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Study of Coral Reef Distribution in Pejarakan Waters, Bali Using Sentinel-2A Imagery

Studi Persebaran Terumbu Karang di Perairan Pejarakan, Bali Menggunakan Citra Sentinel-2A

Bambang Semedi[1*], Seftiawan Samsu Rijal[1], Dhika Anggi Arviani[1*]
[1]Department of Marine Science, Faculty of Fisheries and Marine Sciences,
Universitas Brawijaya, Malang 65145 Indonesia
**email:* bambangsemedi@ub.ac.id

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Abstract

The existence of coral reef ecosystems in Indonesia is a potential marine resource that needs to be preserved due to the many benefits of the coral reef ecosystem. Utilization of Sentinel-2A imagery for coral reef mapping can be done using two approaches, namely pixel-based and object-based. In this study, pixel-based classification and object-based classification are used to determine the dynamics of the distribution of coral reefs in the waters of Pejarakan Village, Bali, during the dry and rainy seasons. The data used are Sentinel-2A image data for 2018, 2020, and 2022 and field data used for the research accuracy test process. Field data was collected using the purposive sampling method, and the accuracy test process was carried out using the confusion matrix method. The data processing results using pixel and object classification show that classification using the object classification method is considered more accurate than pixel classification because it produces an accuracy value of up to 69.4%. Meanwhile, the pixel classification accuracy value is only 61.1%.

Keywords: Coral reefs, GIS, Object-based, Pixel-based, Sentinel-2A

Abstrak

Keberadaan ekosistem terumbu karang di Indonesia merupakan potensi sumberdaya laut yang perlu dilestarikan karena begitu banyaknya manfaat yang diberikan oleh ekosistem terumbu karang. Pemanfaatan citra Sentinel-2A untuk pemetaan terumbu karang dapat dilakukan dengan dua pendekatan, yaitu pendekatan berbasis piksel dan pendekatan berbasis objek. Pada penelitian ini, dilakukan kajian mengenai penggunaan metode klasifikasi berbasis piksel dan klasifikasi berbasis objek untuk mengetahui dinamika persebaran terumbu karang di Perairan Desa Pejarakan, Bali pada musim kemarau dan musim hujan. Data yang digunakan yaitu data citra Sentinel-2A tahun 2018, 2020, dan 2022 serta data lapang yang digunakan untuk proses uji akurasi penelitian. Pengambilan data lapang dilakukan menggunakan metode *purposive sampling*. Sedangkan proses uji akurasi dilakukan menggunakan metode *confusion matrix*. Berdasarkan hasil pengolahan data menggunakan klasifikasi *pixel-based* dan *object-based* menunjukkan bahwa tidak terdapat perbedaan yang berarti antara kedua metode klasifikasi tersebut. Sedangkan musim berpengaruh terhadap persebaran terumbu karang yang ditunjukkan oleh adanya penurunan selama pergantian musim hujan ke kemarau maupun sebaliknya. Namun berdasarkan nilai akurasi, diketahui bahwa klasifikasi menggunakan metode OBIA menghasilkan nilai lebih akurat yaitu mencapai 69.4% sedangkan metode PBIA hanya menghasilkan nilai akurasi sebesar 61.1%.

Kata kunci: Terumbu karang, SIG, *Object-based, Pixel based,* Sentinel-2A

1. Introduction

Coral reefs are underwater ecosystems consisting of a group of coral animals that form calcium carbonate structures. The form of calcium carbonate produced is almost the same as limestone (Tjhin et al., 2016). Coral reefs have the potential to become a precious natural resource because they have various important roles in the ecological, social, economic, and cultural fields. Ecologically, coral reefs are a habitat for small fish and marine biota that live in shallow waters. Meanwhile, for social, economic, and cultural values, people living in coastal areas use marine biota in shallow waters for consumption. Besides that, coral reefs also have benefits such as ecotourism, which has great potential to support economic activities in the area (Rumahorbo et al., 2018). Because of the many benefits of coral reef ecosystems, efforts to preserve and monitor these ecosystems are necessary. One effort to protect coral reef ecosystems can be made using remote sensing technology.

Remote sensing of coral reefs is used in the coral reef mapping process. The results of coral reef mapping are helpful as a source of information regarding the distribution of coral reefs in waters so that the diversity of coral reefs in these waters can be maintained. Remote sensing for coral reef mapping is also considered superior in providing spatial data and information compared to conventional mapping resulting from direct observations in the field (Mastu et al., 2018). Various types of satellite imagery can be used to map coral reefs with varying spatial resolutions, from low resolution to high resolution (Anggoro et al., 2020). One of the satellite images that can be used for mapping coral reefs is the Sentinel-2A image.

