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Development of bathymetry extraction model from SPOT 7 satellite image

Development of bathymetry extraction model from SPOT 7 satellite image

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Abstract. Bathymetry extraction using remote sensing technology still continues up to now. The technology improvement should be parallel with the accuracy product. The high accuracy of bathymetry extraction become a hope for all users. Improvement accuracy of bathymetry information from remote sensing data extraction is done by various processing method. In this study, in-situ sampling data technique is used to object aquatic marine habitat. The purpose of this study was to determine the bathymetric information model of SPOT 7 satellite image extraction and determine the accuracy produced. The model used is band ratio by Stumpf. The SPOT 7 satellite image data acquisition on June 28th 2018 Is used in the shallow waters of Gili Trawangan, Gili Meno, and Gili Air, Lombok Island, West Nusa Tenggara Province. The determination of bathymetry extraction results from the method is 62.64% and the mean error value of 4.32m.

1. Introduction

Information of depth distribution is an important parameter in many aspects of marine activities, especially for Indonesia which is surrounded by the sea. Depth information especially shallow water will help in planning the construction of ship docks, shipping safety, maintenance of submarine cables and pipes, realizing sea tolls [1], aquaculture activities [2]. In addition, Bathymetry is also able to help distinguish and classify coral reef habitats such as basic substrate, seagrass, seaweed, and living and dead corals [3].

Conventional methods have been used to obtain water depth data where the method is quite costly and time consuming and inefficient in shallow water [4]. In addition, information on bathymetry in shallow waters is constantly changing due to sedimentation and other activities so that the need for accurate bathymetry information both on the spatial and temporal scale is very necessary. Remote sensing technology is an alternative methods. This opportunity has been seen by International Hydrographic Organization (IHO). IHO through the IHO-ICO GEBCO Cook Book [5] issued procedures for processing Landsat 8 data using the ratio method to obtain bathymetry information.

There are four components are used in the principle of shallow sea bathymetry extraction using satellite images, such as; atmospheric scattering, sea surface reflectance, water column scattering, and sea floor surface reflectance, illustrated in figure1.

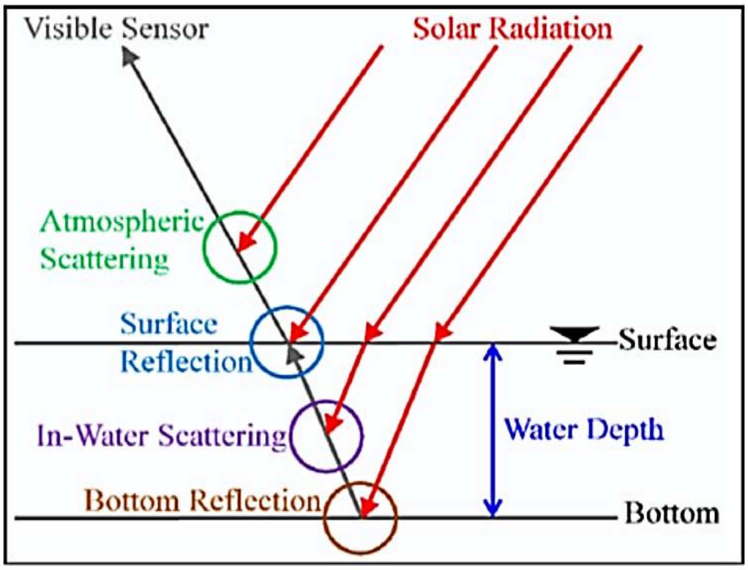

Figure 1. Bathymetry extraction concept [9].

Surface reflectance of the sea floor is the main component is used as a value for generating ocean depth, while three others are residual or noise components that need to eliminate or find out for correcting the image spectral value from satellite sensor.

The use of optical sensing remote data with various resolutions to obtain bathymetry information has been done [6] using ratio method on Landsat 8 data in the southwest coast of India. The correlation between bathymetry from Landsat 8 data and hydrographic of 0.8781 [7] and [8] used SPOT 6/7 data for this method [9-12] used World view data for bathymetry method.

