Detection of seagrass distribution in Bintan Island using SPOT-7 Satellite Imagery and Unmanned Surface Vehicle (USV)

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Abstract. Seagrass has a very important role as a natural barrier to currents and waves from open water. In addition, it plays a significant role in carbon sequestration and storage. In this study, we used SPOT-7 Satellite to detect seagrass distribution in Bintan Island. Bintan Island has the largest seagrass conservation area in Indonesia. The field survey for data collection used an Unmanned Surface Vehicle (USV). Seagrass area is obtained by classifying several objects in the shallow water by using Maximum Likelihood Classification algorithm. The seagrass area in the Bintan Island covered about 142.45 ha in 2018, and from the underwater visual system, it was detected that the type of seagrass that dominates the area is Thallasia hemprichii and Enhalus acroides. Therefore, by combining the SPOT-7 satellite imagery and USV we can detect and quantify the seagrass.

Keywords: seagrass, SPOT-7 satellite, unmanned surface vehicle

1. Introduction

Seagrass is a plant (Angiospermae) where seagrass can live in high salinity seawater that lives submerged in water. Seagrasses are usually found in tropical and subtropical areas. Seagrass communities have important ecological and biological functions in coastal areas and estuaries [1]. In general, seagrass ecosystems are located in coastal areas near the coast with a depth of less than 5 m. Seagrass ecosystems have ecological roles and functions and important values for humans, namely as the main source of primary productivity, food source for benthic organisms, stabilizer of the sea bottom, shelter for marine biota, breeding place, nurturing, food source for biota - marine life, coastal protection by reducing currents and generate and reduce CO₂ in the bottom waters [2]. Seagrass in Indonesia with an area of three million hectares are the second largest after Australia [3]. In 2018, the area of seagrass was recorded at 293,464 ha and was included in an unhealthy condition. In general, the distribution of most seagrass species in Indonesia is dominated by seagrass species Enhalus acroides and Thalassia hemprichii [4]. Based on observations of seagrass health in Bintan by COREMAP-CTI 2019, the seagrass health were classified as moderate with an average cover of 31.36±10.9%. In Bintan Island, there are nine species of seagrass as have high species diversity [5]. Shallow water mapping can be done using remote sensing technology by optical sensors of various low, medium, and high resolutions. Technology from remote sensing is needed for data correction to reduce the effects or errors from recording the satellite image used [6]. Using remote sensing for the detection of shallow water does not require a long time, and the cost is relatively cheap. There are also many remote sensing satellites that have many sensors and good capabilities to detect various shallow marine ecosystems [7]. One of the satellite images that can be used to detect the area and vegetation of seagrass is the SPOT-7 image. The SPOT-7 image has a spatial resolution of 6 meters and the sensor is equipped with a wavelength of 0.6 – 0.7µm for the red band, 0.7 – 1.0 m for the infrared band, it shows that the SPOT-7 image has a high...
sensitivity to vegetation [8]. This research Unmanned Surface Vehicle is used which functions to retrieve and collect required data information such as detect underwater vegetation, namely seagrass. USV is a vehicle that can operate on the surface of the water without having a crew that reaches the waters. USV as a vehicle for detecting seagrass ecosystems has several advantages, namely the USV can be used for a longer duration of time than other rides that have a crew, the costs used to carry out maintenance on the USV are relatively cheap. The USV is a vehicle with a lighter weight made it easier to transport. Move in shallow water and the USV can accommodate a large payload [9]. The purpose of this research to detect the area seagrass based image SPOT-7 satellite imagery and test accuracy with USV data on Beralas Pasir and Beralas Bakau Island. In this study, mapping of seagrass in Bintan Island with a study of the Beralas Pasir and Beralas Bakau Island area using SPOT-7 imagery and testing with USV field data has never been carried out. With the results of the combination of satellite imagery and USV field data, classification and accuracy tests can be obtained from image detection and the extent of seagrass beds in the study area.

2. Materials and Methods
The field survey was conducted in September 2018 in Pulau Beralas Pasir, Bintan, Riau Islands. The map of the research location is presented in Figure 1. The data analysis process was carried out at the Marine Remote Sensing Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University.

