The Relationship between the Health of Coral Reefs to The Damages of Jelateng Sub Watersheds in the Northern Coast of Sekotong, West Nusa Tenggara

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Abstract. Coral reefs are unique ecosystem and most of them are found in tropical areas. Remote sensing technology has the ability to present the information about the existence of marine resources, such as coral reefs. Remote sensing technology also provide the spatial information on wider area. This study is aimed to see how significant the effect of watersheds damage toward the condition of coral reefs because of erosion which is occurred in the upstream and sedimentation which is occurred in the downstream of the watershed. Acquisition of the data in this study used remote sensing image Landsat 7 ETM+ and Lansat 8 OLI in multi temporal, the data collection of this study used photo-quadrate technique and taking sample in the field. Spectral analysis and transformation of CTA (Classification Tree Analysis) was used to generate the level of the health of coral reefs. The method of RSI (Red Silt Index) was used to find out the degree of turbidity of the water. Analysis of the changes was done to find out the changes which were occurred on coral reefs based on the changes of turbidity that were occurred between 2000 till 2015. Based on the result, it shows that there is no effect on the changes of turbidity value toward the health condition of coral reefs in the northern coast of Sekotong Sub District 2000 till 2015. This is due to the use of RSI index or turbidity index that cannot be used in the condition of shallow water.

Keywords: Coral reefs, Landsat, Sekotong

1. Introduction
Coral reefs are a landform formed by the activity of organisms in the marine environment. The shape and the formation of coral reefs is influenced by some factors such as temperature, salinity, depth of sea, ocean circulation, supplies nutrients, turbulence and turbidity. To achieve maximum growth, coral reefs require clear water, with the water temperature relatively warm or hot (23°-25°C), big wave motion and smooth water circulation, also protected from sedimentation process. Secondary term for the existence of coral reefs is constant salinity of seawater. Coral reefs in Indonesia estimates occupy an area of 7,500 km² with the richness biological type of coral reef in the world [8]. Only 6.2% of those coral reefs are in good condition. This damage of coral reef is caused by some factor such as:
1. Human greed
2. Ignorance and indifference
3. Weak law enforcement
The appropriate way to help research the detection of the distribution of coral reefs is by using Remote Sensing. Remote Sensing more efficient in the use of time and cost, also data image can be analyzed visually and digital [6]. Landsat TM imagery commonly used for observation and management of coral reefs, because Landsat TM imagery has a high enough spatial and spectral resolution [11]. Landsat TM has 2 bands with spectral resolution which able to identify objects under the water. The ability of electromagnetic waves to penetrate to the water is very low because water will absorb some of the electromagnetic energy. It makes the ability to identify object under the water surface limited. Object can be observed or detected only at the depth of 15 to 30 meters. The condition of a watershed can be seen by the condition of the watershed downstream. Many downstream conditions contained sediment can be associated that the conditions experienced erosion. Watershed conditions which are decrease will certainly affect to the condition of coral reefs in the coastal area [4]. We need study to know how the erosion and watershed damage affected to the coral reef condition.

This study has some purposes:
1. Monitoring and mapping of the coral reef health conditions, especially on the northern coast of Sekotong some part of Jelatang watershed.
2. Monitoring and mapping the water conditions, especially the turbidity level of the northern coast of Sekotong some part of Jelatang watershed.
3. Analyze the relationship effect of pollution on the coral reef health condition in multi-temporal.

2. Study Area
The area in this study is northern coast of Sekotong, West Nusa Tenggara. Sekotong in West Lombok is well known with its sea ecosystem diversity. Pearl, seaweed, and fish are some commodities from Lombok. Unfortunately, the condition of coral reef in Sekotong are not in good condition. Only 10% of the coral reef are life coral and the other are death coral and smashed coral [4]. The high level of sedimentation is suspected as the main factor of the coral reef damage in Sekotong. Because of the condition of the coral reef and its diversity of sea ecosystem, Sekotong are choosen as the study area.

![Figure 1](image_url). The changes of sedimentation at Northern coast of Sekotong.(a) Landsat 7 ETM+ true color composit image recorded in 2000.(b) Landsat 8 OLI true color composit image recorded in 2015.

