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Integration in situ measurement and medium resolution imagery to develop digital health chart; preliminary study of coral reefs on small islands, Spermonde Archipelago Indonesia

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ABSTRACT

Characteristics of corals spectral from different species are expected have optically different characters. This study classified the dominant substrate of shallow water base on spatial resolution of imagery and in situ measurement and analyzed the accuration of Landsat 8 OLI_TIRS and Sentinel-2A satellite imagery to determine health of coral reefs. The image processing are atmospheric correction, cropping, masking, Depth Invariant Index, Unsupervised classification, ground truthing, reclassify, accuracy assessment, and spectral reflectance analysis. Unsupervised classification used IsoData method with Lyzenga application to detection of coral reefs condition. Spectral measurement by spectroradiometer underwater, photo underwater, and geotagging are conduct as in situ measurement. Spectral reflectance of medium spatial resolution image and insitu measurement are integrated to discriminate of live coral, dead coral cover with algae, rubble and algae. The results of this study show a baseline for develop the Digital Coral Health Chart as an approach to determine living coral condition using remote sensing techniques. It can be used as an effective way for detecting and monitoring of dynamic changes of coral reefs on small islands in Spermonde Archipelago. Image analysis integration and in situ survey results show that rubble and dead coral with algae were indicating as coral death due to either damaging human activity and natural death.

Keywords: Coral, Landsat 8 OLI_TIRS, Sentinel 2a, spectral, Spermonde Archipelago

1. INTRODUCTION

Remote sensing technology utilization has been highly developed for coastal area natural resources identification and monitoring, such as for coral reefs. Coral reef functions to protect other components of marine and coastal ecosystems from wave pressure and storms. Besides, coral reefs also providing attractive tourism spot. Compared to other ecosystems, coral reefs is the most vulnerable and easily destroyed [12]. A study of coral reefs using satellite imagery aims to produce a color change equation on damaged coral reefs by image processing approach and the least squares method based on the average value of Red, Green, Blue (RGB) [11], although the color classification

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determination was still manually done by relying on the eyesight of a person. In 2014-2017 a study was carried out on the geospatial dynamics of shallow water ecosystem cover on the outer islands, middle inner, and middle outer Spermonde Islands [17]. From the result of this study, spatial information of the cover, status and condition of coral reefs and sea grass beds from 1972-2016 (44 years) were obtained.

Some fundamental studies of remote sensing on spectral reflectance of corals and other bottom substrates collected from different parts of the world [8]; [13]; [15]; [16]; [6]; [10]; [19]; [18]; [21] shows that the shapes of reflectance spectra of live corals, dead corals, sand, sea grasses, green, brown and red algae are consistent in different locations of the world. There are several types of coral in coastal areas that have different life forms, species and pigments. Each coral species will emit different electromagnetic energy and the emission will be captured by multispectral and hyperspectral sensors [14]. Collecting spectral reflectances of different bottom types is an important step in shallow water mapping using remote sensing

Coral disease is defined as an abnormal conditions of associated organisms which have important role in coral reefs that are caused by external factors such as infected disease or internal factors that are not functioning properly [1]. Based on these causes, coral disease can be divided into two kinds, pathogenic infections and non-infectious pathogens [20].

Continuous damage to coral reefs can lead to diseases that can reduce the quality and quantity of coral in Indonesia and even in the world [5]. The causes of coral disease are still largely unknown [9], but from several studies, various human activities can change environmental conditions in coral reef ecosystems which have the potential to reduce coral's resistance to microbial infections or increase virulence of pathogens. 95% of threats to coral reefs in Indonesia are caused by human activities [2].

The purpose of this study is to conduct basic research as a preliminary study to develop a digital health chart. This preliminary study includes the analysis of spectral patterns on coral reefs through the integration of in situ measurements with Landsat 8 OLI_TIRS imagery to compare similarities and differences in digital reflectance on the same object and different objects. In situ measurements consist of cover on coral reefs condition measurement using the LIT (Line Intercept Transect) method, and spectral measurements on coral reefs using an underwater spectroradiometer.

2. MATERIALS AND METHODS

2.1 Study area and data collection

This research is located in Barrang Caddi Island 11,48 km west of Makassar City centre. The area of the island reaches more than 6.79 ha with coral reefs surrounding the island (Figure 1). Barrang Caddi Island is one of small islands of the Spermonde archipelago. There is a marine protected area at South of Barrang Caddi Island, which is developed by the community with the government to maintain and improve the quality of coral reefs ecosystem and at the same time maintaining and improving the quality of other resources associated with coral reefs.

