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Spatial Water Quality and Plastic Buoy of Seaweed Culture in Coastal Area, Indonesia

Nurjannah Nurdin[a,d], Riza Yuliratno Setiawan[c], Muhammad Helmi[b], Lilik Maslukah[b], Agus[d], M. Akbar AS[d], Aswar Anas[d], Muh. Nurfitrah[d], Teruhisa Komatsu[e,f]

[a] Faculty of Marine Science & Fisheries, Hasanuddin University, Makassar, 90245. Indonesia.
[b] Marine Science & Fisheries Faculty, Diponegoro University, Semarang, 1269. Indonesia
[c] Marine Science & Fisheries Faculty, Gadjah Mada University, Yogyakarta, 55281. Indonesia
[d]Research and Development Center for Marine, Coast and Small Islands, Hasanuddin University, Makassar 90245. Indonesia
[e]Atmosphere and Ocean Research Center Institute, The University of Tokyo, Kashiwa 277-8564, Japan
[f]Present Affiliation: Yokohama College of Commerce, Yokohama 230-8577, Japan.

nurj_din@yahoo.com

ABSTRACT

Remote sensing has provided some water quality data that can be used to assess the suitability of water quality for cultivation. It is the main approach used to map seaweed farming. The aims of this study were to map the seaweed farming potential of the study area and calculate the amount of plastic waste likely to be produced from the use of plastic buoys in seaweed aquaculture. SPOT 6 and Sentinel 2 provide high and moderate resolution satellite imagery that can be used as primary data to map seaweed farming at fine and broad scales. ArcMap application was applied to analyse the vector data of water quality. Weighting and scoring were carried out to give value to the parameters for culture suitability. The plastic waste used as a buoy during cultivation is calculated based on primary data from field surveys. The results suggest that the simple analysis of high and moderate spatial resolution imagery with digitation on screen method can delineate seaweed farming areas efficiently. Furthermore, this method could be applied in the future to monitor the extent of seaweed farms and to predict the amount of plastic waste produced by seaweed farming activities.

Keywords: *Water quality, seaweed, SPOT, Sentinel, plastic waste*.

1. INTRODUCTION

Indonesia's tropical water has a large seaweed diversity with approximately 555 types of seaweed [13]. Seaweed is an important economic commodity that has the potency to be cultivated in Indonesian waters, especially agarophytes (*Glacilaria*), caraginophytes. (*Eucheuma* and *Kappaphycus*) and alginophytes (*Sargassum* and *Turbinaria*).

The growing trend of seaweed demand in the global market has made seaweed cultivation a necessity. However, one of the key factors for successful cultivation is the determination of a suitable area. Nowadays, this process can cover a wide continuous area by the utilization of remote sensing technology and Geographic Information Systems. Seaweed mapping using Landsat satellite imagery has been widely used in several studies [12], [14], [2]. The Landsat Data Continuity Mission (LDCM) satellite or better

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known as Landsat 8 OLI was launched on February 11, 2013, by NASA and began providing image products that can be accessed for free since May 30, 2013. Landsat 8 OLI imagery has 11 bands, including the Visible bands, Near Infrared (NIR), Short Wave Infrared bands (SWIR), Panchromatic bands (Bands 1, 2, 3, 4, 5, 6, and 7), and Thermal bands. Bands 1, 2, 3, 4, 5, 6, 7, and 9, have 30 m spatial resolution, band-8 has 15 m, while band-10 and 11 have 100 m spatial resolution. Landsat remote sensing data has spectral channels that can be used for various applications related to vegetation, water, and soil. Various spectral channel combinations are utilized according to the analysis objectives. The bands that can be used to map objects in the water column are 1, 2, 3, and 4 [15].

The annual production of global macroalgae continued to increase and reached 31.2 million tonnes (fresh weight) in 2016 [3]. Hence, only 3.5% out of this number harvested from natural populations, while the remaining 96.5% was from seaweed culture which constitutes 27% of the total world aquaculture production. Nearly all of these were cultivated in China, Indonesia, and other Asian countries (47.9, 38.7, and 12.8% of global production in 2016, respectively), It is produced particularly for human food and food additives.

Nevertheless, there are still some obstacles that need to be addressed in developing seaweed cultures, such as the unavailability of accurate data, information on the total area, and the feasibility level of the location. Although a location can be determined visually, it still needs to be further analyzed to obtain accurate feasibility data. The purpose of this study was to determine suitable locations for seaweed culture, map the existing conditions of seaweed cultivation area and estimate the use of buoys from plastic bottles used in the coastal areas of Pangkep and Takalar Regencies. Data and information on the level of suitability for seaweed cultivators obtained in this study intended to be an input for policymakers for the development of seaweed cultivation and management of plastic waste in Pangkep and Takalar Regencies.

2. MATERIALS AND METHODS

2.1 Study Site

The development of seaweed culture is one alternative to empower coastal communities by increasing farmers' income in Pangkep and Takalar Districts. In general, the locals who live in coastal areas and small islands in Pangkep and Takalar Regencies live as a fisherman. The development is an alternative to marine resources exploitation, by creating jobs and improving community welfare. *K.alvarezii* seaweed has been cultivated for a long time by the people of Pangkep and Takalar Districts, scattered in coastal areas and islands. Although it has been done for a long time, the seaweed culture managed by the community still experiences several obstacles and problems. Therefore, the result obtained by farmers from the seaweed was not optimal. The success of seaweed production can be achieved by optimizing the supporting factors such as the selection of suitable locations, the use of good quality seaweed types (superior seeds), the right cultivation techniques or methods, and harvest and post-harvest techniques [11].

