EFFECT OF LOW PASS FILTER ON BATHYMETRIC DETECTION IN PULAU PUTRI SHALLOW SEA, KEPULAUAN SERIBU USING PLANETSCOPE SATELLITE IMAGERY

Alberto Junior Hutagaol[1], Kuncoro Teguh Setiawan[2], Muhammad Sulaiman Nur Ubay[2], Hastuadi Harsa[2]
[1] Faculty of Fisheries and Marine Sciences, Brawijaya University
[2] Research Center for Remote Sensing, BRIN, Jakarta, Indonesia
e-mail: alberto13@student.ub.ac.id

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Abstract. This research explores the use of satellite imagery for bathymetry mapping in shallow marine waters, focusing on the effects of low pass filtering and methods for achieving high accuracy. The study employs the Stumpf method, a ratio model comparing two bands to mitigate water albedo effects, and utilizes PlanetScope imagery from Norway's International Climate & Forests Initiative (NICFI) program. Conducted around Pulau Putri in Pulau Seribu Regency, the research examines the impact of a low pass filter in smoothing raster data, particularly addressing the issue of spatial generalization that such filtering can cause. While low pass filters are effective for reducing noise, they can oversimplify spatial details, leading to a loss of important bathymetric features. This study investigates the balance between smoothing effects and detail preservation, evaluating how different levels of filtering influence the accuracy of bathymetric maps. Using the confusion matrix method and RMSE calculations, the research finds that bathymetry detection without the application of a low pass filter results in higher accuracy, with an overall accuracy value of 94.17% and an RMSE value of 1.61. The findings highlight the need for methodological considerations in filtering techniques to minimize spatial generalization while maintaining data integrity for accurate shallow sea bathymetry detection.

Keywords: *bathymetry detection, stumpf algorithm, low pass filter, planetscope*

1 INTRODUCTION

Sea depth is very important information in the study of marine resource activities. Until now, bathymetry mapping has evolved for various research purposes such as fisheries management, tsunami modeling, as well as offshore oil and gas industries. Bathymetry data can generally be obtained only using echosounders at locations capable of passing through ships, so shallow water measurements are often not possible (Manessa *et al.*, 2018). However, bathymetric information on shallow waters also has various benefits, which can be used for the study of the seabed morphology as a basic step of coastal resource management. Furthermore, knowledge of the detailed structure of the bottom of waters can help identify the presence of variability of the bentic habitat thus facilitating the characterization of the habitat, both for coral reefs and various other ecosystems that exist in the waters (Rahman & Wicaksono, 2019).

Along with the development of remote sensing technology, currently shallow water bathymetry mapping can be done using remote sensing technology (Setiawan *et al.*, 2019). The utilization of satellite imagery can help to obtain information about the depth of shallow waters that are difficult to access by survey vessels. Bathymetry mapping using satellite imagery is not a new thing in the marine field, but until now this method has not been widely used. Bathymetry mapping is not only influenced by the estimation method but also by the satellite vehicle used because in general each vehicle has a different spatial resolution. Some satellite images that can be used for bathymetry estimation include SPOT, Formosat, Ikonos, Quickbird, and WorldView-2 satellites. Information about the depth of shallow water by analyzing satellite images is also known as SDB or Satellite-Derived Bathymetry (Sesama *et al.*, 2021).

The application of the (Stumpf *et al.*, 2003) method in shallow water bathymetry detection is still rarely used by researchers in Indonesia. The Stumpf method is a ratio model that compares two bands with the assumption that the use of two bands will reduce the effect of water albedo which has been a problem in mapping bathymetry or aquatic habitat (Syaiful *et al.*, 2019). The use of visible bands, especially the blue/green band ratio, can produce bathymetry maps with a better level of accuracy when compared to other band ratios. This is because both bands are in the wavelength range of 450 to 580 nm, which is a wavelength that has the ability to penetrate waters quite well when compared to other wavelengths (Prayogo & Basith, 2020). Another thing that needs to be considered in shallow water bathymetry detection in order to get good results is conducting research in relatively clear waters (Putri *et al.*, 2018). This is because clear waters have good sunlight penetration so that depth variations at the bottom of the water can be clearly identified (Eugenio *et al.*, 2015).

