Application of Landsat-TM data and Geographic Information Systems For Inventorying the Degradation of Mangrove Forest in East Kalimantan Province

SYARIF BUDHIMAN , RATIH DEWANTI ,
Remote Sensing Application and Technology Development Center (PUSBANGJA) LAPAN
JL. LAPAN 70, Jakarta 13720, Fax. 021-8722733, Phone. 021-8717714. Email: bankdata@lapanrs.com.

CECEP KUSMANA
Faculty of Forestry - Bogor Agricultural University (IPB),
Kampus IPB Darmaga, P.O. Box 168 Bogor 16001, Fax. 0251-621256, Phone. 0251-621677. Email: sifahut@bogor.wasantara.net.id.

ABSTRACT
Indonesia has very large mangrove forest area. About 16% of Indonesian mangrove forest area is exist in Kalimantan Island or known as Borneo Island. East Kalimantan is one of four Province in Kalimantan Island that has large area of mangrove forest.

This study was conducted to know the existing of mangrove forest in East Kalimantan and also to inventory the degradation of the mangrove forest judging from the mangrove potential area. Mangrove potential area derived from the land system map, and the land system classes that have potential parameters for mangrove living are called as mangrove potential area. The method of this study was to analysis mangrove degradation from Landsat-TM data and Geographic Information Systems (GIS). Land use / land cover derived from Landsat data using Maximum Likelihood Classification. The canopies index vegetation of mangrove derived from Landsat data using Normalized Difference Vegetation Index (NDVI). The result of Land use classification and the canopy index were overlaying with land system digital map, and the field data.

The mathematical model for identifying mangrove degradation is $TNS = (N \times 30) + (Np \times 20) + (L \times 15) + (A \times 15) + (P \times 10) + (C \times 10)$, where $TNS$ is for total score; $N$ is for total tree per hectare; $Np$ is for total young tree per hectare; $L$ is for width of mangrove green belt; $A$ is for abrasion; $P$ is for pyrite; and $C$ is for water pollution.

From the data processing result, the mangrove potential area in East Kalimantan is about 759.583,89 ha. Mangrove forest that still exist in East Kalimantan is about 389.426,76 ha, with the area of dense mangrove forest 163.682,82 ha, medium mangrove forest 171.025,83 ha, and sparse mangrove forest 54.718,11 ha. The mangrove potential area that is not degraded is 369.908,19 ha, degraded area 354.814,56 ha, and very degraded area 34.861,14 ha.

Judging from the factor that caused the degradation indicated that social economy factor has become the potential factor that caused the degradation. Especially the land use changes between mangrove forest areas become the fishponds.

Keywords: Landsat, GIS, Mangrove Degradation

INTRODUCTION
A mangrove forest is a salt tolerant forest ecosystem of the intertidal regions along coastlines. Mangroves are coastal vegetation that has specific characteristics, which allow them to survive on mix marine and terrestrial environment. They have biological adaptation mechanism to adapt to daily fluctuations of the environment, such as temperature, salinity and inundation period.

Mangroves have an important function in coastal ecosystems such as 1) protection of area from erosion of sea waves or wind, 2) production of organic matter so that it can be components of chain of food web for fish and shrimp, 3) protection of area for young fauna, like birds and bats (Notohadipoero and Siradz, 1978).

Mangrove forest is a special type of forest found on coastlines or river mouths, which are influenced by tide. The most common, mangroves grow on bay with calm sea current and a gentle slope (Anwar and Subiandono, 1997). Mangrove ecosystem, both structure and function, depend heavily on various important environments factors such as climate, tides, waves and current, salinity, dissolved oxygen, soil and nutrients (Aksornkoae, 1995).

Mangrove forest has been widely and variously used by people who live in or close to them and who
traditionally have made a living from the mangrove ecosystem for thousands of years. In Indonesia, the people have used mangrove tree for timber (Burbridge and Koesoeibiono, 1980; Aksornkoae, 1995), grazing and. Moreover, in some countries, mangroves are used as wildlife sanctuary, protecting coastline and riverbanks against tidal bores and cyclones and also for park and study area (Aksornkoae, 1995).

Indonesia is the most extensive place in the world for the mangrove community. Out of the total mangrove area in the world at 15.9 million hectares, 4.25 million hectares or 27% is in Indonesia. The mangrove area is also recorded in Brazil at 16% and Australia at 7% (Anonym, 1997).