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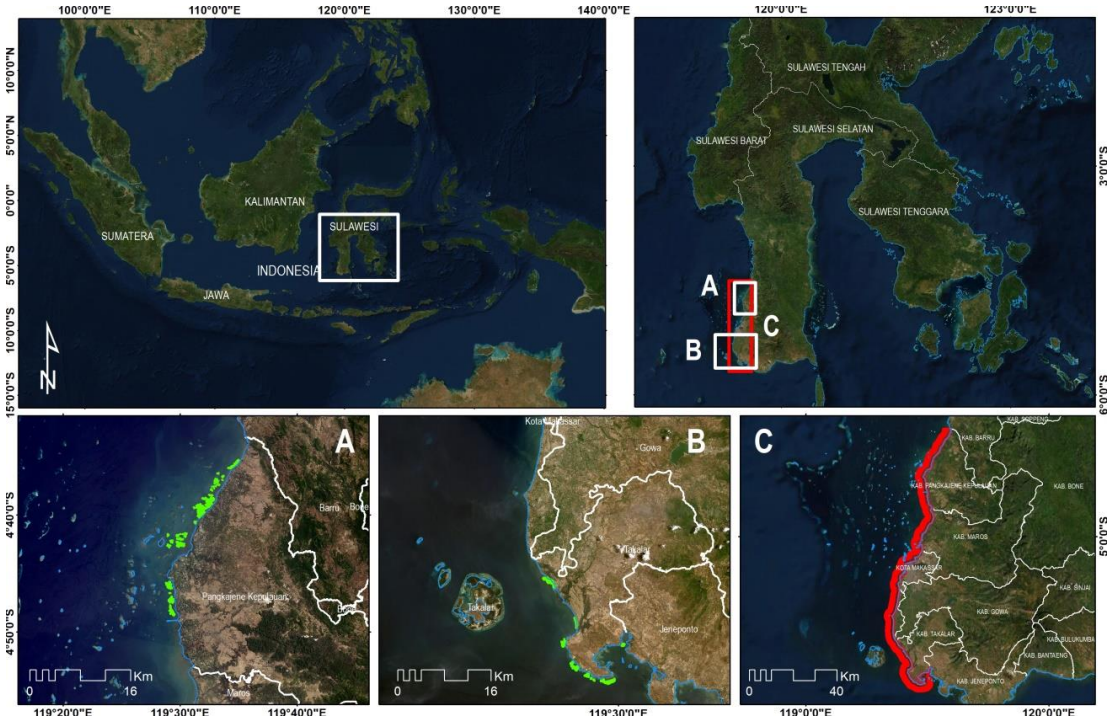


Figure 1. Study site in South Sulawesi, Indonesia. (A) Pankep Regency, and (B) Takalar Regency.

2.1 Data Collection

The first step to determine suitable areas for seaweed culture in this study was database collection and initial image processing. Database collection was done by collecting field data from each parameter and secondary data from related agencies and researchers. The data used in this study were currents, bathymetry, substrate, salinity, temperature, TSS, pH, DO, Nitrate, Nitrite, and Phosphate (Table 1). In data processing, it was necessary to pay attention to seasonal patterns, when every season changes occur, the conditions of the physical and chemical parameters of the circulation that affect the growth of seaweed would also change.

Table 1. Data collection and Source

No	Parameters	Source
1	Digitation	Satellite imagery SPOT 2018 and Sentinel 17 September 2019
1	Currents	Satellite Imagery Aviso+ 15 August 2020
2	Depth (m)	LPI Map 50.000 Scale, Indonesia One Map Policy 2017
3	Substrate	2019 field Survey and secondary data
4	Salinity (ppt)	2020 field Survey & secondary data
5	Temperature (^oC)	Landsat 8 imagery 20 August 2020 & Field Survey 2020
6	MPT (mg/l)	Landsat 8 imagery 20 August 2020
7	pH	2019 field Survey & secondary data
8	DO (mg/l)	2019 Field Survey & secondary data
9	Nitrate (mg/l)	2019 Field Survey & secondary data
10	Phosphate (mg/l)	2019 Field Survey & secondary data

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2.2 Determination of Seaweed Suitability Criteria

Weighting and scoring were carried out to give value to the parameters for culture suitability. The weighting of each criterion was based on how much the parameters contribute to the final result. The criteria considered to be very influential on the growth of seaweed were given a higher rate so that it would be considered much on the final score. The determination was based on a predefined suitability matrix for the growth of seaweed (Table 2).

