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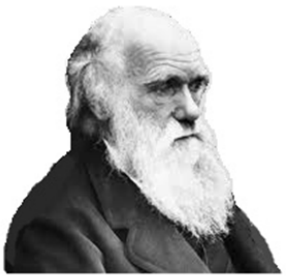

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The patterns of changes in coral reef coverage (1994-2006) in the Seribu Islands National Park, Jakarta, Indonesia

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ABSTRACT

Coral reef ecosystems are unique ecosystems that can live and reproduce well in the tropics. Corals that makeup reefs are a very important component of ecosystems on the earth's surface. These ecosystems are habitats for a large number of diverse organisms in the oceans. However, in recent years coral reefs have experienced significant degradation as a result of the impact of human disturbances and natural factors on biodiversity and ecosystem functions. It is known that 90% of coral reef damage comes from human activities and 10% comes from climate change (natural events). In addition to natural events, such as waves, storms, and rising sea surface temperatures, the use of island land and the increasing population and utilization of coral reef resources around the island, including those that may cause a decrease in coral cover, can indirectly change the morphology of the island. To find out about the pattern of changes in coral reef cover area based on zoning in TNKpS, it is necessary to conduct a quick and effective study by utilizing digital processing of satellite imagery. The data used are Landsat images (1994, 2000, and 2006) with change detection method using CVA technique. The results of the analysis showed that there was a change in the increase in coral reef cover over 12 years (1994-2006). The pattern of changes that occur is dominated towards the Northeast and Northwest in the area 1, meanwhile, for area 2 it varies in all directions.

***Keywords*:** Change analysis, Coral reef, CVA, Landsat Imagery, Lyzenga, TNKpS, Seribu Islands National Park

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1. INTRODUCTION

One of the potential natural resources in TNKpS (Taman Nasional Kepulauan Seribu/ Kepulauan Seribu's Marine National Park), Jakarta is a coral reef ecosystem. Coral reef ecosystems are unique ecosystems that can live and reproduce well in the tropics. Corals that makeup reefs are a very important component of ecosystems on the earth's surface. These ecosystems are habitats for a large number of diverse organisms in the oceans [1, 2]. Coral reef ecosystems have important functions and benefits, both economically and ecologically. From an ecological point of view, coral reefs serve as spawning grounds, nursery grounds, and foraging areas for fish and biota associated with coral reefs [3]. Meanwhile, from an economic point of view, coral reefs can be used as job opportunities through fishery activities, marine tourism, building materials, cosmetic products, and anticancer drugs [4].

However, in recent years coral reefs have experienced significant degradation as a result of the impact of human disturbances and natural factors on their biodiversity and ecosystem functions [5–12]. In this case, coral reefs become unstable, although there is plenty of room for coral reefs to attach and grow they are very sensitive and vulnerable to stressors [13, 14]. Impacts that arise range from the increased appearance of coral bleaching, coral disease, to coral death [15–19].

It is known that 90% of coral reef damage comes from human activities and 10% comes from climate change (natural events). In addition to natural events, such as waves, storms, and rising sea surface temperatures, the use of island land and the increasing population and utilization of coral reef resources around the island, including those that may cause a decrease in the level of coral cover, can indirectly change the morphology of the island. The area of Indonesia's coral reefs based on the analysis of satellite imagery data is estimated at 2.5 million hectares which is part of 18% of the world's coral reefs [20]

According to [21], based on a study in 1,153 coral reef sites in Indonesia, 33.82% of coral reefs are in poor condition, 37.38% categorized fair, 22.38% categorized good and only 6.42% categorized excellent. The condition of coral reefs is determined by the percentage of live coral cover. For example, based on the results of a study by the TERANGI Foundation on Pulau Semak Daun, Kepulauan Seribu, Jakarta, until 2007, the percentage of hard coral cover was only 24.7%. [15].

Based on the description above, a rapid assessment with a large area is very necessary to obtain a solution for the sustainable management of coral reef ecosystems in TNKpS. Therefore, it is necessary to conduct a study to find out the pattern of changes in coral reef cover area based on zoning in TNKpS. An effective approach so that the study is faster and covers a large area, this study is carried out by utilizing satellite imagery.

2. MATERIALS AND METHODS

2. 1. Scope of the study area

The research location was carried out in the Seribu Islands, Jakarta - Indonesia with an analytical focus on the islands that represent each zoning. The zoning representation was taken in two sample areas (Figure 1).

Then look at the changes in coral reef cover area.

2. 2. Dataset and method

This study uses an observation method with a remote sensing approach, carried out through 3 stages (Figure 2), that are: (1) Pengumpulan data; (2) Pengolahan digital citra satelit; and (3) Analisis deteksi perubahan (Change Detection) dengan menggunakan metode CVA (change vector analysis). (1) Data collection; (2) digital processing of satellite imageries; and (3) change detection analysis using the CVA (change vector analysis) method.

2. 2. 1. Data collection

The main material used in this research is Landsat satellite imagery. The image covers the Seribu Islands region with path row 122/64 with the recording years 1994, 2000, and 2006. The satellite data were obtained from the official website of USGS and P2O LIPI (Indonesian Institute of Sciences). As a base map, a map of the earth (scale 1:50,000) from the BIG (Geospatial Information Agency) is used as a reference map.

2. 2. 2. Image correction

At the image correction stage, geometric and radiometric corrections are carried out. Geometric correction aims to correct the image against the earth's coordinate system so that all image information matches its existence on earth. The geometric correction process can be done in two ways, namely image to map classification and image to image classification [22, 23]. Meanwhile, radiometric correction is done to improve or sharpen the image by improving the value of individual pixels in the image, in contrast to spatial correction which fixes the value of a pixel based on the surrounding pixels. This correction also aims to eliminate stripping or banding, line dropouts, and atmospheric effects (fog, smoke, clouds, and dust) that often occur in image data caused by detector instability or malfunctioning detectors and not recording image data normally [24–26].

2. 2. 3. Image cropping and training area

Image cropping aims to crop the image according to the scope of the research area. The image coverage of this cropping result includes only the study area being analyzed. Before performing the image transformation, a training area process is carried out which aims to take a sample of pixels whose number must be the same between one image data and another, this is related to the area to be studied. In addition, the value of each pixel will be used to calculate the variance and covariance of the digital number (DN) value.

