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Comparative Study of Pixel-Based and Object-Based Classifications in Benthic Mapping

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Abstract – Coral reefs have been degrading rapidly throughout the last decade due to climate change and other human activities. Classification and mapping of benthic floors and associated ecosystems such as coral reefs are both inefficient and expensive using traditional ground-based methods. New technologies using publicly available and commercial satellite imageries are crucial for accurate classification and mapping of coral reefs' distribution, management and monitoring. The study utilized the medium (Sentinel 2B with 20 m) and high (SPOT 7 with 1.5m) resolution satellite imageries for benthic mapping of Mabul island's benthic using pixel-based and object-based classification methods. Results of the study show that the overall accuracy of the pixel-based classification method for Sentinel 2 and SPOT 7 were 97.5% and 90%, respectively. For the object-based technique, the overall classification was slightly lower with 87.05% and 82.81%, respectively. This study suggests pixel-based classification provides better overall accuracy than object-based classification. However, conducting more assessments at different water depths and field surveys is necessary to determine accurate results. This can be achieved in the future by using more advanced technology such as drones and lidar data.

Keywords *– SPOT 7, Sentinel-2, OBIA, Coral Reef, Benthic Mapping*

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1.0 Introduction

The coral reef is one of the most complex marine environmental systems, biodiverse, and productive ecosystems on the planet, which play important roles for millions of people in significant social, economic, and cultural especially for the future generation. They only cover 0.1% of the sea, but they support 25% of other marine life species in the ocean, as they are widely known as the "rainforest of the sea". These ecosystems benefit the country as they give income through marine-based industry, fisheries, and tourism activities, as they are not just beautiful underwater fixtures that make the ocean more colourful and vibrant. The island, with clear blue water with beautiful beaches, will have a coral reef ecosystem and rich diversity of marine flora and fauna (Spalding et al., 2017). The four groups, namely coral reef, seagrass, macroalgae and sand rubble, were determined as benthic ecosystems. The final classification structure and categories' definitions suit this objective project. This classification range is versatile enough to satisfy this project's necessity with additional integration without remote sensing data (Wicaksono et al., 2019).

However, most of the islands are highly threatened by humans because the coral reef is considered the most vulnerable marine ecosystem (Bajjouk et al., 2019; Bellwood et al., 2004). Global scale degradation rates are increasing due to global warming, climate change, coastal development, fishing and tourism. Human activities destroy the coral reef ecosystem, cover, and marine pollution. Therefore, it is necessary to take the required action and improve the monitoring of the coral reef ecosystem, including reef islands, to effectively manage the coral reef resources (Khaled et al., 2019; Zhou et al., 2018). Remote sensing techniques have been widely used in identifying and monitoring resources of an area. Their ability to record information on a large scale in a relatively short time can save cost and reduce time to get the information at site study (Siregar et al. 2018). Closet objects and certain depth limits called optical depth limits can be distinguished from the image recording result. The most frequent use to detect nature or any changes is from Landsat multispectral images. For example, to monitor land use changes and disaster management. However, the spatial resolution of this sensor is not suitable for capturing the dynamic of coral reef ecological status.

SPOT-7 satellite is a SPOT generation with a high-resolution image; this is the first generation with a large multispectral colour channel, such as a blue spectral channel, which often detects the bottom of shallow water habitats (Wahidin et al., 2015). Medium-resolution images

such as Sentinel 2, which have 20 m spatial resolution, can also detect the primary object of the water, especially seagrass and coral reef (Thalib et al., 2018).

2.0 Materials and Method

The project involves five stages. The first stage required project planning to define the problem statement, aim, objectives, study area and software. This research used two types of imagery, namely SPOT 7 and Sentinel 2A, both from 2019. The next stage involves data processing for the acquired data. For current condition analysis, ERDAS 2014 and eCognition Developer 9.0 support remote sensing techniques in identifying coral reefs. Then, based on the results from both data, a comparison of two data with two different methods will be performed.

