DIGITAL IMAGE PROCESSING OF SPOT-4 FOR SHORELINE EXTRACTION IN LAMPUNG BAY

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Abstract. Shoreline is an imaginary line separating land and seawater. The intensification of land used/land cover at Lampung bay causes shoreline change either abrasions or accretions. The objectives of this study were to compare the shoreline extraction based on the digital image processing of SPOT-4 using ratio band of infrared and green band, Normalized Difference Vegetation Index (NDVI), and (band infrared) methods and to analyze shoreline change at Lampung Bay. Those methods applied on both cloudy free and cloudy SPOT-4 images and the result compared with RBI map as reference. The result showed that the best metod for shoreline axtraction was ratio band due to accuracy high and stable eventhough it applied on cloudy image. The shoreline changes at Lampung Bay along 2008 to 2012 caused by accretions. The total area of accretion at Lampung Bay for fours years were 662 Ha with the rates 165 Ha/year. The high of accretion rate caused by reclamation for urban built up, fishponds and mangrove.

Keywords: *Shoreline, SPOT-4 image, Ratio method, NDVI, Single band infrared, Lampung Bay*

1 INTRODUCTION

Indonesia is an archipelagic country; with the shoreline length is around 95,181 km (Mukhtar, 2009). The shoreline length is to the fourth in the world. Indonesian legislation (UU No. 22, 1999), mentioned that shoreline can be used to determine the boundaries, either countries or within the country, for example to determine the boundaries of the province, district and city. Therefore, the technology is needed to cover the entire shoreline in Indonesia with a short time and low cost. The shore is a dynamic area that influenced by natural and human activities. Therefore, continuous updating and monitoring of shoreline change is needed.

Lampung Bay is one of the coastal area in Indonesia which has high activity of urban land use and marine cultivation. There are Bandar Lampung city, port, fishing ground, fishponds, pearl cultivates and so on. Based on spatial planning of Lampung province, there are development of international and regional port and military based in Lampung Bay which are constructing since 2010 (Perda-Lampung, 2010). It is known that land use intensification is increasing the sediment load into water. According Dianpurnama et al (2013) and Triatmodjo (1999), shoreline deformation in Lampung Bay caused by sediment transport process. Lampung Bay coastal area is vulnerable to damage caused by densely populated with rapid physical development or reclamation which affect abrasion and accretion around coastal area (Dianpurnama et al., 2013). Therefore, updating and monitoring of shoreline in Lampung Bay is necessary.

Remote sensing technology can be used to updating monitoring of shorelines information with effective, efficient and sustainable (Ryu, *et al.*, 2002; Pardo-Pascual, *et al.,* 2012 Winarso, *et al.*, 2009, and Arief, *et al.*, 2011). Remote sensing data can cover all of Indonesia until remote area with short time and low cost compared with direct measurement. Studies for the shoreline extraction using digital processing of satellite images have been widely applied. One of the study was conducted by Ryu, et al. (2002), which extracted the shoreline from Landsat TM, ETM + and EOS-Terra ASTER imagery based on single band (infrared band) and NDVI. Maiti and Bhattacherya (2009) also used NIR bands of Landsat MSS, Landsat TM, Landsat ETM+ and ASTER to study shorelines change. Additionally, Winarso, *et al.*, (2009) also conducted the shoreline extraction based on the ratio of NIR to green band on Landsat ETM + imagery. Furthermore, Bismoko, *et. Al.*, (2012) and Dianpurnama *et al.*, (2013) have studied the analysis of shoreline changes with sediment cell identification based on Landsat image to highlight the patterns of sediment distribution.

The development of remote sensing technology provided some new satellite imagery such as SPOT-4 (Satellite Pour I 'Observation de la Terre-4). SPOT-4 satellite was multispectral remote sensing satellite which launced in March 1998. SPOT-4 is the fourth generation of SPOT satellites which have 20-meter spatial resolution and a four-channel wavelength.

