Changes of seagrass area in Beralas Pasir and Beralas Bakau Island observed from Sentinel-2 Satellite and verified by Unmanned Surface Vehicle (USV)

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Abstract. Today, the area of seagrass ecosystems in Indonesia is estimated to have shrunk significantly. Bintan Island has quite a large seagrass ecosystems area. Along with the development of satellite technology, monitoring of conditions and changes to a coastal ecosystem can be carried out effectively through remote sensing technology. One satellite image that is relatively new and has good spatial quality is Sentinel-2 with a spatial resolution value of 10x10 m² / pixel. Field data retrieval is facilitated by the use of Unmanned Surface Vehicle (USV). This research went through several stages such as image pre-processing, water column correction, masking, unsupervised classification, and detection of changes of seagrass area. The data obtained from the USV becomes the data for the accuracy-test in the supervised classification. Seagrass area was obtained in Beralas Pasir and Beralas Bakau Island is 84.27 ha (2016), 81.3 ha (2019) and 77.4 ha (2021). Detection of seagrass to non-seagrass area changes resulting 31.35 ha (2016-2019) and 30.91 ha (2019-2021). On the other hand non-seagrass to seagrass area is 24.84 ha (2016-2019) and 27.98 ha (2019-2021). The accuracy test of 2019 image classification and Unmanned Surface Vehicle data resulting overall accuracy at 62.20%.

Keywords: Beralas Bakau, Beralas Pasir, seagrass, Sentinel-2, USV

1. Introduction

Seagrass is an aquatic flowering plant that has the ability to adapt to live and grow in the marine environment [1]. Seagrass has high primary productivities and is a place for nutrient cycle and habitat for marine biota [2]. Seagrass is also the only flowering plant in the sea that has an important role in carbon sequestration in the sea [3]. Apart from holding carbon concentration in the sea, seagrass as an ecosystem with high primary production also functions to maintain and keep the productivity and stability of coastal and estuary ecosystems [1]. Today, the area of seagrass ecosystems in Indonesia is estimated to have shrunk significantly. This results from physical development on the coastline, pollution, destructive fishing, and over-fishing [3]. In addition, anthropogenic activities result in a decrease in water quality and natural activities which then damage the seagrass ecosystem [4].

Bintan Island has a quite large seagrass ecosystems area due to the mild sloping topography of the coast of the island and enhanced by a sandy and muddy bottom substrate that makes seagrass grow well [5]. However, the development of time and high activities such as development in coastal areas can suppress environmental changes that affect the seagrass ecosystem [6]. Along with the development of satellite technology, monitoring of conditions and changes to a coastal ecosystem can be carried out.
effectively through remote sensing technology [7-8]. One satellite image that is relatively new and has good spatial quality is Sentinel-2 with a spatial resolution value of 10x10 m² / pixel [9].

The difficulty of collecting underwater and seabed visual data directly in the field is due to the vast terrain and limited equipment to collect data [10]. One of the developed tools to assist data collection in shallow water is the Underwater Visual System. This tool is a vehicle that operates on the surface of the water without personnel in it. Monitoring activities of a study can be made more accessible by using USV because this vehicle can run autonomously on the desired location path [11]. The purpose of this research is to map the area and the changes are of seagrass in Beralas Pasir and Beralas Bakau Islands using Sentinel-2 Satellite and verification using data from Unmanned Surface Vehicle.

2. Materials and methods

2.1. Time and research location

This research is divided into two stages, conducted with field data collection and data processing. Field data collection was carried out in September 2018 in the waters of Pulau Beralas Pasir, Bintan, Riau Islands (Figure 1). Data processing is carried out at the Mapping and Spatial Modeling Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University from September 2020 to July 2021.