Table 2. Suitability criteria for seaweed culture

Parameters	Weight	Unsuitable (N)	Total Score	Marginally Suitable (S2)	Total Score	Suitable (S1)	Total Score
		1		3		5	
Currents (cm/s)	3	<10 & >40	3	>10 - <25 & >40 – 60	9	25 – 40	15
Water Depth (m)	3	<2 & > 10	3	2 - <3 atau >5 - <10	9	3 – 5	15
Water bottom (Substrate)	3	Mud & Coral	3	Medium muddy sand	9	Fine Sand, Cracked Coral & Macro Algae	15
Salinity (ppt)	3	< 25 & > 37	3	>25-<28 atau >34 - <37	9	28 – 34	15
Temperature (°C)	3	< 20 & > 30	3	20 – 24	9	24 – 30	15
MPT (mg/l)	2	>80	2	>25 - 80	6	<25	10
pH	2	<4 atau >9,5	2	4 – 6,4 atau 8,5 - 9	6	6,5 – 8,5	10
DO (mg/l)	3	<3	3	3-7	9	>7	15
Nitrate (mg/l)	2	<0,01 atau >0,5	2	>0,01-<0,04 atau >0,1-<0,5	6	0,04 – 0,1	10
Phospate (mg/l)	2	<0,01 atau >1	2	>0,01-<0,1 atau >0,2-<1	6	0,1 – 0,2	10
	26		26		78		130

Source: [1], [4], [7], *with modification.*

The suitability value for each parameter that was considered to be the most important was based on calculations with the following formula (scoring):

$$N = \Sigma(Bi \times Si) \quad \text{..... (1)}$$

where :
N = Total weighted value
Bi = Weight for each criterion
Si = Score on each criterion

The suitability class interval was obtained based on the Equal Interval method [10], where the total of the maximum value of weight multiplied by score deducted with the total of the minimum value of weight multiplied by score, which was then divided into three classes, suitable, marginally suitable, and unsuitable. As stated by the formula below:

$$\text{Class Interval} = \Sigma (Bi \times Si)max - \Sigma (Bi \times Si)min \quad \text{..... (2)}$$

Based on the formula above, the value between each class was determined as follows:
Suitable (S1): 44 - 60
Marginally Suitable (S2): 28 - 43
Unsuitable (S3): 12 - 27.

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2.2 Spatial Analysis of Seaweed Culture

The existing seaweed distribution in Pangkep and Takalar Districts was mapped with the visual interpretation of Landsat 8 OLI-TIRS imagery.It was carried out based on the spatial recognition of object characteristics using elements of interpretation, such as color/hue, shape, size, pattern, shadow, texture, site, and association [6]. To get the characteristics of the object in visual interpretation, the image was displayed in RGB (Red Green Blue) format from a combination of 3 bands to produce a composite color.

Interpolations were made for temperature, salinity, substrate, depth, pH, DO, Nitrate, and Phosphate to predict the grid values that were not represented by the sample points. The interpolation method used was Inverse Distance Weighting (IDW). The determination of a suitable location for seaweed culture was using the Multi-Criteria Evaluation (MCE) method. The layers of the suitability parameters for seaweed culture maps can be overlaid with other data, resulting in a thematic map of the suitability of seaweed.

2.3 Litters from Seaweed Farming Data

The long-line seaweed culture method is widely applied in South Sulawesi, especially in Pangkep and Takalar Districts. This method uses a lot of plastic bottles that functioned as floats. This plastic would then turned into waste once it was no longer in use. The amount of this waste was estimated by calculating the number of lines of ropes used in the farm, multiplied by the number of plastic bottle buoys per stretch.

3. RESULT AND DISCUSSION

3.1 Water quality in the existing seaweed culture area

The spatial distribution of water quality parameters, which were currents, bathymetry, substrate, salinity, temperature, TSS, pH, DO, Nitrate, Nitrite, and Phosphate resulting from spatial data processing is shown in Figure 2. The bottom substrate of waters in existing cultivation locations in Pangkep and Takalar Districts was dominated by sand and mud substrate. Corals, coral fragments, and coarse sand substrate was considered good for seaweed farming because it indicates good water movement. Meanwhile, the mud substrate could interfere with the growth of seaweed, because mud particles are easily stirred in the water column and will cover the clumps of seaweed [13]. The ideal currents velocity for cultivation ranges from 25 - 40 cm / s. This speed of water flow is necessary for nutrients absorption from the water into the seaweed, while also accelerating the metabolic process and at the same time cleaning the unwanted things that stick to the thallus. According to [13], gentle currents left the seaweed dirty with many epiphytes and also more prone to diseases, when there were enough currents, there would be better water circulation in the area so that the seaweed would not be susceptible to diseases. The currents velocity in the waters of the Pangkep and Takalar Regencies hinted that the area was not good for seaweed culture, the currents speed ranges from 2 - 10 cm/s. The currents speed data can be seen in Figure 2.

The water depths in the coastal areas of Pangkep and Takalar Districts range from 0 to 30 meters (Figure 2). Suitable water depth for seaweed culture is in the range of 3-5 meters. The long-line method can be applied not only at shallow water with 1 meter lowest tide but also at deep water as long as the seaweeds

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always submerged. The most suitable water depth for seaweed culture with a long-line system is in the range of 5 - 20 meters. The water depth was intended to prevent seaweed from accumulating substrate particles when a strong current occur, even more so if the bottom substrate was mud. This depth also helps the anchor installation in this method becomes easier [13].

