APPLICATION OF VAN HENGEL AND SPITZER ALGORITHM FOR INFORMATION ON BATHYMETRY EXTRACTION USING LANDSAT DATA

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Abstract. Remote sensing technology provides an opportunity for effective and efficient bathymetry mapping, especially in areas which level of depth changes quickly. Bathymetry information is very useful for hydrographic and shipping safety. Landsat medium resolution satellite imagery can be used for the extraction of bathymetry information. This study aims to extract information from the Landsat bathymetry by using Van Hengel and Spitzer rotation algorithm transformation (1991) in the water of Menjangan Island, Bali. This study shows that Van Hengel and Spitzer rotation algorithm transformation (1991) can be used to extract information on the bathymetry of Menjangan Island. Extraction of bathymetric information generated from Landsat TM imagery data in March 19, 1997 had shown the depth interval of (-0.6) m to (-12.3) m and R2 value of 0.671. While Data LANDSAT ETM + dated June 23, 2000 resulted in depth interval of 0 m to (-19.1) m and R2 value of 0.796. Furthermore, data LANDSAT ETM + dated March 12, 2003 resulted in depth interval of 0 m to (-22.5) m and R2 value of 0.931.

Keywords: *Bathymetry, LANDSAT ETM+, Van Hengel and SpitzerAlgorithm*

1 INTRODUCTION

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon by analyzing acquired data which device is not in physical direct contact with the object, area or phenomenon under investigation (Lillesand *et al.*, 2007). Remote sensing technology is developed and derived from photographic remote sensing or photogrammetry. Before 1960 photographic remote sensing was well known as aerial photographs (Sutanto, 1986). Remote sensing data is useful for natural resource planning and management (Lillesand and Kiefer, 1994; Danoedoro, 1996).

Depth measurement with remote sensing technology can be performed by analyzing spectral values of each channel from satellite imagery. Depth measurement with remote sensing data follows the principle that light is weakened through interaction with water column, referred as Attenuation, and how far the light penetrates the water depends on wavelength of the light. Shorter wavelength light penetrates water deeper than those with longer wavelength (Hutomo, 2010). This principle is based on Beer-Lambert Law which relates the absorbance of sunlight will be expotentially increased with increasing concentration of water. Lambert's law explains that the absorbance of light is expotentially increased to the thickness of media through which the light is transmitted (Bukata et al., 1995). The process is known as attenuation or weakening and may affect the electromagnetic signal received by satellite sensor. Magnitude of attenuation process depends on the wavelength.

One of the satellites that can be utilized to perform bathymetry mapping on shallow waters is LANDSAT for its imagery has medium-resolution. LANDSAT imagery is_equipped with visible channel which is needed to extract bathymetry information with spatial resolution of 30 meters. Visible channels (blue, red and green) have the ability to penetrate water to certain depth. Each channel has different capability to penetrate deep into water, especially blue channel which penetrates the deepest. Jupp (1988) mentions that LANDSAT imagery can be used to determine the depth of water; for Band 1 has the ability to penetrate 25 meters deep, Band 2 to penetrate 15 meters, Band 3 to penetrate 5 metres, and Band 4 to penetrate 0.5 meters.

Bathymetry information is one of the most important aspects in marine resource study, both bathymetry information of shallow as well as deep water. Bathymetry is generally obtained by measuring the distance between average ocean surface and bottom of the sea. Bathymetry measurement technique generally uses pre-measured heavy rope lowered over a ship's side and acoustic method usually called as pemeruman. The main limitation of these two techniques is both are only able to perform measurements in one position and strongly influenced by vessel as well as current movement, therefore both techniques are inefficient. Algorithm for bathymetry measurement of coastal region by using satellite imagery was developed by Lyzenga (1978, 1981, 1985), Paredes and Spero (1983), and Spitzer and Dirks (1987). Algorithm for extracting bathymetry implemented in this study is Van Hengel and Spitzer Algorithm, 1991 (V-S (1991)). V-S (1991) introduced an algorithm to generate bathymetry information from LANDSAT Thematic Mapper (TM) imagery data by using rotational transformation matrix. V-S Method (1991) had been used to generate information on bathymetry of Pari Island, DKI Jakarta Province by using LANDSAT 7 ETM+ imagery data with combination of Band 1, Band 2, and Band 3 (Wahyuningrum, et al., 2008).