![Figure 1. Research site map in Beralas Pasir, Bintan, Riau.](image)

2.2. Data and tools

The tools and materials used in this study are divided into two parts. In the first part, the tool used for field data retrieval is Unmanned Surface Vehicle, which then the results of this tool are used as field data. While the second part is the tools used for data processing, such as laptops, ArcGIS 10 software, QGIS 3.14 software, ENVI 5.3 software, Microsoft Word 2013 software, and Microsoft Excel 2013 software, Image Sentinel-2 2016, 2019, and 2021. Materials and sources can be seen in Table 1.

| No | Data                          | Data Sources          | Resolution   |
|----|-------------------------------|-----------------------|--------------|
| 1  | Sentinel-2A image             | Scihub Copernicus     | 10x10 m      |
|    |                               | ([https://scihub.copernicus.eu](https://scihub.copernicus.eu)) |             |
| 2  | Unmanned Surface Vehicle data | Satria MGA, 2019      |              |
2.3. Data processing and analysis
The stages of data processing consist of image pre-processing, water column correction, image classification, accuracy test, and image change analysis. The stages of the research procedure can be seen in Figure 2.

![Data processing flow chart.](image)

The field data in this study was obtained from the research conducted by Satria MGA (2019) in Beralas Pasir Island, Bintan Islands, Riau which was taken via an Unmanned Surface Vehicle (USV) equipped with an underwater camera [11]. USV records a 19-minute water column video with a resolution of 640x480 pixels with a framerate of 30 fps. The field data were then visually classified into three density classes [12] as shown in Table 2.

| Classification       | Description                  |
|----------------------|------------------------------|
| Dense Seagrass       | Percentage of seagrass cover >70% |
| Medium Seagrass      | Percentage of seagrass cover 30-70% |
| Rare Seagrass        | Percentage of seagrass cover 1-30% |
The satellite image data used is Sentinel-2A image which was acquired on 5 July 2021 from the https://scihub.copernicus.eu page. Sentinel-2 image pre-processing begins with geometric correction. This correction was done by looking at the value represented by the difference between the coordinates of the transformed control point and the coordinates of the control point, known as the RMS error. The lower the RMS error value will produce accurate results [13]. A geometric correction was carried out through image data and field data obtained from the Unmanned Surface Vehicle. Then the stage of image cropping is carried out to have an appropriate location. This cropping makes it easier for researchers or image users to carry out further analysis and processing on the image [14]. The last step of the image pre-processing is Atmospheric correction, which is a process to eliminate errors caused by the influence of the atmosphere on the image [15].

Identifying something that is in the water column certainly does not escape the disturbances contained in the water column. Turbidity and depth affect the penetration of light into the water column which then interferes with the image processing process. Described in [7] research, one method to reduce water column disturbances can use the water column correction using the Depth Index Invariant (DII) method developed by Lyzenga [18], with the following equation.

\[
DII = \ln Li - \left[ \frac{Ki}{Kj} \times \ln Lj \right]
\]

This water column correction aims to correct the pixels value due to the effect of attenuation of energy by the water column. The weakening effect of the water column causes different pixel values on the same object but at different depths [19]. This study uses sand object reflectance values at different depths because sand objects are most easily recognizable visually.

Unsupervised classification is the process of grouping pixels in the image into several classes using cluster analysis [20]. This study uses the unsupervised classification Iterative Self-Organizing Data Analysis Technique (ISODATA) method. The ISODATA method uses a minimal formula to group pixels in a multispectral image to produce relatively homogeneous clusters [21].

The accuracy test was carried out to ensure and confirm that the analytical method used was appropriate [22]. This stage is carried out by comparing the image from the result of the classification to the actual class or object obtained based on observations in the field [23]. The accuracy test was carried out using the data from the Sentinel-2 2019 image classification with field data obtained through the Unmanned Surface Vehicle. The accuracy calculation method uses the Confusion Matrix method [24].

The detection of seagrass cover changes is using the post-classification comparison method. This method uses the extraction of information changes from two classified images, either thematic or categorical information [25]. This method detects changes by comparing two classifications obtained by classifying them independently and seeing the changes between two images from the same area at different times [3, 26]. This study detects changes in Sentinel-2A Image from 2016 to 2019 and Sentinel-2A Image from 2019 to 2021.