2.1. Data processing procedure
Data processing includes collecting SPOT-7 2018 image and collecting in-situ data using USV. The underwater camera of USV produces video footage of seagrass vegetation observed at the waypoints. USV moves to follow predetermined waypoints in parallel with three transects with a length of 100 meters each, and the distance between one transect and another is 50 meters (Figure 2). Therefore it is in accordance with seagrass data collection, and then the category of seagrass cover was determined.
(Table 1). After that, the USV recording data (*txt) began to be separated by 40% of the data for training data and 60% of the data for the accuracy test.

![Line and square transects for data collection of seagrass](image)

**Figure 2.** Line and square transects for data collection of seagrass [10]

**Table 1.** Category of seagrass cover percentage.

| Category          | Percentage of seagrass coverage |
|-------------------|---------------------------------|
| Rare Seagrass     | 1-30 %                          |
| Medium Seagrass   | 30-70 %                         |
| Dense Seagrass    | 70 %                            |

Source: Federal Geographic Data Committee/FGDC [11]

Data processing starts with cropping the image using ENVI 5.3 software. Then, atmospheric correction and radiometric calibration were carried out. In the image used, geometric correction is no longer carried out because it has been geometrically corrected from the National Institute of Aeronautics and Space (LAPAN). The images band used consist of red band (b3), blue band (b2), green band (b1), and band NIR to perform band composites. Furthermore, correction of the water column is carried out, which is very important for detecting and identifying underwater objects including seagrass. After that, the classification was carried out using a supervised classification which is a guided classification, and then the accuracy test was carried out. The schema of the data processing procedure is presented in Figure 3.
2.2. Data processing

2.2.1. Image cropping. Image cropping is a technique used to determine exactly which part of the image contains the object area to be processed to be cropped and separated from areas that are not needed for further processing.

2.2.2. Radiometric calibration. Radiometric calibration are errors caused by disturbances in the atmosphere and topographic variations, so that is extrinsic. Disturbances caused by refraction, absorption, scattering [10]. The radiometric correction carried out includes several steps to convert the pixel value (DN) to the radiance of the object’s reflection. Calibrate the Digital Number (DN) value to the Top of Atmospheric (TOA) spectral radiance value. The formula table is presented in Table 2. The equations used are:

\[ \text{Lb}(p) \frac{\text{DN}(p)}{\text{GAIN}(b)} + \text{BIAS} \]  

(1)

Notes:
- Lb (p): value at-sensor radiation (watts/m².sr.μm)
- DN: bands (p)
- GAIN (b): Gain value

**Table 2. SPOT-7 Image gain and bias formula**

| Band       | Gain   | Refraction | Formula            |
|------------|--------|------------|--------------------|
| Band 0 (Blue) | 10.28  | 0          | (B0/10.28) + 0     |
| Band 1 (Green) | 11.19  | 0          | (B1/11.19) + 0     |
| Band 2 (Red)  | 16.95  | 0          | (B2/16.95) + 0     |
| Band 3 (NIR)  | 8.92   | 0          | (B3/8.92) + 0      |

Converting the spectral radian to the spectral reflectance by normalizing the irradiance value by converting the spectral radian value by notice to the cosine value of the sun angle (LAPAN). The equations used are:
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\[ Pb (p) = \frac{\pi \cdot Lb(p) \cdot d^2}{E0 (b) \cdot \cos (\theta s)} \]  

(2)

Notes:
Pb: reflectance above the atmosphere
\(\pi\): 3.141593 (22/7)
Lb: radians above atmosphere
E0 (b): Irradiance sun for each band (b)
\(\cos (\theta s)\): Sun zenith angle, \(\cos (\theta s) = (900 - \text{sun elevation}) (0) (53.5781876773) \times (\pi/180)\)
d²: earth sun distance ratio, \(d^2 = (1-0.01674 \times \cos(((\text{julday}/365) \times 360)/180 \times \pi))\)