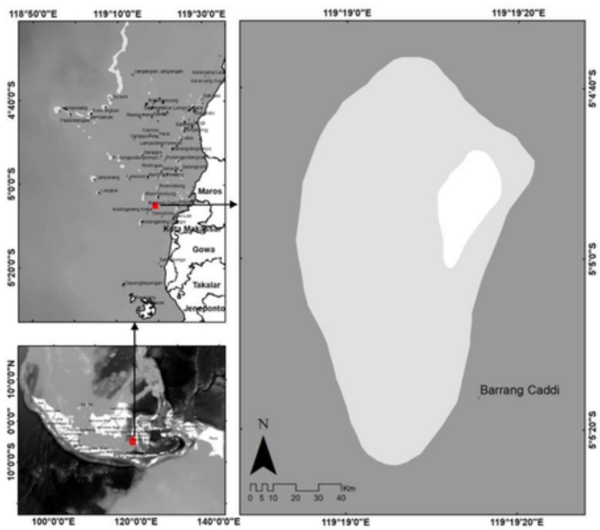


Figure 1. The study was conducted among the coral reefs in Barrang Caddi, Spermonde Archipelago, Indonesia which the geographical boundary between 119º19'13,51" – 119º19' 17,57"E longitude and 5º4'46,83" – 5º5'1,57"S latitude. Barrang Caddi island is one of the small islands in Spermonde Archipelago which has the largest coral reefs. The livelihoods of the people on Barrang Caddi island is a fisherman.

2.2 Methods

2.2.1 LIT (Line Intercept Transect)

The form of coral growth was identified using the LIT (Line Intercept Transect) Method. Transects are installed at 50 meters lenght which are placed along the coastline. These transects are placed at depths of 3 and 5 meters. This method aims to distinguish between live coral and dead coral cover. Data retrieval was carried out at the same time. Data was collected along the transect and records were made based on live forms. Live form data recording technique using the line transect method is shown in Figure 2.

Determination of the condition of coral reefs was based on the calculation of coral cover per life forms category which then be used as a benchmark for the condition of coral reefs. The percentage of coral cover for each category was calculated based on the field measurements data. After the station was confirmed, the condition of the coral reef was observed by the line transect method [4]. Each location coordinates point was taken using GPS. The advantage of this method is that it can measure the structure of coral communities, conditions, and disease rates of all colonies rather quickly. It provides information about the structure size, colony density, and coral cover.

2.2.2 Spectral measurement

Spectral measurements were conducted in Barrang Caddi island under generally clear skies using LOT-2 Spectra Corp. The data collection occurred between 9:00 a.m. and 15.00 p.m. Central Standard Time, when the sun is high in the sky. Prior to the measurement, firstly the tool was calibrated following the spectral references. After being calibrated, the tool was used to collect reflectance and absorbance data for each sample. Samples were measured by irradiating the spectroradiometer sensor at the surface of the samples. Spectral graphs will be displayed at the monitor and these data will be stored in the computer.

The dataset includes 128 spectra of live corals, 118 of Dead Coral covered Algae (DCA), 99 of Rubble and 70 spectra of Sand. The total number of substrates for which reflectance spectra were collected was 415.

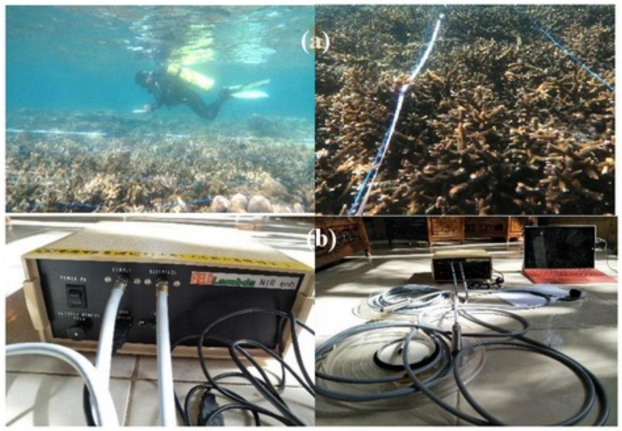


Figure 2. The Instrument: a). Line Intercept Transect method, b). Spectrofotometer Field Lambda NIR enh with a spectral range 350-1000 nm and underwater sensor measure reflectance

