The spatial pattern of seagrass distribution and the correlation with salinity, sea surface temperature, and suspended materials in Banten Bay

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Abstract. Seagrass is a flowering plant (Angiospermae) that lives submerged in the water. The sustainability of seagrass meadow depends on oceanographic conditions on its habitats including salinity, sea surface temperature, and total suspended solids (TSS). In the Banten Bay, there has been a change in oceanographic condition by natural process and human activities. The change of oceanographic condition will have an impact on the seagrass growth. Remote sensing method can be used to determine the spatial distribution of seagrass and the oceanographic condition that consist of salinity, sea surface temperature, and suspended materials. Therefore, the purposes of this study were 1) mapping the spatial distribution of seagrass and oceanographic condition using Sentinel-2A and Landsat 8 OLI/TIRS imagery and 2) to explain the correlation between seagrass distribution and the salinity, temperature, and suspended materials distribution. The results of this study are seagrasses in Banten Bay were lives in the salinity condition between 27‰ - 32‰, at the sea surface temperatures between 29°C-31°C, and at total suspended solids value between 19mg/l - 30 mg/l. The sea surface temperature is the oceanographic parameters that have the highest correlation with seagrass, followed by total suspended solids and salinity.

1. Introduction
Seagrass is a true flowering plant (Angiospermae) that lives in the water. Seagrasses are included into the three families of monocotyledonous, they have a root, rizhomes, and leaves. Seagrass has an important role in the coastal ecosystem. Seagrasses are providing habitat and for various marine biota, they have a role as a feeding ground, nursery ground, and spawning ground for various fish species [1]. In addition, seagrass has the ability to bind carbon dioxide (CO2), keep the stability of sediment in the water, and reduce the sea wave movement [2]

Indonesia sea territory is included in Asia-pacific bioregion of seagrass with the highest diversity of seagrass with 15 of 69 species found in the world [3]. Banten Bay is one of many regions in Indonesia that have a high diversity of seagrass with 5 of 15 species of seagrass found in the Indonesia sea territory. Seagrass in the Banten Bay can be found in the sand, sandy mud, and coral reefs [4].

Seagrass life is very dependent on water conditions. Seagrass can live optimally under conditions of temperatures between 25°C - 3°C, salinity 24‰ - 35‰, and suspended materials below 20 mg/l [5]. Recent years, seagrasses in Banten Bay are found to be under pressure from human activities and the changes of oceanographic condition. In 2010, there is some report about decreased of seagrass in Banten Bay from 45,2 ha in 2008 to 43,8 ha in 2010 [6]. The increased of human activity in the form of increased population, industry, coastal reclamation, sand mining, and shipping are reported causing the changes of oceanographic condition and make the coastal ecosystem are damaged [7].

The purposes of this study were to explain the distribution of seagrass in the Banten Bay and the relation with the oceanographic parameters that consists of salinity, temperature, and suspended materials. This study is used remote sensing imagery to mapping the distribution of seagrass, salinity, temperature, and suspended materials. Therefore, the seagrass distribution and the oceanographic condition can be mapped with a smaller time and can be recorded periodically.
2. Methods

2.1 Area of Study

The Banten Bay is located at $5^\circ 55' - 6^\circ 5' S$ dan $106^\circ 5' - 106^\circ 15' E$ and has a distance of about 175 km from the capital city of Indonesia, Jakarta. On the west side, the Banten Bay area was bordered by Tanjung Pontang, east by Tanjung Kapo, and north by the Java Sea. The total area of Banten Bay is 120 km$^2$ with a depth of not more than 10 meters, of mud and sand [4]. In Banten Bay area there are a group of small islands that consist of Pulau Panjang, Pulau Pamujan Besar, Pulau Pamujan Kecil, Pulau Pisang, Pulau Kubur, and Pulau Tarakan. Pulau Panjang is the only small island inhabited, while other islands used as tourism objects such as Pulau Pamujan Besar or that can be called Pulau Lima, Pulau Pamujan Kecil with the name of Pulau Empat, and Pulau Pisang called Pulau Lima. While other islands still untouched by humans or not yet managed.