3. Method
Spectral correction at level radiance at sensor and reflectance at surface are applied to Landsat 7 ETM+ and Landsat 8 OLI. Corrected images at the level of reflectance at surface used to build make coral reef mullet map and corrected images at the level of radiance at sensor used to build Red Silt Index (RSI) to estimated the level of sedimentation. The value of sedimentation from RSI index compared to the filed condition using regresion analysis[7]. To get the RSI value we can use the formula as shown bellow.

\[
RSI = \frac{V_{\lambda 2} - V_{w}}{V_{\lambda 1} - V_{w}}
\]

(1)
where $V_2$ : wave length of band 2 in image  
$V_1$ : wave length of band 1 in image  
$V_{\infty}$ : darkest pixel value in sea area

RSI value are between 0 - 2. 0 value are located in sea far from the land (low sedimentation) and 2 are located in sea near the land (high sedimentation). Figure 3 shown the map as result of RSI value which represent the sedimentation condition.

Figure 2. Red Silt Deposition Index (RSI) Map Northern coastal of Sekotong West Lombok 2015

Radiometric correction process to get the reflectance at surface is using FLAASH (Fast Line Of Sight Atmospheric Analysis of Hypercubes)[10]. The sun glint correction also applied to the images to reduce the disturbance causing by the water column in the sea that will change the pixel value[2]. Sun glint correction[9] are applied by using this formula

$$R'_i = R_i - b_i \times (R_{\text{NIR}} - \text{Min}_{\text{NIR}})$$  \hspace{1cm} (1)

Where $R_i$ : reflectance value in visible band  
$b_i$ : regression value  
$R_{\text{NIR}}$ : reflectance value in near infra red band  
$\text{Min}_{\text{NIR}}$ : minimum reflectance value in near infra red band

After radiometric correction is done at level of at surface reflectance we assume that there is no atmospheric disturbance in the image so the spectral value in images are appropriate with the spectral reflectance curve. Radiometric correction are applied to image recorded in 2000 and 2015 so we can assume that pixel value in 2000 and 2015 are represent the same condition. The coral reef mapping are build using unsupervised classification with iso-data algorithm. This method classified the coral reef into 8 classes based on the value of sepectral reflectance. Figure 6 is the map represent the ditribution of coral reef as the resul of unsupervised classification.
Sample for the field check are obtained using transect line. Transect line are made by notice the variation of the condition in area study. Figure 7 are show the transect line of the sample.

**Figure 3.** Coral reef  Map Northern coastal of Sekotong West Lombok 2015

**Figure 4.** Transect line field sample on both of map unit, (a) Transect Sample RSI; (b) Transect sample coral reef condition

**4. Discussion**

Classification Tree Analysis method is used for benthic habitat mapping. This method is a part of image mining (data mining) methods as a variation of the decision tree or regression decision tree method. The advantage of this method is there is no minimum limit on the training sample so that the sample still can be processed, although only one pixel. Samples were gained 1 pixel only since the limitation of sampling in the field.

**Figure 5.** Map of Coral reef habitat in 2015
After getting the data benthic habitat, the next method is extracting a class that has a limit reef mapping to map the health of coral reefs.

The field survey is aimed to determine the composition of benthic habitat with photoquadrat methods [3]. However, in the practice there were various limitations in the field survey. The photo shoot was done without the use of frames or quadrant assistance as restrictions. The result which was obtained in the Sekotong Sub District showed that there are eight categories of benthic habitat, they are coral, coral rubble, coral sand, seagrass sand, coral sand, seagrass sand reefs, coral rubble sand, seagrass and sand which can be seen in Figure 3.