2.2.3 Medium resolution imagery

Image data used is Landsat 8 OLI_TIRS was acquired on 02 October 2018 and Sentinel 2a on 15 May 2018 scenes was obtained from path/row number 114/63, are cloud-free, and were projected to UTM 50 zone at reference datum WGS 84. Data Landsat 8 OLI_TIRS imagery and Sentinel 2a was used in this research to obtain information about actual coral reefs condition. It has been corrected geometric and radiometric. Visualize the image of the composite RGB 543 on Landsat 8 OLI_TIRS. Depth-invariant processing was performed in this study to assess whether any significant changes in coral reefs. Satellite imageries was interpreted by unsupervised classification with the computer program automatically groups the pixels in the image into separate clusters, depending on their spectral features and ground truth data with GPS. To determine the spectral pattern in Sentinel 2A and Landsat 8 images are converted digital number to spectral radiance and convert radiance to reflectance.

2.2.4 Test accuracy

Accuracy assessment was being conducted by Kappa Coefficient (k) for accuracy assessment which relies on image training area. Training area was delineation based on ground observation with 50 samples of training area with random sampling method. Kappa ‘ mathematical accuracy is:

$$K = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r}(X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} * X_{+i})} \text{ [3] } \ldots\ldots (1)$$

Where :

N : the total Number of cell in the matrix

r : the number of rows in the matrix

X_{ii} : the number in row i and column i

x_{+1} : the total observations for column i, and

x_{1+} : the total observations in row i

2.2.5 Pdf Maps

Pdf Maps is an application available for android and iOS devices that can read geospatial PDFs. It can download and open saved maps, pan, zoom, locate yourself on the map using GPS, add placemarks (points) and attributes, plot photos, as well as measure distance and area. Users can then export the created placemarks and associated data to various formats and share with incident or park GIS personnel.

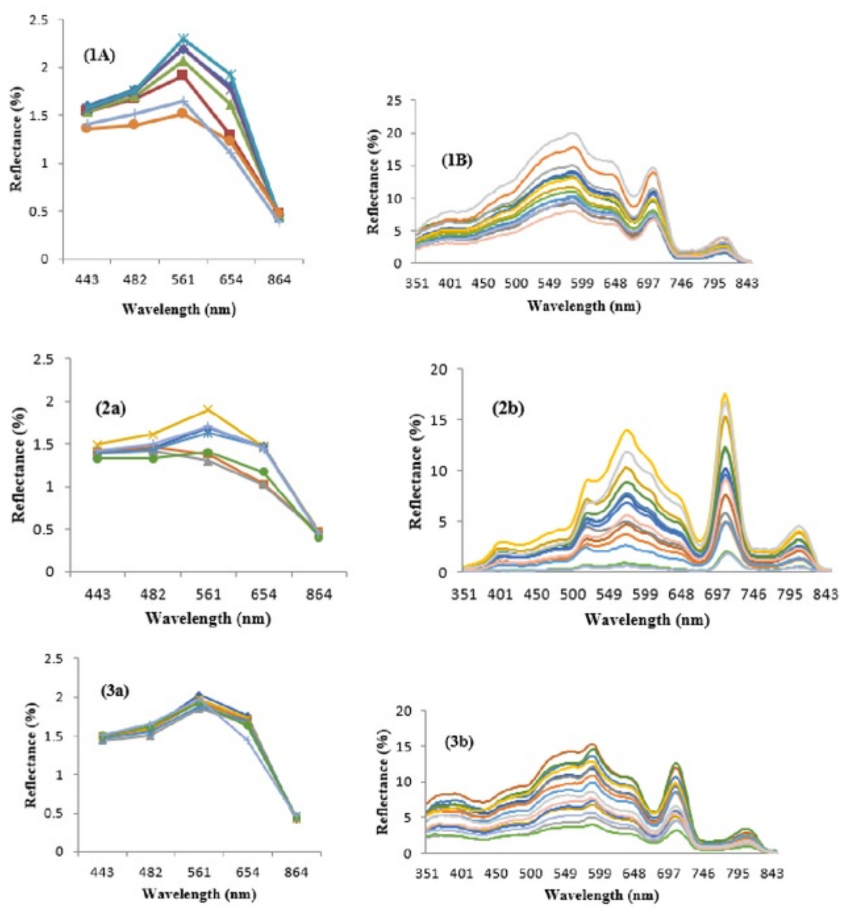
Incident mapping often utilizes PDF documents of maps to be created for printing, archiving, and now for the ability to use these products in the field. With the release of Adobe Acrobat 9 a new geospatial feature set was introduced. Geospatial PDF documents contain information such as real world location and/or GIS attributes. The data contained in a geospatial PDF may be accessed and used to locate a specific point or measure a distance/area.

