Suitability analysis of land based seaweed cultivation on seasons in Tanjung Selayar, Kotabaru Regency, South Kalimantan

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Abstract. Seaweed cultivation presents promising prospects in the fisheries sector. Apart from having high market value in both local and international markets, it offers diverse uses for processed products such as food, pharmaceuticals, cosmetics, health food, and bioactive substances, thus opening opportunities for drug discovery. Kotabaru Regency is one of the districts in South Kalimantan Province with the potential for seaweed cultivation activities. Although seaweed production increased annually over a period of 10 years (1995–2005), it fell short of meeting market demands. Since 2005, seaweed production in this area has declined yearly, and since 2010, there has been no seaweed production in Teluk Tamiang Village, Pulau Laut Subdistrict, Tanjung Selayar. This research aimed to determine the zoning/land suitability map for seaweed cultivation. In this study, data collection in the field was conducted during the west season, transition season, and southeast season. The results of the analysis conducted for seaweed cultivation locations in Tanjung Selayar waters demonstrate spatial variations in suitability, including: suitable, moderately suitable, and unsuitable areas for seaweed cultivation. This discrepancy is due to seasonal differences influencing oceanographic factors and land suitability parameters for seaweed cultivation.
Key Words: fisheries sector, land suitability map, processed products, seasonal variations.

Introduction. The global population is expanding rapidly, according to the World Resource Institute, prompting every nation to identify alternative food and production sources to meet the growing demand (Hunter et al 2017). In this context, aquaculture is a viable option to address food requirements, experiencing rapid development in the late 20th century (Subasinghe et al 2009; Merino et al 2012; Krag et al 2015). In the concept of blue economy framework, seaweed cultivation has been recognized as a significant intervention across several countries, including China, Indonesia, Korea, the Philippines, Japan, and Malaysia (FAO 2018).

Based on available data, seaweed productivity in Indonesia is estimated at 1.14 tons per km, the lowest figure compared to other countries, which achieve up to 4.55 tons per km (Valderrama et al 2013). The introduction of seaweed cultivation in many developing countries along coastal areas as an alternative livelihood option, specifically in areas lacking fisheries resources, has empowered women and contributed to poverty reduction (Mantri et al 2017). Specifically, the cultivation of *Eucheuma* sp. seaweed has improved the socio-economic status of coastal communities where alternative livelihood options are limited, such as gardening. Cultivation in a particular area is influenced by significant environmental changes over time (Harley et al 2012; Campbell et al 2019).

Biological, physical, and chemical factors of water are key determinants of successful cultivation (Akib et al 2015). According to Maryunus et al (2019), several factors must be considered in seaweed cultivation production, with one of the most critical being the selection of the area or land to be used. Heriansah & Fadly (2015) outlined several requirements for determining the area of seaweed cultivation activities, including considerations of water quality, natural disturbances, predators, shipping lanes, and security. This area determination also considers factors that can influence the growth and spread, such as the movement or dynamics of seawater and aquatic substrates (Ain & Widyorini 2014).

Seaweed is often found in shallow water areas (intertidal and sublittoral) with sandy water conditions, minimal mud, or a combination of both (Wong & Cheung, 2000). The cultivation presents promising prospects in the fisheries sector, offering high market value in both local and international markets. Moreover, it offers diverse uses for processed products such as food, pharmaceuticals, cosmetics, health food, and bioactive substances, opening opportunities for drug discovery.

Kotabaru is a regency in South Kalimantan Province with potential for seaweed cultivation activities. This regency has a coastline length of 923.53 km^2 and a sea area of 384900 ha (DKP Kotabaru 2014). Based on data from Kotabaru Regency Maritime and Fisheries Service, seaweed production was 398.01 tons in 2001, 465.10 tons in 2002, and 2403.7 tons in 2003. Despite the annual increase in production during these periods, market demands were not met. Starting from 2005, seaweed production in this area has declined every year, with no significant production in Teluk Tamiang Village, Pulau Laut Subdistrict, Tanjung Selayar since 2010.

The development of seaweed cultivation areas can be influenced by the biophysical environmental conditions of the waters and climatic conditions. Several feasibility studies on seaweed land have been conducted, both through manual assessments and spatial analyses (Radiarta et al 2012). However, these studies do not guarantee the success of cultivation in an area because oceanographic factors, including highly dynamic water quality parameters, and the influence of seasons, which have recently been difficult to predict (seasonal anomalies), also play significant roles. The presence and distribution of seaweed are strongly affected by season, making seasonal patterns the most critical challenge faced by the industry in south Asia (Zamroni & Yamao 2011; Ginigaddara et al 2018; Waters et al 2019). Therefore, season is considered a crucial factor in the sustainability of a seaweed cultivation business.