Pulau Putri is one of the tourist islands in the Pulau Seribu Regency. The opening of Pulau Putri as a resort in the early 1970s was the beginning of tourism in the Kepulauan Seribu (Bahri *et al.*, 2017). The potential of Pulau Putri as a sustainable tourist destination can be developed by studying its shallow marine waters. In this research, PlanetScope imagery from the NICFI program will be used for bathymetry detection of shallow marine waters on Pulau Putri, Pulau Seribu Regency using the Stumpf algorithm. In addition to learning how to process satellite image data, this research also aims to find out the effect of low pass filters on bathymetry detection results and the right method to get bathymetry detection results with high accuracy. The results of shallow marine bathymetry detection in Pulau Putri, Pulau Seribu Regency are expected to be used for seabed morphology studies and coastal resource management in the Kepulauan Seribu. In addition, the results of bathymetry detection are expected to be used as material for future research opportunities in an effort to study the characterization of benthic habitats on Pulau Putri.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

Bathymetry detection of shallow marine waters was carried out around the waters of Pulau Putri. Pulau Putri is a small island located in Pulau Harapan Village, Kepulauan Seribu Utara District, Kepulauan Seribu Regency, DKI Jakarta Province. Pulau Putri itself is divided into two based on its location, so local residents usually call the two islands the East Pulau Putri and the West Pulau Putri. Astronomically, East Pulau Putri is located at the coordinates 05° 35' 32'' South Latitude and 106° 34' 07'' East Longitude (KKP, 2022). Apart from Pulau Putri, there are also several islands around Pulau Putri waters which are included in the study area. These islands include Pulau Melintang Besar, Pulau Melintang Kecil, Pulau KA Melintang, Pulau Tongkeng, Pulau Perak, Pulau Panjang, Pulau Kayu Angin Puteri, Pulau Macan Kecil, and Pulau Putri Gundul. Figure 2-1 show the map of the study area used in the processing of shallow sea bathymetry detection data (red dots are modeling data and yellow dots are accuracy test data).

PlanetScope imagery can be accessed through Norway's International Climate & Forests Initiative (NICFI) program in collaboration with https://www.planet.com/ called Planet & NICFI Basemaps for Tropical Forest Monitoring. The PlanetScope image downloaded from the NICFI program is one of the high spatial resolution images with a spatial resolution of 4.77 meters. Planet & NICFI Basemaps provides PlanetScope satellite imagery in the form of mosaics, which are composites of multiple satellite images. The recording products are also called Normalized Surface Reflectance Mosaics or Normalized Analytic Mosaics which consist of 4 bands: Red, Green, Blue, and Near-infrared (Table 2-1). Data from Planet & NICFI Basemaps has been preprocessed in advance in the form of scene selection, atmospheric correction, cloud masking, normalization, and BRDF Effects so that the data provided to the public is ready for processing. In this research, the satellite imagery needed is PlanetScope satellite imagery in the Pulau Putri area, Pulau Seribu Regency. Bathymetry detection of shallow marine waters using high-resolution satellite imagery can provide better accuracy because it allows for more detailed detection of shallow marine depths so that it can approach the actual conditions in the field.