3 RESULTS & DISCUSSION

3.1 Characteristic of *in situ* hyperspectral and multispectral data

Coral reefs will reflect different light spectral under different conditions. The existence of a thin layer of algae that covers coral reefs and/or zooxanthellae in symbiosis with coral reefs will give a spectral pattern of chlorophyll absorption. Furthermore, because coral reefs are located under water, light penetration capability is limited and depend on the ability of each channel. This condition adds complexity to the process of identifying coral reef variations based on their spectral reflection. Therefore in the identification of coral reefs health, it is very important to know the influential factors, between the sensor spectral ability to distinguish the characteristics of coral reefs and the ability to penetrate water bodies

Reflectance pattern on live coral, dead coral with algae (DCA), rubble, seagrass, and algae based on spectrophotometer measurement and image analysis are presented in Figure 2. Based on spectral reflectance values it is known that live coral, dead coral with algae (DCA), rubble, seagrass, and algae are different



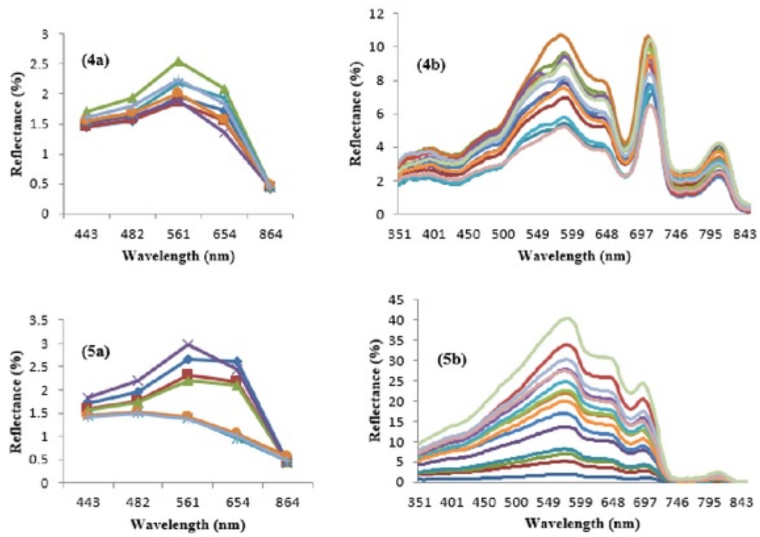


Figure 3. (a) Multispectral and, (b) Hyperspectral data: 1a & 1b (Dead Coral Alga/DCA), 2a & 2b (Live Coral/LC), 3a & 3b (mixbottom/LC. DCA, Rb), 4a & 4b (Rubble/Rb).

Comparison of the reflectance values at coral, dead coral with algae (DCA), rubble, seagrass, mix bottom, and sand by applying spectrophotometer and reflectance values at Landsat 8 image having similar patterns with different magnitude. The Reflectance of them increases at wavelength 520-580 nm in multispectral data. In Figure 4, there was a similar pattern in which increase reflectance from coastal blue canal (430-450 nm) to blue canal (450-510 nm), then the reflectance increased at green canal (530-590 nm), and decreased reflectance values at red canal (640-670 nm).