The salinity of waters in Pangkep and Takalar Districts in the east monsoon ranges from 26.7 - 33.9 ppt (Figure 2). *Eucheuma* seaweed grows well at high salinity from 28 - 35ppt. The decrease in salinity due to excessive intake of fresh water will cause the growth of seaweed to be abnormal so it is recommended that seaweed cultivation should be far from the estuary.

Water temperature in Pangkep and Takalar Districts in the east monsoon season ranges from 22.24 to 30^{o}C (Figure 2). This condition shows that the sea surface temperature is more suitable for seaweed cultivation during the east monsoon season. The average annual sea surface temperature in Pangkep and Takalar Districts is 30 oC. The temperature has an important role in the growth of seaweed. The higher the increase in temperature will cause the thallus of the seaweed to turn pale yellowish and unhealthy. Seaweed grows well in a temperature range of 24 - 30 ^{o}C.

Very acidic or alkaline pH conditions will endanger the survival of the organism because it causes metabolic and respiratory disorders. The range of pH values at the research location during east monsoon is 6,7-8,19. This pH value is suitable for seaweed cultivation. The water condition in Pangkep and Takalar Districts is influenced by the season, wherein the dry season the temperature, salinity, degree of acidity, and transparency of the waters tend to increase.

Turbidity due to suspended material will inhibit light penetration into the water column and affect the growth of seaweed, therefore a form of water pollution can be known from the TSS value. TSS levels in the study area ranged from 5-80 mg/L, which means that the water was suitable for the growth of K. *alvarezii*. The low TSS content can be caused by the influence of seabed deposition or coastal sedimentation [9].

Dissolved Oxygen (DO) at the research location was ranged from 3.20-7.24 ppm. This value was qualified for seaweed cultivation. Nitrate is one of the nutrients needed for the growth of seaweed. The analysis of the nitrate concentration of the study site shows results of 0.012 to 0.044 mg / L. The most suitable nitrate concentration for seaweed cultivation was in the range of 0.04 - 0.1 mg / L.

Meanwhile, the concentration of phosphate levels in the study location ranged from 0.006 to 0.024 mg / L. This range indicates that the waters have low to insufficient fertility levels. Waters with low fertility levels have a phosphate content less than 0.1 mg/L. Phosphate concentration is a water condition variable that also affects the growth of seaweed [8].

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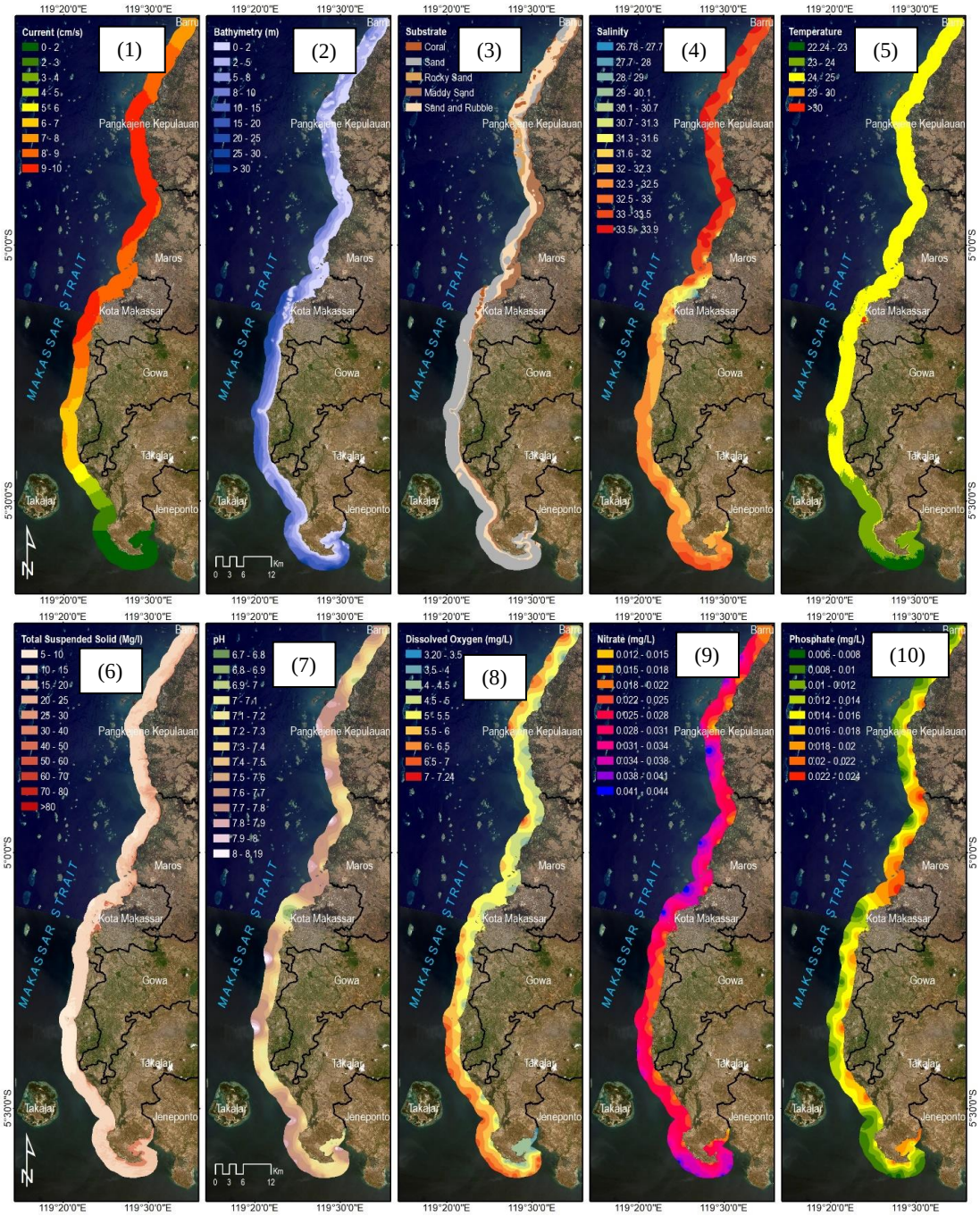


