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Original research article

*The Changes in Coral Reef Area on Semujur Island, Central Bangka*

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ABSTRACT

Semujur Island, located in Kebintik Village, Pangkalan Baru Subdistrict, Central Bangka Regency, covers an area of approximately 40 hectares and is home to 47 households, the majority of whom are fishermen. The island is known as a center for fishing activities and grouper cultivation and has potential for marine tourism through its diverse coral reefs and reef fish. This study aimed to analyze changes in coral reef area using Sentinel-2A satellite imagery and to assess the influence of sea surface temperature on these changes. Ground truth data were collected in March 2023, consisting of 60 samples classified into four categories: coral reef, dead coral, seagrass, and sand. Image analysis included sunglint correction, water column correction, and supervised classification using the Maximum Likelihood Classifier method. The results indicated a decrease in coral reef area from 104.61 hectares in 2016 to 99.91 hectares in 2023, representing a reduction of approximately 4.5%. Analysis of sea surface temperature data showed an increasing trend, contributing to coral reef degradation. These findings highlight the urgent need for sustainable management efforts to protect the coral reef ecosystem of Semujur Island.

## Introduction

Coral reefs are among the ecosystems with high biodiversity and economic value, providing essential services such as coastal protection, fisheries, and tourism opportunities (Nurdjaman et al., 2023; Chaijaroen, 2023). However, coral reef ecosystems are increasingly threatened by various stressors, including climate change, ocean acidification, sedimentation, and local impacts from human activities, which significantly contribute to the decline in coral reef health (Jury & Toonen, 2019). The degradation of coral reef ecosystems not only reduces biodiversity but also affects the livelihoods of coastal communities.

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Semujur Island, located in Central Bangka Regency, Indonesia, is known for its role as a center for fishing and fish processing, and it also holds potential for marine tourism. The island is surrounded by an extensive and shallow fringing coral reef system, which is an important component of its marine ecosystem. Arifin (2021) reported that coral cover in Semujur Island ranged from 46.4% to 73.8%, with an average of 62.8%. Despite its important ecological and economic role, the coral reefs of Semujur Island are increasingly vulnerable to the impacts of environmentally damaging human activities.

Coral reef degradation on Semujur Island poses a threat to marine biodiversity, coastal protection, and the sustainability of local fisheries. Therefore, accurate and up-to-date information on the extent and condition of coral reefs is crucial for the sustainable management of coral reef ecosystems. However, coral reef monitoring on Semujur Island generally consists of ecological data on reef cover conditions (Adibrata et al., 2023). There has been no report on temporal changes in coral reef area using remote sensing technology.

The use of satellite imagery such as Sentinel-2A has demonstrated significant potential for spatial and temporal mapping of coral reefs in various regions of Indonesia (Satya et al., 2023). This technology enables more systematic and periodic monitoring to detect changes in ecosystem conditions, thus providing more responsive information as a basis for decision-making in sustainable natural resource management (Satya et al., 2023). This study aims to analyze changes in coral reef area using Sentinel-2A satellite imagery and to assess the influence of sea surface temperature on coral reef changes.

## Research methods

*Time and place*

This research will be conducted in May 2023 in the waters of Pulau Semujur, Bangka Tengah Regency. Map location This research showed in Figure 1.

