FOREST DEGRADATION DETECTION USING MODIS AND LANDSAT DATA IN UNDERSTANDING THE IMPLEMENTATION OF REDD SCENARIO IN EAST KALIMANTAN PROVINCE, INDONESIA*)[1]

Mulyanto Darmawan
Researcher, Center for Land Resources Survey,
National Coordinating Agency for Survey and Mapping (Bakosurtanal).
Jln. Raya Jakarta Bogor, km 46 Cibinong 16911, Indonesia -- drmoel@yahoo.com

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ABSTRACT: An important role of Kalimantan Tropical Rain forests in a global ecosystem play as the lungs of the world and a natural laboratory to support of human life. In the context of climate change, forests play an important role in carbon cycle sequence, mainly to reduce greenhouse gas emissions. REDD is a climate change mitigation strategy that involves a lot of players that are designed to take advantage of the market or using intensive financing to reduce emissions of greenhouse gases from deforestation and degradation in developing countries. In this study to understand the implementattion of REDD scenario in East Kalimantan, multi temporal Landsat data with spatial resolution of 30 meters period of 2003, 2006 and 2009 and MODIS Data of 2003-2008 were initially used to detect forest degradation. A fragmentation and change detection methods were then applied to recognize level of Degradation of the study area. A baseline factor analysis was performed for understanding the implementation of REDD as a response to the forest degradation. Results showed that the fragmentation of forests into patch, perforated, edge and core forest facilitate the understanding of level of degradation. Core forest represents a primary forest, while pacth, perforated and edge represent degraded forest. MODIS data analysis showed largely change in forest area due to changes in forest function from primary forest into degraded forest. Analysis of Landsat Data also showed similar result, degraded forest area increased since the year 2003-2009 at about to 498.368 ha. REDD Adaptation in east Kalimantan communities scattered in the degraded forest than in primary forest.

I. Introduction

An important role of Kalimantan tropical rain forest in the global ecosystem according to Whitmore (1975) is lungs of the world's second largest tropical forest in the world next after South America centered on Amazon. For Indonesia, forests play as natural laboratories supporting human livelihoods and also a source of revenue of the State.

Over the past two decade, satellite data become important in managing natural resources, studying environmental change and the earth's land cover mapping. Remote sensing technology may become an effective and helpful tool to monitor forest area. However, remote sensing data are not easily interpreted in tropical rain forest due to spectral diversity and complex pattern within tree layer of forest and the cloud conditions that hampering the application of remote sensing.

The Landsat Program is the longest program to get the image of the Earth from space. The first Landsat satellite was launched in 1972; most recent Landsat 7, launched on 15 April 1999 has a resolution of 15-30 meters and still operates untill now. Landsat satellites instruments have resulted in millions of images. The images are archived in the United States and Landsat receiving stations around the world, wherein a unique resource for global change research and applications in agriculture, geology, forestry, regional planning, education, and national security.

Understanding of change pattern and regional landcover types are important to yield new insight into the study of global environmental problem and social adaptation on global change. Since 1972 the Landsat series of satellite and other high resolution imagery has provided magnificent tools of landcover mapping and historical changes in tropical forest overtime and future forest detection as well. However for regional and global scale, the use of these Landsat higher resolution imageries will cause some problems such as time and cost consume and infrequent data acquisition. Therefore, medium resolution is playing a vital role in the development of validated tools to study

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regional to global environmental change to assist policy makers in making quick decisions concerning the protection of our environment.

To achieve the aim of this project regional landcover of Kalimantan at scale of 1:1000,000 was derived from MODIS (Moderate Resolution Imaging spectroradiometer) data as well as form Landsat data. MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument mounted on terra (EOS AM) and Aqua (EOS PM) satellite of NASA United States. Terra satellite launched on 18 December 1999, with a fixed orbit from north to south crosses the equator in the morning. While the Aqua satellite launched n 4 May 2002, orbits from South to North over the line equator in the afternoon. This mechanism allows the entire surface of the earth can be captured every day, enabling its use. for predicting global change accurately to assist policy makers in making sound decisions concerning the protection of our environment as well as for monitoring deforestation and forest degradation.