Figure 2. Map of the interpolation result of the water quality conditions along the coast from the north of the Pangkep Regency to the South of Takalar Regency in the east monsoon; Water parameters include 1). current, 2) .bathimetry, 3) .substrate, 4). salinity, 5). temperature, 6). TSS, 7) .pH, 8) .DO, 9). Nitrate, and 10).Phosphate

3.2 Seaweed culture area suitability compared to existing locations

There are four stages in developing a seaweed culture, which are: 1) location selection, 2) cultivation method selection, 3) maintenance, and 4) harvesting and drying. Out of these stages, location selection is

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the most important aspect to avoid predators and potential diseases such as “ice ice”. Other important things related to site selection that could affect the quality and quantity of seaweed production are ecological factors (oceanographic parameters and water quality), convenience factors, risk factors, and conflicts of interest.

Suitability analysis for seaweed culture was carried out by combining all parameters. The results of this analysis shows 3 classes of location distribution which are (1) suitable, (2) marginally suitable, and (3) unsuitable, which presented in the form of a suitability map for seaweed culture in Pangkep and Takalar Regency. From the weighting and scoring and overlay of the parameters (currents, water bottom substrate, temperature, salinity, pH, DO, Nitrate, and Phosphate), it can be concluded that the water condition at the cultivation zone in Pangkep and Takalar Districts in the east monsoon season was mostly in the marginally suitable level (Figure 3). It should be noted that the suitability of waters near estuary was lower due to low salinity from the input of freshwater. This condition is not suitable for the growth of seaweed *Eucheuma spp*.