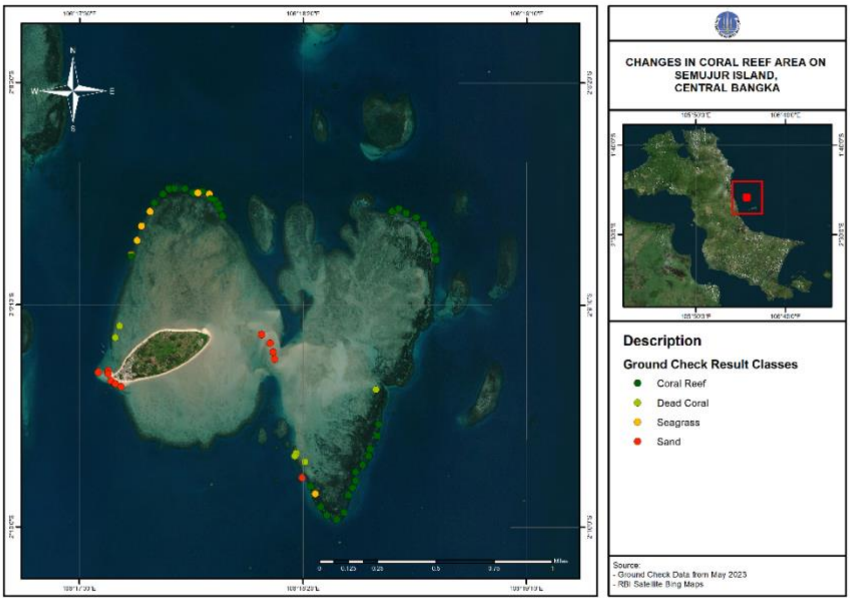


Figure1. Location Map

*Tools and materials*

The tools and materials used in this research consist of a Global Positioning System (GPS) and an underwater camera. In this study, multitemporal images and reference maps were utilized. The multitemporal image data utilized Sentinel 2A satellite imagery taken in the years 2016, 2018, 2020, and 2023.

This research is divided into 2 stages: Processing Sentinel 2A images and coral reef ecosystem surveys. Field data collection was conducted by taking coordinates and photos, with a total of 60 data samples. These samples were classified into four classes: coral reefs, dead coral, seagrass, and sand. Meanwhile, the image data processing stage can be explained as follows:

- Stacking Band

Stacking band involves combining multiple bands into a single layer of data through overlay processing. The selection of channels is based on considerations of simplicity and ease of operation, particularly in tasks such as image processing and classification.

- Geometric Correction

Geometric Correction is a process of rectifying errors caused by satellite movement, Earth's rotation, mirror movement in scanner sensors, and also the effect of Earth's curvature to have coordinates and projections that match the orientation and location points in the image according to the Earth's location. Parameters corrected in Sentinel images include image distortions related to the sensor, changes in satellite altitude during recording, and Earth conditions such as Earth's rotation, curvature, and relief (Fawzi and Husna, 2021). Geometrically corrected images may appear "tilted" due to satellite recording angles.

- Radiometric Correction

According to Fawzi and Husna (2021), Radiometric Correction is a correction performed to improve the pixel values of the image. The pixel values recorded by the satellite are reflections of electromagnetic waves that undergo attenuation in the atmosphere during the process. Radiometric correction is used to correct pixel values that are disturbed by atmospheric interference, such as cloud scattering or scattering of other objects. Atmospheric effects blur the original values of the reflections of objects on the Earth's surface recorded by the sensor. There are two commonly used methods in radiometric correction, namely histogram shifting and linear regression.

- Sunglint Correction

According to Prayuda (2014), to eliminate or reduce the glint effect, one can use a linear regression equation between near-infrared bands as a reference (x-axis) and the corrected visible spectrum bands (y-axis). Samples taken represent three conditions of glint effect: heavy glint, moderate glint, and no glint effect. The equation used for sunglint correction is:

$$R_i" = R_i - b_i x \,(R_{NIR} - Min_{NIR})$$

Infromation
Ri : Reflectance value in each band
bi : Regression slope value from statistics
RNIR : Reflectance value in the near-infrared band
MinNIR : Minimum reflectance value in the near-infrared band

*Water Column Correction*

The influence of water column occurring on objects at the bottom of shallow waters causes changes in the reflectance values of objects. The change in values is due to the attenuation of electromagnetic energy caused by differences in the water column. The effect is that the same object will appear visually and digitally different depending on the depth of the object. The technique commonly used to correct for water column effects is an algorithm developed by Lyzenga (1981).

$$\text{Depth Invariant Index} = \ln(Li) - [(Ki/Kj).\ln(Lj)]$$

Information :
Li : Digital value in band i.
Lj : Digital value in band j.
Ki/Kj : Attenuation coefficient ratio for band pair i and j.

