Evaluation of the critical level of mangrove ecosystems using Spatial Technology in East Aceh Coastal Areas

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Abstract. Coastal zones are areas that are vulnerable to ecological damage. One type of ecosystem that is vulnerable to damage in coastal zones is mangroves. The coastal area of East Aceh is one of the areas where the existence of mangrove ecosystems has a high level of criticality. The level of criticality of mangroves in the area is caused by various factors such as exploitation of natural resources, physical development such as residential areas, and conversion of land to other designation areas without considering to the sustainability of mangrove ecosystems. By utilization of Landsat 8 and Bing Map Imagery satellite image data using the concept of geographic information systems, the extent of mangrove forest and its critical level can be inventoried. Determination of the critical level of mangrove forests was carried out by referring to the mangrove inventory guidelines issued by the Indonesian Ministry of Forestry in 2005. The results of data processing showed that the critical level of mangrove forests reached 4,200.02 hectares in severely damaged conditions, 7,286.93 hectares in damaged condition, and 9.704, 01 hectares are not damaged. Based on these results, forest management efforts are needed through the method of rehabilitating mangrove forests to improve the condition of heavily damaged mangrove forests.

1. Introduction

Problems about the environment have hit Indonesia a lot. One of the developing environmental problems is climate change. This happened due to global warming caused by increasing greenhouse gas emissions. One of the most influential greenhouse gas emissions for global warming is carbon dioxide (CO\textsubscript{2}). \cite{1} suggests that an increase in CO\textsubscript{2} in the atmosphere comes from human activities such as fossil combustion, industrial activities, and motor vehicle exhaust gases. In addition, damage to forests such as burning and logging of trees further aggravates the situation because deceased trees release CO\textsubscript{2} stored in plants into the atmosphere. Related to these problems, one of the efforts that can be done to reduce CO\textsubscript{2} in the atmosphere is through absorption of greenhouse gases by various forest vegetation. One of the forest vegetation that is able to absorb carbon dioxide is mangrove.

Mangrove forests are a unique forest ecosystem that acts as a link between terrestrial and marine ecosystems. According to the forestry minister's regulation No. P.03/MENHUT-V/2004, mangrove forests are the forests that can grow on alluvial land in coastal areas and around river estuaries which are affected by tides and are characterized by tree species \textit{(Avicennia, Sonneratia, Rhizophora, Bruguiera, Lumnitzera, Xylocarpus, and Nypa)}. The ideal place for mangrove growth is around the coast, estuary, or delta with sediments in the form of sand or mud, sloping, and relatively protected.
One of the locations of mangrove forests in Indonesia, especially in Aceh province, is the coastal area of East Aceh. The natural vegetation of mangrove forests is found in most coastal areas of East Aceh Regency which is one of the best mangrove forests owned by the Aceh Province. There are even some opinions that East Aceh mangrove forest is one of the best mangrove forests in Indonesia. However, since the beginning of the 1980s with the issuance of HPH (Rights of Forest Entrepreneurs) licenses to several companies in the management of mangrove forests causing damage to the mangrove forest ecosystem on a regular basis causing the condition of mangrove land to be increasingly critical [3]. The existence of mangrove forests in this region has decreased a lot. This decline is caused by human activities that do not pay attention to the sustainability aspects of mangroves such as physical development and land conversion functions into other land use. Based on this, to reduce human activities for the exploitation of mangrove forests, an effort should be made in the form of rehabilitation of mangrove forests.

The unsuitability in the use of mangrove forests that is currently being carried out causes a variety of damage so that it can change its ability to carry out its environmental and biological functions. Consequently, to preserve the sustainability of mangrove ecosystems and maintain environmental functions and biology, research is conducted on the criticality and conservation level of mangrove ecosystems by utilizing the spatial technology [4]. In this study, it was conducted with the aim to determine the area of mangrove forest based on its critical level, so that later the results of this study can be used as a reference for designing a development policy that is ideal and suitable for coastal areas without damaging their ecological conditions.

2. Material and Methods
This research was conducted at the Remote Sensing and Cartography Laboratory of the Faculty of Agriculture, Universitas Syiah Kuala with the location of the study in East Aceh coastal areas from March to August 2018.

The tool used in this study is a set of computers equipped with ArcMap 10.1 software and field equipment GPS (Global Positioning System). While the materials used in this study include Landsat 8 imagery, Bing Maps imagery obtained from SAS PLANET software ver. 17, the administrative map, the land use map, the land system map (geology/soil type) of East Aceh Regency.