2.2.3. Atmospheric correction. Atmospheric correction is a correction made to improve image quality due to disturbances that occur in the atmosphere, such as cloud scattering [10]. Atmospheric correction using Dark Object Subtraction (DOS). Atmospheric correction is carried out by considering several factors of atmospheric parameters such as weather, the climate at the location of image recording. The assumption is that some pixels are covered by clouds considering that some targets on the earth's surface are black, and it is assumed that the minimum reflectance percent is better than zero percent [11]. The equations used for atmospheric correction are:

\[ NP' = NP - NP_{min} \]  

(3)

Notes:
NP': Score corrected pixels
NP: Score image pixels on a particular channel
NP_{min}: Minimum pixel value

2.2.4. Water column correction. Water column correction serves to reduce spectral habitat errors due to the water depth factor because the light upward from below is an exponential function of water depth [13]. The effect of the water column correction can be done using the Lyzenga algorithm with the formula:

\[ \frac{Ki}{Kj} = \sqrt{a + (a^2 + 1)} \]  

(4)

\[ a = \frac{\text{var } Bi - \text{var } Bj}{2 \times \text{cov } BiBj} \]  

(5)

Thus, the formula for Lyzenga [16] is obtained:

\[ Y = \ln(Bi) - \left[ \left(\frac{Ki}{Kj}\right) \times \ln (Bj) \right] \]  

(6)

Notes:
Ki/Kj: Ratio of coefficient of attenuation of water column
a: weakening of the water
var Bi/Bj: Variance of band i, band j, and so on
covar Bi/Bj: Covariance of band i, band j, and so on
Y: Water column corrected image (Lyzenga)
Ln: Function ln
Bi: Blue band reflectance value
Bj: Green band reflectance value
2.2.5. **Image Masking.** The image masking process is carried out to separate land and water or other objects. Masking is the stage of separating land and water areas by creating a DN value block with a zero value. Image masking is done so that the restricted area does not affect shallow waters [14]. When classification is carried out. Masking is done by a manual technique that is visually seen from the study area with manual digitization on land and high seas. The cutting or digitization process is carried out by applying a near infrared (NIR) band on the SPOT-7 image for a visual display of the image so that the boundary between land and sea is clearly visible.

2.2.6. **Supervised classification** The supervised classification method identifies the information class first, which is then used to determine the spectral class that represents the information class [15]. The method used in this research is Maximum likelihood classification which considers the probability factor of one pixel to be classified in a certain category [16].

2.2.7. **Accuracy Test.** The accuracy test is used to determine the level of error caused when the classification process is carried out. The accuracy test was carried out using the confusion matrix, which is presented in Table 3.

| Reference Data | Classified into class 9 data class on the map | Amount | User's accuracy |
|----------------|-----------------------------------------------|--------|----------------|
| A              | xii                                           | Xi+    | Xii/Xi+         |
| B              |                                               |        |                |
| C              |                                               |        |                |
| D              |                                               |        |                |
| Column Total   |                                               | Xi+    | Xii/Xi+         |
| Producer       |                                               |        |                |
| accuracy       |                                               |        |                |

| Formula         | Equation |
|-----------------|----------|
| User's accuracy | $\frac{X_{ii}}{X_{i+}} \times 100\%$         | (7)    |
| Producer's accuracy | $\frac{X_{ii}}{X_{i+}} \times 100\%$         | (8)    |
| Overall accuracy | $\sum_{i} \frac{X_{ii}}{X_{i+}} \times 100\%$ | (9)    |

Mathematically, the accuracy test can be stated as follows:

Information:
- $x_{ii}$ : the diagonal values of the i-th row and i-th column contingency matrices
- $X_{i+}$ : number of pixels in row i
- $X_{i}$ : number of pixels in column i