South Kalimantan Province comprises 13 regencies and municipalities, among which four, Barito Kuala, Tanah Laut, Tanah Bumbu, and Kotabaru directly border the coast of the Java Sea. The most abundant and potentially developed marine resources are in Kotabaru Regency, contributing significantly to the results and production of marine fisheries in the area (DKP Kotabaru 2016). This regency consists of several small islands and directly borders Makasar Strait and the Java Sea. From 1995 to 2005, seaweed producers in South Kalimantan Province primarily originated from Kotabaru Regency. The area for seaweed cultivation is located in Teluk Tamiang Village, Pulau Laut Subdistrict, Tanjung Selayar. Numerous coastal communities in the village depend on seaweed cultivation for livelihoods, with various groups of farmers and fishers engaged in processing, particularly producing dodol and syrup.

Since 2010, seaweed cultivation in the area has ceased to be productive due to environmental degradation of the supporting resources, leading to suboptimal results (DKP Kotabaru 2016). Teluk Tamiang Village, Tanjung Selayar, borders the Java Sea to the south and Makasar Strait to the east, experiencing oceanographic conditions influenced by three seasons. These include east (May–September), west (December–April), and transition season (October–November). Furthermore, rapid development of oil palm plantations as well as ongoing coal and iron ore mining activities in Kotabaru Regency, particularly for transportation through sea waters, are observed. There is currently no study examining suitability of seaweed cultivation land in the area. It is important to examine oceanographic factors, coastal area conditions, and the influence of seasonal differences to determine suitability of land for seaweed cultivation, aiming to achieve optimal production results. Rejuvenating Tamiang Bay Village as a center for seaweed cultivation will significantly improve the economy of the people along Tanjung Selayar coast.

The primary problems and issues related to the development of businesses in the waters include: (1) the absence of a suitable and appropriate area for seaweed cultivation; (2) lack of data regarding biological, physical, and chemical condition parameters in the waters for assessing suitability of land; and (3), the absence of studies on the influence of seasonal differences on seaweed production levels in the area. To address these challenges, a comprehensive study covering suitability of land based on biological, physical, and chemical parameters of waters, as well as the influence of seasonal differences, is necessary to identify suitable areas for cultivation and achieve optimal harvests. The aim of this study was to assess the zoning suitability for seaweed cultivation in the waters of Teluk Tamiang Village, Tanjung Selayar District, Kotabaru Regency, considering seasonal variations.

Material and Method

Description of the research sites. This study was conducted in Teluk Tamiang Village, Tanjung Selayar District, Kotabaru Regency. The timeline spanned from April to November 2019, comprising literature review, preliminary survey, field data collection, seaweed cultivation, laboratory data analysis, data processing, and final report preparation. The water area under study was approximately 1670.2 ha and data collection was conducted using a survey method designed based on geographic information systems (GIS). The determination of sampling points was carried out randomly according to the requirements and the distribution of sampling points was considered representative of the entire study area (Sugiyono 2012). Primary data collection entailed direct measurements in the field of water environmental quality variables, in each season with three repetitions, but also the area protection, area, water depth (using a Garmin 178C Echosounder-GPS). Temperature, salinity, pH, and dissolved oxygen were determined using YSI 650 DO meter MDS, as well as current speed with a current kite. Chemical variables, including salinity, were observed using a refractometer. Analysis of seawater samples was conducted at PPLH Laboratory, Lambung Mangkurat University, Banjarmasin. Water sampling carried out using a single pre-prepared sample container at each measurement station. The analysis of seawater samples to determine nitrate, total suspended solids (TSS), and phosphate content was conducted at the PPLH Laboratory, Lambung Mangkurat University, Banjarmasin.

Data collection method. This research used the primary data as the main dataset and secondary data as supporting information. The tools used in the field are presented in Table 1.

Table 1

Tools used in the field

No	*Tools*	*Utility*
1	Motorboat	Means of transportation
2	Global Positioning System (GPS)	Determines the position of the station
3	Flow Kite	Measuring current
4	Stopwatch	Measuring time
5	Plumb	Measuring depth
6	Secchi disk	Measuring brightness
7	Scale pole	Measuring wave height variations
8	Hand refractometer	Measuring salinity
9	pH meter	Measuring pH
10	DO meter	Measuring dissolved oxygen
11	Thermometer	Measuring sea water temperature
12	Grab sampler	Analyzing the basic substrate
13	Sample container	Collecting samples
14	Coolbox	Preserving samples
15	Compass	Measuring wind direction
16	Stationery	Writing field data

The tools used in the laboratory include the DREL 2800 Spectrophotometer, test tubes, tube racks, funnels, flasks, pipettes, measuring flasks, and rubber bulp. For data processing and preparation of the final report, a personal computer (PC) with MS software was used. The materials used in this study were: brucine indicator, concentrated sulfuric acid, and sodium nitrate for nitrate analysis; ammonium molybdate, boric acid 1%, sulfuric acid 2.5M, ascorbic acid 1%, Whatman filter paper no. 42 for phosphate analysis. Other materials such as seedlings of *Eucheuma cottoni*, 70 kg, come from Sidoarjo, East Java Province, and 70 kg of *Eucheuma spinosum* come from Takalar, South Sulawesi Province. Other materials such as millipore filter (Watman filter paper pore size 0.45 μm, tissues, Aquades and others were used.

