Mangrove density level and area change analysis in small islands case study: Untung Jawa Island, Seribu Islands, DKI Jakarta

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Abstract. This study was conducted to analyze the changes in mangrove area and the density level of mangrove based on satellite imagery and field surveys in Untung Jawa Island. The image data used was Landsat image data acquired in 2000, 2005, 2010, 2015 and 2019. Apart from those, sentinel-2 data received in April 2019 were also retrieved to be compared with field data to see the density level and its accuracy. Image analysis to determine the area and density of mangroves was the Normalized Difference Vegetation Index (NDVI) model. Measurement of mangrove vegetation in the field was obtained by the line plot transect method. The results of temporal image data analysis showed the changes in mangrove area from 2000 (8.46 ha), 2005 (7.56 ha), 2010 (8.45 ha), 2015 (10.65 ha) and 2019 (6.89 ha). In 2019 the mangrove density was dense, while the result of the field survey was categorized as very dense. The level of accuracy for density using remote sensing data is 92.5%. Through the results of the field survey, the mangrove diversity was relatively low, mangrove species on the island was very uneven, and the dominant species was Rhizophora mucronata.

1. Introduction
Marine tourism is one of the potential resources of local revenue that must lead to the comprehensive planned development so that optimal benefits can be obtained [1]. As with marine tourism, coastal tourism is also an important part of the national economy as long as the management is good to maintain both environment and tourism aspect [2]. Related to this, coastal tourism must be considered in the framework of sustainable management. Tourism development often transforms land functions into the infrastructure that is not based on the principle of sustainability so that it exceeds the carrying capacity of the region [3]. Seribu Islands, Province of DKI Jakarta is a group of islands which is a marine tourism destination. Untung Jawa Island is located in the southern part of Seribu Islands, close to Tanjung Pasir and Jakarta. Due to geographic and accessible factors, Untung Jawa become one of the most visited tourism destinations in Seribu Islands [4]. However, the high number of tourists assumed to be overcapacity. In 2013, the number of tourists in Untung Jawa was 649846 persons which means 44% of the number of tourists in Seribu Islands [5]. Untung Jawa has the land area of 40.1 ha with 3.1 ha covered with mangrove area. Mangrove ecosystem has crucial role of supporting coastal area and marine ecosystem [6]. The main functions of mangrove ecosystem are physical function such as reducing wind and abrasion and carbon storage, chemical function as a nutrient producer, and biological function as nursery and spawning ground [7][8]. The increasing
number of tourists and unsustainable tourism management has led to a large number of land uses. They changed mangrove ecosystems became touristic area and settlements [9]. Land use changes must be monitored annually to maintain the function of mangrove ecosystems. Tourist growing numbers need management strategy that suitable for both social economics and environmental aspects. This study was conducted to analyze mangrove changes and condition through years since there is no time series data of mangrove densities.

2. Material and methods

2.1. Remote sensing data

Images that has been used are from three Landsat types of satellites and one data using Satellite Sentinel-2 image, the data are as follows (Table 1):

| Satellite          | Acquisition date | Spatial resolution (m) | Path and Row |
|--------------------|------------------|------------------------|--------------|
| Landsat 7 ETM+     | 2000 – 09 – 14   | 30                     | Path :122; Row : 64 |
| Landsat 5 TM       | 2005 – 07 – 02   | 30                     | Path :122; Row : 64 |
| Landsat 5 TM       | 2010 – 08 – 01   | 30                     | Path :122; Row : 64 |
| Landsat 8 OLI      | 2015 – 03 – 24   | 30                     | Path :122; Row : 64 |
| Landsat 8 OLI      | 2019 – 07 – 06   | 30                     | Path :122; Row : 64 |
| Sentinel-2B        | 2019 – 05 – 30   | 10                     | Untung Jawa Island |

Imagery data from Landsat used to determine changes mangrove areas on Untung Jawa Island over 20 years. The Sentinel-2B imagery is used to determine the density of mangrove at 2019. These remote sensing data has been corrected using field observation, which is held close to acquisition date of Landsat 8 OLI (acquisition date on 2019 – 07 – 06) and Sentinel 2B image data.