LANDSAT-TM satellite were initially designed to gain data on land natural resources. However along the way, it turns out that thematic mapper sensor can also be applied on coastal and marine resource studies (Butler et al. 1988). The latest generation of Landsat is Landsat 7 (L7) with Enhanced Thematic Mapper Plus (ETM +) sensor. Landsat-7 provides repetitive and synoptic coverage of continental surfaces data. The spectral bands cover electromagnetic spectrum visible rays, infrared, near infrared and thermal infrared as well as absolute radiometric calibration.

This research is conducted in Menjangan Island water which is located in Labuan Lalang Gerokgak Village, Buleleng Regency, Bali. Menjangan Island is part of Bali Barat National Park. Water of Menjangan Island is relatively calm. It has strong water clarity and natural coral reefs where sunlight can reach them to a maximum depth (Sidabutar, 2000).

Purpose of this research is to study V-S algorithm (1991) in extracting bathymetry information from LANDSAT imagery and counting accuracy of the algorithm in the water of Menjangan Island, Bali. This paper is developed from previously published paper in the proceedings of national seminar on remote sensing.

2 RESEARCH METHODE

This research takes place in Menjangan Island, Bali Province (Figure 2.1). The island is geographically located between Longitude of 114° 31' 1.20" E and Latitude of -8° 04' 59.99" S.

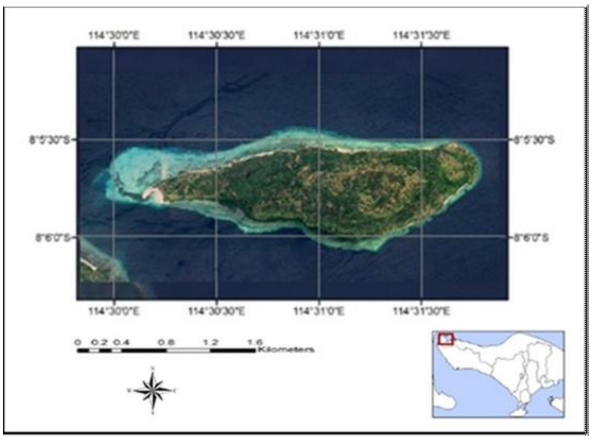

Figure 2-1: Research Location

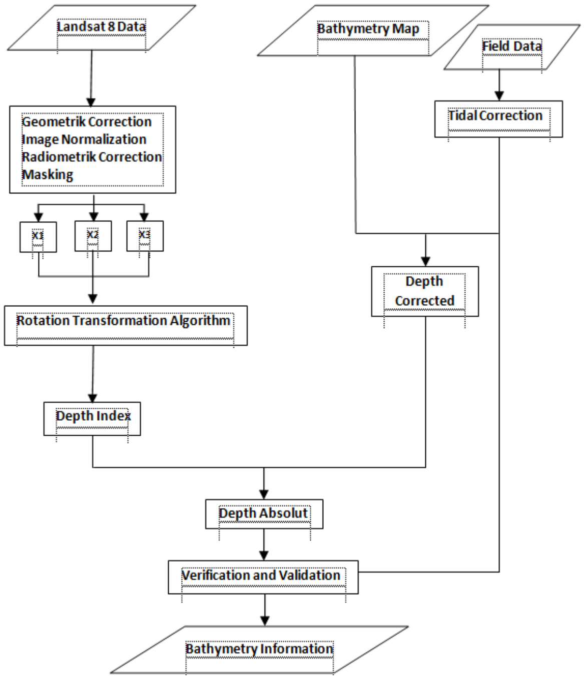

Figure 2-2: Research Flowchart

This research is conducted by using three LANDSAT satellite imagery data. The three imagery data are one LANDSAT TM imagery data acquired on March 19, 1997 and two LANDSAT ETM+ data acquired on June 23, 2000 and March 31, 2003. Other supplementary data used are BIG's Topographical Map (scale of 1 : 25,000), Bathymetry Map (scale of 1 : 50,000) from Hydrographic Offic acquired on February 2006, tidal wave data from Celukan Bawang Monitoring Station acquired since October 2006 to August 2012, and field survey on May 21, 2013.