[3] using Quickbird imagery in the study area of Karang Lebar lagoon and Panggang Island. The Jupp method is used to extract bathymetry information. This method produced the highest correlation in the Karang Lebar lagoon of 0.802 [4] was analysis the bathymetric mapping technologies by means of satellite remote sensing (RS) with special emphasis on bathymetry derivation models, methods, accuracies, advantages, limitations, and comparisons. For the method, the result show that the ratio algorithm is quite accurate in determining the depth in very turbid shallow waters with sufficiently representative field data requirements.

The transformation ratio method has fewer empirical coefficients that make this method easier to use and more stable in a broad geographical area. The ratio model is better at analyzing depth with non-homogeneous environmental characteristics. This research was conducted using the band ratio method developed by [13], and by using the ratio between the blue band and the green band. The satellite image data used SPOT 7 which is equipped with blue bands, green bands, red bands and NIR bands. The purpose of this study was to determine the bathymetric information model of extraction of SPOT 7 satellite images and determine the accuracy produced from these models.

2. Method

2.1 Data set and location

Location for this research was in the shallow waters of Gili Matra covering the waters of Gili Trawangan, Gili Meno and Gili Air Lombok NTB (figure 1). The data is used in this study are SPOT 7 satellite image data with a multispectral 6 m spatial resolution. These image data are recorded on June 28th 2018 at 10:12:49 Central Indonesian Time. The study was conducted in June because of the conditions of the transition season so that the weather was very good for field data collection and SPOT 7 Image data used free of clouds. SPOT 7 satellite launched by SPOT Image and its satellite obtains 16-bit data consist four spectral bands, such as blue, green, red, and NIR.

In addition, hydrographic survey data is used in the waters of Gili Matra Lombok, NTB Province. The data was collected during the field survey conducted on June 22th-28th, 2018 by measuring using a single beam sonar and differential global positioning system (DGPS). The depth data and recorded coordinates are combined into xyz table data using hydropro software carried out by the PUSHIDROSAL team. This study examined the effect of basic water objects on bathymetry extraction using multiple linear regression methods in Gili Matra Islands, Lombok, West Nusa Tenggara.

Figure 2. Research location.

2.2. Method

Tidal Correction

Depth measurement data from hydrographic survey is affected by tidal conditions. Therefore, it is necessary to make correction the depth measurement by the mean sea level (MSL) by reducing the measured depth of the tidal level. Processing tidal uses an Automatic Water Level Recorder (AWLR) for the sea with the tide gage model.

Image Pre-rocessing

Pre-processing of satellite imagery is a process of processing satellite imagery before main processing is carried out, that is extraction of ocean depth information. The processing includes radiometric and atmospheric correction. Radiometric Correction is a process to improve the visual quality of the image, in terms of correcting pixel values that do not match the reflectance value or the spectral emission of the actual object. Atmospheric correction is done because the atmosphere can increase the spectral value because atmospheric particles have a higher reflection, so that the presence of these particles can cause bias.

Bathymetry Extraction

Extraction of the depth of the sea is the stage of the process of decreasing sea depth information from remote sensing images by utilizing each pixel value of the image which is reflected from each visible wavelength of SPOT 7. Estimating the depth of the sea with satellite imagery can use several model Satellite Derived Bathymetry (SDB) including the band ratio method. The band ratio method is developed by [13] utilizes green and blue canals in extracting depth. This is because the radiation in the blue band will decrease with depth comparing to the green band radiation. This is the reason why blue and green bands are used. Red bands is used to separate sea and land because generally bands with wavelengths 700 above have low transmission in sea water. The equations used is adjusted for the exponent model used.

