JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 8 No 2 2024

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Web GIS Based Benthic Habitat Mapping Update Supports Smart Island Lemukutan

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Received: October, 10 2024
Accepted: December 26, 2024
Published: December 26, 2024

Abstract

Benthic habitats are important for the quality of life and global climate. Systematic and efficient information is important for the monitoring, mapping, and recording of aquatic bottom habitats, thus providing a habitat database. In the last decade, object-based image analysis (OBIA) has been accepted as an effective method for extracting and classifying information from high spatial resolution satellite imagery. Our study's goal is to use WebGIS to combine coral reef monitoring data from Lemukutan Island and find out how much coral cover there is on the island using the smart island WebGIS. This study took place from August 6th to August 13th, 2024, and used a total of 1097 field points to show where all the benthic habitats and Sentinel 2A image data sources were located. The research results obtained the extent of shallow water benthic habitat classification with different variations in each habitat class. The Rock Class covers an area of 41,940 ha, the mixed class 2,409 ha, the coral class 130,340 ha, the dead coral class 49,249 ha, the macroalgae class 2,840 ha, and the sand class 12,140 ha. The overall accuracy (OA) results for the waters of Lemukutan Island obtained the highest value, namely 89.5833%, using the SVM algorithm. Regular monitoring of coral reefs can help update Lemukutan Island Smart Island data to become a catalyst in realizing a smart island ecosystem in West Kalimantan Province by presenting benthic habitat maps through web GIS services and realizing technology development for coastal areas and small islands.

Keywords: Mapping, Benthic Habitat, WebGIS, Smart Island Lemukutan

1. Introduction

Coastal ecosystems are characterized by high biodiversity and primary production. High primary production includes benthic habitats including coral reef and seagrass ecosystems (Yasir Haya and Fuji, 2019). Benthic habitats are important for the quality of life and global climate. Systematic and efficient information is important for monitoring, mapping and recording of marine benthic habitats thus providing a reference collection of habitat types for the diversity of objects that make up the benthic habitats to enable the availability of a habitat database (Lima et al., 2019; Wölfl et al., 2019).

Machine learning algorithms are powerful approaches used in classifying benthic habitats on detailed and primary classification schemes to produce accurate benthic habitat maps (Wicaksono et al., 2019). In the last decade, object-based image analysis (OBIA) has been accepted as an effective method for extracting and classifying information from high spatial resolution satellite imagery (Roelfsema et al., 2018). Benthic habitat mapping using satellite imagery and its accuracy assessment, including benthic habitat mapping using sentinel 2A: A, obtained generalized results of benthic habitat maps with four classes, namely hard coral, hard coral-algae, sand, and seagrass (Munawaroh et al., 2021). Lazuardi & Wicaksono (2021) stated that PlanetScope (3m) and Sentinel-2A MSI (10m) can be used to map coral reefs with higher complexity with multiresolution can be used to produce complex coral reef life form maps with varying levels of information detail. Mastu et al., (2018) used object-based classification (OBIA) with the SVM algorithm on Sentinel-2 images with the results of benthic habitat classification in the classification of 12 and 9 benthic habitat classes showing that the live coral class, rubble + seagrass class, algae class.

One of the tools that can be used in management including monitoring and supervision of resources is the Geographic Information System (GIS). Geographic information systems are an important tool for spatial modeling in the analysis of various coastal issues. Therefore, synergy is needed between GIS data and the help of the latest multimedia software technology to help interactive and easily accessible displays in this case is webGIS technology (Jeong et al., 2011; Gros et al., 2023). Smart Island Lemukutan through WebGIS-based benthic habitat data collection can be done by directly collecting benthic habitats at the research location, then data from field observations and analysis results are displayed on the Smart Island Lemukutan website and can be accessed at https://webgissmartisland.com (Zibar et al., 2023).

Smart islands are currently being implemented in a number of small islands in developing countries or Small Island Developing States (SIDS) with one of the challenges faced being technology-based (Domínguez et al., 2017). Routine coral reef monitoring can help input the Lemukutan smart island to become a catalyst in realizing a smart island ecosystem, by presenting benthic habitat maps through webGIS services and actualizing the development of coastal and small island technology based on smart islands through the concept of smart destinations by integrating benthic habitat information through webGIS services (Zibar et al., 2023).

So far, research on smart islands through webGIS-based benthic habitat mapping has rarely been carried out and there is a need for updating of webGIS-based benthic habitat mapping to support the smart island of Lemukutan Island, and it is necessary to develop webGIS-based smart islands on small islands in Indonesia.