3. Results and discussion

3.1. General condition of research site

Beralas Pasir Island and Beralas Bakau Island are located in the Gunung Kijang District, Bintan Regency, Riau Islands. These two islands are bordered by the South China Sea in the east and Bintan Island in the west. Some of the ecosystems found on these two islands are seagrass ecosystems, coral reefs, and mangrove vegetation.
The characteristic of this area is in the form of a white sandy coastal area. Beralas Pasir Island is a tourism destination and there are several small huts. Beralas Pasir Island waters are also used by the local community to catch fish and are one of the dive spots for tourists [27]. The waters around Bintan Island have a sloping topography with sandy and muddy substrates so that seagrass grows well [5]. Several types of seagrass found on Beralas Pasir Island are *Enhalus acroides*, *Halophila oralis*, *Halophila minor*, *Thalassia hemprichii*, *Cymodocea rotundata*, *Cymodocea serulata*, and *Syringodium isoetifolium* [28].

3.2. Water column correction
The value of the attenuation coefficient ratio \((k_i/k_j)\) in the images of 2016, 2019 and 2021 is successively \(0.667880076\), \(0.616032988\) and \(0.69711487\). The water column correction is the resulting difference value \((k_i/k_j)\) on each image. This thing can be caused due to the wavelength of the band and the level of turbidity of the water at the time of image was captured [3]. The result of the transformation of the Lyzenga algorithm will then be in the form of a new image display that shows the shallow water benthic class.

3.3. Unsupervised classification
Unsupervised classification is carried out after the image has been corrected through the pre-processing and water column correction. The advantages of using unsupervised classification are that operator errors are minimized and unique classes are considered as distinct units [29]. In addition, that knowledge about the area of the classified area (reference data) is not required for the initial separation of image pixels [30]. The results of the unsupervised classification of Sentinel-2A images in this study were divided into 2 classes, namely seagrass and non-seagrass, which can be seen in Figure 3.

![Figure 3](image_url)

**Figure 3.** Seagrass classification in 2016, 2019, and 2021 using ISODATA.

The unsupervised classification carried out resulted that in 2016 the distribution of the seagrass class was more dominant than the distribution of the non seagrass class. Meanwhile, in 2019 and 2021 there was a decrease in the distribution of the seagrass class and an increase in the distribution of the non-seagrass class. The value of the distribution of the seagrass area can be seen in Figure 4.
Figure 4. Area of seagrass in 2016, 2019, and 2021.

Figure 4 showed the changes in area of the seagrass class are decreasing as increment of years and on the other hand, the area of the non-seagrass class is increasing.

The classification of the seagrass and non-seagrass classes is then reclassified for the seagrass class. This was done to see the distribution of seagrass density on the Beralas Pasir and Beralas Bakau Island clearly. Classification is done by dividing seagrass classes into three classes, namely dense seagrass, medium seagrass, and rare seagrass [12]. While the non-seagrass class includes groups of sand, coral and macroalgae. Where is the data, please include in the method how you re-class the non-seagrass

The classification results are shown in Figure 5 with 4 distribution classes, namely non-seagrass, rare seagrass, medium seagrass, and dense seagrass. In 2016 and 2021, the dominant class was the rare seagrass class. While in 2019, the dominant is the medium seagrass class.
The area of the classes of rare seagrass, medium seagrass, and dense seagrass in 2016, 2019, and 2021 can be seen in Figure 6 and the seagrass percentage classification can be seen in Table 3.

![Figure 6. Area of seagrass density classification in 2016, 2019, and 2021.](image)

| Classification       | 2016  | 2019  | 2021  |
|----------------------|-------|-------|-------|
| Rare Seagrass        | 38.51 | 33.88 | 28.59 |
| Medium Seagrass      | 32.5  | 36.52 | 11.88 |
| Dense Seagrass       | 34.27 | 28.59 | 14.54 |

The lower density classes of seagrass compared to non-seagrass classes can be due to the substrate condition on the Beralas Pasir and Beralas Bakau islands which lack nutrient supply to the sea which is usually dominated by human activities [28].

### 3.4. Accuracy test
The accuracy test was carried out using the confusion matrix method. This method produces three accuracies, namely overall accuracy (OA), producer accuracy (PA), and user accuracy (UA) [9]. The user accuracy value is an accuracy value that shows the right classification class based on the field data and the producer accuracy value is the accuracy value in the classified class from the classification results [31]. While the overall accuracy value is an overall picture of the error rate of image data processing that is applied, where the closer to the maximum value, the smaller the error data generated [32-33]. Table 8 shows the results of the calculation of the accuracy-test using the confusion matrix method for the classification of Sentinel-2 images in 2019 and Unmanned Surface Vehicle field data.