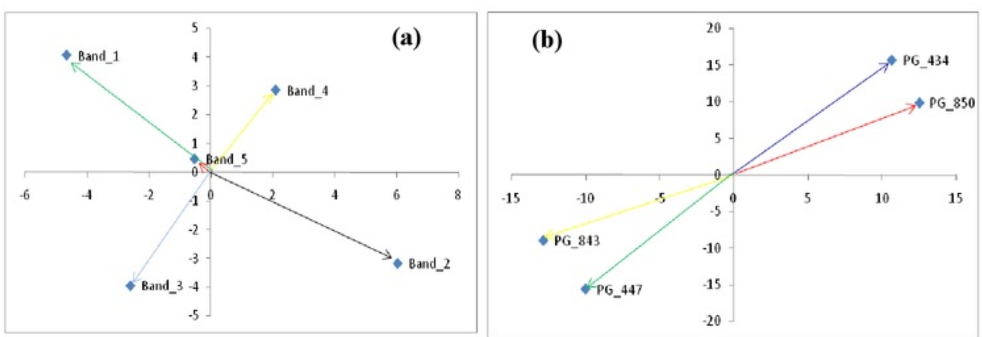


Figure 4. a). Distribution of band variables (left) and classes of bottom at 2 main axes based on the results of discriminant analysis for multispectral technique, b) Distribution of the wavelength distribution based on results of discriminant analysis using hyperspectral data.

Discriminant analyses concluded that the coverage of class 5 (sand) was discriminated or characterized by high value of spectral reflectance by wavelength 434 and 850 um and in contrast, lower spectral reflectance values by wavelength 843 and 447um. This phenomenon was contradictive to the coverage class 2 (live coral/LC) that characterized by high spectral value of wavelength 447 and 843 um, however, low spectral value of wavelength 434 and 850um. Meanwhile, coverage classes 1 (Dead Coral Covered with Algae/DCA), 3 (Mix Bottom), and 4

(Rubble) had reflectance value in medium level at the four wavelengths used. For multispectral technique, 5 bands were used to the 5 classes of bottom coverage indicated that these five bands showed results that significantly different among five coverage classes. Results of the discriminant analysis of these five bands (wavelengths) may be used to discriminate five classes of the bottom coverage analyzed. Utilization of two main axes (discriminant function) 1 and 2) may explain as much as 86.5% relationship of class distribution of bottom coverage by the 5 bands used (Figure 4).

The analysis found that coverage class 5 (sand) was discriminated well by high value of the spectral reflectance by length of band 4 and conversely, low spectral value of band 3. Coverage of class 1 (Dead coral covered with algae/DCA), was characterized by the high spectral value of band 3, however, lower spectral value of band 4. For coverage class 2 (Live Coral/LC), was characterized by spectral reflectance of band 1 and low spectral reflectance of band 2. It contradicted to the coverage class 4, by high characterizing value at band 2 and lower spectral values of band 1. For coverage of class 3 (Mix Bottom), the reflectance value was classified as medium level for band 1, band 2, band 3, and band 4.

Based on the visual appearance of the nine hard corals that averagely brownish yellow in color, thus results of this study was similar to the statement of [7] that the object will tend to reflect similar color to the object color and absorb the other colors causing these objects would have high reflectance.

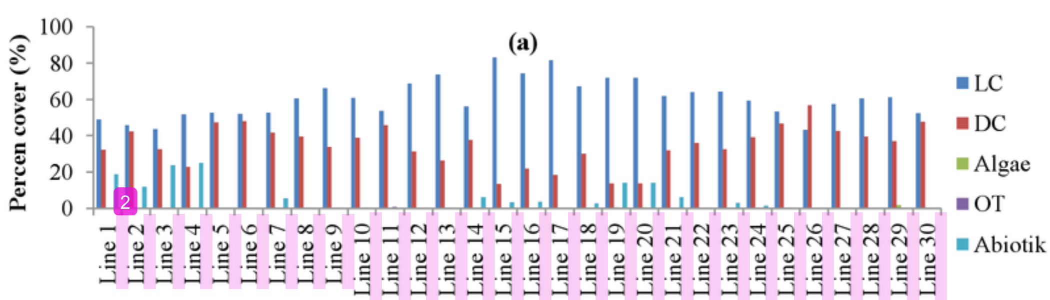
The result of measurement at shallow water is represent difference reflectance in the magnitude and shape of from different bottom substrate. This is caused variations in symbiote pigment concentrations and proportions of bottom substrates. Using in situ measurements of spectral reflectance from different bottom substrate shows similarity pattern of multispectral data and hyperspectral data. Live coral has strong reflection at green band of multispectral data, at 500nm-550nm of hyperspectral data.