2. Method

2.1. Time and Location of Reseacrh

Observations of shallow water habitats were conducted on 06 - 15 August 2024 with 1097 field observation points representing the entire benthic habitat on Lemukutan Island, Bengkayang Regency, West Kalimantan (Figure 1).

2.2. Tools and Materials of Research

The data sources used are field observation data with 1097 ground check station points representing the entire distribution of benthic habitats and Sentinel 2A Imagery data S2A_MSIL1C_20240727T025531_N0511_R032_T49NBA_20240727T071121.SAFE.

The equipment used for data collection in the field is basic diving equipment, SCUBA diving equipment, stationery, data sheet paper, meter, 1x1 meter square transect, Garmin 60 Csx Global Positioning System (GPS), and underwater camera, secchi disc, Water Quality Meter. Data processing and analysis using a laptop with erMapper, ArcGIS, eCognition, and Ms. Excel software.

2.3. Data Collection

The data collected in this study consisted of two stages, namely field data collection and image data. Field data collection used transect quadrat 1 x 1 m^2. The area of the transect quadrat used is an adjustment to the accuracy of the GPS (global positioning system) used. The transect quadrat with this area also serves to facilitate the determination of the dominant components of shallow water benthic habitats. The coordinate points taken will be used as a reference for the RoI (region of interest) in the image classification process and some of them will be used as data for testing the accuracy of the image classification results (Nababan et al., 2021). Benthic habitat type information obtained from the distribution of observation points is used to determine the classification scheme, the classification process with imaging satellites, and for accuracy testing (Hartoni et al., 2021). The image data collected is Sentinel-2, which was obtained through the ESA Copernicus site. The Sentinel-2 imagery to be downloaded in this study is Level 1C data, which has been geometrically corrected. The sensors or image channels used are visible and infrared channels with a spatial resolution of 10 m, namely channel 2 (blue), channel 3 (green), channel 4 (red), and channel 8 (Infrared) (Alifatri et al., 2022).

The stages of data processing for updating benthic habitat mapping based on WebGIS supporting the smart island of Lemukutan Island are as follows (Figure 2).

2.4. Data Collection

Accuracy testing is carried out on all classified maps to determine the accuracy of the classification technique applied. The accuracy test commonly performed on remote sensing classification data is the error matrix with calculations of overall accuracy (OA), producer accuracy (PA), user accuracy (UA) (Congalton and Green, 2009).

3. Results and Discussion

The results of the research conducted in 2024 on Lemukutan Island obtained the extent of shallow water benthic habitat classification with different variations in each habitat class. The classification results of each habitat class are shown in Table 1.

Table 1. Distribution of benthic habitats on Lemukutan Island

Class	Area (Ha)	Area (Km^2)
Rock	41,940	0,419
Mixed	2,409	0.024
Coral	130,340	1,303
Dead Coral	49,249	0,492
Macro Algae	2,840	0,028
Sand	12,140	0,121