The research starts with data collecting, geometric correction, imagery normalization and atmospheric modification (Triskati *et al.*, 2011). In detail, the research process includes atmospheric correction with Jensen Method (1986), geometric correction, and image normalization with reference to LANDSAT ETM + on March 12, 2013. Then radiometric process is conducted, i.e. conversion of digital number into Reflectance value prior to land and water object separation by using Band Ratio between Band 4 and Band 2. Then, rotation algorithm transformation of V-S (1991) conducted on water to generate information of relative depth (depth index). The depth value derived from field survey (on site data) is used to create regression model in order to generate absolute depth.

This study utilizes 4 Bands of LANDSAT imagery; they are Band 1, Band 2, Band 3, and Band 4, each of which has a spatial resolution of 30 meters. Normalization Process begins by selecting four areas with invariant object; the objects are vegetation, open land, sand and sea. Afterward, radiometric correction is performed through conversion of digital value number into reflectance values. To obtain reflectance value of each band we use equation (1). For the water and ground object separation process we use band ratio between Band 4 spectral value and Band 2 spectral value.

$$\rho_p = \frac{\pi \times L\lambda \times d^2}{\mathbf{ESUN\lambda} \times \mathrm{Cos}\ \theta s} \qquad (2\text{-}1)$$

$$L = \frac{(L\ Max\boldsymbol{\lambda} - L\ Min\boldsymbol{\lambda})}{(255-\mathbf{1})}\ (DN-1) + L\ Min\boldsymbol{\lambda} \qquad (2\text{-}2)$$

Where

ρ_p : Reflectance (value 0-1)

π : Constanta (3,142)

$L\lambda$: Spectral Radians (μm)

d : Earth-sun distance in astronomical units

ESUNλ : Iradians (watt)

θs : Solar Zenith angle
Lmaxλ : Maximum Radiance of wavelength λ
LMixλ : Minimum Radiance of wavelength λ
DN : Digital number

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 (3).

$$Y1 = (\cos(r)\times\sin(s)\times X1) + \sin(r)\times\cos(s)\times X2) + (\sin(s)\times X3) \quad (2\text{-}3)$$

$$r = \arctan\ (Ur + \sqrt{Ur^2 + 1}\ ) \quad (2\text{-}4)$$

$$s = \arctan\ (Us + \sqrt{Us^2 + 1}\ ) \quad (2\text{-}5)$$

$$Ur = \frac{Var\ x2 + Var\ x1}{2\ Cov\ x1x2} \quad (2\text{-}6)$$

$$Us = \frac{Var\ x3 + Var\ x1}{2\ Cov\ x1x3} \quad (2\text{-}7)$$

Where,
Y1 : Relative water depth (depth Index)
Xi : Spectral Reflectance Band of i (i=1,2,3)
r and s : Rotation parameters
VarXi : Variance value of spectral band i
CovXiXj : Covariance value of spectral band-i and band-j

3 RESULT AND DISCUSSION

Data processing is started by perform geometric correction using topographical map scale 1:25,000 as reference. Whereas, atmospheric correction is performed by using Jensen Method (1986).

The next process is normalization. In this process, LANDSAT ETM + imagery data acquired on March 12, 2003 is used as reference. Then, radiometric correction is performed through conversion of digital value into reflectance value.

Bathymetry information extraction then is performed on water area shown on the imagery data. Therefore we perform land and water object separation. In separation process, we use Band 4 and Band 2 ratio. Band 4 ratio is selected as it is near infrared band as well as a strong water absorber, while Band 2 has large reflectivity in water object.