2. 2. 4. Lyzenga transformation

The reflection of the bottom of the water can not be observed directly on the satellite image because it is influenced by absorption and scattering in the water surface layer. This stage needs to be done to correct the water column so that information about underwater habitats is obtained, one of which is coral reefs.

The results of this water column correction are obtained from the image transformation with the Lyzenga algorithm [27, 28]. The value of the Lyzenga algorithm that has been obtained will be used to calculate the magnitude and direction values in the CVA (change vector analysis) method. To calculate the value of the Lyzenga algorithm [29] using the following equation:

$$Y = \ln(TM_1) + \frac{k_i}{k_j}\ln(TM_2)$$ ……. Equation 1

where:

Y is the image extracted from the bottom of the water; TM_1 is the DN of Landsat TM channel 1; TM_2 is the DN of Landsat TM channel 2; $\frac{k_i}{k_j}$ is the value of the attenuation coefficient,

where:

$$\frac{k_i}{k_j} = a + \sqrt{a^2 + 1}$$ ……. Equation 2

where:

$$a = \frac{var\ ETM_1 - var\ TM_2}{2 + covar\ TM_1.TM_2}$$ ……. Equation 3

where:

var is the variance value of the DN value and $covar$ is the coefficient of variance of the DN value.

2. 2. 5. Analysis

To detect changes in coral reef cover used the CVA technique and then analyzed descriptively comparative that is comparing the results of changes in coral reef cover area between 1994, 2000, and 2006. In the CVA method, the change detection process uses magnitude variables (area/distance) and direction using the value of DN [30–32]. The application of CVA is carried out on the results of the Lyzenga transformation image in the two images to be compared. The algorithm used in this method is as follows:

Direction value:

	- Blue +	
- Red +	I	II
	III	IV

where:

If (DN22-DN12) < 0 and (DN24-DN14) < 0 then direction = 1

If (DN22-DN12) > 0 and (DN24-DN14) < 0 then direction = 2

If (DN22-DN12) < 0 and (DN24-DN14) > 0 then direction = 3

If (DN22-DN12) > 0 and (DN24-DN14) > 0 then direction = 4

Magnitude value:

$$CM = \sqrt{\left(DN_{mJi} - DN_{nJi}\right)^2} \text{.....Equation 4}$$

where:

CM is change magnitude; DN is digital number; m is the older imagery; n is the newer imagery and J_i is i-band/channel.

After the magnitude value has been obtained, the magnitude value will be compared with the threshold value, if the magnitude value is greater then the area/region changes, while if the magnitude value is smaller then there is no change. Meanwhile, to calculate the area of change in coral reef cover, it will be done by collecting the number of pixels in each class of coral cover, so that you have to multiply the number of pixels by the area of each pixel to get the area of each class.

Furthermore, changes in the magnitude value and changes in the coral reef area will be linked to several existing research results to help determine the causes of changes in the coral reef area in the four zones of TNKpS.

3. RESULT AND DISCUSSION

The results of the analysis related to the area of coral reefs can be seen in Fig. 1. In general, the area of coral reef cover in the study area has increased. To further see the change in coral reef cover obtained from the calculation of the magnitude value which is compared with the threshold value. The average threshold value obtained is 5.8333. The image from the water column transformation that has been classified is converted into a vector grid before the CVA method is performed by calculating the magnitude value. The results of images that have calculated magnitude values using the model builder are reclassified into 2 classifications, namely areas that change and do not change.

3. 1. Changes in coral reefs in area 1

In the span of 12 years (1994-2006), there was a change in coral reef cover. Changes that occurred in area 1 in the 1994/2000 period experienced a change of 1,169.13 m^2, while the area that did not experience changes was 695.59 m^2. The pattern of distribution of changes that occur can be seen in Figure 3. If we examine further, it shows that more changes occur in the core zone, while the pattern that does not change is in the utilization zone. The changes that occurred in 1994/2000 were more directed to quadrant II as seen from the visual map, and seemed to dominate towards the northeast for the direction of change.

Meanwhile, in 2000/2006, the area that changed the most was still dominant in the same area. This pattern is seen in Figure 4, where the change in the area of coral reefs that occurred

in that period was 1,619.73 m^2, while the area that did not change was 609.30 m^2. The direction of change that occurred in 2000/2006 entered quadrant I, which dominated to the northwest.

Based on the area results obtained in 1994/2000 and 2000/2006, the figures obtained in areas changing are large numbers for changes in coral reefs. But not all the changes that occur are in a negative direction where the changes immediately become dead corals, there are some changes from live corals to dead coral algae and there are also changes from dead coral algae to dead corals or vice versa.

On the graph of Figure 5, it is seen that there is an increase and decrease in each coral classification. The area of live coral in 1994 was smaller than the area of coral in 2000 which was 297.2 m^2, while the percentage of live coral in 2000 was 456.2 m^2. Then the percentage of dead coral algae in 1994 was the highest percentage when compared to the area of dead coral algae in 2000 and 2006. In 2000 the area of dead coral algae was reduced to 958.3 m^2, while live and dead corals increased to 456.2 m^2. and 450.2 m^2. Then from 2000/2006, the percentage of live corals increased to 951.4 m^2, while dead coral algae and dead corals decreased in areas of 714.4 m^2 and 563.2 m^2.

This can happen to increase or decrease the area of coral reefs given the efforts made to preserve coral reefs, one of which is through coral transplants carried out by the community or from the TNKpS officers as well as increased supervision or monitoring. So that every year coral reefs are not decreasing but increasing every year. Looking at the numbers of changes that are quite large, it is stated that every year there is a significant degradation of coral reefs.

Changes that occur in the zone of area 1 can occur due to the islands in area 1 being far from settlements and the lack of supervision from the authorities. In addition, there are still many fishermen who enter the zone and catch fish by using bombs. Looking at the functions of each zone in area 1, the core zone should be an absolute protected zone and no changes are allowed by human activities. Penjaliran Island and Corn Island are representatives of the core zone and protection zone. In addition, these two zones can only be used or designated for education, research, monitoring of marine living natural resources, and the construction of infrastructure facilities for monitoring that do not change the landscape.

