

Mapping of seagrass ecosystem on Bontosua Island, Pangkep District, South Sulawesi, Indonesia

DWI ROSALINA^{1,✉}, KHAIRUL JAMIL¹, YASSER ARAFAT¹, REZKI AMALIA¹, ANI LEILANI²

¹Program of Marine Engineering, Politeknik Kelautan dan Perikanan Bone. Jl. Sungai Musi, Bone 92719, South Sulawesi, Indonesia.

✉email: uwie_18laut@yahoo.co.id

²Program of Aquaculture Technology, Politeknik Kelautan dan Perikanan Bone. Jl. Sungai Musi, Bone 92719, South Sulawesi, Indonesia

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Abstract. Rosalina D, Jamil K, Arafat Y, Amalia R, Leilani A. 2023. Mapping of seagrass ecosystem on Bontosua Island, Pangkep District, South Sulawesi, Indonesia. *Biodiversitas* 24: 2023-2030. Bontosua Island is one of the islands in South Sulawesi, Indonesia, that has a seagrass ecosystem. The purpose of this study was to assess the density, cover, area, and condition of seagrass on Bontosua Island. The data collection involved the use of a quadratic transect method in the field and the Lyzenga method for remote sensing. The identification of seagrass areas was made using Landsat 8 OLI/TIRS satellite. Six seagrass species were identified, namely *Cymodocea rotundata*, *Thalassia hemprichii*, *Halodule uninervis*, *Halodule pinifolia*, *Syringodium isoetifolium* and *Halophila* sp. The results showed that *C. rotundata* had the highest density value of 89 Ind/m² and was categorized as rather dense, while *C. rotundata* also had the highest percentage cover of 58%, and *Halophila* sp. had the lowest percentage cover of 2%. The distribution area of seagrass beds on Bontosua Island was approximately 28.26 ha, out of a total area of 92 ha, of which approximately 6 ha was land. Observations on the condition of seagrass beds showed that 16.65 ha was healthy, 6.3 ha was unhealthy, while 5.31 ha was poor.

Keywords: Coral reef, *Cymodocea*, *Halodule*, *Halophila*, Lyzenga, Sentinel 2A, *Syringodium*, *Thalassia*

INTRODUCTION

Coastal and small island ecosystems exhibit remarkable diversity, encompassing a wide range of habitats such as mangrove forests, seagrass beds, estuaries, coral reefs and many other ecosystems (Dutta et al. 2013). Among these habitats, seagrass beds have been identified as important from a biodiversity point of view (Rodil et al. 2022). In Indonesia, seagrass beds cover an area of 150,693.16 ha, with 4,409.48 ha in the western part and 146,283.68 ha in the eastern part. These dense seagrass beds provide effective wave attenuation (Adi et al. 2019; Spalding et al. 2014) and are primary producers, supporting a diverse array of fauna, including fish and turtles (Hoffmann et al. 2020; Abrantes et al. 2015). Furthermore, seagrasses play a crucial role in influencing water flows, nutrient cycling, food webs, and provide a refuge for various marine organisms (Simpson et al. 2022). Despite the ecological importance of seagrass beds, their conservation has received limited attention from coastal communities. In Indonesia, approximately 30-40% of seagrass ecosystems are in a damaged state (Rifai et al. 2023; Barañano et al. 2022; Ha et al. 2021). The United Nations Environment Program (UNEP) has highlighted the value of seagrasses for the environment and human well-being (UNEP 2020). However, seagrass beds are shrinking globally due to multiple anthropogenic factors such as eutrophication, disease, coastal modification, and rising water temperatures (de los Santos et al. 2019). Cullen-Unsworth and Unsworth (2016) identified decreased coverage as a result of increased nutrient inputs, sedimentation, toxic chemicals,

global warming, coastal reclamation, the felling of mangrove trees, and garbage disposal.

