Analysis of Various Vegetation Indices of Landsat Thematic Mapper Satellite Data to Identify the Distribution of Coral Reef (Case Study in Enggano Island, District of North Bengkulu, Bengkulu Province)

Bambang Sulistyo

Faculty of Agriculture, University of Bengkulu, Bengkulu, Indonesia
Jalan WR. Supratman, Kandang Limun, Bengkulu 38371, Indonesia
E-mail: bambangsulistyounib@gmail.com

ABSTRACT

This research was aim at performing analysis of various vegetation indices of Landsat *Thematic Mapper* satellite data to identify the distribution of coral reef in Enggano Island, District of North Bengkulu, Bengkulu Province. This research is based on the realities that: 1. Vegetation indices analysis are generally only used for objects on the land; 2. Analysis of coral reef using remotely-sensed data are mainly use multispectral classification technique, Shallow Water Image Mapping, and Lyzenga's. Materials used were mainly Landsat *Thematic Mapper* satellite data and Map of Joint Operation Group. GIS Programs used to analyze were ILWIS (Integrated Land and Water Information Systems) version 3.4 and ArcView version 3.5. Methods applied was by performing analysis of various vegetation indices of Landsat *Thematic Mapper* satellite data, which are RVI (*Ratio Vegetation Index*), NDVI (*Normalized Difference Vegetation Index*), and SAVI (*Soil Adjusted Vegetation Index*). The result of every analysis of vegetation index then was used as a base for on-screen digitizing in areas where the boundary of coral reef existence is probably exist such that can be gained digital data of coral reef. The accuracy of the result was checked by overlaying it (overlay analysis) onto Map of Coral Reef derived from topographic map published in 1942 (Map of Joint Operation Group, and used as a Reference). Analysis of vegetation index is said to be **"*Good*"** if the accuracy is ≥ 80% (according to Daels and Antrop).The result of research shows that the overall accuracy were 67.60% (RVI), 65.40% (NDVI), and 73.16% (SAVI). It revealed that the accuracy of coral mapping using all vegetation indices can be said as "***Not Good***".

Key words: remote sensing, vegetation indices, Landsat TM, coral reef, accuracy

INTRODUCTION

Former President Susilo Bambang Yudhoyono on the Archipelago National Day in Padang on December 13, 2006 stated that: "*If we do not exploit the potency of the sea for the welfare of the Indonesian people, then there must be something wrong in this country*" (Gandawilaga, 2012; Sulistyo, 2012). This concern is justified because Indonesia has the very large potency of marine resources, but it has not been used optimally (Dahuri *et al*. 2001).

Almost 2 decades ago some of the provinces in Indonesia, including the Province of Bengkulu, conducted an inventory of coastal and marine areas through project-based activities called Marine and Coastal Resource Management (MCRM). This activity is an early stage in order to draw up a plan on coastal and marine areas (Sulistyo, 2007).

In any event planning required the availability of complete, detailed, and up to date data (Sutanto *et al*, 1986; Sutanto, 1987). Such data is generally obtained by resource inventories. One of the necessary data in the integrated planning of coastal and marine areas is the Coral Reef Map. By knowing the distribution of coral reefs, the determination of the planning and development of coastal and marine areas can be conducted better.

Coral reef ecosystems are fertile and rich in food (Soekarno, 2001) and have bio-diversity and high productivity. Coral reefs also serve as a provider of food, breeding sites, and shelter for a population of organisms that live in it. A variety of organisms that live in the coral reefs are also a source of biodiversity that can be exploited for the benefit of humans, such as pharmaceuticals, and foodstuffs. In addition reefs also contribute to marine fisheries and tourism. However, these ecosystems are extremely sensitive to the changes in the surrounding environment. Coral reefs growths are affected by the sunlight, temperature, salinity, water transparency, water movement, and the

substrate. While the limiting factors include the water depth (coral reefs can not thrive in waters deeper than 50-70 meters) and air (coral reefs grow at a rate of the lowest tides). There are 3 types of coral are: Fringing Reefs / Shore Reefs, Barrier Reefs and Atoll.

Procurement of an update Coral Reef Map is not easy to be prepared only with conventional technology because it will take time, effort and costly. Remote sensing is a technology that offer solutions to provide update map with the time, effort and cost relatively less for very large areas.