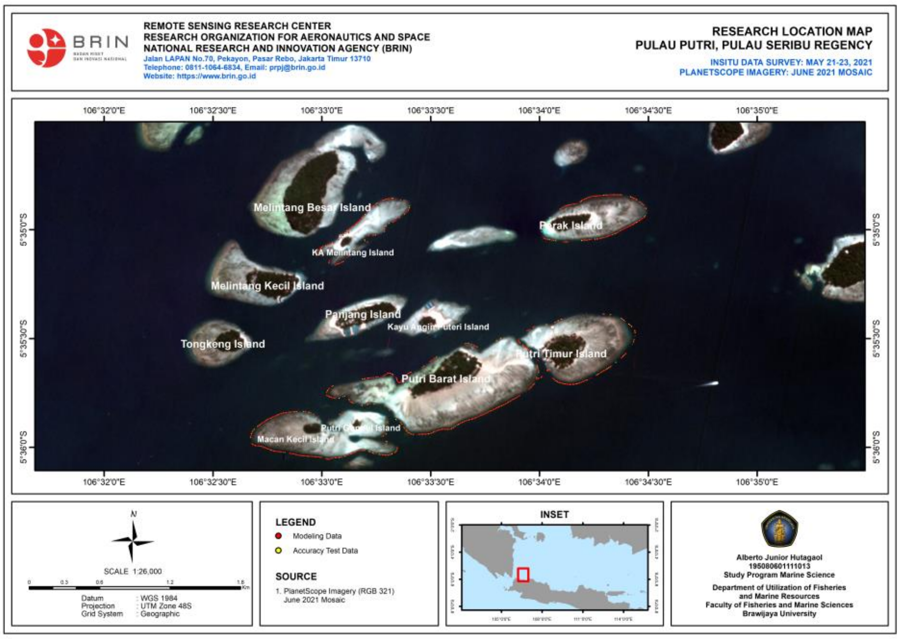


Figure 2-1. Study site (Pulau Putri)

Table 2-1: NICFI program PlanetScope image band information

Name	Description	Sensor Frequency	Resolution
B	Blue	455 - 515 nm	4.77 meters
G	Green	500 - 590 nm	
R	Red	590 - 670 nm	
NIR	Near-infrared	780 - 860 nm	

2.2 Methods

The data processing method in this research is broadly based on an understanding of masking satellite images, detecting bathymetry by applying the Stumpf algorithm, and performing accuracy test calculations.

2.2.1 Bathymetry Detection

Bathymetry detection of shallow marine waters on Pulau Putri, Pulau Seribu Regency using PlanetScope satellite imagery was carried out by applying an algorithm developed by (Stumpf *et al.*, 2003). The Stumpf algorithm or also known as the band ratio algorithm is a ratio model that compares two bands which are the reflectance factor of water. The use of a two-band comparison is assumed to reduce the effect of water albedo which has been a problem in the detection of bathymetry in shallow sea waters (Syaiful *et al.*, 2019). The band ratio algorithm requires input of pixel values in each band in the form of reflectance values. The calculation of the band ratio is done by making the band which has a shorter wavelength as the numerator (blue band) and the band which has a longer wavelength as the denominator (green band).

The equation of the Stumpf algorithm (equation 1) can be written as follows:

$$Z = m_1 \frac{\ln(nR_w(\lambda i))}{\ln(nR_w(\lambda j))} - m_0 \quad \text{......................(1)}$$

where Z = estimated depth, m_1 = calibration coefficient of each band, m_0 =

correction factor for depth 0, ln = constant to keep the ratio positive, $R_w(\lambda)$ = pixel reflectance value in each band. The coefficients m_1 and m_0 are obtained from the regression results of band ratio to depth of field (in-situ data), thus equation (1) can be rewritten based on simple linear regression equation (2) to become:

$$Y = aX + b \text{..............................(2)}$$

where the value a represents the coefficient m_1, the value b represents the coefficient m_0, and the value X represents the ratio of the reflectance band values used.

2.2.2 Low Pass Filter

Filter is one of the tools contained in the ArcMap 10.8 software. The filter is divided into two options, namely low pass filter or high pass filter. The low pass filter is an option that can be used to smooth a raster. Low pass filter smoths the data by reducing local variation and removing noise. It calculates the mean value for each 3 x 3 neighborhood. The effect is that the high and low values within each neighborhood will be averaged out, reducing the extreme values in the data. A low pass filter can be applied to a bathymetric map before performing an accuracy test to refine the data (Vahtmäe & Kutser, 2016). The results of bathymetric maps using the Stumpf algorithm with the application of a low pass filter have the opportunity to produce maps with better results, based on the R2 values obtained (Pe'eri *et al.*, 2014). Research utilizing the application of low pass filters was also conducted by (Matta *et al.*, 2014). Low pass filters can be used in reducing residual noise of satellite sensors for seagrass mapping so as to increase accuracy.