Bontosua Island, located in the Pangkajene and Islands District, is one of the islands in South Sulawesi that harbors a seagrass ecosystem. Remote sensing is a necessary process to determine the extent of seagrass beds on islands like Bontosua Island (Yang and Yang 2009). Mapping seagrass ecosystems through remote sensing is an effective way to monitor seagrass distribution and obtain important spatial information about seagrass ecological characteristics as they change over time, supporting coastal management and conservation efforts (Simpson et al. 2022). The remote sensing process involves using satellite sensors or image recording devices to obtain images of the Earth's surface (Hossain et al. 2015). Remote sensing is also an efficient and cost-effective tool for monitoring and mapping seagrasses since the 1990s (Hossain et al. 2015; Kutser et al. 2020).

The present study aimed to identify the distribution of seagrass on Bontosua Island using the Sentinel 2A satellite with level 1C of blue, green, red and near infrared (NIR) bands at a resolution of 10 m (Ha et al. 2020; Rosalina et al. 2023). The Sentinel-2A satellite, with its multi-spectral imager (MSI) onboard, is efficient in monitoring marine ecosystems, including those under the seabed, as well as producing high-resolution images. The satellite has an onboard multi-spectral imager (MSI) with 13 spectral bands at visible, near-infrared and shortwave-infrared wavelengths, with spatial resolutions of 10, 20 and 60 m respectively. With its wide swath of 290 km and frequent repeat visits, this satellite is a potential tool for various

applications and is freely obtainable. Furthermore, the satellite data have been geometrically and radiometrically corrected, making water column corrections, such as the Lyzenga method, easier to perform. In this study, the mapping of seagrass distribution areas was conducted using the Lyzenga method (Rosalina et al. 2022a; Lubis et al. 2020). The Lyzenga method not only determines the area of seagrass but also distinguishes other bottom water objects, such as coral reefs and sand. Additionally, this method can differentiate between live and dead coral. The purpose of the study was to assess the distribution of seagrass in waters with high human activity on Bontosua Island.

MATERIALS AND METHODS

Location and time of research

A field survey was conducted from February to March 2022 on Bontosua Island, Mattiro Bone Sub-district, Pangkajene and Kepulauan (Pangkep) District, South Sulawesi, Indonesia, as can be seen in Figure 1. Remote sensing was carried out from September to November 2022 at the Nypah Indonesia office, Makassar City, South Sulawesi Province. This research was conducted by taking 9 station points.

Implementation stages

To ensure accurate identification and mapping of aquatic objects, such as seagrasses, coral reefs, and sand, image data processing was carried out using the Lyzenga method in conjunction with remote sensing. This method takes advantage of light waves in the water to produce visible light with different spectrum colors, allowing for the classification of underwater objects. Once the image data was processed, an accuracy test was conducted to assess the compatibility between the processed data and data collected in the field. To carry out this accuracy test, field data collection was necessary. Utilizing remote sensing with the Lyzenga method for image processing allowed for accurate identification and mapping of aquatic objects, essential for the monitoring and management of coastal ecosystems (Figure 2).

Field data retrieval

In the present study, data retrieval in the field was conducted using the Quadratic Transect Method, which is a commonly used method for collecting seagrass ecosystem data. The Quadratic Transect Method was carried out at nine stations with three repetitions, employing a frame size of 50×50 cm and a transect line length of 100 m from the shoreline to the shore. Additionally, water quality parameters, including temperature, pH, salinity, current, and brightness, were measured to support the data collection.