Mangrove forest in Indonesia was approximated 3.8 million hectares in 1992, with distribution 31% for the conservation, 36% for the production forest and the rest (33%) for others (Anwar and Subiandono, 1997). All provinces have mangrove, however the largest part is in Irian Jaya (1,327,000 hectares or 34.8%) and then followed by East Kalimantan (776,000 hectares or 20.3%), South Sumatra (363,000 hectares or 9.5%), Riau (221,000 hectares or 5.8%) and Maluku (148,000 hectares or 3.9%) (Anwar and Subiandono, 1997).

Destruction of mangrove can be found everywhere in the world due to various reasons. The main reason is the population of each country increases and this leads to increases demands for food, fuel, building materials, land cultivation and urbanization (Aksornkoae, 1995). Conversion of mangrove to other use can be classified as follows: 1) over-exploitation by traditional users, 2) conversion to aquaculture, 3) conversion to agriculture, 4) conversion to salt pans, 5) conversion to urban or industry development (Aksornkoae, 1995).

The mangrove degradation also occurred in East Kalimantan, many human settlements have been developed at places where there are mangrove forests. Lack of information about mangrove degradation makes the situation worse.

This study was conducted to know the existing of mangrove forest in East Kalimantan and also to inventory the degradation of the mangrove forest judging from the mangrove potential area. Mangrove potential area derived from the land system map, and the land system classes that have potential parameters for mangrove living are called as mangrove potential area. The method of this study was to analysis mangrove degradation from Landsat-TM data and Geographic Information Systems (GIS). Land use / land cover derived from Landsat data using Maximum Likelihood Classification. The canopies index vegetation of mangrove derived from Landsat data using Normalized Difference Vegetation Index (NDVI).

**MATERIALS AND METHODS**

In this study, it was assumed that long before the human activities occurred in the mangrove forests area, mangroves grows without any disturbance. This assumption was developed to determine mangrove potential area. The mangrove potential area is an area that has some potential parameters for mangrove to live and to grow.

This mangrove potential area derived from RePProt Landsystem Map produced by Bakosurtanal (1988). There are two landsystem classes that have potential parameters for mangrove to grow, "Kajapah" (KJP) and "Kahayan" (KHY). The potential parameters explained in the Map Legend (Table 1).

![Picture 1. Flowchart of The Study](image)
Table 1. Land System Characteristic of Mangrove Potential Area

<table>
<thead>
<tr>
<th>Land System Class</th>
<th>General Description</th>
<th>Parameter</th>
<th>Life Form</th>
<th>Soil Association</th>
<th>Climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kapas (KPF)</td>
<td>Inter-tidal marsh</td>
<td>Height: 2%</td>
<td>Alkaline</td>
<td>Subaqueous, soft</td>
<td>Mean annual rainfall: 2000-3000 mm (snow)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wetness: 20%</td>
<td></td>
<td></td>
<td>Low Temperature: 23°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width: 10%</td>
<td></td>
<td></td>
<td>High Temperature: 31°C</td>
</tr>
<tr>
<td>Kahayan (KHT)</td>
<td>Coastal intertidal</td>
<td>Height: 10%</td>
<td>Alkaline</td>
<td>Subaqueous, soft</td>
<td>Mean annual rainfall: 2000-3000 mm (snow)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wetness: 20%</td>
<td></td>
<td></td>
<td>Low Temperature: 23°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width: 10%</td>
<td></td>
<td></td>
<td>High Temperature: 31°C</td>
</tr>
</tbody>
</table>

Table 2. Parameters, Weight, and Score of Mangrove Degradation Level Analysis

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Weight</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Trees/ha (N)</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Young Trees/ha (Np)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mangrove green belt (L)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Abrasion (A)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Pyrite (P)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Water pollution (C)</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

This study used digital analysis of Landsat-TM data and Geographic Information System (GIS). Some maps of study area were also included, such as Peta Rupa Bumi Indonesia (1:50,000), Peta Land System and Land Suitability (1:250,000), and Peta Tata Guna Hutan (1:500,000). The field survey conducted by IPB team also supports the analysis of this study.

In digital analysis, it used computer and digital data processing software (ER Mapper, Erdas, Arc View, Arc Info dan Auto Cad) conducted in LAPAN.