Data collection in the sampling points in the field were performed during the west, transition, and east seasons. Subsequently, the data were analyzed to determine the area or suitability map of land categorized as suitable, quite suitable, and not suitable for cultivation during the three different seasons.

Data analysis method. This stage represents the initial phase of the study, covering literature review and field observation activities. The preparation stage was conducted over a period of 5 days in March 2019. The determination of stations was carried out randomly to represent all study areas, comprising a total of 30 data collection stations. Data collection was carried out by measuring biological, physical, and chemical oceanographic parameters. At each station, the following measurements were conducted: wave height, current speed (using a current kite and stopwatch), depth, water temperature, salinity, dissolved oxygen (DO), tide levels, pH of seawater, and characteristics of the bottom water substrate. Additionally, chemical parameters such as nitrate, total suspended solids (TSS), and phosphate were measured in the laboratory using water samples collected in the field over one week. Water samples for nitrate, TSS, and phosphate (PO_4) were collected using containers provided at each measurement station. Samples were collected by submerging the containers into the water and tightly sealing. Analysis of seawater samples to determine the levels of nitrate, TSS, and phosphate was conducted at the PPLH Laboratory, Lambung Mangkurat University, Banjarmasin. The references for criteria used to determine suitability of seaweed cultivation waters based on environmental conditions are Prayogi (2017) modified by Amir et al (2018). After determining the criteria for physicochemical oceanographic parameters affecting suitability of seaweed cultivation waters based on the water suitability matrix (Table 2) for seaweed cultivation, including parameters such as wave height, current speed, TSS, salinity, temperature, substrate type, nitrate, phosphate, pH, and depth, a quantitative assessment of suitability levels was conducted using scoring and weighting methods. Parameters with a big impact of seaweed habitat were assigned higher weights, while those with less influence or minimal impact were assigned lower weights, as outlined by Jailani et al (2015).

To determine the suitability of water for seaweed cultivation based on environmental conditions, criteria are needed as a reference for assessing water feasibility in Table 2.

Table 2

Water suitability matrix for seaweed cultivation of *Eucheuma* species

No	*Criteria*	*Land suitability level*		
		Suitable	*Moderately suitable*	*Not suitable*
1	Wave height (m)	0.2-0.3	0.1-0.19 or 0.31-0.40	<0.1 or >0.41
2	Current speed (m s^{-1})	0.2-0.3	0.1-0.19 or 0.31-0.41	<0.1 or >0.41
3	TSS (mg L^{-1})	< 25	25-50	>50
4	Salinity (‰)	28-32	25-27 or 33-35	<25 or >35
5	Temperature (^oC)	28-30	26-27 or 30-33	<26 or >33
6	Waterbed substrate	Sand–coral	Sandy mud	Mud
7	Nitrate (ppm)	0.9-3.5	<0.1 or >4.5	<0.1 or >0.45
8	Phosphate (ppm)	0.051-1	0.21 – 0.05	<0.21 or >1
9	pH	7-8.5	6.5-6.9 or 8.5-9.5	<6.5 or >8.5
10	Depth (m)	0.6-2.1	0.3-0.5 or 2.2-10	<0.3 or >10

Note: Prayogi (2017) modified by Amir (2018).

After determining the criteria for the physical-chemical oceanographic parameters for water suitability in seaweed cultivation, a quantitative assessment of water feasibility was conducted using scoring and weighting methods. A higher weight was given to parameters that had a dominant influence on determining the area, while parameters that were less dominant or had little impact on cultivation were given a smaller weight. The weighting can be seen in Table 3.

Table 3

Weight matrix and suitability scores for *Eucheuma* seaweed cultivation

No	*Parameter*	*Criteria*		*Value limit*	*Weight*	*Score value*
1	Wave height (m)	0.2-0.3	3	Suitable	0.3	0.9
		0.1-0.19 or 0.3-0.4	2	Moderately suitable		0.6
		<0.1 or >0.41	1	Not suitable		0.3
2	Current speed (m s^{-1})	0.2-0.3	3	Suitable	0.15	0.45
		0.1-0.19 or 0.31-0.41	2	Moderately suitable		0.3
		<0.1 or >0.41	1	Not suitable		0.15
3	TSS (mg L^{-1})	<25	3	Suitable	0.15	0.45
		25-50	2	Moderately suitable		0.3
		>50	1	Not suitable		0.15
4	Salinity (‰)	28-32	3	Suitable	0.15	0.45
		25-27 or 33-35	2	Moderately suitable		0.3
		28–30	3	Suitable		0.45
5	Temperature (°C)	28-30	3	Suitable	0.15	0.45
		26-27 or 30-33	2	Moderately suitable		0.3
		<26 or >33				0.15
6	Waterbed substrate	Sand-coral	3	Suitable	0.1	0.3
		Sandy mud	2	Moderately suitable		0.2
		Mud	1	Not suitable		0.1
7	Nitrate (ppm)	0.9-3.5	3	Suitable	0.025	0.075
		<0.1-0.8 or >3.6-4.4	2	Moderately suitable		0.05
		<0.1 or >0.45	1	Not suitable		0.25
8	Phosphate (ppm)	0.051-1	3	Suitable	0.025	0.075
		0.021-0.05	2	Moderately suitable		0.05
		<0.021 or >1	1	Not suitable		0.25
9	pH	7-8.5	3	Suitable	0.025	0.075
		6.5-6.9 or 8.5-9.5	2	Moderately suitable		0.05
		<6.5 or >8.5	1	Not suitable		0.25
10	Depth (m)	0.6-2.1	3	Suitable	0.025	0.075
		0.3-0.5 or 2.2-10	2	Moderately suitable		0.05
		<0.3 or >10	1	Not suitable		0.25