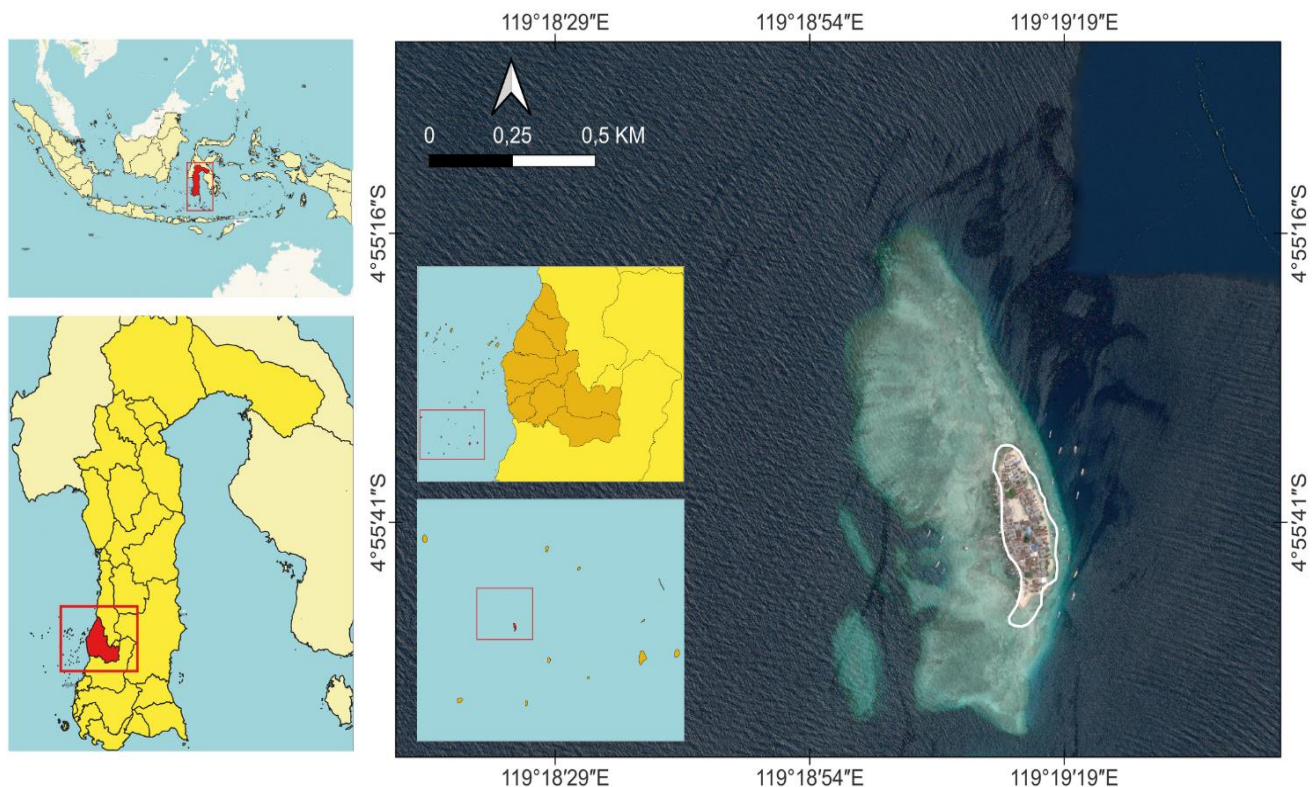


Figure 1. Map of the study area in Bontosua Island, Mattiro Bone sub-district, Pangkep (Pangkajene and Kepulauan) District, South Sulawesi, Indonesia