2.2. Mangrove density using NDVI

The Normalized Difference Vegetation Index (NDVI) is used to obtain information about density and level of vegetation greenness. NDVI value is calculated as the ratio between the NIR (Near Infrared Radiation) bands with the red band in the electromagnetic wave spectrum. The NDVI equation as follows [10]:

\[
NDVI = \frac{(NIR - Red)}{(NIR + Red)}
\]  

(1)

NDVI will produce a new image with a range of values -1 to +1, vegetation is characterized by high NDVI value. In contrast, water bodies are represented as negative NDVI values due to electromagnetic absorption by water [11]. The vegetation index for green plants in general is around 0.1-0.7 [12].

2.3. Mangrove supervised classification using Support Vector Machine (SVM) algorithm

This classification method used to determine the mangrove and non-mangrove vegetation using the point that we observed from field observation (ground truth). In general, problems in the real world are rarely linear separable, most are nonlinear [13]. To solve non-linear problem, SVM is modified by insert kernel functions into it [14]. One of the kernels that used for this study is RBF (radial basis function) with the equation as follows:

\[
RBF: K(x, x_b) = \exp\{-||x - x_b||^2/\alpha^2\}
\]  

(2)
2.4. Accuracy test
The NDVI transformation results for mangrove density from remote sensing data are validated using confusion matrix, this is done by comparing the image of classification results as a map and the results of field observations. Overall accuracy between those that mentioned before can be seen as follows [15]:

\[
\text{Overall accuracy} = \frac{\sum_{i=1}^{k} n_{ii}}{n}
\]

(3)

\[
\text{Producer’s accuracy } j = \frac{n_{jj}}{n+j}
\]

(4)

\[
\text{User’s accuracy } i = \frac{n_{ii}}{n_{i+}}
\]

(5)

Ground check was done in April 2019 in 4 stations in Untung Jawa Island.

![Figure 1](image)

**Figure 1.** Map of sampling location in Untung Jawa Island.

2.5. Data collection
Mangrove sampling was conducted with Systematic Random Sampling method. Data collection was using line transect and quadrat transect 10 x 10 m. Transect (line transect) was drawn from the direction of the sea towards the land and placed a quadrant with a measurement of 10 x 10 m as many as 5 plots in each station.

2.6. Data analysis
Mangrove data was analyzed with formula as below [16]:
Density and relative density was measured by formula as follow:

\[
D_{i} = \frac{\text{the total number of individuals}}{\text{total area}}
\]

(6)

\[
RDi = \frac{Di}{\sum_{1}^{n} Di} \times 100
\]

(7)
Coverage and relative coverage was measured by formula as follow:

\[ C_i = \frac{\text{basal area}}{\text{total sample plot area}} \]  \hspace{1cm} (8)

\[ RCI = \frac{C_i}{1-C_i} \times 100\% \]  \hspace{1cm} (9)

Mangrove density and coverage then used to determine mangrove damage level to categorize whether the mangrove ecosystem is good or damaged. Mangrove damage level was measured based on Decree of the Minister of Environment, number 201 of 2004 [17] (Table 2).

| Criteria   | Coverage (%) | Density (tree/ha) |
|------------|--------------|-------------------|
| Good       | Very dense   | \( \geq 75 \)     | \( \geq 1500 \) |
|            | Dense        | \( 50 - < 75 \)   | \( 1000 - < 1500 \) |
| Damaged    | Rare         | < 50              | <1000             |

3. Results and discussion

3.1. Land use change

The area of mangrove on Untung Jawa Island is changed after 20 years period, as seen at the map (Figure 1). The changes of mangrove area was calculated using data from Landsat imagery. Mangrove density are dense along the shoreline at the northern part to the east part of the island and some parts along the coast of the island in 2000. In 2005 to 2019 there is different distribution pattern, the mangrove areas is found mostly at the northern part of this island. Changes in the area of mangroves from 2000 to 2019 using satellite imagery data can be seen in Figure 3. In 2000 the total area of mangrove was 8.46 hectares decreased in 2005 to 7.46 hectares but then increased to 8.45 hectares in 2010, until 2015 it increased to 10.65 hectares. In 2019 the mangrove area has been degraded to 6.89 hectares (Figure 2).

![Figure 2. The changes of mangrove areas on Untung Jawa Island from 2000 – 2019.](image-url)
Figure 3. Mangrove areas changes from 2000 – 2019.

Data used to calculate mangrove density on Untung Jawa Island is an image from Sentinel-2B and the results obtained using NDVI are shown in Figure 4. The density category using NDVI is shown in Table 3, the dense has value between 0.8-0.1, moderate density 0.6-0.7 and rare density 0.4-0.6.