2.2.3 Accuracy Test

The accuracy test was carried out on the results of shallow sea bathymetry detection using the confusion matrix method and the calculation of Root Mean Square Error (RMSE). The confusion matrix method is generally used to rank accuracy tests as a result of extracting information (Tamta *et al.*, 2015). The percentage of accuracy of a class is obtained from a comparison of the number of pixels that are correct according to the field data with the total number of pixels used for the accuracy test. The results of the accuracy test on the confusion matrix are calculations of producer accuracy (PA), user accuracy (UA), and overall accuracy (OA) (Hendrawan *et al.*, 2018). In this study, the bathymetry detection results will be divided into several classes and an accuracy test will be carried out using the confusion matrix method to see which class has the highest accuracy and to see a comparison of the results of the overall accuracy value between the bathymetry detection results with a low pass filter and without a low pass filter.

Accuracy tests were also carried out on the bathymetry detection results by calculating the (RMSE). Root Mean Square Error or commonly abbreviated as RMSE is the root of the average sum of the squares between the difference in depth values from field measurements and the results of depth detection using satellite imagery (Syaiful *et al.*, 2019). The information that can be obtained from the RMSE value is that the smaller the RMSE value, the closer the detection value to the observed value. The reason for the use of RMSE calculations for accuracy test in this study is that RMSE is able to draw conclusions about the results of bathymetry detection that have the best precision through the values obtained (Rahman *et al.*, 2020).

RMSE can be calculated by equation (3) as follows:

$$RMSE = \sqrt{\frac{\Sigma_{t=1}^{n}(At - Ft)^2}{n}} \text{..................(3)}$$

where At = the value of the estimated depth from the image, Ft = the value of field measurements, n = the number of depth points used in the validity of the model.

3 RESULTS AND DISCUSSION

3.1 Relative Depth

Figure 3-1 shows the results of the relative depths in the Shallow Sea of Pulau Putri, Pulau Seribu Regency. The results of bathymetry detection were obtained in the form of Relative Depth of Shallow Sea of Pulau Putri, Pulau Seribu Regency using PlanetScope Satellite Imagery. Relative depth results are obtained from the application of the Stumpf algorithm with the use of blue and green bands. The resulting layer of the Stumpf algorithm is then duplicated to make a comparison result with and without the low pass filter tools. Figure 3-1 shows the relative depth ratio in the form of blue/green band ratio values ranging from 0.82 to 1.18 for the relative depth results with a low pass filter and 0.79 to 1.18 for the relative depth results without a low pass filter. The conclusion that can be drawn from the value of the blue/green band ratio is that the value will decrease with increasing depth. In Figure 3-1, shallow waters are marked in light blue, while deeper waters are marked in blue to dark blue.

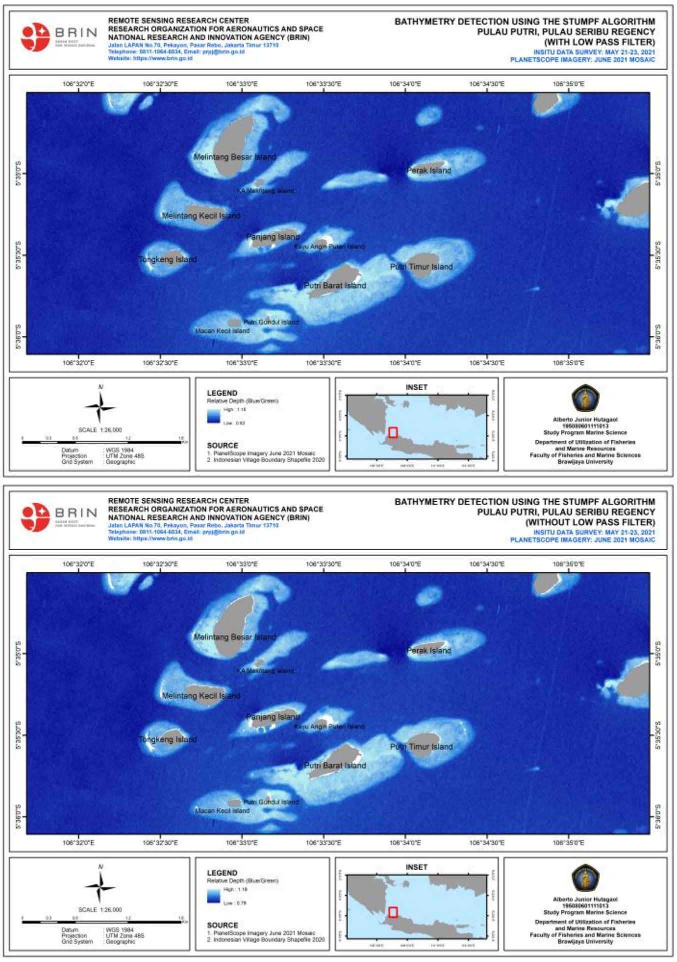
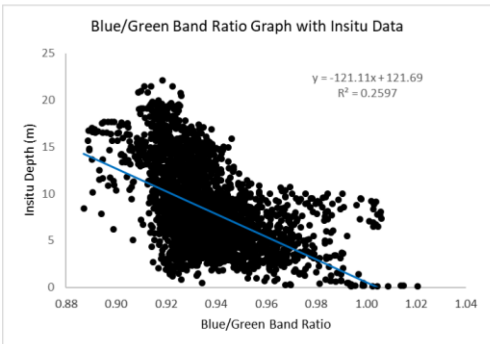


