Bathymetry extraction of empirical models using SPOT 7 satellite imagery

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Abstract – Bathymetry is information on the depth of the sea that can describe the hydrographic conditions of the seabed. Satellite derived bathymetry has several methods that can be applied to the batimetric extraction process using optical satellite images. One of the satellite images that can be used is SPOT 7. The image is the latest generation of SPOT which has 4 multispectral channels with a spatial resolution of 6 meters so that it can be extracted to obtain information on shallow water bathymetry. The bathymetry extraction method uses the Van Hengel and Spitzer methods, 1991. The VS method is the principal component analysis method of three bands with respect to the rotation transformation factor. The purpose of this study is to extract SPOT 7 satellite image data to produce relative bathymetry information in shallow seas using the VS algorithm. The location of the study was carried out on Karimunjawa Island, Jepara Regency, Central Java. The data used is SPOT 7 imagery that was acquired May 18, 2017. The extraction algorithm is used the VS 1991 method. The results show that from SPOT 7 images produce depth index values ranging from 0.0985 to 0.6378.

1. Introduction

The bathymetry extraction method using satellite image data is the development of satellite remote sensing technology. The method takes into account the principle of the propagation of light waves in water and the intensity of incident light that decreases in accordance with the increase in depth traversed. Since 1970, satellite remote sensing technology has been adopted as an alternative to minimize the mapping bathymetry [1]. Depth measurement with remote sensing technology can be performed by analyzing spectral values of each channel from satellite imagery. Shorter wavelength light penetrates water deeper than those with longer wavelength [2]; [3]. Lambert’s law explains that the absorbance of light is exponentially increased to the thickness of media through which the light is transmitted [2, 4] mentions that blue band has the ability to penetrate 25 meters deep, green band to penetrate 15 meters, red band to penetrate 5 metres. The sunlight that enters the body of water in intensity continuously decreases exponentially with increasing depth [5]. Multispectral sensor, especially green and blue bands, can penetrate up to 20 meters below the sea surface in a clear water condition [6-8].

Bathymetry was generally obtained by measuring the distance between the average of sea surface to the sea floor. Preliminary technique of bathymetry measured using heavy ropes or cables lowered from the ship side. The main limitation of this technique is only able to perform one measurement in one position and is strongly influenced by the movement of the vessel and flow that is considered
inefficient. In addition, the use of ecosunder that utilizes sound waves is also used to measure the
depth of waters. Echosounders work by sending sound waves that will propagate through the medium
of water and reflect waves after touching the water base. The main parameter in the bathymetry
measurement process using the acoustic method is the time difference between when sound waves
are emitted and received again. Each block will get depth information of one point so that when each
point is connected it will produce depth profile and when the ship moves it will produce images that
illustrate the surface of the sea floor. This technique is also less efficient for obtaining bathymetry
information for a very wide area and has a weakness for very shallow waters due to the limitations
of ships to reach the area. Alternatively, remote sensing images can be used in coastal and shallow
water bathymetric mapping is considerably cost effective [9, 10]

The challenge of utilizing remote sensing technology to obtain depth information is the accuracy of
the information. Various data extraction and resolution methods are used. The previous research that
used remote sensing data to derive depth information such as [11-13] using Landsat 8 OLI data. [14-
16] and [17], and [12]; [15]; [5]; using better spatial resolution, Worldview.

Furthermore, the methods used to extract water depths such as [7] using the stump method, [14], [12]
using a method developed on worldview data. Otherwise, there are still many other methods used to
extract water depths using remote sensing data. However, in this study the Van Hengel and Spitzer
(VS) Algorithm method, 1991 will be used. This method has been applied by [22] using LANDSAT
7 ETM + imagery data in Pari Island, DKI Jakarta Province by comparing the combination of red,
green and blue bands. V-S (1991) introduced an algorithm to generate bathymetry information by
using the rotational transformation matrix. Based on research conducted by [22], the tree band
combination showed the best results for estimating the depth of shallow waters on Pari Island by the
Van Hengel and Spitzer Algorithm method.

The purpose of this study is to extract SPOT 7 satellite image data to produce relative bathymetry
information in shallow seas using the V-S algorithm. SPOT -7 had four channels such as spectral
blue, green, red, and near infra red. Blue spectral channels are channels that are more sensitive to
the identification in the territorial waters when compared with other spectral channels. The choice of
location in the Karimunjawa Island in Jepara Province of Central Java because the island had a clear
waters which is also is one of the National park areas so that it becomes one of the tourist destination
so the results of this study can be used to support marine tourism especially for bathymetric mapping
information.

2. Methodology
This research was conducted in the Karimunjawa Island, Jepara, Province of Central Java who are
geographically located at coordinates 5º44'18.16” - 5º55’22.76” LS and 110º24’37.85” - 110º31’03.06”
BT (Figure 1). The data used in this study is the SPOT-7 imagery acquisition date of May 18, 2017
which channels in the visible wavelengths. The relative bathymetry extraction method in this study
uses the Van Hengel and Spitzer algorithm. Stages of the research conducted is summarized in the
flow diagram in Figure 2.
Figure 1. Area of Study

Figure 2. Flow Chart of Research
Algorithm V-S (1991) is the development of previous algorithm popularized by Lyzenga (1981). This algorithm produces relative depth index value as it is defined in equation (1).

\[ Y1 = (\cos(r) \times \sin(s) \times X1) + (\sin(r) \times \cos(s) \times X2) + (\sin(s) \times X3) \] (1)

\[ r = \arctan \left( \frac{U_r + \sqrt{U_r^2 + 1}}{1} \right) \] (2)

\[ s = \arctan \left( \frac{U_s + \sqrt{U_s^2 + 1}}{1} \right) \] (3)

\[ U_r = \frac{\text{Var} X_2 + \text{Var} X_1}{2 \text{Cov} X_1 X_2} \] (4)

\[ U_s = \frac{\text{Var} X_3 + \text{Var} X_1}{2 \text{Cov} X_1 X_3} \] (5)