This research was carried out by referring to the Guidelines for Inventory and Identification of the Mangrove Forest's Critical Levels issued by the Indonesian Ministry of Forestry in 2005. Based on these guidelines there were two ways that were carried out to determine the critical level of mangroves, namely by means of directly determine in the field and by using GIS technology. This study uses the method that is carried out by utilizing GIS (Geographic Information System) technology. This method assessment system uses 3 criteria to determine the critical level, namely the type of land use (JP), the density of head (Kt), and soil resistance to abrasion (Kta).

The method used in this study is descriptive method with survey techniques, while data analysis is done through weighting and scoring methods. The stages of research include preparation, data collection, data analysis, field observation, discussion and conclusion. The flow of research can be seen in Figure 1.

The use of Bing Maps Imagery data is a reference to determine the distribution of mangroves and the type of land use in the mangrove area. Bing Maps Imagery was analyzed using visual on-screen digitation methods to obtain mangrove distribution and land use type in mangrove forests. The distribution of mangroves was used as a reference for subsequent criterion analysis, while the type of land use was classified according to the Department of Forestry criterion classes of 2005. The land use classes used were forests, irrigation and plantation plots, and other types of uses such as settlements, industries, non-overlapping mounds, fields, and bare land. The field observations are performed to match previously analyzed data to field conditions. The field observations are performed using the help of GPS (Global Positioning System). Data that has been matched to the field conditions is then re-analyzed to produce more accurate data.
The canopy density analysis is done by using Landsat 8 imagery data and NDVI (Normalized Difference Vegetation Index) formulation. Mathematically the NDVI value can be obtained using the following formula:

\[
NDVI = \frac{(\text{Band Infra Red} - \text{Band Red})}{(\text{Band Infra Red} + \text{Band Red})}
\]  

(1)

The results of calculation of formula (1) are then classified according to the desired number of classes. In this study three classes were used, namely dense, medium and thin canopy classes. Mathematically the formula for determining the interval (distance) between density classes is as follows:

\[
\text{Classification} = \frac{\text{Maximum Value} - \text{Minimum Value}}{\text{Total Classes}}
\]  

(2)

Soil resistance to abrasion was analyzed using land system maps or geological maps, namely maps of soil types and maps of mangrove distribution obtained from previous analysis. The maps of soil types and maps of mangrove distribution are overlaid so that the maps of soil types in the mangrove area are obtained. The classification of soil resistance to abrasion is based on the sensitivity of each type of soil to erosion. The types of soil obtained from land system maps are categorized into three categories, namely the type of soil that is not abrasion sensitive, the type of abrasion sensitive soil, and
the type of soil is very sensitive to abrasion based on the level of sensitivity to erosion in accordance with Indonesian Ministry of Agriculture Decree No.837/Kpts/Um/11/1980 [5]. The three criteria were then classified according to the class of mangrove critical criteria according to the [5] and given weights and scores to calculate the critical level. Tabularly the critical criteria for mangroves are presented in Table 1.

Table 1. Criteria, Weight, and Scoring for Determining the Level of Critical Mangrove Land using Remote Sensing Technology and GIS

| No. | Criteria                          | Weight | Score | Rating Description                                      |
|-----|----------------------------------|--------|-------|---------------------------------------------------------|
| 1.  | Types of Land Use (JPL)          | 45     | 3     | Forest (forested area)                                  |
|     |                                  |        | 2     | Ponds Intercropping, plantation                         |
|     |                                  |        | 1     | Settlements, industries, non-intercropping ponds, rice fields, bare land |
| 2.  | Dense of Canopy (Kt)             | 35     | 3     | Dense canopy density (70 – 100%, or 0.43 ≤ NDVI ≤ 1.00) |
|     |                                  |        | 2     | Medium canopy density (50 – 69%, or 0.33 ≤ NDVI ≤ 0.42) |
|     |                                  |        | 1     | Thin canopy density (<50%, or -1.0 ≤ NDVI ≤ 0.32)        |
| 3.  | Soil resistance to abrasion (Kta) | 20     | 3     | Type of soil not sensitive to abrasion                   |
|     |                                  |        | 2     | Type of soil sensitive to abrasion                       |
|     |                                  |        | 1     | Type of soil very sensitive to abrasion                  |

Source: Guidelines for Inventory and Identification of Mangrove Land Critical Levels (Department of Forestry, 2005)

3. Result and Discussion
3.1. Distribution and Types of Land Use Around Mangrove Forest in East Coast of Aceh
The results of Bing Maps imagery analysis produce the data on the distribution of mangroves in the mangrove areas and the type of land use around the coastal areas of the East Aceh mangrove forest. Based on the results of data analysis, the mangrove forest area was 12,452.77 hectares. Mangrove forests in the coastal areas of East Aceh are spread in 11 sub-districts.