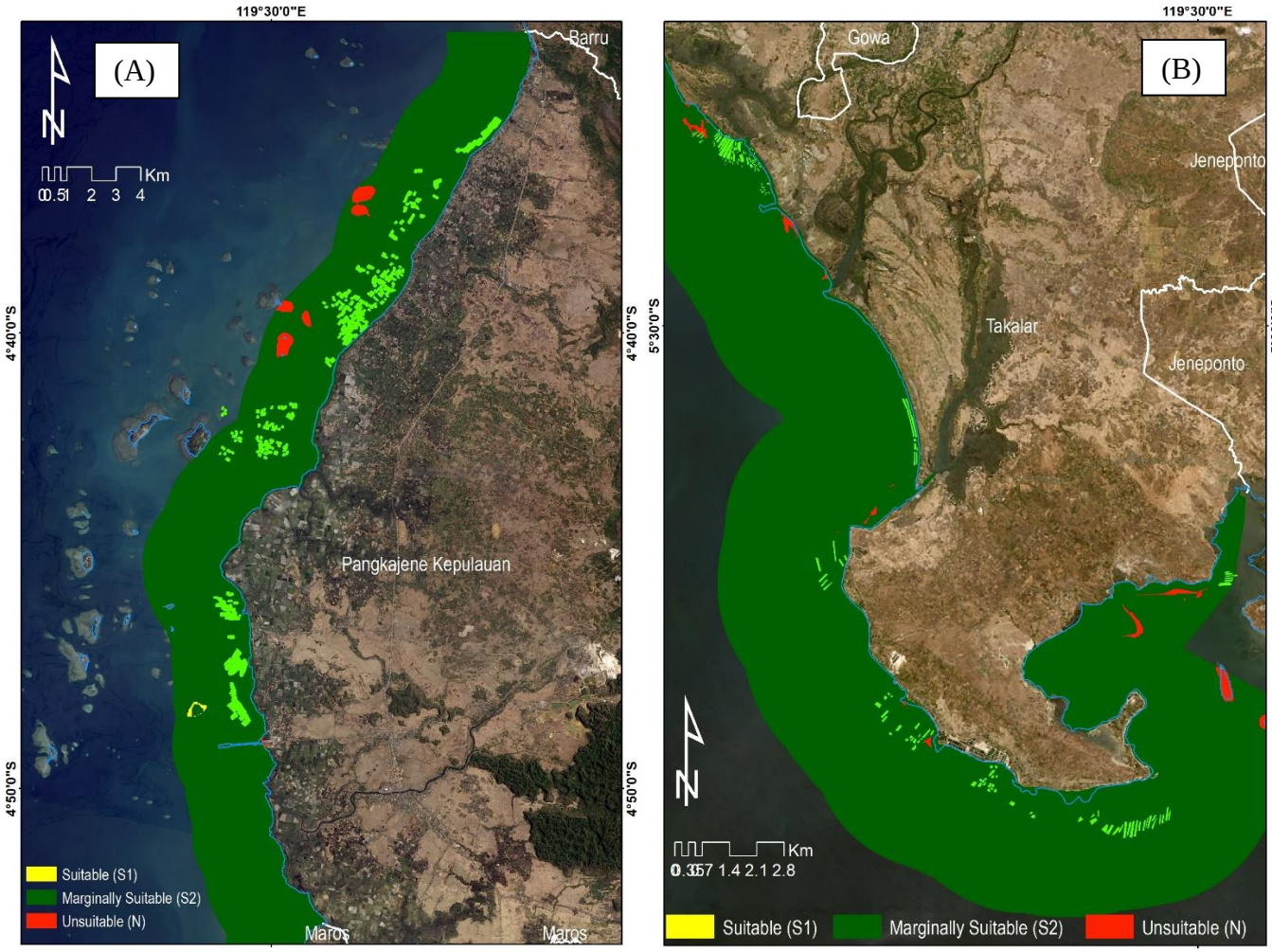


Figure 3. Suitability of water conditions for seaweed culture overlapped with the existing seaweed location, 1) Pangkep Regency in the east monsoon and 2) Takalar Regency in the east monsoon.

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From the result analysis, it can be seen that along the coastal area of the Pangkep Regency was mostly marginally suitable for seaweed culture and only a small part of the area was not suitable. Besides, there was also a small suitable area (Figure 3). Meanwhile, the coastal area of Takalar Regency was also mostly marginally suitable for the development of seaweed culture and only a small part of the area was not suitable (Figure 3). To conclude, the suitability percentage for seaweed culture of the waters of Pangkep and Takalar Regencies in the east monsoon season were: 15% unsuitable (S3), 80% marginally suitable (S2), and 5% suitable (S1) category which was highly recommended to do seaweed cultivation (Figure 3). Based on the location determination, water parameter fluctuation, cultivation infrastructure configuration, and the seaweed type, productivity can reach 20-150 tons/year per hectare (Kerrison et al., 2015).

3.3 Seaweed culture and its plastic buoys

The seaweed culture system used in these 2 districts was a long-line system. This method is one of the methods for cultivating seaweed in the water column near the water surface (euphotic) using a stretched rope from one point to another in the form of loose lanes or arranged in a rectangular shape with the help of buoys and anchors. Nylon rope was stretched at two ends of stakes or anchors along 25-50 m, while clumps of seaweed were tied to a rope with 20-50 cm distance between clumps, a plastic bottle buoy was tied every 2-5 m. These long lines can be stretched as much as 4-5 lines, the distance of each line was 1-2 m. Nowadays, this system is very popular in almost 2-10 m depth locations which are easily found in Indonesian waters. Besides, this system is economically cheaper than the bamboo raft frame which is quite expensive and limited. A sketch of seaweed culture using a long-line system can be seen in Figure 4 (Modified from Sulistijo, 2002).

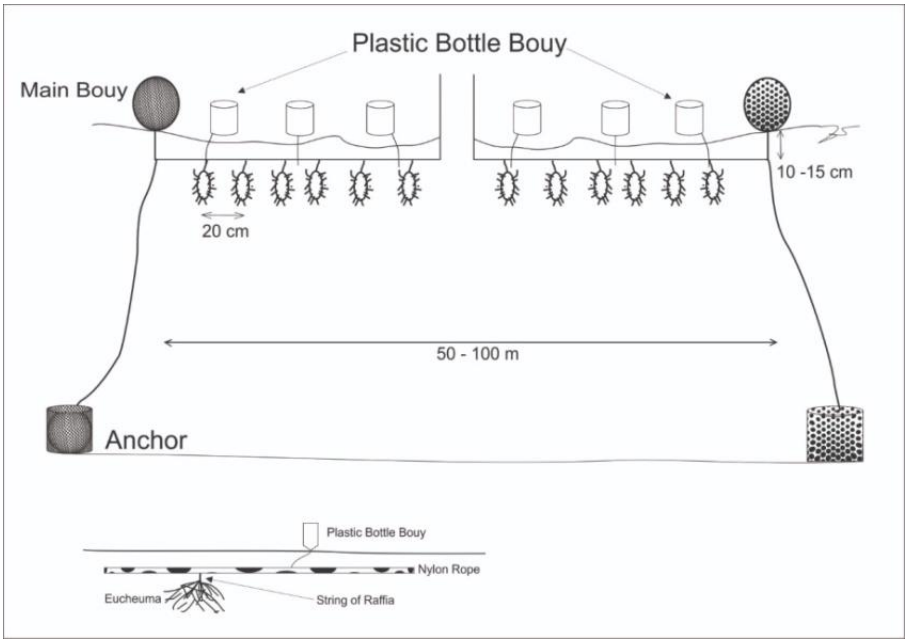


Figure 4. Sketch of seaweed culture with the long-line system. Notice the placement of plastic bottle buoy and space/seaweed' clumps (modified from, Sulistijo, 2002)

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Nevertheless, this long-line method has an impact on the environment from the plastic bottle waste it produces. The plastic bottle that functions as a buoy usually has a long usage period. However, if it is starting to leak after some time, it could no longer be used and would automatically become trash. During harvest, these bottles would be checked and discarded if they were torn. In this study, we estimated the number of plastic buoy bottles used in the long-line method (Figures 5 & 6). The calculation was based on the length and number of ropes used for each cultivation group.