Where:
- \( Y1 \): Depth Index
- \( X1 \): Reflectance value of band 1
- \( X2 \): Reflectance value of band 2
- \( X3 \): Reflectance value of band 3
- \( \text{Var} X1 \): Variance of 30 data of band 1
- \( \text{Var} X2 \): Variance of 30 data of band 2
- \( \text{Var} X3 \): Variance of 30 data of band 3
- \( \text{Cov} X1X2 \): Covariance of 30 data of band 1 and band 2
- \( \text{Cov} X1X3 \): Covariance of 30 data of band 1 and band 3

3. Result

Processing begins with collecting SPOT 7 image data and proceed with the data correction process. Data correction process carried out includes atmospheric and radiometric corrections. Atmospheric correction is useful for eliminating or reducing the effects of the atmosphere. Therefore after the correction process the digital value received by the sensor is the result of reflection from the surface bottom. Radiometric correction is done to provide stability of the digital reflection value of each object that is based on water. The radiometric process is carried out by changing the digital value of each pixel into a reflectance value. Reflectance values of blue, green, and red channels of bathymetry from SPOT-7 imagery in the waters of Karimunjawa Island, shown in Figure 3.
Bathymetry extraction is a process to produce depth information values from a water location. The data used in the extraction process is the reflectance value of the wavelengths owned by the SPOT 7 image. The wavelengths of the SPOT 7 Image used are the blue band, green band and red band. From the three bands the depth index is generated using the VS algorithm. The algorithm is a model developed using rotational transformation. In bathymetry extraction using the VS algorithm is the determination of the two transformation angles \( r \) and \( s \) used. Determination of the two transformation angles through a pair of wavelength values. The angle \( r \) is obtained from the pair between the band's value and the green band. The angle \( s \) is obtained from the pair between the blue band and the red band. The two pairs of bands are then calculated the value of each variant and the covariance of each pair. The formula for calculating the angle \( r \) and \( s \) values follows the equations found in no (2) and (3). Determination of the transformation \( U_r \) and \( U_s \) according to equation no (4) and (5). Furthermore, the determination of the depth index using the VS algorithm in accordance with equation (1).

The first pair consisting of the blue band and the green band produced a variant value of 0.000572 and 0.001011 respectively and covariance of 0.000729. The second pair consisting of the blue band and the red band produced a variant value of 0.000572 and 0.000155 respectively and a covariance of 0.000218. The two pairs the band produces a rotation transformation angle of 68.667\(^\circ\) and 74.512\(^\circ\). The equation used to produce the depth index value is according to the following equation:

\[
\text{Depth Indeks} = (0.36379 \times 0.96369 \times X1) + (0.93148 \times 0.26704 \times X2) + (0.96369 \times X3)
\]

The results of the depth index values using the VS algorithm using SPOT 7 image data are shown in Figure 4.
The next processing is modeling making depth class. The depth class is created based on the resulting depth index value. From this index five classes of depth were produced. Determination of the class is made based on the division of depth index range. The process is extraction of SPOT 7 satellite imagery to produce bathymetric information in relative terms.

The depth index value generated from the VS algorithm is 0.0985 to 0.06378 as shown in Figure 4. From the depth index value is made into five depth classes. The five classes are very shallow, quite shallow, shallow, quite deep and deep (Figure 5). The depth welding is done by grouping the depth index values generated by the VS algorithm. Very shallow class has a depth index value of 0.5786 - 0.6378, quite shallow class has a depth index value of 0.4586 - 0.5785, shallow class has a depth index value of 0.3386 - 0.4585, quite deep class has a depth index value of 0.2186 - 0.3385, deep class has an index value depth of 0.0985 - 0.2185. A very high depth index value results in a very shallow depth class, whereas a very low depth index value results in the deepest depth class.

**Figure 4.** Depth Index
The use of the VS algorithm has been done using LANDSAT TM imagery data. Setiawan et.al (2014) by using of LANDSAT ETM+ image with VS algorithm transformation may generate depth information up to -22.5 m with $R^2$ value of 0.62 on Menjangan Island, Bali Province. Wahyuningrum et. al. (2008) used LANDSAT ETM+ imagery with the same algorithms was able to extract depth information up to -15 m with value $R^2$ value of 0.67 on Pari Archipelago, Kepulauan Seribu, DKI Jakarta Province. Another research had been performed by Arief et. al. (2013) by using spectral bands correlation of SPOT-4 satellite imagery data to predict bathymetry of shallow waters in Ratai Bay, Pesawaran Regency, Lampung Province. The data can only estimate to approximate depth of 18 meters. Meanwhile, according to results of Jupp (1988) LANDSAT TM on clear waters is able to extract depth value up to -25 m.

The results of this study aim to provide depth information that is still realistic in qualitative classes. Quality depth classification is done to get preliminary information on shallow sea depth conditions in coastal areas. With the information on bathymetry, it is hoped that it will be useful for the regional or central government to manage the inventory planning of natural resources. The results of this study need to be continued with quantitative depth determination and accuracy calculation. To produce this information, data on depth of field around shallow sea waters is certainly needed. Field depth data is used to build empirical models to produce quantitative depth and accuracy calculations.

4. Conclusion

The SPOT-7 image acquired on 18 May 2017 can be used to extract relative bathymetry information on Karimunjawa Island in Jepara, Central Java Province. Batimetr information relatively produces 5 depth classes consisting of very shallow, quite shallow, shallow, quite deep and deep. The...
bathymetry information is expected to be useful as preliminary information to support the management of coastal resource management.

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