Base on the previous studied and characteristics of SPOT-4 then shoreline information at Lampung Bay can also be extracted using SPOT-4 images. Therefore, the first objective of this study was to compare shoreline extraction methods using infrared band, Normalized Difference Vegetation Index (NDVI) and ratio of infrared and green band. The second objective of this study was to analyzed the abrasion and accretion based on SPOT-4 images.

2 MATERIALS AND METHOD

The study was conducted in Lampung Bay, Indonesian with latitude 5º25'57.74"- 5º38'12.67" South and longitude 105º8'45.26" - 105º19'40.05" East. While the location for comparison the best shoreline extraction methods test is Klara Beach, due to there was not significant changes between the reference data with SPOT 4 images at Klara Beach. So, it can be assumed that the error occurs only due to digital processing of the image.

This study used a cloud-free of SPOT 4 image (time of acquisition June 16, 2012) and a cloudy SPOT 4 image (time of acquisition December 20, 2012). Figure 2-1 shows the study area and data used. Geographical Map of Indonesia (Peta Rupa Bumi Indonesia/RBI) for Lampung Province 2008 was used as reference for existing shoreline.

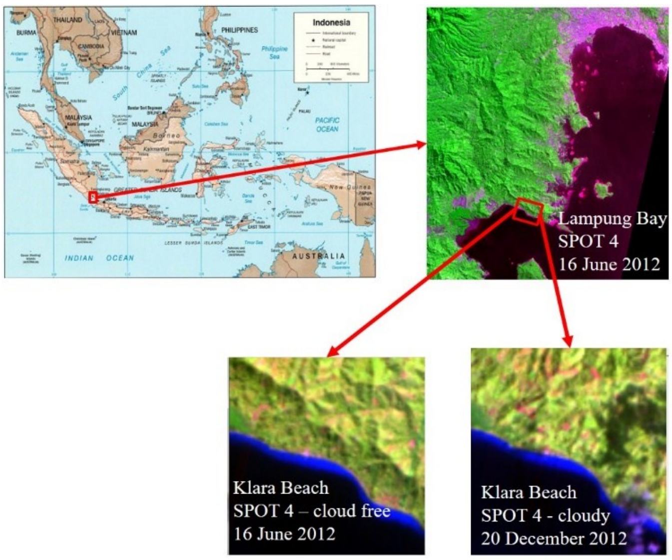

Figure 2-1: Study area and data used

Tabel 2-1: Specifications of SPOT-4

Orbit	835 km, 98.70, sun-synchronous, 10:30 AM crossing, rotation in 26 days (repeat cycle)
Sensor	Two sensor HRVIR (High Resolution Visible and Infrared)
Swath width	60 km (3000 pixels CCD-array)
Off-track viewing	Available ± 270 across-track
Revisit Time	4-6 day (depend on latitude)
Spectral Band	Band 1 (Green): 0.50 - 0.59 µm Band 2 (Red): 0.52 - 0.68 µm Band 3 (NIR): 0.78 - 0.89 µm Band 4 (SWIR):1.58 - 1.75 µm
Spatial Resolution	10 m (PAN), 20 m (band 1-4)

The specification of SPOT-4 can be seen at Table 2-1. SPOT 4 had the same geometric imaging characteristics with swath of 60 km per instrument and oblique viewing capability of 27° on each side of the local vertical. Compare with previous SPOT satellite, SPOT-4 performance had been increased by adding a new shortwave infrared spectral band (SWIR). SPOT-4 image has four wavelengths which are green band (b1), red band (2), near infrared (NIR) band (3) and SWIR band.

Water bodies will be absorbed at NIR region and beyond (Bakker et al., 2009). Waters reflects the light energy in visible region and a litthe in the NIR region. Turbid water has high reflectance than clear water due back scatter of suspended sediment in waters. Thus b1, b2, b3 can be used for shoreline extraction. Based on SPOT-4 spesifcation.