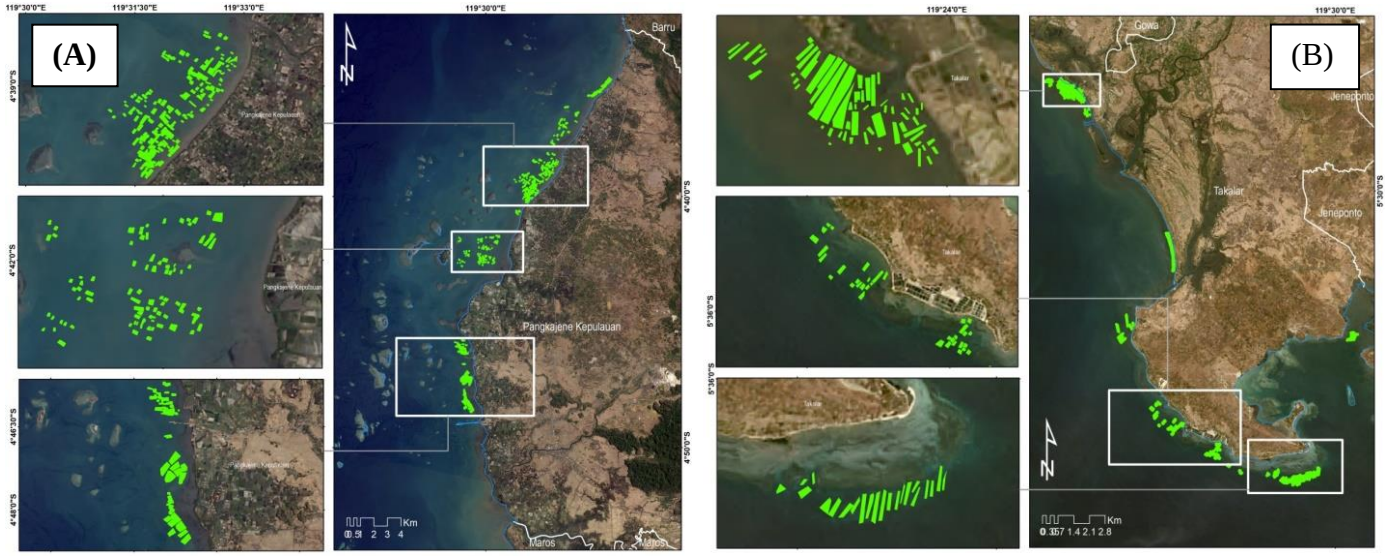


Figure 5. Visual interpretation of seaweed cultivation distribution in Pangkep and Takalar Districts using SPOT 2018 and Sentinel 17 September 2019 imagery.

The estimated area of seaweed culture in Pangkep District was 248.04ha. If one stretch of rope was 50 meters long it would consume 100 plastic bottle buoys. Based on the existing cultivation area in Pangkep from satellite imagery, the estimated number of ropes stretched was 24,800 ropes. Therefore the estimated number of plastic bottle buoys being used was around 2,480,000 pieces. These plastic bottles can be used for 3-4 harvests in one year. The same thing also happened in Takalar District. The area of cultivation was 112.67ha. The estimated number of ropes stretched out in this area was 11,200 ropes, so the number of plastic bottle buoys used was around 1,120,000 pieces.

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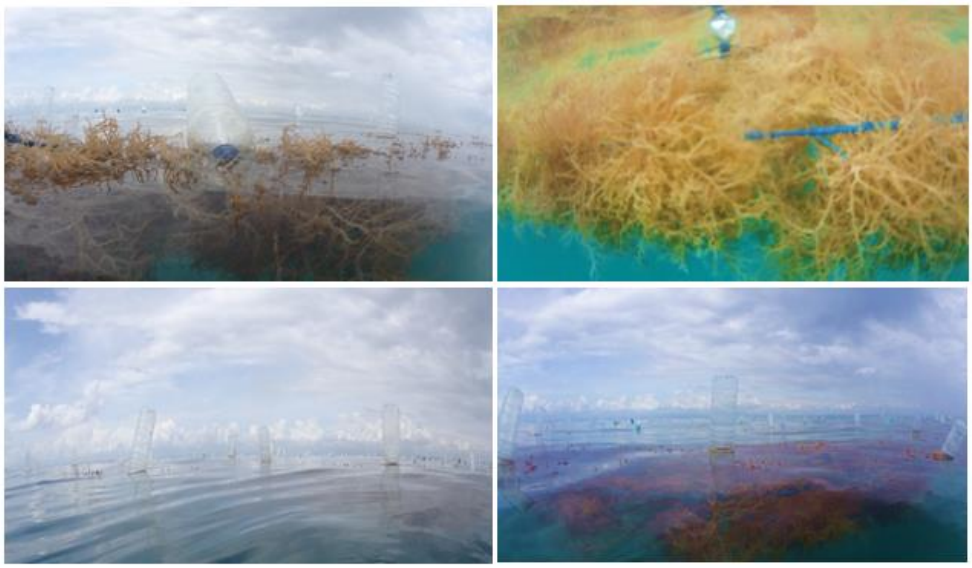


Figure 6. Seaweed culture using the long line method. Notice the plastic ropes and plastic bottles used as buoys. Both of these materials become sources of litter on a regular basis

In addition to using 1500 ml volumed plastic bottles, this cultivation also uses plastic ropes. These plastic ropes can also be used for three times harvests period or one year. Given the previous number of ropes described, the length of plastic rope waste accumulated in one (1) year can be as much as 1,240,000 meters in Pangkep and 560,000 meters in Takalar Regencies.

