IRSAJ
International Remote Sensing Applied Journal

e_ISSN = 2775-3409
p_ISSN = ______-

Vol 4 No 2 | Desember 2023

MAPPING THE DISTRIBUTION OF SEAGRASS IN NIRWANA BEACH, PADANG CITY USING SENTINEL-2 IMAGERY

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ABSTRACT: Seagrass (Lamun) is a flowering plant (Angiospermae) that thrives in shallow marine environments. Seagrass meadows play a crucial role in aquatic ecosystems, and the degradation or loss of seagrass can impact the balance of these ecosystems. The use of remote sensing technology in mapping the distribution of seagrass beds can support monitoring efforts and contribute to the conservation and protection of marine ecosystems. This research aims to map and measure the extent of seagrass beds in Nirwana Beach, Padang City, in the year 2022. The method employed involves using Sentinel-2A imagery from 2022 and the Object-Based Image Analysis (OBIA) approach for seagrass detection. The Sentinel-2A imagery is processed using ArcGIS and eCognition software, including atmospheric correction, data clipping, composite image creation, segmentation, image classification, and accuracy assessment. The results of processing the Sentinel-2A data in 2022 for Nirwana Beach, Padang City, indicate that seagrass beds are distributed along the Nirwana Beach area, particularly in the eastern and southern regions. The detected seagrass bed covers an approximate area of 25.06 hectares. The use of Sentinel-2A imagery with the OBIA method has proven to be effective in detecting the distribution of seagrass beds in Nirwana Beach, Padang City.

Keywords: Seagrass, Remote Sensing, Distribution Mapping, Marine Ecosystem, Conservation

1. INTRODUCTION

Indonesia is blessed with abundant marine resources that need to be well-managed, and one of these resources is seagrass (Lamun). Indonesia has the largest seagrass meadows in Southeast Asia and ranks second in the world, covering approximately 150,693.16 hectares [1]. These meadows are home to a significant diversity of seagrass species, with 15 out of the world's 60 species found in Indonesia [2]. Seagrass is a flowering plant (Angiospermae) that thrives in shallow marine environments. Unlike algae, all seagrasses are monocots with roots, rhizomes, leaves, flowers, and fruits, similar to terrestrial vascular plants [3]. Seagrasses typically grow in dense clusters and inhabit shallow, warm, marine waters, connecting mangrove ecosystems to coral reefs. Areas of the sea floor covered by seagrass are referred to as seagrass beds and can form distinctive and valuable ecosystems.

The seagrass ecosystem provides significant benefits, including shoreline protection, primary production, habitat for marine life, and carbon storage [2,4]. As a blue carbon ecosystem, Seagrass can sequester more CO2 in its biomass and sediments than many terrestrial ecosystems [5]. Despite its importance, seagrass ecosystems have often been overlooked in recent decades, resulting in the degradation of seagrass beds in Indonesian waters by approximately 30-40% [7]. Factors contributing to seagrass ecosystem degradation include uncontrolled coastal development, pollution from inorganic waste, destructive fishing practices, and overfishing. These factors have had detrimental effects on the waters surrounding small islands [8].

Coastal areas, being the meeting point of land, sea, and air, are the most dynamic yet vulnerable regions [9]. According to data from the Maritime and Fisheries Office of West Sumatra, seagrass coverage in West Sumatra in 2018 reached 394.94 hectares. The city of Padang boasts several well-known beaches, such as Pasia Jambak Beach, Pasia Nan Tigo/Pasia Kandang Beach, Pasia Sabalah – Muaro Penjalinan Beach, Gajah Beach, Parkit Beach (freshwater area), Muaro Lasak Beach, Purus Beach, Padang Beach, Air Manis Beach, Nirwana Beach (coral springs), Sako Beach, Carolina Beach, Pasa Laban Beach, Cindakir Beach, and Batang Beach. Seagrass ecosystems can be found in the Nirwana Beach area along the shallow coastal waters [9]. These coastal areas are often utilized by local communities, not only for tourism and enjoying the beauty of the beach and its ecosystems but also for fishing and other activities. Water pollution can occur due to economic pressures that drive destructive fishing practices, such as the use of explosives or poisons [10]. Furthermore, seagrass ecosystems in tourist beach locations are threatened by the activities of tourist boats, which can damage seagrass roots with their propellers or anchors, as well as by sedimentation from household waste. Seagrass ecosystems can also be harmed by boat propellers or anchors, which are common problems in various coastal areas, leading to a decrease in seagrass density and coverage in coastal regions [10]. Given these conditions, continuous monitoring and surveillance are required, and remote sensing technology can play a crucial role in this regard.