![Figure 1. Area of Study](image)

2.2 The Data collecting

This study is used Sentinel 2A (June 16 and 2 November 2018) for mapping seagrass, salinity, and suspended materials in summer and rainy season, and Landsat 8 OLI/TIRS data (path / row: 123/64) for mapping the sea surface temperature. All of the imagery data were acquired from the United States Geological Survey (USGS). In this study, the band channels that used in Sentinel-2 are bands 4, 3, and 2 and in Landsat 8 OLI/TIRS in Band 10. The purpose of the selection these bands is to obtain spectral values from seagrass more efficiently.

Data on seagrass and oceanographic distribution consisting of salinity, temperature, and total suspended soil were taken from the field from 17-20 May 2018 and 2-4 November 2018. Data collected will be used as a validation of mapping results that using satellite imagery. Oceanographic data collecting was taken at 5 observation station points. The first station is in the western region of Panjang island, the second station is in the eastern region of Panjang island, the third station is on the Pamujan Besar island, the fourth station is on the Pamujan Kecil island, and the last station is on the Pisang island.

2.3 Data pre-processing

Data processing in this study were divided into three parts that consist of image correction, modeling, and classification. Sentinel 2A and Landsat 8 OLI/TIRS images were corrected using the Semi-Automatic Classification method to correct atmospheric errors and obtain reflectance values. The results of this step will be processed using several methods to obtain seagrass maps, salinity, temperature, and suspended materials.
2.4 Modeling

In this step, the atmospheric and radiometric corrected of Sentinel 2A images will be processed into three parts. The first will be corrected again using the dept invariants index (DII) method to reduce the influence of water in seagrass mapping. The second will be processed using the Buddhiman algorithm (2004) to calculate the distribution value of suspended materials. The third will be processed using the Cimandiri algorithm (2016) to obtain the value of salinity distribution. In the case of Landsat 8 OLI / TIRS images that have been atmospheric and radiometric corrected, band 10 will be taken to obtain the value of sea surface temperature.

2.4.1 Water column correction

Increased the depth of the water will affect the intensity of sunlight that enters the water. This causes the signals received by the remote sensing sensor will be different at the different depths. This difference will affect the results of submarine substrate mapping [8]. To reduce the influence of the depth of the sea water, an equation or algorithm is needed. In this study the method that used to reduce the influence of seawater in seagrass mapping is the depth invariance index (DII) [9] with the equations.

\[
DII_{ij} = \ln(L_i) - \left[\frac{k_i}{k_j}\ln(L_j)\right] \quad (1)
\]

\[
\frac{k_i}{k_j} = \alpha + \sqrt{\alpha^2 + 1} \quad (2)
\]

\[
\alpha = \frac{\sigma_{ii} - \sigma_{jj}}{2\sigma_{ij}} \quad (3)
\]

Where, \( L_i \) and \( L_j \) is the reflectance values of the band all \( i \) and \( j \), \( k_i / k_j \) is ratio attenuation coefficient of the band all \( i \) and \( j \), \( \sigma_{ii} \) is variance of the band \( i \), \( \sigma_{jj} \) is variance of the band \( j \) and \( \sigma_{ij} \) is covariance of the band.

![Image](image.jpg)

**Figure 2.** Image transformation results of Sentinel 2 (a) Original visual with RGB composite(b) atmospheric correction results (c) visual results of water column correction with DII

2.4.2 Oceanographic Parameters

To understand the seagrass distribution and the correlation with the oceanographic condition, this study is used three oceanographic parameters that consist of total suspended solids, salinity, and sea surface temperature. These three parameters are chosen because the role in influencing the seagrass growth is very important. These three parameters also have an unstable condition and these value can change periodically in a short time.

To measure the number of total suspended solids on Sentinel 2 Imagery, the algorithm that will be used in this study is Budhiman algorithm (2004)[10] with the equation is

\[
\text{TSS}^{(mg/l)} = 8.1429 \times \exp (23.704 \times \text{Red Band}) \quad (4)
\]

To mapping the distribution of salinity on Sentinel 2 Imagery, The algorithm that will be used in this study is Cimandiri Algorithm (2016) [11] with the equation is
Salinity = 29.983 + 165.047(Blue Band) + 260.227(Green Band) + 2,609 (Red Band) \hspace{1cm} (5)

To mapping the distribution of sea surface temperature on band 10 of Landsat 8 OLI/TIRS Imagery, The alghorithm that will be used in this study is Ardiansyah Algorithm \cite{12} with the equation is

\[
\text{Temperature} = \frac{K_2}{\ln\left(\frac{K_1}{\text{thermal band}+1}\right)} \hspace{1cm} (6)
\]

2.5 **Image classification**

The next step after modeling is to classification the seagrass area and oceanographic condition. To make the classification of seagrass distribution, the method that used is supervised classification Maximum Likelihood method with the help of 100 ground truths that obtained in the field. This classification divided into 3 classes that consist of seagrass, water, and land.

