BATHYMETRY DATA EXTRACTION ANALYSIS USING LANDSAT 8 DATA

Kuncoro Teguh Setiawan*), Syifa Wismayati Adawiah, Yennie Marini, and Gathot Winarso
Remote Sensing Application Center, LAPAN
*)e-mail: kunteguhs@gmail.com

Received: 6 June 2016; Revised: 7 July 2016; Approved: 30 August 2016

Abstract. The remote sensing technique can be used to produce bathymetric map. Bathymetric mapping is important for the coastal zone and watershed management. In the previous study conducted in Menjangan Island of Bali, bathymetric extractin information from the top of the atmosphere (TOA) reflectance image of Landsat ETM+ data has R^2 = 0.620. Not optimal correlation value produced is highly influenced by the reflectance image of Landsat ETM+ data, were used, hence the lack of the research which became the basis of the present study. The study was on the Karang Lebar water of Thousand Islands, Jakarta. And the aim was to determine whether there was an increased correlation coefficient value of bathymetry extraction information generated from Surface reflectance and TOA reflectance imager of Landsat 8 data acquired on August 12, 2014. The method of extraction was done using algorithms Van Hengel and Spitzer (1991). Extraction absolute depth information obtained from the model logarithm of Landsat 8 surface reflectance images and pictures TOA produce a correlation value of R^2 = 0.663 and R^2 = 0.712.

Keywords: *bathymetry, Landsat 8, reflectance, Van Hengel and Spitzer algorithm*

1 INTRODUCTION

Bathymetric mapping is important for the coastal zone and watershed management. Bathymetry measurement conventionally in the shallow area and wavy as in a reef area is very difficult and expensive even sometimes very dangerous. (Kanno *et al.*, 2011). The bathymetry intertidal zone is needed to study the morphology of the seabed, the environment management of coastal resources and oceanographic modeling (Stumpf *et al.*, 2003). The coastal oceanographic research and the protection of the water environment require the use of the high accuracy bathymetric data. The use of Lidar and Radar Bathymetry for the collection of bathymetric data with high resolution and accuracy is expensive (Kaimaris *et al.*, 2012). Siregar *et al.*, 2009 conducted a bathymetric study using three methods Kriging interpolation method, namely, the method of inverse distance to power, and minimum curvature method.

One of the satellites that can be used for mapping shallow water bathymetry is Landsat 8. Landsat imagery has a spatial resolution of 30 meters are equipped with visible channel that required in the extraction of bathymetry map. Visible channel (blue, red and green) has the ability to penetrate the water to a certain depth, the blue channel has the ability to penetrate deeper into the water body. Jupp (1988) concluded that Landsat imagery can be used in Determining the water depth, band 2 (blue channel) has the ability to penetrate up to 25 meters of water depth, band 3 (green channel) up to 15 meters, band 4 (red channel) up to 5 meters, while band 5 (SWIR-1 channel) is only Able to penetrate 0.5 meters of water depth. The method developed by Jupp (1988) has been used to study the bathymetry estimation of SPOT satellite imagery (Selamat and Nababan, 2009), FORMOSAT (Kholil *et al.*, 2007), Landsat and Quickbird (Nurlidiasari, 2004). The coefficient of determination (R^2) is used to give a more detailed picture of the ability of channel 1,2 and 3 of Quickbird imagery in explaining variations in water depth (Siregar *et al.*, 2010).

The maximum depth that can be detected by satellite imagery is a function of wavelength and brightness waters. On clear water condition, 490 nm spectral channel can detect up to 30 m depth. For the same water condition, channels with a spectrum of 430 to 580 nm and 400 to 610 are capable to detect up to 20 m and 10 m depth respectively. This spectral variation per depth is the basis of remote sensing system (visible light) to detect bottom waters objects and bathymetric (IOCCG, 2000, in Siregar and Slamet, 2010). Multispectral sensor, especially green and blue band, can penetrate up to 20 meters below the sea surface in a clear water condition (Sutanto, 1992).