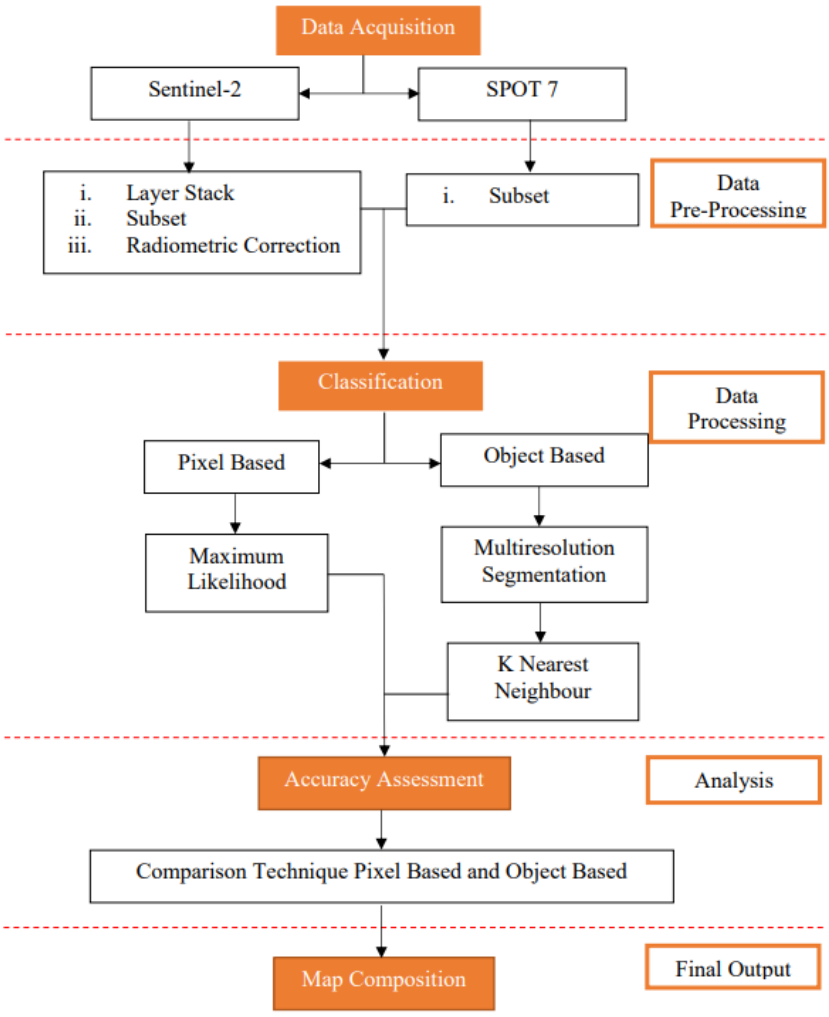

Figure 1. Flow of methodology

2.1 Selection of Study Area

Mabul is a small island on Sabah's southeast coast. Since the seventies, Mabul has been a small island on Sabah's southeast coast. Since the seventies, the island has been a fishing village. Because of its proximity to Mabul Island, it first became popular with divers in the 1990s. Located 15 km from Mabul, this 20-hectare piece of land has a surface area of 2–3 m above sea level and is mostly flat, with an oval-shaped aerial view. Sandy beaches surround it on a larger 2 km² reef northwest corner. The reef is on the edge of the continental shelf, and the sea cliffs around the reef are 25 to 30 m deep.