This study using ER Mapper 7.0 for image processing and Microsoft Excel for statistical analysis. The flowchart of this study described briefly at Figure 2-2. Firstly, all images were geometric and radiometric corrected to reduce some geometric and radiometric errors that occurs when the sensor recorded data. Geometric correction was carried out using orthorectification method to reduce some errors caused by terrains. The atmospheric corrected using dark pixel method was carried out after geometric and radiometric corrected. The unit of images was converted into reflectance of surface to describe reflected value of sunlight which recorded by sensor.

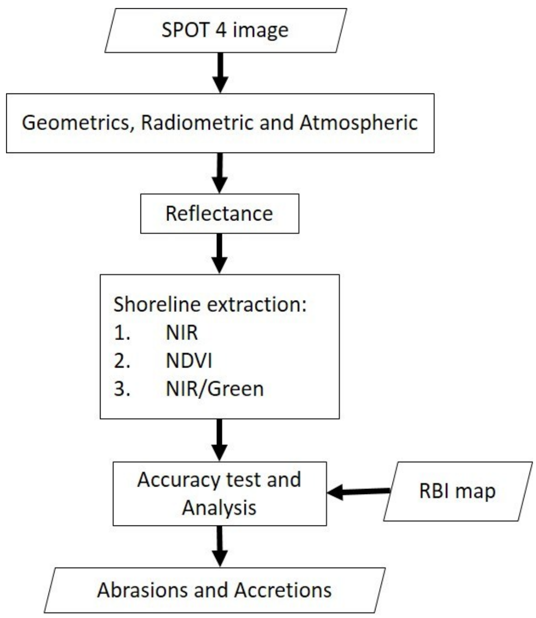

Figure 2-2: Research flow diagram

The shoreline extractions were carried out by using single band of near infrared, NDVI, and ratio of infrared and green band. According Ryu *et al.* (2002) NDVI can reduce the effect of suspended sediment near shoreline. Band ratio using NIR and a visible band can reduce the effect of turbidity to some extent eventhough it is not always reliable under extremely high turbidity conditions.

Based on SPOT-4 specification at Table 1, this study used infrared band (b3) for single method; band 2 and 3 (b2 and b3) for NDVI method, and band 1 and 3 (b1 and b3) for ratio band method. Formula for shoreline extraction on single band method (Ryu *et al.*, 2002) and Maiti and Bhattacherya (2009) as follow:

$$b_3 < t \qquad (2\text{-}1)$$

b_3 is reflectance of near infrared (NIR) band and t is threshold (the boundaries reflectance between land and seawater).

Formula for shoreline extraction using NDVI method (Ryu *et al*, 2002) as follow:

$$NDVI = \frac{b_3 - b_2}{b_3 + b_2} < t \qquad (2\text{-}2)$$

b_3 is reflectance of infrared band, b_2 is reflectance of red band, and t is threshold (the boundaries reflectance between land and seawater. While the formula for shoreline extraction using the ratio method (Winarso, 2009) as follow:

$$\frac{b_3}{b_1} < t \qquad (2\text{-}3)$$

b_3 is reflectance of infrared band, b_1 is reflectance of green band, and t is threshold (the boundaries reflectance between land and seawater.

The accuracy was calculated based on comparing of SPOT-4 cloud free and cloudy images with RBI map. The accuracy test used convolution matrix with Cohen's Kappa coefficient test (Sim and Wrigh, 2005) with formula as follows:

$$k = \frac{P_a - P_e}{1 - P_e} \qquad (2\text{-}4)$$

P_a is a fixed number of pixels, P_b is the number of multiplication percentage of each class and k is the coefficient of kappa Cohen. The result from calculation of Cohen's kappa coefficient is classified into:

- sufficient, if $0.21 \leq k \leq 0.40$
- moderate, if $0.41 \leq k \leq 0.60$
- good, if $0.61 \leq k \leq 0.80$
- very good, if $0.81 \leq k \leq 1$

The best method for shoreline extraction was obtained from raster analysis in ER Mapper and will be used for shoreline extraction at Lampung bay to analyzed the abrasions and the accretion which happen on 2008 till 2012. Because this study used RBI map on 2008 and the SPOT-4 image on 16 June 2012.This study used SPOT-4 image on June 2012 due to reduced atmospheric distortion caused by season.