3.2 Coral health identification using LIT (Line Intercept Transect) and medium resolution imagery

3.2.1 Line intercept transect

In the identification of coral reefs condition and health using Line Intercept Transect (LIT) method, the observed objects was live coral (LC), dead coral (DC), algae, other (OT), and abiotic. The area of observation is 15m^2. Each area consists of line transects made up from roll meter which stretches 30 m along 15 lines (for rubble and algae categories) and 30 lines (for live coral and mix bottom categories). Observations were made in four areas based on 4 categories of coral conditions: 1) live coral dominant, 2) rubble dominant, 3) mix bottom / dead coral alga dominant and, 4) algae.

At observation station 1 (area 1) which is located at live corals dominant location, percentage of live corals obtained was ranging from 43% to 83%. The condition of coral reefs is categorized as moderate to good based on the percentage value. The percentage of coral cover is presented in Figure 3a. Observation area 2 has 85% to 95% rubble cover, so does observation area 3, which is dominated by dead coral alga (Figure 3b and 3c). The observation area 4 is a transect dominated by algae which has a cover percentage of 81% and 19% abiotic (3d).



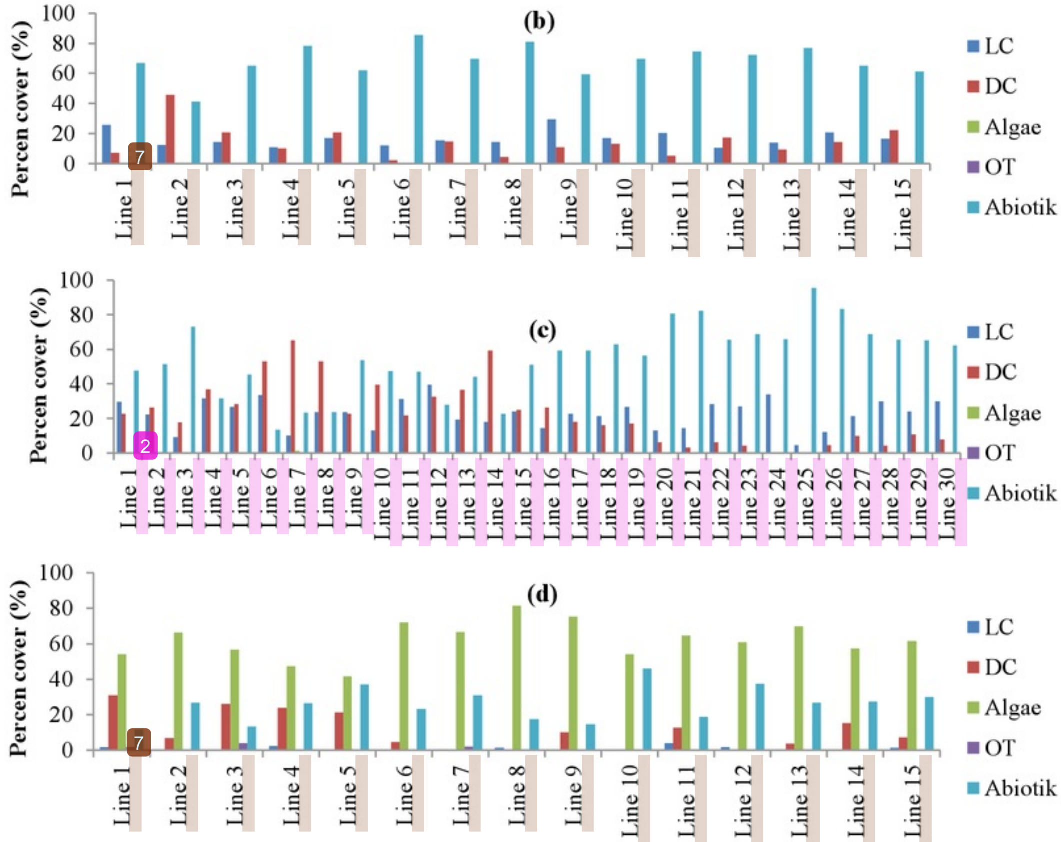


Figure 5. Measurement of in situ data using LIT method at four different observation areas on dominant cover percentage on coral reefs; a). live coral, b). rubble, c). mix bottom, d). algae