The calculation of the accuracy test resulted in the Overall Accuracy (OA) value in the seagrass classification in 2019 and the USV field data is 62.20%. The OA value obtained meets the lowest standard of accuracy for shallow water mapping, which is 60% [34].

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Table 3. Seagrass percentage classification.

| Classification       | 2016  | 2019  | 2021  |
|----------------------|-------|-------|-------|
| Rare Seagrass        | 23.71%| 20.01%| 21.10%|
| Medium Seagrass      | 20.86%| 22.48%| 17.60%|
| Dense Seagrass       | 7.31% | 7.56% | 8.95% |
| Non-Seagrass         | 48.12%| 49.95%| 52.35%|
| Total                | 100.00%| 100.00%| 100.00%|
Table 4. Confusion Matrix.

| Image Classification | Unmanned Surface Vehicle data | User Accuracy (%) |
|----------------------|------------------------------|-------------------|
| RS                   | 9  | MS  | 0  | DS  | 0  | NS  | 9  | Total | 100% |
| MS                   | 0  | 9   | 0  | 1   | 10 | 90.00% |
| DS                   | 1  | 0   | 4  | 0   | 5  | 80%  |
| NS                   | 8  | 13  | 8  | 29  | 58 | 50.00% |
| Total                | 18 | 22  | 12 | 30  | 82 |       |

Description: RS (Rare Seagrass), MS (Medium Seagrass), DS (Dense Seagrass), NS (Non-Seagrass)

The accuracy values obtained depend on several factors. For example, the producer accuracy value is influenced by the calculation factor of the Lyzenga algorithm, while the user accuracy value is influenced by the input or calculation process. In addition, factors such as training samples, correction process, spatial resolution, GPS accuracy also affect the accuracy value obtained [32]. Please explain why such things have influenced the result of the accuracy test. Don't just guess.

3.5. Changes detection

The results of the unsupervised classification of images in 2016, 2019, and 2020 showed a change in seagrass classification over time. To see changes in the classification, detection of changes in the seagrass area is carried out using the post-classification method. Overlay was carried out on the results of seagrass classification in 2016 and 2019 and the classification results in 2019 and 2021. This detection is carried out to see changes in 2 classes of classification, namely seagrass and non-seagrass. This overlay resulted in 4 classes changes detection, namely seagrass to non-seagrass, seagrass, non-seagrass to seagrass, and non-seagrass. The distribution of the 4 classes can be seen in Figure 7. The results of the overlay showed the location of changes from one class to another. To find out in detail the changes that occur, the calculation of area changes can be seen in Figure 8.

The calculation of the area per class showed that in 2016 and 2019, the area of the seagrass class to non-seagrass is 31.35 ha, the seagrass not change class is 51.27 ha, the non-seagrass did not change class is 54.96 ha, and the non-seagrass class to seagrass is 24.84 ha. Meanwhile, in 2019 and 2021, the area of the seagrass to non-seagrass class is 30.91 ha, the seagrass still class is 47.62 ha, the non-seagrass still class is 55.91 ha, and the non-seagrass class to seagrass class is 27.98 ha. It can be seen that the value of the area of changes in each class is not too far from each other. This can be interpreted that changing in the area of seagrass happen continuously.

The results of seagrass density classification in 2016, 2019, and 2021 are then overlaid to see more detailed changes in seagrass density on Beralas Pasir and Beralas Bakau Islands, Bintan, Riau Islands. The map of seagrass density changes in 2016 and 2019 can be seen in Figure 9.
Figure 7. Seagrass changes detection.

Figure 8. Area of seagrass changes detection.
Figure 9. Density seagrass class changes detected in 2016 – 2019.

