Potential Region for development of seaweed genus *Eucheuma cottonii* based on ENSO variability in east coast of Tarakan Island, Indonesia

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Abstract. *Eucheuma cottonii* is one of seaweed type that has high economic and important ecosystem for people living at coastal areas such as at the east coast of Tarakan island. This research aimed to analyse potential region of *Eucheuma cottonii* against ENSO variability. The suitability level required form calculation of sea surface temperature, total suspended solids, salinity, and dissolved oxygen (DO) in the east coast of Tarakan island. Remote sensing of Landsat 8 OLI has been applied to study environmental changes of those variables. The results showed the spatial and temporal condition of the Amal Coast conditions strongly influenced by the ENSO variability and it became barrier factor on the suitability of *Eucheuma cottonii* cultivation. In the El Nino period, the coast of northern and centre of east coast Tarakan Island shows the most potential areas for seaweed cultivation while in the period of La Nina the most potential area is along the coast and dominated in all parts of east coast Tarakan Island. Overall, in the La Nina period the potential area for seaweed cultivation was wider than El Nino.

1. Introduction

Indonesia is known as a country that has abundant natural resources. One of the potential natural resources in Indonesia is the resources of the coastal area [1,2]. Seaweed is a commodity that is in great demand today. The many benefits are the main reason for developing the cultivation of this plant. This potential also makes Indonesian seaweed popular in various parts of the world. Almost 555 types of seaweed in Indonesia currently become promising export commodities for Indonesia, both dried seaweed and processed from seaweed itself [1].

Tarakan city which is located in the geographical area 3°14'30" LU - 3°26'37" LU and 117°30'50" BT - 117°40'12" BT has a has a water area of 61.8% of the land area, equivalent to an area of 40,653 hectares. Seaweed cultivation in Tarakan Island has been going on for a long time, especially for the type of *Eucheuma cottonii*. At first it was only an alternative business for capture fishermen, when they stopped going to sea. But apparently this seaweed cultivation business is a very promising cultivation so that the seaweed cultivation business in Tarakan Island develops very rapidly and has a pretty good prospect, because it has an attractive market and price. It's just that, the development of seaweed cultivation still has problems there are no legal rules governing the activity of the cultivation, so it is not exposed to the wider community [3].
With the rapid advancement of remote sensing oceanography, can used to know the characteristics of seaweed cultivation *Eucheuma cottonii* which has high economic value and is currently a prima donna seaweed farmers community in Amal Coast. Remote sensing of oceanography can be use to determine the rapid changes in seawater conditions due to the seasons and climate and how changes in parameters of aquatic environments such as temperature, salinity, currents, and so on affect the conditions of seaweed growth in on the east coast of Tarakan island accurately. However, at present, the provincial government of Tarakan Island does not yet have sufficient spatial (space) or temporal (time) oceanographic data and information [3]. Therefore, this research is conducted by utilizing satellite oceanographic technology to simplify the monitoring of Amal Coast environmental condition caused by ENSO change and how its effect on the development of seaweed cultivation type of *Eucheuma cottonii*. This study is expected to provide general information on the variability of oceanographic conditions with parameters sea surface temperature, total suspended solids, chlorophyll-a, salinity, and dissolved oxygen (DO) in the east coast of Tarakan Island which is influenced by ENSO changes through satellite oceanographic studies in particular by using Landsat 8 OLI. From this research, it is expected to know the area of development of seaweed cultivation of *Eucheuma cottonii* which is optimal in the east coast of Tarakan Island by paying attention changes in aquatic environments.