The abrasions and accretions were obtained from raster analysis in ER Mapper, which some conditions as follow:

- If class of SPOT-4 image was sea waters and class of reference image was sea waters, then the class inditified as sea waters.
- If class of SPOT-4 image was land and class of reference image was land, then the class inditified as land.
- If class of SPOT-4 image was sea waters and class of reference image was land, then the class inditified as abrasion.
- If class of SPOT-4 image was land waters and class of reference image was sea waters, then the class inditified as accretions.

The analysis will identify the abrasion and accretion area at Lampung Bay.

3 RESULTS AND DISCUSSION

Extraction of shoreline digitally means identified water bodies signature which capture by satellite sensor. The spectral signature of water characterized by high absorption at near infrared wavelength range and beyond (Bakker *et al.*, 2009). Because of the absorption property, water bodies as well as features containing water can easily be detected, located and delineated with remote sensing data.

Red Green Blue (RGB) 432 composite of SPOT-4 images which geomterict, radiometoric and atmospheric corrected can be seen in Figure 3-1. This study made attempt with transect line from the land until sea waters to saw the change of reflectance value of earth surface object. This transect were applied on different image condition which was cloud free and cloudy. The result showed that the shoreline can be identified on reflectance value < 0.2 from band 1 and band 3, and <0.1 for band 2 and band 4.

Figure 3-1 showed that each band has specific spectral signature. Band 1, 2 and 3 (b1, b2 and b3) have high reflectance value and more sensitive with object cloud than band 4 (b4). It was showed also that b1 has higher reflectance value than b2. It was same with theory which said that the green wavelength reflects light more than red wavelength for water bodies (Bakker et al., 2009). Furthermore, based on spectral signature between cloud free and cloudy images at Figure 3 can be seen that object cloud can reduce the values of reflectance b1, b2 and b3. Therefore, the utilization of b1, b2 and b3 will give more information regarding shoreline extraction.