Note: TSS – total suspended solids; source: Prayogi (2017) modified by Amir (2018).

Based on the score values of each parameter, an assessment is conducted to determine whether the location is suitable for seaweed (Table 4) cultivation land using the formulation proposed by Utojo et al (2004) as follows:

Evaluation score values = (Total score of each station/3) x 100

Table 4

Determination of feasibility category class intervals

No	*Score range (%)*	*Evaluation results*
1	85–100	Suitable - the station has no significant limitations
2	60–84	Moderately suitable - the station has limitations that can be tolerated
3	<60	Not suitable - the station has severe limitations

Note: source: Source: Jailani et al (2015).

The next step is to conduct spatial analysis or create thematic maps, which involves several stages, including the preparation of spatial databases and overlay techniques.

Results and Discussion

Physical and chemical conditions of water factors. The growth of seaweed is strongly influenced by the physicochemical parameters of seawater, namely temperature, salinity, and pH. Water quality serves as a crucial factor supporting seaweed growth, thereby playing a crucial role in sustaining seaweed cultivation businesses in aquatic environments.

To assess the suitability of ecological zoning for seaweed cultivation, it is essential to consider the physical and chemical parameters of the waters. The selection of waters for cultivation is a critical determinant of the success or failure of a seaweed cultivation venture. The measurement results on the physicochemical condition of water factors, conducted during west, transition, and east seasons, are presented in Tables 5, 6, and 7.

Table 5

Water quality in Tanjung Selayar waters during the west season

Sta	*pH*	*DO*	*Temp*	*Sal*	*Phosp*	*Nit*	*TSS*	*Depth*	*Substrate_d*	*Current*	*Wave height*
1	5.6	6	29.6	33	0.74	4.4	5	0.8	sand	0.17	0.14
2	7.2	6.3	29.7	31	0.98	1.6	9	0.4	sandy mud	0.12	0.13
3	5.9	7.8	29.8	29	0.91	0.9	7	0.4	mud and gastropoda shells	0.1	0.19
4	6.1	6	30	32	0.38	0.1	10	0.2	mud and gastropoda shells	0.21	0.14
5	6.1	5.2	30.7	33	1	1.2	13	1.3	mud and gastropoda shells	0.2	0.18
6	6.4	6.9	29	32	0.87	2.1	11	0.6	muddy sand	0.09	0.14
7	6	7.4	29.8	32	0.74	1.8	7	0.6	sandy mud and coral shrubs	0.15	0.21
8	7.4	6	30.2	31	0.98	1.6	15	2.1	mud	0.1	0.24
9	7.1	6.1	29.7	32	0.67	0.9	5	0.8	mud	0.25	0.22
10	7.3	5.6	29.7	32	0.87	1.7	3	0.5	muddy sand	0.25	0.17
11	7.4	5.7	31	32	0.9	2	3	1.4	sand	0.08	0.14
12	7.4	6	30.2	34	0.98	1.6	9	1.7	muddy sand	0.21	0.17
13	6.2	6.3	30.1	32	0.67	2.2	29	1.5	muddy sand	0.16	0.21
14	6.1	6.2	30.2	34	0.91	1.8	27	3.3	mud	0.21	0.18
15	6.2	7.2	30.7	34	1.67	2.4	23	4.2	mud	0.23	0.17
16	6.3	5.9	30.1	33	0.74	1.6	4	1.8	mud	0.17	0.14
17	6.2	5.6	30.1	32	0.67	2.6	7	3.6	mud	0.09	0.14
18	6.3	6	29.2	33	0.98	1.6	3	2.7	muddy sand	0.14	0.12
19	6.3	6.3	31.8	34	1.74	2.1	20	4.4	mud and gastropoda shells	0.23	0.17
20	6.1	6.5	30.1	32	1.98	2.4	7	1.2	muddy sand	0.33	0.17
21	8.3	6.1	30	32	0.31	2	3	1.7	mud	0.06	0.14
22	6.2	6.1	30.1	33	1.94	2.2	2	4.2	sand	0.25	0.21
23	6.1	5.4	29	32	0.87	2.2	6	2.3	sand and gastropoda shells	0.14	0.14
24	6.1	6.4	30	32	1.09	2.1	5	0.5	muddy sand and algae	0.13	0.11
25	6.2	6.3	30.9	31	1.67	3.8	6	2.3	sand	0.28	0.22
26	6.2	6	30.4	33	0.74	2.1	9	1.4	mud	0.14	0.14
27	6.1	6.2	30	32	0.71	2.1	25	4.3	mud	0.28	0.25
28	6.1	7.2	29.7	32	0.9	1.8	17	3	mud	0.19	0.22
29	6.1	7	30.6	32	0.38	0.1	3	0.3	mud	0.18	0.22
30	6.2	6.6	30.8	32	1.38	2.6	4	4.3	sand	0.22	0.24

Note: DO – dissolved oxygen; Temp – temperature; Sal – salinity; Phosp – phosphate; Nit – nitrate; TSS – total suspended solids; Substrate_d – waterbed substrate.