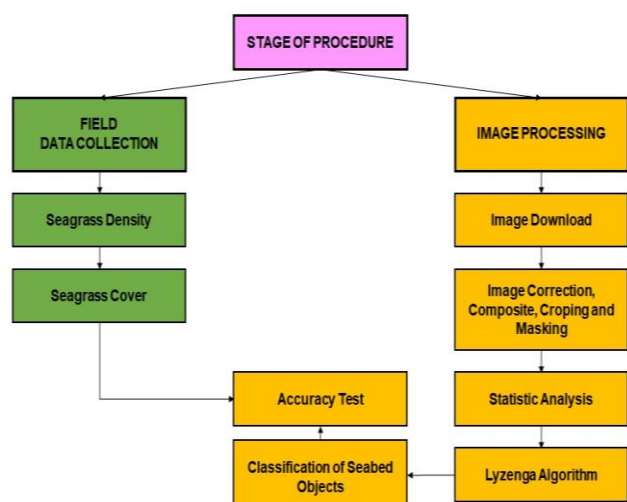


Figure 2. Stages of seagrass ecosystem mapping work

Data processing

The steps in processing remote sensing data are as follows: The first step in mapping is to download satellite imagery. We used Sentinel 2A imagery, which was obtained from the USGS website (<https://earthexplorer.usgs.gov/>). Sentinel 2A is one of the satellites launched by the European Space Agency in 2015 and has 13 different bands with spatial resolutions ranging from 10 × 10 meters.

Atmospheric correction played an important role in image processing. It was carried out to remove the influence of the atmosphere that was also recorded during image capture. This process was performed using ENVI 5.1 software. Atmospheric correction was applied if the Npts value was 0, which indicates the presence of atmospheric interference in the image.

After performing atmospheric corrections, the next stage was compositing bands or combining bands from several bands into one. This was done to create a combination of colors in the band to facilitate the image analysis process. The next step was to crop out the desired area. Cropping was conducted to facilitate the processing of the area to be identified. After obtaining the cropping results, the masking process was carried out to separate the land and sea areas. This was done to facilitate the identification of basic water objects.

Statistical analysis involved obtaining the ratio coefficient value between the green band (Band 3) and the blue band (Band 2). Before obtaining these values, the variance values of the green and blue bands were determined, and then the covariance values between the two bands were calculated.

The equation to get the ratio coefficient of the green and blue bands is as follows:

$$a = \frac{\text{Varian } B2 - \text{Varian } B3}{\text{Covarian } B2, B3}$$

After obtaining the value of a, then proceed with the ki/kj equation:

$$ki/kj = a + \sqrt{a^2 + 1}$$

Lyzenga analysis

The Lyzenga algorithm was used to perform Lyzenga analysis, which aimed to display basic water objects such as sand, coral reefs, and seagrass. These objects were then classified. Data processing in the Lyzenga Method utilized the Depth Invariant Index (DII) algorithm or water column correction in the image. The equation is as follows:

$$Y = \ln(Li) - \left[\left(\frac{ki}{kj} \right) \times \ln(Lj) \right]$$

- Y : Base substrate extraction yield value.
- Li : Input blue band (band 2 on Landsat 8)
- Lj : Green Input Band (band 3 on Landsat 8)
- ki/kj : Coefficient of ratio between green band and blue band
- ln : Natural logarithm

The seagrass ecosystem is a type of ecosystem found in shallow seas. The Lyzenga analysis technique greatly facilitates the analysis of shallow waters, making it an important tool for obtaining a better visual representation of underwater objects, including seagrass.

Image classification

After color differences were identified through the Lyzenga analysis process, the next stage involved classifying the seabed objects by distinguishing the different colors that appeared in the image. The provisions for the color classification of the Lyzenga method can be seen in Table 1.

This research used supervised classification to classify seagrass. This study used 4 classes, namely seagrass, sand, live coral and dead coral.

Data analysis

Seagrass density (ind/m²)





The density of seagrass species was obtained from the number of seagrasses stands that entered the observation frame. The equation is as follows:

$$Di = \frac{ni}{A}$$

Where:

- Di : Seagrass Density (ind/m²)
- ni : Total number of seagrasses in the i-th sampling (stands)
- A : Transect area (m²)

Table 1. Lyzenga classification of seabed objects with corresponding pixel colour

Pixel colour	Seabed objects
	Sand
	Seagrass
	Live Coral
	Dead Coral

Seagrass cover (%)

The calculation of seagrass cover percentage is an important step in assessing the health and condition of seagrass beds in a particular area (Adi et al. 2019). It enables the determination of the dominant seagrass species and can also provide insights into the overall condition of the seagrass ecosystem. The equation for the calculation of seagrass cover (%) is as follows:

$$C_i = \frac{a_i}{A}$$

Where:

- C_i : Closure of the i-th type of seagrass (%)
- a_i : Total area of closure of the i-th species
- A : Total area of sampling

The health status of seagrass is determined based on the Decree of the Minister of State Environment Number 200 of 2004 RI concerning Criteria for Standard Damage and Guidelines for Determining the Status of Seagrass (Table 2).