The lack of knowledge and utilization of remote sensing technology has often led to manual classification of seagrass distribution. Manual classification, however, is time-consuming and costly. Therefore, by harnessing remote sensing technology, the classification of seagrass distribution can be accomplished quickly and cost-effectively.

Remote sensing is a technology capable of providing fast and accurate data for information. The completeness and accuracy of remote sensing information depend on the quality of image data and the methods used [11]. The precise information on seagrass distribution obtained through remote sensing technology will facilitate the monitoring of changes in seagrass coverage. Remote sensing technology can effectively and efficiently be used for mapping seagrass distribution as it can provide spatial and temporal information. Remote sensing data can support the provision of information on seagrass area, percent coverage, and changes in seagrass beds [6].

2. LITERATURE REVIEW

2.1. Remote Sensing

Remote sensing is the science and art used to obtain information about an object or phenomenon using instruments without direct contact with the object, area, or phenomenon. The instruments referred to are remote sensors mounted on platforms, typically including balloons, aircraft, satellites, or space shuttles. Remote sensing is defined as a technique developed to obtain and analyze information about the Earth's surface. This information is typically in the form of electromagnetic radiation reflected or emitted from the Earth's surface [12].

2.2. Geographic Information System (GIS)

GIS is a specialized information system that manages data with spatial information (georeferenced). Essentially, GIS is a computer-based system used to collect, integrate, and analyze information from existing data, creating new information in the process.

GIS is a system oriented towards geographic location on the Earth's surface, based on a computer that can process, manipulate, and display both spatial and attribute data [14].

2.3. Sentinel-2 Imagery

Sentinel is satellite image data that can be obtained at no cost. Sentinel-2 is a satellite imagery with medium spatial resolution, wide swath coverage, revisiting the same location every 5 days (compared to Landsat's 16-day revisit), and can be used for monitoring land cover, including vegetation, soil, and water, as well as water networks and coastal areas.

2.4. Seagrass Meadows (Padang Lamun)

Seagrass is a flowering plant (Angiospermae) that thrives in shallow marine environments. All seagrasses are monocots with roots, rhizomes, leaves, flowers, and fruits, similar to terrestrial vascular plants [3]. This distinguishes them from algae. Seagrasses grow well in intertidal zones and coastal waters with substrates consisting of mud, sand, gravel, and broken dead coral, at depths of up to 4 meters. Seagrass meadows are crucial for aquatic life, so the loss or damage of seagrasses disrupts an important part of the aquatic food chain. Seagrass is mainly concentrated in two major regions: the Indo-Pacific and the coasts of Central America. Worldwide, seagrass plants consist of 2 families, 12 genera, and 49 species [15].

2.5. Object-Based Image Analysis (OBIA)

OBIA is an approach to image classification that considers not only spectral aspects but also spatial object aspects. The OBIA method does not solely depend on spectral values but also optimizes spatial features in satellite imagery based on interpretative elements such as shape, size, texture, and other contextual information [2].

The OBIA method is a classification approach that takes into account both spectral and spatial object aspects. This method involves a segmentation process that groups nearby pixels with similar qualities. Typically, the OBIA method consists of two stages: image segmentation and classification within each segment [2].

3. METHODS

This research employs a quantitative method with a comparative approach to classify seagrass ecosystems in Pantai Nirwana, Kota Padang. Sentinel-2A satellite imagery is used in this study, applying the Object-Based Image Analysis (OBIA) method to identify and map the distribution of seagrass ecosystems. The primary objective of this research is to reveal the distribution patterns of seagrass ecosystems in the area.