$$\text{Depth Index} = \left(\frac{\ln\left(L_{obs}\left(Band_i\right)\right)}{\ln\left(L_{obs}\left(Band_j\right)\right)}\right) \quad (1)$$

where: L_{obs} = bands radians, i = blue band, and j = green band

Accuracy Testing

To test the accuracy of the model, we calculate the R^2 correlation and the average RMSE error. The equation used to calculate the correlation R^2 and RMSE error is as follows:

$$R^2 = 1 - \sum_i \left(h_i - \hat{h}_i\right)^2 / \sum_i \left(h_i - \bar{h}\right)^2 \quad (2)$$

$$\text{RMSE} = \left(\sum_{i=1}^{n} \left(h_i - \hat{h}_i\right)^2 / n\right)^{0.5} \quad (3)$$

where :

h	:	Insitu depth
$\hat{h}$	:	Depth based on SPOT 7 image data
$\bar{h}$	:	mean of in situ depth
n	:	Amount of input data

The next validation process is determining the fulfillment of accuracy standards based on IHO S44 [14]. Bathymetric data from the results of multiple linear model methods were analyzed using field data and calculated order accuracy based on IHO-S44 standards consisting of special orders, order 1A / 1B, and order 2. The criteria were used the value of total vertical uncertainty (TVU). There are two kinds of errors that can affect the depth of uncertainty, errors that depend on depth and the other is not depend on depth. The following equation 4 is used to calculate maximum TVU. The parameters "a" and "b" in each order are explained in Table 1. The flow diagram of research activities is shown in figure 3.

Table 1. Total vertical uncertainty (Source : IHO, 2008).

Order	a	b
Special	0,250	0,0075
1A	0,500	0,0130
1B	0,500	0,0130
2	1,000	0,0230

$$\text{TVU} = \pm\sqrt{a^2 + (b \, x \, d)^2} \quad (4)$$

where:

a	:	uncertainly coefficient that not depend on depth
b	:	untertainly coefficient that depend on depth
d	:	depth

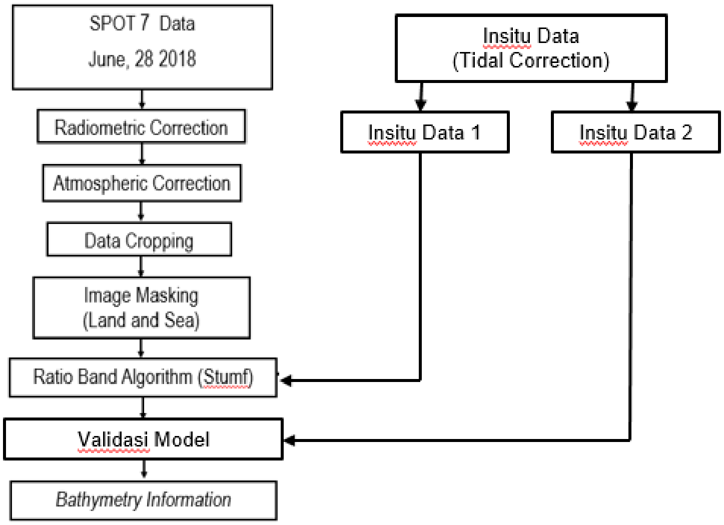

Figure 3. The flow diagram of research.

3. Results and discussion

The bathymetry calculation using the band ratio method starts with calculating the band ratio value between the blue band and the green band from the SPOT 7 image that has been carried out by the initial treatment process including atmospheric and radiometric correction. The calculation results of the band ratio are referred to as the results of relative depth or depth index. The results of the relative depth are shown in figure 4.

