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THE RELATIONSHIP BETWEEN TOTAL SUSPENDED SOLID (TSS) AND CORAL REEF GROWTH (CASE STUDY OF DERAWAN ISLAND, DELTA BERAU WATERS)

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Abstract. Total suspended solid (TSS) is one of the water quality parameters and limiting factor affecting coral reef growth. In this study, we used the algorithm of $TSS = 3.3238 * e^{(34.099 * \text{Green band})}$ (where green band is reflectance band 2) to extract TSS from Landsat satellite data. The algorithm was validated with field data. Water column correction method developed by Lyzenga was used to map coral reef. The result showed that the coral reef area in Berau waters decreased significantly (about 12,805 ha or around 36 %) from the year of 1979 to 2002. The most coral reef reduced area was detected around Derawan Island (about 5,685 ha). Further, some areas changed into sand dune. TSS concentration around Delta Berau and Derawan Island increased aproximately twice from 15- 35 mg/l in 1979 to 20-65 mg/l in 2002. The increase of TSS concentration was followed by the decrease of coral reef area.

Keywords: *Landsat,, total suspended solid (TSS), coral reef, Berau waters*

1 INTRODUCTION

Coral reef plays an important role in coastal ecosystem and coastal communities. Other function of coral reef ecosystem is coastal protection from mechanical energy of sea wave causing abration.

Coral reef ecosystem in Indonesia has the highest biodiversity in the world. However, with many activities of people in upland region including landuse changing caused an increase of total suspended solid (TSS) entering into coastal region. This can be a threat for coral reef health leading into coral reef degradation.

Study on the sedimentation effect on coral reefs has been widely reported by several researchers in the world. Mechanisms through shading and smothering coral sediments can cause stunted growth to mortality (Hubbard, 1997). Effects of sedimentation on the coral reef is a major factor resulting in the death of corals during the recruitment process through smothering mechanism (Fabricius *et al.* 2003).

Remote sensing technology and Geographic Information System can be used to map and monitor natural resources including coral reefs sinotpically in a wide area.

Many studies about TSS and coral reef using remote sensing data has been reproted such as Hasyim *et al.* (1997) produced TSS algorithm in Indonesia and Trisakti *et al.* (2005) used digital number for extraction information TSS in Surabaya waters.

Budhiman (2004) produced algorithm for TSS information extraction using remote sensing data for the Mahakam delta with an analytical approach. Parwati (2006) conducted an empirical approach to produce TSS algorithm by utilizing TSS data measured in the field (Delta Berau waters)., Many researchers used Lyzenga algorithm for coral reef studies emplyoing remote sensing data such as Siregar (1996).

One of the limiting factors for the growth of coral reefs is the fluctuation of sediment in the waters and the information regarding TSS and coral reef in teh Berau waters is still limited. Therefore, the purpose of this study was to examine the relationship between TSS and the coral reef colonies in Delta Berau waters of East Kalimantan.

2 MATERIALS AND METHOD

The study area was Delta Berau waters in East Kalimantan . Berau District bordering with Bulungan City in the west/ north and Makassar Strait in the east of the Kutai Regency. There are two major rivers flow into the Berau Delta i.e., Berau and Tabalar rivers. Those rivers are flowing through the district capital of Berau regency, then enter to the open sea with coral reef around Derawan island (Figure 1). The upland side was dominated with forest and along the rivers were dominated coal mining industry, plantations, rice fields, and settlements. The estuary was dominated with mangrove and fish ponds with some rice fields and settlements, while in the sea was dominated by coral reef.

Remote sensing data used in this research were Landsat 3 MSS and Landsat 7 ETM (Table 1). The selected Landsat data were relatively free from cloud coverage.

Research procedures such as data processing and analyses were described in Figure 2. Data standardization was conducted
by doing some image processing, such as image cropping, geometric correction, and atmospheric correction Parwati (2006).

Water conditions are affected by physical conditions of the surrounding environment. In general, the condition of the waters can be grouped according to the geographical conditions. TSS extraction using remote sensing data was analyzed by two approaches i.e., empirical and analytical approaches.

Budhiman (2004) produced algorithm for TSS extraction using remote sensing data for the Mahakam delta with an analytical approach. While, Parwati (2006) conducted an empirical approach to adjust the algorithm produced by Budhiman (2004) by utilizing TSS data measured in the field (Delta Berau waters), then produced the new algorithm

Figure 1. Study area located in Delta Berau waters.

Table 1. Remote sensing data, path/row, and acquisition date.