3.1. Time and Location of Research

This research was conducted during one odd semester, from October 2022 to June 2023. The research location covers Pantai Nirwana, which stretches across the waters of Teluk Bayur and includes the land areas in the Bungus Teluk Kabung and Lubuk Begalung Districts, Kota Padang. Pantai Nirwana is situated at geographic coordinates 1°0'23.87" - 1° 2'39.81" South Latitude and 100°22'33.24"- 100°23'40.26" East Longitude.

3.2. Tools and Materials

In this research, tools such as a laptop and software including ArcGIS 10.8, Google Earth Pro, Sen2cor 2.9 Plugin, and eCognition were used to support data analysis and processing. The research materials include Sentinel-2 imagery from the year 2022 downloaded from the official website https://scihub.copernicus.eu, as well as administrative data from Indonesia obtained from Ina Geoportal.

3.3. Data Processing Procedure

The data used consists of Sentinel-2 imagery of Pantai Nirwana, Padang Selatan District, Kota Padang. This data was downloaded from the official website https://scihub.copernicus.eu/dhus/#/home and had to meet the minimum requirements for cloud cover over the water. The imagery was processed using ArcGIS through the following steps: Atmospheric Correction, Data Cropping, Image Composite, Segmentation, Image Classification, converting raster to Vector/Polygon, and Accuracy Assessment. Subsequently, the classification results of seagrass distribution in 2022 in Pantai Nirwana, Kota Padang, were calculated using the described method.

Overall, this research method provides a comprehensive framework for classifying and mapping seagrass ecosystems by utilizing satellite image technology and object-based analysis.

4. RESULT AND DISCUSSION

4.1. Result

4.1.1. Mapping the Distribution of Seagrass Meadows in 2022 in Pantai Nirwana, Kota Padang Using the OBIA Method

Based on the first objective of this research, which is to determine the distribution of seagrass in Pantai Nirwana, Kota Padang in 2022 using Sentinel-2A imagery, the mapping process of seagrass distribution was conducted using the OBIA (Object-Based Image Analysis) method with the SVM (Support Vector Machine) algorithm. This involved several data processing stages, including image correction, cropping the image to focus on the study area and segmentation.

a. Processing

1. Atmospheric correction

The formula used in the atmospheric correction process is to open the CMD by pressing the Windows key + R > CMD > OK. After the CMD window is open, type the formula to perform the correction: cd > space > copy and paste the storage address of the Sen2Cor processor on the computer > enter. If the storage address of Sen2Cor on the computer is successfully recognized, then type the formula again, which is L2A_Process.bat --resolution 10 "> copy and paste the address of the image storage that will undergo atmospheric correction > " > enter. The atmospheric correction process will be processed until progress [%]: 100.00 application terminated successfully, which takes about 10-15 minutes depending on the computer's specifications used. If the progress reaches 100% as shown in the image above, a new file with the label level-2A will be created in the image storage folder, indicating that the image has been successfully corrected to level-2A, which is the Bottom Of Atmosphere (BOA). As shown in the image below, a new folder named L2A will be created. This means that the Sentinel-2 image has been successfully atmospherically corrected.

e_ISSN= 2775-3409
p_ISSN =______-
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2. Cropping

Cropping an image involves cutting the image to separate the area within the research study's scope from the areas outside of it. This is done to ensure that the subsequent data processing is more focused, detailed, and optimized.