The main information derived from the Landsat-data was: land cover / land use, mangrove existing, and mangrove density vegetation index. The classification of land use/land cover used supervised classification with Maximum Likelihood Classification (MLC) method. The vegetation index used Normalized Difference Vegetation Index (NDVI) method. The mangrove potential area derived by digitized the land system map. Picture 1 shows the flowchart of this study.

The mathematical model for identifying mangrove degradation is $TNS = (N \times 30) + (Np \times 20) + (L \times 15) + (A \times 15) + (P \times 10) + (C \times 10)$, where TNS is for total score; N is for total tree per hectare; Np is for total young tree per hectare; L is for width of...
mangrove green belt; A is for abrasion; P is for pyrite; and C is for water pollution.

Acid sulphate soils are formed in marine or brackish sediments. During their sedimentation, sulphate (SO₄) from sea water is reduced by organic matter produced by mangrove vegetation to form pyrite (FeSO₄). Further sedimentation gradually changes the environment into freshwater swamp forest, which is waterlogged for most of the year due to the poor drainage of the terrain. As long as the pyrite in topsoil has not yet oxidized, these soils are called potential acid sulphate soils (AARD and LAWOO, 1992). If the soil dried out and oxygenated, pyrite is oxidized to sulphuric acid (H₂SO₄) and iron hydroxide (FeOH₃), producing large amounts of acid. The pH of soil will drop below 3, and acid cations (H⁺) and aluminium will occupy most of the exchange of the soil. This causes toxicities and nutrient deficiencies in the crop (AARD and LAWOO, 1992).

Afterwards, the TNS score divided in three groups, i.e.

a. Score of 100 - 200 : Heavy Degraded
b. Score of 201 - 300 : Degraded
c. Score > 300 : Not Degraded

The parameters, weight, and score of mangrove degradation level shown in Table 2.

Besides the physical factor, this study also conducted the social economy factor of the mangrove degradation. There are four social economy factor included in this study, such as; means of livelihood, location of working area, mangrove wood utilization, and local community perception of the mangrove forest.

RESULT
1. Kajapah (KJP)

According to the mangrove canopy vegetation index from image processing, there are three type of canopy index in this area, i.e. dense mangrove, medium and sparse mangrove.

Dense mangrove forest area has 6 (six) mangrove tree species, i.e. Avicennia marina, Bruguiera sexangula, Rhizophora apiculata, Heritiera littoralis, Ceriops tagal, and Excoecaria agallocha. This dense area dominated by Rhizophora apiculata with density of 660 ind/ha.

Medium density mangrove forest area has the same species with the dense area. Rhizophora apiculata also dominated this area with the density of 223 ind/ha.

Sparse mangrove forest area in this land system class has 6 (six) mangrove tree species, i.e. Avicennia marina, Rhizophora apiculata, Heritiera littoralis, Sonneratia caseolaris, Aegiceras corniculatum and Aegiceras florindum. Also found the vegetation species that always associate with mangrove vegetation, i.e. Hisbiscus tiliaceus.

For the non-forest area in this land system class, according to the image processing result, it has 4 (four) land use cover categories, i.e. settlement, fishpond, bare land, and plantation.

Settlements build in the area that still get tidal effect from the sea and located in coastal area. Mangrove vegetation were very hard to find in this area. The mangrove species left, mostly grows sporadically in the coastal and the river edge.

Fishponds were made by land clearing activities. It caused the degradation of mangrove forest. Mangrove species only found in the edge of the river and the coastal area with the density of 20 ind/ha. The mangrove species that were found in this area are Avicennia marina, Rhizophora apiculata, Rhizophora mucronata, Sonneratia caseolaris and Nypa fruticans.

Actually, bare land that was found in this area consists of bush. Usually, this area was a mangrove forest area, which got so many pressures from human activities, such as felling of trees, so it became an open area. That caused ground vegetation to grow, because they get sufficient sunlight. The ground vegetation that dominated this area are Acrostichum aureum and Acanthus ilicifolius. Mangrove species left only Sonneratia caseolaris with the density of 5 ind/ha.

Plantation that found in this area is Coconut tree plantation, which has established for more than 15 years. This plantation belongs to the local society.

Soil that found in land system KJP generally developed from fresh marin sediment. According to the formation process, this soil formed from muddy land in high tide under halophytic vegetation, which indicate by the water stagnated in the soil. According to the soil observation in the field, soil types in KJP are Sulfaquents and Tropopsammens.

