CORAL REEF HABITAT CHANGING ASSESSMENT OF DERAWAN ISLANDS, EAST KALIMANTAN, USING REMOTE SENSING DATA

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Abstract

Coral reefs in Dcrawan Islands are astonishingly rich in the marine diversity. However, these reefs are threatened by humans. Destructive fishing methods, such as trawl, blasting and cyanide fishing practise, are found to be the main cause of this degradation. The coral reefs habitat reduction is also caused by tourism activities due to trampling over the reef and charging organic and anorganic wastes. The capabilities of satellite remote sensing techniques combined with field data collection have been assessed for the coral reef mapping and the change detection of Derawan Island. Multi-temporal Landsat TM & ETM images (1991 & 2002) have been used. Comparison of the classified images of 1991 and 2002 shows spatial changes of the habitat. The changes were in accordance with the known changes in the reef conditions. The analysis shows the decrease of the coral reef and patchy seagrass percentage, while the increase of the algae composite and patchy reef percentage.

Keywords : Coral Reef, Change Detection, Landsat-TM, Derawan

I. Introduction

The health of the world's coral reefs is in serious decline. Approximately 11 percent of coral reefs with a high level of marine diversity are under threat, including reefs in the Philippines, Indonesia, Tanzania, the Comoros, and the Lesser Antilles in the Caribbean (Bryant et. al., 1998). Principally, human activities are the main cause of the coral reef degradation. These include destructive fishing methods, over-fishing, inappropriate inland management; human and industrial waste disposal, coral mining and even careless diving activity. Global wanning may also enforce reefs stress, such as increased flood and storm events and a rise of the seawater temperature.

Information on the health of coral reefs status is crucial for their conservation and sustainable utilization. Unfortunately, in most cases only a small amount of this information is available. The International Coral Reef Initiative (ICRI) Framework for Action emphasizes the needs of research and monitoring of the coral reefs status. Particularly the reefs in tropical ecosystem because reefs in this area are still not well understood as compared to the temperate system (ICRI, 1995).

Coral reefs in Derawan Islands are astonishingly rich in the marine diversity. The high diversity of corals and fishes, the

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presence of turtles and Kakaban salt lake make Dcrawan Islands one of the most famous diving sites. One of the outcomes of the "World Heritage Marine Diversity" Workshop, in Hanoi 2002, stated that the Derawan islands area has a high priority to be nominated as **World** Heritage Site. There are about 120 areas in the world identified as potential sites of outstanding universal values. Within those, 25 sites ranking in Southeast Asia, Dcrawan islands area is among the top seven (UNESCO, 2002).

However, these reefs are threatened by humans. WWF Indonesia (2002) reported there arc 4 main threats in Derawan Islands: 1) Habitat reduction, 2) Fisheries activities, 3) Tourism and 4) Policy. East Kalimantan once had approximately 950,000 ha of mangrove-nipa forest formation and only 266,800 ha left in 1980 (Mac Kinnon, et.al cited in Jompa and Pct-Soede, 2002). These mangroves have been converted or degraded due to logging, the making of fishponds, human settlements and industrial facilities. As a result, the mangrove function as the barrier for erosion and as a filter of sediment also decreases. Destructive fishing methods, such as trawl, blasting and cyanide fishing practice, are found to be the main cause of this degradation. The coral reefs habitat reduction is also caused by tourism activities due to trampling over the reef and charging organic and anorganic waste. Moreover, the unwise practice development decisions also contribute to habitat degradation, such as stock collapse and habitat reduction due to intensification and industrial development (Ismuranty, 2002; Jompa and Pet-Soede 2002).

A monitoring program to detect changes of the coral reef environment is essential to promote sustainable management. The monitoring has to be repeated over time at the same location. An appropriate time scale is needed to study statistically changes in the main variables, but also to determine ecologically meaningful changes (Reese and Crosby, 2000).

The objective of the study was to assess the coral reef habitat change by comparing classified images of Landsat of 1991 and 2002 for coral reef habitat mapping and change detection of Derawan Island using multi-temporal Landsat TM & ETM images (1991 & 2002).

II. Mcthododology

This study focuses on the coral reefs of Derawan Island and Masimbung reef and Tubabinga reef in the southern part of Derawan Island. The Derawan islands region is a sub-district (Kecamatan) of the Berau district of the East Kalimantan Province, Indonesia. Geographically, it is situated between 118"09'53"-118°46'28" East and the 02°25'45"-02°03'49" North. The islands of Derawan, Rabu-Rabu, Panjang, Samama and Sangalaki are part of the Berau barrier reef. The two up lifted atolls are Maratua, with an open lagoon and Kakaban, with a closed lagoon (Figure lc).

