the waters between the east west monsoon season so the risk factor is more easily accounted for.

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