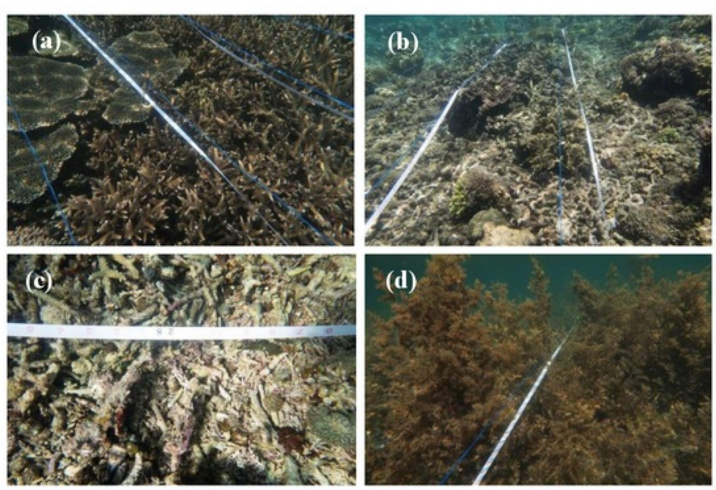


Figure 6. Is a photograph of insitu measurements in four observation areas using line tracts; a) live coral, b) dead coral algae, c) rubber, d) algae with > 80% percent cover

3.2.2 Medium resolution imagery

The results of coral reefs identification based on image classification method in Barrang Caddi are live coral, dead coral with algae (DCA), rubble, seagrass, mix bottom, and sand. Coral health classification of shallow water area based on the dominant condition and percent cover on four locations using the LIT method is presented in map (Fig. 5)

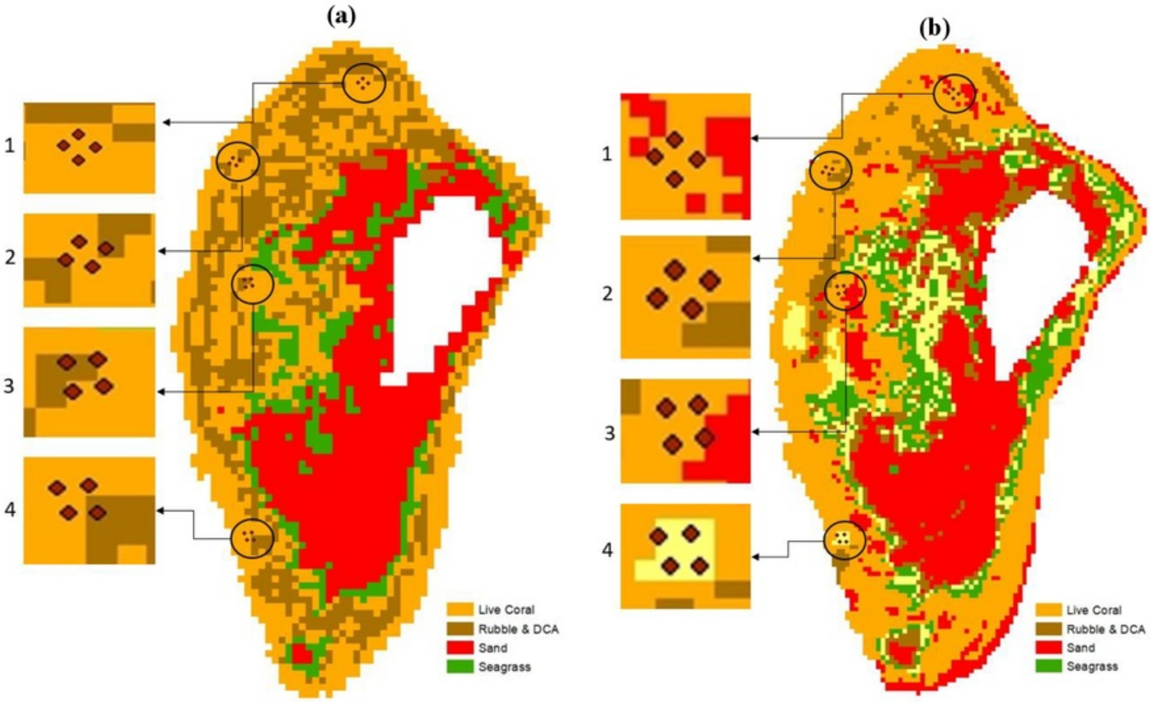


Figure 7. Reclassification imagery overlapping with four transect area of LIT in black circle and zooming block; a) Landsat 8 and b) Sentinel 2a .