Figure 3-1. Relative depth results with and without a low pass filter

3.2 Effect of Low Pass Filter and Data Adjustment

The results of the relative depth are then extracted from the in-situ data to see the regression results obtained between the image data and the in-situ data before adjusting the data. Figure 3-2 shows a graph of the ratio of blue/green bands to all in-situ data for both data processing with and without the application of a low pass filter before adjusting the data.



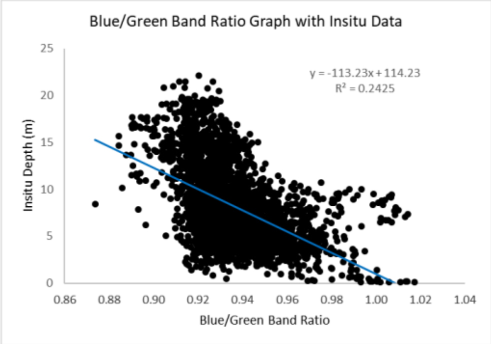
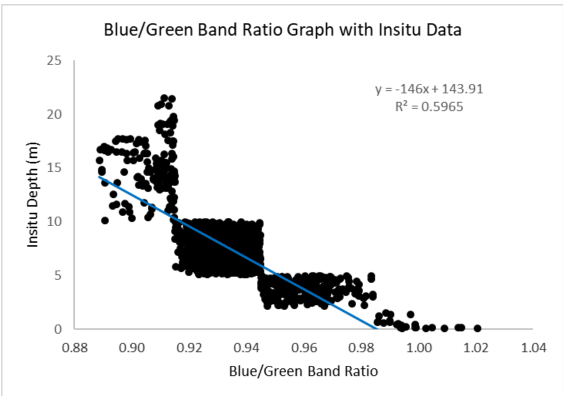


Figure 3-2. Satellite image data with insitu data before data adjustment with and without a low pass filter

Based on the graphs obtained, the results of the relative depth layer regression with the application of a low pass filter produce a better coefficient of determination (R2), which is 0.2597. If seen from the correlation coefficient (r) between the image data and the overall in-situ data obtained, namely 0.5096, the two variables have a close relationship that is not good enough to produce shallow sea bathymetry detection results with high accuracy. One way to increase the coefficient of determination (R2) and the correlation coefficient (r) between image data and in-situ data is by making adjustments to the data. Data adjustment is made based on the fact that the reflectance value will decrease with increasing depth.

The results of the relative depth are then extracted again to the in-situ data to see the regression results obtained between the image data and in-situ data after adjusting the data. Figure 3-3 shows a graph of the ratio of the blue/green bands to all in-situ data for both data processing with and without the application of a low pass filter after data adjustment.



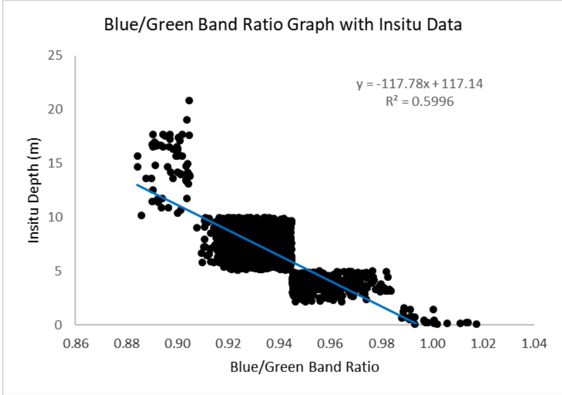


Figure 3-3. Satellite image data with insitu data after data adjustment with and without a low pass filter