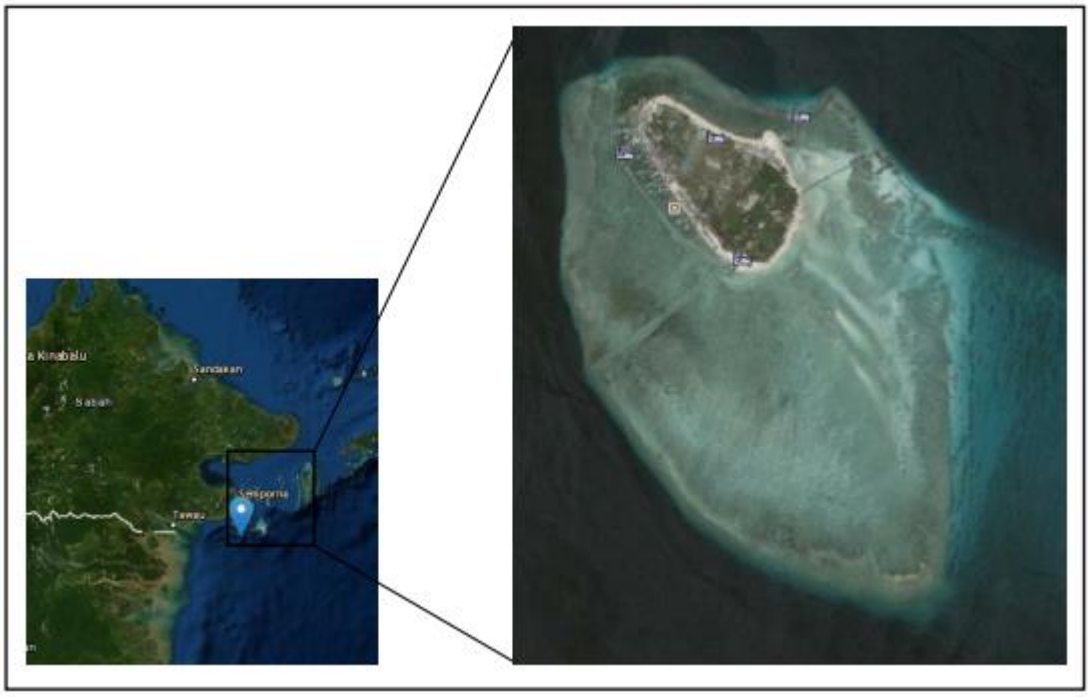

Figure 2. Mabul Island, Sabah, as a study area

2.2 Selection of Software Used

This research used two software for analytics; ERDAS IMAGINE 2014 and eCognition. Code also serves as a supporting key medium or resource. It guarantees that the relevant program is consistent with the information or the device's instructions.

In this study, the Sentinel 2 and SPOT 7 image was processed with ERDAS IMAGINE 2014 software as the primary operating system for pre-processing and processing for pixel-based classification. While for object-based classification, after the pre-processing process was done in

ERDAS IMAGINE 2014, the result was used in eCognition 9.01 for the segmentation and classification process.

2.3 Data Processing

Pre-processing is needed before data processing and information extraction and is usually classified as geometric and atmospheric corrections. The raw data will be processed before proceeding to the classification stage.

2.4 Image Classification for Pixel-Based

Image classification is used for classifying the image into benthic habitat classes by digitally identifying and classifying using each pixel in the data. Two satellite imageries were applied with both supervised classifications using the Maximum Likelihood technique for this data. This method has been used because of a more accurate classification method compared to the unsupervised classification method. This classification method was also used when the spatial resolution's remote sensing imagery is low, such as Landsat, Sentinel, Terra and Aqua satellite platforms (Lightfoot, 2018). This classification is crucial in this study to produce a benthic habitat map for the study area corresponding to two different techniques, pixel-based and object-based image analysis. The temporal image should first be classified into five classes (Table 1) to identify the accuracy between the two techniques. Ensure that minimum, maximum, mean, and standard deviation are checked for the attribute option in the signature box section. In the parametric rule section, users can choose from three methods: maximum likelihood, Mahalanobis distance and minimum distance. The maximum likelihood method was used for this study because it is more accurate than others which can read at short distances. Figure 3 shows the result of the benthic classification map pixel-based.