Table 2. Seagrass cover conditions

Condition	Coverage (%)
Healthy	≥ 60
Unhealthy	30 - 59,9
Poor	≤ 29,9

RESULTS AND DISCUSSION

Seagrass density and cover

Seagrass density

Seagrass density per station on Bontosua Island can be seen in Table 3. The seagrass species with the highest density value, based on the average of three transect repetitions at each station from highest to lowest, were *Cymodocea rotundata* with a density value of 39.74, followed by *Thalassia hemprichii* with a density value of 13.33, *Halodule uninervis* with a density value of 11.89, *Halodule pinifolia* with a density value of 2.23, *Syringodium isoetifolium* with a density value of 1.23, and *Halophila* sp. with a density value of 1.22. These six species of seagrass were found scattered in the waters of Bontosua Island. The low density of *Halophila* seagrass is due to its narrow distribution, which is limited to near-shore and sandy substrates (Udagedara et al. 2017).

Seagrass cover

The percentage of seagrass cover is a standard measure for the presence of seagrass in an area (Ricart et al. 2020). This measure refers to the area covered by a particular seagrass species (Rosalina et al. 2022b). Figure 3 shows the percentage of seagrass cover calculated from the average value of three transect repetitions for each species at each station on Bontosua Island.

The dominant seagrass species on Bontosua Island was *C. rotundata*, accounting for 58% of the total seagrass cover, followed by *T. hemprichii* (22%), *H. uninervis* (13%), *H. pinifolia* (3%), *Syringodium isoetifolium* (2%) and *Halophila* sp. (2%). The high percentage of *C. rotundata* was attributed to its easy adaptation to the island's environment. According to Riniatsih et al. (2019), Rosalina et al. (2019a), and Rosalina et al. (2019b), *C. rotundata* prefers waters exposed to sunlight and grow can grow in almost all habitat categories. Berkström et al. (2013), reported that seagrass cover is closely related to the habitat, morphology and size of a seagrass species. However, on Bontosua Island, dense human activities have negatively impacted seagrass growth (Lebrasse et al. 2022). Areas with human disturbance have the lowest seagrass cover, while natural areas have a high cover. Fishing activities at stations 6, 7, 8 and 9 were classified as dense, and these areas were dumping grounds for fishermen's anchors. Consequently, turbidity usually occurs in these areas due to fishing activities, which can interfere with the process of seagrass photosynthesis (Ondiviela et al. 2014), leading to inhibited growth. Manning et al. (2019), also emphasized the close relationship between seagrass cover and habitat, morphology and size of a seagrass species. Dense human activities on Bontosua Island can have a negative impact on seagrass growth (Nurdin et al. 2019). The obtained seagrass cover data and the standard deviation are as follows

From Table 4 it can be seen the value of the deviation at seagrass cover per station. The lowest value is 0.79 ±1,3 at station 7 and the highest value is around 12.62±4,4 at station 4.