The islands are situated in two different systems: a shelf reefs system, which has developed as barrier reef, known as the Berau barrier reef, and tectonically uplifted atolls. The Berau barrier reef system is found in the Northern part of the Berau delta, part of Mangkalihat Peninsula; and it extends about 60 km to the South. It is located at the inner side of the 200 m iso-depth at the margin of the Sunda shelf (Tomascik et al. 1997).

Multi-temporal remote sensing satellite data were used in the study. The Landsat-5 TM, of June 1991 has been downloaded from the Global Land Cover Facilities achieved images data (http://glcfapp.umiacs.umd.edu). The Landsat-7 ETM data, of July 2002 was obtained from the National Institute of Aeronautic and Space-LAPAN, Indonesia. Table 1 describes the details of the available remote sensing data.

Table 1. Available Remote Sensing Data

Sensor	Path/ Row	Acquisition		Number of Bands	Resolution	Spectral range (nm)
		Date	Time (GMT)			
Landsat-5TM	116/58	16 June 1991	09:43 a.m.	**(Band 1-7)**	30 m 120m(B6)	Bl=450-520 B2= 520 - 600 B3= ,630 - 690 B4= 760 - 900 B5= 1550-1750 B6= 1040- 1250 B7= 2080 - 2350 Pan- 450 - 900

The fieldwork activities were carried out in October 2003 for one month, including one week secondary data collection and research equipment preparation, and 3 weeks in Derawan Islands (4 - 25 October 2003) for *insitu* data collection. The field methods in Derawan Islands consisted of: ground control points collection, habitat ground truth points, *insitu* spectral data measurements, water depth measurements and habitat data collection along the transects (Figure lc).

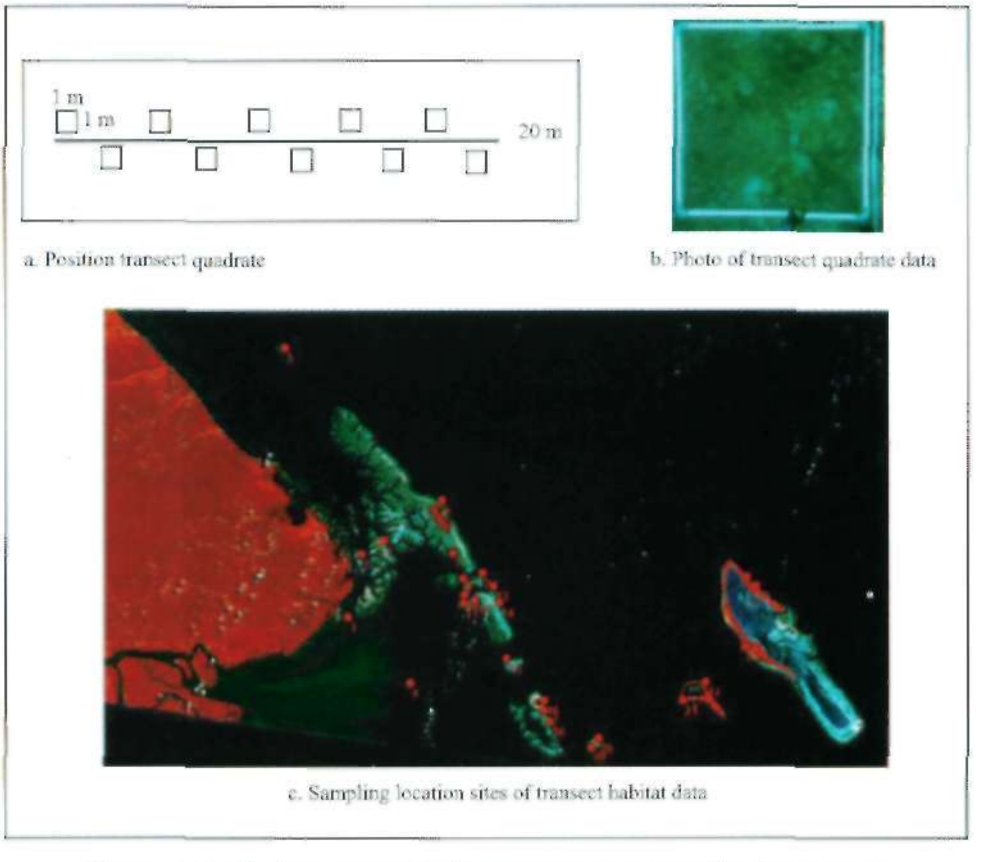


Figure 1. Study Area, transect habitat approach and sampling location sites

Habitat transect data were collected to obtain more details of the coral reef conditions, such as live coral percentage, the dominant species etc. A quadrate transect technique was used to collect the data. A 20 m line was placed parallel to the coastal line. The data were collected at three different depths; 10, 6 and 2 m, starting at the deeper part (10 m) until the shallow part (2m). The transect quadrant (1 x 1 m) was placed along this line, with 2 m intercept; so there were 10 transect quadrants along each line (see Figure la). A digital underwater camera was used to record the data in each transect quadrant (Figure lb).

