HARMFUL ALGAL BLOOM 2012 EVENT VERIFICATION IN LAMPUNG BAY USING RED TIDE DETECTION ON SPOT 4 IMAGE

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Abstract. In mid-December 2012, harmful algal bloom phenomenon occurred in Lampung Bay. Harmful Algal Bloom (HAB) is blooming of algae in aquatic ecosystems. It has negative impact on living organism, due to its toxic. This study was applied Red Tide (RT) detection algorithm on SPOT 4 images and verified the distribution of HAB 2012 event in Lampung Bay. The HAB event in 2012 in Lampung Bay can be detected by using RT algorithm on SPOT 4 images quantitatively and qualitatively. According to field measurement, the phytoplankton blooming which happen at Lampung Bay in 2012 were *Cochlodinium sp*. Image analysis showed that *Cochlodinium sp* has specific pattern of RT with values, digitally, were 13 to 41 and threshold value of red band SPOT 4 image was 57. The total area of RT distribution, which are found in Lampung Bay, was 11,545.3 Ha. Based on the RT classification of RT images and field data measurement, the RT which is caused many fishes died on the western coastal of Lampung Bay spread out from Bandar Lampung City to Batumenyan village. By using confusion matrix, the accuracy of this this method was 74.05 %. This method was expected to be used as early warning system for HAB monitoring in Lampung Bay and perhaps in another coastal region of Indonesia.

Keywords: *harmful algal bloom, Lampung Bay, SPOT 4 image, red tide algorithm*

1 INTRODUCTION

In mid-December 2012, algal bloom occured in Lampung Bay (Radar Lampung 2012). The algal bloom was indicated not only by many fishes died in the west coast of Lampung Bay (Pesawaran district), but also the occurrence of algal species in coastal waters. According to (Radar Lampung 2012), the phenomenon of algal bloom occurred from TPI Lempasing to Batumenyan Village. The areas which had the biggest impact regarding algal bloom was Hurun Bay.

According to (Damar 2012) HAB 2012 event in Lampung Bay started gradually since October 2012 and the peak of blooming occurred in December 2012. It was caused the red color of coastal water (Red Tide). According to (Sutardjo, *et al* 2013), the red tide distribution was found firstly at Hurun Bay, then it was spreaded out widely to the west coast of Lampung Bay with high concentration and its found on floating net. It was found, the specific phytoplanktons blooming were *Cochlodinium sp*. However, Harmful Algal Bloom (HAB) in Lampung Bay has been observed since 2006 when *Pyrodinium Bahamense* was found at Hurun Bay (Sidabutar 2007).

Pyrodinium Bahamense and *Cochlodinium sp* are *Dinoflagellata* are known as harmful algal bloom due to its toxic (Ahmad, *et al* 2009). Harmful algal

bloom (HAB) is defined as the blooming of algae population in aquatic ecosystems. HAB has negative impact on living organisms, because it tends to be toxic. Algae is one of phytoplankton which have a pigment colors such as green, blue or red color. The blooming of certain phytoplankton in waters will affect the color of waters. That is why the color of waters at Lampung Bay become red when *Cochlodinium sp* blooming, due to its has the red pigment.

According to (Anderson 1989) and (Wardiatno, *et al* 2004), HAB increased in frequency, intensity and widely distribution spatially. HAB causes the decreasing of fisheries resources, economic losses in aquaculture and wild fisheries, even human life due to it could be toxic (Tang, *et al* 2004; Wardiatno, *et al* 2004). Thus, early warning system in detecting of algal bloom and reducing the risks of HAB is needed.

Detection and monitoring algal bloom could be carried out by using satellite remote sensing imagery. Remote sensing data has been used widely for HAB detection, spatially and temporally, in a long time [Tester, *et al* 1991; Keafer and Anderson 1993; Tang, *et al.* 2004]. Previous studied which performed by (Gower 1994) was analysed the HAB using Red Tide (RT) detection on NOAA-AVHRR satellite data. While (Ahmad, *et al* 2009) has detected RT by using green and NIR channel from SPOT 4 image in Sabah Malaysia.

SPOT 4 (Satellite Pour'l Obseravtion de la Terre 4) imagery is medium-resolution satellite imagery (20 meters). SPOT 4 has four spectral channels (Green, Red, NIR and SWIR). It is known that the green and red channel are sensitive with chlorophyll absorption, while NIR and SWIR are sensitive with water absorption. Therefore, based on previous studied and SPOT 4 characteristics, the objectives of this study were to applied and verification the distribution of HAB 2012 event in Lampung Bay using RT detection algorithm on SPOT 4 image. This method was also expected to be utilize as early warning system for monitoring and reducing the HAB effects.