No	Data	Path /Row	Acqusition Date
1	Landsat 3 MSS	124/58 and 125/59	February 20, 1979
2	Landsat 7 ETM	116/58 and 116/59	July 8, 2002

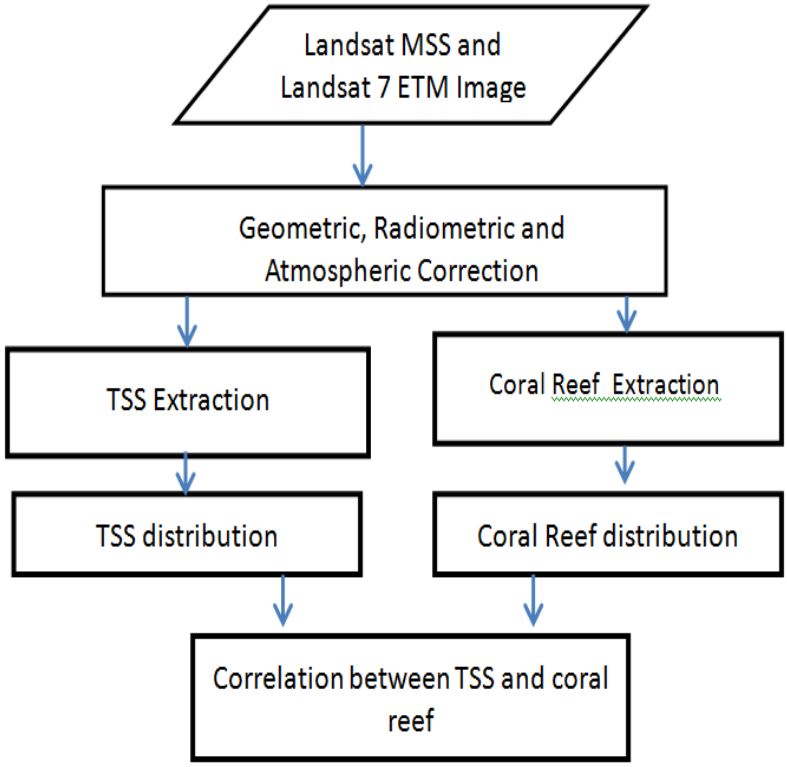

Figure 2. Flowchart of data processing and analyses.

for TSS in Berau waters as formulated as follows:

$$TSS\ (mg/l) = 3{,}3238 * e^{(34{,}099 * Green\ Band)} \quad (1)$$

where, Green Band = band 2 Reflectance.

Coral reef extraction using remote sensing data was formulated by Lyzenga (1981) including a water column correction. The intensity of light penetration decreases exponentially with increasing water depth, this process is known as attenuation. The water column correction approach was used to reduce the attenuation of light due to the water depth by using the ratio of two-band attenuation. Band one (blue) and band two (green) of Landsat were used to obtain the value of ki/kj. The value of ki/kj was the attenuation coefficient of the band one and band two which was obtained through the following equation:

$$ki/kj = a + \sqrt{\ } (a2 + 1) \quad (2)$$

Where, a=(var i band - band var j)/(2 x (covar band band i j)).

The depth-invariant index was calculated using the following formula:

$$Depth\text{-}invariant\ index = \ln band\ i - (ki/kj) \ln band\ j \quad (3)$$

where, i and j was band one and band two. The final step was to classify the results into several classes as needed. In this study the classes used were coral reef, seagrass, sand, and other class for cloud or unclassified data.

3 RESULTS AND DISCUSSION

3.1 TSS distribution

The implementation of TSS extraction algorithm in equation (1) from Landsat data in 1979 and 2002 produced a varied range of TSS values. TSS distribution for 2002 in Berau Delta waters was presented in Figure 3. The concentration of TSS around shore line reached up to 50 mg/l, but the concentration decreased toward the sea. Meanwhile, the TSS distribution in 1979 varied in wider range (Figure 4). Therefore, it was difficult to make a comparison between TSS in 2002

vs. 1979. We, therefore, sliced the TTS concentration into 22 classes (Table 2).
Figure 4 and 5 showed TSS distribution on 20 February 1979 and 8 July 2002 after conducting TSS concentration slicing into 22 classes. In general, TSS concentration in 1979 ranged of 15-35 mg/l, while TSS concentration in 2002 ranged of 20-65 mg/l. This result indicated that TSS concentration increased during the period of 1979-2002, and the concentration increased approximately twice within 23 years. The TSS distribution was significantly increased in the Berau Delta (Figure 4 and 5).