4.1. Mapping of coral reefs health

Mapping of the health of coral reefs used empirical method in which this method used regression value of 3 visible bands with the percentage of coral reef health on the field which was taken by transect photos.

| Koordinat X | Koordinat Y | B1 | B2 | B3 | Mean Percent Cover (%) | Percent cover (%) |
|-------------|-------------|----|----|----|------------------------|------------------|
| 391815      | 9035665     | 263| 389| 115| 33.3                   | 25 - 50          |
| 391785      | 9035695     | 267| 463| 187| 68.3                   | 50 - 75          |
| 392685      | 9034765     | 352| 496| 139| 40.0                   | 25 - 50          |
| 392715      | 9034795     | 363| 566| 215| 83.5                   | 75 - 100         |
| 392745      | 9034795     | 369| 550| 238| 39.0                   | 25 - 50          |
| 392715      | 9034765     | 438| 627| 225| 97.5                   | 75 - 100         |
| 392175      | 9035515     | 515| 745| 237| 70.0                   | 50 - 75          |
**Regression Statistics**

|                      |           |
|----------------------|-----------|
| Multiple R           | 0.691558  |
| R Square             | 0.478252  |
| Adjusted R Square    | -0.0435   |
| Standard Error       | 25.23169  |

**Table 2.** Statistic value from the regression result of pixel value and percentage of coral reef health.

|            | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|------------|--------------|----------------|--------|---------|-----------|-----------|-------------|-------------|
| Intercept  | -26.856      | 56.281         | -0.477 | 0.666   | -205.966  | 152.255   | -205.966    | 152.255     |
| B1         | -0.480       | 0.636          | -0.755 | 0.505   | -2.503    | 1.543     | -2.503      | 1.543       |
| B2         | 0.492        | 0.591          | 0.833  | 0.466   | -1.388    | 2.372     | -1.388      | 2.372       |
| B3         | -0.026       | 0.447          | -0.059 | 0.957   | -1.450    | 1.397     | -1.450      | 1.397       |

The result of equation in the regression analysis can be seen as follow:

\[ y = -26.856 - (0.48 \times B1) + (0.492 \times B2) - (0.02 \times B3) \]  \hspace{1cm} (2)

Where:
- \( B1 \) = Blue band
- \( B2 \) = Green band
- \( B3 \) = Red band

Then, the equation was applied to Landsat 8 OLI 2015 that had been corrected by surface reflectance and masking of coral reef. Previously, delimitation of sea boundary derived from the spectral values manually using PCA bands PC 2, which PC 2 gives a clear boundary between deep water and shallow water.

![Figure 8. Map of Coral Reef health in 2015](image-url)
The equation was also applied to the image in 2000 with the assumption that the pixel values in 2000 and 2015 represented the same reef conditions which were clear from atmospheric disturbances because it has already corrected till surface reflectance.

North coast of Sekotong in some parts of DAS Jelatang is generally swifting water area, because of the large ship traffic from outside Lombok Island, tourist boats and or fishing boats. From 4 classes of existing coral reef health, in 2000 the health of coral reefs were dominated by a class of 25-50% health, covering to 1.7424 million m² from the total covering area of Coral reef amounted to 5.8824 million m² on the north coast Sekotong. In 2015, the health condition was dominated by 25-50% class health with 2.5101 million m² width from 7.9713 million m² of total covering area of coral reefs. Coral reef area with class of 0-25%, which is still in the same condition to 2015, is 486 900 m² area. Coral reef area with class of 25-50%, which still in the same condition to 2015, is 550 800 m² area. Coral reef area with class of 50-75%, which still in the same condition to 2015, is 520 200 m² area. Coral reef area, with class of 75-100%, which still in the same condition to 2015, is 249 300 m² area.

4.2. Monitoring and mapping the condition of water turbidity level

The first stage to do in the process of mapping the level of turbidity is to make linear regression analysis between the actual turbidity value in the field and the value of RSI index which were obtained from the previous work. Values of correlation (R²) from regression between the pixel values of the RSI index and turbidity index shows the value is 0.87 which shows that there is a match between the pixel values and field of turbidity data.

\[ y = (246,69 \times b1) - 109,62 \]  

Note: \( b1 \) is pixel value from RSI index since the regression turbidity value in the field does not use pixel value from the real imagery.
Table 4. Regression of pixel value of RSI index with the value of turbidity as the results of laboratory in 2015.