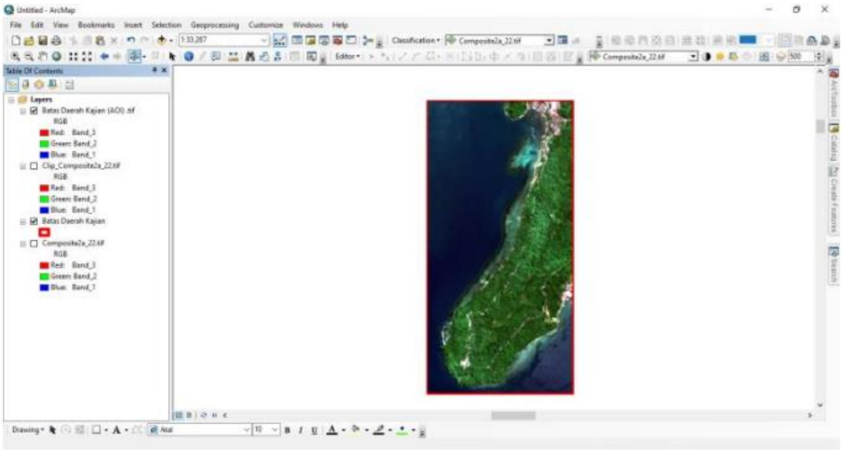

Figure. 1. The Result of Cropping Citra

3. Level 1 segmentation

In the segmentation process, Ecognition software is used. Before entering the segmentation process, several pieces of data need to be prepared. These include satellite image data, specifically Sentinel-2A images, and sample point data. It's important to ensure that the coordinate system or zone of both the satellite image and the sample data match, which is typically WGS 1984 UTM Zone 47 S.

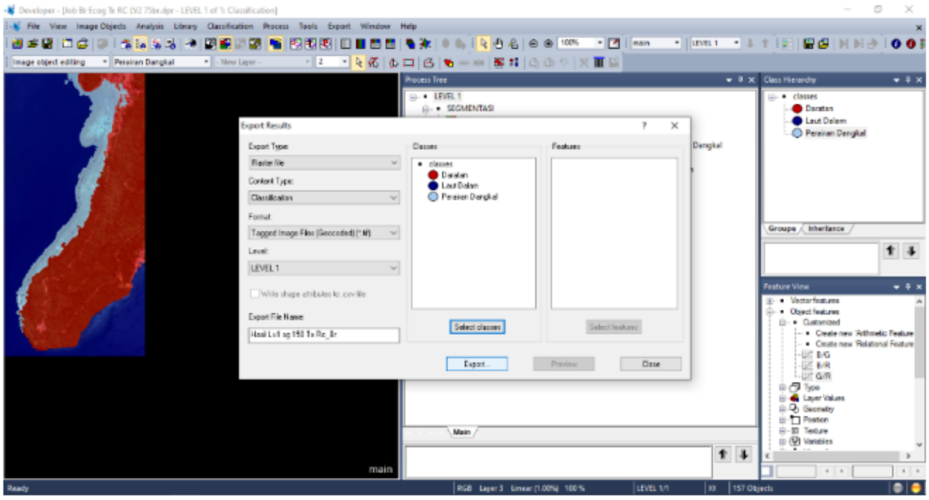

Figure. 2. The result of Level 1 segmentation

4. Level 2 Segmentation SVM Algorithm

After performing Level 1 segmentation, Level 2 segmentation is carried out, which is a continuation of Level 1 segmentation.

IRSAJ
International Remote Sensing Applied Journal
e_ISSN= 2775-3409
p_ISSN =_____-
Vol 4 No 2 | Desember 2023