Depth information is one very important aspect for marine resource assessment activities, either depth in deep water and shallow water. In general, the depth information provided only to the area or water location which the ship is able to passed. For shallow water often, not be measuredso that the distribution point information to the shallow water depth is very limited. Under these conditions the satellite image was instrumental in providing information about the depth of the shallow water. The use of remote sensing images in coastal and shallow water bathymetric mapping is considerably cost effective (Mumby *et al.*, 1999).

One method for the extraction of bathymetry by using remote sensing imagery is a rotation transformation method developed by Hengel and Spitzer (1991). The method has been carried out by Setiawan *et al.*, (2013) in the Menjangan Island waters of Bali and produced an inadequate correlation which was R2 = 0,62. The data used in that study were TOA imagery of Landsat ETM+. This study used two different types of data from the Landsat 8 which were the surface reflectance image and TOA imagery of Landsat 8. The aim of this study was to determine whether there were differences in the correlation result between the depth information of both type image data used.

The research was conducted in Panggang Island Water of Seribu Island Jakarta. Panggang Island water is part of the Taman Nasional Kepulauan Seribu, located in Kabupaten Kepulauan Seribu DKI Jakarta. This location was chosen with consideration; that the region has clear waters for the conservation of marine resources, and the waters are relatively calm, so that sunlight can penetrate the water to a maximum depth. This paper is development of the previous paper with the title "Study of Bathymetry Extraction Information Using Landsat 8 Data" published in proceedings of the Asian Conference of Remote Sensing (ACRS) (2015).

2 MATERIALS AND METHODOLOGY

2.1 Research Location

The research location coordinates in the Rally of the Thousand Island, Jakarta bake with boundary between 5 ° 44 '02.47 "- 5 ° 45' 00.85" N and 106 ° 35'03,78 "- 106 ° 36 '29, 60 "E (Figure 2-1). Panggang Island of Thousand Island, Jakarta is close to Pramuka Island, which is the administrative center of the Tousand Islands. Data used in this research were Landsat 8 acquired

Figure 2-1: Reaserach Location (Source: Google Earth)

2.2 Data

The research method started with the data collection. The data used in this study consisted of two types of data Landsat satellite image 8. Both types of data are the data surface reflectance data TOA of the Landsat 8. For TOA of data from Landsat imagery conducted radiometric process, this converts the digital number into reflectance values. Atmospheric correction of an image is a path radiant removal operation of the image.

Atmospheric correction was done on TOA data of Landsat 8 using equation (2-1) and (2-2) which provided by USGS (USGS, 2015) as below. (http://landsat.usgs. gov/ Landsat8_Using_Product.php)

$$\rho\lambda' = M_\rho Q_{cal} + A_\rho \qquad (2\text{-}1)$$

Where:

$\rho\lambda'$ = Reflectance value before sun angle correction

$M\rho$ = REFLECTANCE_MULT_BAND_x, from each band

on 12 August 2014.

$A\rho$ = REFLECTANCE_ADD_BAND_x, from each band

$Qcal$ = Digital Number from each band

$$\rho\lambda = \frac{\rho\lambda'}{\cos(\theta_{SZ})} = \frac{\rho\lambda'}{\sin(\theta_{SE})} \qquad (2\text{-}2)$$

Where:

$\rho\lambda$ =Reflectance value after sun angle correction

$\rho\lambda$ =Reflectance value before sun angle correction

θSE =Sun elevation angle

θSZ =Zenit angle (θSZ = 90° - θSE)

Atmospheric correction was done using Dark Pixels method by reducing the value of each band with an average value of each band then divided by 2 times the standard deviation (Green *et al.*, 2000). The average value and standard deviation of each band can be obtained from a representative pixel values of the sea waters over 30 regions as a data standard statistical calculations. The atmospheric correction method Pixels Dark was done using equation (2-3).

$$Xi\,(kor) = (Xi - Xi\_rata) \,/\, 2\,Sd \qquad (2\text{-}3)$$
$$\text{For } i = 2, 3, 4 \text{ and } 5$$

Where:

Xi (kor) = Value Band i after atmospheric correction

Xi = Value Band i before atmospheric correction

Xi_rata = Average value of band i

Sd = Standard deviation of band i

Determination of the angles r, angles s, and the Depth Index were done using a rotation transformation equation algorithm Van Hengel and Spitzer (1991). The magnitude of the r and s angle were used to determine the value of the index of depth using equation (2-8).