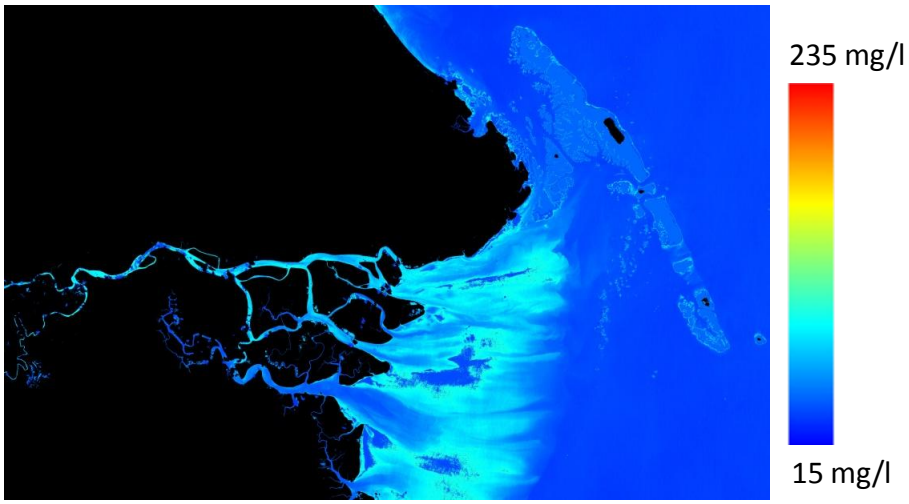

Figure 3. TSS distribution for 2002 in Berau Delta waters.

Tabel 2. List of 22 classes of TSS concentration by slicing method.

Class Number	TSS concentration (mg/l)
1	0 - 10
2	10-15
3	15-20
4	20 - 25
5	25-30
6	30 - 35
7	35-40
8	40-45
9	45-50
10	50 - 55
11	55-60
12	60-65
13	65-70
14	70-75
15	75-80
16	80-90
17	90-100
18	100-125
19	125-150
20	150-200
21	200 – 300
22	➢ 300

