THE EFFECT OF DIFFERENT ATMOSPHERIC CORRECTIONS ON BATHYMETRY EXTRACTION USING LANDSAT 8 SATELLITE IMAGERY

Kuncoro Teguh Setiawan*), Yennie Marini, Johannes Manalu, and Syarif Budhiman
Remote Sensing Applications Center, LAPAN
***)e-mail: kunteguhs@gmail.com**

Received: 30 January 2015; Revised: 6 March 2015; Approved: 31 March 2015

Abstract. Remote sensing technology can be used to obtain information bathymetry. Bathymetric information plays an important role for fisheries, hydrographic and navigation safety. Bathymetric information derived from remote sensing data is highly dependent on the quality of satellite data use and processing. One of the processing to be done is the atmospheric correction process. The data used in this study is Landsat 8 image obtained on June 19, 2013. The purpose of this study was to determine the effect of different atmospheric correction on bathymetric information extraction from Landsat satellite image data 8. The atmospheric correction methods applied were the minimum radiant, Dark Pixels and ATCOR. Bathymetry extraction result of Landsat 8 uses a third method of atmospheric correction is difficult to distinguish which one is best. The calculation of the difference extraction results was determined from regression models and correlation coefficient value calculation error is generated.
Keywords: *atmospheric correction, bathymetry, Landsat 8 imagery*

1 INTRODUCTION

Remote sensing technology has been widely applied because of the effectiveness and efficiency, as well as its significant utilization in compiling and revising the resources maps. It is also useful to support planning and management of a resource (Butler, 1988; Lillesand and Kiefer, 1994; Danoedoro, 1996). Bathymetry is the measurement of the depth from the sea surface to the seabed. Nowadays, remote sensing technology provides an opportunity for bathymetric mapping effectively and efficiently. It could improve shallow water mapping to be a rapid and low cost mapping, while increasing the spatial resolution could also provide a wide range of applications and methods for underwater mapping.

LANDSAT imagery has spatial resolution of 30 meters and equipped with visible channels that required in the extraction of bathymetry information. 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 since band 2 (blue channel) has the ability to penetrate up to 25 meters of the 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 process of bathymetric extraction from remote sensing data should be started by atmospheric correction. Atmospheric correction is required to obtain a consistent value or appearance of each object. Radiation through the atmosphere can produce considerable attenuation resulting in different reflectance measurements of the surface reflectance actual object studied. Removal of atmospheric effects is important, and considerable research effort is passed on this issue.

The techniques of atmospheric scattering effect removal are performed to remove the effects of scattering by estimating the radiation in the atmosphere (path radiance). This method is usually used before band ratio on one image, but usually not to be used for image to image comparison. The underlying reason of band ratio was that the recorded radian can be adjusted until the radian was proportional approach to the reflection ratio of the object's surface. There are three main methods applied to eliminate the atmospheric scattering effects in this study which were Jensen (1986), Dark Pixel and ATCOR methods. The focus of this research was to analyze the differences that occurred in extraction of bathymetry information generated due to the different atmospheric correction applied. Data correction reduces/ eliminates position errors and differences spectral sensor and the object due to differences in recording time, so that the results more accurate and consistent (Trisakti, *et.al.*, 2012).

The research was conducted in Menjangan Island waters. Menjangan Island is part of the West Bali National Park, located in Labuan Lalang Gerokgak village, Buleleng district, Bali Province. This location was chosen by consideration that the region has clear waters for the conservation of marine resources, and the waters is relatively calm so that sunlight can penetrate the water to a maximum depth (Sidabutar, 2000). This paper is a development of the previous paper published in proceedings of 12th Biennial Conference of Pan Ocean Remote Sensing Conference (PORSEC) 2014.

2. MATERIALS AND METHODOLOGY

The research location is in Menjangan Island, Bali with boundary coordinate between 114 ° 29 '00 "- 114 ° 32' 00" East Longitude and 08 ° 05 '00' - 08 ° 06 '30 "South latitude (Figure 2-1). Data used in this research were LANDSAT 8 acquired on 19 June 2013, tidal data on October 2006 – August 2012 from BIG Celukan Bawang Station, and also depth data from field survey on 21 May 2013.