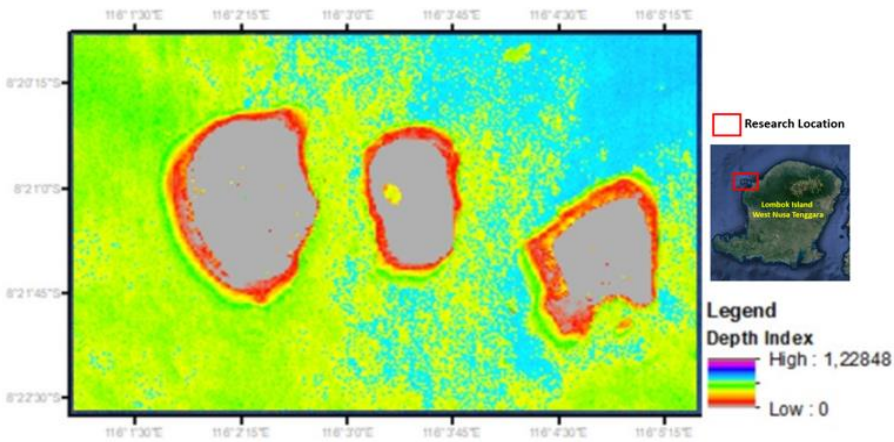

Figure 4. Depth index.

Tidal correction is carried out on field depth data measured using a single beam during field surveys, so that the depth of field (in-situ) used in the modeling of this research has been corrected by tides. The next calculation process is extraction modeling from SPOT 7 satellite images to produce bathymetry information. Extraction modeling uses data from relative depth with depth of corrected tides. Extraction modeling was chosen using exponential regression with the relative depth data on the X axis of internal depth funds on the Y axis. The exponential function is chosen by looking at the

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distribution of data in the XY diagram which tends to follow the exponential curve pattern (figure 5). The exponential regression equation produced is:

$$Y = 4\text{ E-}29\ e^{63.791X} \quad (5)$$

where :

Y : Bathymetry value from ratio band method

X : Depth index value

This equation is used to produce estimated bathymetry from SPOT 7 satellite images for shallow marine waters in Gili Matra, West Nusa Tenggara Province. The result of bathymetry extraction using the equation 5 produces a determination value R^2 of 0.803. The R^2 determination value illustrates the representation of pairs of data fulfilling the resulting model of 80.3%. Therefore, the determination value of 80.3% indicates that the exponential model is feasible to be chosen to produce bathymetric information in these waters.

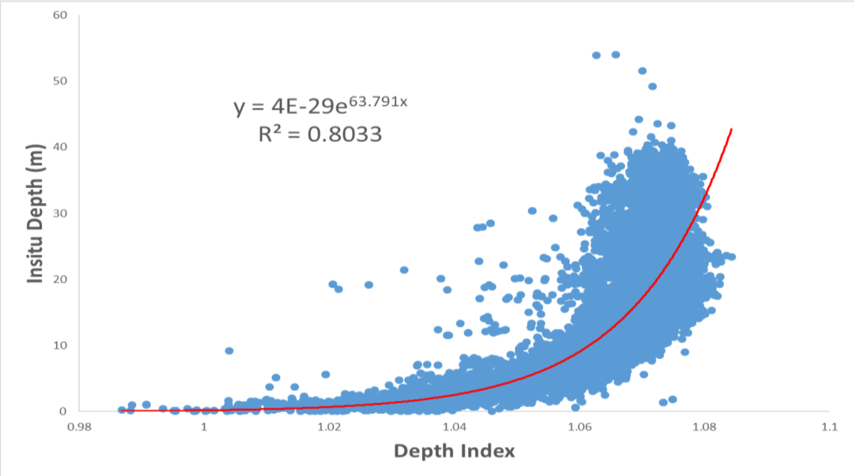

Figure 5. Distribution exponential model.

The results of the bathymetry information extraction from the exponential equation above are shown in Figure 5. The results of depth information are separated in 7 classes; the first class is less than 1m, the second class is between 1m to 2m, the third class is 2m to 5m, fourth class is 5m to 10m, the fifth class is between 10m and 15m, the sixth class is between 15m and 20m. (figure 6.)