2. Methods

Seaweed cultivation that has been running has not achieved optimal results, because the unsuitable between the seaweed biota with the cultivation area or unsuitable cultivation patterns based on the optimal development season for seaweed. Based on these conditions, one of the efforts made to improve the optimization of seaweed cultivation production is to conduct a good study on the suitability of the land as well as the suitability of spatial and temporal sea cultivation vegetation (based on ENSO variability) using remote sensing approach [3]. Data processing for variables such as sea surface temperature, chlorophyll-a and salinity can be known by remote sensing data using image data, in this study the image used by Landsat 8 OLI. The algorithm used is Mono-window Brightness Temperature which is basically used for surface surface temperature and then carried out land-to-sea surface conversion due to differences in heat absorption between water and land with Ali El Battay, Alaa El Sadek, and Mona Radwan in this following steps [3-5]:

**Digital number conversion into radians value**

\[ L_\lambda = M_L * Q_{cal} + A_L \]  

Where:
- \( L_\lambda \) = radians value
- \( M_L \) = Radian rescalling constant
- \( Q_{cal} \) = pixel value (DN)
- \( A_L \) = radians increasing constants

**Converting Spectral Radian into Kelvin**

\[ T_b = K_2/(ln(K_1/L_\lambda + 1)) \]  

Where:
- \( T_b \) = Brightness Temperature Satellite (K)
- \( K_1 \) = Calibration spectral constant
- \( K_2 \) = Constant temperature absolute calibration (K)
- \( L_\lambda \) = Spectral radians

**Conversion of temperature in units of Kelvin to Celsius**

\[ T_{Celcius} = T_{Kelvin} - 273 \]  

Where:
- \( T_{Celcius} \) = Temperature (°C)
- \( T_{Kelvin} \) = Temperature (°K)

**Conversion to the land surface temperature sea surface temperature**

\[ NST = (0.97*WST) \]
Where:
NST = Near Surface Water Temperature (°C)
WST = Water Surface Temperature (°C)

**Near Surface Water Temperature (NST)**
Algorithm will be converted to Near Surface Dissolved Oxygen (NDO) using the Ali El Battay algorithm, Alaa El Sadek, and Mona Radwanyat in this following step [4,5]:

1. NSDO = (-0.19*NST)……………………………………………………………………………… (5)
   Where:
   NSDO = Near Surface Dissolved Oxygen (mg/l)
   NST = Near Surface Water Temperature (°C)

To determine the total suspended solids in east coast of Tarakan Island, using algorithms that have been developed from previous studies (Budiman, 2004)

2. TSS (mg/l) = 8.1429 * exp \((23.704 \times \text{red band})\)…………………………………………………………………….. (6)

The algorithm equation in determining salinity value of aquatic uses algorithm obtained from research of estuary zonation boundary determination with equation of algorithm as follows:

3. Salinity = 29,983 + 165,047 \((B2) - 260,227 \ ((B3) + 2,609 \ (B4))………………………..……… (7)
   Where
   B2 = reflectance blue channel
   B3 = reflectance green channel
   B4 = reflectance red channel

In this study descriptive analysis and comparative analysis were conducted to see the spread and potential of *Eucheuma cottonii* seaweed area based on ENSO. Descriptive analysis is used to describe the data that has been collected descriptively so as to create a general conclusion, and comparative analysis by comparing the general value or data in each variable [3] [19]. To get the area of suitability, matrix and weighting method were used [3-5] (table 1).

| Parameters | Class / Class | Score | Weight |
|------------|---------------|-------|--------|
| Temperature (°C) | 26-32 | 3 | 1 |
| | 20-26 | 2 | 1 |
| | <20 or >32 | 1 | |
| Total suspended solids (mg/l) | 3.5-10 | 3 | |
| | 0.2-3.5 | 2 | 1 |
| | <0.2 | 1 | |
| Salinity (%) | <20 | 3 | |
| | 21-80 | 2 | 1 |
| | >80 | 1 | |
| Dissolved oxygen (mg/l) | 3-8 | 3 | |
| | 1-3 | 2 | 2 |
| | <1 | 1 | |

Weighting is based on the importance of each parameter sequentially, from the most important to the least important. Other than that each parameter will be divided into several classes that are scored and weighted based on the level of conformity value. Each parameter, weighting, and class score are determined by literature study, and justification from competent experts in the field fisheries, both in writing and orally. The total value of the multiplication of the weighted value of the parameter with the score then used to determine the suitability class of seaweed cultivation area based on water quality characteristics with the following calculation [3]:

4. \(Y = \Sigma a_i \cdot X_n\) ...................................................................................(8)
   Where:
   Y = Final Value
ai = Weight factor
Xn = Value of land suitability

The suitability class is obtained based on the Equal Interval method [7] to divide the range of values attribute into sub-ranges of the same size. Calculation are as follows:

5. \[ I = \frac{((\Sigma ai \cdot Xn) - (\Sigma ai \cdot Xn) \text{ min})}{k} \]

Where:
I = Interval of land suitability class
k = Number of land suitability classes used
ai = Score parameter to i,; i = 1,2,3 ... etc
Xn = weight to n

3. Discussion
Analysis of spatial (space) and temporal (time) distribution of oceanographic parameters of sea surface temperature, total suspended solids, salinity, and dissolved oxygen (DO) in the waters of the east coast Tarakan Island due to regional climate change ENSO (El Nino Southern Oscillation) specially at the period of El Nino and La Nina conducted using remote sensing of oceanography (Landsat 8 OLI) in order to know the best condition / in accordance with the growth of seaweed.

ENSO (El Nino / La Nina Southern Oscillation) is an anomaly that occurs in extreme climatic changes that occur beyond its normal frequency over the long term [6]. El Nino occurs because the East Pacific Ocean is under low pressure and the West Pacific Ocean is under intense pressure, causing the winds to weaken, even reversing the direction that causes eastern Australia to have rainfall under normal conditions. This resulted in some areas in Indonesia being dry, due to the decrease in rainfall under normal conditions [6]. On the other hand, La Nina occurs because the temperature of the sea surface in the East and Central Pacific Oceans is so low that the winds blow very hard and bring a moist air mass, resulting in the rainfall in eastern Australia to exceed its normal condition. This resulted in some regions in Indonesia will experience an increase in rainfall above normal conditions [6,8]. ENSO variability reviewed on period of El Nino were represented by the data on 01 March 2017 and La Nina are represented by the data on 15 September 2016.

3.1 Sea Surface Temperature
Temperature has a very important role for the growth of seaweed. Temperature affects the physiological functions of seaweed, such as photosynthesis, respiration, metabolism, growth and reproduction [9]. The ability of seaweed to adapt to the temperature of the environment is different, so that required temperature suitable for seaweed growth [10]. The appropriate temperature for seaweed cultivation is in the range of 26° -32° C. Analysis of variability of sea surface temperature during El Nino is shown in the Fig.1(left). Sea surface temperatures that were unsuitable with the suitability of seaweed (< 20°C and > 32°C) only slightly at east coast Tarakan Island. Sea surface temperature that were moderately suitable dominate mainly in the northern and western of east coast Tarakan Island with temperature of 20°- 36°C. Sea surface temperatures in suitable class spread at centre and southern of east coast Tarakan Island, precisely located at was around Amal Coast with the temperature 26° -32° C.

Whereas the analysis of variability of sea surface temperature during the La Nina is shown on the Fig.1 (right). Sea surface temperatures were unsuitable with the suitability of seaweed only slightly at east coast Tarakan Island with temperature (< 20°C and > 32°C), Sea surface temperatures that were moderately suitable class with temperature of 20°- 36°C was dominated same as El Nino period specially in the part of northern, centre and southern of east coast Tarakan Island. For the suitable class of sea surface temperatures (26° -32° C) were spread over the centre and southern of east coast Tarakan Island. Overall, sea surface temperatures that suitable for seaweed cultivation were found greater in La Nina than El Nino. The suitable class of sea surface temperature region of La Nina is spread by 48% while in El Nino it spreads only 21% of the total water area. However, the moderately suitable class were found more in El Nino which is which is 77% of the total area while at La Nina by 51% of the total area.
3.2 Salinity