The research method started with data collection, then atmospheric correction process with three methods, which Minimum Radiant (Jensen, 1986), Dark Pixel, and ATCOR, and continued by the radiometric process. Atmospheric correction of an image is the process of removing the atmospheric effects on the image so the image could provide accurate information. Jensen atmospheric correction method was done by reducing the value of each band with a minimum value of each band. The minimum value of each band was considered as a bias value of each band. The equation for atmospheric correction using Jensen's method using equation (2-1).

$$Xi\ (cor) = (Xi) - (Min\ Xi) \quad \text{for } i = 2, 3, 4 \text{ dan } 5 \qquad (2\text{-}1)$$

Where:

Xi(cor) : DN of Band i after atmospheric correction

Xi : DN of Band i before atmospheric correction
Min : Minimum value of band i

Dark Pixel Atmospheric correction method was done by reducing digital number of each band with mean of each band and divided by 2 times the standard deviation (equation 2). Mean and standard deviation of each band generated by representative pixel values that are made from the 30 regions around the sea.

$$X_i(cor) = (X_i - X_{i\_mean})/2\,SD \quad \text{for } i = 2, 3, 4 \text{ and } 5 \qquad (2\text{-}2)$$

Where :
Xi (cor) : Band i value after atmospheric correction
Xi : Band i value before atmospheric correction
Xi_mean : Mean of Band i
SD : Standard Deviation of Band i

Atmospheric correction by ATCOR method was done automatically by the ATCOR software. ATCOR is abbreviation for Atmospheric/Topographic Correction, there are two ATCOR models available, one for satellite imagery (ATCOR 2/3), the other one for airborne imagery (ATCOR-4). In this study we used ATCOR-3 software.

adiometric process is the conversion process from digital number into reflectance values. Reflectance value of each bands was calculated by using the equation (2-3) and (2-4). The flowchart of this study can be seen in Figure 2-2.

$$\rho_p = \frac{\pi \times L\lambda \times d^2}{ESUN\lambda \times \cos\theta_s} \qquad (2\text{-}3)$$

$$L\lambda = \times (DN-1) + L\,Min\lambda \qquad (2\text{-}4)$$

Where:

ρp : Reflectance (value between 0 and 1)
π : Phi (3.142)
Lλ : Radians (µm)
d : Distance between sun and earth (m)
ESUNλ : Iradians (watt)
θ_s : Zenith Angle (°)
L Maxλ : Maximum radians on wave length λ (µm)
L Minλ : Minimum radians on wave length λ (µm)
DN : Digital Number (0 – 255)

Furthermore did the land and water objects separation using band ratio of band 5 and band 3. Band 5 is the SWIR band on LANDSAT imagery which has a high absorption of water, while band 3 is the green band which has a large reflectivity of the water object. The separation was performed because this research focused on the water object therefore land object not included in the processing.

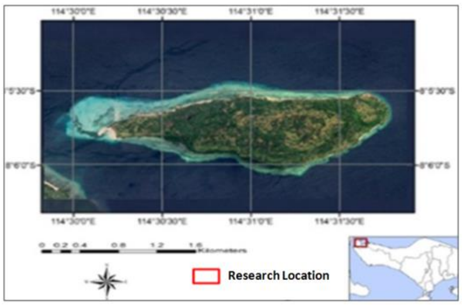

Figure 2-1: Research location

Depth index was determined by Van Hangel and Spitzer (V-S), 1991 algorithms (equation 2-5). V-S (1991) rotation transformation algorithm is the development of Lyzenga (1978, 1981, 1985) algorithms. V-S (1991) rotation transformation algorithm was performed to generate a depth index which is the relative depth information. Depth Value of in situ data was used to create a regression model between the depth index and the in situ depth. The regression equation used to generate absolute depth (Setiawan, 2013).

$$Y1 = (\cos(r) \times \sin(s) \times X1) + (\sin(r) \times \cos(s) \times X2) + (\sin(s) \times X3) \qquad (2\text{-}5)$$

Where:
Y1 : Depth Index
X1 : Reflectance Value of band 2
X2 : Reflectance Value of band 3
X3 : Reflectance Value of band 4