The results of coral reefs identification based on image classification Landsat 8 OLI-TIRS and Sentinel 2a are live coral, dead coral with algae (DCA), rubble, seagrass, mix bottom, and sand. Coral health classification of shallow water area based on the dominant condition and percent cover on four locations using the LIT method is presented in map (Fig. 5). The integration of in situ measurement data with multispectral imagery in medium resolution shows that the two methods support one another and do not show contradictory results.

Results of image analysis of Landsat 8 OLI-TIRS showed area of in Barrang Caddi as high as 74,16 ha. Distribution of live coral was identified in the western side as high as 21.03% of total areas of the shallow water in Barrang Caddi, whereas, Mix Bottom is the largest area with areas of 26.18%. While category DCA was the smallest areas with 9,04%. The overall accuracy of the image was 80.78%.

At the same location, in one observation area with the same pixels and coordinates, Landsat 8 and Sentinel 2a image analysis and the LIT method show the high similarity observations result, which is dominated by healthy corals or live corals (Table 1).

Table 1. List of in situ measurement by LIT area category and image classification of Landsat 8 with spasial resolution 15 meter and Sentinel 2a with spasial resolution 10 meter

LIT Transect Area	LIT Area Category		Landsat 8		Sentinel 2a	
	Category dominant	Percent cover (%)	Pixel area	Clasification	Pixel area	Clasification
15mx15m	Live Coral	60.50	15x15m	Live Coral	10x10m	Live Coral
15mx15m	Dead Coral Algae	38.0	15x15m	Live Coral, Seagrass, Rubber and Dead Coral Algae	10x10m	Live Coral
15mx15m	Rubber	68,59	15x15m	Rubber and Dead Coral Algae	10x10m	Live Coral and Sand
15mx15m	Macro Algae	61.92	15x15m	Live Coral, Rubber and Dead Coral Algae	10x10m	Live Coral

On first area observation transect, the percent cover of healthy coral is at 60.50%, which is the highest on this transect. Although 44.76% among them is dead coral covered with algae, this percentage still match the criteria that at one pixel size (15x15m) area is mixed with dead coral overgrown with algae. Some of the results of previous studies [13; [15]; [16] shows that there is difficulty to distinguish between certain types of living coral from algae covered coral.

Death corals from various causes will soon be overgrown with algae. Items that were originally categorized as mix bottom, which is a mixture of several coral reef conditions, such as dead coral, live coral, rubble and sand, has been converted into dead coral covered with algae class. The coral conditions in this transect are 29.58% live coral, 16.94 mix bottom, and the rest are rubble and macro algae 7% respectively. This phenomenon confirms that there are similarities between live coral and dead coral covered with algae. They have pigments that are similar at green wavelengths so that one pixel in a landsat image with a spatial resolution of 15mx15m is identified as living coral. But the results of in situ measurement using the LIT method shows a maximum live coral cover of 60% and the rest are dead coral covered with algae and rubble which has also been overgrown with algae.

The classification results on sentinel-2 images show a slight difference with Landsat 8. Sentinel 2a has a resolution of 10x10m, it is more precise compared to Landsat 8 for one-pixel observations. The fact on the ground shows that the results of LIT method measurements on the second transect observation are 34.79% live coral and 37.1% dead coral and rubble covered with algae. This condition allows them to be one category in the image classification as living corals. The difficulty of separating between live corals and dead corals covered with algae has been proven in their spectral reflectance analysis which shows a high similarity, as seen in some spectral reflectance patterns of some live corals in Figure 2.

3 CONCLUSION

The result of measurement at shallow water is represent difference reflectance in the magnitude and shape of from different bottom substrate. This is caused variations in symbiote pigment concentrations and proportions of bottom substrates. Using in situ measurements of spectral reflectance from different bottom substrate shows similarity pattern of multispectral data and hyperspectral data. Live coral has strong reflection at green band of multispectral data, at 500nm-550nm of hyperspectral data.

The condition of coral reefs on Barrang Caddi Island is categorized as moderate to good health. The level of accuracy using in situ measurement with the LIT method is very thorough because observations are made by centimeters. However, integration with the classification results using medium resolution satellite imagery, shows level of similarity on the object dominance scale. The phenomena of small islands in Spermonde archipelago is that there are a lot of dead corals and rubbers covered with algae which is increasingly widedspread as the consequence of continuously decreasing live coral. These result can be a reference to develop a digital health chart that will be useful for monitoring the status of corals, especially in Spermonde archipelago, Indonesia.

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