Algorithm V-S (1991) generates relative depth index defined in equation (3). There are three bands used in this algorithm, they are Band 1, Band 2, and Band 3 which has the best spectral response for water object. The use of V-S algorithms (1991), is started by defining the value of r and s rotation direction. Then the angular value of r and s are defined by using equation (4) and (5) formula. Rotation value of r and s generated are respectively 74.3934° and 77.4170° for LANDSAT TM imagery data dated March 19, 1997; 69.6075° and 81.7182° for LANDSAT ETM + imagery data dated June 23, 2000; and 70.3309° and 75.6532° for LANDSAT ETM + imagery data dated March 12, 2003. After acquiring r and s values, then the next process is defining depth index value (relative depth of water) using formula (3). Relative depth values of the three imagery data are shown in Figure 3-1.

The next process is to determine absolute depth value of satellite imagery data. Absolute depth value (Y) is obtained using regression equation which is formed from relative depth value (X) imagery data and depth data on field. Figure 3-2 shows regression model which is made to determine the absolute depth value. For LANDSAT TM imagery dated March 19, 1997 the regression equation used is Y = 1,874Ln (X) + 0.639 with R2 value of 0.671; whereas for LANDSAT ETM + dated June 23, 2000 the equation used is Y = 2.447Ln (X) + 5.336 with R2 value of 0.796 and for LANDSAT ETM + date of 12 March 2003 the equation used is Y = 2,988Ln(X) + 5,535 with R2 value of 0.931. The resulting absolute depth value is in meters.

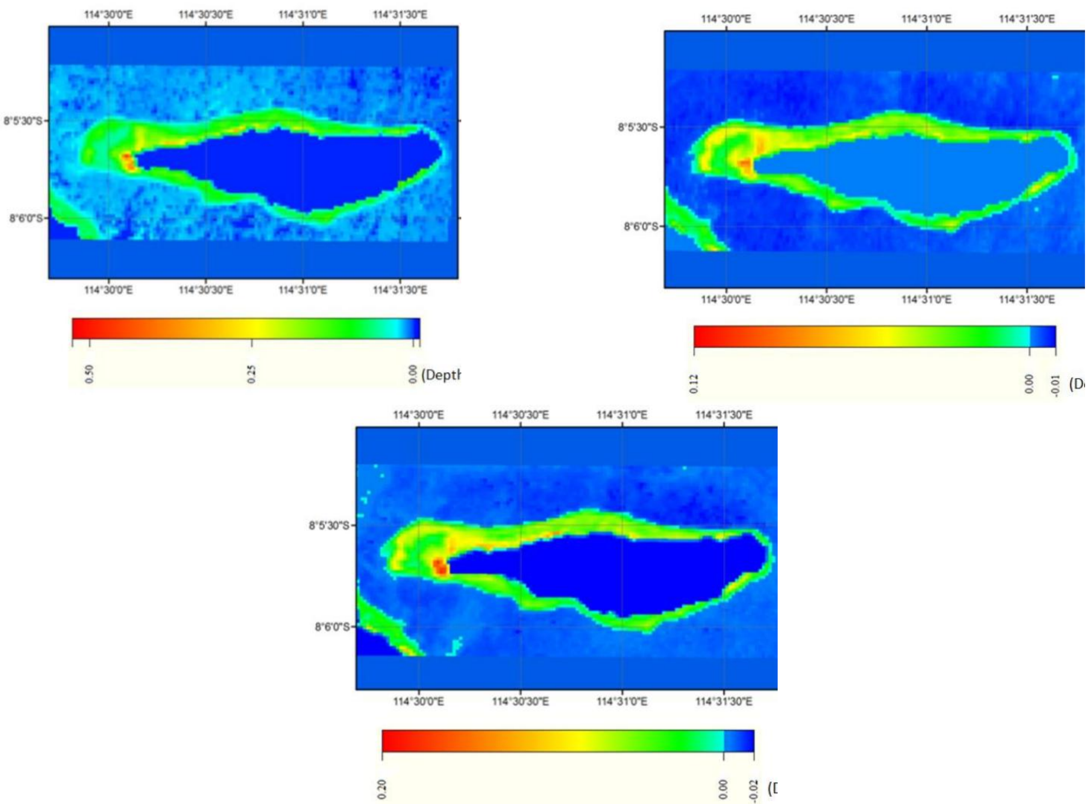

Figure 3-1: Relative Water Depth as the result of V-S Rotation Algorithm Transformation (1991) from LANDSAT TM imagery dated March 19, 1997 (above), LANDSAT ETM+ dated June 23, 2000 (middle) and LANDSAT ETM+ image dated March 12, 2003 (below)