The Sentinel-2A is a satellite image launched by the European Space Agency (ESA) program. Sentinel-2A imagery includes satellite imagery with multispectral channels and high resolution (Putri et al., 2018). Sentinel-2A imagery can assist the process of monitoring and managing coral reefs. Compared with other image data, Sentinel-2A is superior in image resolution and has several advantages, such as selecting the most explicit images and having comprehensive area coverage (Hedley et al., 2018).

Sentinel-2A satellite image data can be downloaded via the USGS website. The bands in the Sentinel image have different pixel resolutions for each band. Bands with a pixel resolution of 10 m are bands 2, 3, 4, and 8. Meanwhile, bands 1 and 9 have a resolution of 60 m, and bands 5, 6, 7, and 8A have a resolution of 20 m (Selamat et al., 2019). The spatial resolution of Sentinel-2A imagery is known to reach 10x10 m^2/pixel (Mastu et al., 2018). The high spatial resolution of Sentinel-2A facilitates identifying coral reefs (Saifuddin & Yusdian, 2022).

Utilizing Sentinel-2A imagery for coral reef mapping can be done using two approaches, namely a pixel-based approach and an object-based approach (Mastu et al., 2018). Pixel-based classification is a technique carried out in a supervised manner by grouping unknown image pixels into samples with an identity. This classification uses classification rules to field observation data (Anggoro et al., 2020). Meanwhile, object-based classification not only relies on the image's pixel texture but also pays attention to the unity of an object. Even though there are differences in image processing, both methods require field data as input for image processing. Field data is also used to determine accuracy by comparing image classification results with field research results (Lutfi & Machmudi, 2018).

In this research, a study was conducted regarding the use of pixel-based classification methods and object-based classification to determine the dynamics of the distribution of coral reefs in the waters of Pejarakan Village, Bali, during the dry season and rainy season. Research was conducted in different seasons because seasonal changes can affect the distribution of coral reefs in an area (Rachmawati et al., 2018). The data used is Sentinel-2A image data for 2018, 2020, and 2022, as well as field data used for the research accuracy testing process. Field data collection was carried out using the proportional random sampling method. Meanwhile, the accuracy testing process uses the confusion matrix method.

2. Material and Method

2.1. Time and Place

The research location is in the Pejarakan Village Waters area, which is located in Gerokgak District, Buleleng Regency, Bali. The selection of research locations was based on the potential of coral reefs in the area. This area has the potential for large marine biological resources, including the coral reef ecosystem. The research location is presented on a map (Figure 1).

2.2. Data Processing Flow

This research's image data processing method is divided into three stages: pre-processing, processing, and post-processing. The flow of image data processing and an explanation of each data processing (Figure 2). The data used in this research is sentinel-2A satellite image data, which can be accessed via the Copernicus website. Downloaded image data goes through cropping, masking, and image correction before processing. Two image correction processes are carried out, namely, radiometric and atmospheric correction, using the Dark Object Subtraction method. The image data processing stage is done by correcting the water column using solar gloss correction and applying the Lyzenga algorithm. In the image classification process, processing will be carried

out using two different methods, namely pixel-based and object-based methods. The classification process with a pixel-based method uses the SVM (Support Vector Machine) algorithm. Meanwhile, data processing using an object-based method uses the MRS (Multiresolution Segmentation) algorithm for the segmentation process and the SVM (Support Vector Machine) algorithm for the classification process. After the classification process, accuracy testing uses a confusion matrix table.