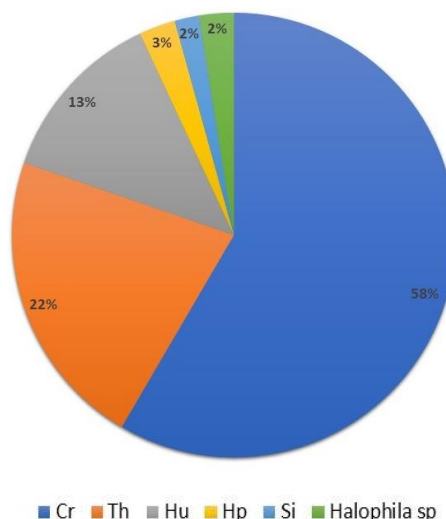


Figure 3. Seagrass cover. Cr: *Cymodocea rotundata*; Th: *Thalassia hemprichii*; Hu: *Halodule uninervis*; Hp: *Halodule pinifolia*; Si: *Syringodium isoetifolium*

Table 3. The density value of seagrass species per station

Station	Seagrass species						Standard Deviation
	<i>Cymodocea rotundata</i>	<i>Thalassia hemprichii</i>	<i>Halodule uninervis</i>	<i>Halodule pinifolia</i>	<i>Syringodium isoetifolium</i>	<i>Halophila</i> sp.	
ST 1	85.1	9.8	20.2	11.8	0	0	10.121
ST 2	89.03	19.06	30.7	0	1.36	0.61	8.9668
ST 3	45.12	21.58	9.39	0	0	10.39	10.918
ST 4	52.91	23.52	21.24	8.3	0	0	20.405
ST 5	48.36	29.33	15.3	0	0	0	4.5821
ST 6	13.48	5.3	5.12	0	0	0	3.5455
ST 7	3.79	2.45	2.15	0	0	0	2.3765
ST 8	10.12	6.818	1.606	0	1.636	0	1.7154
ST 9	9.88	2.15	1.39	0	8.06	0	4.721

Table 4. Seagrass cover standard deviation

Station	Seagrass cover	Standard deviation
ST 1	10.26	4.5
ST 2	12.17	4.8
ST 3	12.62	4.4
ST 4	8.49	9.8
ST 5	8.81	2.0
ST 6	3.28	2.7
ST 7	0.79	1.3
ST 8	2.09	0.9
ST 9	2.58	3.5

Table 5. Water quality

Water quality	Value
Temperature	31-35°C
Salinity	21-25‰
pH	6-7.5
Current	0.12-0.24 m/s
Brightness	100%

Water conditions are crucial for the growth of seagrass, with the temperature on Bontosua Island ranging from 31-35°C (Table 5). According to Pedersen et al. (2016), the optimal temperature range for seagrass photosynthesis is between 25-35°C. The salinity, at 21-25‰, falls short of the optimal range of 27-34‰ (Margiotta et al. 2021). The pH level is approximately 6-7.5, still within normal conditions but leaning towards acidic, whereas the seawater quality standard (Kepmen LH No. 51 of 2004) suggests a good pH range for marine biota growth is between 7-8.5. The current on Bontosua Island is around 0.12-0.24 m/s, which is not ideal for seagrass growth since seagrass ecosystems typically grow in calm waters with current speeds up to 3.5 knots (0.7 m/s) (Turissa et al. 2021). The seagrass on Bontosua Island is visible from the top of the bridge down to the bottom of the water, indicating that it is not getting enough cover from the sun, which could negatively impact its growth.

Map of seagrass area and condition with Lyzenga Method
Seagrass area map

The distribution area of seagrass beds on Bontosua Island was determined using the Lyzenga method, which involved the use of several software tools, including ArcGIS, Global Mapper, ENVI, and Excel. The results of the Lyzenga analysis, which depict the seagrass distribution area on Bontosua Island, can be observed in Figure 4.

The Lyzenga analysis of Bontosua Island generated an image with a different spectrum of colors corresponding to the Lyzenga classification color table (Table 1). Seagrass beds appeared yellow to orange on the image display and had an estimated area of 30 ha. Subsequently, the field data was entered into the image data for classification. The accuracy test revealed that the seagrass beds covered an area of approximately 21.74 ha, as shown in Figure 5.