Image processing activities as described in Figure 2 consists of: geometric correction, atmospheric correction, water column correction, habitat classification and change detection.

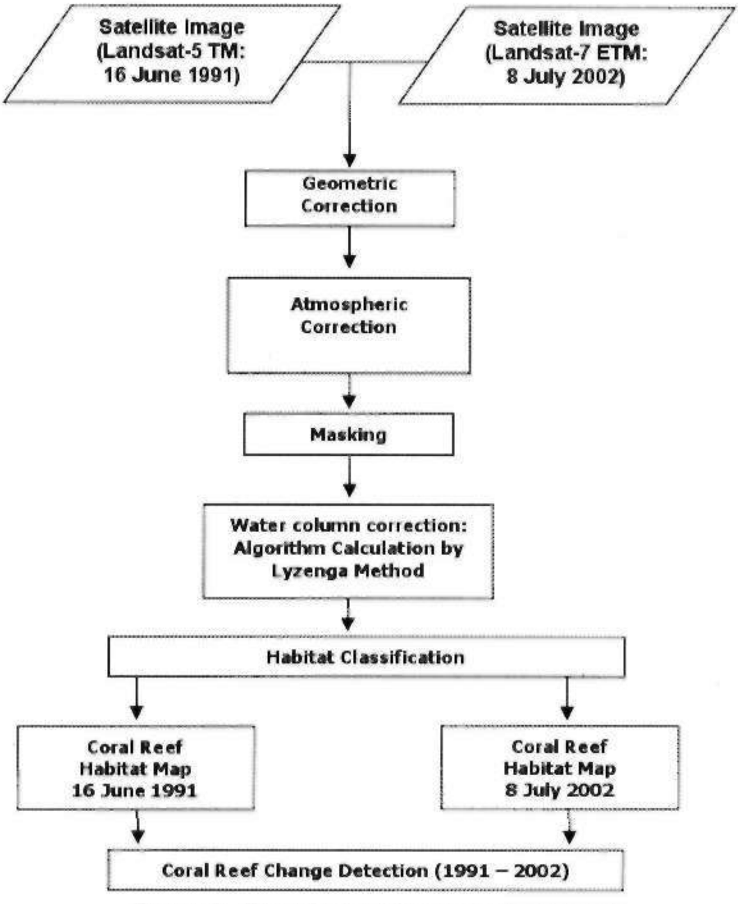


Figure 2. Flowchart of the research approach

2.1 Geometric Image Correction

It was difficult to find suitable ground control points. The Derawan Island is only a very small island, approximately 1 km long and 0.5 km wide. The high spatial resolution of the panchromatic QuickBird band (resolution 0.6 m) gave the possibility to use infrastructural elements as ground control points. In the field, the corner of some jetties surrounding the island, corners of a helicopter base and sand pit in the east part of the island were collected as ground control points.

However, those points could not be used for the geometric correction of the Landsat image, due to its relative low spatial resolution. Thus, for the geometric correction of Landsat TM (1991) and Landsat ETM (2002), the geometric corrected image of QuickBird was used as the master image. The two Landsat images were subset first to the same area as the QuickBird image. Table 2 gives information about the Root Means Square Error (RMSE) of the geometric image correction.

Table 2. RMS error of geometric corrected images

Images	Number of points	Reso-luiion	RMSE
QuickBird panchromatic	5	0.6 m	4.667
QuickBird MS	10	2.4 m	0.468
Landsat ETM	12	30 m	0.557
Landsat TM5	7	30ni	(1.544

Table 3. Parameters of Landsat-5 TM 1991 and landsat-7 ETM 2002 images

Sensor	TM	ETM
Date of Acquisition	16 June 1991	8 July 2002
Bands	1-7 exclude b6	1-7 exclude b6 and pan
Pixel size	30 m	30 m
Factor scale	4 (default)	4 (default)
Solar zenith angle	40.32	35,6
Calibration file	Tm51991.cal	Tm7-2002.cal
Model for solar region	Others. Type: tropica! ocean	Others. Type: tropical ocean
Visibility	30 km	30 km
Ground elevation	0.1 km (default)	0.1 km (default)