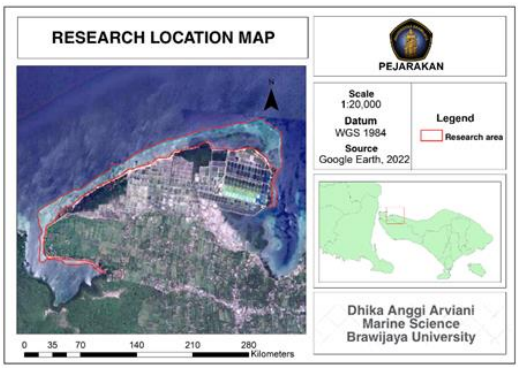

Figure 1. Research location map

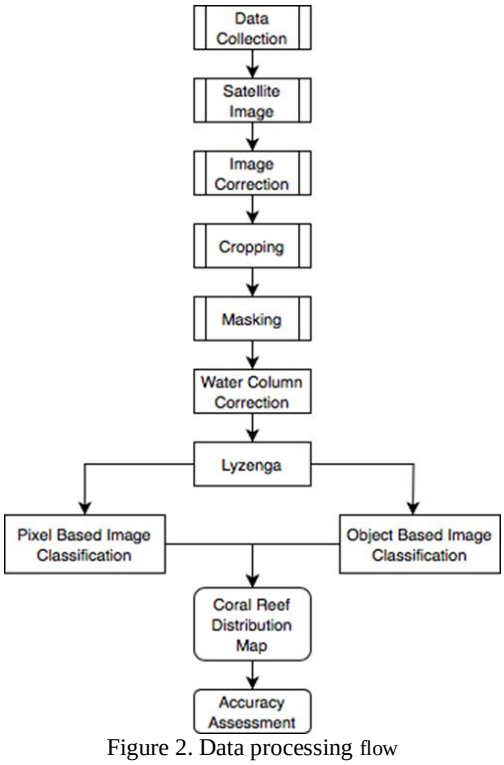

Figure 2. Data processing flow

2.3. Data Analysis

The data analysis method in this research can be carried out after the image data downloading process and field data collection process have been completed. The data used in this research is Sentinel-2A image data for 2018, 2020, and 2022. This data was analyzed using two image classification methods: pixel-based and object-based. The results of the two classification methods are then divided based on the study area's dry and rainy seasons. The final data processing results determine the distribution of coral reefs in the research area during the dry and rainy seasons. Apart from that, an accuracy test process was also carried out using a confusion matrix table. The results of accuracy testing are used to determine which classification method has a better level of accuracy.

3. Result and Discussion

3.1. General Description of Research Location

The Pejarakan Waters Area is located in Pejarakan Village, Gerokgak District, Buleleng Regency, Bali. This area has the potential for extensive marine biological resources. One of the leading marine ecosystems in this area is the coral reef ecosystem. Coral reef ecosystems in this area have significant benefits for coastal communities. However, the coral reef ecosystem is experiencing threats due to natural and anthropogenic

factors. One effort that can be made to avoid damage to coral reef ecosystems is to carry out conservation activities. The coral reef ecosystem in the Pejarakan Village area is included in the medium category, with a coral reef cover of 28.43%. Management of coral reef ecosystems in Batu Ampar waters through coral transplantation activities. Cleaning activities are carried out in the coral reef ecosystem area. Management of the coral reef ecosystem in the Batu Ampar Waters area also involves local communities in conservation activities to optimize the coral reef conservation process (Januarsa & Luthfi, 2017).

3.2. Result of Filed Data Collection

The data collection results in the field consist of three data strata, namely data on live coral, dead coral, and sand. The strata division is based on the number of classes displayed on the map. This research produces a map of the distribution of coral reefs with three classes: live coral, dead coral, and sand. Making coral reef distribution maps requires field data, which is used in classification. The field data collection process produces 30 sample points for each class displayed on the map.

3.3. Pixel-Based and Object-Based Image Classification

The following are the results of coral reef mapping in Pejarakan Village, Bali's waters during the dry and rainy seasons of 2018, 2020, and 2022 using Pixel-Based Image Classification. The distribution of coral reefs experienced changes from 2018 to 2022. The changes can be seen in the extent of coral reefs in the area. The extent of each classification class is shown in Table 1 and ***Error! Reference source not found.***.

Table 1. Coral reef distribution area with pixel-based image classification in the dry season of 2018, 2020, and 2022

Classification	Area (ha)		
	2018	2020	2022
Coral	50.55	44.34	24.90
Death coral	54.41	59.86	62.80
Sand	22.72	26.76	20.03

Table 2. Coral reef distribution area with pixel-based image classification in the rainy season of 2018, 2020, and 2022

Classification	Area (ha)		
	2018	2020	2022
Coral	47.74	44.10	23.87
Death coral	52.53	38.45	30.81
Sand	30.04	29.82	34.76

Based on these results, it can be seen that the distribution of coral reefs with pixel-based classification in the waters of Pejarakan Village during the dry and rainy seasons of 2018, 2020, and 2022 shows a decrease in the classification of live coral. Using object-based image classification, the following results of coral reef mapping Pejarakan Village, Bali's waters, during the dry and rainy seasons of 2018, 2020, and 2022. The distribution of coral reefs experienced changes from 2018 to 2022. The changes can be seen in the extent of coral reefs in the area. The extent of each classification class is shown in Table 3 and Table 4.