*Supervised Classification*

According to Gao (2009), Supervised Classification is an image classification method that allows users to determine desired categories by selecting several pixels that represent those categories. There are four types of methods used in Supervised classification, namely Per-pixel Image Classifier, Parallelipiped Classifier, Minimum-Distance-to-Mean Classifier, and Maximum Likelihood Classifier (Figure 2). By using this method, users can obtain more easily understandable information from image data.

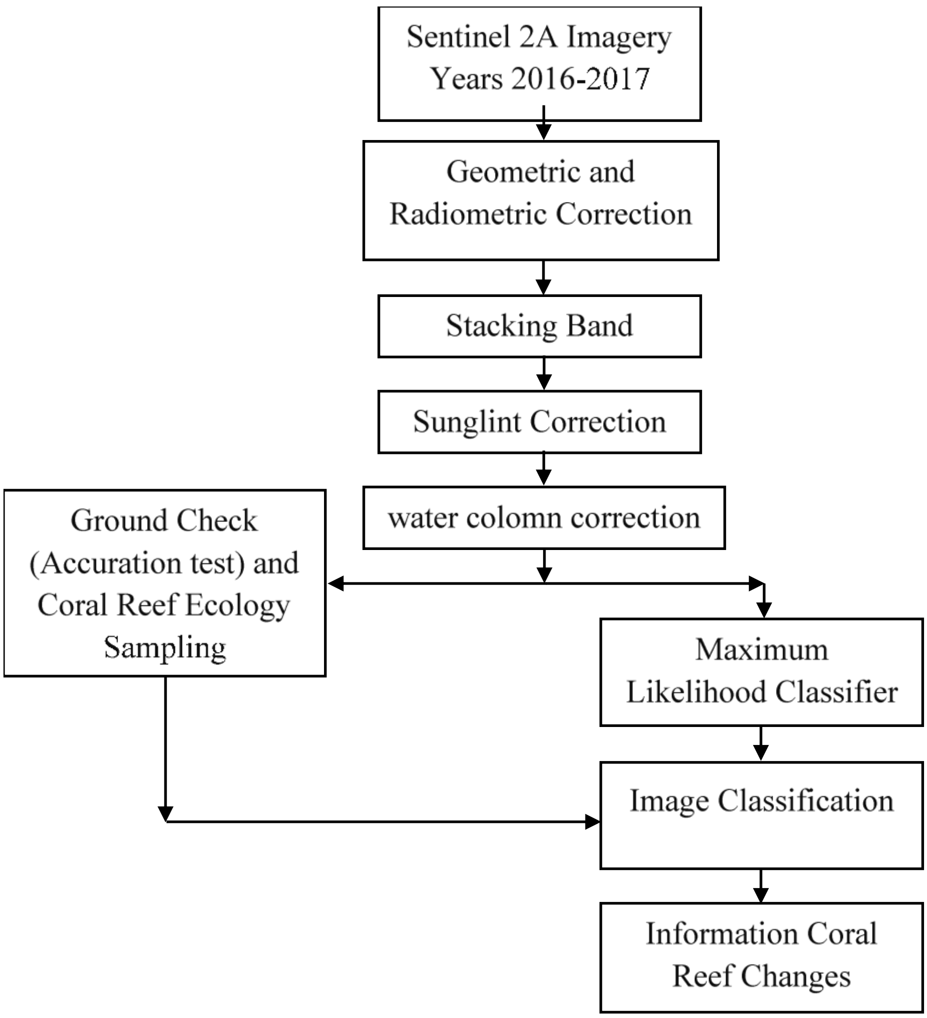


Figure 2. Supervised Classification Diagram

*Data Analysis*

*Accuration Test*

The classification results of remote sensing data are validated using an error matrix (confusion matrix). This is done by comparing the classified image against the ground truth classes. The ground truth classes are obtained from field observations. The accuracy between the classified remote sensing data and the field data can be calculated as follows:

$$Accuracy = \frac{Number\ of\ correctly\ classified\ pixels}{Total\ number\ of\ pixels}\ x\ 100\%$$