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

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

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

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

Where:

Var X1 = Variance of 30 data of band 2
Var X2 = Variance of 30 data of band 3
Var X3 = Variance of 30 data of band 4
Cov X1X2 = Covariance of 30 data of band 2 and band 3
Cov X1X3 = Covariance of 30 data of band 2 and band 4

$$Y1 = (\mathrm{Cos}(r) \times \mathrm{Sin}(s) \times X1) + (\mathrm{Sin}(r) \times \mathrm{Cos}(s) \times X2) + (\mathrm{Sin}(s) \times X3) \quad (2\text{-}8)$$

Where:

Y1 = Depth Index
X1 = Reflectance value of band 2
X2 = Reflectance value of band 3
X3 = Reflectance value of band 4

The flowchart of this study can be seen in Figure 2-2.

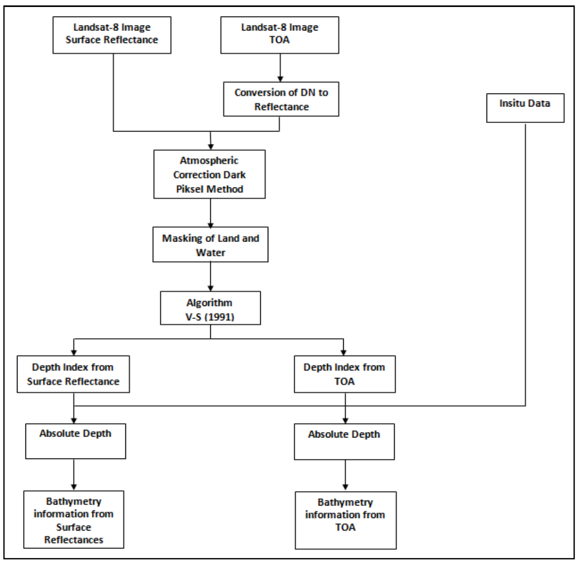


Figure 2-2: Research flowchart

The next step was land and water object separation using a band ratio of band 5 and band 3. Band 5 or NIR band of Landsat imagery has high absorption of water, while band 3 or green band has large reflectivity of the water object. The separation was performed as this research was focused on water object, so that land object was not included in the image processing.

V-S (1991) rotation transformation algorithm was used to determine the depth index calculation. Furthermore, the depth index was then used to determine the absolute depth using a regression equation. The regression equation was developed from a depth data of field survey (in situ data) with an index of depth.

3 RESULT AND DISCUSSION

This research used 4 bands of both reflectance types of Landsat 8 imagery. The four bands were band 2, band 3, band 4, and band 5 with spatial resolution of 30 meters. Data processing was started with radiometric correction. Radiometric correction was performed only for TOA data of Landsat 8. Radiometric correction is a process of converting data from digital number into reflectance value. The atmospheric correction process is then performed for both types of reflectance data.

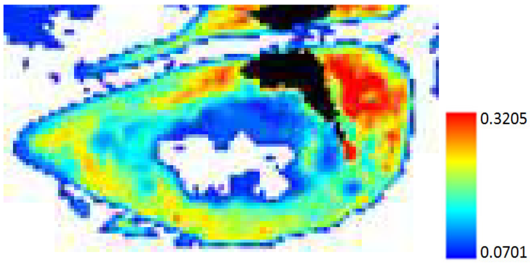
The process to separate land and water objects on Landsat 8 image data was done after atmospheric correction. The separation process of water and ground objects was done using the ratio between the spectral values of band 5 and spectral value of bands 3. The band ratio method was chosen since band 5 has a high absorption of water object while band 3 has high reflectivity over water object.