Table 3. Coral reef distribution area with object-based image classification in the dry season of 2018, 2020, and 2022

Classification	Luas (ha)		
	2018	2020	2022
Coral	43.27	29.16	23.16
Death coral	22.61	35.85	25.47
Sand	55.41	49.52	57.85

Table 4. Coral reef distribution area with object-based image classification in the rainy season of 2018, 2020, and 2022

Classification	Luas (ha)		
	2018	2020	2022
Coral	29.16	25.92	15.22
Death coral	35.85	48.36	68.07
Sand	49.52	9.55	84.50

Based on these results, it can be seen that the distribution of coral reefs with object-based classification in the waters of Pejarakan Village during the dry and rainy seasons of 2018, 2020, and 2022 shows a decrease in the classification of live coral.

3.4. Accuracy Assesment

The Based on the accuracy test of the pixel-based classification method using a matrix confusion table, it can be seen that the distribution of live coral shows an accuracy value based on the Producer Accuracy (PA) value, which is 77.7%. This indicates that not many pixels of live coral are included in other classes of pixels.

Meanwhile, the highest User Accuracy (UA) value was obtained from the sand class, which shows that the sand class has the lowest classification error rate by not taking pixels from other courses. The accuracy test using confusion matrix calculations was classified into three classes with an overall accuracy value of 61.1% and a kappa value of 0.43. This value shows that the classification results are quite good. If the kappa value is close to 1, the results are better.

Meanwhile, based on the accuracy test of the object-based classification method using a matrix confusion table, it can be seen that the distribution of live coral shows an accuracy value based on the Producer Accuracy (PA) value of 83.3%. This indicates that not many pixels of live coral are included in other classes of pixels. Meanwhile, the highest User Accuracy (UA) value was obtained from the sand class, which shows that the sand class has the lowest classification error rate by not taking pixels from other courses. The accuracy test using confusion matrix calculations was classified into three classes with an overall accuracy value of 69.4% and a kappa value of 0.54. This value shows that the classification results are quite good. If the kappa value is close to 1, the results are better.

The following are the differences between coral reef maps using pixel-based image classification and object-based image classification. A coral reef map using pixel-based image classification can be seen in Figure 3, and object-based image classification is shown in Figure 4

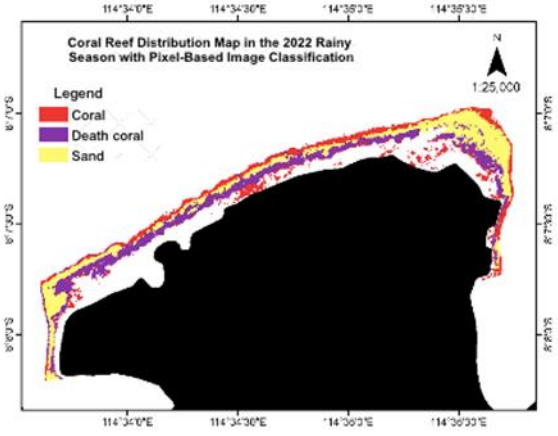

Figure 3. Coral reef mapping with pixel-based image classification

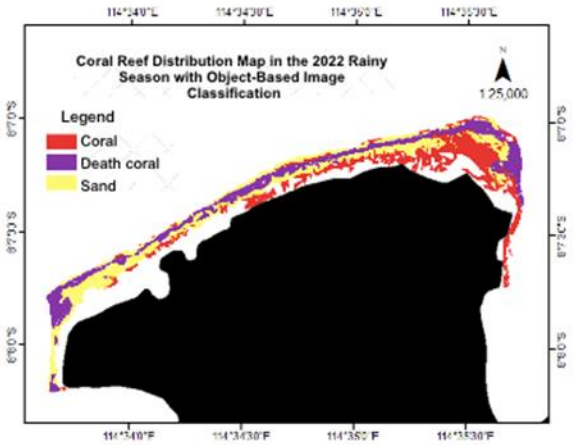

Figure 4. Coral reef mapping with object-based image classification

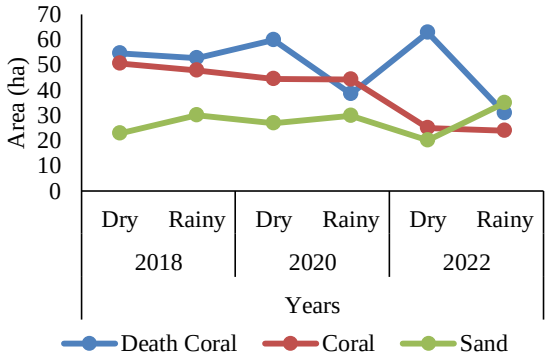

Figure 5. Dynamics of coral reef distribution with pixel-based image classification