To know the information of objects that have been recorded by the sensors one needs to interpretate, i.e. an attempt to connect data recorded with real objects on the surface of the earth and assess their importance (Lillesand *et al.,* 2004). Interpretation or classification by using digital data is one important process to obtain information from satellite data. Classification is done based on the spectral value because every object has a special nature in reflecting energy.

There are several interpretation techniques that can be used to obtain the distribution of coral reefs, namely multispectral classification using maximum likelihood, as done by Mumby *et al.*, (1997), Andréfouët *et al*., (2000), Mumby and Edwards (2002), Andréfouët *et al*., (2003), Pahlevan *et al.*, (2006), and Benfield *et al*., (2007), using the algorithm SWIM (Shallow Water Image Mapping) and methods Lyzenga (Lyzenga, 1981). Another method also used by Mumby *et al.* (1997) is agglomerative hierarchical classification with group-average sorting. An alternative proposal is object-oriented classification, which consists of two steps, segmentation and classification. Segmentation creates image-objects and is used to build blocks for further classifications based on fuzzy logic. Another method that has been used is ISODATA (iterative self-organizing data analysis), which uses a combination of Euclidian squared distance and the reclassification of the centroid (Call *et al*., 2003).

Sulistyo (2007) has done mapping the distribution of coral reefs using multispectral classification methods in Enggano using Landsat Thematic Mapper satellite imagery. The results showed that the Overall Accuracy obtained was 80.47%, ommission of Error was 19.53% and Commission of Error was 28.66%. Those results indicate that the accuracy obtained can already be considered as Good (according Daels and Antrop).

In the analysis of digital of remote sensing data it is known an analysis called vegetation index. Vegetation index is a mathematical combination of satellite bands, which have been found to be sensitive indicator of the presence and condition of green vegetation. It is based on the reflectance properties of vegetation in comparison with water on the one hand and bare soil on the other hand. Vegetated areas have high reflectance in the near infrared and low reflectance in the visible red (Lillesand et al., 2004). Normalized difference vegetation index (NDVI) calculated from the visible and near-infrared light reflected by vegetation and the healthy vegetation absorbs most of the visible light that hits it and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Calculations of NDVI for a given pixel always result in number that ranges from minus one (−1) to plus one (+1); however, no green leaves give a value close to zero. A zero means no vegetation and close to +1 (0.8–0.9) indicates the highest possible density of green leaves, while negative values (< 0) indicates waterbody.

Normalized Difference Vegetation Index (NDVI) is formulated as (Silleos *et al*., 2006):

$$NDVI = (NIR - IR) / (NIR + IR) \quad (1)$$

where NIR and R indicate channel or band of Landsat Thematic Mapper which are near infrared and visible red respectively.

NDVI that was initially developed by Rouse *et al*. (1974). Then, the concept of NDVI has been modified by other scientist by considering some other factors. Huete (1988) modifies NDVI into SAVI intended to minimize the effects of soil background on the vegetation signal by incorporating a constant soil adjustment factor L into the denominator of the NDVI equation, and is formulated as (Silleos *et al*., 2006):

Soil Adjusted Vegetation Index:

$$SAVI = (NIR - IR)*(1 + 0.5)/(NIR + IR + 0.5) \quad .....(2)$$

where: NIR is the near infrared band, IR is the red band, X is the noise soil, i.e. 0.08, γ is the slope of soil line, i.e. 1.05, b is the coefficient value, i.e. 0.044, and c is the coefficient value to reduce the variation of soil calibration, i.e. 0.5.

Another simple vegetation index is called Ratio Vegetation Index (RVI) and is formulated as:

Ratio Vegetation Index:

RVI = NIR / IR .....(3)

Evaluation of the accuracy of the analysis of data derived from remote sensing has been recognized as a tool to test whether or not the data for a particular application (Jansen and van der Wel, 1994), as well as the classification of coral reefs. Evaluation of accuracy will provide the level of confidence for subsequent use, such as for input into the GIS that will be used in planning. Evaluation of accuracy must be done because the quality of data generated is depends on many parameters which are not free from errors, examples of which include the sensor system, the devices and the software, and also human error. One evaluation of the accuracy of the classification of Landsat Thematic Mapper can be done by overlaying it onto the reference data (Short, 1982). Daels and Antrop (1981) states that the interpretation of the results is said to be as Good if it has at least 80% accuracy.

This research was aimed at performing analysis of various vegetation indices of Landsat *Thematic Mapper* satellite data to identify the distribution of coral reef in Enggano Island, District of North Bengkulu, Bengkulu Province.