4. CONCLUSION

The suitability analysis of seaweed culture locations indicates that the locations currently used by the fishermen community were only in the marginally suitable category and not the suitable ones. This was closely related to locations near several river estuaries in Pangkep Regency where the bottom substrate was less suitable and water was more turbid. Although only marginally suitable, the seaweed culture in this area is still yielding. However, the quality of the seaweed harvest can be further improved if the cultivation location is in a suitable zone.

The accumulation of waste caused by seaweed farming using the long-line method is a phenomenon that needs serious attention. Regulations are needed to strictly regulate the disposal of plastic bottle waste that occurs continuously and accumulates in coastal areas and is likely to be carried into the sea and become dangerous marine debris. Apart from this, an alternative buoy that is not only cheap and affordable but also environmentally friendly needs to be created for the seaweed farmer communities.

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REFERENCES

[1] Agustina, N.A., Nirmala. I.W. & Vivi, D.P. 2017. Land Criteria for Cultivating Seaweed (Eucheuma cottonii) on Gili Genting Island, Madura. XII National Seminar on Marine. Universitas Hang Tuah. Surabaya. [in Indonesian).

[2] El Shoubaky G.A, Kaiser M. 2014. Monitoring Spatial and Temporal Seaweeds Variation Using Remote Sensing Data in Al-Shoaiba Coast, Red Se**a.** British Journal of Environment and Climate Change 4(4):409-422. DOI: 10.9734/BJECC/2014/10034

[3] FAO (2018). The State of World Fisheries and Aquaculture 2018: Meeting the Sustainable Development Goals. Roma: FAO, 210.

[4] Gazali. I., Bambang. R.W. & Ruslan, W. 2013. Evaluation of the Impact of Paper Mill Liquid Waste Disposal on Water Quality in the Klinter River, Nganjuk Regency. Journal of Tropical Agriculture and Biosystems Engineering. 1(2):1-8. [in Indonesian].

[5] Kerriso P.D, Stanley M.S, Edwards M.D, Black K.D, Hughes A.D. 2015. The Cultivation of European Kelp for Bioenergy: Site and Species Selection. Biomass and Bioenergy 80 (Supplement C): 229–42.

[6] Kohl M, Magnussen S, Marchetti M. 2006. Sampling Methods, Remote Sensing and GIS Multiresource Forest Inventory.Editor: Dieter Czeschlik. Berlin Heidelberg (EN): Springer-Verlag. https://doi.org/ 10.1007/978-3-540-32572-7.

[7] Nirmala, K., Ratnasari, A. & Budiman, S. 2014. Determination of the Suitability of Seaweed Cultivation Location in Gerupuk Bay Waters - West Nusa Tenggara Using Remote Sensing and GIS. Jurnal Akuakultur Indonesia, 13(1):73–82. [in Indonesian].

[8] Patty S.I, Arfah H, Abdul M.S. 2015. Nutriens (Phosphate, Nitrate), Dissolved Oxygen, and Dissolved pH And They Relation to Productivity of Jikumerasa Waters, Buru Island. Jurnal Pesisir dan Laut Tropis, 1(1): 43-50. [in Indonesian].

[9] Pong-Masak P.R, Asaad A.I.J, Hasnawi A.M, Pirzan, Lanuru M. 2010. Analysis of Waters Suitable for Development of Seaweed Culture in Batua Reef, Badi Island Pangkep Regency, South Sulawesi. Jurnal Riset Akuakultur, 5(2): 299-316. [in Indonesian].

[10] Prahasta, E. 2002. Basic Concepts of Geographic Information Systems. Informatika Bandung. Bandung. [in Indonesian].

[11] Serdiati.N., Widiastuti.I.M, 2010. Growth and Production of *Euchema cottonii* Seaweed at Different Depths. Media Litbang Sulteng III (1)21-26. [in Indonesian].

[12] Siddiqui, M.D.; Zaidi, A.Z.; Abdullah, M. Performance Evaluation of Newly Proposed Seaweed Enhancing Index (SEI). *Remote Sens.* **2019**, *11*, 1434. [in Indonesian].

[13] Sulistijo, 2002. Research on Cultivation of Seaweed (Macro Algae / Seaweed) in Indonesia. Main Research Expert Inauguration Speech in the Field of Aquaculture, Research Center for Oceanography LIPI. Page : 8. [in Indonesian].

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[14] Xing Q. An D, Zheng X, Wei Z, Wang X, Li L, Tian L, Chen J. 2019. Monitoring seaweed aquaculture in the Yellow Sea with multiple sensors for managing the disaster of macroalgal blooms. Remote Sensing of Environment. Volume 231, 15 September 2019, 111279. https://doi.org/10.1016/j.rse.2019.111279.

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