3. **Result and Discussion**

3.1. **Seagrass condition in Beralas Pasir Island**

Seagrass beds in the eastern waters of Bintan Island have a high diversity of seagrass because they have nine types. Beralas Pasir and Beralas Bakau are located in the eastern waters of Bintan Island and with the North Natuna Sea. In the 2019 observations, the seagrass beds on Bintan Island had seagrass moderate health conditions with an average cover ranging from 10.9% to 31.36%. Seagrass are dominated by *Thalassia hemprichii* and *Enhalus acroide* species. Beralas Pasir and Beralas Bakau Island with characteristic rocky beaches. Around the monitoring station, several stake houses function as shelters or lodging for tourists. Tourist activities include fishing and taking shellfish. The seagrass beds on the Beralas Pasir Island have a substrate that is dominated by coral rock, coral fragments, and a little sand (Figure 4). At the time of observation, the weather was clear with low tide conditions. The
Seagrass communities in the study area were composed of four species observed; they were *E. acoroides, T. hemprichii, H. uninervis, H. ovalis*. Seagrass communities had an average cover of 27.72±19.9%, which was dominated by *T. hemprichii* (16.63±12.9%). Meanwhile, the seagrass stands at this station are 25.68±26.7 m-2 stands. Seagrass communities at this station are classified as moderate and unhealthy status.

![Figure 4](image.jpg)

**Figure 4.** Research location of Beralas Pasir and Beralas Bakau Island, Bintan Islands [5].

### 3.2. Image Correction

#### 3.2.1. Radiometric calibration

Radiometric calibration is an initial correction that needs to be done prior to the atmospheric correction stage. The SPOT-7 image used in this study has a radiometric resolution of 12-bit. Brightness level the digital value is converted to TOA spectral radiance into energy units Watt/m² str.μm. The following describes the difference between before and after the TOA spectral radiance correction by displaying the digital-pixel values. Visually there is no visible difference in Figure 5 because the image used is a high resolution image. Therefore, the differences can be seen in Table 4 and Table 5. In the results of the radiometric calibration conversion, it can be seen the changes in the values generated from the max, mean, and standard deviation columns for the digital number conversion and spectral radiance conversion. At each processing, the function is to reduce disturbances in the atmosphere and topographic variations in the form of refraction, absorption, and scattering.
3.2.2. Atmospheric correction. This study used Dark Object Subtraction (DOS). DOS functions to correct pixel values due to atmospheric disturbances, increase pixel values due to atmospheric disturbances. The histograms for the four bands (blue, green, red, NIR) are presented in Figure 6. In addition, the histogram results from atmospheric correction using dark object subtraction. In the histogram, we can see that each band in the data value has shifted to zero, which means that in the four bands, namely the red, blue, green, and NIR bands, the pixels have been corrected due to disturbances in the atmosphere. If there is no error in the atmosphere, the object will be dark, or usually water and the cloud shadow should have a zero pixel value. If there is no 0 value on the object, then the value is biased.
3.2.3. **Water column correction.** The method used in this water column correction is the algorithm developed by Lyzenga. The first step is to select a point of ROI (Region of Interest) for the sand substrate at various depths. Two depth categories were selected for the sand ROI, namely near shore and seafront. The assumption of sand selection is because objects are easily found or recognized with varying pixel values at different depths. From 100 samples of sand, ROI was selected for further extraction of pixel values, and all pixel values were normalized (ln). The normalized pixel values (ln) are entered into the bi-plot to create a linear regression between the visible band pairs. Regression analysis shows that the relationship of sand values at different depths between channel pairs appears to be high. It is indicated by all the values of R² (determinant coefficient) between the channel pairs that appear to be more than 0.6. The results of the linear regression for each bi-plot are shown in Figure 7. The results of the DII are presented in Figure 8.

![Figure 7. Bi-plot band pairs of B1 (blue) and B2 (green) with 100 samples ROI.](image1)

**Figure 6.** Histogram of DOS atmospheric correction at SPOT-7 Image.

**Figure 8.** Result of DII.
3.3. *Classification of seagrass in Beralas Pasir Island.*

The classification of seagrass is based on the percentage category of seagrass cover presented in Figure 9. The classification results using SPOT-7 imagery are divided into four density classes, namely rare seagrass, dense seagrass, medium seagrass, and not seagrass. It is clear visually in Figure 9 that seagrass is more dominant in the study area. Seagrass on the Sand-Based Island has a substrate that is dominated by coral, coral rubble, and a little sand, and the total sample used in this classification is 40% of the 82 sample points generated by USV. The selection of field points for the classification process by taking into account the homogeneity of the field sample points in each category is spread out to represent the region in the image.