Table 4. Calibration parameter for Landsat-5 TM and Landsat-7 ETM images

Band	Landsat-5 TM (1991) [mW/cm^2 /sr/micron]		Landsat-7 ETM (2002) [mW/cnr /sr/ micron)	
	CO	CI	CI	CO
1	-0.15200	0.06024314	-0.6200	0.0775686
2	-0.28399	0.11750981	-0.6400	0.0795686
3	-0.11700	0.08057647	-0.5000	0.0619216
4	-0.15100	0.08145490	-0.5100	0.0965490
5	-0.03700	0.01080784	-0.1000	0.0125725
6	0.12378	0.12377996	0.0000	0.0066824
7	-0.01500	0.00569804	-0.0350	0.0043725

2.2 Atmospheric Correction

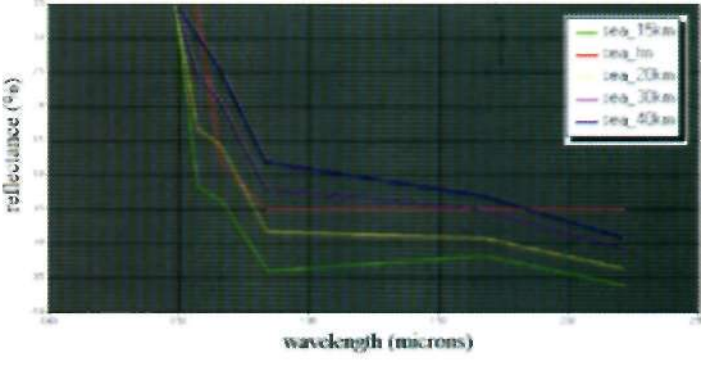
Satellite sensors record the intensity of electromagnetic radiation (EMR) as digital number (DN) values. The DN value of each image is specific to the type of sensor and the atmospheric condition during the image acquisition. To make different images comparable, the DN values should be converted to a physical unit, using the calibration dala given in the header file of the image (Richter. 2002).

ATCOR2 for ERDAS IMAGINE software was used for the radiometric and atmospheric correction. There are several options under ATCOR; Calculate Sun Position, ATCOR 2 workstation, ATCOR3 Derive Terrain File and ATCOR 3 workstation. For our analyses ATCOR2 was used because it is a model for the atmospheric correction of flat terrain. The ATCOR approach refers to ATCOR user manual (Richter, 2002). The following steps were performed for atmospheric correction: 1) specify input parameters; 2) estimate the visibility and the atmosphere model with Spectra module; 3) apply atmospheric correction with constant atmospheric conditions using ATCON module.

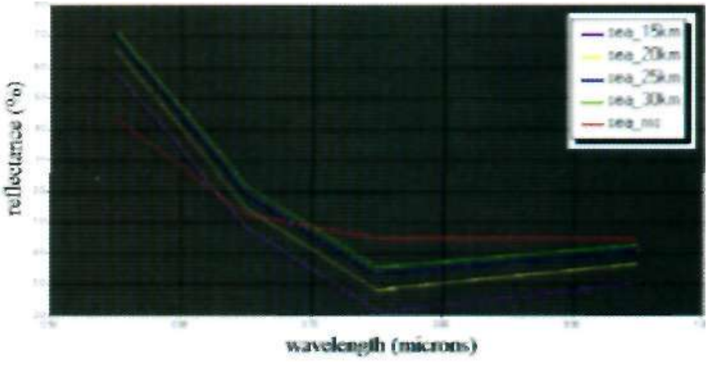
Most of the parameters are provided in the image header file, which is attached to the image by the provider. The parameters of the acquired TM images are displayed in Table 3.

The calibration file contains the calibration coefficients cO (bias) and cl (gain) for each image band. These coefficients are used to convert the DN values to radiance at sensor. The revised Landsat-5 TM calibration parameters (USGS, 2003) were used to create the calibration file for Landsat-5 TM, 16 June 1991, image. The calibration values for Landsat-7 ETM, 8 July 2002, were extracted from the header file. The bias and gain values of Landsat-5 TM and Landsat-7 ETM that are used in this study are listed in Table 4.

Estimating the visibility and the atmosphere model with Spectra was conducted after input parameters have been specified. The purpose of this module was to determine the appropriate atmospheric condition (aerosol and humidity) and visibility. Moreover this spectra module can also be applied to confirm the influence of the calibration file.



sea spectral library' for TM



Comparison of several spectra, using different visibility, with the sea spectral library for ETM 7

Figure 3. Spectral reflectance versus various visibilities in comparison with spectral library

Figure 3 shows spectral signatures of deep sea at various visibilities. These spectral signatures are compared to the spectral library from the deep sea as a reference (the red line). The graph shows that the visibility of 30 km has a relatively similar pattern, comparing to the spectral library signature.

