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UTILIZATION OF SENTINEL-2 IMAGES FOR MAPPING THE CORAL REEF AREA IN THE CONSERVATION AREA OF PIEH ISLAND WATERS 2022

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ABSTRACT: Coral reefs are known as complex and productive shallow tropical marine ecosystems. They serve as a habitat for various species of marine plants, marine animals, and marine microorganisms. The deterioration of coral reefs threatens the survival of this shallow marine ecosystem. Mapping the distribution of coral reefs using remote sensing technology is a crucial instrument in the effort to monitor and protect coral reefs while preserving the marine environment. This research aims to map and measure the extent of coral reefs in the Pieh Islands Marine Conservation Area in 2022. In this study, we used Sentinel-2 imagery from 2022 and applied the Object-Based Image Analysis (OBIA) method to detect the extent of coral reefs. Sentinel-2 imagery was processed using ArcGIS and eCognition software, involving atmospheric correction, image clipping, image compositing, segmentation, image classification, and accuracy testing. The data processing results indicate that coral reefs are distributed around the waters of Pieh Islands, with the highest density located to the south of Pieh Islands's waters. The total extent of detected coral reefs in this study is 15.76 hectares. The use of Sentinel-2 imagery with the OBIA method has proven to be effective in detecting the extent of coral reefs in the Pieh Islands Marine Conservation Area.

Keywords: Coral reefs, Sentinel-2 imagery, OBIA method, Pieh Islands

1. INTRODUCTION

Indonesia, as the world's largest archipelagic nation with over 17,000 large and small islands, boasts a coastline spanning nearly 81,000 kilometers, which is home to diverse ecosystems including coral reefs, seagrass beds, and mangroves. Indonesia plays a pivotal role in the global preservation of marine biodiversity. Coral reefs, a key component of shallow tropical marine ecosystems, have a crucial role to play. They not only serve as habitats for a wide array of fish species but also function as tourist attractions while providing coastal protection against waves and the suspension of suspended materials. Identifying the distribution of coral reefs in shallow waters is essential for the conservation of this ecosystem. Indonesia, with its extensive coral formations spread across almost all of its islands, makes a significant contribution to the global preservation of coral reefs. Coral reefs are organisms that inhabit shallow tropical waters, exhibiting high productivity [1].

Coral reefs are closely linked to environmental conditions, where a favorable water quality environment promotes coral growth. One of the areas in Indonesia that features coral reefs is the Pieh Islands Marine Conservation Area. The management of coral reefs must be based on human involvement, as they are direct users of marine resources. According to the 2020 data from the Ministry of Maritime Affairs and Fisheries, the Pieh Islands Marine Conservation Area has experienced coral bleaching events that resulted in coral mortality. High waves and fishing activities carried out by humans can lead to coral damage or death. Therefore, human involvement in the management of coral reef resources is crucial, starting from the planning phase, implementation, monitoring, and assessment of various management methods. Efforts to determine the distribution of coral reefs are essential for the development of marine and coastal energy resources.

One of the observation methods used to determine the existence of an aquatic ecosystem is the utilization of remote sensing technology, which can be applied to marine environments, especially in detecting objects in shallow water areas, such as coral reefs [2]. Spatial information regarding the composition, condition, and dynamics of coral reefs at an appropriate spatial scale is a fundamental prerequisite for understanding and managing shallow water ecosystems [3].

Mapping shallow-water ecosystems is crucial for the optimal management and conservation efforts of these ecosystems [4]. Remote sensing technology produces various types of images recorded by various sensors