MATERAILS AND METHODS

Location

The research location is Enggano Island which is administratively part of the District of North Bengkulu, Bengkulu Province. Geographically lies between 102.13^{o} and 102.44^{o} East Longitude and between 5.27^{o} and 5.52^{o} South Latitude. From the sea depth data published by the Department of Hydro Eceanografi (Dishidros) it shows that reefs are at a depth of about 25 meters below sea level, a condition that allows assessing the existence of coral reefs using Landsat Thematic Mapper.

The main data required in the study include:

- Map Sheet of Enggano (Map of JOG) at scale of 1: 100,000.
- Topographic Map of Sheet 0910 at scale 1: 250,000
- Satellite Imagery covering Enggano (ie path/row 125/064) and were recorded in 2000.

Software and tools for research include:

- ILWIS (*Integrated Land and Water Information System*) version 3.4.
- ArcView version 3.5.

Stage of the Research

Stages of research include: 1) preparation, 2) vegetation indices analysis, 3) digitization, 4) comparative analysis through overlay analysis, and 5) writing a report and mapmaking.

RESULTS AND DISCUSSION

The color composite of Landsat Thematic Mapper satellite imagery covering Enggano Island is presented in Figure 1. In general, the object of the reef appears in dark blue, the sea water is presented in black, clouds in white, while the green is vegetation.

Figure 1. Landsat Thematic Mapper satellite imagery covering Enggano Island prior to interpretation

Map of Coral Reefs as a result of the analysis of various vegetation indices from Landsat Thematic Mapper satellite imagery is presented in Figure 2, while their areas is presented in Table 1.

Table 1. Total area of reef as a result of digitization (hectares)

No	Sources	Area
1	Map of JOG (Refernce)	6,116.18
2	Analysis using NDVI	4,914.93
3	Analysis using RVI	5,052.99
4	Analysis using SAVI	5,716.06
Average		5,450.04

Results of interpretation of Landsat Thematic Mapper satellite imagery which was recorded in 2000 showed that the area of coral reefs in Enggano Island is 5,450.04 hectares (in average). Reefs grow at around Enggano Island with thickness (the distance from the shoreline towards the sea) ranging between 200 meter (in the North) up to 1,300 meter (in the East, South and West).

The accuracy of the analysis of a variety of vegetation indices are presented in Table 2. Overall Accuracy is the area of correctly analyzed, that is coral reef exists not only in the Reference Map but also in the Results of Digitizing. Two errors are Ommission of Error and Commission of Error. Ommission of Error is where coral reef is found only in the Reference.

Map but it isn't found in the Results of Digitizing, while Commission of Error is where coral reef isn't found in the Reference Map but it is found in the Results of Digitizing.

Table 2. The level of accuracy of the results of the analysis of a variety of vegetation indices from Landsat

No	Vegetation Index	Overall Accuracy	Ommission of Error	Commission of Error
1.	NDVI	65.60	34.40	14.76
2.	RVI	67.60	32.40	15.02
3.	SAVI	73.16	26.78	20.29

The test results in this study show that the Overall Accuracy obtained is 65.40% for NDVI, 67.60 for RVI, and 73.16 for SAVI. This shows that the Overall Accuracy of the digitization of Landsat image analysis results obtained from the analysis of vegetation index can not be considered as **Not Good**, according to Daels and Antrop, so that the information obtained should not be used for further purposes. That is, the analysis of a variety of vegetation indices of the Landsat Thematic Mapper satellite imagery to obtain information related to the deployment of the coral reef does not produce better accuracy than the results of the analysis that had been previously suggested, namely

multispectral classification, using the algorithm SWIM (Shallow Water Image Mapping), Lyzenga and other methods.

As the name implies, the analysis of vegetation indiex is only going to work well when used for the analysis objects that were indeed associated with vegetation that is located on the mainland and not the other objects located in the ocean, as well as the presence and distribution of coral reefs.

The value of Omission of Error and Comission of Error are logically smaller than the figures obtained. This is because in fact there is a time difference between the reference map (which was published in 1940 in the framework of the Joint Operation Group) and the results of interpretation from Landsat Thematic (which was recorded in 2000). The time difference between 1940 to 2000 are in fact naturally has provided an opportunity of coral reefs to grow and change. So, for the future reference, the interpretation of the analysis of vegetation index using Landat Thematic Mapper image can not be used.