Constanta r and s is the rotation angle that was used to calculate the depth index of the V-S (1991) rotation transformation algorithm, r and s angle was determined by using equation (2-6) and (2-7).

$$r = \arctan\left(Ur + \sqrt{Ur^2 + 1} \right) \quad (2\text{-}6)$$

$$s = \arctan\left(Us + \sqrt{Us^2 + 1} \right) \quad (2\text{-}7)$$

Where:

$$Ur = \frac{Varx2 + Varx1}{2\ Covx1x2} \quad (2\text{-}8)$$

$$Us = \frac{Varx3 + Varx1}{2\ Covx1x3} \quad (2\text{-}9)$$

Where:
Var X1 : Variance of band 2
Var X2 : Variance of band 3
Var X3 : Variance of band 4
Cov X1X2 : Covariance of band 2 and 3
Cov X1X3 : Covariance of band 2 and 4

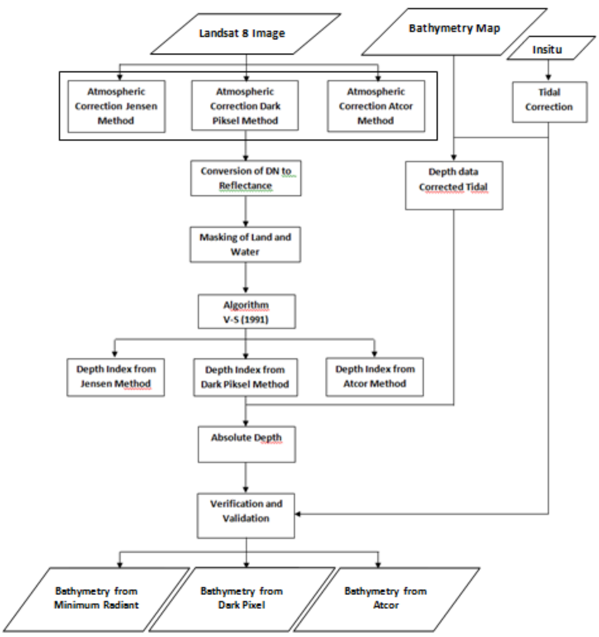

Figure 2-2: Research flowchart

3 RESULTS AND DISCUSSION

3.1 Minimum Radiant

Extraction of bathymetry information was done after atmospheric correction process. Atmospheric correction of an image is the process of removing the atmospheric effects on the image so the image could provide accurate information.

Subsequent atmospheric correction was done then r and s was determined, rotation angle r and s respectively were 69.44609° and 74.47514°. Depth index Image based on r and s were generated is shown in Figure 3-1.

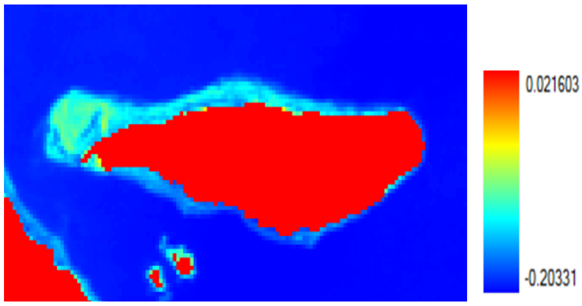

Figure 3-1: Depth Index Image after Atmospheric Corrected by Dark Pixel Method

Absolute index (Y) generated by using regression equation formed from image depth index (X) and in situ depth. Regression equation used was Y = 75,50X + 7,335 with R^2 was 0.839 (Figure 3-2). The unit of depth index is meter. Figure 3-3 shown the absolute depth image of LANDSAT 8 atmospheric corrected by Jensen (1986) and had resulting absolute depth interval of 0 - 7.5 meters.

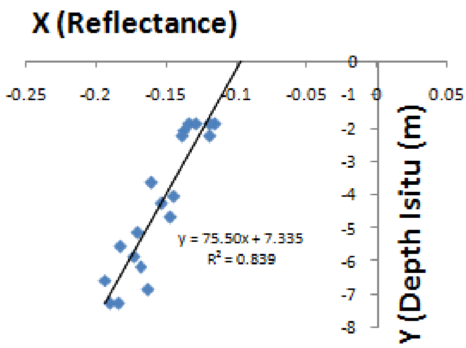

Figure 3-2: Graphic absolute depth

Accuracy testing was done by using the in situ data conducted on 21 May 2013. The error was 34.09% (Table 3-1).