![Seagrass Classification in Beralas Pasir Island and Beralas Bakau Island](image)

**Figure 9.** Result of seagrass classification using SPOT-7 image in Beralas Pasir and Beralas Bakau Islands.

3.4. *Seagrass area calculation results*

The results of the calculation of the seagrass area can be seen that non-seagrass has an area of 14.21 ha, dense seagrass is 41.37 ha, medium seagrass is 61.67 ha, and rare seagrass is 38.94 ha. The distribution of seagrass in Beralas Pasir Island and Beralas Bakau Island varies, but seagrass is currently occupying the highest area of 61.87 ha. Thus, the total area of seagrass in the study area based on the SPOT-7 image classification and several sample points from USV is 142.45 ha. From the seagrass area results, that medium seagrass dominates in this area, because in general seagrasses usually have muddy, sandy, clay, and coral substrates. Meanwhile, this area only has a coral substrate and is slightly sandy, so that it is difficult for seagrass to grow either homogeneously or heterogeneously to form thick grasslands. In addition, human activities such as fishing and taking shellfish also affect the growth of seagrass. Figures 10, 11 and 12 can also be seen in the detection results from USV, which are then visually classified for density.

![Dense seagrass by USV detection.](image)

**Figure 10.** Dense seagrass by USV detection.
3.5. *Accuracy Test*

The accuracy test presented in Table 6. The highest producer accuracy was in medium seagrass, which was 83.33% and the smallest was in dense seagrass at 12.5%. The low value of producer accuracy in dense seagrass is due to the large number of sample points that fall on pixels classified as medium seagrass. The highest user accuracy value is in the non-seagrass class of 92.86%, which indicates the class is classified correctly, and the smallest value is in the dense seagrass, which is 33.33%. The overall accuracy value is a value that describes the correct classification of a classification. The overall accuracy value is 66.66%, which means that 66.66% of the pixels in the SPOT-7 image classification are correctly classified. This value is most widely used to show the accuracy of classification. However, the weakness of this method is that it does not consider the error aspect of each existing class; therefore, overall accuracy is usually accompanied by the user's accuracy and producer's accuracy for each class [17]. The resulting kappa coeff value is 0.53 which means that the classification results can avoid 0.53 errors that will appear in random classification. According to LIPI (2014), the results of the SPOT-7 image accuracy test using DII can be said to be good because the acceptable accuracy limit for shallow water basic habitat maps is 60%. The result can be seen in Table 6.
Table 6. Result of accuracy test.

| Classification Results | Rare Seagrass | Medium Seagrass | Dense Seagrass | Not Seagrass | Total | UA (%) |
|------------------------|---------------|-----------------|----------------|--------------|-------|--------|
| Rare Seagrass          | 15            | 2               | 0              | 8            | 25    | 60.23% |
| Medium Seagrass        | 7             | 15              | 2              | 0            | 24    | 62.50% |
| Dense Seagrass         | 1             | 1               | 1              | 0            | 3     | 33.33% |
| Not Seagrass           | 1             | 0               | 0              | 13           | 14    | 92.86% |
| Total                  | 24            | 18              | 3              | 21           | 66    |        |
| PA (%)                 | 78.95%        | 83.33%          | 12.5%          | 61.90%       |       |        |
| OA (%)                 | 66.66%        |                 |                |              |       |        |

4. Conclusion

Based on the analysis of the SPOT-7 image data classification, the distribution of the seagrass area on Beralas Pasir and Beralas Bakau Island the highest is medium seagrass with an area of 61.78 ha, and the total seagrass area based on the SPOT-7 image classification is 142.45 ha in 2018. Mapping of seagrass on the Beralas Pasir and Beralas Bakau Island resulted in an overall accuracy value of 66.66%, which means 66.66% is classified correctly.

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