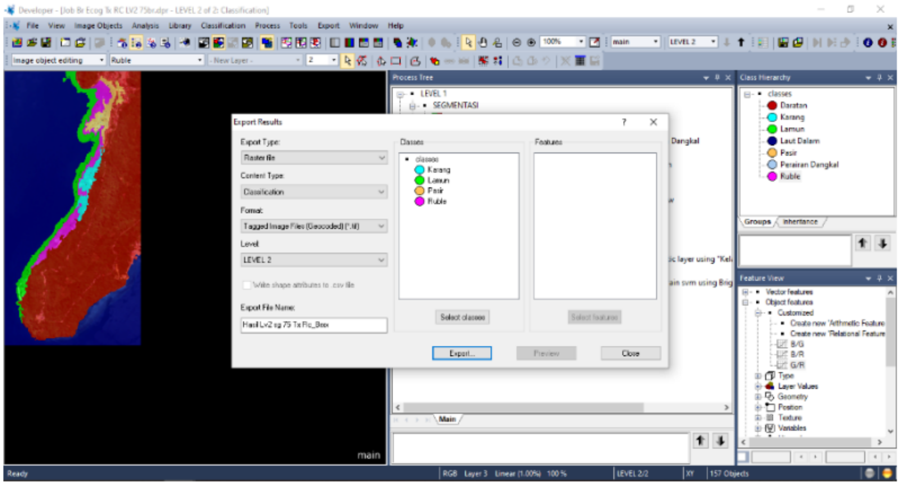

Figure 3. The result of Level 2 segmentation

Based on the data processing conducted for seagrass mapping in Pantai Nirwana, Kota Padang, in 2022, the results obtained are Level 1 Classification, as shown in Figure 2, and Level 2 Classification, as shown in Figure 3. The Level 1 Classification resulted in three classes: deep sea, shallow waters, and land, as presented in Figure 4. In the Level 2 classification, it is divided into four classes: coral, seagrass, sand, and rubble. This segmentation uses scale, shape, and compactness values of 75, 0.1, and 0.5, respectively. There are no fixed rules for these shape, scale, and compactness values. The map of Level 2 classification results for coral, seagrass, sand, and rubble in Pantai Nirwana, Kota Padang, uses the SVM method, as shown in Figure 5.

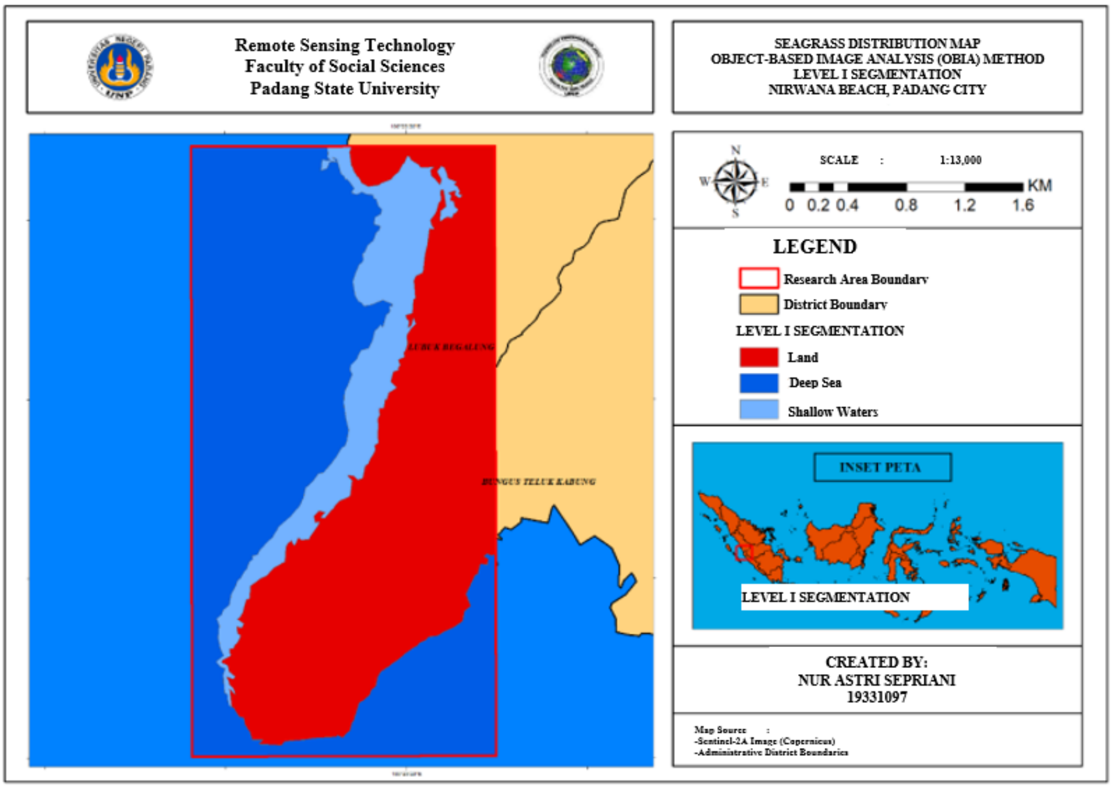

Figure 4. Level 1 Classification Map

IRSAJ
International Remote Sensing Applied Journal
e_ISSN = 2775-3409
p_ISSN = ______-
Vol 4 No 2 | Desember 2023