V-S (1991) rotation transformation algorithm is the development of algorithms that have been popularized by Lyzenga

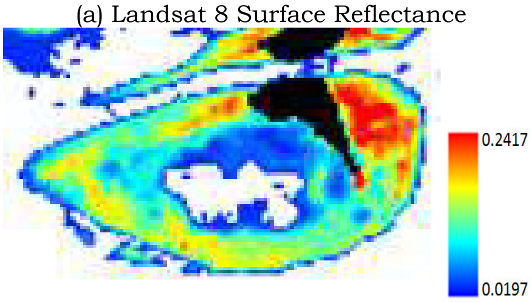
(1981). This algorithm generates an index value namely the depth value relative. The bands used in this algorithm were band 2, band 3 and band 4 since those three bands have the best spectral responses for aquatic objects (Setiawan, 2013).

The algorithm process derived the depth index from 30 randomized points over water areas of Landsat 8 image which visually have homogeneous appearance. The concept of region determination such as water column correction carried by Lyzenga and the use of 30 data were aimed to fullfil minimum standard statistical processing. The next calculation is determination of angle r and s values.

By using equation (4) and (5) above it resulted rotation angle parameter values r and s were respectively 70.22097° and 70.86098° for surface reflectance data and 69.8070191° and 70.0193391° for TOA reflectance data. The rotation angle of parameters r and s were used to calculate depth index values using the equation (8) for both data. Depth index generated from the surface reflectance data produced values between 0.0701 to 0.3205, while for TOA reflectance data produced values between 0.0197 to 0.2417 (Figure 3-1).



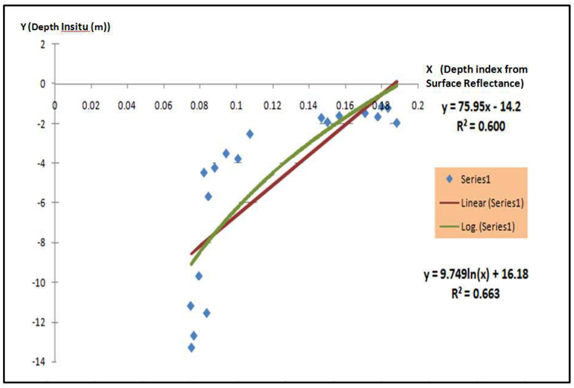
(a) Landsat 8 Surface Reflectance



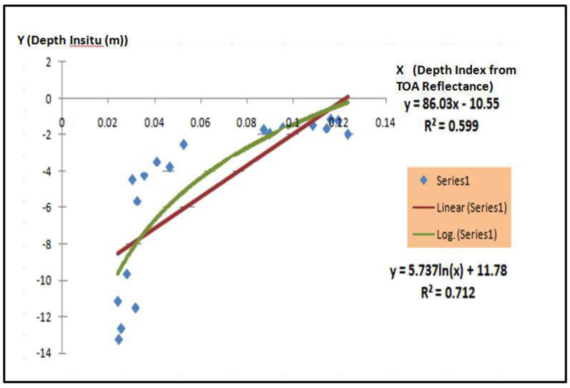
(b) Landsat 8 TOA Reflectance
Figure 3-1: Depth Index Distribution

As seen from Figure 3-1, the depth index distribution resulted from both data types was relatively the same. Scope depth distribution index value of both data types does not differ significantly, i.e. 0.2504 for surface reflectance data and 0.222 for TOA data.

From the above logarithmic regression model equations, then we generated the absolute depth of surface reflectance and of TOA reflectance from Landsat 8. Absolute depth extracted from Landsat 8 surface reflectance could generate water depth up to 10m and up to 5m height information. Meanwhile TOA data of Landsat could generate water depth up to 10m and height information up to 3.5 m. The results of absolute depth extraction of both data types are shown in Figure 3-3.