The Altitude terra and Aqua satellites orbit is 705 km, with a wide coverage (swath width) 2330 km and 10 km at Nadir point. Modis Data has 36 bands with 12 bit radiometric resolusion and spatial resolution are 250, 500 and 1,000 m with a wavelength between 0405-14385 μm. Modis data Specification are listed in Table 1.

Table 1. Spesification of MODIS data

MODIS 32-day Composites Specifications		MODIS Sensor
Mode	Multispectral	Multispectral
spatial Resolusion	500m	250m (bands 1, 2), 500m (bands 3-7), 1km
Number of band	7	36 (7 bands for land)
Band Range	620-670 nm (1)	620-670 nm (1)
	841-876 nm (2)	841-876 nm (2)
	459-479 nm (3)	459-479 nm (3)
	545-565 nm (4)	545-565 nm (4)
	1230-1250 nm (5)	1230-1250 nm (5)
	1628-2652 nm (6)	1628-2652 nm (6)
	2105-2155 nm (7)	2105-2155 nm (7)

As for Forest degradation, it is more complex and ambiguous of forest lost. It is difficult to derive indicator of forest degradation from remotely sensed data without intensive measurement in the field. This study elaborated FAO definition for forest degradation as "changes within the forest, which negatively affect the structure of function of forest or site, and thereby lower the capacity to supply product or service" (FA0 2001). As various shape and size of forest, known as geometrical shape, were produced as the aftermath of land conversion in Kalimantan, measuring the remaining forest as result of the deforestation does not give a complete picture of forest degradation. The geometrical shape (shape and size) of forest has been applied for ecological landscape study (e.g. Frohn 1997) or for landcover mapping (e.g. Reed at al. 1994).

REDD is a climate change mitigation strategy that involves conservation organizations, project developers and governments in developing countries. REDD strategies designed to capitalize on the market or use financial incentives to reduce emissions of greenhouse gases from deforestation and degradation. Forests play an important role in climate change scenarios in particular carbon sequence and conservation of tropical forests, in terms of generating the greatest potential for reducing greenhouse gas emissions.

Analysis in conjunction with the implementation of REDD deforestation through three (3) phases of activities (Figure 1), namely: a review of historical land use change area, interpretation and analysis of historical trends and the location of deforestation. In particularly the identification of agents, driving factors, and conditional factors of deforestation, Merger all driving factors can determine the potential future scenario (darmawan and suhato, 2010).

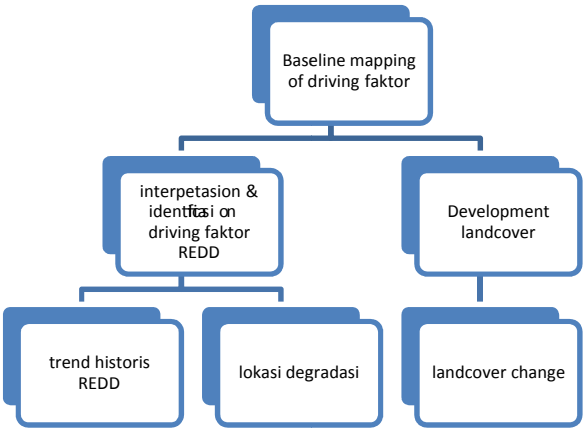

Figure 1. the draf desain of Scenario of REDD implementation on degraded forest area

The aim of this study are as follows: (1) To evaluate moderate remote sensing data (MODIS) and higher resolution data (Landsat) for detecting forest degradation, and (2) to understand scenarios of REDD implementation on land degradation issues related to the determination of the level of emission reductions. In addition, Results of this study is expected to assist in the implementation of REDD in determining the level of reduction of emissions from deforestation and forest degradation.

2. Study area

The study area is located in East Kalimantan province (Figure 2), which is known as the region with the largest tropical forest in Indonesia. East kalimantan province is one of province in Kalimantan. Forests in East Kalimantan province since the 1970s have been targeted for timber exploitation by logging firms and caused degraded and threatened of forest fires. No less about 600,000 forest in East Kalimantan heavily damaged by forest fires in 1997/1998 and hundreds thousands of hectares in the previous years.