The absolute depth from each imagery data; LANDSAT TM dated March 19, 1997; LANDSAT ETM+ dated June 23, 2000 and LANDSAT ETM+ dated March 12, 2003 are shown in Figure 3.3. The figure shows that LANDSAT TM imagery data on March 19, 1997 generates absolute depth values in the interval of -0.6 m to -12.3 m. LANDSAT ETM+ imagery data on June 23, 2000 generates absolute depth interval of 0 m to -19.1 m. Whereas LANDSAT ETM + imagery on March 12, 2003 generates absolute depth interval of 0 m to -22.5 m (Figure 3-3).

Absolute depth extraction from three LANDSAT imagery data produces different depth-range values. The difference in absolute depth value is caused by several factors, such as image quality of LANDSAT data. In addition to depth range difference, there is extraction of depth value on the sea which has more than 25 m depth value according to hydrographic map, this condition dominantly occurs on LANDSAT TM imagery dated March 19, 1997. The same factors also effect in the calculation of the two other LANDSAT ETM+ images, yet relatively less. This occurs for there are thin clouds on the imagery data. The absolute depth extraction on LANDSAT ETM + image dated March 12, 2003 also generates red area with positive value which is identified as accretion area.

Absolute depth extraction values resulting from three imagery data, shows that extraction of LANDSAT ETM+ image dated March 12, 2003 with Van Hengel and Spitzer rotation algorithm transformation (1991) may generate depth information up to -22.5 m with R2 value of 0.931. Wahyuningrum et. al. (2008) used LANDSAT ETM+ imagery with the same algorithms was able to extract depth information up to -15 m with value R2 value of 0.8 on Pari Archipelago, Kepulauan Seribu, DKI Jakarta Province. Meanwhile, according to results of Jupp

(1988) LANDSAT TM on clear waters is able to extract depth value up to -25 m. 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. Several other researches using V-S algorithm (1991) also find it very potential to generate information on bathymetry extraction.