3. 2. Perubahan terumbu karang area 2

Area 2 is representative of the core zone, utilization zone, and residential zone, where this area is definitely close to densely populated settlements and can still be reached by supervision from the community and the TNKpS. The changes that occurred between 1994/2000 are very visible in Figure 6 not many areas have changed. The area of coral reefs that did not change was 2,120 m^2, while the area that changed was 1,664 m^2.

The changes that occurred in 1994/2000 in this area were almost all included in the four quadrants, namely quadrants I, II, III, and IV have seen visually from Figure 6. Whereas in 2000/2006 visually drawn a map, it looks like nothing has changed in all the islands, this might have happened because there were so few areas that changed so it was not detected in Figure 7. In addition, judging from the DN value used in calculating the magnitude between 2000 and 2006 the DN is the same for each area.

On each island, it can be seen that the area that changes is almost flat around each island, although if you look at the area that changes less than that which doesn't change. Like area 1 above, not all changes are negative. Even the changes can also be positive. This can be seen from each area on the graph in Figure 8.

The area of dead coral algae in 1994/2000 increased by 42.4 m^2, while dead corals decreased to 433.4 m^2. The area of dead coral algae in 1994 was 1,734.8 m^2 to 1,777.2 m^2 in 2000. At least, during the 12 years to 2006, the area of dead coral algae was 1,752.1 m^2. Meanwhile, the area of live coral from 1994 to 2006 seemed to be increasing, from 195.3 m^2 in 1994 to an area of 1,414.7 m^2 in 2006. Gradually yearly (1994-2006) it was seen that coral reef cover had expanded by approx. 819.3 m^2. This indicates that the changes that have occurred are for the better because the area of dead coral decreases every year. In addition, the decrease in the area of dead coral algae from 1994-2006 indicated that many dead coral algae had turned into dead corals, however, dead corals were replaced with live corals even though the area of living corals increased was not too large.

Seeing the function of each zone in area 2 where this area is the core zone, utilization zone, and residential zone. The occurrence of a significant reduction in the area of live coral can occur due to a large number of community activities in one area [14]. Because in area 2, two zones are used as centers of human/fisherman activity (fishing), recreation and tourism centers, education/research, as well as ship traffic. With so many activities in this area as shown in Figure 8, the coral reefs are increasing in size, this is an indication that this area is under management and supervision from various parties, both the community and from the TNKpS side, which is more affordable because it is not too far away.

Overall, in area 1, changes were seen starting in 1994/2000 and 2000/2006, in the core zone represented by the west Penjaliran island and the west Penjaliran island. The protection zone in this area is only represented by the island of corn which is seen to have changed in the northwest and southeast. Meanwhile, in the utilization zone, the direction of change is more evenly distributed around the island, which is represented by Sebaru Besar Island and Nyemplung Island.

In area 2, the changes that occurred in 1994/2000, the core zone experienced not too significant changes, it can even be said that only a few changes were experienced, represented by the island of Bira and the island of the Netherlands. Likewise, the utilization zone and residential zone are represented by Pamegaran Island and Kelapa Island. But in 2000/2006 seen in Figure 7, no area has changed the size of the coral reef.

Over the last 50 years according to [33], the proportion of the decline in the condition of Indonesia's coral reefs has increased from 10% to 50%. Between 1989-2000, coral reefs with 50% live coral cover have declined from 36% to 29%. Coral reefs in western Indonesia face the greatest threat. The El Nino event caused widespread coral bleaching in Indonesia in 1997-1998, especially in western Indonesia. Especially in the Thousand Islands, about 90-95% of coral reefs up to a depth of 25 m have died.

Two years later, in 2000, the coral reefs of the Thousand Islands experienced significant recovery, with 20-30% live coral cover. Seeing coral biodiversity as well as high ecological and economic functions are also accompanied by high threats. Various activities are factors that decrease the quality and quantity of coral reefs in the waters, especially the Indonesian Archipelago, namely illegal coral harvesting, use of bombs, fishing, anchor disposal, sedimentation, as well as the current world issue of climate change, all of which can reduce the quality and quantity of reefs. corals in the waters, especially the Indonesian Archipelago [34].

Furthermore, when compared with the results of study 5 (five) years after 2006, based on the research [35-42], the condition of coral reefs in the four zones of TNKpS has decreased on average. In the three zones in KNP, the condition of coral reefs in 2011 decreased, except for the residential zone. The condition of coral reef cover in the core zone in 2011 was 33.71%;

protection zone by 26.71%; tourism utilization zone by 56.62%. Meanwhile, in the residential zone, the condition of coral reefs in 2011 increased by 63.17%.

4. CONCLUSIONS

The application of the CVA method to Landsat satellite imagery that has been transformed using water column correction based on Lyzenga's algorithm can be carried out to produce information on patterns and changes in coral reef cover area. In area 1 and area 2 as a whole experienced an increase in coral area. In area 1, there was an increase in the area of coral reefs by 460.2 m^2 from 1768.8 m^2 in 1994 to 2,229 m^2 in 2006. Likewise, the area of coral reefs in area 2, wherein 1994 it was 3007.8 m^2 to 3827.1 m^2 in 2006 or an increase in the area of coral reefs by 819.3 m^2.

Area 1 in the core zone is represented by West Penjaliran Island and West Penjaliran Island. The protection zone in this area is only represented by the island of corn which is seen to have changed in the northwest and southeast. Meanwhile, in the utilization zone, the direction of change is more evenly distributed around the island, which is represented by Sebaru Besar Island and Nyemplung Island. The pattern of change dominates towards the dimensions of quadrants II and I, namely towards the northeast and the northwest.

In area 2 of the changes that occurred in 1994/2000, the core zone underwent changes that were not too significant and it could even be said that only a few changes were experienced, represented by the island of Bira and the island of the Netherlands. Likewise, the utilization zone and residential zone are represented by Pamegaran Island and Kelapa Island. However, in 2000/2006, based on the visualization results, there was no change in the area of coral reefs. Changes that occur in area 2 have a pattern that spreads in various directions to the four quadrants, namely quadrants I, II, III, and IV.