The overlay results of the 2016 and 2019 seagrass density classifications resulted in a map of changes with 16 classifications of changes. The calculation of the area of seagrass density changes can be seen in Table 5.

|                  | Rare Seagrass | Medium Seagrass | Dense Seagrass | Non-Seagrass |
|------------------|---------------|-----------------|----------------|--------------|
| Total Area 2016 (ha) | 38.51         | 33.88           | 11.88          | 78.15        |
| Total Area 2019 (ha) | 32.5          | 36.52           | 12.28          | 81.12        |
| Changing Area (ha)  | -6.01         | 2.64            | 0.4            | 2.97         |
| Percentage (%)      | -15.61%       | 7.79%           | 3.37%          | 3.80%        |

The calculation of the changing area resulting value of the rare seagrass class in 2019 decreased 6.01 ha from 2016 with a percentage decreasing 15.61%. The medium seagrass class show an increasing area in 2019 in the amount of 2.64 ha from the area in 2016 with a percentage increasing 7.79%. The dense seagrass class is increasing in 2019 with 0.4 ha from the area in 2016 with percentage increasing 3.37%. While the non-seagrass class shows increasing area in 2019 with 2.97 ha from the area in 2016 with percentage increasing 3.80%.
Figure 10. Density seagrass class changes detected in 2019 – 2021.

The overlay results from the seagrass density classification in 2019 and 2021, resulting in 16 classifications of change (Figure 10). The calculation of the area of change in seagrass density can be seen in Table 6.

Table 6 Area and percentage of density seagrass changes in 2019 and 2021.

|                | Rare Seagrass | Medium Seagrass | Dense Seagrass | Non-Seagrass |
|----------------|---------------|-----------------|----------------|--------------|
| Total Area 2019 (ha) | 32.5          | 36.52           | 12.28          | 81.12        |
| Total Area 2021 (ha)  | 34.27         | 28.59           | 14.54          | 85.02        |
| Changing Area (ha)     | 1.77          | -7.93           | 2.26           | 3.9          |
| Percentage (%)          | 5.45%         | -21.71%         | -18.40%        | -4.80%       |

The calculation of the changing area resulting value of the rare seagrass class in 2021 increased 1.77 ha from the area in 2019 with percentage increasing 5.45%. The medium seagrass class showed the decreasing area in 2021 in the amount of 7.93 ha from the area in 2019 with percentage decreasing 21.71%. The dense seagrass class showed decreasing area in 2021 in amount of 2.26 ha from the area in 2019 with percentage decreasing 18.40%. Meanwhile, the non-seagrass class shows decreasing area in 2021 in amount 3.9 ha from the area in 2019 with percentage decreasing 4.80%.

Changes that occurred in 2016, 2019, and 2021 could be caused by several factors. Common factors that can affect seagrass in waters are temperature and salinity. According to [35], the optimal temperature range for seagrass species for growth is 28-30°C, while for seagrass photosynthesis, the optimum temperature is between 25-35°C [35-36]. Meanwhile, for salinity, seagrass species have different tolerances with optimum salinity values in the range of 24-30 % [36-37]. In addition, sunlight penetration or brightness is an essential factor for seagrass growth [28, 36]. Tidal factors in water can also affect seagrass growth because tides affect the entry of solar intensity into a water column [39].
Changes in seagrass areas can also be caused by several external factors such as human activities. Beralas Pasir and Beralas Bakau Island are two of the 3000 islands in the Riau Archipelago. The high level of human activity in coastal areas suppresses environmental changes that affect the seagrass ecosystem [40]. Beralas Pasir Island is also well-known as a tourist destination with a private island for sightseeing [41]. Bintan Island and the surrounding islands are famous for their high tourist visits, both local and foreign [42]. In addition to tourism activities, fishing activity in the waters around Beralas Pasir Island is also high [28]. This tourism and fishing activity can certainly be a factor in the changes in seagrass areas in Beralas Pasir and Beralas Bakau, Bintan, Riau Islands.

4. Conclusion
Seagrass area mapping in Beralas Pasir and Beralas Bakau Island, Bintan, Riau Islands using Sentinel-2 imagery, resulting in the amount of seagrass area with 84.27 ha in 2016, 81.3 ha in 2019, and 77.4 ha in 2021. Changes in area from seagrass to non-seagrass are 31.35 ha from 2016 to 2019 and 30.91 ha from 2019 to 2021. Meanwhile, the changes in area from non-seagrass to seagrass are 24.84 ha from 2016 to 2019 and 27.98 ha from 2019 to 2021. The 2019 image classification data accuracy test with Unmanned Surface Vehicle data resulted from an overall accuracy value of 62.20%.

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