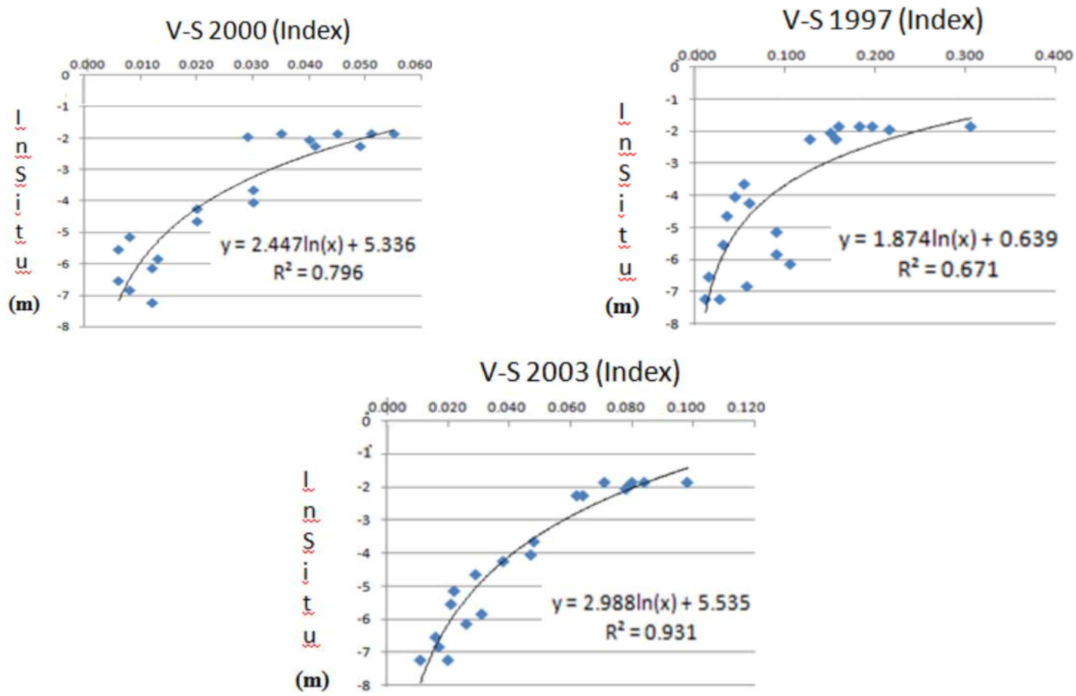

Figure 3-2: Regression equations to generate absolute depth of LANDSAT TM imagery dated March 19, 1997 (above), LANDSAT ETM+ imagery dated June 23, 2000 (middle) and LANDSAT ETM+ imagery dated March 23, 2003 (below)

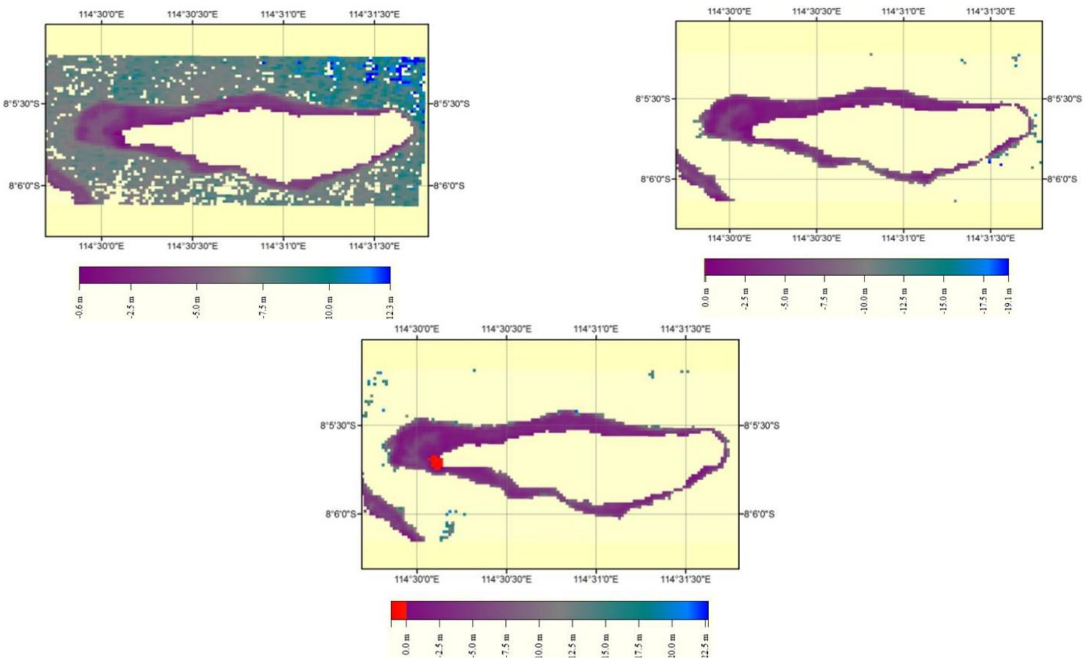

Figure 3-3: Absolute Depth Result from the LANDSAT TM imagery dated March 19, 1997 (above), LANDSAT ETM+ imagery dated June 23, 2009 (middle) and LANDSAT ETM+ imagery dated March 12, 2003 (below)

4 CONCLUSSION

Van Hengel and Spitzer's rotation algorithm transformation (1991) can be used to extract information on bathymetry at Menjangan Island, Bali. LANDSAT TM data on March 19, 1997 generates depth interval of (-0.6) m to (-12.3) m, with regression equation of Y = 1,874Ln(X) + 0,639 and R2 value of 0,671. Whereas LANDSAT ETM+ data on June 23, 2000 generates depth interval of 0 m to (-19.1) m, with regression equation of Y = 2,447Ln (X) + 5.336 and R2 value of 0.796. As for the LANDSAT ETM + data on March 12, 2003 generates depth interval of 0 m to (-22.5) m, with regression equation of Y = 2,988Ln (X) + 5.535 and R2 value of 0.931.

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