Table 1. Classification scheme for pixel-based classification

Image Class Code	SPOT 7	Sentinel 2
1	Sand	Sand
2	Coral Reef	Coral Reef
3	Sand Rubble	Sand Rubble
4	Sand Dense Seagrass	Sand Dense Seagrass
5	Rubble	Rubble

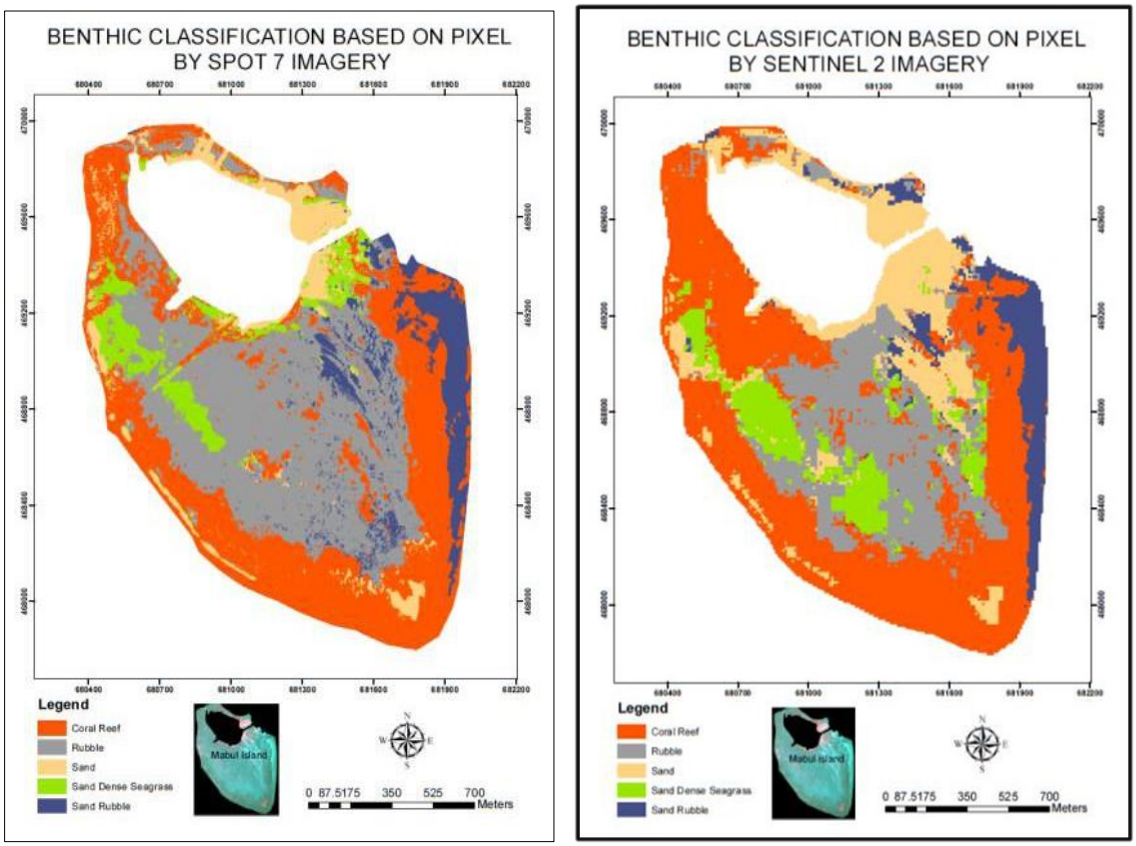

Figure 3. Pixel-based for SPOT 7 (left) and Sentinel (right)

2.5 Image Classification for Object-Based

The object-based classification was executed using a hybrid machine-learning algorithm in eCognition 9.01 software. Before the classification process, multi-resolution segmentation was applied based on scale parameters, shape, and compactness. All band classification parameters were limited to mean and standard deviations. The final phase of the classification process was to determine the accuracy assessment of the classification of benthic, which the result consisted of

user accuracy (UA), overall accuracy (OA), producer accuracy (PA), and the value of Kappa statistic. The classification can be seen in Figure 4.