The atmospheric correction with constant atmospheric condition (ATCON) was conducted after the previous task. Normally, the data collected in the visible wavelengths (e.g. TM bands 1 to 3) have a higher minimum value because of the increased atmospheric scattering taking place in these wavelengths. Figure 4 shows that before the atmospheric correction was applied, the mean DN values are 34.88 and 80.86 and after the atmospheric correction was applied, the means reflectance values (p) are 4.31 and 9.35. These lower mean values indicate that the effects of the atmosphere have been reduced, and the histogram shifted to the left so zero values appear in the data. The total of pixel number is still the same, but the pixel value (Digital Number) was reduced, due to the fact that the increasing DN values are affected by the atmospheric condition.

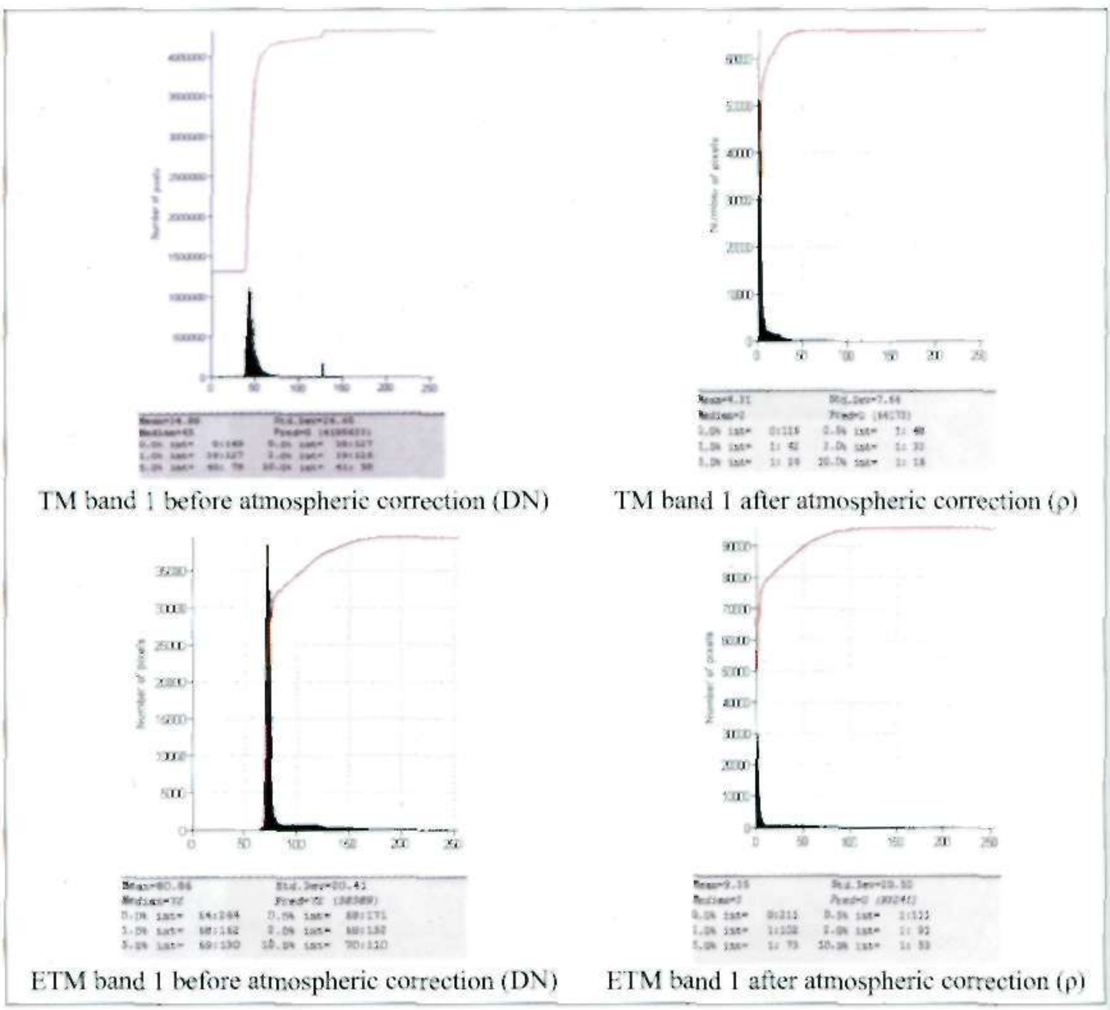


Figure 4. Comparison of histogram band 1 before and after the atmospheric correction is applied

2.3 Water Column Correction

The concept of the water column correction is that bottom reflected radiance is a linear function of the bottom reflectance and an exponential function of the water depth. The intensity of light penetration is decreasing exponentially with increasing water depth; this process is known as the attenuation of underwater optics. The approach proposes a method to compensate light attenuation due to the influence of depth by using the information ratio attenuation of two bands (Lyzenga, 1981).