According to the map, Bontosua Island has a total area of about 92 ha, with only 6 ha of land. The seagrass beds cover around 30% of the island's total area, and there were six species of present, namely *C. rotundata*, *T. hemprichii*, *Halophila* sp., *H. uninervis*, *H. pinifolia*, *S. isoetifolium*. A study by Thalib et al. (2019) who utilized remote sensing using Lyzenga method, estimates the total seagrass meadow area on Bontosua Island to be around 31 ha. However, recent primary data from 2022 shows a seagrass area of approximately 21.74 ha, indicating a decrease in the total area by 9.27 ha over the past three years. The reduction in seagrass area is likely due to various human activities, fishermen throwing their anchors in the seagrass ecosystem area, sand mining for construction activities, and fishing boats anchoring in the seagrass ecosystem (Hossain et al. 2019). To restore the reduced area of seagrass beds, a rehabilitation process is necessary. This is consistent with the findings of Veettil et al. (2020) who stated that the global area of seagrass is rapidly decreasing due to anthropogenic activities, such as climate change, pollution, coastal area development, waste, overfishing, deforestation, land reclamation and seaweed cultivation (Cullen-Unsworth and Unsworth 2016).

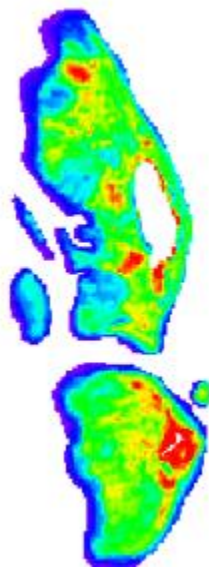


Figure 4. Results of Bontosua Island Lyzenga Analysis

Map of seagrass condition

A map of seagrass conditions can display variations in seagrass cover categories and calculate the area for each category. Figure 6 shows the seagrass condition map. According to Figure 6, the healthy category of seagrass measured 14.3 ha, while the unhealthy and poor categories had areas of 5.4 ha and 2 ha, respectively. Therefore, it can be inferred that the healthy category still dominated the condition of seagrass beds on Bontosua Island. However, the difference in these conditions was influenced by several factors, including environmental factors and community activities. In the western area of Bontosua Island where there was low community activity, seagrass growth was very good. However, in the eastern area of the island where there were more community activities, such as fishermen throwing their boat anchors, the seagrass growth was affected. Additionally, water quality also played a role in affecting seagrass conditions and growth in this area. The reduction in seagrass area can also be attributed to anthropogenic pressure, as stated by (Buonocore et al. 2021).