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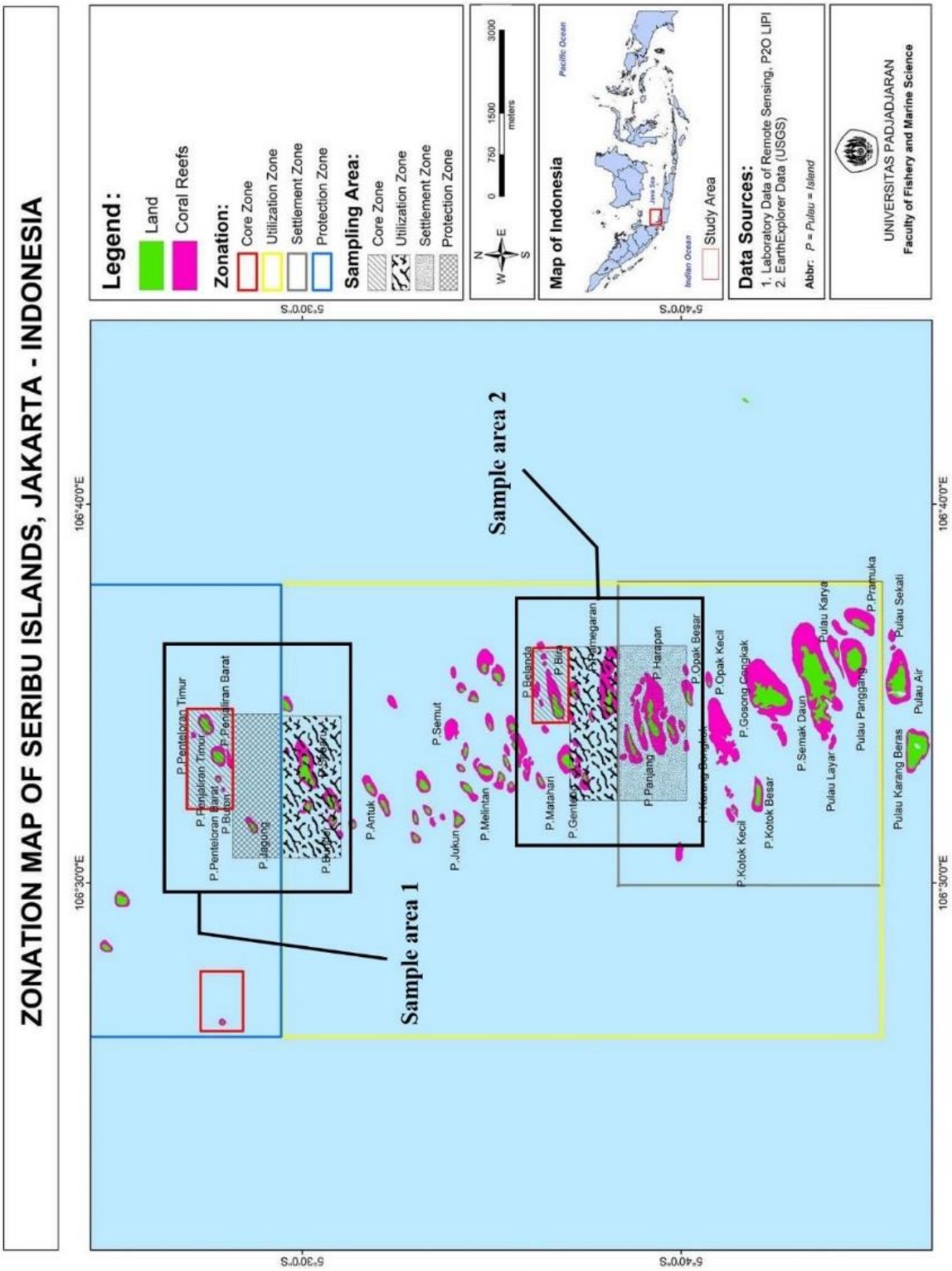