Table 2. Classification scheme for object-based classification

Image Class Code	SPOT 7	Sentinel 2
1	Sand	Sand
2	Coral Reef	Coral Reef
3	Sand Rubble	Sand Rubble
4	Sand Dense Seagrass	Sand Dense Seagrass
5	Rubble	Rubble

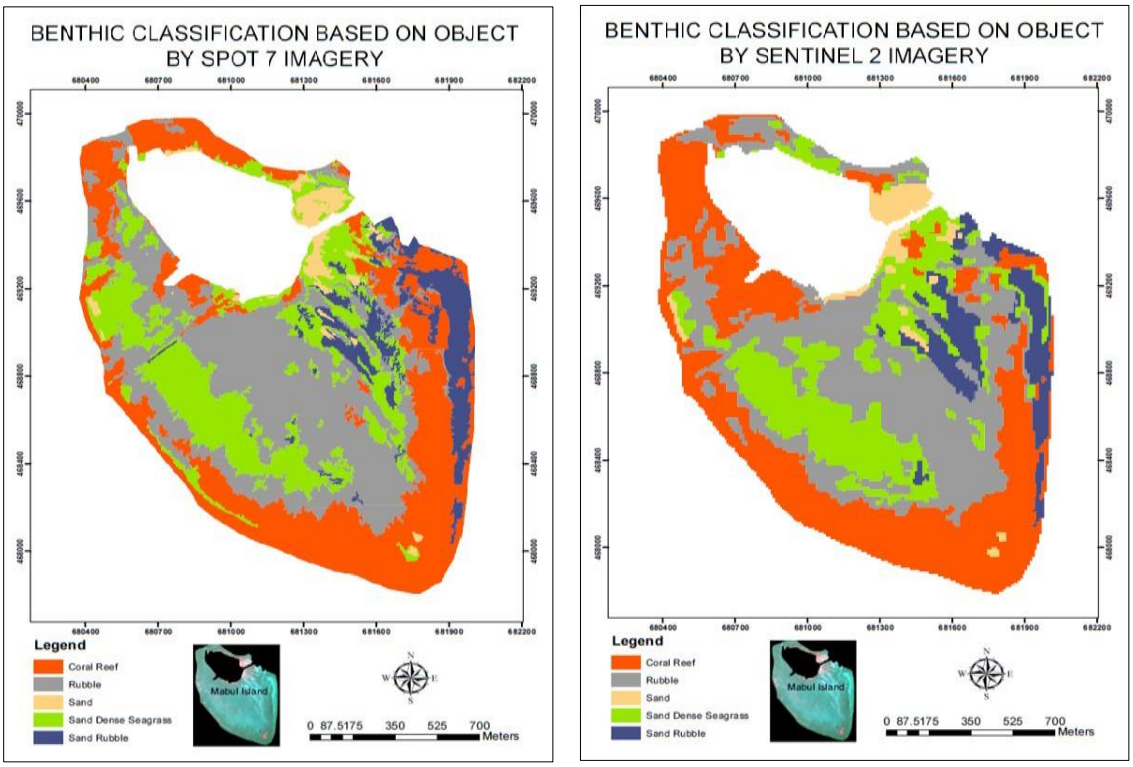

Figure 4. Object-based for SPOT 7 (left) and Sentinel (right)

3.0 Results and Discussions

This section discussed the analysis according to the result obtained to achieve the aim and objectives of this study. The details are as below.

3.1 Accuracy Assessment

Accuracy assessment is an essential process in the classification procedures performed by comparing a map created by remote sensing analysis to a reference map based on different information sources. Tables 3 and 4 show the accuracy assessment of the results gained from the processing. The accuracy assessment for the pixel-based image analysis classification, as referred to in Table 3, was made by creating 40 samples for both classifications. Satellite images from Google Earth Pro were used as the reference for accuracy assessment. Three methods used in the distribution parameter table are Random, Stratified Random and Equalized Random, and this study used the Random method. Overall accuracy for SPOT 7 is 97.5%, and for Sentinel 2 is 90%, respectively. The SPOT 7 Kappa coefficient statistic is 0.9655 and 0.8698 for Sentinel 2.