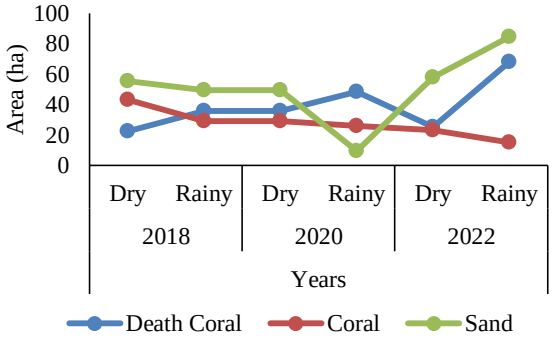

Figure 6. Dynamics of coral reef distribution with object-based image classification

There are differences in classification patterns between pixel and object-based classification methods. The differences in patterns on the map show this. This difference is based on the concepts of the two classification methods, which are undoubtedly different. Object-based image classification has a method that imitates the visual interpretation of the human eye so that this method can be simpler than pixel-based methods. In addition, the pixel-based classification process does not consider the parameters of shape, area, texture, and unity of the object.

Meanwhile, Object-Based Image Analysis can use more detailed parameters in classification. The more parameters used the more complex and specific the classification will be (Pandiwijaya et al., 2013). Meanwhile, Pixel-Based Image Analysis is performed by extracting and classifying features based on spectral information (Sugara et al., 2022). Based on the data processing results, a graph was produced showing the dynamics of the distribution of coral reefs in Pejarakan Village, Bali, in 2018, 2020, and 2022. You can see the graph of the distribution of coral reefs in Figure 5 and Figure 6.

The data processing results using pixel-based and object-based classification show no significant differences between the two classification methods. Meanwhile, the seasons influence the distribution of coral reefs, characterized by a decrease when the rainy season changes to the dry season and vice versa. However, based on the accuracy value, classification using the OBIA method is considered more accurate than PBIA, with a value difference of 8.3%. These results follow research from Benfield et al. (2007), which states that the use of the OBIA method has been proven to increase the accuracy of mapping shallow water benthic habitats.

Based on these results, it can be seen that mapping coral reefs using the OBIA (Object-Based Image Analysis) method is better than mapping coral reefs using the PBIA (Pixel-Based Image Analysis) method. It can increase the accuracy value using high-resolution images compared to medium-resolution images. This follows research by Maksum et al. (2016), which shows that object-based classification with high-resolution images shows an accuracy value of 87.14%. Meanwhile, object-based classification with medium-resolution images only shows an accuracy value of 77.14%. Apart from that, the choice of algorithm used in the classification process also affects the accuracy value. Mapping coral reefs using pixel-based methods is better using the Maximum Likelihood algorithm because this method can differentiate object classes according to research in the field (Hafizt et al., 2017). Meanwhile, the SVM algorithm for object-based methods is best.

Based on the results of this research, it is also known that there has been a decrease in the number of live corals in these waters. The decline in the distribution of live coral can be influenced by seasonal changes that occur. The rainy season and dry season affect the decline in coral populations. During the rainy season, there is an increase in waves that hit the coral reef area. This event causes coral to become brittle and damaged (Rachmawati et al., 2018). Meanwhile, in the dry season, sea surface temperatures increase. If sea surface temperatures rise over a long period, it can cause coral bleaching phenomena. Coral reef bleaching is a condition where coral becomes white due to heat stress, which causes a decrease in the concentration of zooxanthellae in coral (Semedi & Rahmawan, 2016)

4. Conclusions

Based on the results of research on the dynamics of the distribution of coral reefs in the waters of Pejarakan Village, Bali, using pixel-based and object-based classifications in 2018, 2020, and 2022, it can be concluded that the distribution of coral reefs uses pixel-based and object-based classifications in the waters of Pejarakan Village in the dry season of 2018, 2020, until 2022 shows a decrease in the classification of live coral. The OBIA (Object-Based Image Analysis) method is recommended for mapping coral reefs. This is because the OBIA method produces an accuracy value of 69.4% higher than the PBIA (Pixel-Based Image Analysis) method, which only creates an accuracy value of 61.1% with a value difference of 8.3%.

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