Figure 1. Map of the study area and the data sampling area

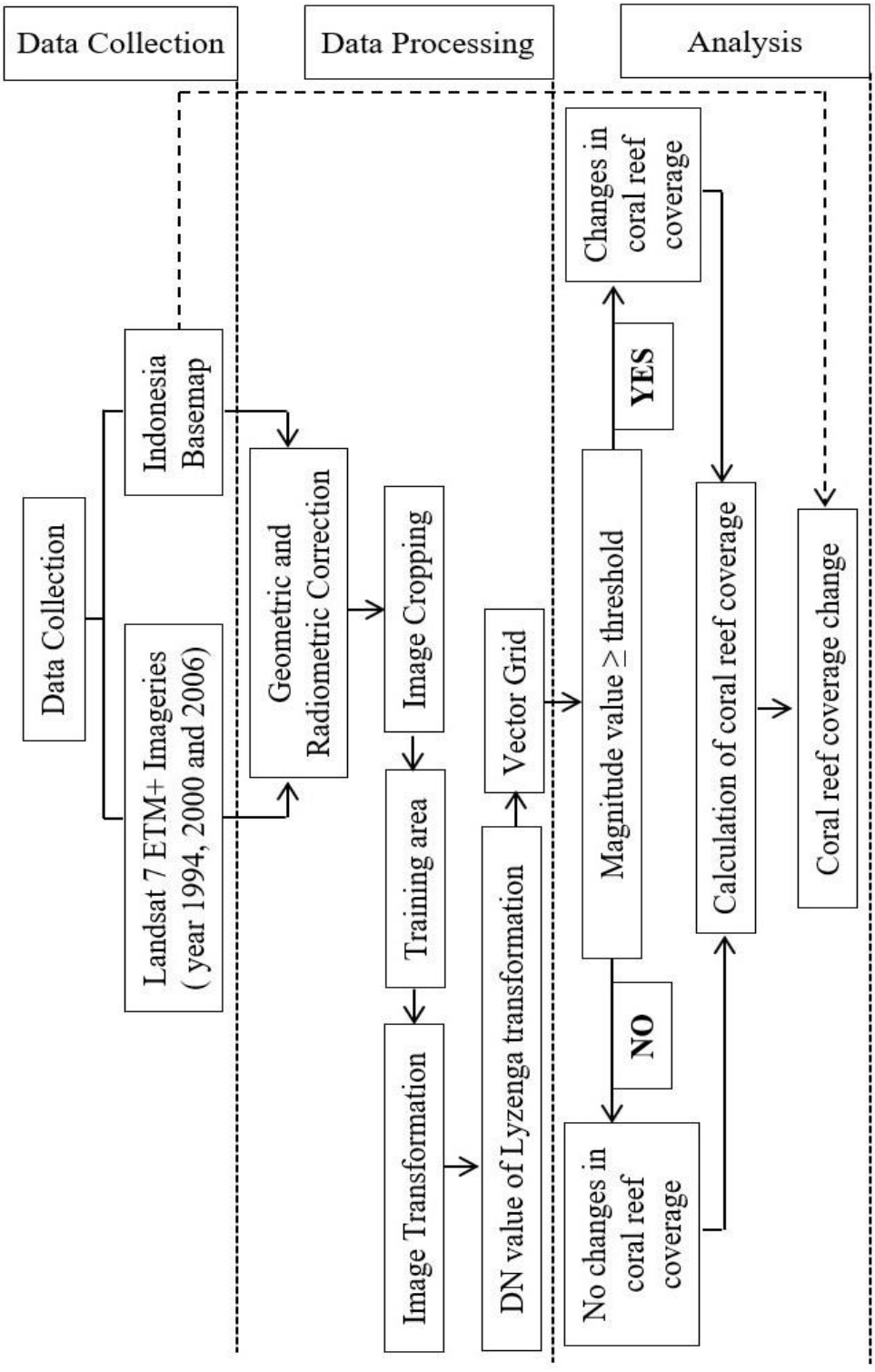

Figure 2. Flow diagram of the method

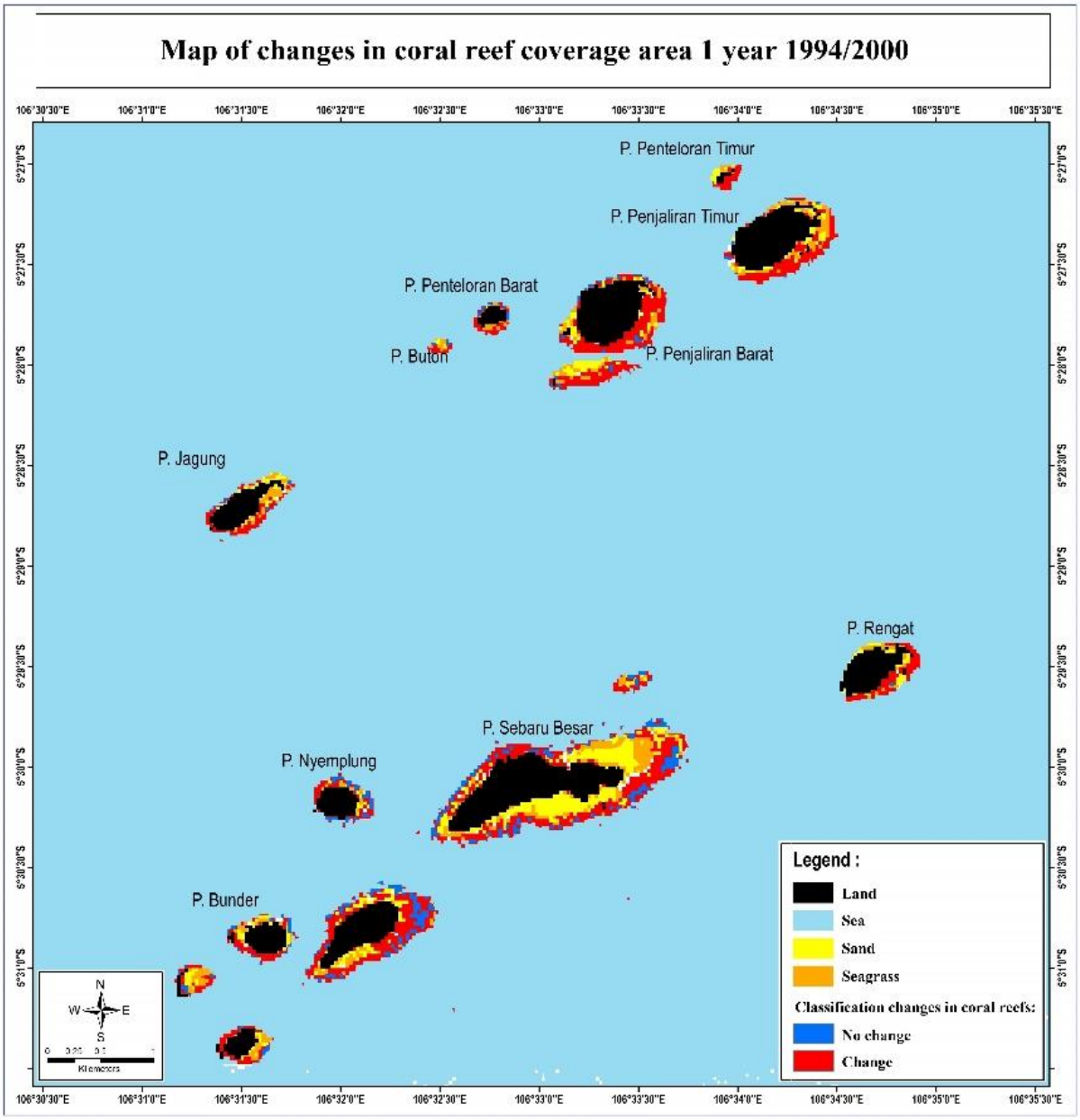