The homogenous substrate at various depths is selected from the image according to the following steps: Firstly, display a false colour composite of RGB 321 of the atmospheric corrected image. Secondly, assess the homogenous substrate values (in this case sand) in the three bands and list them in an EXCELL spreadsheet. These values will be the inputs for the calculations in Equation 1.

The ratio attenuation is obtained using the following equations:

$$K_i / K_j = a + \sqrt{(a^2 + 1)} \qquad (1)$$

where:

$$a = \frac{\sigma_{ii} - \sigma_{jj}}{2\sigma_{ij}} \qquad (2)$$

and:

$$\sigma_{ij} = \overline{X_i X_j} - \overline{X_i}\,\overline{X_j} \qquad (3)$$

On is the variance of X; measurements, Oy is the variance of Xj measurements and oy is the covariance of Xj and Xj. The variance and covariance values are calculated using the values from Equation (1), (2) and (3).

The water attenuation has **an** exponential function with the increase of the depth. By applying a natural algorithm (In) to the atmospheric corrected image (in radiance units), this relationship will be linear. This step is written as:

$$X_i = \ln(L_i) \qquad (4)$$

Where:

X_i = normalized image in b_i

L_i = atmospheric corrected image of b_i (radiance unit)

To generate a depth invariant index of bottom types within a pair of bands, the following formula is used:

$$\text{depth - invariant index}_{ij} = x_i - \left[\left(\frac{k_i}{k_j}\right) * (x_j)\right] \qquad (5)$$

2.4 Categorization of Habitat Classes

The categorization of habitat classes in this study is more based on the ecological classification approach. The ecological classification is not as straightforward as the geomorphological approach. The ecology of a habitat may be limited to the assemblage of plant and animal species and the substrate. Examples of the ecological classification classes are: coral, algal dominated, bare substratum dominated and seagrass dominated (Mumby, 1998).

HI. Results and Discussions

The environmental threats for the coastal environment of East Kalimantan in general are grouped into several issues: land use issues, mining industrial and pollution issues, human settlements, and destructive fishing. Forest degradation due to logging or mangrove conversion (e.g. to shrimp pond) caused the increase of the sediment discharge and the decrease of dissolved organic. Some coastal areas of East Kalimantan, particularly in Balikpapan, have decreased due to the rapid industrial and population growth. For example, the oil and gas industry have two large disposal basins, i.e: one in Tarakan (North part of Derawan Islands) and one in the Mahakam Estuary (South part of Derawan Islands). The East Kalimantan urban centers are mainly located in or near the coast and near the rivers. It is still common practice to use river and sea as public waste disposal sites. These domestic pollutions give some additional problems for the ecosystem. For instance, the disposal of plastic bags in the sea can cover coral and other filter feeder organism, thus cause their mortality. Blast fishing practices cause also a rapid habitat degradation. Although it is illegal, this fishing method is still common in Indonesia including in East Kalimantan. (Jompa and Pet-Soedc, 2002)

Some studies of the Derawan Islands highlighted that the blast fishing is the major cause of coral reef degradation (Siahainenia, 1999; Ismuranty, 2002; Jompa and Pet-Soede, 2002; Malik et. al., 1999). This practice gives a high impact to the coral reef degradation. A bottle of bomb, that explodes near or at coral reefs can destroy all corals within the radius of 1.2 m and can kill most marine organism within the radius of 77 m. This equals that the blast impact area is 1.9 ha. (Jompa and Pet-Soede, 2002).

Siahainenia et.al. (1999) conducted the coral reef assessment in 1999: 14 bomb pits were found in the west part of Derawan Island during the survey. He also noted that the coral reef degradation in Derawan Island is about 75% (comparing observations between 1994 and 1999). It takes decades or more for the damaged coral reefs to be recovered.

3.1 Shallow Marine Habitat

There are 8 species of seagrass found in the surrounding of the Derawan Island. The dominant species is *Thalasia hemprichii*. In the average, the seagrass coverage in Derawan in 2001 is approximately 37%. This coverage is low as compared to the observation of 1994, which was 56%. The substrate is a mixture of sand and rubble. Along the shoreline of the Derawan Island, the seagrass is dominated by *Halodule pinifolia*. (L1PI, 2001).

The coral reef conditions surrounding Derawan were intermediates to good condition. Table 5 illustrates the percent of the coral cover in the Derawan region. A survey done by LIPI in 1995 found 50 kinds of coral species around the Derawan Island. The coral reef growth was found up to a depth of 12 m. At a depth of 10 m, only patchy reef and at a depth of 20m almost no coral reef encountered.