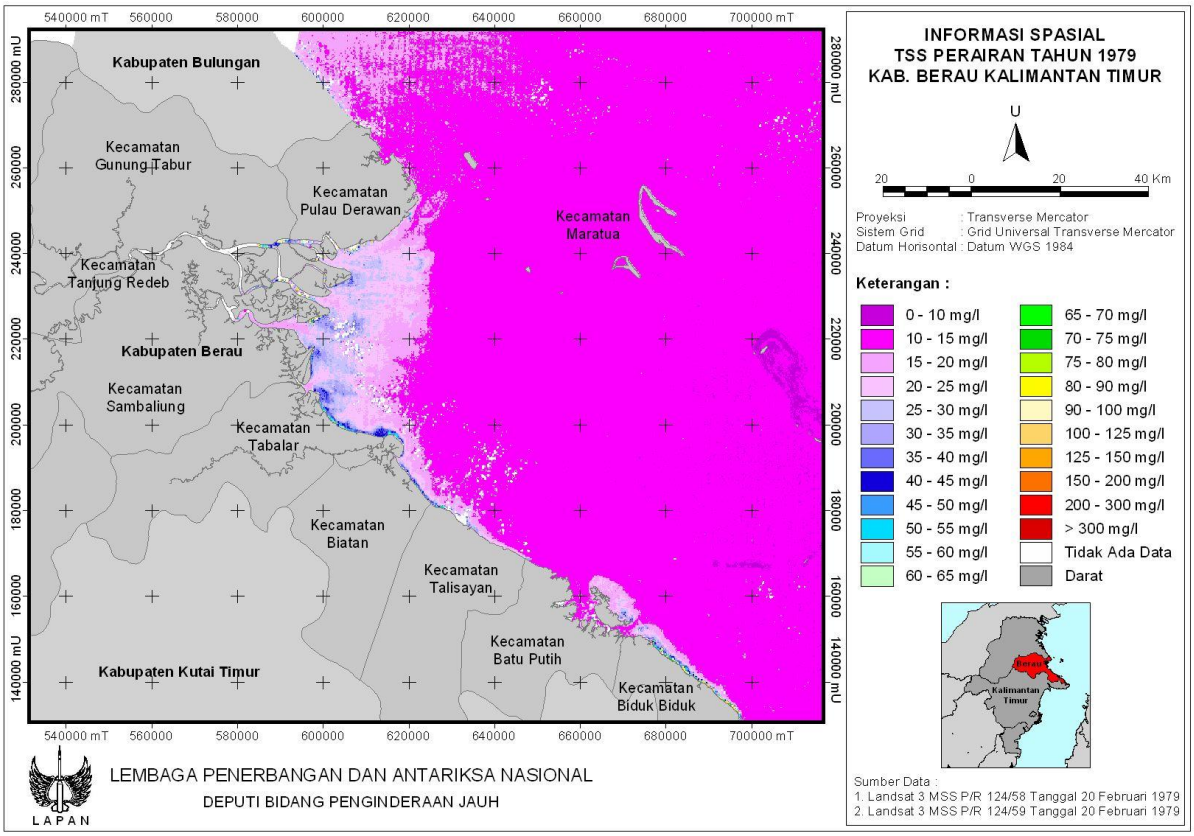

Figure 4. Distirbution of TSS concentration on 20 February 1979.

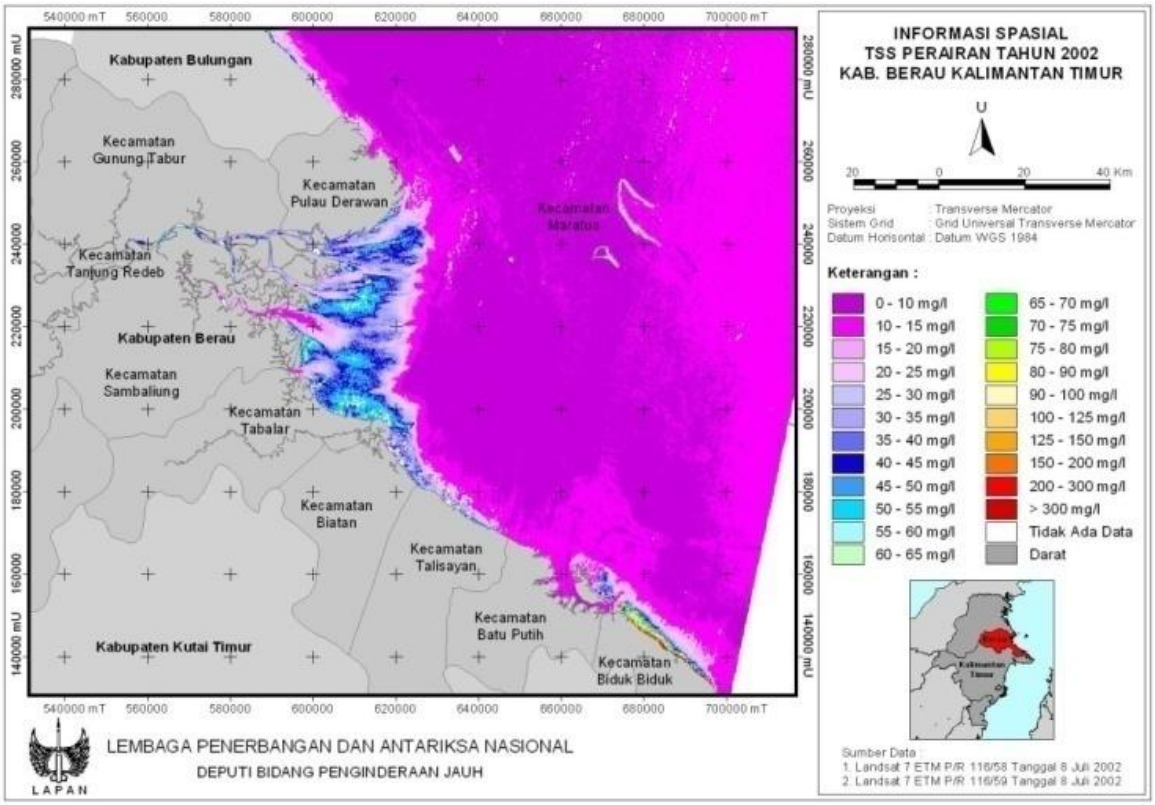

Figure 5. Distribution of TSS concentration in July 8, 2002

3.2 Coral reef analysis

Landsat 3 MSS in 1979 and Landsat 7 ETM in 2002 were also used for analyzing the coral reef coverage in the Delta Berau waters. Band one (Blue band) and band two (Green band) of Landsat were used to obtain value of ki/kj using Equation 2, then the values were used as input for Equation 3. Table 3 and Table 4 showed average of pixel values of blue band and green band for 30 training samples in shallow water region. Based on these data, the value of a and ki / kj were calculated, and the result was shown in Table 5.