![Figure 3. Workflow of this study](image)

2.6 **Accuracy Assesment**

To obtain the value of mapping accuracy of seagrass, the method that used is confusion matrix. To obtain the value of mapping accuracy of oceanographic parameters, the method that used is a normalized mean error (NMAE). The accuracy is tolerated if NMAE value smaller than 30%.

3. **Results and Discussion**

3.1. **The Seagrass distribution**

The results of the seagrass mapping have an accuracy value of 78.31%. Several error sources were found because of the mixed object in one pixel and misclassification. The results of the seagrass mapping in 2018 show that seagrasses are agglomerated in the group of small island in the Banten Bay region. The estimated of the total seagrass area is 56.92 ha. The largest area of seagrass can be found in Panjang Island with the 35.3 ha area of seagrass. The growth pattern of seagrass in Banten Bay is linear with the coastline of the small island. Seagrass in the Banten bay can be found in the coral reef, dead coral, sand, and mud.
3.2 Salinity, temperature and suspended materials
The result of oceanographic parameters mapped are compared with the field data using the normalized mean absolute error (NMAE). The value of mean absolute error from the sea surface temperature is 0.81 (2.66%), the salinity is 2.57 (7.54), and suspended materials is 1.91 (9.75). These results mean that the mapping results can be used to explain the Banten Bay oceanographic condition because the error value is smaller than 30%.

Figure 5. Salinity (‰) distribution in Banten Bay June 2018
Figure 6. Temperature (°C) distribution in Banten Bay June 2018
Figure 7. Total suspended solid distribution in Banten Bay June 2018
The salinity distribution in the Banten Bay in June 2018 are at the interval between 22 \( \% \) - 42 \( \% \) and mostly at the interval between 31 \( \% \) - 34 \( \% \) in summer and 28 \( \% \) - 31 \( \% \) in the rainy season. The pattern of salinity distribution in the Banten Bay is the farther from the land the salinity value will be higher. The small salinity values will also be found in the estuary area, this is due to water input from the land. The most number of water input from the land can be found in the east of Banten Bay region and from Panjang Island.

The sea surface temperature of Banten Bay region is at the interval between 24\( ^\circ \)C - 32\( ^\circ \)C and mostly at the interval between 30\( ^\circ \)C - 31\( ^\circ \)C at the summer and 29\( ^\circ \)C - 30\( ^\circ \)C at the rainy season. The value of the sea surface temperature will be higher when approaching the land. This is evidenced in the south of Banten area that has a high sea surface temperature and reduced in the middle of Banten Bay and then increased again when approaching the Panjang Island. This pattern is caused by the intensity of sunlight that penetrated on water and the depth of water.

The total suspended solids of Banten Bay region is in the interval between 11 mg/l - 55 mg/l and mostly at the interval between 20mg/l - 25 mg/l at the summer and 35 mg/l - 40 mg/l at the rainy season. The value of total suspended solids will be higher when approaching the land, especially the area that nearly with an estuary, river, or fishpond. The highest value of total suspended solids can be found in the west of Banten Bay that nearly with the river.