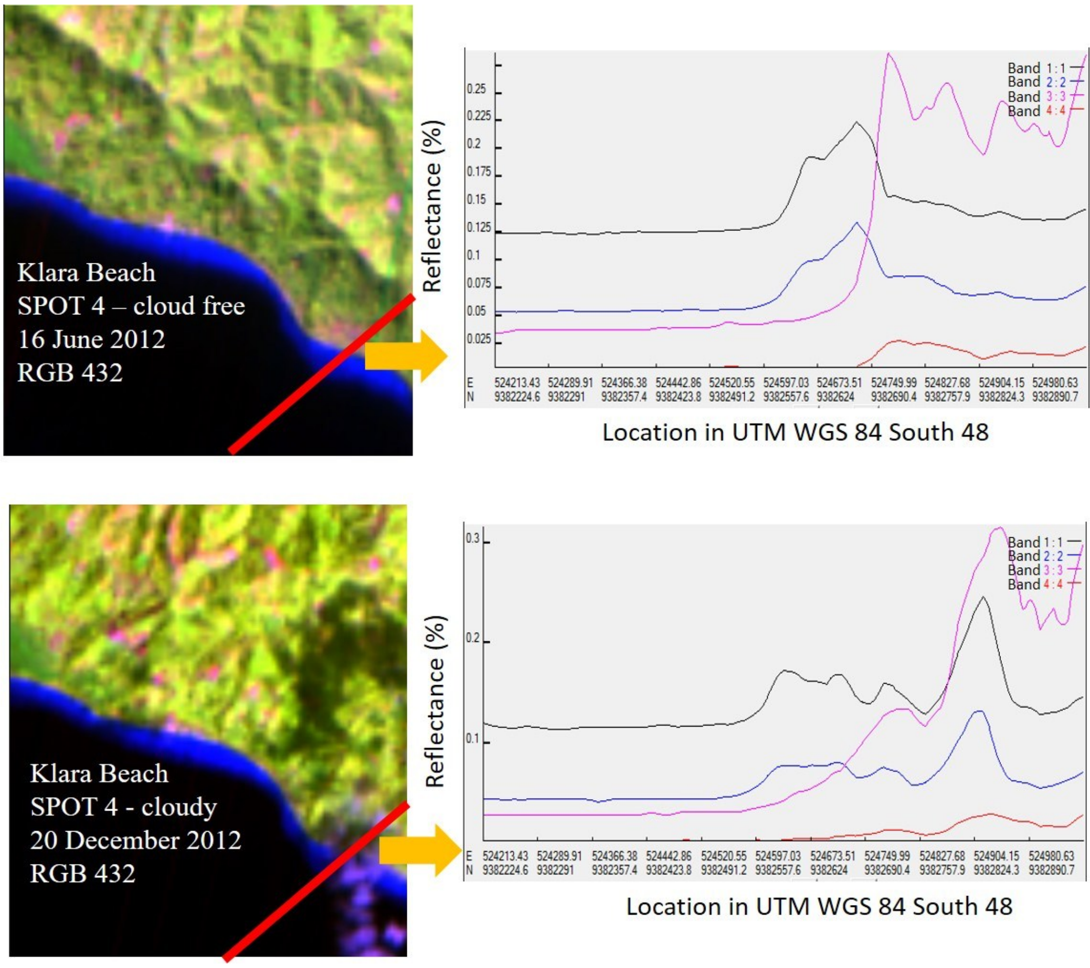

Figure 3-1: RGB 432 and Spectral signature of transect line from band 1, 2, 3 and 4 of SPOT 4 images

Shoreline exctraction test were carried out using three method which describe at equation (1) to (3). Base on Figure 3-1, the t value for equation on (1) both images (cloud free or cloudy) were less then 0.1. The t value for equation (2) on both images were less then 0.01. While the t value for equation (3) on both images were less then 0.5.

Digital image processing results for shoreline extraction from cloud-free SPOT 4 image by using single band, NDVI and ratio band can be seen in Figure 3-2. Figure 3-2 show that all three methods can extract shoreline from cloud-free SPOT 4 image with high accuracy, even there are still some misidentifications occurred if comparing with reference shoreline (Table 3-1). Misidentification happens at the border areas between land and sea water, where land object became sea water objects and vice versa. The accuracy test results showed that kappa coefficient of three methods on cloud free and cloudy image were above 0.9 (Table 3-1). There for it can be categorized that the methods given very good result.