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Vol 5 No 2/December 2023

(multisensors) capable of generating images with different resolutions. To obtain accurate information about coral reef distribution using remote sensing data, various techniques and methods are available. In this study, to produce accurate information about coral reefs, Sentinel-2 imagery was used. Sentinel-2 imagery is already geometrically and atmospherically corrected, with atmospheric correction provided in terms of Top of Atmospheric (TOA) reflectance values. Sentinel-2 imagery offers several advantages, including high accuracy, spatial resolution of 10 meters, short temporal resolution, and wide spectral coverage. Coral reef mapping was conducted using a Red, Green, and Blue composite using bands 4, 3, and 2 of Sentinel-2 imagery. These spectral bands cover the wavelength range of 0.49 to 0.66 µm, which includes visible light and is suitable for mapping shallow coastal waters [5]. Brightness indicates the intensity of sunlight that can penetrate the layers of water. The murkier the water, the lower the intensity of light that can penetrate the water [6]. Sentinel-2 has the capability of reflecting dark substrate, which is highly relevant for monitoring coral reefs in shallow waters. In Sentinel-2, the use of reflectance curves describes the spectral object response to the energy received by the sensor. The spectral reflection in the blue and red regions, associated with healthy chlorophyll absorption in the water, becomes crucial for detecting coral reefs. The identification of coral reef objects can be achieved through image interpretation, considering elements such as location, size, shape, shadow, tone or color, texture, pattern, depth, and the context of the site or associations within the image [6]. The use of spectral reflection in the blue and red regions is highly relevant because it depicts the presence of chlorophyll associated with healthy coral reefs. Image interpretation involves various aspects that aid in identifying coral reefs and assessing their condition, thus providing valuable information for mapping and monitoring shallow-water coral reef ecosystems.

Object-Based Image Analysis (OBIA) is a classification method developed through the process of segmentation and object analysis. It classifies images based on their spatial, spectral, and temporal characteristics, resulting in image objects or segments that are subsequently used for classification [7], [8]. The segmentation results in the OBIA method allow the identification of coral reef objects based on characteristics such as location, color, patterns, and visible depth in Sentinel-2 images.

This research aims to evaluate the extent and conduct accuracy assessments of coral reefs in the Pieh Islands Marine Conservation Area in 2022. By utilizing remote sensing technology and the OBIA method, this study is expected to provide a deeper understanding of the state of coral reefs in this area, ultimately supporting the vital conservation and management efforts of shallow water ecosystems.

2. LITERATURE REVIEW

2.1. Remote Sensing

Remote sensing is the science and art that enables us to acquire information about specific objects, areas, or phenomena through the analysis of data obtained using instruments without direct contact with the objects themselves [9]. On the other hand, another viewpoint explains that remote sensing is an activity aimed at identifying and analyzing objects or features using sensors from a remote observation position [10]. In this context, the primary goal of remote sensing is to collect data and information from images, both photographic and non-photographic, recorded or generated by remote sensing instruments. The data analysis process in remote sensing involves various interpretation and observation tools to analyze visual data, often involving computers to analyze numerical sensor data. Reference data about the natural resources being studied, such as soil maps, plant statistical data, or field test results, are used in this data analysis process. The results of data interpretation are then presented in various forms, such as maps, tables, or reports, and are used to support decision-making processes. The basic components of remote sensing systems include the energy source, the atmosphere, the interaction between energy and objects on the Earth's surface, sensors, data processing systems, and various data applications. Energy interacts with objects and serves as a medium to transmit information from objects to sensors. Sensors are instruments used to collect and record electromagnetic radiation. Data generated by sensors are then processed and formatted for further use.

The advancement of remote sensing technology has made significant progress, and now remote sensing can be accessed by various individuals with the help of devices like laptops or smartphones, as well as applications like Google Earth, Google Maps, ArcGIS, Geo Tracker, and others. The use of remote sensing technology is no longer limited to scientific disciplines such as meteorology, geophysics, forestry, marine science, and agriculture but has also expanded into various fields, including social, political, health, military, security,

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Vol 5 No 2/December 2023

defense, planning, economics, and more. The internet has become a driving force for information providers, creating remote sensing-based informative products and easily accessible geographic information systems, often offered for free, such as Google Earth developed by Google.

2.2. Geographic Information System (GIS)

Geographic Information System (GIS) is a system that focuses on information related to geographic locations on the Earth's surface. GIS is a computer-based system with the capability to process, manipulate, and display both spatial and attribute data [11]. GIS is a specialized information system that focuses on managing data with spatial or geographic reference components. Essentially, GIS is a computer-based system used to collect, integrate, and analyze information from acquired data, enabling the generation of new information [12].

In other words, GIS enables users to explore, analyze, and understand data based on their geographic location. This system is highly valuable in various fields, including urban planning, natural resource management, mapping, environmental monitoring, and more, as it can provide valuable insights into how data and phenomena related to geographic locations are interconnected.