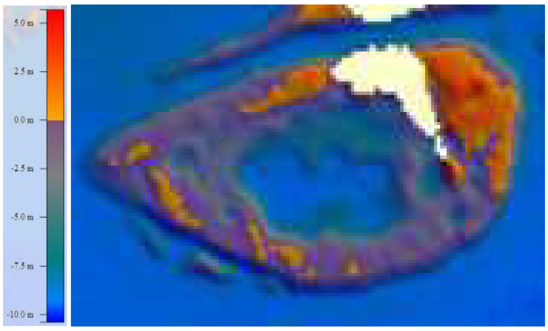


(a) Landsat 8 Surface Reflectance

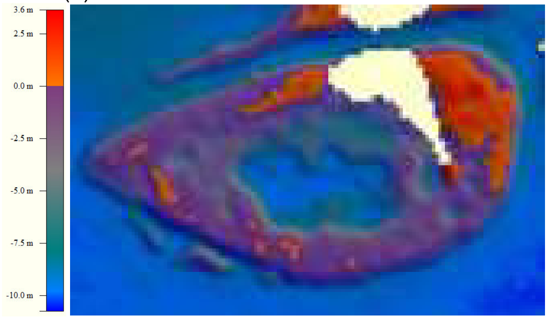


(b) Landsat 8 TOA Reflectance

Figure 3-2: The regression equation



(a) Derived from Surface Reflectance



(b) Derived from TOA Reflectance

Figure 3-3: Absolute Depth from Landsat 8

Atmospheric correction of Landsat 8 data greatly affected the extraction of bathymetry information, because the atmospheric correction affects the distribution of band values of Landsat-8 particularly band 2, band 3, band 4, and band 5. The four band values are taken into account in the correction since atmosphere greatly affects the reflectance information recorded by the satellite sensor.

The result of depth index extracted from surface reflectance and TOA reflectance using algorithm rotation transformation V-S (1991) has shown depth index values of similar range. The difference of depth index values extracted from both data types was small and equal to 0.0284, so visual appearances of resulted imageries were likely the same. From these results it has shown that surface reflectance data and TOA reflectance data of Landsat 8 have generated similar spectral distribution values.

Regression model used to obtain absolute depth index from calculated depth index and in-situ depth data was the logarithmic. In this research, logarithmic model could result better correlation values compared with linear models. In addition, the distribution of 19 plots of field data also tends to be logarithmic curve (Figure 3-2). Those results were then the basis for selecting logarithmic model in determination of absolute depth. Correlation values of logarithmic model for surface reflectance data of Landsat 8 have R^2=0.663 while for TOA has a correlation value or R^2=0.712. Both image data have resulted correlation values relatively better than the results of previous studies in Bali Menjangan Island waters which was 0.62 (Setiawan, 2013).

Results of absolute depth extracted from surface reflectance data and TOA data of Landsat 8 using logarithmic models could generate absolute depth value with the same range for the water depth of 10 m. The extraction of absolute depth in this study was better than previous study by Setiawan *et al.* (2013), which was only able to extract 7.5 m of depth in Menjangan Island waters of Bali. However, the absolute depth extraction in this study could only produced up to 5 m height information from surface reflectance data of Landsat 8 and up to 3.5 m from TOA reflectance data.

Siregar *et al.*, (2010) conducted a study of the extraction of bathymetry in Panggang Island using the algorithm of Jupp (1988) and Quickbird data. Bathymetry extraction in Panggang Island using these methods produces variation of up to 10 meter depth.

The importance of absolute height extraction was due to the waters condition in the study area is very shallow and clear so the reflection of objects at the waters bottom dominated by sand is high enough. However this research did not take tidal information into account in the use of in-situ depth data. Therefore, we suggested to include additional information on tides and in-situ depth data to obtain better results, especially in the area of height extraction.