*Change in Coral Reef Area*

Changes in coral reef area were calculated using the formula from Siregar and Purwanto (2003) *in* Adi (2015).

$$\boldsymbol{\Delta L = \frac{(Lt2 - Lt1)}{Lt1} x100\%}$$

**Results and Discussion**

*Percentage of Coral Cover*

Analysis of multitemporal satellite data using remote sensing technology and Geographic Information Systems (GIS) significantly aids in monitoring the condition of coral reefs on Semujur Island. However, further monitoring using a series of satellite images over time is still necessary to identify changes in coral reef cover areas. Through data analysis from Sentinel 2A satellite, this research was able to determine the spatial distribution and coverage area of coral reef ecosystems from 2016 to 2023. Accuracy testing of digital images through field inspections showed an accuracy level of 83%. The processed data, including the coral reef area from 2016, 2018, 2020, and 2023 on Semujur Island, can be found in Table 1.

Table 1 illustrates the results of image classification showing changes in the area of various substrate types. In 2016, it was recorded that coral reefs covered an area of 104.61 hectares, while the area of dead coral reefs reached 34.63 hectares, seagrass covered 51.5 hectares, and sand reached 205.95 hectares. However, in 2018, there was a decrease in the area of coral reefs to 92.84 hectares, while the area of dead coral reefs decreased to 22.98 hectares. Seagrass area also decreased to 32.79 hectares, but sand increased to 243.61 hectares. In 2020, there was a subsequent increase in the area of coral reefs to 97.49 hectares, but the area of dead coral reefs increased to 36.12 hectares. Seagrass area increased again to 64.48 hectares, while sand decreased to 215.14 hectares. In 2023, there was another increase in the area of coral reefs to 99.91 hectares, while the area of dead coral reefs increased to 41.78 hectares. Seagrass covered an area of 42.16 hectares, and sand covered 212.84 hectares.

Table 1. Image Classification Results for the Years 2016, 2018, 2020, and 2023

| Description/Year | Area (Ha) | | | |
|---|---|---|---|---|
| | 2016 | 2018 | 2020 | 2023 |
| Coral Reef | 104.6 | 92.8 | 97.49 | 99.9 |
| Dead Coral | 34.6 | 24.0 | 36.12 | 41.8 |
| Seagrass | 51.5 | 32.8 | 64.48 | 42.2 |
| Sand | 206.0 | 242.6 | 215.14 | 212.8 |
| Total | 396.7 | 392.2 | 397.0 | 396.7 |

Over the span of 8 years, the coral reefs on Semujur Island experienced a decrease in area by 4.5% or 4.7 hectares from the coral reef area in 2016, accompanied by an increase in the area of dead coral by 21% or 7.15 hectares. The reduction in coral reef area followed by an increase in dead coral area indicates ecosystem degradation in the coral reef waters of Semujur Island. The variation in changes in area may be due to disturbances during this period. Limiting factors affecting coral reef area include human activities and sea surface temperatures. Human activities around coral reef ecosystems, such as damaging fishing practices and coral sand mining, can lead to a reduction in coral reef area (Bellwood et al., 2004). Sea surface temperature is one of the factors influencing coral reef area and affects coral growth and health. Changes in sea surface temperature are directly linked to global warming, which is a major cause of coral bleaching (Hughes et al., 2003).