2.3. Citra Sentinel – 2

Sentinel-2, launched through a collaboration between The European Commission and the European Space Agency as part of the Global Monitoring for Environment and Security (GMES) program, aims to monitor the Earth's surface conditions. This is done to provide real-time data about the Earth from space, which has crucial applications in the fields of the environment and security [13]. Launched in 2015 as part of the European Space Agency (ESA) Copernicus program, Sentinel-2 is a European optical imaging satellite. The satellite carries a multispectral sensor with 13 high-resolution spectral bands. Sentinel-2 aims to support various services, including monitoring marine habitats, detecting land cover changes, and natural disaster management.

Sentinel-2 provides a source of satellite image data available free of charge. It has medium spatial resolution with wide coverage and revisits the same location every 5 days. The Sentinel-2 Multispectral Instrument (MSI) includes 13 spectral bands with various resolutions, including 4 bands with 10-meter resolution, 6 bands with 20-meter resolution, and 3 bands with 60-meter resolution.

The use of Sentinel-2 satellite images in the field of marine science has proven to be promising [14]. This satellite is designed to combine the capabilities of the SPOT and Landsat satellites in monitoring the Earth's surface worldwide, including coastal waters, the Mediterranean Sea, and Antarctica. Its orbit is sun-synchronous at an altitude of 786 km, allowing for precise overpasses at 10:30 AM local time at the descending node. This enables the use of Sentinel-2 data along with existing SPOT and Landsat imagery for time series analysis [15]. Radiometric measurements in these images are provided in Top of Atmosphere (TOA) reflectance and can be converted to radiance.

2.4. Coral Reef

Coral reefs, marine organisms that live in shallow waters, especially in tropical regions, have high productivity [1]. Coral reefs are large and complex associations of various organisms, encompassing a diverse range of habitat types simultaneously [16]. Coral reefs provide a home for over 76% of coral species and 50% of coral fish species, while also serving as a food source for countless other marine animals [17]. Coral reef ecosystems play a vital role in protecting coastlines from erosion, serving as habitats for fish, a source of food, and tourist destinations.

Coral reefs typically thrive in shallow waters, approximately 50 meters below the ocean's surface, and require specific environmental conditions. The requirements for coral life include factors such as temperature, depth, salinity, light, pH, nutrients, sedimentation, freshwater, and water pollution [18]. Other factors that support coral growth include optimal water temperature, appropriate depth, proper salinity levels, sufficient light, and calm water currents [19]. In addition, the conditions for coral reef survival also depend on factors such as temperature, depth, salinity, light, sediment, currents, tectonic activity, and nutrient availability [20].

IRSAJ International Remote Sensing Applied Journal
e_ISSN = 2775 – 3409
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Vol 5 No 2/December 2023

Coral reefs can be distinguished into several types, including fringing reefs, barrier reefs, atolls, and patch reefs (Charles Darwin). The diversity of coral reef types has significant ecological and economic benefits. Coral reefs are essential fish habitats, and destinations for marine tourism, and play a role in protecting coastlines from erosion. Coral reefs also contribute to marine biodiversity. Mapping the extent of coral reefs in the waters of Pieh Islands in 2022 used reference data from previous research conducted by LKKP Pieh Islands in the period from 2010-2020.

2.5. OBIA (Object Based Images Analysis)

OBIA (Object-Based Image Analysis) is a remote sensing image analysis paradigm that focuses on developing analysis methods based on objects, thus generating objects with specific meanings. The OBIA method integrates spectral and spatial aspects in image classification [21], [22]. In the OBIA method, the subject image is divided into objects or segments that are homogeneous based on spatial, spectral, and temporal characteristics. This allows the use of various features, including spectral, textural, contextual, and geometric features in the classification process. Segmentation at various scales can be used to efficiently describe hierarchical patterns and information in the image [23].

The advantages of OBIA include:
1. Separating the image into objects in a way similar to delineation done by humans.
2. Using spectral, textural, contextual, and geometric features.
3. Extracting objects at various scales from the same data.
4. Ability to deal with "salt and pepper" noise in high-resolution data [24].

3. METHODS

This research employs a quantitative method to detect the distribution of coral reefs in the Pieh Islands Marine Conservation Area using Sentinel-2 satellite images and applying the Object-Based Image Analysis (OBIA) classification method. The goal is to identify the location and extent of the coral reefs. This research was conducted in 2022 in the Pieh Islands Marine Conservation Area, West Sumatra Province, and involved both theoretical studies and the collection of secondary data on the distribution of coral reef points. The study area covers the entire Pieh Islands, which is 44.29 hectares in size.