Kalimantan is the Indonesian name for the island of Borneo, covering of approximately two third of Borneo island. The island of Kalimantan is divided into four different administrative boundaries as follows East Kalimantan province with an area approximately 19.6 million ha (195,917 km2), South Kalimantan province with 3.7 million ha (37,142 km2), Central Kalimantan province with 15.3 million ha (152,614 km2), and West Kalimantan province with 14.5 million ha (145,981 km2). In the vein of Kalimantan forest, a Lowland Dipterocarp forest -as well as most of the tree families of are found in the Borneo- is a dominant ecological resource for the world‘s exciting flora and fauna peat swamp forest. These forests has been extensively disturbed and explored for timber extraction – both by illegal or legal logging- since the colonial era, resulted on forest degradation and change within forest type over variety ways and degrees.

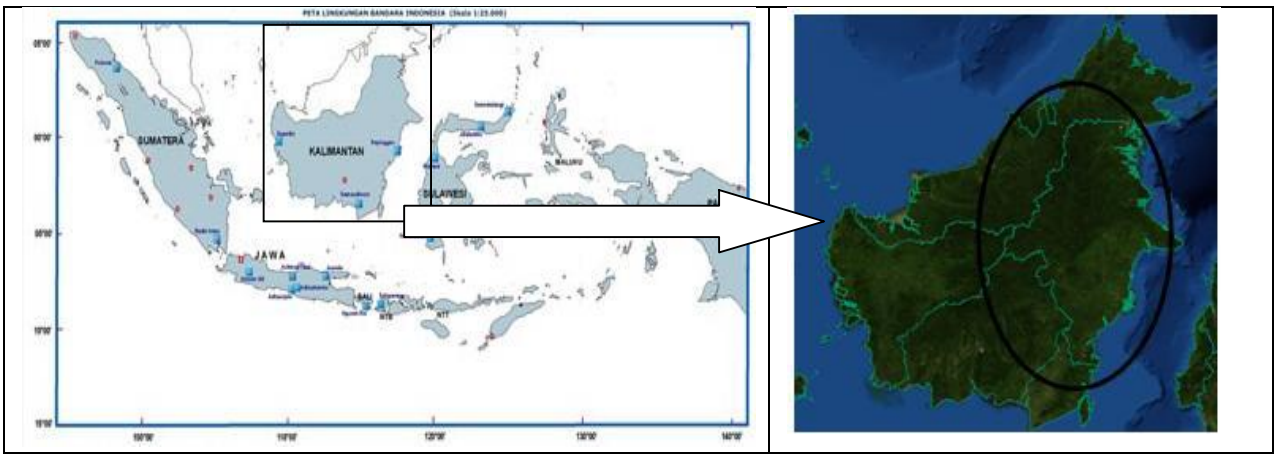

Figure 2. Study area in East Kalimantan province

3. Data and Methods

3.1. Data

Data were used in this study are listed in Table 2. The MODIS data of this project were collected from variety of sources such as ISCGM (international Secretariat Commitee for Global Mapping) and The National Aerospace Agency (LAPAN). The images were acquired from LAPAN in good quality in term of minimum cloud and haze cover for period July 30 2005 to April 4, 2006. Administrative boundary of Kalimantan was extracted from 1:250,000 scale of BAKOSURTANAL topographic maps and aggregated into 1:1000,000 scale by generalization methods. The Combination band 7, 4, and 2 of MODIS were applied for basic key interpretation, this combination is almost similar with band 5, 4 and 2 of Landsat image. Previous landcover data of 2003, 2006, and 2009 and Landsat image of 2003-2009 were used for key interpretation of landcover type.