Table 6

Water quality in Tanjung Selayar waters during the transition season

Sta	*pH*	*DO*	*Temp*	*Sal*	*Phosp*	*Nit*	*TSS*	*Depth*	*Substrate_d*	*Current*	*Wave height*
1	7.6	7.8	27.5	33	0.87	2.6	1	0.8	sand	0.29	0.25
2	7.6	6.6	30	34	0.46	0.9	12	0.4	sandy mud	0.27	0.26
3	7.7	6.7	30	34	0.41	1	11	0.4	mud and gastropoda shells	0.26	0.25
4	7.4	6.3	30	34	0.56	1.1	8	0.2	mud and gastropoda shells	0.28	0.26
5	7.6	6.5	29.7	34	0.51	1.5	10	1.3	mud and gastropoda shells	0.3	0.32
6	7.5	6.8	29	34	0.61	2	15	0.6	muddy sand	0.38	0.35
7	7.6	6.9	29	34	0.62	1.9	6	0.6	sandy mud and coral shrubs	0.28	0.3
8	7.7	5.4	29	34	0.43	1.4	7	2.1	mud	0.3	0.3
9	7.4	7.2	29.5	34	0.58	1.3	5	0.8	mud	0.29	0.3
10	7.3	6.2	29.5	34	0.67	1.5	1	0.5	muddy sand	0.28	0.25
11	7.7	6.2	29.5	34	0.45	1.8	2	1.4	sand	0.38	0.34
12	7.8	13.5	29.2	34	0.51	1.3	4	1.7	muddy sand	0.38	0.35
13	7.1	7	30	34	0.78	1.4	3	1.5	muddy sand	0.25	0.34
14	7.5	10.3	30.3	34	0.69	1.5	2	3.3	mud	0.26	0.34
15	7	6.9	30	34	0.74	2.1	3	4.2	mud	0.34	0.34
16	7.1	6.9	30	34	0.67	1.5	4	1.8	mud	0.38	0.31
17	7.6	6	27	33	0.78	1.7	1	3.6	mud	0.36	0.35
18	7.3	7.4	27.5	33	0.62	1.4	21	2.7	muddy sand	0.28	0.32
19	7.5	7.5	28	33	0.51	1.8	2	4.4	mud and gastropoda shells	0.18	0.25
20	7.4	7.2	30	33	0.54	2	5	1.2	muddy sand	0.2	0.24
21	7.7	7	30	34	0.32	1.5	4	1.7	mud	0.28	0.25
22	7.1	6.3	29	33	0.64	1.7	5	4.2	sand	0.22	0.2
23	7.6	8.1	28	33	0.17	1.7	3	2.3	sand and gastropoda shells	0.29	0.2
24	7.1	6.1	28	32	0.37	1.6	1	0.5	muddy sand and algae	0.3	0.25
25	7.4	7.1	28	33	0.51	2.5	4	2.3	sand	0.36	0.25
26	7.8	6.1	28	32	0.54	1.5	7	1.4	mud	0.32	0.32
27	7.1	7.4	30	34	0.98	1.9	2	4.3	mud	0.4	0.36
28	7.2	8.1	28.8	34	0.51	1.6	2	3	mud	0.44	0.34
29	7.2	6.8	30	34	0.56	1.3	5	0.3	mud	0.36	0.32
30	7.5	6.2	28	33	0.51	1.9	3	4.3	sand	0.44	0.32

Note: DO – dissolved oxygen; Temp – temperature; Sal – salinity; Phosp – phosphate; Nit – nitrate; TSS – total suspended solids; Substrate_d – waterbed substrate.

Seaweed cultivation land suitability. Determining the area for seaweed cultivation required overlaying each variable acquired. The map indicating seaweed cultivation land suitability is depicted in Figures 1, 2, and 3. Subsequently, the map was analyzed to determine suitability of each area using GIS. This analysis showed the extent and suitability (suitable, moderately suitable, and unsuitable) of areas.

West season. The overlay results of calculations evaluating suitability of seaweed cultivation land in Tanjung Selayar waters during west season are presented in Figure 1 and Table 8.

During west season, the waters of Tamiang Bay in Tanjung Selayar had the lowest level of suitability, depicted in red on Figure 3. The unsuitable, moderately suitable, and suitable areas spanned 397.65, 745.06, and 527.49 ha indicated by the red, yellow, and green colors, respectively.