2. Kahayan (KHY)

The result of mangrove vegetation index processing in this land system only found 1 mangrove canopy category, i.e. sparse density mangrove. This area has 7 (seven) mangrove tree species, i.e. Rhizophora apiculata, Heritiera littoralis, Sonneratia caseolaris, Bruguiera sexangula, Bruguiera parviflora, Xylocarpus granatum, and Excoecaria agallocha. The species that dominated this area is Bruguiera sexangula, with density of 136 ind/ha.

Non-forest categories that were found in this land system are settlement, fishpond, plantation, and bare land.

Vegetation found in settlement area, mostly the kind of cultivated trees, such as Cocos nucifera, Mimosa...
Mangrove species are very hard to find in this area. According to the field observation, it was hard to find mangrove species in fishponds area. Mangrove trees only grow in the river edge. The coconut tree plantation found in this area. This plantation has been established for more than 10 years. Bare land in this land system is a land clearing area, which is going to be fishponds.

3. Social Economy Condition

According to the population statistic, the average population in the mangrove potential area is 9 person/km². The lowest population found in Kabupaten Berau (3 person/km²) and the highest population found in Kabupaten Pasir (18 person/km²). The figure above indicates that the populations are not to crowd, but the population growth is quite high. The average of annual population growth is 4.03 % per year.

Education degree of local society in mangrove potential area is mostly Sekolah Dasar (Elementary School) 14.68%. This indicates that the education degree of local society is still low.

DISCUSSION

According to the TNS score, most of the land covers in mangrove potential area are belong to Degraded and Heavy Degraded category. Just two land covers that belong to not degraded category, which are dense and medium mangrove forest in KJP Land system. The heavy degraded category found in land cover of fishponds in either KJP land system or KHY land system. The TNS score and the degradation level shown in Table 3.

Table 3. Mangrove Degradation Scoring

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>N</th>
<th>L</th>
<th>P</th>
<th>C</th>
<th>TNS</th>
<th>Degradation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>KJP</td>
<td>90</td>
<td>75</td>
<td>50</td>
<td>45</td>
<td>30</td>
<td>Not Degraded</td>
</tr>
<tr>
<td>Dense Mangrove</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>Degraded</td>
</tr>
<tr>
<td>Medium Mangrove</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>Degraded</td>
</tr>
<tr>
<td>Fishponds</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>Degraded</td>
</tr>
<tr>
<td>Non Forest</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>Degraded</td>
</tr>
<tr>
<td>Forest</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
<td>Degraded</td>
</tr>
</tbody>
</table>

Mangrove degradation areas in East Kalimantan Province, according to the degradation level are:

1. Non Degraded Area : 369,908,2 ha (48,7%)
2. Degraded Area : 354,814,6 ha (46,7%)
3. Heavy Degraded Area : 34,861,1 ha (4,6%)

Kabupaten Pasir has the most extensive mangrove potential area that found in forest area, which are about 64,793,1 ha. In the non-forest area, the most extensive mangrove potential area found in Kabupaten Bulongan, for about 299,567,1 ha.

Kabupaten Bulongan also has the most extensive heavy degraded category area either in forest area or in non-forest area. The area are 4,385,9 ha and 17,704,2 ha respectively.

Most of the physical environment factors are not have significant impact in the mangrove degradation, but in land cover of dense mangrove and fishponds in KJP land system, these factors have significant impact to the mangrove degradation. Land cover of sparse mangrove and fishponds in KHY land system also has significant impact by physical environment factors.

Social economy parameters in this study are means of livelihood, working location, land utilization, and local society perception. Parameter that has significant impact is means of livelihood. Most of the people in the mangrove potential area are farmers or fishpond farmers. In the field observation, the area with the majority of the people are farmers, have very intensive interaction with the mangrove forest area. They still depend their living from the mangrove ecosystem surrounding.

The land use change from mangrove into another land utilization such as fishponds, settlement, and plantation, practically change the ecological function of mangrove forest.

CONCLUSION

The total area of mangrove potential area in East Kalimantan Province is about 759,583,9 ha, which is 643,509,2 ha or about 84,7% found in non-forest area, and the rest of the mangrove potential area is found in the forest area.

The degradation level of mangrove potential area in East Kalimantan Province are, heavy degraded (34,861,1 ha), degraded (354,814,6 ha) and not degraded (369,908,2 ha).

The potential factor that has significant role in the mangrove degradation is social economy factor, especially the land use change of mangrove forest in others utilization.
REFERENCES