Table 5. Live coral cover percentage in transect locations (LIPI-Ambon, 1995)

Transect Location		Live Coral Cover Percentage (%)		
		Im	3m	10m
1	East part of Panjang Island	28	57	4
2	West part of Panjang Island	38	54	46
3	East part of Derawan Island	21	35	31
4 '	West part of Derawan Island	9	35	55
5	Samama Island	41	51	29
6	Sangalaki Island	72	27	36

3.2 Generating a coral reef habitat map for habitat changing assessment

The input classification used is a depth invariant index of band 1 and band 2. Ground truth habitat points were not used during the selection of training samples. When the ground truth habitat points were used as training samples, their features did not match with their label classes. The mismatch may be due to a GPS position error when it is plotted on the Landsat image. Therefore, the training sample points were selected based on the user knowledge of the study area, and the evaluation of feature space. After the selection of the training samples, a paralellpiped classification decision rule is used to classify the image. The coral reef habitat maps derived from Landsat-5 1991 and Landsat-7 2002 are presented in Figure 5.

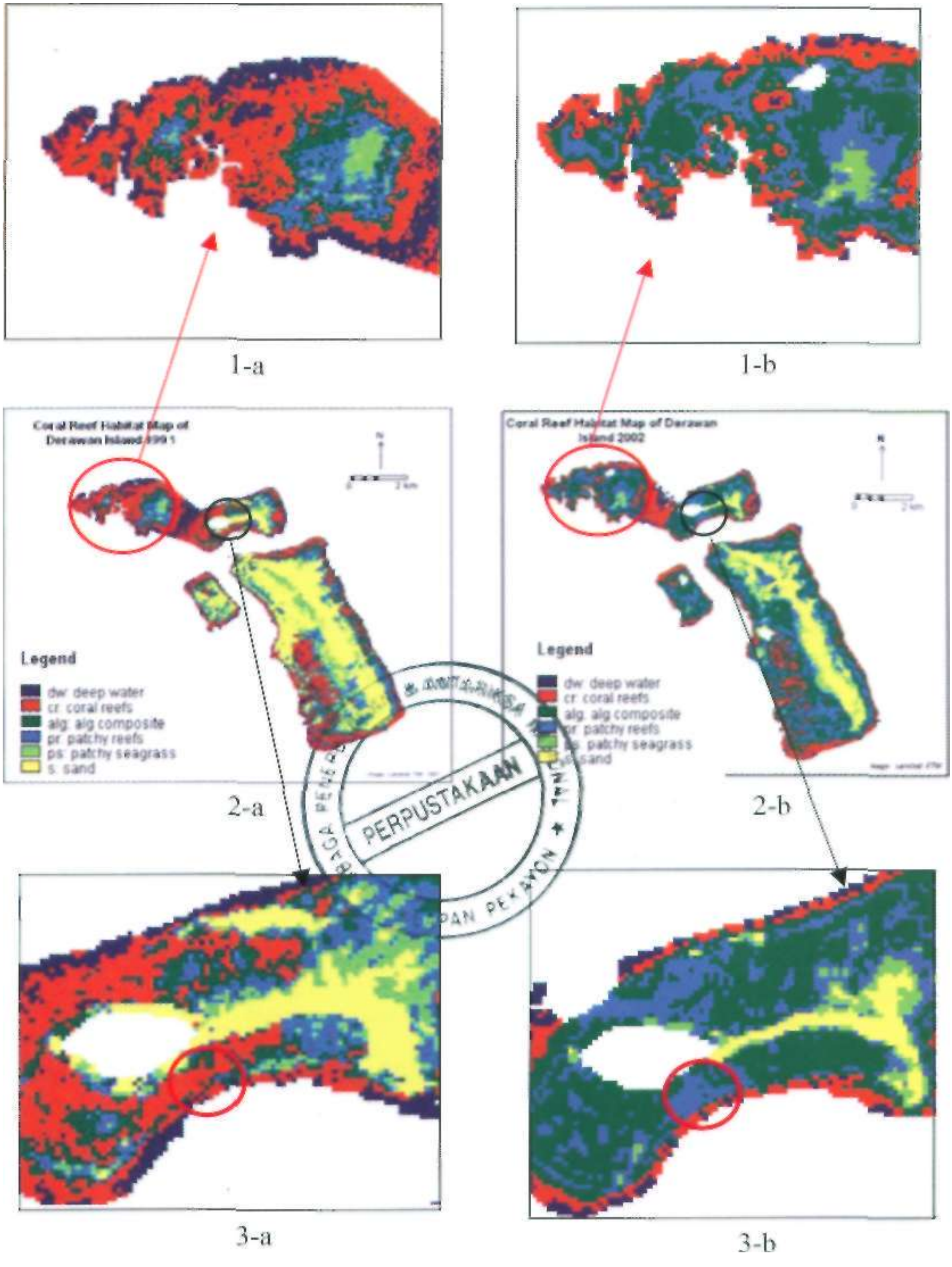


Figure 5. Coral reef habitat map of the Derawan Island in 1991 (1,2,3-a) and 2002 (1.2,3-b)