2 MATERIALS AND METHODOLOGY

The study was carried out in Lampung Bay, Indonesia with latitude 5º25'57.74"- 5º38'12.67" South and longitude 105º8'45.26" - 105º19'40.05" East (Figure 2-1). This study used two images, which are SPOT 4 image on 16 June 2012 (before the events of algal bloom) and SPOT 4 image on 20 December 2012 (when the algal bloom happen).

The flowchart of data processing described briefly in Figure 2-2. The geometric, radiometric and atmospheric correction were applied on SPOT 4 images firstly. Geometric correction was performed to reduce the bias that caused by geometric error. While radiometric and atmospheric correction were conducted to reduce some errors during data recorded by sensor.

This studied used two SPOT 4 images which has corrected geometric systematically. While radiometric correction was carried out using top of atmosphere formula by converting radiance values into reflectance. Furthermore, the atmospheric correction conducted using dark pixel subtraction. After the atmospheric correction, visual classification and false color composite were carried out to extract land cover information of study area and RGB image, which used for further analysis.

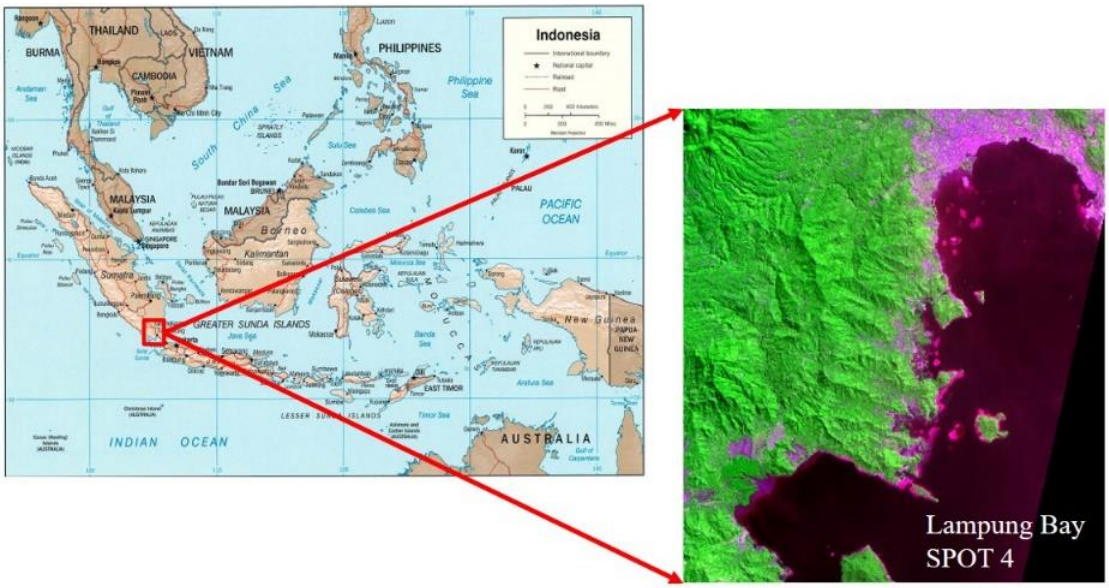

Figure 2-1: Study area

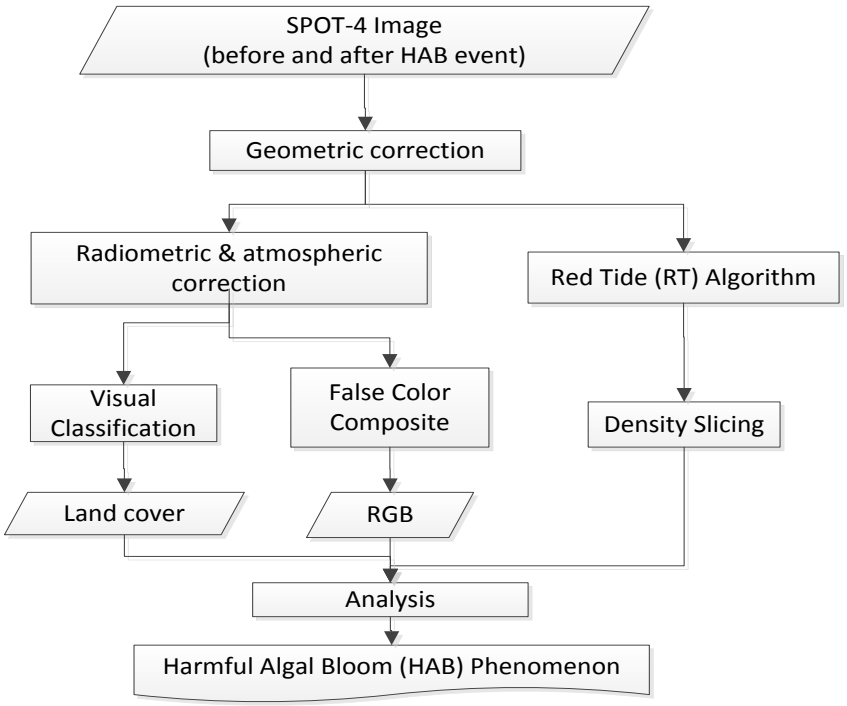

Figure 2-2: Flow of data processing

The qualitative analysis was carried out by observing the Red Tide visually using false color composite, which used NIR channels as Red, Green channel as Green and Red channel as Blue. The quantitative analysis was carried out using the Red Tide (RT) detection algorithm developed by (Gower 1994) and (Ahmad, *et al* 2009). The algorithm is shown below:

$$RT = G \times \left(b_1 - \frac{b_3}{0.93}\right) - A \times G \times \left(\frac{p-1024.5}{1024}\right)^2 + offset \quad (2\text{-}1)$$

If $b_2 > threshold$, then RT = 0

b_1, b_2, b_3, are digital number of green, red and NIR band respectively. A is atmospheric correction, G is physical gain and p is number of pixel in one swath.

Physical gain value can be obtained from SPOT 4 image metadata while the number of pixel in one swath can be seen at SPOT 4 specification. According to (Gower 1994), the value of A=10 gives good average correction for summer daytime imagery. The threshold value is a digital number of band red from SPOT 4 image which is used for RT detection.