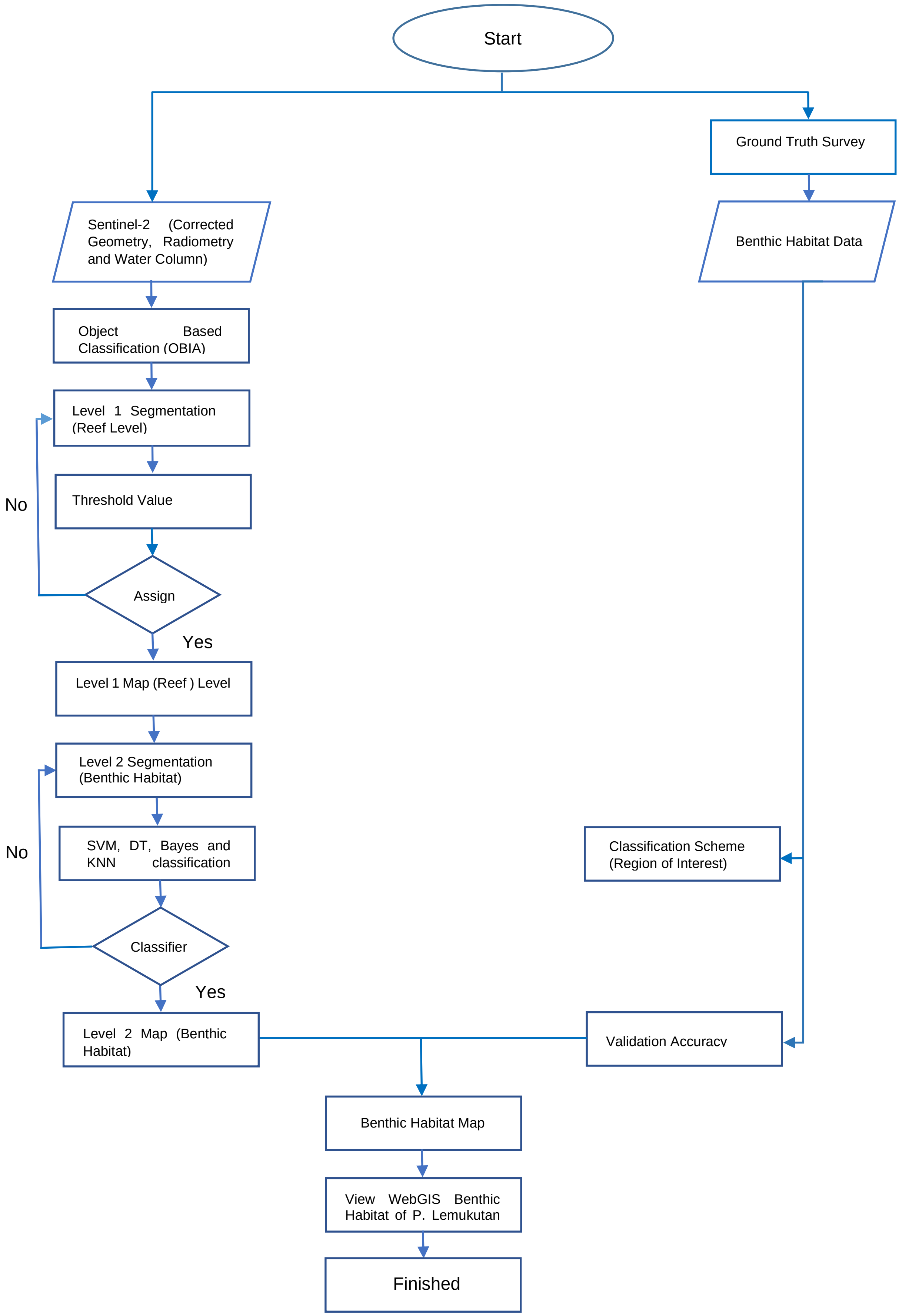

Fig 2. Research Flow Chart

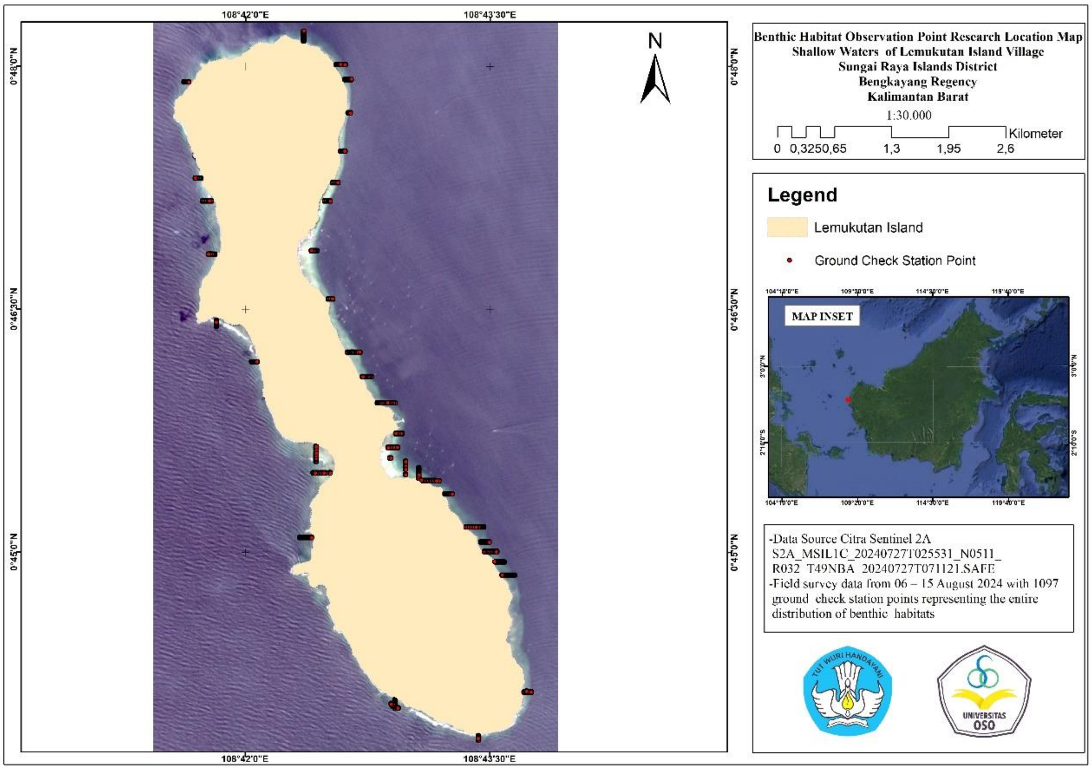

Fig 1. Benthic Habitat Observation Point Research Location Map

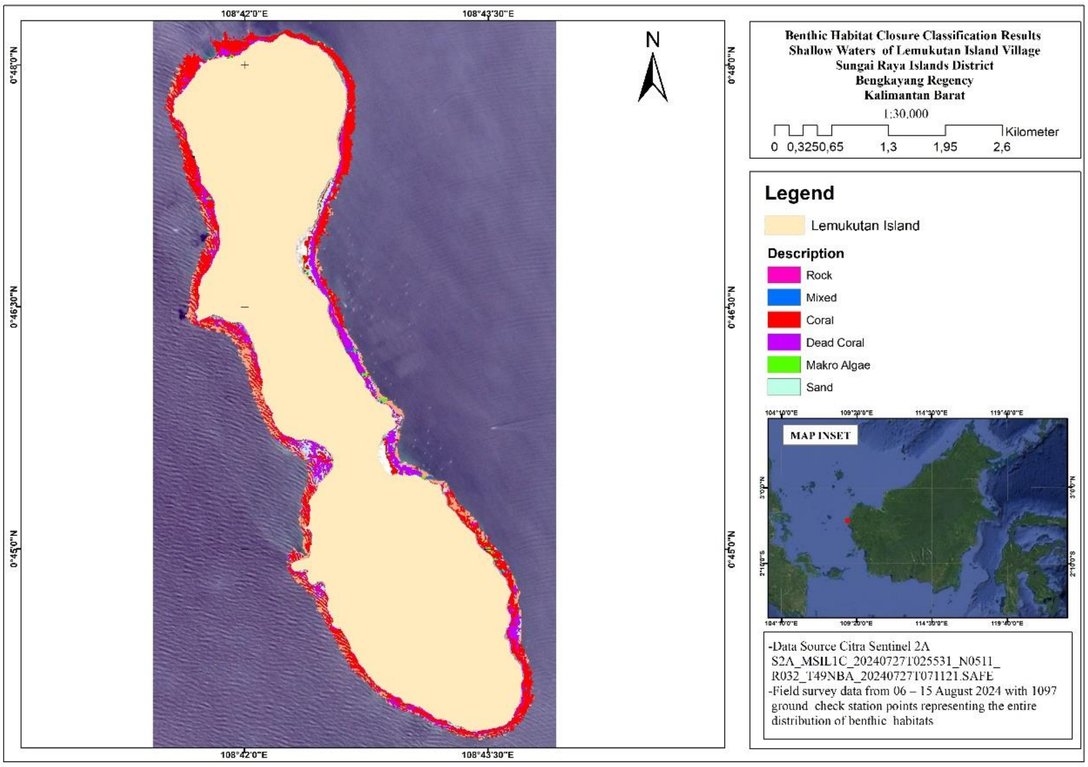

Fig 3. Map of the study area results of the classification of the closed benthic habitat of the Lemukutan Island village waters.

Table 2. Accuracy of benthic habitat classification for each class

Satellite/field	Rock	Mixed	Coral	Dead Coral	Makro Algae	Sand	Total	User Acc (%)
Rock	3	0	0	0	1	0	4	75.00
Mixed	0	10	0	0	2	2	14	71.43
Coral	0	0	44	0	0	3	47	93.62
Dead Coral	0	0	0	37	0	0	37	100.00
Makro Algae	0	2	0	2	30	2	36	83.33
Sand	0	1	0	0	0	5	6	83.33
Total	3	13	44	39	33	12	144	
Overall Accuracy = 89.5833%								
Kappa Coefficient = 0.8630								

The classification results show misclassification, for example, a reef class was found on the coast of East Melanau Bay which is located around the Lemukutan 1 pier. The results of field observations of the location should not have a coral reef class and are included in the dead coral class category. The misclassification is suspected because the pier area has a color appearance that is very similar to the reef area and is one of the factors that causes misclassification by the computer. Lazuardi et al., (2021) stated that misclassification such as seagrass class being identified as seagrass sand or vice versa is due to the similarity of pixel values between the two objects. The ability of satellite imagery to define habitat classes, including coral reefs, is greatly influenced by several things, including field data used as a reference (Subarno et al., 2018).