Figure 3. Changes in coral reef cover in area 1 1994/2000

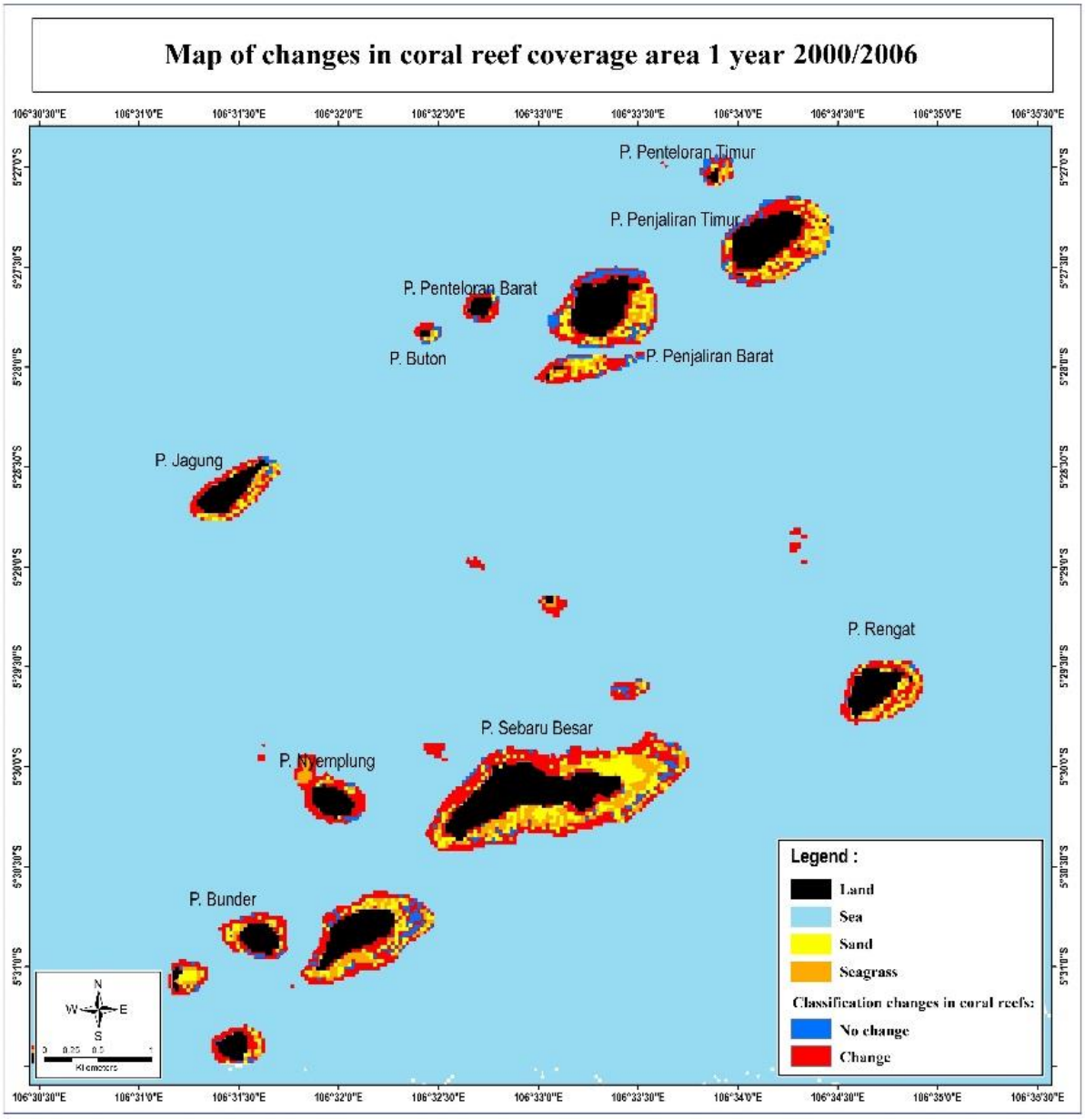

Figure 4. Changes in coral reef cover in area 1 2000/2006