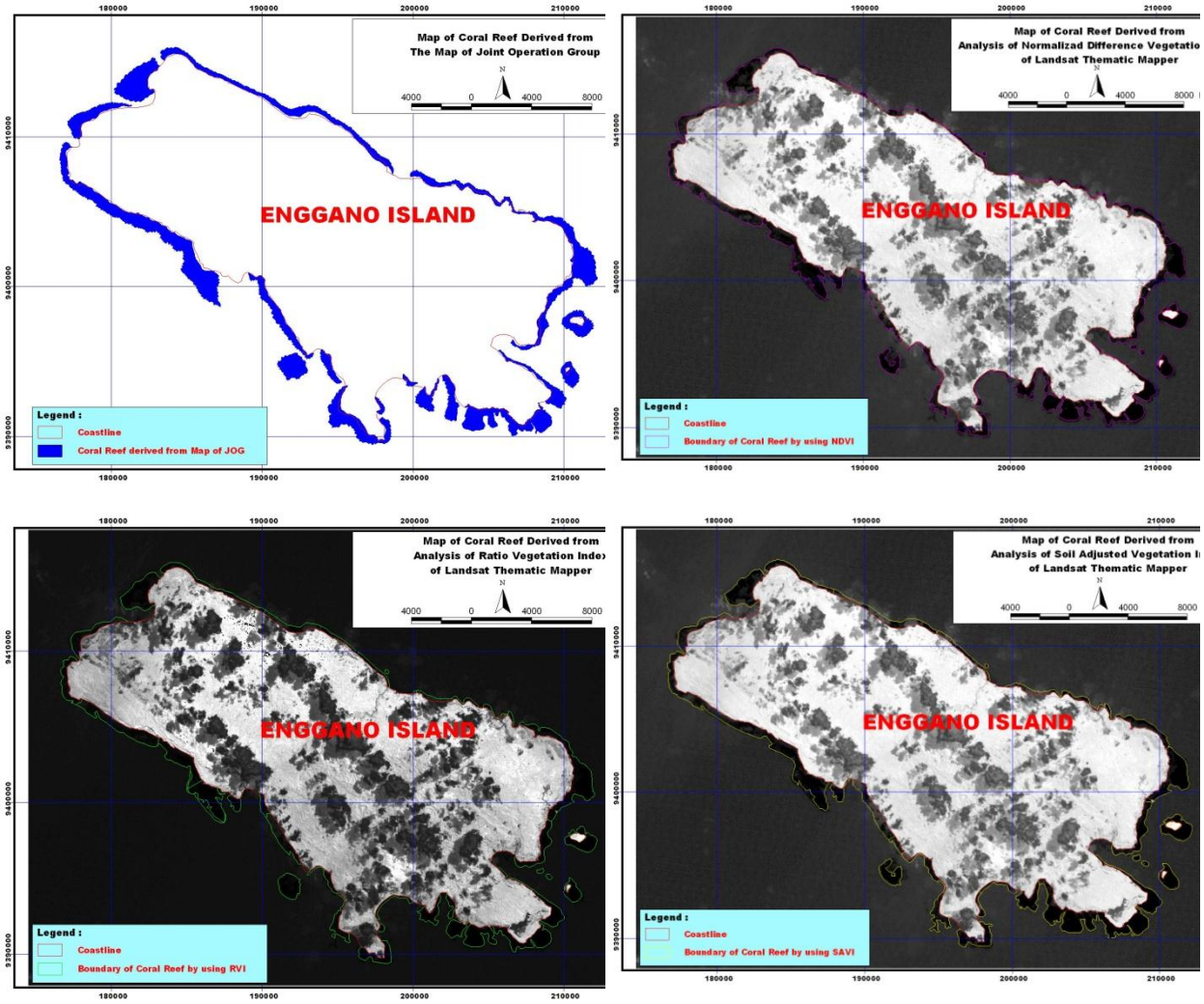

Figure 2. Map of Coral Reefs as a result of the analysis of various vegetation indices from Landsat Thematic Mapper satellite

CONCLUSION

By using remote sensing technology, in particular using various analysis of vegetation indices of the Landsat Thematic Mapper satellite imagery can indeed identified the existence of coral reefs, both the area and its distribution, faster and cheaper. Results of the analysis of Landsat Thematic Mapper satellite imagery recorded in 2000 showed that the area of coral reefs in Enggano is 4,914.93 hectares (with NDVI), 5,052.99 hectares (with RVI), and 5,716.06 acres (with SAVI).

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