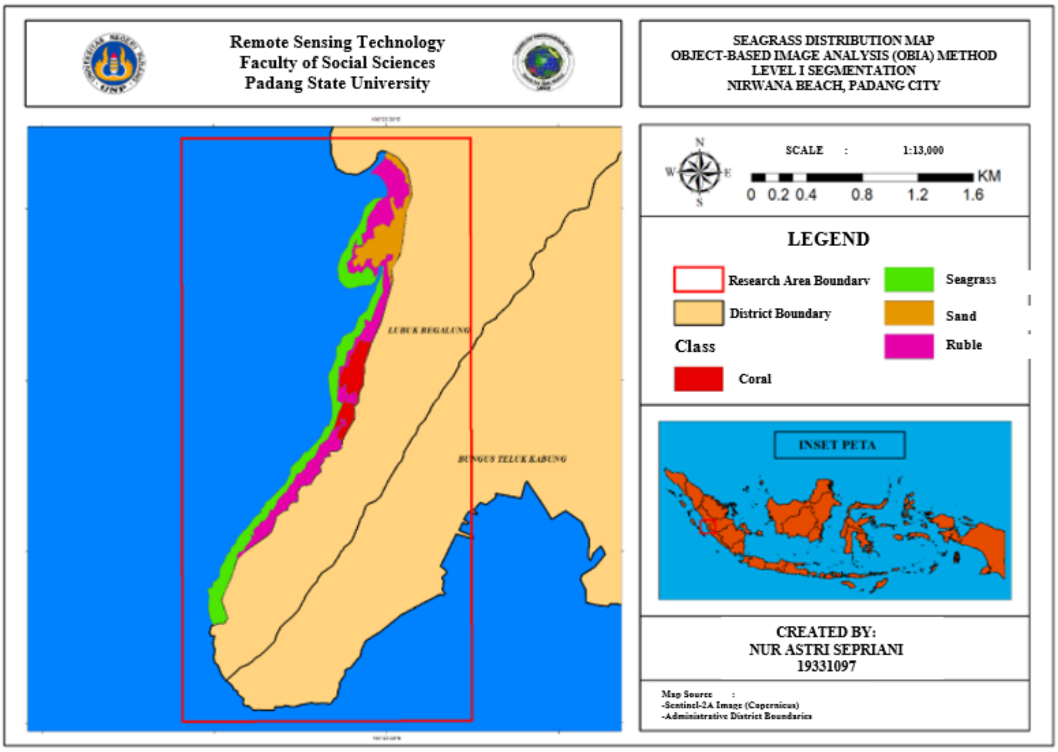

Figure 5. Level 2 Classification Map

4.1.2. Determining the Area of Seagrass Beds in 2022 at Nirwana Beach, Padang City

Based on the second objective of this research, is to process the data from image analysis to determine the extent of seagrass distribution in Nirwana Beach, Padang City. Here are the tables showing the seagrass area. The area classified at level 1 can be seen in Table 1, and the area classified at level 2 can be seen in Table 2.

Table 1. Area of Level 1 Classification

No	Class	Area (Ha)
1.	Deep Sea	416
2.	Shallow Waters	97
3.	Land	356

The results of Level 1 classification yielded 3 classes: Deep Sea with an area of 416 Ha, Shallow Waters with an area of 97 Ha, and Land with an area of 356 Ha.

Table 2. Area of Level 2 Classification

No	Class	Area (Ha)
1.	Coral	7,08
2.	Seagrass	25,06
3.	Sand	10,42
4.	Rubble	25,20
Total		67,76

The Level 2 classification resulted in four classes, namely Coral with an area of 7.08 Ha, Seagrass with an area of 25.06 Ha, Sand with an area of 10.42 Ha, and Rubble with an area of 25.20 Ha. To determine the accuracy of the seagrass distribution, validation was carried out using the ground-check field method, which involved 24 sample points. At each coordinate point, pictures of the environmental conditions were taken and then compared with the classification results from the satellite image used.