The results of the Overall Accuracy (OA) in the waters of Lemukutan Island obtained the highest value of 89.5833% using the SVM algorithm. All classification classes in the shallow waters of Lemukutan Island can be mapped well, except for the mixed class which received a low UA (User Accuracy Value) of 71.43% (Table 2). As seen in Table 2, several mixed class points were identified as macroalgae and sand classes. The influence of the mixture of sand with other benthic cover such as macroalgae, sand and coral fragments can make it difficult for the algorithm to classify cover in one area. In addition, noise from the image, cloud cover and water turbidity can cause differences in benthic cover identification (Mohamed et al., 2020). The complexity of benthic habitats in the shallow waters of Lancang Island and almost similar spectral values can be the influence of low UA values (Nababan et al., 2021). Differences in accuracy levels during the classification process are influenced by the process and characteristics of each method or algorithm (Sutrisno et al., 2021).

The results of the shallow water benthic habitat mapping classification using the OBIA technique can now be accessed on the Smart Island Pulau Lemukutan website available at https://webgissmartisland.com (Figure 4).

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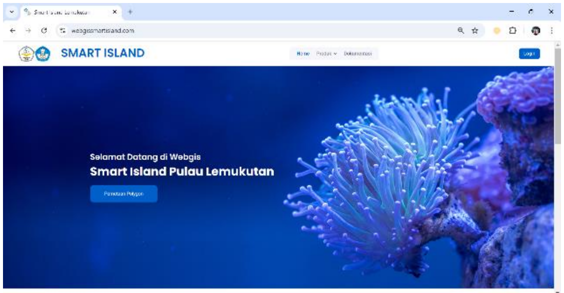

Fig 4. Home page of the Smart Island Lemukutan WEBSITE (webgissmartisland.com)

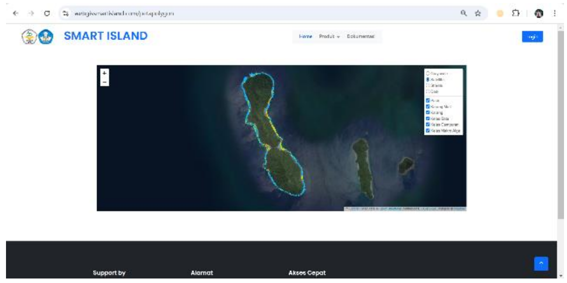

Fig 5. The results of the classification of the closed benthic habitat of the Lemukutan Island village waters are displayed on WebGIS

The presence of the Lemukutan smart island website is expected to contribute to reducing the digital divide and provide opportunities for small island communities to utilize digital solutions to gain better access to benthic habitat conditions. Regular coral reef monitoring can help input Smart Island Lemukutan Island to become a catalyst in realizing a smart island ecosystem in West Kalimantan Province, by presenting benthic habitat maps through webgis services and realizing technological development for coastal areas and small islands based on smart islands through the concept of smart destinations by integrating benthic habitat information through webgis services (Zibar et al., 2023). Research conducted by Taki and Lubis (2017) stated that the use of GIS can be implemented in spatial data analysis and can analyze problems that exist in the community. Lubis et al., (2017) stated that the combination of GIS and Google Sketchup (GE) in its use can be a solution in decision making.

4. Conclusions

The results of the shallow water benthic habitat mapping classification using the OBIA technique can now be accessed on the Smart Island Pulau Lemukutan website available at https://webgissmartisland.com. The distribution of benthic habitats on Lemukutan Island consists of 5 classes including rock class with an area of 41,940 (Ha), mixed class with an area of 2,409 (ha), coral class with an area of 130,340 (ha), dead coral class with an area of 49,249 (ha), macroalgae class with an area of 2,840 (ha), and sand class with an area of 12,140 (ha). The results of the Overall Accuracy (OA) in the waters of Lemukutan Island obtained the highest value of 89.5833% using the SVM algorithm. All classification classes in the shallow waters of Lemukutan Island can be mapped well, except for the mixed class which received a low UA (User Accuracy Value) of 71.43%.

Acknowledgements

The author would like to thank the Directorate of Research, Technology and Community Service of the Ministry of Education, Culture, Research and Technology for covering this research activity through Decree Number 0459/E5/PG.02.00/2024 and agreement/contract number 113/E5/P.G.02.00.PL/2024;64/LL11/KM/2024; 09/UNOSO/.4/PL/VII/2024. We also thank LLDIKTI Region XI and LPPM OSO University who have facilitated funding and reporting of research activities, as well as other parties involved in this research activity, including the West Kalimantan Provincial Marine Affairs and Fisheries Service as the manager of the marine conservation area, the Bengkayang Regency Government and students majoring in marine science at OSO University who have assisted in the field survey.

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