Table 2. Types of Land Use Around the Mangrove Forest of the East Aceh Coastal Area

| No.  | Sub-district   | Forest (Forested areas) | Ponds Intercropping, plantation | Settlements, industries, non-intercropping ponds, bare land |
|------|----------------|-------------------------|----------------------------------|-------------------------------------------------------------|
| 1.   | BiremBayeun    | 2,355.91                | 806.90                           | 638.80                                                      |
| 2.   | RantauSelamat  | 3,545.24                | 1,037.94                         | 1,263.40                                                    |
| 3.   | Sungai Raya    | 781.00                  | 512.23                           | 1,275.13                                                    |
| 4.   | PeureulakTimur | 843.94                  | 297.51                           | 1,302.27                                                    |
| 5.   | Peureulak      | 1,701.76                | 0                                | 2,000.73                                                    |
| 6.   | Peureulak Barat | 370.41                | 0                                | 184.98                                                      |
| 7.   | Peudawa        | 1.32                    | 0                                | 0                                                           |
| 8.   | Nurussalam     | 153.90                  | 75.89                            | 100.79                                                      |
| 9.   | Julok          | 206.24                  | 3.18                             | 0                                                           |
| 10.  | Madat          | 967.19                  | 0                                | 0                                                           |
| 11.  | SimpangUlim    | 1,525.86                | 793.44                           | 54.09                                                       |
| Total|                | 12,452.77               | 3,527.09                         | 6,820.19                                                    |
The types of usage analyzed consisted of several land use classes, namely forests, intercropping ponds and plantations, as well as settlements, non-intercropping ponds and bare land covering an areas of 12,452.77 hectares functioned as forest (forested area), while intercropping and plantations covering an area of 3,527.09 hectares and residential areas, non-intercropping ponds and bare land covering an area of 6,820.19 hectares.

The density level of canopy of mangroves in the coastal area of East Aceh is classified into three classes, namely dense, medium and thin. The density level in the dense category covering an area of 6,505.72 hectares, medium category covering an area of 9,355.48 hectares, and in thin category covering an area of 6,923.65 hectares.

Table 3. The Density of Canopy of Coastal Mangrove in East Aceh

| No. | Sub-district     | Density Canopy Classes (ha) |
|-----|------------------|----------------------------|
|     |                  | Dense | Medium | Thin     |
| 1   | BiremBayeun      | 1,136.03 | 2,015.67 | 647.60 |
| 2   | RantauSelamat   | 2,259.53 | 2,503.57 | 1,085.61 |
| 3   | Sungai Raya      | 404.52 | 829.57 | 1,332.51 |
| 4   | PeureulakTimur  | 402.46 | 715.17 | 1,325.07 |
| 5   | Peureulak       | 693.76 | 1,403.30 | 1,601.68 |
| 6   | Peureulak Barat | 252.42 | 229.58 | 71.48 |
| 7   | Peudawa         | 60.95 | 0.65 | 0.52 |
| 8   | Nurussalam      | 90.52 | 165.64 | 103.24 |
| 9   | Julok           | 299.56 | 823.5 | 34.39 |
| 10  | Madat           | 0 | 0 | 0 |
| 11  | SimpangUlim     | 0 | 932.17 | 533.82 |
|     | Total           | 6,505.72 | 9,355.48 | 6,923.65 |

Soil resistance to abrasion in the East Aceh coastal area is divided into three classes based on soil type, namely very sensitive to abrasion, sensitive to abrasion, and not sensitive to abrasion. The class of very sensitive to abrasion covering an area of 1,091.33 hectares, sensitive to abrasion covering an area of 1,238.31 hectares, and not sensitive to abrasion covering an area of 20,470.43 hectares.