The tools used in this research include a laptop, software such as ArcGIS, eCognition, Google Earth, and Microsoft Office 2019, as well as the Sen2Cor plugin. The research data includes Sentinel-2 satellite images from ESA in 2022, coral reef distribution points in 2020 from the Ministry of Maritime Affairs and Fisheries (KKP) website, and the Administrative Map of the Pieh Islands Marine Conservation Area in 2020 from the KKP website.

The data analysis phase involves the following steps:
1. Mapping the Extent of Coral Reefs in 2022
   - Processing Sentinel-2 satellite image data in the Pieh Islands waters, including atmospheric correction using Sen2Cor software.
   - Cropping the images to focus the analysis on the relevant area.
   - Creating image composites by combining multiple bands.
   - Image segmentation to partition the image into objects based on specific properties.
   - Image classification using the Support Vector Machine (SVM) algorithm to map the coral reef ecosystem.
2. Accuracy Testing of Coral Reef Extent in 2022
   - Involves accuracy testing of the classification by using an error matrix to compare the classified data with ground-truth data, including calculating producer accuracy, user accuracy, and overall accuracy.

This research aims to generate accurate information about the distribution of coral reefs in the Pieh Islands Marine Conservation Area using Sentinel-2 satellite imagery and an object-based analysis method.

IRSAJ
International Remote Sensing Applied Journal
e_ISSN = 2775 – 3409
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Vol 5 No 2/December 2023

4. RESULT AND DISCUSSION

4.1. Result

4.1.1. Mapping the extent of coral reef distribution

The method used is Object-Based Image Analysis (OBIA) with data processing stages such as image correction, image cropping, and segmentation. Afterward, the classified coral reef results will be converted from raster to polygon to calculate their area. The next stage involves segmentation at level 1 and level 2 using the OBIA method and the Support Vector Machine (SVM) algorithm with the assistance of eCognition software.

The level 1 segmentation process involves using eCognition software. Before starting the segmentation, the necessary data includes Sentinel-2 imagery and sample points. It is important to ensure that the coordinate system or data type between Sentinel-2 imagery and sample points matches, i.e., WGS 1984 UTM Zone 47S. The data processing results for mapping the distribution of coral reefs in the Waters Conservation Area of Pieh Islands, West Sumatra Province in 2022, yielded classifications at Level 1 Segmentation with three classes: Land, Shallow Waters, and Deep Waters.

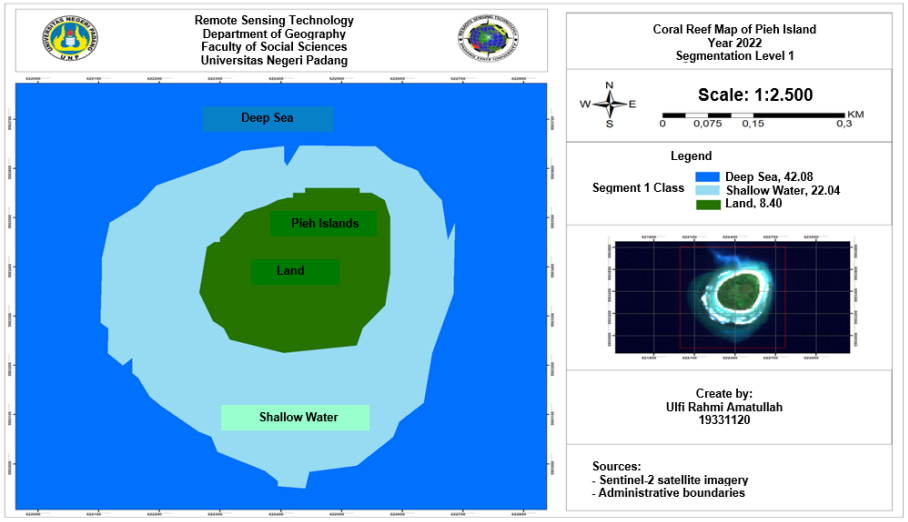
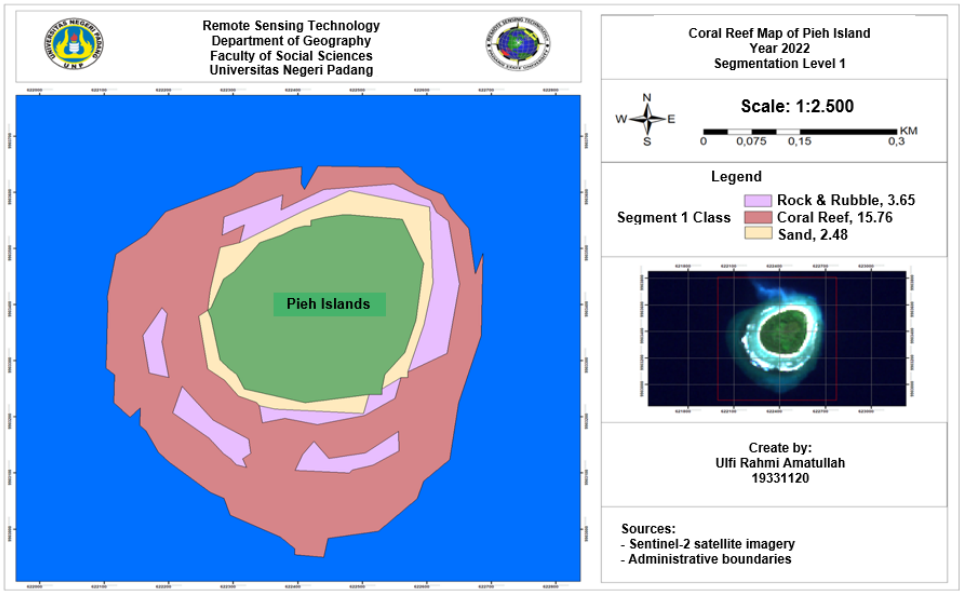