The analysis was performed for RT detection by using green, red and NIR band of SPOT 4 image which applied on formula (2-1). The formula (2-1) was applied on the image both SPOT 4 image, before and after HAB event in Lampung Bay to obtain RT image. Furthermore, density slicing technique was carried out on RT image for observed the interval value of RT which contains information of HAB in Lampung Bay. The density slicing was carried out by divided the RT image into two classes which are RT and non-RT.

This research used confusion matrix to calculate the accuracy of RT detection using SPOT 4 images. The accuracy was carried out by comparing RT detection using SPOT 4 image and field measurement which was conducted by Indonesian Ministry of Marine and Fisheries on December 22 to 23, 2012.

3 RESULTS AND DISCUSSION

RT pattern could be seen qualitatively (visually) by using false color composites from NIR band, green band and red band of both SPOT 4 images (Figure 3-1). Figure 3-1 shows, the SPOT 4 images on June 16, 2012 does not have significant RT pattern. Whereas the SPOT image on December 20, 2012 shows the green pattern which was thought as RT in Lampung Bay.

The suspicious pattern which predict as HAB event in Lampung Bay can also be seen digitally from the digital number distribution of SPOT 4 image bands as seen in Figure 3-2. According to formula (2-1), red band has influence for RT detection, so an attempt was carried out to found the threshold value of band red as indicator HAB and non HAB event.

Based on Figure 3-2, It was found that HAB event can be predicted using threshold value of red band was 57. Because HAB event did not found when the digital number of red band were above 57. The HAB event was found when digital number of red band lower than 57. By using that threshold value of band red on both SPOT-4 images to detect HAB event, it shows that the digital number of red band which were lower than 57 has specific pattern of RT, otherwise has not. Since the specific of RT pattern did not found on SPOT-4 image December 16, 2012, both using visual and digital analysis, then RT image was obtained by applied the formula (2-1) on SPOT-4 image December 20, 2012.