4 CONCLUSION

Extraction of absolute depth information obtained from Landsat 8 surface reflectance image and of TOA image using logarithmic model has produced correlation values of R^2=0.663 and R^2=0.712 respectively. The result of the correlation value showed an improvement compared with previous research by Setiawan (2013) which was R^2=0.62. The correlation results have shown the consistency of Landsat 8 in producing bathymetric information. The result of height information from absolute depth extraction indicated the need of additional information related to in-situ water depth data.

ACKNOWLEDGEMENT

This research was supported and facilitated by Remote Sensing Applications Center, Indonesian National Institute of Aeronautics and Space (LAPAN).

REFERENCES

Green EP, Mumby PJ, Edward AJ, Clark CD, (2000), Remote sensing handbook for tropical coastal management: UNESCO.

Jupp DLB, (1988), Background and Extensions to Depth of Penetration (DOP) Mapping in Shallow Coastal Waters, Proceedings of the Symposium on Remote Sensing of the Coastal Zone. Gold Coast. Queensland. IV.2.1 – IV.2.19.

Kaimaris D., Patias P., Stylianidis E., (2012), Evaluation of Methodologies for the Determination of Bathymetry Using Worldview-2 Imagery: A Case Study at Lake Pramoritsa, Greece. Appl Rem Sens J, ISSN 2146 0922.

Kanno A., Koibuchi Y., Isobe M., (2011), Statistical Combination Of Spatial Interpolation And Multispectral Remote Sensing For Shallow Water Bathymetry. IEEE Geoscience And Remote Sensing Letters 8(1):64-67.

Kholil M., Sukojo BM, Wahyudi Y., Cahyono AB, (2007), Pembuatan Peta Batimetri Menggunakan Citra Satelit Formosat 2 di Kepulauan Seribu. Proceeding Geo-Marine Research Forum, 187-201.

Lyzenga DR, (1981), Remote Sensing Of Bottom Reflectance and Water Attenuation Parameter in Shallow Water Using Aircraft and Landsat Data, International Journal of Remote Sensing 2:71-82.

Mumby PJ, Harborne AR, (1999), Development Of A System- Atic Classification Scheme Of Marine Habitats To Facilitate Regional Management and Mapping Of Caribbean Coral Reefs. Biological Conservation 88: 155–163.

Nurlidiasri M., (2004), The application of Quickbird and Multi temporal Landsat TM data for Coral Reef Habitat Mapping. Case Study: Derawan Island, East Kalimantan, Indonesia. Thesis. ITC, Netherlands.

Selamat MB, Nababan B., (2009), Bathymetric Mapping Using SPOT Satellite of Pandangan Island Waters in The Makassar Strait. Jurnal Kelautan Nasional, 2.

Setiawan KT, (2013), Study Of Bathymetry Map Using Landsat Etm+ Data - A Case Study At Menjangan Island, Bali, Postgraduate Thesis. Udayana University.

Siregar VP, Selamat MB, (2009), Interpolator In Bathymetric Map Contouring. E-Jurnal Ilmu dan Teknologi Kelautan Tropis 1(1): 39-47.

Siregar VP, Selamat MB, (2010), Evaluasi Citra Quickbird untuk Pemetaan Batimetri Gobah dengan Menggunakan Data Perum: Studi Kasus Gobah Karang Lebar dan Pulau Panggang, Jurnal Ilmu Kelautan 1: 99 – 109. ISSN 0853 – 7291.

Stumpf, Richard P., Holderied K., Sinclair M., (2003), Determination Of Water Depth With High-Resolution Satellite Imagery Over Variable Bottom Types Limnol. Oceanogr., 48:547-556.

Sutanto, (1992), Penginderaan Jauh Jilid 2. Gadjah Mada Press, Yogyakarta.

USGS, (2015), http://landsat.usgs.gov/ Landsat8_ Using_Product.php. Retrieved 19 June 2015.

Van Hengel W., Spitzer D., (1991), Multi-temporal Water Depth Mapping by Means of Landsat TM. International Journal of Remote Sensing 12:703-712.