| Coordinate X (E) | Coordinate Y (N) | Pixel value | Turbidity |
|------------------|------------------|-------------|-----------|
| 394305           | 9032395          | 0.4635      | 1.53      |
| 394275           | 9032605          | 0.5080      | 12.96     |
| 394605           | 9031735          | 0.4524      | 7.35      |
| 394515           | 9031765          | 0.5267      | 23.05     |
| 395415           | 9031465          | 0.7031      | 66        |
| 395385           | 9031555          | 0.6336      | 55        |
| 396645           | 9031915          | 0.4857      | 21.66     |
| 396555           | 9032065          | 0.4628      | 12.68     |
| 397275           | 9033775          | 0.4761      | 4.91      |
| 397245           | 9033685          | 0.4639      | 3.87      |
| 398965           | 9034645          | 0.6864      | 64        |
| 398385           | 9034375          | 0.6575      | 41.73     |
| 391005           | 9035965          | 0.5133      | 0.84      |
| 391695           | 9036085          | 0.4870      | 0.95      |

Map of modeling result of turbidity level in 2015 and 2000 can be seen in Figure 10 and Figure 11 as follows:

Figure 10. Map of Turbidity level in 2015

Figure 11. Map of turbidity level in 2000

Table 5. Comparison between turbidity value and condition of coral reef health in 2000-2015.

| Coordinate X | Coordinate Y | Turbidity value in 2000 (FTU) | % Coral reef health in 2000 (%) | Turbidity value in 2015 (FTU) | % Coral reef health in 2015 (%) |
|--------------|--------------|-------------------------------|---------------------------------|-------------------------------|---------------------------------|
| 394305       | 9032395      | 17.49                         | 0-25                            | 62.30                         | 25-50                            |
| 394275       | 9032605      | 34.96                         | 50-75                           | 36.37                         | 50-75                            |
| 394605       | 9031735      | 15.73                         | 0-25                            | 19.81                         | 0-25                             |
| 394515       | 9031765      | 2.06                          | 25-50                           | 39.70                         | 50-75                            |
| 395415       | 9031465      | 43.19                         | 50-75                           | 63.44                         | 75-100                           |
| 395385       | 9031555      | 52.85                         | 25-50                           | 64.12                         | 75-100                           |
| 396645       | 9031915      | 60.46                         | 75-100                          | 36.57                         | 50-75                            |
| 396555       | 9032065      | 50.87                         | 50-75                           | 48.87                         | 75-100                           |
From 14 existing sample points, most of them have higher turbidity value in 2015. This shows that the process of sedimentation during last 15 years in the northern coastal areas of Sub District Sekotong increased, which caused the turbidity levels in the water also increased. The condition indicates the mutual influential relationship between the increasing of turbidity and the degradation of coral reef health. This happens because the increasing of turbidity can reduce the photosynthesis ability of coral reef organisms which causes the degradation of coral reef condition and eventually the death of coral reef.

Based on the values in the table above, it can be seen that the turbidity value is not related to health condition of coral reef. The inversely patterns of both conditions are not found. Indeed, the pattern changes value which indicate the relation from both condition are not found. The reason of the inverse pattern is bias in reading the pixel value. Bias in the reading the value is due to the use of algorithm for modeling the health of coral reefs, reading the value of sediment which is very high as a coral reef, as the result, it can be seen on the table that the sample number 6 of turbidity is high but the value for the percentage of healthy reef in the sample is also high. Error in reading the value of coral reefs health also occurs in other samples. These results indicate that the hypothesis used in this study was rejected. It is due to the value of turbidity resulting from RSI index using Landsat 7 and Landsat 8 can not be directly used to estimate the health condition of coral reefs.

5. Conclusions
1. Monitoring of the health condition of coral reefs in the northern coast of the Sekotong Sub District shows that within 15 years, from 2000-2015 there has been a deterioration of the health of coral reefs, especially in coastal area because it has a lot of land use activities, such as land use change into residence and tourism place, while for the more remote areas of the coastal reef health condition is better.
2. Monitoring of waters condition, especially the level of turbidity in the north coast of the Sekotong Sub District shows that within 15 years, from 2000-2015 there has been turbidity increasing/improvement, especially in the Lembar bay area because of the activities on loading and unloading ships and pond.
3. Based on the result of this research, there is no effect of changes in turbidity value on the health condition of coral reefs in the northern coast of the District Sekotong in 2000-2015. This is due to the use of the index RSI cannot be used for shallow water.
4. Assessment of the relationship between turbidity waters and coral reef health conditions should not be done using the RSI index. It should be done by using the interpolation method which does not depend on the value of the pixel.

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