To determine the level of accuracy, the results of the ground check can be calculated using the following Table 3:

Table 3. Confusion Matrix

Classification	Data lapangan				Total	User Accuracy
	Coral	Seagrass	Sand	Ruble		
Coral	5	0	0	0	5	80%
Seagrass	0	7	0	1	8	87,5%
Sand	0	0	5	0	5	100%
Rubble	0	1	0	5	6	83,33%
Total	5	8	5	6	24	
Producer Accuracy	100%	87,5%	100%	83,33%		

$$\text{Ground Truth Interpretation Points} = \frac{\text{Total True Points}}{\text{Number of surveyed points}} \times 100\%$$

$$= \frac{22}{24} \times 100\ \%$$

$$= 91.67$$

The calculation results in Table 3 indicate that the interpretation's accuracy level reached 91.67%. According to the policy set out in Regulation No. 15 of 2014 by the Geospatial Information Agency, where the minimum expected accuracy value is 85%, it can be confirmed that the interpretation result of 91.67% has met the established standards. Although there are errors in the categories of seagrass and rubble, this is due to inaccuracies in the classification process.

Based on the Object-Based Image Analysis (OBIA) method used in the classification process, objects have been grouped into several classes, such as coral, seagrass, sand, and rubble. The total area of Pantai Nirwana is approximately 67.76 hectares. Data obtained from the classification of objects in shallow coastal waters require field inspections (Ground check). This step serves as a guide in performing the classification and can be used to verify the accuracy of the information present at the research location.

4.2. Discussion

This research, titled "Utilization of Sentinel-2A Imagery for Mapping Seagrass Distribution in Pantai Nirwana, Padang City," aims to analyze and map the distribution of seagrass in Pantai Nirwana, Padang City, using the Object-Based Image Analysis (OBIA) method on Sentinel-2A satellite imagery.

Pantai Nirwana, located in the West Sumatra province, is a significant area for this research. This beach is situated in part of Teluk Bayur waters, Padang City, with geographic coordinates of 1°0'23.87" - 1° 2'39.81" South Latitude and 100°22'33.24"- 100°23'40.26" East Longitude.

The mapping of seagrass distribution in 2022 was conducted by processing Sentinel-2A imagery using the OBIA method. This method is based on object-based remote sensing image analysis, which creates homogeneous segments based on spectral and spatial aspects [16]. In this research, the segmentation method was used with parameters such as scale, shape, and compactness at two levels, namely level 1 and level 2. In level 1 classification, there are three classification classes, including deep sea, shallow water, and land. Meanwhile, in the level 2 classification, there are four classes: coral, seagrass, sand, and rubble.

The mapping results show that seagrass is widely distributed in the Pantai Nirwana area, especially in the eastern and southern parts. The seagrass area in 2022 covers 25.06 hectares, experiencing a significant decrease from previous research in 2019, which recorded an area of 49.92 hectares.

The causes of changes in seagrass areas can be attributed to various factors, including human activities. Pantai Nirwana, as a tourist attraction, also plays a role, especially through ship propellers and anchors that can damage the seagrass ecosystem [17]. Additionally, natural factors such as waves, currents, storms, earthquakes, and tsunamis also contribute to changes in seagrass areas [18].

To measure the accuracy of the method, a ground-check field test was conducted with an interpretation accuracy of 91.67%, meeting the requirements of the Geospatial Information Agency in 2014. The OBIA method with the Support Vector Machine (SVM) algorithm was also effectively applied, resulting in an accuracy that complies with the 2014 Geospatial Information Agency standards.

5. CONCLUSION

Based on the problem statement outlined earlier, this research concludes the following:

1. Through the analysis and mapping of seagrass distribution in the Pantai Nirwana area of Padang City, it was found that seagrass is distributed along the coastline of Pantai Nirwana. Specifically, seagrass was most detected in the eastern and southern parts of Pantai Nirwana.
2. In mapping seagrass distribution in Pantai Nirwana, Padang City, the Object-Based Image Analysis (OBIA) method was employed to analyze the satellite imagery. The research results indicate that the seagrass area in this region is approximately 25.06 hectares. This area has experienced a significant decrease from the findings of previous research conducted in 2019, which recorded a seagrass area of 49.92 hectares.

This research suggests changes in the extent of seagrass distribution in Pantai Nirwana, Padang City, over a specific period. The significant reduction in the seagrass area highlights the potential changes in the marine ecosystem's condition, emphasizing the need for conservation and protection efforts in the marine environment of this area.

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