The suitability analysis was consistent with the recommendations derived from direct *in situ* measurements of oceanographic parameters, suggesting that the coastal waters of Tanjung Selayar were not suitable. Suitability parameters had low values during the measurement period. This was attributed to the closed or land-protected currents prevalent in the waters of Tanjung Selayar during the west season. Areas classified as suitable and moderately suitable were located farther from the coast. This corresponds to the results of oceanographic parameter measurements, consistent with the water requirements for seaweed cultivation. Furthermore, a conformity level matrix analysis was conducted to provide spatial information regarding suitable, moderately suitable, and unsuitable areas based on land suitability parameters and seasonal changes (Table 4).

Table 7

Water quality in Tanjung Selayar waters during the east season

Sta	*pH*	*DO*	*Temp*	*Sal*	*Substrate_D*	*Phosp*	*Nit*	*TSS*	*Depth*	*Wave height*	*Current*
1	7.3	6.8	28.5	35	sand	0.12	2.2	1	0.8	0.32	0.48
2	7.2	6.7	30.4	36	sandy mud	0.02	1.2	1	0.4	0.3	0.45
3	7.3	6.8	30	36	mud and gastropoda shells	0.03	1.5	3	0.4	0.36	0.44
4	7.3	5.9	28	37	mud and gastropoda shells	0.02	1.2	2	0.2	0.37	0.47
5	7.3	6.4	30.7	36	mud and gastropoda shells	0.04	1.7	8	1.3	0.32	0.5
6	7.3	6.7	29.5	36	muddy sand	0.16	2.2	2	0.6	0.33	0.49
7	7.4	6.8	30.1	38	sandy mud and coral shrubs	0.23	2.1	5	0.6	0.35	0.52
8	7.4	6.5	31.1	35	mud	0.04	0.8	3	2.1	0.35	0.48
9	7.46	6.7	30.5	46	mud	0.24	1.8	1	0.8	0.31	0.47
10	7.45	6.7	30.4	46	muddy sand	0.24	1.8	3	0.5	0.31	0.45
11	7.38	6.9	29.6	46	sand	0.04	1.5	3	1.4	0.32	0.53
12	7.47	6.5	30.3	35	muddy sand	0.02	1.2	3	1.7	0.32	0.5
13	7.42	6.7	30.4	46	muddy sand	0.02	1.2	5	1.5	0.36	0.44
14	7.4	6.7	30	36	mud	0.06	0.7	2	3.3	0.32	0.44
15	7.39	6.9	30.2	35	mud	0.43	1.5	4	4.2	0.34	0.48
16	7.4	6.6	31.2	36	mud	0.08	1.2	5	1.8	0.31	0.54
17	7.4	6.7	31	36	mud	0.07	1.1	2	3.6	0.33	0.51
18	7.43	6.4	32.3	36	muddy sand	0.02	1.3	8	2.7	0.36	0.47
19	7.37	7.1	29	36	mud and gastropoda shells	0.03	1.1	1	4.4	0.3	0.45
20	7.21	6.4	31.7	36	muddy sand	1.16	1.4	4	1.2	0.31	0.42
21	7.32	6.2	32.7	36	mud	0.17	1	5	1.7	0.39	0.47
22	7.36	6.7	31.3	36	sand	0.4	1.2	2	4.2	0.31	0.58
23	7.42	6.3	32.4	36	sand and gastropoda shells	0.11	1.5	5	2.3	0.38	0.56
24	7.28	6.8	31.4	36	muddy sand and algae	0.04	1	3	0.5	0.32	0.44
25	7.38	6.8	31.7	36	sand	0.05	1.3	2	2.3	0.28	0.43
26	7.42	7.1	31	36	mud	0.04	1.3	3	1.4	0.34	0.49
27	7.35	6.9	30	35	mud	0.08	1.5	4	4.3	0.33	0.47
28	7.51	6.8	31.3	35	mud	0.06	0.8	2	3	0.31	0.56
29	7.41	6.6	30.9	35	mud	0.05	1.2	5	0.3	0.34	0.58
30	7.37	6.9	30	36	sand	0.41	1.3	2.1	4.3	0.38	0.56

Note: DO – dissolved oxygen; Temp – temperature; Sal – salinity; Phosp – phosphate; Nit – nitrate; TSS – total suspended solids; Substrate_d – waterbed substrate.