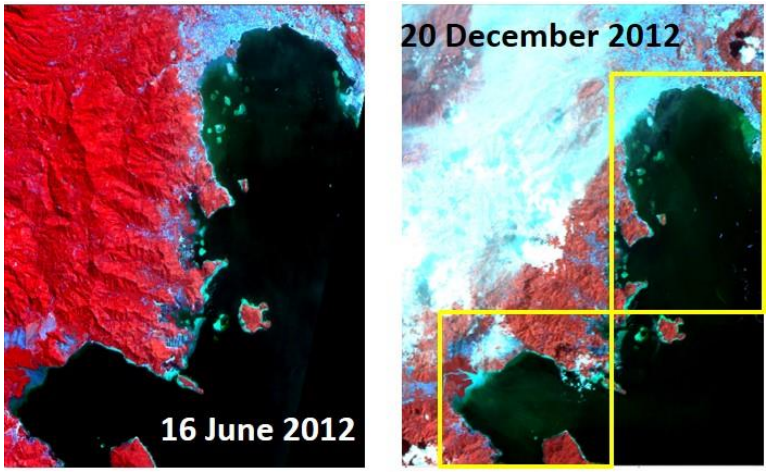

Figure 3-1: SPOT 4 images on June 16 and December 20, 2012. The areas in yellow boxes were expected as RT

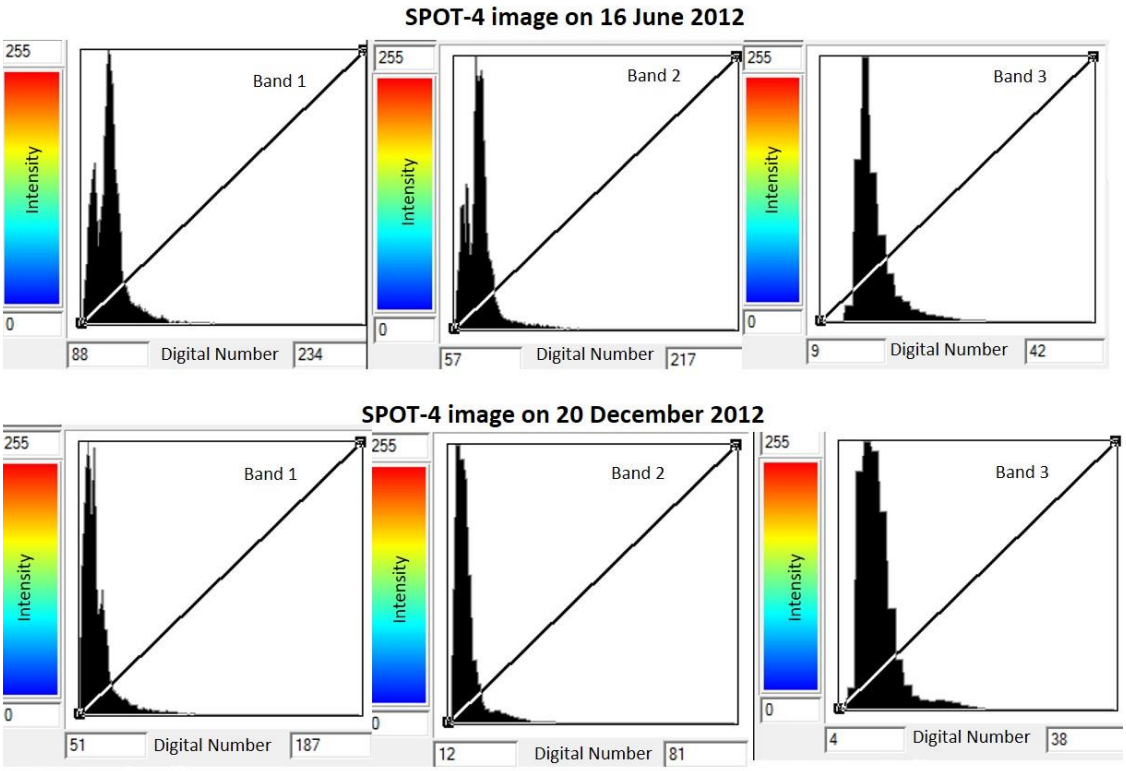

Figure 3-2: The Histogram of digital number distribution each band from SPOT image June 16 and December 20, 2012

RT classification results from density slicing on RT image can be seen in Figure 3-3. The RT values which indicator of HAB event, digitally, were 13 to 41. The RT is widely distributed along the west coastal of Lampung Bay, from Bandar Lampung city to Batumenyan Village. The total areas of RT which found in Lampung Bay 2012 are 11,545.3 Ha.

According to (Irawan, *et al* 2015), the increasing of abundance HAB in Lampung Bay lead to the increasing the risk death of fish. Based on (Radar Lampung 2012), many fishes died occurred in TPI Lempasing, Kanalar Lampung Hurun Bay to Batumenyan village. Based on field data acquired from Center for Development of Marine Aquaculture Lampung, it is found that a number of fishes died occurred in the western coastal area and its caused by *Dinoflagellata* Algae from species *Cochlodinium Polykrikoides* (Damar 2012).