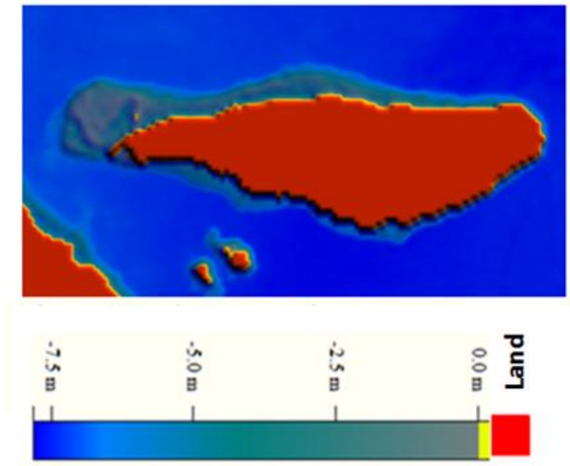

Figure 3-3: Absolute Depth Image Corrected by Jensen (1986) Method

Table 3-1. Table of Error

Insitu (m)	Jansen (m)	DarkPixel (m)	Atcor (m)	Jensen Error	Jensen Persent	DarkPixel Error	DarkPixel Persent	Atcor Error	Atcor Persent
-6,76	-6,659	-6,295	-6,203	0,0149	1,49	0,0688	6,88	0,0824	8,24
-7,26	-7,715	-7,601	-7,3353	0,0627	6,27	0,047	4,7	0,0128	1,28
-9,26	-6,16	-5,941	-6,112	0,3348	33,48	0,3584	35,84	0,3399	33,99
-6,26	-5,984	-5,753	-5,494	0,0441	4,41	0,081	8,1	0,1224	12,24
-4,86	-4,235	-6,129	-5,994	0,1286	12,86	0,2611	26,11	0,2333	23,33
-12,26	-7,012	-7,004	-7,154	0,4281	42,81	0,4287	42,87	0,4165	41,65
-1,76	-4,054	-3,707	-3,687	1,3034	130,34	1,1063	110,63	1,0949	109,49
-5.26	-2,944	-2,657	-2,514	0,4404	44,03	0,4949	49,49	0,5221	52,21
-1,96	-2,571	-2,491	-2426	0,3117	31,17	0,2709	27,09	0,2378	23,78
	Average of Error			0,3409	34,09	0,3463	34,63	0,3402	34,02

3.2 Dark Pixel Method

Landsat 8 was corrected atmospheric by dark pixels methods produced r and s respectively were 69.40984° and 73.46504°. Depth index Image shown in Figure 3-4.

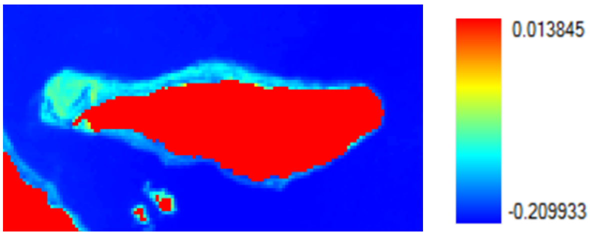

Figure 3-4: Depth Index Image after corrected atmospheric by dark pixel method

Absolute depth generated by regression equation Y = 80,06X + 8,994 with R^2 = 0,874, which was shown in Figure 3-5.