Table 3. Average of pixel values of blue and green band for 30 training samples for Landsat 3 MSS in 1979.

Region	Band1	Band2	Region	Band1	Band2	Region	Band1	Band2
1	0,059	0,048	11	0,104	0,047	21	0,105	0,149
2	0,105	0,106	12	0,083	0,035	22	0,082	0,022
3	0,086	0,051	13	0,100	0,048	23	0,104	0,023
4	0,069	0,068	14	0,077	0,057	24	0,089	0,088
5	0,099	0,114	15	0,106	0,072	25	0,103	0,062
6	0,088	0,053	16	0,098	0,062	26	0,063	0,048
7	0,073	0,065	17	0,054	0,026	27	0,103	0,059
8	0,104	0,053	18	0,078	0,061	28	0,105	0,053
9	0,105	0,127	19	0,105	0,026	29	0,105	0,043
10	0,093	0,04	20	0,105	0,170	30	0,103	0,077

Table 4. Average of pixel values of blue and green band for 30 training samples for Landsat 7 ETM in 2002.

Region	Band1	Band2	Region	Band1	Band2	Region	Band1	Band2
1	0,196	0,205	11	0,208	0,223	21	0,237	0,251
2	0,195	0,208	12	0,207	0,242	22	0,143	0,137
3	0,151	0,156	13	0,230	0,257	23	0,161	0,169
4	0,143	0,146	14	0,124	0,117	24	0,240	0,254
5	0,114	0,102	15	0,143	0,131	25	0,123	0,112
6	0,200	0,209	16	0,209	0,229	26	0,173	0,176
7	0,173	0,170	17	0,221	0,243	27	0,216	0,232
8	0,183	0,180	18	0,117	0,108	28	0,126	0,131
9	0,145	0,157	19	0,276	0,332	29	0,242	0,283
10	0,111	0,101	20	0,276	0,333	30	0,227	0,243

Table 4. The values of a and ki/kj.

Parameter	Landsat 3 MSS, 1979	Landsat 7 ETM, 2002
a	-2.6999	-0.3107
ki/kj	0,1792	0,7364

The result of coral reef distribution for 1979 and 2002 for the Delta Berau waters was presented in Figure 6. For 23 years, coral reef coverage in Delta Berau waters decreased significantly from 35,505 ha in 1979 to 22,700 ha in 2002, a decrease of 12,805 ha (36.06%) (Table 5). Seagrass and sand coverages also decreased about 1,545 ha and 1,4387 ha, respectively. Derawan Island is located in red box. Figure 7 showed zoom up of coral reef distribution in Derawa Island waters for 1979 and 2002. Large number of coral reef reduction occurred in Derawan Island, coral reef decrease significantly from 16,122 ha in 1979 to 10,436 ha in 2002 (35% decrease; Table 6).

From the results, the increase TSS concentration in Delta Berau in the period of 1979-2002 was considered affecting the coral reef condition, where the coral reef in this waters significantly decreased, especially for coral reef in Derawan Island waters. Further, detail analysis is needed to make valid conclusion about factors affecting the coral reef condition since the phenomenon could be as result of its natural decay or human activities.