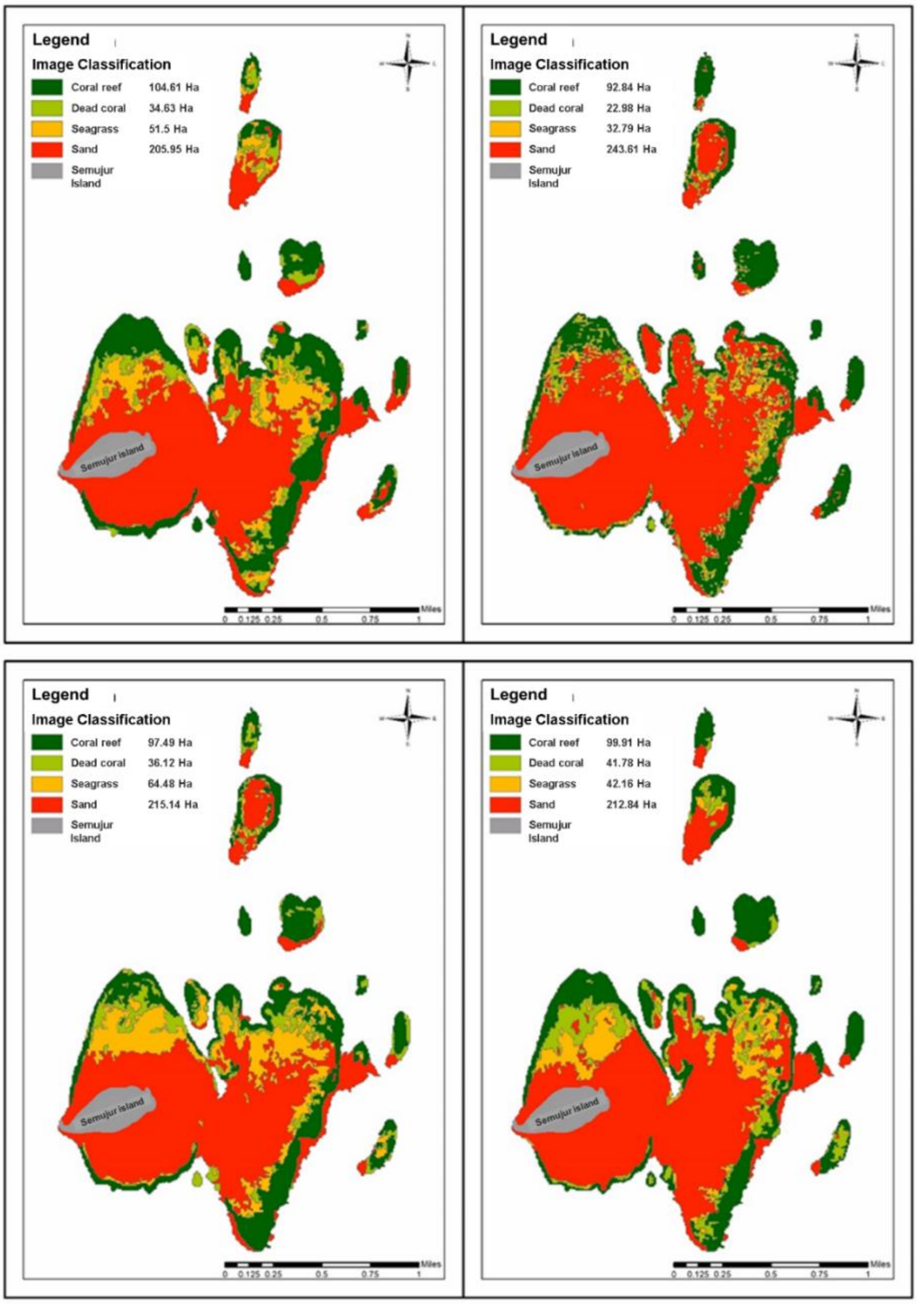

Figure 3. Classification of satellite imagery in the waters of Semujur Island

## Conclusion

The coral reefs on Semujur Island experienced a decrease in area by 4.5% or 4.7 hectares from the coral reef area in 2016, and there was an increase in the area of dead coral by 21% or 7.15 hectares over an 8-year period. The variation in changes in area may be due to disturbances during this period, and limiting factors affecting coral reef area include human activities and sea surface temperatures. Human activities around coral reef ecosystems, such as damaging fishing practices and coral sand mining, can lead to a reduction in coral reef area. Sea surface temperature is one of the factors influencing coral reef area and affects coral growth and health. Changes in sea surface temperature are directly linked to global warming, which is a major cause of coral bleaching.

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