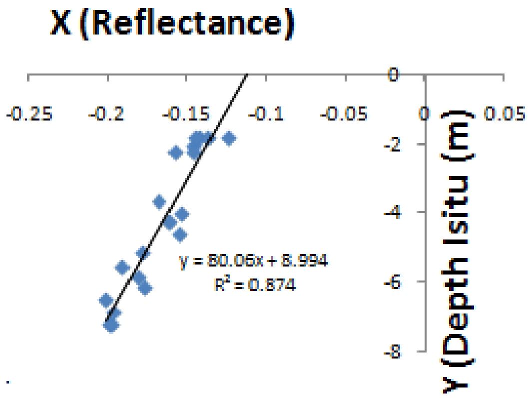

Figure 3-5: Graphic absolute depth

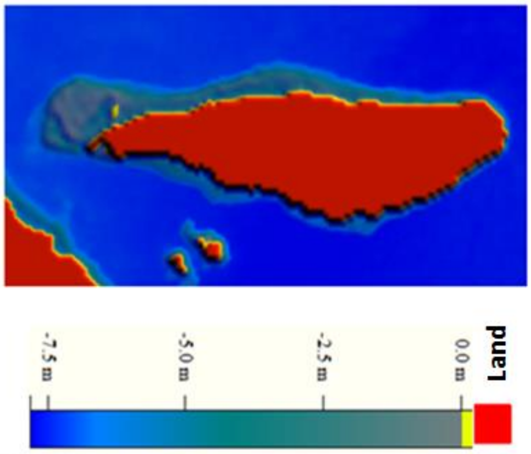

Figure 3-6: Absolute Depth Image After Corrected Atmospheric by Dark Pixel Method

Figure 3-6 shown the absolute depth image of LANDSAT 8 atmospheric corrected by dark pixel method, it also had absolute depth interval of 0 - 7.5 meters, with the error 36.63% (Table 3-1).

3.3 ATCOR Method

Bathymetric extracted after using corrected atmospheric by ATCOR-3 produced rotation angle r and s respectively were 69.06432° and

72.45264°. The depth index result is shown in Figure 3-7.

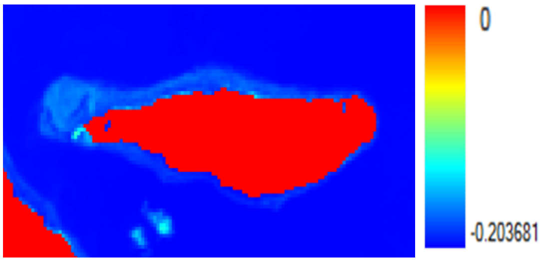

Figure 3-7: Depth Index after Corrected Atmospheric by ATCOR Method

Absolute depth value (Y) of the depth index results using atmospheric correction by ATCOR method obtained a regression equation Y = 204,6X + 33.99 with R^2 = 0.715 which is shown in Figure 3-8.

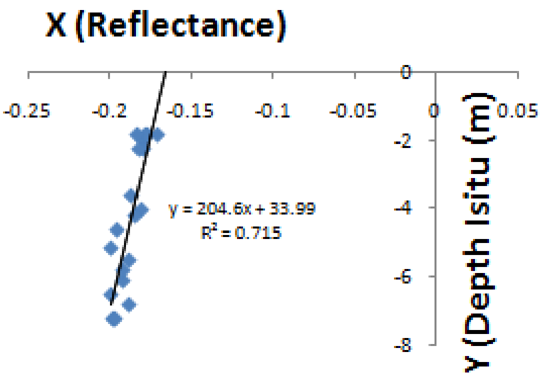

Figure 3-8: Graphic absolute depth

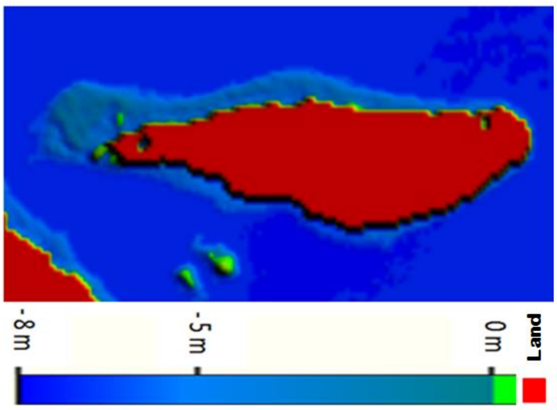

Figure 3-9: Absolute Depth after Corrected Atmospheric by ATCOR Method

Absolute depth of Landsat 8 image result was shown in Figure 3-9 with the interval of absolute depth was 0 – 8 meters. The error between depth in situ and absolute depth from the image by this method was 34.02% (Table 3-1).