Based on the graphs obtained, each of the relative depth layer regression results with and without the application of a low pass filter produces a much better coefficient of determination after adjusting the data. In this case it can be concluded that the low pass filter can provide a better coefficient of determination (R2) between the blue/green band ratio values and in situ data compared to data processing without a low pass filter. However, after adjusting the data, it turns out that the regression equation with the application of a low pass filter no longer has a significant effect on the resulting coefficient of determination (R2), even in Figure 3-3 it shows that data processing without a low pass filter produces a better coefficient of determination (R2).

After adjusting the data, the in-situ data will then be divided into modeling data and accuracy test data with a proportion of 60% for modeling data and 40% for accuracy test data. Data processing with a low pass filter has 971 modeling data and 646 accuracy test data, while data processing without a low pass filter has 935 modeling data and 623 accuracy test data. The results of the relative depth are extracted against the modeling data to see the regression results. obtained between image data and modeling data. Figure 3-4 shows a graph of the blue/green band ratio (image data) with modeling data for both data processing with and without the application of a low pass filter.

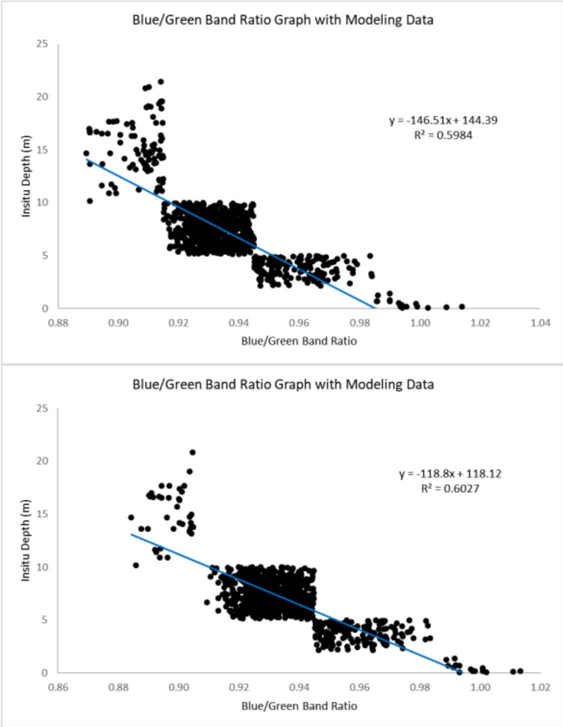


Figure 3-4. Satellite image data with modeling data with and without low pass filter

The regression results obtained are in the form of a regression equation which will be used to perform regression modeling. The resulting regression equation is:

$$y = -146.51x + 144.39 \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$y = -188.8x + 118.12 \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

3.3 Absolute Depth

The results of equation (4) and equation (5) are then entered into the Stumpf algorithm layer (relative depth) to obtain an image with an absolute depth value. Figure 3-5 shows the results of the absolute depth in the Shallow Sea of Pulau Putri, Pulau Seribu Regency with and without a low pass filter. Based on the data processing that has been done, the bathymetry detection results are obtained in the form of Absolute Depth of Shallow Sea Waters of Pulau Putri, Kepulauan Seribu Regency using PlanetScope Satellite Imagery. The bathymetry detection results in Figure 3-5 produce values that range from a negative value to a maximum value of 24.3 m for detection results with a low pass filter and 23.9 m for detection results without a low pass filter. In this study, depth values below 0 will be removed from the accuracy test calculations because these values are depth values with a high error rate. This is confirm by Sesama *et al.*, (2021), who state that depth values below 0 must be removed from the bathymetric detection results because these depth values are values with a high error rate. Figure 3-5 shows the absolute depth class generated by grouping the range of absolute depth values obtained after carrying out regression modeling into four depth classes when adjusting the data, so that the depth values is no longer based on absolute depth layer pixel values but based on depth classes marked in red towards blue.