Table 4. Soil resistance Against Coastal Abrasion in East Aceh

| No. | Sub-district     | Resistance to Abrasion (ha) |
|-----|------------------|----------------------------|
|     |                  | Very Sensitive Abrasion | Sensitive Abrasion | Not Sensitive Abrasion |
| 1   | BiremBayeun      | 40.27 | 605.15 | 3,156.20 |
| 2   | RantauSelamat   | 327.15 | 632.55 | 4,886.88 |
| 3   | Sungai Raya      | 59.85 | 0.61 | 2,507.91 |
| 4   | PeureulakTimur  | 0 | 0 | 2,443.72 |
| 5   | Peureulak       | 264.39 | 0 | 3,438.10 |
| 6   | Peureulak Barat | 398.35 | 0 | 157.04 |
| 7   | Peudawa         | 1.32 | 0 | 0 |
| 8   | Nurussalam      | 0 | 0 | 330.58 |
| 9   | Julok           | 0 | 0 | 209.42 |
| 10  | Madat           | 0 | 0 | 967.19 |
| 11  | SimpangUlim     | 0 | 0 | 2,373.39 |
|     | Total           | 1,091.33 | 1,238.31 | 20,470.43 |


3.2. Critical Level of Mangrove Forests

Based on the results of the study it was obtained that the critical level of the East Aceh coastal mangrove forest of 4,002.02 hectares belonged to the category of severely damaged, damaged category covering an area of 7,286.93 hectares, and the not damaged category covering an area of 9,704.01 hectares. The highest critical distribution which is classified as heavily damaged and not damaged is in the area of Peureulak covering an area of 1,151.69 hectares, while the highest distribution of not damaged areas is in the District of RantauSelamat with an area of 3,256.24 hectares. The distribution and extent of the critical level of mangroves in East Aceh Regency are presented in Table 5 and visually presented in Figure 2. Based on Table 5, the condition of mangroves on the coast of East Aceh is dominated by uncritical critical classes. However, it is the possibility that the remaining mangrove forests are not maintained and continue to be exploited without any effort to improve the condition of the mangrove forests will deteriorate.

Table 5. The critical level of coastal mangrove forests in East Aceh

| No. | Sub-district     | SeVERely Damaged | Damaged     | Not Damaged |
|-----|------------------|------------------|-------------|-------------|
| 1   | BiremBayeun      | 332.99           | 1,076.69    | 2,064.06    |
| 2   | RantauSelamat    | 573.83           | 1,713.16    | 3,256.24    |
| 3   | Sungai Raya      | 825.24           | 1,067.58    | 540.00      |
| 4   | PeureulakTimur   | 916.44           | 934.62      | 521.55      |
| 5   | Peureulak        | 1,151.69         | 1,150.41    | 980.36      |
| 6   | Peureulak Barat  | 128.86           | 127.27      | 202.77      |
| 7   | Peudawa          | 0                | 0           | 0           |
| 8   | Nurussalam       | 47.61            | 142.28      | 81.32       |
| 9   | Julok            | 0                | 24.38       | 92.16       |
| 10  | Madat            | 0                | 131.48      | 706.01      |
| 11  | SimpangUlim      | 25.36            | 919.06      | 1,259.54    |
| Total|                 | 4,002.02         | 7,286.93    | 9,704.01    |

Figure 2. The Map of the Critical Level of Mangrove Forest in the East Aceh Coastal Zone
3.3. Mangrove Forest Conservation Efforts

One the effort that can be conducted to restore the condition of mangrove forests that have been damaged is through efforts to rehabilitate forests using the reforestation method in the coastal areas of East Aceh. Th reforestation activities are expected to be able to withstand the rate of abrasion, seawater intrusion, and as a protector of residential areas. The important function of coastal vegetation is realized by the community when the vegetation is damaged. The wind blow that carry hot air from the sea are felt by the community, especially in the west wind season (July-November). That season strong winds blow from the Malacca Strait hit the East Aceh District of the coastal region without any obstacles. This season faces sea waves caused by wind blow reaching a height of + 3m.

4. Conclusion

The critical level of mangrove forests in the coastal areas of East Aceh is categorized into severe damage covering an area of 4,002.02 hectares, damaged covering an area of 7,286.93 hectares, not damaged covering an area of 9,704.01 hectares. Through land rehabilitation efforts, the condition of damaged mangrove forests can be preserved. In addition, rehabilitation efforts are also carried out to provide benefits to the environment and improve welfare coastal communities.

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