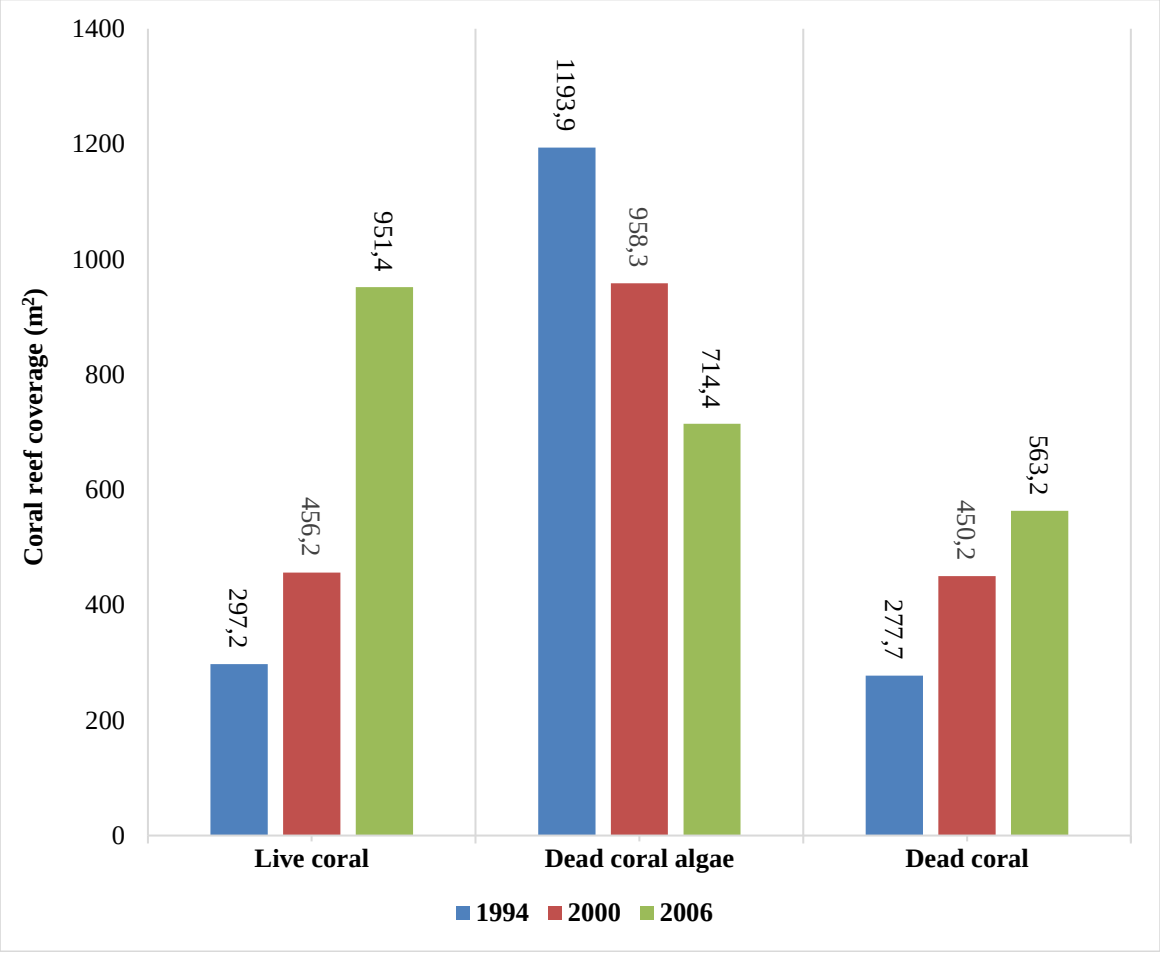

Figure 5. Graph of coral reef area in area 1

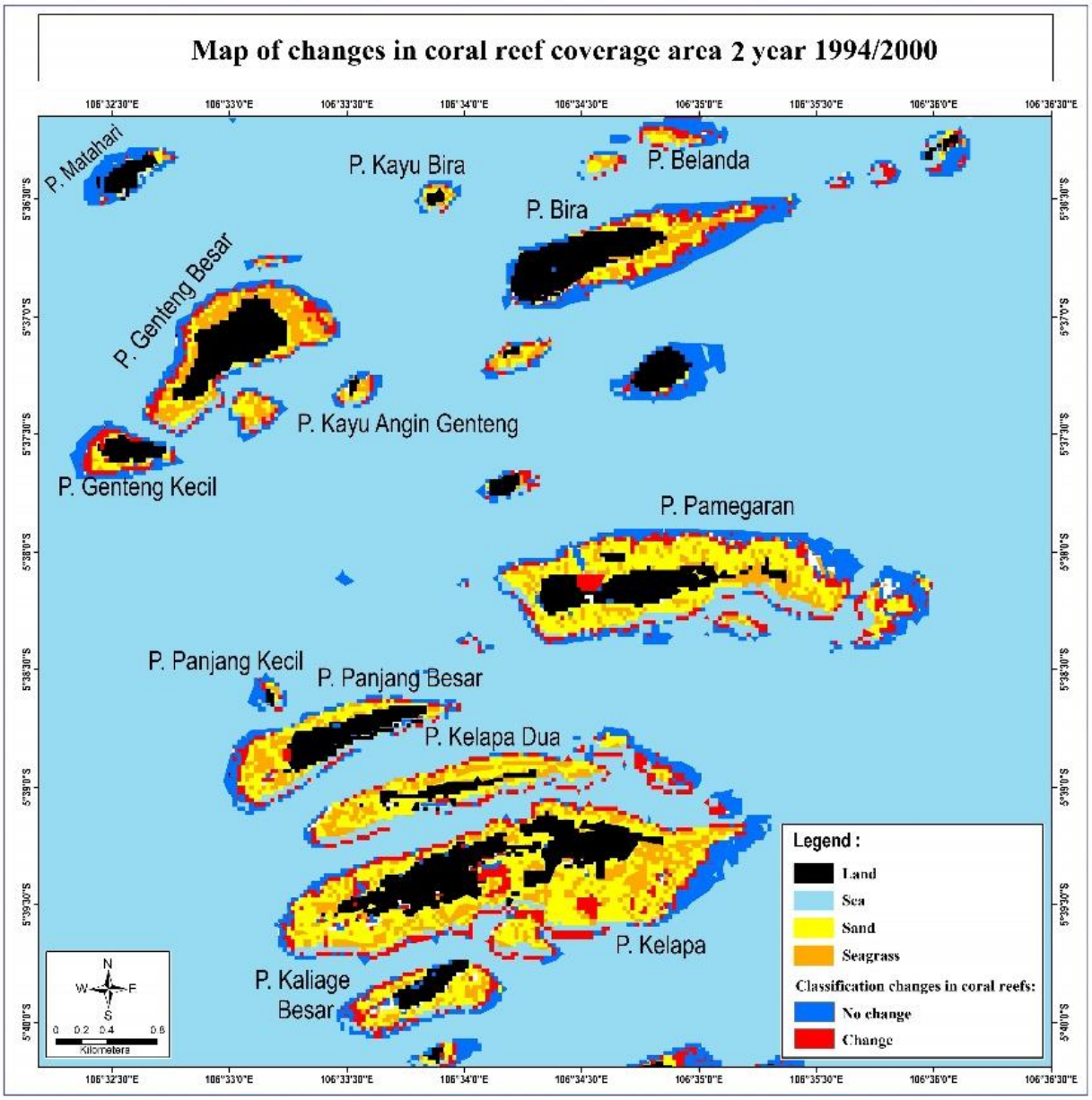

Figure 6. Changes in coral reef cover of area 2 in 1994/2000