The comparison of the coral reef habitat maps of 1991 and 2002 shows a decrease of the coral reef habitat. This is clearly shown in the western part of the Derawan Island (Figure 5(1-a, 1-b)). Based on the reports and interviews with the local people, there was no significant natural disturbance occurred in the Derawan Islands. According to the thematic map of threats in Derawan Islands, produced by The Nature Conservancy, this particular area is affected by the fish bombing. The result is coincide with the study done by Siahainenia et.al (1999), where they found 14 bomb pits in the western part of Derawan Island during their survey.

Besides the bombing, an other human activity such as the boat transportation may also cause the degradation of the coral reef. For example, the dive resort in the southern part of the island (indicated with a circle in Figure 5(3-a, 3-b) started its operation in 1992. Based on the habitat map of 1991, there were more coral reefs in this area as compared to the map of 2002, when the area was dominated by the algae composite and patchy reef. This habitat degradation might be due to the fact that this zone is used as a dive boat transportation track.

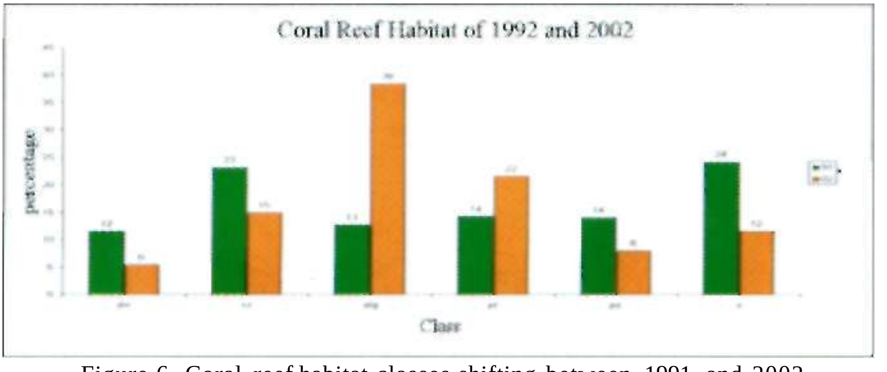


Figure 6. Coral reef habitat classes shifting between 1991 and 2002.

The overall coral reef habitat change between 1991 and 2002 is presented in Figure 6. Based on Figure 6, the percentage of coral reef and patchy seagrass have decreased from 1991 to 2002, whereas the percentage of algae composite and patchy reef has increased 38% and 22% respectively.

Table 6. Error matrix of the classified image

	(cr)	(dw)	(ps)	(pr)	(s)	(alg)	User Accuracy (%)
Coral reef (cr)	5	2	0	0	0	0	71
Deep water (dw)	0	2	0	0	0	0	100
Patchy seagrass (ps)	0	0	4	1	0	0	80
Patchy reef (pr)	0	0	1	14	0	0	93
Sand (s)	0	0	0	0	9	0	100
Algae (alg)	1	0	0	1	0	17	89
Producer Accuracy (%)	83	100	80	88	100	100	

Total accuracy: 89 %

3.3 Accuracy assessment

The most common accuracy assessment of the classified remotely sensed data is the error matrix, known as the confusion matrix. This is done by comparing the classified image as the result map with the 'true world classes. Half of the total numbers of habitat ground truth points were compared with the classified image, with the total accuracy for the map is 89%. The result of the accuracy assessment is presented in Table 6.

IV. Conclusions

It has been demonstrated in this researches how remotely sensed data can be used to detect the changes of coral reef habitat. Using data of Landsat-5 TM and Landsat-7 ETM of 1991 and 2002 respectively, it is possible to monitor the historic status of the coral reef environment in the Derawan Island.

There was a coral reef habitat change from 1991 to 2002, which represented a decrease of the percentage of coral reef and patchy seagrass. On the other hand, it was an increase of the algae composite and patchy reef percentage. The threats of coral reef in Derawan Islands were mainly from human activities, in particular blast fishing. In addition, the accumulation of oil spills from the boats, careless diving activity and domestic pollution also contributes to the degradation of the coral reef in this area.

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