Figure 1. Map of Level 1 Classification

After completing level 1 segmentation, the next step is to perform level 2 segmentation. The Classification of Level 2 Segmentation, three classes were successfully identified: Coral Reefs, Sand, and Rock and rubble.



IRSAJ International Remote Sensing Applied Journal
e_ISSN = 2775 – 3409
p_ISSN = ____ – ____
Vol 5 No 2/December 2023

Figure 2. Map of Level 2 Classification

Here is the table of the areas obtained from the processing:

Table 1 Area of Level 1 Classification

No	Class	Area (Ha)
1	Land	8,40
2	Shallow Waters	22,04
3	Deep Waters	42,08

The results of level 1 classification yielded 3 classes: Land 8.40 hectares, Shallow Waters 22.04 hectares, and Deep Waters 42.08 hectares.

Table 2 Area of Level 1 Classification

No	Class	Area (Ha)
1	Coral Reefs	**15,76**
2	Sand	2,48
3	Rock & Rubble	3,65

The results of the level 2 classification show 3 classes with the following areas: Coral Reefs 15.76 Ha, Sand 2.48 Ha, and Rock and rubble 3.65 Ha.

Based on data from the KKP TWP Pieh Islands in 2020, the extent of Coral Reef coverage was 37.17%. For the data processing results in 2022, obtained in this study, the extent of Coral Reef coverage is 35.58%. This indicates a decrease in Coral Reef coverage by 1.59% from 2020 to 2022.

$$\boldsymbol{L = \frac{Li}{N} \times 100\%} \quad (1)$$

In measuring the percentage of coral reef cover, we calculate L, which represents the percentage of coral covering a particular area. The value of L is calculated by dividing the total length of all categories of coral life forms (Li) by the length of the transect line (N). In this formula, Li is the total length of various categories of coral organisms, and N is the length of the transect line used in the measurement. Using this formula, we can accurately estimate how much coral dominates a particular reef area, which is crucial information for reef monitoring and understanding.

4.1.2. Determining the accuracy test of coral reefs

Based on the data processing conducted in this research, the results of the area and distribution of coral reefs were obtained through the classification process at segmentation levels 1 and 2. Subsequently, an accuracy test was conducted to determine the accuracy of the data processed using the OBIA method and the SVM algorithm.