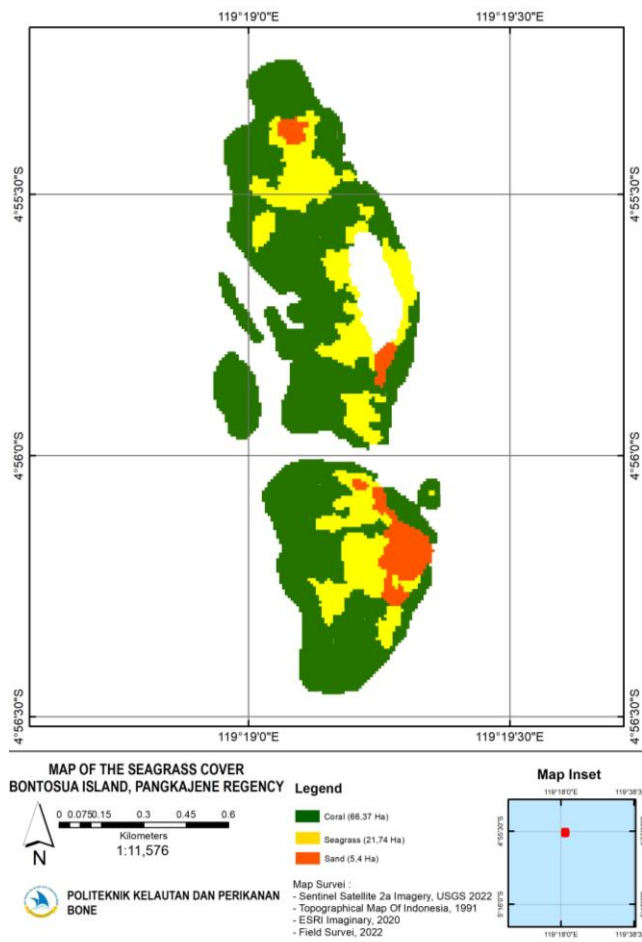


Figure 5. Seagrass cover

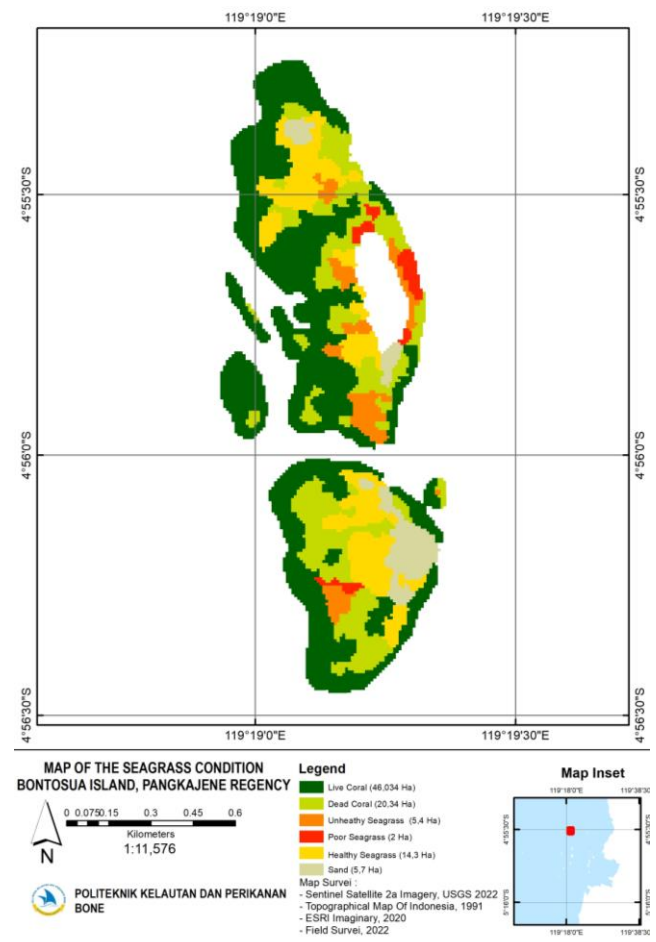


Figure 6. Seagrass condition map on Bontosua Island

In conclusion, *Cymodocea rotundata* was the seagrass species with the highest density values at stations 1 and 2, with 85 Ind/m² and 89 Ind/m², respectively, falling into the slightly dense category. *Cymodocea rotundata* also had the highest percentage cover value of 58%, while *Halophila* sp. had the lowest at 2%. The distribution area of seagrass beds on Bontosua Island was approximately 21.74 ha, which was 30% of the total area of the island, while the healthy, unhealthy, and poor seagrass condition covered 14.3 ha, 5.4 ha, and 2 ha, respectively. The reduction in seagrass area, especially in areas with high anthropogenic pressure highlights the need for conservation efforts to protect and restore seagrass beds. Remote sensing, with its ability to monitor large areas, can be a useful tool in mapping and monitoring seagrass beds, but it should be combined with field surveys, the use of adequate resolution satellite imagery, and good classification methods and schemes to ensure accuracy. Future studies can explore the potential of hyperspectral imagery to improve seagrass classification accuracy. Ultimately, conservation efforts and sustainable management practices should be implemented to ensure the long-term health and productivity of seagrass ecosystems on Bontosua Island and beyond.

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