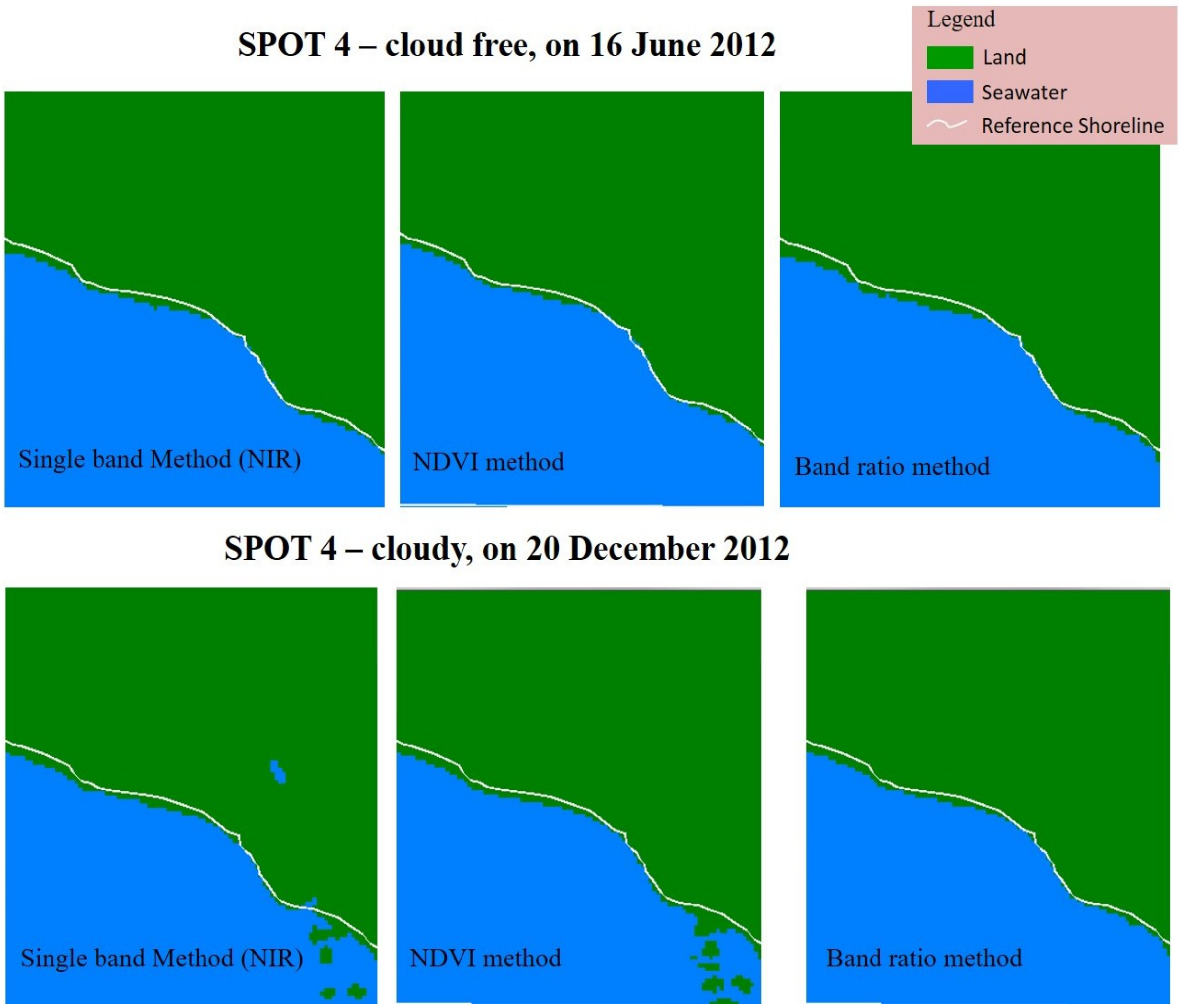

Figure 3-2: Shoreline extraction from three methods on cloud-free and cloudy SPOT 4 images

Table 3-1: Accuracy of the three methods on cloud-free and cloudy SPOT 4 images

Cloud free image, total observations: 10379 pixels			
	Ban ratio (b3/b1)	NDVi ((b3-b2)/(b3+b2))	Single band (b3)
Land to be Sea waters	209	130	157
Sea waters to be Land	0	2	2
Accuracy	97.99%	98.73%	98.47%
Kappa	0.959	0.974	0.969
Cloudy image, total observations: 10272 pixels			
Land to be Sea waters	198	342	286
Sea waters to be Land	0	0	19
Accuracy	98.07%	96.67%	97.03%
Kappa	0.96	0.931	0.939

However, band ratio method result showed the cloud does not affect the accuracy significantly. The ratio of two bands was canceled out the clouds on image. While the NDVI method was adjusting the value into normal distribution, hence the influence of clouds was not eliminated, as well as the single band. The number of misidentification pixels becoming high when used single band and NDVI methods on cloudy image and it did not happen when used ration method. Therefore, ratio band was more stable method than single band NDVI due to it also canceled out the cloud on image.