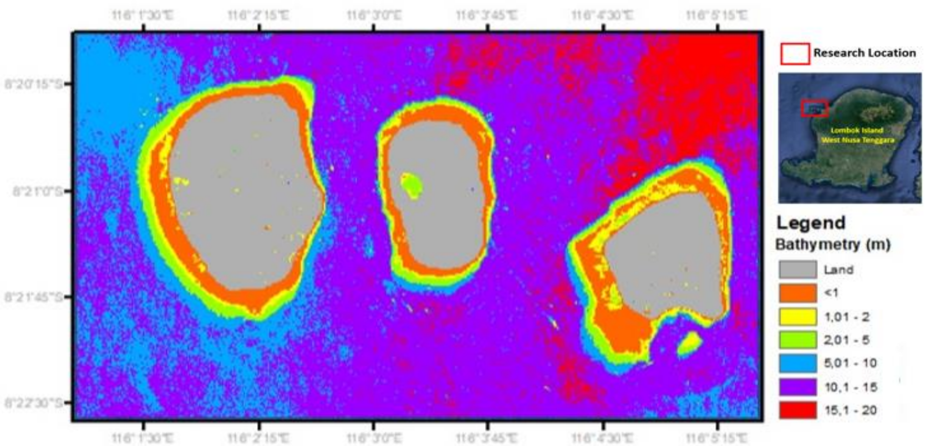

Figure 6. Bathymetry extraction.

Accuracy testing is carried out after the extraction results from the exponential model are determined to obtain the information of bathymetry. Accuracy testing uses bathymetric extraction data from modeling results with internal depth data that are not used in building the exponential model above. In the Cartesian diagram below, the X axis is the bathymetric extraction value of the exponential model, and the Y axis is the internal depth value. The two pairs of data are displayed on the Cartesian XY diagram to see the determination value of R^2 produced. Figure 7 is the distribution of the results of bathymetry extraction from SPOT 7 image data with In situ data. The image shows that at a depth of less than 10 meters the model is better than the depth of more than 10 m.

The accuracy of this study with the band ratio method and exponential regression model produces a R^2 value of 62.64% and an average error of 4.32 m. These results were higher in R^2 when compared with the [15] study using the band ratio method and linear regression models in Gili Matra and Menjangan Island. The research of [15] resulted in a determination value of R^2 of 20% and 14% by using SPOT 6 image data in 2013. So that this study results in a higher R^2 determination value than research [15].

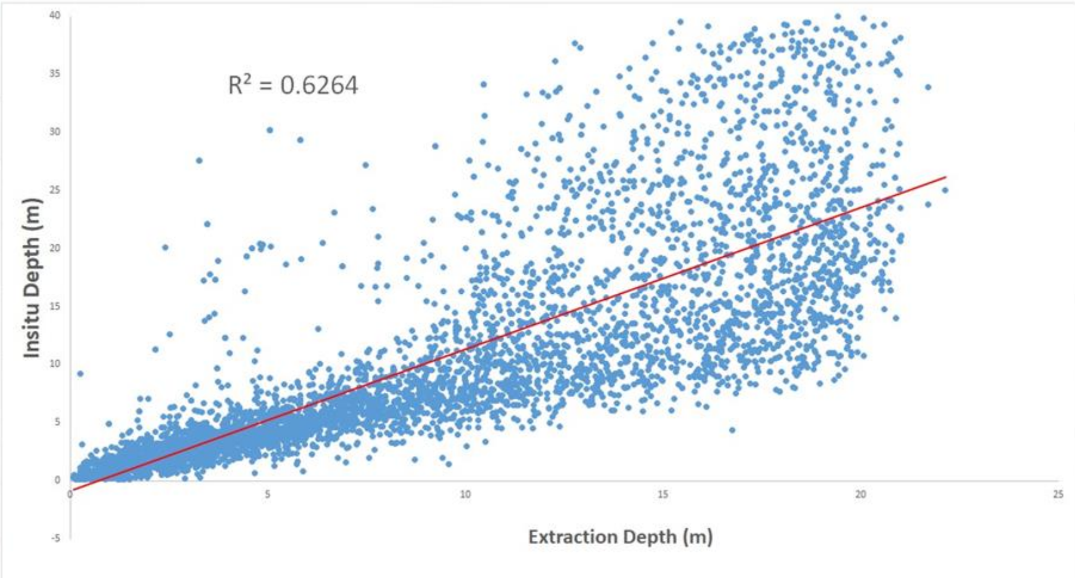

Figure 7. Distribution of the results of bathymetry extraction.