Table 3. Result for pixel-based

Benthic Habitats Class	SPOT 7		Sentinel 2	
	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy
Sand	100%	100%	66.67%	50%
Coral Reef	100%	91.67%	75%	100%
Sand Rubble	66.67%	100%	100%	80%
Sand Dense Seagrass	100%	100%	100%	85.71%
Rubble	100%	100%	100%	100%
Overall Accuracy	97.5%		90%	
Kappa Accuracy	0.9655		0.8698	

Table 4 below shows the result accuracy for object-based image analysis supervised classification. Four methods were used for the accuracy assessment of object-based in eCognition 9.01 software: classification stability, best classification result, error matric based on TTA mask and error matrix based on a sample. This study uses an error matrix based on the sample, and 139 samples are created for classification accuracy. Overall accuracy for SPOT 7 is 87.05% and 82.81% for Sentinel 2, respectively.

Table 4. Result for object-based

Benthic Habitats Class	SPOT 7		Sentinel 2	
	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy
Sand	64.70%	95.65%	77.78%	100%
Coral Reef	98.18%	98.18%	100%	83.33%
Sand Rubble	30.77%	47.06%	88.89%	80.00%
Sand Dense Seagrass	93.33%	66.67%	58.82%	90.90%
Rubble	87.10%	100.00%	92.86%	72.22%
Overall Accuracy	87.05%		82.81%	
Kappa Accuracy	0.8252		0.7823	

3.2 Analysis Between Pixel-Based and Object-Based Classification

As in Table 5, the pixel-based image classification method's overall accuracy is higher than the object-based image analysis method. However, the error remains even though the pixel-based classification method has higher accuracy than object-based classification. Error in similarity occurs between coral reefs and rubble.

Table 5. Comparison of accuracy assessment for pixel-based and object-based

Accuracy	Object-Based		Pixel-Based	
	SPOT 7	Sentinel 2	SPOT 7	Sentinel 2
Overall Accuracy	87.05%	82.81%	97.5%	90%
Kappa Accuracy	0.8252	0.78.23	0.9655	0.8698

This result was due to the similarity of both objects in the spectral structure. The similarity of the spectral value of these two objects causes the error of classification between the two objects. In addition, the use of imagery in the study has different resolution ranges and affected the result of the accuracy assessment. The spatial resolution of SPOT 7 imagery data is higher than Sentinel imagery data and caused the result of classification accuracy for Sentinel 2 imagery data to be lower than SPOT 7 imagery data.

For object-based classification, low accuracy results in the classification caused by several factors for both the image processing technique and the accuracy testing process. This method uses parameters such as scale parameters (SP), colour or shape factor and smoothness or compactness as a reference in producing the segmentation polygon-polygon form. That method differs from the result of the pixel-based classification, which focused on using pixel value as guidance in classifying the object. In addition, using other algorithms and the parameter attributes in the object-based classification methods make it possible to achieve good accuracy values.

4.0 Conclusion

This study's finding is to compare pixel-based and object-based image analysis in monitoring benthic classification using remote sensing techniques. This study concludes that SPOT 7 and Sentinel 2 image data can map benthic habitats in the shallow water of Mabul Island, Sabah, using pixel-based and object-based classification approaches. From the comparison analysis, pixel-based classification using K-Nearest Neighbour is significantly better than the object-based method, although it shows a classification error with an accuracy value above 85%.

Spatial information generated from Sentinel 2 and SPOT 7 for object-based classification image data shows a lower accuracy than pixel-based. However, these results can provide an overview of the shallow water condition of Mabul Island, Sabah. The overall accuracy for pixel-based is 97.55% for SPOT 7, and Sentinel 2 is lower at 90%. Meanwhile, SPOT 7 produced 87.05% for the object-based classification method and only 82.81% for Sentinel 2's overall accuracy assessment. This study concludes that not all object-based techniques could increase classification accuracy compared to pixel-based methods. However, different classification methods, such as SVM with another high-resolution image, can be proposed to improve accuracy. Therefore, it helps us with data such as Sentinel 2, which can be provided from open source to detect changes and extensions of an island's benthic habitat in cases lacking or not easy to obtain high-resolution images such as SPOT 7 using object-based classification.

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