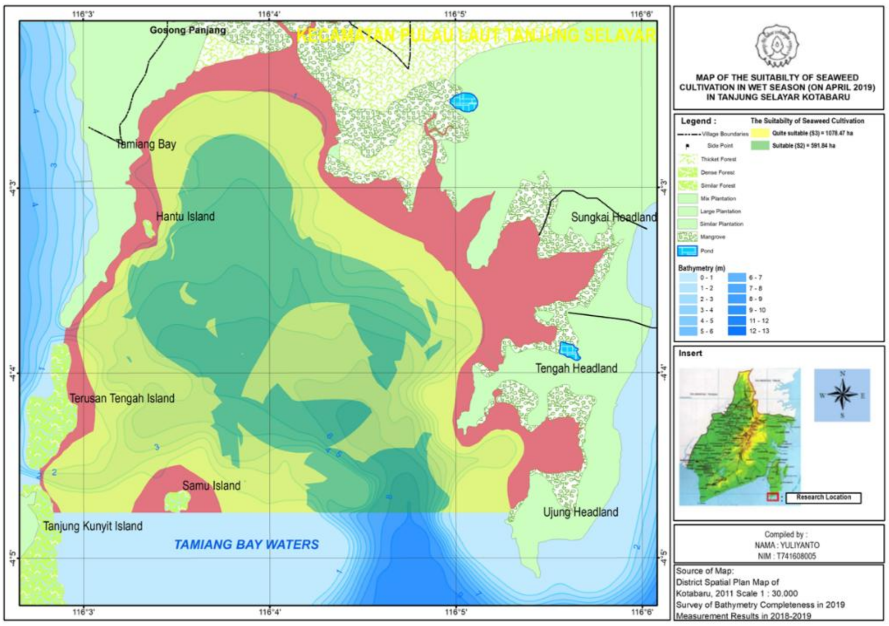

Figure 1. Map of land suitability for seaweed cultivation during west season.

Table 8
Suitable area for seaweed cultivation during west season in Tanjung Selayar waters

No	*Land suitability category*	*Area (Ha)*	*Percentage*
1	Suitable	527.49	31.6%
2	Moderately suitable	745.06	44.6%
3	Unsuitable	397.65	23.8%

Transition season. The overlay results of calculations evaluating the suitability of seaweed cultivation land in Tanjung Selayar waters during the transition season are depicted in Figure 2 and Table 9.

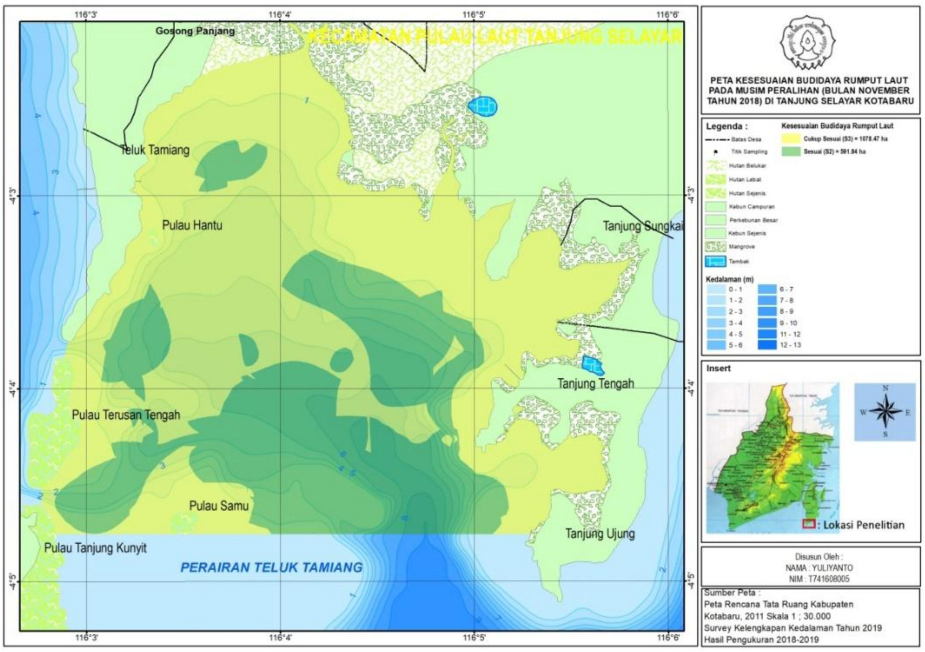

Figure 2. Map of land suitability for seaweed cultivation during the transition season.

Table 9

Area of land suitability for seaweed cultivation during transition season in Tanjung Selayar waters

No	*Land suitability category*	*Area (Ha)*	*Percentage*
1	Suitable	591.73	35.4 %
2	Moderately suitable	1078.47	64.6 %

During the transition season, the waters of Tamiyang Bay in Tanjung Selayar had suitability levels falling in suitable and moderately suitable categories (Figure 2). This was attributed to suitability parameters for seaweed cultivation, which remained conducive. The area classified as moderately suitable, depicted in yellow, spanned 1078.47 ha, while the suitable category, shown in green, covered an area of 591.73 ha.

This suitability analysis was consistent with the recommendations derived from direct *in situ* measurements of oceanographic parameters, indicating that the waters of Tanjung Selayar during the transition season fulfilled the conditions for seaweed cultivation. Almost all of the suitability parameters had favorable values or numbers during the measurement period. This was because during transition season, the currents in the waters were slightly stronger. Areas classified as suitable and moderately suitable were distributed in the waters. Suitable areas were slightly more concentrated towards the middle due to the support provided by a sandy bottom substrate.

East season. The overlay results of calculations evaluating suitability of seaweed cultivation land in Tanjung Selayar waters during east season are depicted in Figure 3 and Table 10.