Table 3. Confusion matrix

Classification	Field Data			Total	UA
	Coral Reefs	Land	Rock & Rubble		
Coral Reefs	10	0	3	13	76,92 %
Land	0	5	0	5	100 %
Rock & Rubble	3	0	2	5	40 %
Total	13	5	5	23	
PA	76,92 %	100 %	40 %		

The level of truth of interpretation = $\frac{\textit{Number of True Points}}{\textit{Number of Surveyed Points}}$ *x 100 %* (2)

= $\frac{20}{23}$ x 100%

= 86,95 %

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p_ISSN = ____ – ____
Vol 5 No 2/December 2023

The results of the analysis show that the level of interpretation accuracy is 86.95%. Based on the policy established in the Geospatial Information Agency Regulation No. 15 of 2014, where the minimum accuracy value is 85%, it can be confirmed that the interpretation results of 86.95% meet the requirements. Errors occurred in the categories of Coral Reefs and Rock and rubble, which were due to misclassifications during the classification process.

Based on the classification results using the Object-Based Image Analysis (OBIA) method, objects were grouped into several classes, namely Coral Reefs, Sand, Rock, and rubble. The total area of the Pieh Islands Marine Conservation Area is approximately 44.29 hectares. The data obtained from the classification of objects in shallow coastal waters requires field verification (Ground Check), which serves as a guideline for classification and can be used to verify the accuracy of the research location.

4.2. Discussion

This research aims to utilize Sentinel-2 imagery from 2022 to detect the distribution of coral reefs in the Pieh Islands Marine Conservation Area, West Sumatra Province. The geographic location of this area is approximately between 99°59’36”-100°59’28” E and 00°45’10”-01°03’08” S, and it is situated about 17 nautical miles from the coast of Padang Pariaman Regency, reachable within a 2-hour boat journey.

The research involves processing Sentinel-2 imagery using the Object-Based Image Analysis (OBIA) method and the Support Vector Machine (SVM) algorithm. The OBIA method includes a segmentation process that groups neighboring pixels with similar characteristics, conducted in two stages: image segmentation (at the pixel level) and classification of each resulting segment. The SVM algorithm has proven to be effective in remote sensing, especially when dealing with limited data, and is capable of achieving high accuracy [25].

This research involves two classification levels. At the first level, there are three classes: land, shallow water, and deep water. The classification results at the first level serve as the basis for classification at the second level, which includes three classes: coral reefs, sand, and rock rubble. Segmentation is carried out by considering scale, shape, and compactness values of 75, 0.1, and 0.5, respectively, although there are no strict rules regarding these values [26].

The research results in 2022 identified a coral reef area of 15.76 hectares. This finding indicates a decrease of approximately 0.7 hectares compared to the previous research conducted by LKKP in 2020, which recorded a coral reef area of 16.46 hectares. Referring to the 2020 LKKP data, the coral reef area in Pieh Islands experienced a 1.59% decrease in 2022.

Changes in the coral reef area over a specific period are influenced by natural factors, such as high waves and storms around the waters of Pieh Islands. Coral reefs act as wave energy dissipaters, reducing the impact of wave energy reaching the coast. This aligns with previous research findings that explain how changes in wave velocity as they enter shallow waters can lead to wave refraction or bending [27].

Accuracy testing was conducted through ground checks in the field with 23 sampling points, where there were 3 misclassified points due to errors in identifying objects in shallow coastal waters. However, the level of interpretation accuracy reached 86.95%, exceeding the minimum accuracy threshold of 60% set by the 2014 Regulation of the National Geospatial Information Agency. The accuracy test results for Sentinel-2 imagery using the OBIA method and SVM algorithm are considered satisfactory.

In conclusion, the characteristics of coastal regions have proven to be sensitive to changes, and the changes in the coral reef area in Pieh Islands are suspected to be due to natural factors, especially high waves and storms. The use of remote sensing and OBIA methods has proven to be an effective approach in mapping coral reef distribution, despite a decrease in coral reef area from 2020 to 2022.

5. CONCLUSION

This research yields two main conclusions. First, the use of the OBIA method and the SVM Algorithm to map the extent of coral reef distribution in 2022 on Pieh Islands, West Sumatra, indicates that the coral reef area is approximately 15.76 hectares. This represents a decrease of about 0.7 hectares when compared to the results

of previous research conducted by the Marine and Fisheries Service (LKKP) on Pieh Islands in 2020. Second, the accuracy test results using 23 sampling points revealed an interpretation accuracy rate of 86.95%, exceeding the minimum accuracy threshold set for basic shallow water habitat maps, which is 60% according to the 2014 Regulation of the National Geospatial Information Agency. Therefore, the OBIA method and SVM Algorithm have proven to be effective in mapping coral reefs in this area, despite the decrease in coral reef area.

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