Figure 4. Distribution of mangrove density using NDVI.
Table 3. Mangrove density category on Untung Jawa Island.

| Category | Index Vegetation Value | Reference [18] |
|----------|------------------------|----------------|
| Rare     | 0.4 – 0.6              | 0.37 – 0.61    |
| Moderate | 0.6 – 0.7              | 0.61 – 0.76    |
| Dense    | 0.8 – 1.0              | 0.76 – 1.0     |

Figure 5. Mangrove density on Untung Jawa Island.

After the NDVI value was obtained then the supervised classification is used to see the mangrove cover density by using SVM algorithm of the Sentinel-2B satellite imagery of Untung Jawa Island, and the results are shown in Figure 5. Level of accuracy using Sentinel-2B satellite images based on NDVI values is quite high, the results of confusion matrix can be seen in Table 4. The accuracy test result that overall accuracy is 92.5% and kappa coefficient is 0.88 (Table 5). This shows that overall accuracy has good accuracy and can be used [19].

Table 4. Confusion matrix of mangrove density based on NDVI values.

| Class   | Dense | Moderate | Rare | Total |
|---------|-------|----------|------|-------|
| Dense   | 13    | 0        | 0    | 13    |
| Moderate| 2     | 15       | 1    | 18    |
| Rare    | 0     | 0        | 9    | 9     |
| Total   | 15    | 15       | 10   | 40    |

Table 5. Accuracy test results for mangrove density based on NDVI values.

- Overall accuracy : 92.5%
- Kappa coefficient : 0.88

| Class   | Prod. Acc (%) | User Acc (%) |
|---------|---------------|--------------|
| Dense   | 86.67         | 100          |
| Moderate| 100           | 83.33        |
| Rare    | 90k           | 100          |
3.2. Mangrove damage level
Data analyses of mangrove coverage, mangrove density and mangrove damage level from field sampling on Untung Jawa Island are shown in Table 6. The dominant species can be seen from the percentage of mangrove cover, which was *Rhizophora mucronata*. Mangrove density was measured to determine the Mangrove Damage Level. Of the four stations on the island of Untung Jawa, stations categorized as Damaged or Rare were stations 1 and 3 with the number of ind/ha <1000. The density at station 1 was worth 620 ind/ha while at station 3 was worth 860 ind/ha. Stations 2 and 4 were categorized as Good / Very Dense with the number of individuals/ha ≥ 1500. Mangrove density at station 2 was 2,460 ind/ha and station 4 was 3380. Overall, the average density on the island of Untung Jawa seen from the 4 stations was 1,830 ind/ha. Although Untung Jawa Island is a tourist destination with an increasing number of tourists, the Mangrove Damage Level was still classified as Good / Very Dense. The coverage and density of mangrove in 4 stations are showed in Table 6.

| Station | Species          | Ci (m²/ha) | RCi (%) | Di (Ind/ha) | RDi (%) | Mangrove Damage Level     |
|---------|------------------|------------|---------|-------------|---------|---------------------------|
| 1       | *Rhizophora mucronata* | 7.21       | 100     | 620         | 100     | damaged/rare              |
| 2       | *Rhizophora mucronata* | 56.96      | 92      | 2380        | 96.75   | good/very dense           |
| 3       | *Avicennia lanata*  | 4.75       | 8       | 80          | 3.25    | damaged/rare              |
|         | *Ceriops tagal*    | 1.23       | 9       | 60          | 6.98    | good/very dense           |
| 4       | *Rhizophora mucronata* | 12.46      | 91      | 800         | 93.02   | damaged/rare              |
| 5       | *Lumnitzera racemosa* | 0.13       | 0       | 20          | 0.6     | good/very dense           |

As in the map of mangrove area changes each year, it can be seen that there was an increase in mangrove area from 2015 to 2019. One of the factors causing this increase is mangrove planting in Untung Jawa Island. In 2012, mangrove restoration was carried out one of them by the Terbuka University with a success rate of 72% [9]. Mangrove degradation from 2015 is likely due to dense settlements. Although the current conditions are classified as good, supervision also needs to be done for sustainable management.

4. Conclusion
The dominant mangrove species on the island of Untung Jawa was *R. mucronata* and the category of mangrove damage level was good/very dense. Furthermore, monitoring is needed to monitor the condition of mangrove ecosystems from time to time. Changes in the area of mangroves using satellite imagery data in 2000 decreased in 2005 but then increased in 2010, until 2015 it increased and 2019 has been degraded. The accuracy test result shown that overall accuracy is a good accuracy and can be used.

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