Absolute depth of Landsat 8 using V-S (1991) rotation transformation after atmospheric correction process by all three methods produced different depths range. Atmospheric corrections were done on Landsat 8 imagery influenced on the extraction of bathymetry information generated. This was caused by atmospheric correction affected the distribution spectral value of each band of Landsat 8, especially in band 2, band 3 and band 4, that were used in generating the depth index value. Therefore difference of atmospheric correction applied produced different depths index.

Depth index used to generate absolute depth using regression equation was made. Regression equation obtained from the relationship between the depth index with depth in situ that has been corrected tides. All three method obtained different regression model and coefficient correlation as well, but the distribution of absolute depth of Landsat 8 data extraction tend to be similar. Jensen (1986) and Dark Pixel method showed similar distribution of depth that were between 0 – 7.5 meters, while depth interval by ATCOR method was 0 – 8 meters.

Absolute depth on Landsat 8 data atmospheric corrected by ATCOR method gave slightly different result with two other methods. There needs to be a comparison in atmospheric correction by ATCOR methods to see the effectiveness of the method. It can not directly say that the ATCOR method was more effective because the correction was done automatically by the software. When viewed from the coefficient correlation regression models generated seen that the atmospheric correction minimum radiant methods by Jensen (1986) had the greatest correlation coefficient compared with dark pixel and ATCOR atmospheric correction methods although the differences were not significant.

Validation and verification of bathymetry information generated by all three atmospheric correction processes were done for the accuracy of bathymetry information. Error value calculated by using 10 position of depth in situ. Error values were obtained from all three bathymetric information produced different values. However, the difference between the value of the error that occurred on three atmospheric correction methods did not very significant, because the range of 34% error rate. When seen the error accuracy calculation of the results obtained that the bathymetric information extraction using ATCOR atmospheric correction method smaller than the two other methods that was 34.02%.

4 CONCLUSION

Atmospheric correction impact on the extraction of bathymetry information generated from the Landsat-8 data. But the difference of the three atmospheric correction methods above were difficult to differentiate which one was best because very small differences occur views of the correlation coefficient regression models were produced as well as from the calculated error value. Therefore; Jensen (1986), Dark Pixel and ATCOR atmospheric correction methods can be used to extract information bathymetry. To produce bathymetric information extraction with better accuracy, it is suggested to use more field data for the regression model and to calculate the accuracy.

ACKNOWLEDGEMENT

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

REFERENCES

Butler MJA, Mouchot C., Barote V., Blanc LC, (1988), The Application of Remote Sensing Technology to Marine Fisheries. An Introductory Manual. FAO Fisheries Technical Paper No.295. Rome: FAO.129.

Danoedoro P., (1996), Digital Image Processing: Theory and Its Application in the Field of Remote Sensing. Yogyakarta: Fakulty of Geography Gajah Mada University. 254.

Jensen JR, (1986), Introductory Digital Image Processing: A Remote Sensing Perspective. New Jersey: Prentice Hall. 276 p. Jerlov NG, Nielsen ES. 1974. Optical Aspect of Oceanography. London and New York: Academic Press. 494.

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. Quennsland. IV.2.1 – IV.2.19.

Lillesand TM, Kiefer RW, (1994), Remote Sensing and Image Interpretation. Dulbahri.

Lyzenga DR, (1978), Passive Remote Sensing Techniques for Mapping Water depth and Bottom Features. Applied Optics 17:379-383.

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.

Lyzenga DR, (1985), Shallow-water Bathymetry Using Combined Lidar and Passive Multispectral Scanner Data. Int. J. Remote Sens. 6: 115–125.

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

Sidabutar HM, (2000), Coral Reef Mapping Using Satellite Imagery LANDSAT TM in Menjangan Island, Bali Barat. [Thesis]. Bogor: Faculty of Fisheries and Marine Science, Bogor Agricultural University.

Trisakti B., Nugroho G., (2012), Standardization of multi temporal and multi Sensor satellite Data correction (Landsat TM/ ETM+ and Spot - 4). Remote Sensing Journal. LAPAN.

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