Salinity is one of the parameters that is very important to know the growth of seaweed. According to [2] various salinity can produce seaweed growth to be abnormal. The most ideal salinity for seaweed cultivation is that it has water salinity ranging from 28-34 ppt, however, the optimum salinity for seaweed is 32 ppt [2,11]. Ideal salinity for the growth of Eucheuma cottonii seaweed activated 32 - 35 ppt. Analysis of salinity variability during El Nino is shown in the fig.2 (left). The value of salinity that were in unsuitable area (<28 ppt and > 35 ppt) were dominated almost at all the waters of east coast Tarakan Island except in northern. The salinity value that were in moderately suitable (28 - 32 ppt) were at the coast of Amal Beach. The salinity value that were suitable for seaweed (32-35 ppt) were at the coast of the Amal Beach that close to the moderately suitable area.

While the analysis of salinity variability during La Nina is shown in the fig.2 (right). The salinity value for unsuitable area (<28 ppt and > 35 ppt) were few and scattered on the waters of the northwest region of east coast Tarakan Island. For the moderately suitable area (28-32 ppt) were dominated and spread almost all parts of the waters of the east coast Tarakan Island. Then, for suitable area of salinity
value (30-34 ppt) were spread over the eastern, northern and southern waters of the east coast Tarakan Island. Overall, salinity value that suitable for seaweed cultivation were found greater in La Nina than El Nino. The region with an appropriate salinity value in La Nina is spread by 34% of the total area while in El Nino it is 26% of the total water area. The area of salinity value with moderately suitable class is also found in La Nina by 69% of the total area, while in El Nino only 18% of the total area.

3.3 Total Suspended Solid (TSS)
Total Suspended Solids (TSS) are positively correlated with turbidity. The higher the value of suspended solids, the higher the turbidity value [7]. However, high dissolved solids are not always followed by high turbidity as well as sea water [12]. According to Akbar and Sudaryanto (2002), the value of suspended solids suitable for seaweed cultivation activities is 0-20 mg / l, while the most appropriate one is 20-80 mg / l, and the one that is not suitable is more than 80 mg / l. Analysis of variability of Total Suspended Solids (TSS) during El Nino is shown in the fig.3 (left). Total Suspended Solids (TSS) that were unsuitable with the suitability of seaweed (> 80 mg/l) only slightly at northern of east coast Tarakan Island. Total Suspended Solids (TSS) in moderately suitable class (20 < x < 80 mg/l) spread at centre and northern of east coast Tarakan Island near the land. Total Suspended Solids (TSS) in suitable class (< 20 mg/l) spread at centre and southern of east coast Tarakan Island, precisely located at was around Amal Coast with the temperature 26°-32° C.

![Figure 3](image1.png)

**Figure 3** Total Suspended Solids (TSS) in El Nino period (left) and Total Suspended Solids (TSS) in La Nina period (right).

Whereas the analysis of variability of Total Suspended Solids (TSS) during the La Nina is shown on the fig.3 (right). Total Suspended Solids (TSS) in unsuitable class (> 80 mg/l) spreads in eastern of east coast Tarakan Island. Total Suspended Solids (TSS) that were moderately suitable (20 < x < 80 mg/l) was dominated almost all parts of east coast Tarakan Island. For the suitable class of Total Suspended Solids (TSS) (< 20 mg/l) were spread very slightly of east coast Tarakan Island. Overall, Total Suspended Solids (TSS) that suitable for seaweed cultivation were found greater in La Nina than El Nino. The suitable class of sea surface temperature region of El Nino is spread by 78% while in El Nino it spreads only 2% of the total water area. However, the moderately suitable class were found more in La Nina which is which is 87% of the total area while at El Nino by 18% of the total area.

3.4 Dissolved Oxygen
DO values will affect the growth of seaweed because of its effect on photosynthesis. According to SNI (2010), DO values that fall into the appropriate criteria are 3-8 mg / l [13,11]. Analysis of variability of Dissolved Oxygen during El Nino is shown in the fig.4 (left). Dissolved Oxygen that were unsuitable
with the suitability of seaweed (<1 mg/l) only slightly at southeast of east coast Tarakan Island. Dissolved Oxygen that were moderately suitable (1 < x < 3 mg/l) were dominated almost all parts pf east coast Tarakan Island except centre and north part. Dissolved Oxygen in suitable class (3-8 mg/l) spread at centre and northern of east coast Tarakan Island.