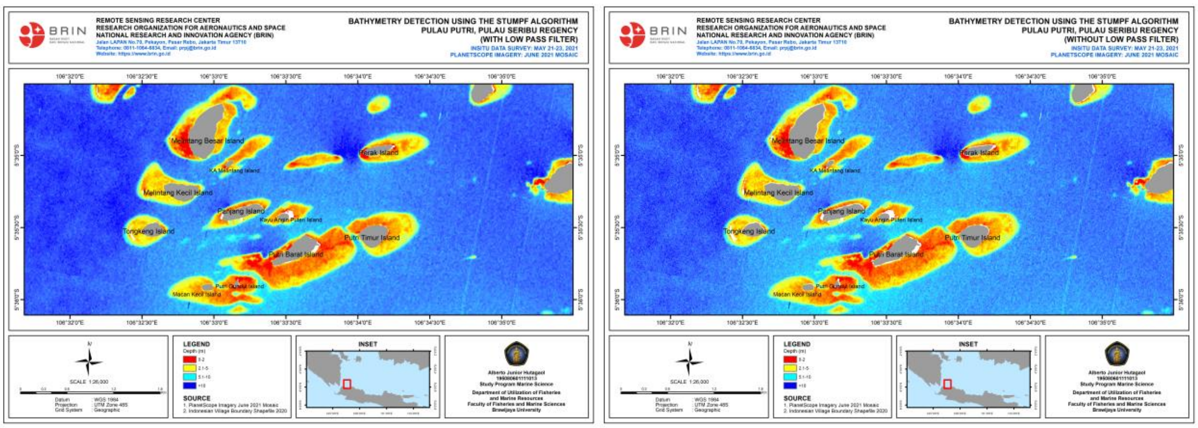


Figure 3-5. Absolute depth results with and without low pass filter

3.4 Accuracy Test Results

The results of the absolute depth are extracted from the accuracy test data to see the regression results obtained between the image data and the accuracy test data. Figure 3-6 shows the graph of absolute depth with accuracy test data for both data processing with and without the application of a low pass filter.

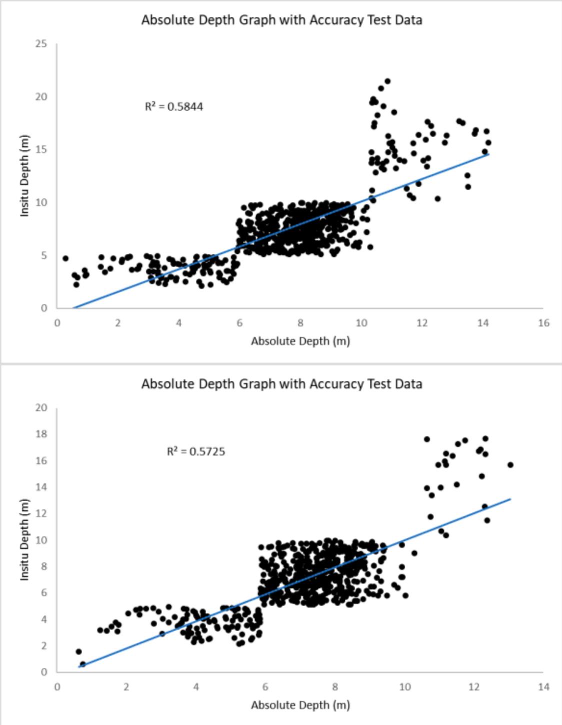


Figure 3-6. Satellite Image data with accuracy test data with and without a low pass filter

From the regression graph of data processing results with and without the application of a low pass filter, it can be seen that the data plot points form a straight line pattern from the bottom left to the top right. This shows that there is a linear and positive relationship between image data and accuracy test data. The resulting regression coefficient of determination (R2) is 0.5844 and 0.5725 respectively. This shows that the insitu depth value can be explained linearly by 58.44% and 57.25% by the absolute depth value.

Bathymetry detection results from processing satellite imagery data cannot be directly used as the final result before an accuracy test is carried out. The accuracy test was carried out with the aim of knowing how accurate the bathymetry detection results were. One of the accuracy test methods can be done through an error matrix or commonly called the confusion matrix (Bashit *et al.*, 2019). Table 3-1 and Table 3-2 shows the results of the calculation of the confusion matrix method from the detection of shallow water bathymetry using PlanetScope satellite imagery.