### 3.3 The correlation between seagrass and the oceanographic condition

| Table 1. The correlation table |
|--------------------------------|
| **Salinity** | **TSS** | **Temperature** | **Seagrass** |
| 1              |          |              |            |
| -0.656377178  | 1        |              |            |
| -0.413205797  | 0.337243 | 1            |            |
| -0.056063141  | -0.05425 | 0.130443     | 1          |
Table 2. Seagrass optimum oceanographic condition in Banten Bay

| Condition in Banten Bay | Seagrass optimum condition | Oceanographic category |
|-------------------------|----------------------------|------------------------|
| Salinity                | 27%0/00 - 32%0/00          | 24-35 %0/00            | Good                   |
| TSS                     | 29°C-31°C                  | 25-30°C                | Good                   |
| Temperature             | 19mg/l -30 mg/l            | <20 mg/l               | Enough                 |

In the result of seagrass mapping, there are 55 samples are taken that consist of 40 seagrass points and 15 non-seagrass points. The samples were taken are processed using correlation table method to explain the correlation between seagrass and the oceanographic condition that consist of salinity, temperature, and suspended materials. The results from the correlation table show that seagrasses have a tendency to live in conditions of salinity that not too high, the value of suspended solid that not too concentrated, and the condition of temperature that not too low. Table 1 also shows that the sea surface temperature has the highest correlation with seagrass, followed by total suspended solids and salinity. Seagrass that lives in the Banten Bay is in the range of salinity between 27%0/00 - 32%0/00, at the sea surface temperatures between 29°C-31°C, and at total suspended solids value between 19mg/l -30 mg/l. According to seagrass optimum oceanographic condition, the sea surface temperature and salinity in the Banten Bay are still good for seagrass, but the suspended materials must be evaluated again to make the seagrass habitats condition better.

4. Conclusions

The seagrass distribution pattern in the Banten Bay is agglomerated linearly in the coastline of the groups of the small island with the estimated large at 56,92 ha in 2018. Seagrass life growth is very dependent on oceanographic conditions of their habitat, including salinity, sea surface temperature, and total suspended solids. The sea surface temperature is the oceanographic parameter that has the highest correlation with seagrass, followed by total suspended solids and salinity. The seawater condition in the Banten Bay that seagrass were lives are in the salinity condition between 27%0/00 - 34%0/00, at the sea surface temperatures between 29°C-31°C, and at total suspended solids value between 19mg/l -30 mg/l. According to both season, summer and rainy season, the oceanographic condition that consists of salinity, sea surface temperature, in the Banten Bay is still feasible for seagrass life.

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References

[1] Phillips R C and Milchakova N A 2003 Marine Ecological 2
[2] Hernawan E U, Sjafrrie N D M., Supriyadi I H, Suyarso, Iswari M Y, Anggraini K and Rahmat 2017 Status padang lamun indonesia (Jakarta: Puslit Oseanografi LIPI)
[3] Short F, Carruthers T, Dennison W, and Waycott M 2007 Journal of Experimental Marine Biology and Ecology, 350(1-2), 3-20.doi:10.1016/j.jembe.2007.06.012
[4] Kiswara W 2004 Kondisi Padang Lamun (seagrass) di Teluk Banten 1998-2001 (Jakarta: Pusat Penelitian dan Pengembangan Oseanologi-LIPI)
[5] Hemminga, Marten A, and Carlos M Duarte 2000 Seagrass ecology. (Cambridge University Press) doi:10.1017/cbo9780511525551.001
[6] Setiawan F, Harahap S A, Andriani Y, & Hutahaean A A 2012 Jurnal Perikanan Kelautan 3 3
[7] Yunus S 2008 *Penilaian Dampak Aktivitas Manusia Pada Kerusakan Ekosistem Padang Lamun di Pantai Barat Teluk Banten* (Jakarta: Tesis Program Studi Ilmu Lingkungan – Universitas Indonesia)

[8] Chen C F, Lau V K, Chang N B, Son N T, & Chiang S H 2016 *Ecological informatics* **35** 43-54. doi:10.1016/j.ecoinf.2016.07.005

[9] Lyzenga D R 1981 *International journal of remote sensing* **2** 71-82 doi:10.1080/01431168108948342

[10] Budhiman S, Suhyb S M, Vekerdy Z, and Verhoef W 2012 *Journal of Photogrammetry and Remote Sensing* **68** 157–169. doi:10.1016/j.isprsjprs.2012.01.008

[11] Supriatna L, Supriatna, J, Koetsoer R H, & Takarina N D 2016 *AIP Conference Proceedings* **1729** AIP Publishing. doi:10.1063/1.4946982

[12] Ardiansyah 2015 *Pengolahan Citra Penginderaan Jauh Menggunakan ENVI 5.1 Dan ENVI Lidar Jakarta* : Lab SIG Inderaja Islim)