Figure 4 Dissolved Oxygen in El Nino period (left) and Dissolved Oxygen in La Nina period (right).

Whereas the analysis of variability of Dissolved Oxygen during the La Nina is shown on the fig.4 (right). Dissolved Oxygen were unsuitable with the suitability of seaweed (<1 mg/l) only slightly at southeast of east coast Tarakan Island same as El Nino Period. Dissolved Oxygen that were moderately suitable class (1 < x <3 mg/l) were spread in southern and northern of east coast Tarakan Island. For the suitable class of Dissolved Oxygen in suitable class (3-8 mg/l) were dominated almost all parts of east coast Tarakan Island except south and north part. Overall, Dissolved Oxygen that suitable for seaweed cultivation were found greater in La Nina than El Nino. The suitable class of sea Dissolved Oxygen of La Nina is spread by 77% while in El Nino it spreads only 19% of the total water area. However, the moderately suitable class were found more in El Nino which is which is 79% of the total area while at La Nina by 30% of the total area.

3.5 The Potential Region of Eucheuma cottonii During El Nino and La Nina

Model Builder used with enter a formula consisting of a matrix calculation suitability of parameters having weights and scoring [3]. Model Builder is an application that is inside the ArcGIS software useful for creating, modifying and organizing models, ie deep layers raster shapes that can be connected to each other by using geoprocessing device [14]. Matrix analysis of conformity for marine aquaculture activities begins with the preparation of suitability matrix. The computation matrix of suitability was performed for the grading of the rating scale as shown at Table 2.

Table 2. Suitability scores area of Eucheuma cottonii.

| No. | Total Score | Suitability level | Evaluation  |
|-----|-------------|-------------------|-------------|
| 1   | 67.336 – 76 | S1                | Very suitable |
| 2   | 58.668 – 67.335 | S2                | Suitable    |
| 3   | 0 – 58.667 | N                  | Unsuitable  |

fig.5 (left) is a map of the suitability of Eucheuma cottonii seaweed in east coast Tarakan Island in El Nino period. At the time of El Nino there are only two suitability classes that are suitable and very
suitable classes. In El Nino period, there were only two suitability classes, very suitable class and suitable class. The suitable class were dominated almost the entire territorial waters with an 85% of the total area whereas the very suitable class was located in the coastal area with 25% of the total area. A very different pattern was found on the map of the suitability of *Eucheuma cottonii* seaweed in east coast Tarakan Island at La Nina period. In La Nina period same as in El Nino period only has two classes, but in La Nina are unsuitable and very suitable class. The class of very suitable were dominated with 81% of the total area. Then for unsuitable class were scattered in the southeast, east and north of east coast Tarakan Island with 19% of the total area. Overall, at the La Nina period the potential area for seaweed cultivation was wider than El Nino period.

![Suitability Level](Figure 5) Potential Region of *Eucheuma cottonii* in El Nino period (left) and Potential Region of *Eucheuma cottonii* in La Nina period (right).

4. Conclusion

*Eucheuma cottonii* is one type of seaweed that has high economic value for people in east coast Tarakan Island. The remote sensing of oceanographic (Landsat 8 OLI) shows the spatial and temporal condition of the Amal Ocean coastal conditions strongly influenced by the ENSO variability and became barrier factor on the suitability of seaweed cultivation of *Eucheuma cottonii*. In the El Nino period, the coast of northern and centre of east coast Tarakan Island shows the most potential areas for seaweed cultivation while in the period of La Nina the most potential area is along the coast and dominated in all parts of east coast Tarakan Island. Overall, in the La Nina period the potential area for seaweed cultivation was wider than El Nino period. Based on the results of data processing, at the El Nino period and La Nina period, the coastal part of Amal Beach has the highest recommendation or appropriate for the development of seaweed cultivation.

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