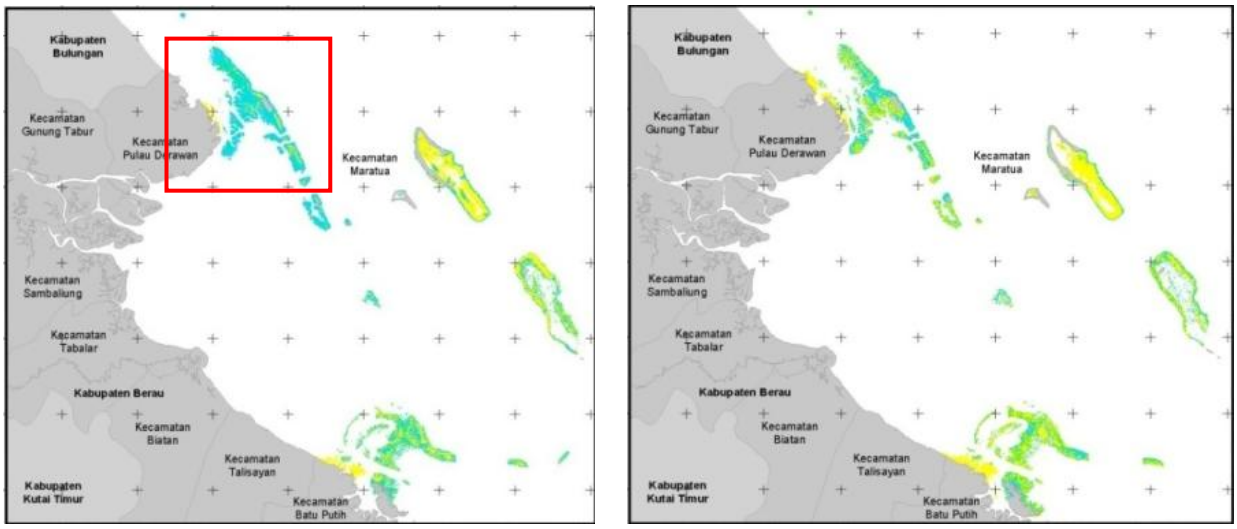

Figure 6. Coral reef distribution of Delta Berau Waters in 1979 and 2002 (cyan: coral reef, green: sea grass, yellow: sand)

Table 5. Coral reef change in Delta Berau in periods 1979 to 2002

Legend	(ha)		Changes	
	1979	2002	(ha)	%
Coral Reef	35505,51	22700,56	-12804,95	-36,06
Seagrass	4353,94	5899,27	1545,33	35,49
Sand	27648,45	42036,06	14387,62	52,04

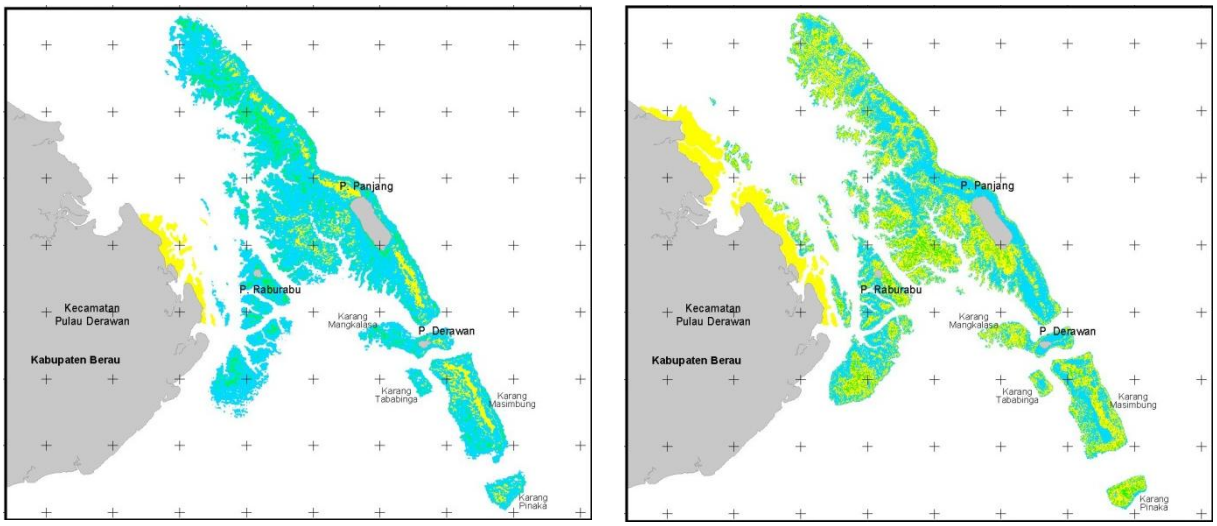

Figure 7. Coral Reef distribution of Derawan Island Waters in 1979 and 2002 (Cyan: coral reef, Green: sea grass, Yellow: sand)

Table 5. Coral reef change in Delta Berau in periods 1979 to 2002

Legend	(ha)		Changes	
	1979	2002	ha	%
Reef	16121,82	10436,00	-5685,83	-35,27
Sea Grass	1706,37	1354,83	-351,54	-20,60
Sand	1870,28	8993,63	7123,35	380,87

4 CONCLUSION

In Delta Berau waters, the coral reef area decreased significantly (about 12,805 ha or about 36%) in period of 1979-2002. The most coral reef reduction area was detected around Derawan Island (about 5,685 ha). Further, some area was changing into sand dune. TSS concentration in waters around Delta Berau and Derawan Island increased aproximately twice from 15-35 mg/l in 1979 and to 20-65 mg/l in 2002. We speculated that the increase of TSS concentration resulted in decreasing coral reef area.

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