Table 3-1. Results of the calculation of the confusion matrix with a low pass filter

		Actual					
Estimated	Class	0-2	2.1-5	5.1-10	>10	Row Total	User's Accuracy
	0-2	1	11	0	0	12	8.33%
	2.1-5	4	68			72	94.44%
	5.1-10	1	56	432		489	88.34%
	>10			10	55	65	84.62%
	Column Total	6	135	442	55	638	
	Producer's Accuracy	16.67%	50.37%	97.74%	100%		
	Overall Accuracy						87.15%

Table 3-2. Results of the calculation of the confusion matrix without a low pass filter

		Actual					
Estimated	Class	0-2	2.1-5	5.1-10	>10	Row Total	User's Accuracy
	0-2	2	7			9	22.22%
	2.1-5		65			65	100%
	5.1-10		27	491		518	94.79%
	>10			2	23	25	92%
	Column Total	2	99	493	23	617	
	Producer's Accuracy	100%	65.66%	99.59%	100%		
	Overall Accuracy						94.17%

Table 3-3. RMSE calculation results with and without a low pass filter

Number	**Depth class (m)**	**Amount of data**		**RMSE**	
		(With)	**(Without)**	**(With)**	**(Without)**
1.	0 – 2	12	9	2.65	1.71
2.	2.1 – 5	72	65	1.20	1.11
3.	5.1 – 10	489	518	1.53	1.46
4.	>10	65	25	4.43	3.96
Total		638	617	2.02	1.61

The column in the matrix shows the pixel class of the actual (in situ) value, while the rows in the matrix represent the pixel class of the detected (estimated) value. The value of the producer accuracy shows how well the in-situ depth value can be detected, while the user accuracy value shows how similar the depth value of the detection results from the data processing that has been carried out to the in-situ depth value (Rohim *et al.*, 2021). The diagonal section of the table shows the correct amount of data from the detection results. The value of overall accuracy is obtained from a comparison of the correct amount of data according to the in-situ data with the total in-situ data used for the accuracy test.

The highest accuracy based on the producer accuracy value from data processing with and without the application of a low pass filter is 100% for a depth class of >10 m and 100% for a depth class of 0-2 m and >10 m respectively. The highest accuracy based on the user accuracy value of data processing with and without the application of a low pass filter is 94.4% respectively in the 2.1-5 m depth class and 100% in the 2.1-5 m depth class. Accuracy tests carried out from data processing with and without the application of a low pass filter produced very good overall accuracy values of 87.15% and 94.17%.

Accuracy test is also carried out by calculating the Root Mean Square Error (RSME). Table 3-3 show the RMSE calculation results from each depth class and from the overall accuracy test data for data processing with and without the application of a low pass filter. The results of the accuracy test using RMSE calculations show that the bathymetry detection results in the shallow seas of Pulau Putri, Pulau Seribu Regency without the application of a low pass filter have a smaller value than the results of the detection of bathymetry with the application of a low pass filter which is equal to 1.61. Bathymetry detection results without the application of a low pass filter which has a smaller RMSE value are results with a higher level of accuracy.

4 CONCLUSION

In the field of shallow sea water bathymetry detection, the use of a low pass filter is a common technique to smooth data by reducing local variations and noise. This method averages out the high and low values within each data neighborhood, effectively reducing extreme values. However, an intriguing finding from recent analysis is that the use of a low pass filter, while smoothing data, may not significantly impact the coefficient of determination in a regression equation. This observation is particularly notable after adjusting the data. Accuracy tests further reveal a compelling outcome: bathymetry detection achieves higher accuracy without the low pass filter, evidenced by an impressive overall accuracy of 94.17% and an RMSE value of 1.61. These results suggest that, contrary to initial expectations, the reduction in feature spatial detail caused by the filter does not necessarily enhance the accuracy of the detection process. Instead, data adjustment methods emerge as a more effective approach for accurate bathymetry detection. Consequently, future research could benefit from focusing on data adjustment techniques rather than low pass filtering, as this approach seems to offer a more promising path to improving accuracy in bathymetric measurements. This insight underscores the nuanced balance between data smoothing for noise reduction and the preservation of crucial spatial details in geographic data analysis.

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