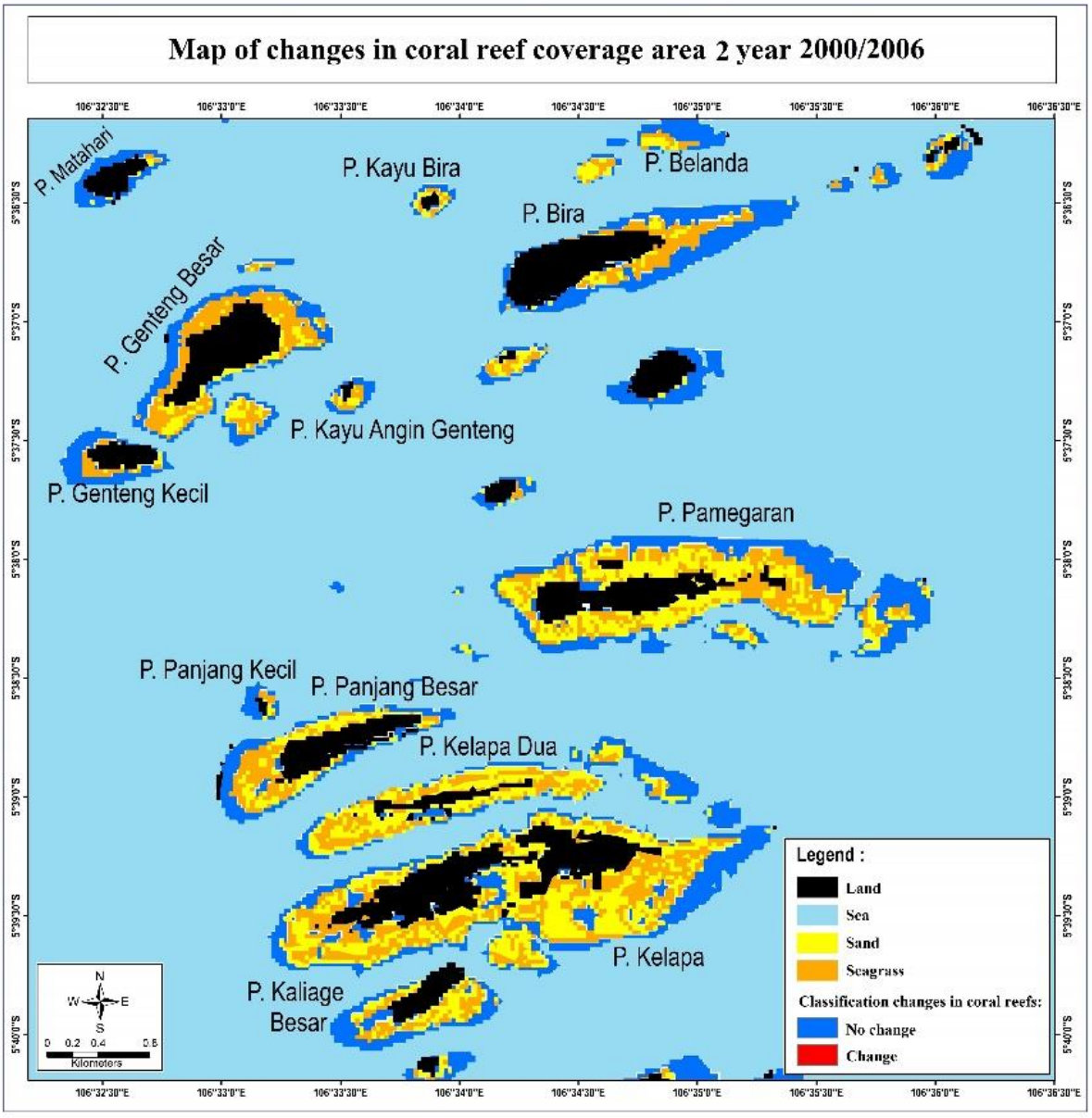

Figure 7. Changes in coral reef cover of area 2 in 2000/2006

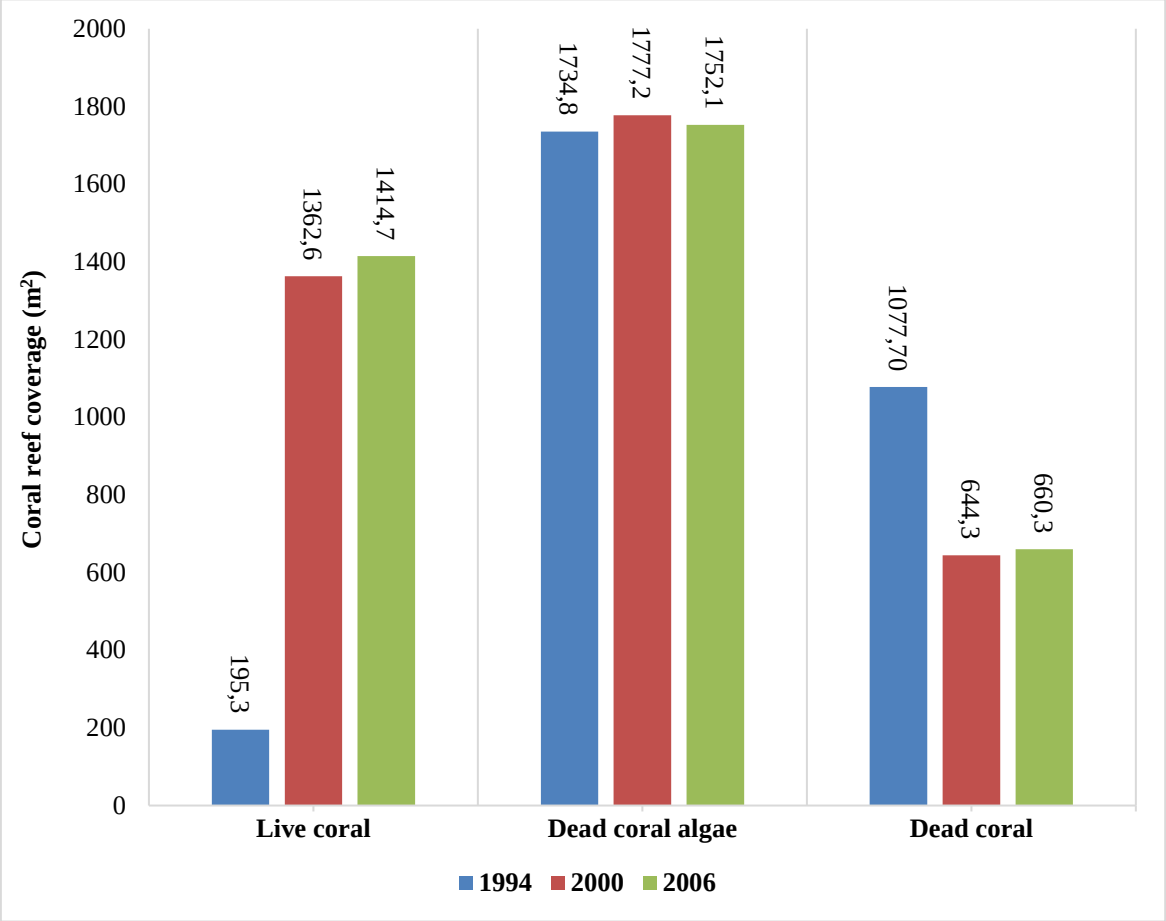

Figure 8. Graph of coral reef cover in area 2