Bathymetry extraction from exponential modeling as a whole if its accuracy is measured based on IHO S44 standard produces a precision of 4.32 m with details of depth data obtained as many as 4910 data consisting of 10% entering the accuracy of special order; 9% goes to accuracy of order 1a/1b; 17% entered on 2nd order accuracy and 64% entered in exclude (Table. 2).

Table 2. Results of accuracy of bathymetry extraction (TVU, IHO S44).

Depth DATA (meter)	Number of Data	Order (%)			Exclude (%)	Accuracy (meter)
		Special	1A/1B	2		
All Depth	4910	10	9	17	64	4.32

Then by analyzing the accuracy value of bathymetric extraction made in 6 depth intervals. Table 3 shows the distribution of accuracy results based on IHO S44 standard per-interval depth made. By using field data as many as 4910 points of data which are divided into 6 depth intervals produce

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different accuracy values. At a depth of less than 1 m it has a precision of 1.07 meters with detailed depth data obtained as many as 175 data and consists of 26% entered in the accuracy of the special order; 18% goes to accuracy of order 1a/1b; 27% entered on 2nd order accuracy and 29% exclude.

Table 3. Results of accuracy of bathymetric extraction per depth interval (TVU, IHO S44).

Depth DATA (meter)	Number of Data	Order (%)			Exclude (%)	Accuracy (meter)
		Special	1A/1B	2		
< 1	175	26	18	27	29	1.07
1 - 2	374	19	17	32	32	1.35
2.1 - 5	1269	16	15	25	44	1.64
5.1 - 10	1335	7	8	16	69	3.41
10.1 - 15	886	4	3	8	85	5.47
15.1 - 20	871	3	3	6	88	6.27

At a depth of 1 to 2 meters has an accuracy of 1.35 meters using 374 data and consists of 19% entered in the accuracy of special order; 17% goes to accuracy of order 1a/1b; 32% entered on 2nd order accuracy and 32% exclude.

At a depth of 2.1 meters to 5 meters has a precision of 1.64 meters with detailed depth data obtained by 1269 data and consists of 16% entered in the accuracy of the special order; 15% goes to accuracy of order 1a / 1b; 25% goes to 2nd order accuracy and 44% exclude.

At a depth of 5.1 meters to 10 meters has a accuracy of 3.41 meters with detailed depth data obtained by 1335 data and consists of 7% entered in the accuracy of the special order; 8% goes to accuracy of order 1a / 1b; 16% goes to 2nd order accuracy and 69% exclude.

At a depth of 10.1 meters to 15 meters it has a accuracy of 5.47 meters with detailed depth data obtained by 886 data and consists of 4% entered in the accuracy of special order; 3% goes to accuracy of order 1a / 1b; 8% goes to precision 2nd order and 85% exclude.

At a depth of 15.1 meters to 20 meters has a accuracy of 6.27 meters with detailed depth data obtained by 871 data and consists of 3% entered in the accuracy of the special order; 3% goes to accuracy of order 1a / 1b; 6% entered at 2nd order accuracy and 88% did not enter the order of accuracy.

The depth of bathymetry extraction from exponential modeling produced when measured according to the IHO S44 standard made based on depth intervals showed that the largest special order entered at a depth interval of less than 1 meter by 26% with an accuracy of 1.07 meters.

Determination of the bathymetric value calculation method of the band ratio with the exponential model is based on the distribution of relative depth data with internal depth data which tends to have an exponential distribution pattern. The results of bathymetry extraction with exponential regression models are better than the linear regression models performed by [15] when viewed from the value of R^2.

4. Conclusion

Determination of bathymetry using SPOT 7 image acquisition data on June 28th 2018 with a band ratio model in shallow marine waters of Gili Trawangan, Gili Meno and Gili Air Lombok Island West Nusa Tenggara Province has R^2 value of 62.64% and an average error of 4.32 m. The extraction model produced is more accurate at depths less than 10 m compared to depths of more than 10 m.

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