The ability of canceled out the cloud on image will be useful for land or sea water masking on farther study especially on coastal area monitoring such as mangrove or ocean color monitoring. Eventhough according Winarso *et al.,* (2009) ratio of NIR and green will make missidentification at land border. Ryu, *et al.*, (2002) and Winarso, *et al.*, (2009) also found that band ratio given better result for shoreline extraction based on digital image processing using satellite data. Thus, band ratio will be used for abrasion and accretion analysis at Lampung Bay. The result of shoreline extraction using band ratio on SPOT-4 image 16 June 2012 at Lampung Bay can be seen at Figure 3-3. Shoreline changes at Lampung Bay can be seen by compared SPOT-4 image on June 2012 with RBI map on 2008 (Figure 3-4) using raster analysis.

Figure 3-3: Shoreline extraction at Lampung Bay using band ratio

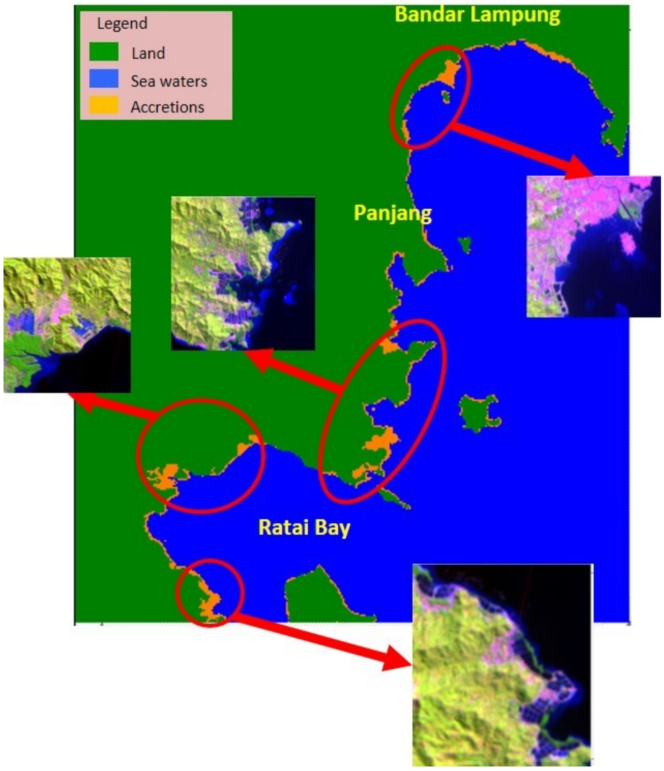

Figure 3-4: Accretion were occurred at Lampung Bay on 2008 to 2012

Raster analysis at Figure 3-4 showed there is not abrasion at Lampung Bay as long as 2008 to 2012. It was found only accresion which occured at Lampung Bayalong four years. Accretion ares which happen at Lampung Bay along 2008-2012 were 662 Ha with the rates of shoreline changes 165 Ha/year. The big accreation areas occurred at coastal areas of Bandar Lampung, Panjang and Ratai Bay. The accretion at Lampung Bay caused by reclamation of coastal areas which were used for urban built up, fishponds and mangrove.

The reclamation caused by some reason such as increasing marine aqua culture, mangrove reforestation and urban development. According Perda-Lampung (2010), beside acceleration ofrevitalization and development cities growth center, there are also international and regional port and military based development in Lampung Bay which are constructing since 2010. According Dianpurnama *et al.*, (2013), sediment transport direction at Lampung Bay were north and northwest. Base on SPOT-4 image also can bee seen that morphology of Lampung Bay coastal areas is pocket sediment shaped. Thus, there were sediment loads potential at west to north of Lampung Bay,beside of reclamation were made by human activities.