Meanwhile, according to the field measurement conducted by The Indonesian Ministry of Marine and Fisheries on December 22 to 23, 2012, it was found that, the phytoplankton blooming which happen at Lampung Bay were *Cochlodinium sp* (Sutardjo, *et al* 2013). The distribution map of RT at Lampung Bay in December, 2012 based on field measurement can be seen in Figure 3-4. Figure 3-4 shows that RT was detected along west coastal of Lampung Bay, which were from Bandar Lampung city to Batumenyan village. Therefore, there is nearly closed agreement between RT detection at Lampung Bay in December 2012 using SPOT 4 image and field measurement.

The accuracy assessment was carried out by using confusion matrix between distribution map of RT based on field measurement and RT detection using SPOT 4 image (Table 3-1). The confusion matrix resulted overall detection accuracy to 74.05%. Meanwhile the producer's accuracy for RT detection was 79.54% and user's accuracy was 79.83%. It is mean, the method can describe well the RT distribution at Lampung Bay in December 2012 as indicator of the blooming of algae.

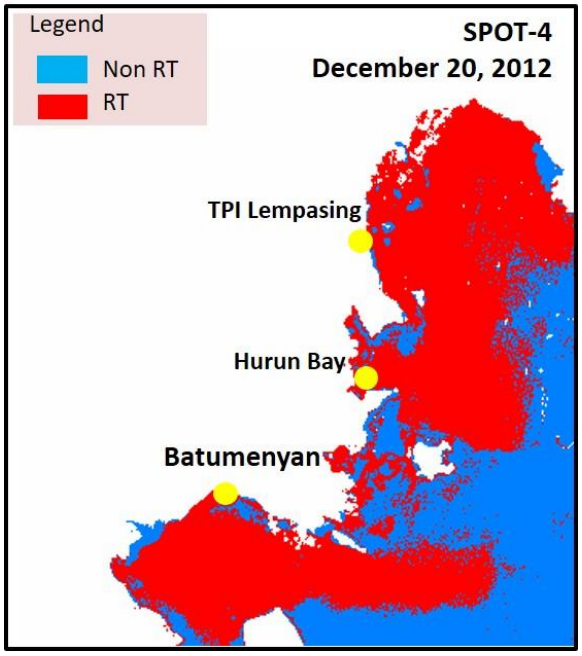

Figure 3-3: RT detection at Lampung Bay using SPOT 4 image December 20, 2012

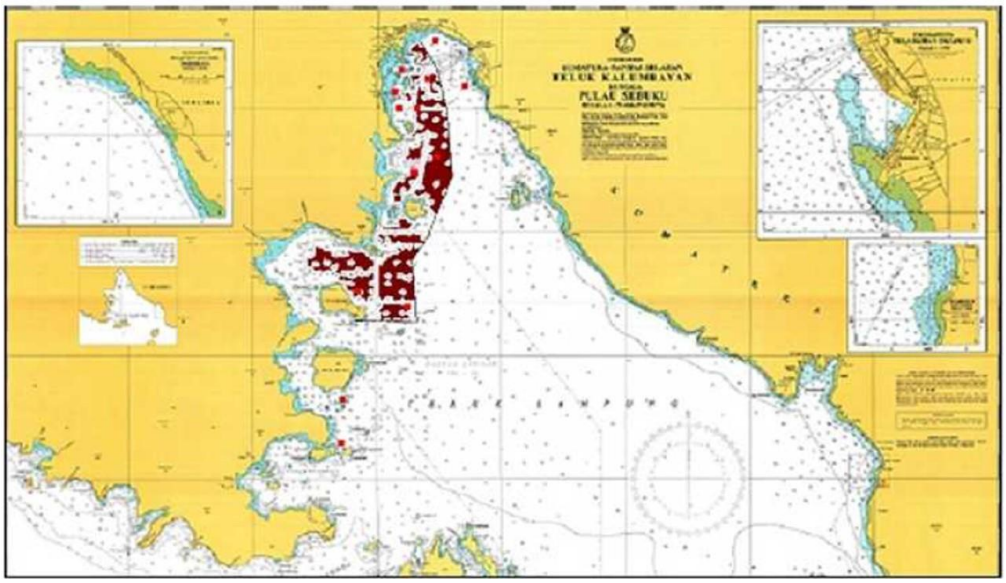

Figure 3-4: The distribution map of RT at Lampung Bay in December, 2012 based on field measurement (source: Sutardjo, *et al* 2013)