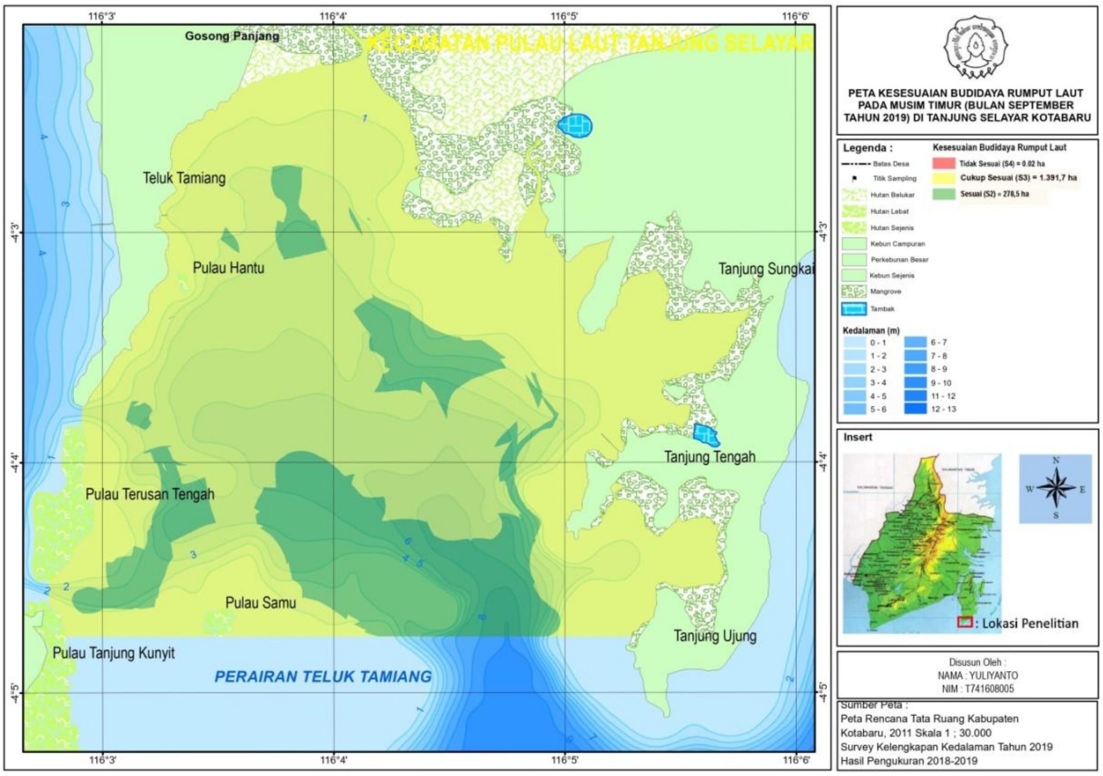

Figure 3. Map of land suitability for seaweed cultivation during east monsoon.

Table 10
Area of land suitability for seaweed cultivation during east season in Tanjung Selayar waters

No	*Land suitability category*	*Area (Ha)*	*Percentage*
1	Suitable	278.5	10.8 %
2	Moderately suitable	1391.7	89.2 %

The waters in Tamiyang Bay, Tanjung Selayar, during the east monsoon season, had a predominantly suitable and moderately suitable level (Figure 3 and Table 10). Most waters were considered suitable for mariculture during east season because suitability parameters met the requirements for seaweed cultivation. The moderately suitable area indicated in yellow, spanned 1391.7 has, and the suitable category represented in green covered 278.5 ha.

This suitability analysis was consistent with the recommendations derived from direct *in situ* measurements of oceanographic parameters, suggesting that Tanjung Selayar waters during east season met the conditions for seaweed cultivation. Almost all of suitability parameters had favorable values during the measurement period. This was because during the east season, the currents in the waters were strong. Areas classified as suitable and moderately suitable were distributed in the waters.

Conclusions. The analysis conducted for seaweed cultivation areas in Tanjung Selayar waters showed spatial variations in suitability, including suitable, moderately suitable, and unsuitable areas. This discrepancy was due to seasonal differences influencing oceanographic factors and land suitability parameters. During west season, the spatial area considered suitable for seaweed cultivation was 527.49 ha, with 745.06 ha falling into the moderately suitable category. In the transition season, areas suitable for cultivation covered 591.73 ha, with the moderately suitable category spanning 1078.47 ha. Meanwhile, during east season, the waters of Tanjung Selayar comprised 278.5 ha in suitable and 1391.7 ha in the moderately suitable category.

Conflict of Interest. The authors declare that there is no conflict of interest.

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Received: 20 August 2024. Accepted: 26 August 2024. Published online: 18 April 2025.
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How to cite this article:
Yuliyanto, Sutarno, Astuti S., Setyono P., Johan Y., Salim D., Tony F., Nursalam, 2025 Suitability analysis of land based seaweed cultivation on seasons in Tanjung Selayar, Kotabaru Regency, South Kalimantan. AACL Bioflux 18(2):903-915.