4 CONCLUSION

Extraction of shoreline based on cloud free and cloudy SPOT 4 images, can was carried out digitally by using three methods, namely single band, NDVI and band ratio. The accuracy of shoreline extraction result from the cloudy-free SPOT-4 image processing for the ratio band method is 97.99%, NDVI method is 98.73% and single band method is 98.47%. However, shoreline extraction result from cloudy SPOT-4 image processing give an accuracy of ratio band method is 98.07%, NDVI method is 96.67% and single band method has accuracy 97.03%. Thus the accuracy of the three methods is very good. The results showed that the band ratio method can cancle out the clouds compare to a single band and NDVI method. Therefore, band ratio method was better for shoreline changes monitoring due to misindetification caused by cloud can be reduced.

This sudy used band ratio as best method for shoreline change at Lampung Bay. Along 2008 to 2012, it was found that shoreline changes at Lampung Bay caused by accretions. The accretion ares at Lampung Bay for 2008 until 2012 were 662 Ha with the rates of shoreline changes 165 Ha/year. The accretion caused by reclamationfor urban built up, fishponds and mangrove.

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REFERENCES

Arief M, Winarso G, Teguh P., (2011), *Kajian Perubahan Garis Pantai menggunakan Data Satelit Landsat di Kabupaten Kendal.* Jurnal Penginderaan jauh 8:71-80.

Bakker, Wim H, et. al, (2009), Digital Book: Principle of Remote Sensing. ITC, Enschede- Netherlands.

Bismoko S, Atmodjo W, Adi S., (2012), *Pendekatan Sel Sedimen untuk Analisa Perubahan Garis Pantai di kecamatan Kaliwungu dan Kecamatan Brangsong, Kabupaten Kendal.* Jurnal of Marine Research, 1(1): 1-9.

Dianpurnama, Helmi M, Yusuf M., (2013), *Analisa Sel Sedimen Sebagai Pendekatan Studi Erosi Di Teluk Lampung, Kota Bandar Lampung Provinsi Lampung.* Journal of Marine Research. 2(1):1 43-153.

Maiti S, Bhattacharya AK., (2009), Shoreline change analysis and its application to prediction: A remote sensing and statistics based approach. Journal of Marine Geology 257(1-4): 11–23.

Mukhtar, (2009), *Garis Pantai Indonesia Terpanjang Keempat di Dunia*. http://www.kkp.go.id/index.php/arsip/c/1048/Garis-Pantai-Indonesia-Terpanjang-Keempat-di-Dunia/?category_id (accessed on 10th September 2013).

Pardo-Pascual JE, Almonacid-Caballer J, Ruiz LA, Polamar-Vazquez J., (2012), Automatic extraction of shoreline from Landsat TM and ETM+ multi temporal images with subpixel precision. Journal Remote sensing of Environment 123: 1-11.

Perda-Lampung, (2010), *Rencana Tata Ruang Wilayah (Rtrw) Provinsi Lampung Tahun 2009 Sampai Dengan Tahun 2029*. http://www.pu.go.id/uploads/services/infopublik20120423155030.PDF.

Ryu J, Won J, Min KD., (2002), Waterline Extraction from Landsat TM data in a tidal flat, a case study in Gomso Bay Korea. Journal Remote sensing of Environment 83(3):442- 456.

Sim J, Wrigh CC., (2005), The Kappa Statistic in Reliability Studies: Use, Interpretation, and Sample Size Requirements. Journal of Physical Therapy 85(3): 257-268.

Triatmodjo B., (1999), *Teknik Pantai*. Beta Offshet, Yogyakarta, 397.

Winarso G, Joko H, Arifin S., (2009), *Kajian Penggunaan data Inderaja untuk Pemetaan Garis Pantai (studi kasus: Pantai Utara Jakarta)*. Jurnal Penginderaan Jauh 6: 65-72.