Table 3-1: Accuracy assessment based on confusion matrix between distribution map of RT based on field measurement and RT detection using SPOT 4 image

Classification	**Producer's Accuracy**		**User's Accuracy**	
	RT	non RT	RT	non RT
RT	79.54%	35.71%	79.83%	20.17%
non-RT	20.46%	64.30%	36.12%	63.88%
Overall Accuracy: 74.05%			**Kappa statistic: 0.438**	

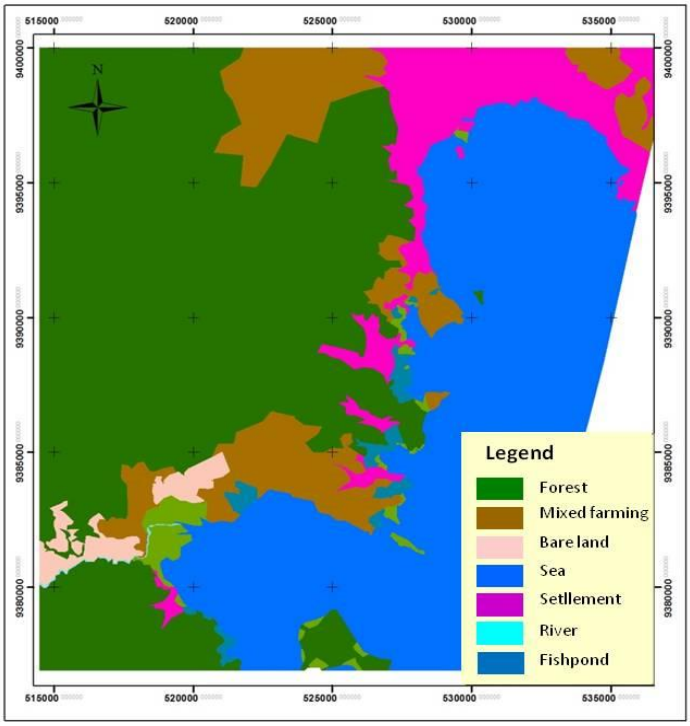

Figure 3-4:Classification of land cover of Lampung Bay based on SPOT 4 image

Based on the land cover classification from SPOT 4 image, it could be seen that there were settlement, fishpond and river in Lampung Bay which were located in the Batumenyan village, Hurun Bay and even at Bandar Lampung City (Figure 3-4). The landuse intensification around coastal area in Lampung Bay causes the increasing of HAB abundance (Qiptiyah, *et al* 2008; Irawan, *et al* 2015). While the river was thought as transport of sediment and nutrient which produced by settlement, fishpond and another aquatic cultivation to coastal waters. Therefore, it was predicted that algal bloom was caused by the presence of food (nutrients), which related to the pollution of coastal waters caused by domestic sewage and urban aquaculture.

(Sutardjo, *et al* 2013) said that Hurun Bay and Lampung Bay were vulnerable with Red Tide in the future due to the condition of their coastal environmental support. Tidal has dominant role to generate vertical current at Lampung Bay, especially when upwelling happens which have lower temperature than normal. The warm sea surface temperature with a small daily variation, made Lampung Bay favored by organisms which causes RT. The algal bloom occurred together with the increasing of Nitrogen in waters. The increasing of Nitrogen caused by surface runoff and decomposition of organic material derived from fish and shrimp farming activities along the west coast of Lampung Bay. Therefore, nutrient control by emphasizing on coastal landscape management to prevent large blooming is more preferable than eradicate HAB when they appeared in coastal area (Heisler, *et al* 2008).

4 CONCLUSION

This study has shown the ability of SPOT 4 image to determine the red tide in Lampung Bay in quantitative and qualitatively. HAB, which caused many fish deaths, spreaded out along west coastal of Lampung Bay, from Bandar Lampung City until Batumenyan village. It was found that RT of *Cochlodinium sp* has specific pattern with RT digital value ranged between 13 to 41 by using threshold value on SPOT red band equal to 57. The total area of RT which are found in Lampung Bay is 11,545.3 Ha.

The overall accuracy in detection of RT using SPOT 4 image was 74.5%. Thus, the method could describe the RT distribution well. Furthermore, advanced research need to be done in order to integrate the correlation between the distribution of HAB and the influence of other variables such as the quality in coastal water, current and the wave.

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