Tabel 2. List of data used

No	Data	Specifications	Source	Utility
1	Data MODIS 32 days composite	The year 2003 and 2008, band 1-7, resolution 250 m	Global Mapping landcover data set, ISCGM and LAPAN	Landcover and fragmentation
2	Landsat data	The year 2003, 2006, 2009 band 1-7 resolution 30 m, geometric correction	Download from USGS	Landcover and fragmentation
3	Topographic map	Scale 1:50.000	Bakosurtanal	geometric correction and feature thematic
4	Landcover map	The years of 2003, 2006, 2009	Bakosurtanal	fragmentation
5	Statistic data	The year of 2009	Province	reference
7	SRTM	90 m	bakosurtanal	DEM

3.2. Method of Analysis

3.2.1. Landcover data

Landcover analysis was performed on Landsat data through land cover mapping program conducted routinely at Bakosurtanal, the available data are in 2003, 2006 and 2009 as part of the duties and functions of Bakosurtanal in providing thematic maps of land cover (Bakosurtanal Strategic Plan, 2010). Global Data landcover was from MODIS data available at ISCGM.

Since 2005, BAKOSURTANAL became active in the global mapping, a global data preparation and delivery of trained personnel to Japan. The main goal of global mapping project is to bring all nations and world mapping organizations, such BAKSOURTANAL, to get together to develop and provide easy and open access in digital form on a global geographic scale 1:1 million. Participation BAKOSURTANAL purpose in setting global product mapping is to facilitate the implementation of global agreements and conventions environments, monitoring key environmental phenomena and to encourage economic growth in the context of sustainable development, including disaster. Figure 3 is global landcover map from ISCGM which actually represent of landcover from Global Land Cover by National Mapping Organizations.

Figure 3. Global landcover by National mapping Organization

3.2.2 Fragmentation analysis

"Forest fragmentation is the process of dividing large tracts of forest into smaller isolated tracts surrounded by human-modified environments." (Society of American Foresters , 1998). Riitters et al. (2000) developed forest fragmentation model. The model was developed based on the calculation of the proportion of forest (pof) and forest connectivity to non-forest (cof). Based on this procedure forest fragmentation was examined. Six categories of fragmentation metrics (interior, perforated, edge, transitional, patch, and undetermined) was developed.

Vogt et al. (2007) propose a method that classifies forest based on pixel-level patterns. The authors found this method to yield more accurate results than the method proposed by Riitters et al. (2002). This study elaborate Vogt method (2007) to derive forest fragmentation based on high resolution of land cover maps derived from Landsat ETM+ of 30 m resolution and MODIS (Moderate Resolution Imaging Spectroradiometer) for 250-500 meters resolution. Forest area was extracted from the previous land cover classification of Landsat ETM+ for each study area and Global landcover from MODIS. To avoid complexity classification land cover map was re-classified based on the term forest and non-forest. Therefore, for instance natural swamp forest, secondary swamp forest, mountain forest, dense lower mountain forest, and lowland forest were all grouped as single forest cover. Then four classes of forest are identified, in terms of the type of fragmentation as listed in table 3. Fragmentation analysis is shown in Figure 4.

Table 3. Fragmentation type used in this study

Fragmentation type	Definition	Interpretation in respect with land cover association
Core	interior forest pixels that are not degraded from "edge effects"	Primary forest or undistrubed forest area
Perforated	forest along the inside edge of an small forest perforation	Distrubed of degraded forest area
Edge	forest along the outside edge of a forest patch	Distrubed of degraded forest area
Patch	small fragments of forest that are entirely degraded by "edge effects".	Distrubed of degraded forest area
Non forest	non forest	open land, pasture, residential, mining areas and non-vegetation areas

Figure 4.Fragmentation Analysis flowchart

4. Results and Discussion

Forest fragmentation is the process of dividing large tracts of forest into smaller isolated tracts surrounded by human-modified environments. To avoid the complexity of classification, reclassification of data landcover into forest and non-forest (Riitters et al., 2000 and Vogt et al., 2007). The process of fragmentation performed on data that only has two landcover class. Fragmentation of the forest area produces 5 types of fragmentation. In general it can be seen that the non-forest areas dominated by land cover such as open land, pasture, residential, mining areas and non-vegetation areas. The core forest area in general associated with an area of natural forest while patches, edge and perforated was interpreted as degraded forest areas (Table 3).

Tabel 4, 5 and Figure 5 and 6, showed forest and non forest change produced from MODIS and Landsat data for Kalimantan. Results of MODIS data analysis for forest cover change of the Kalimantan island shows in forest area decreased by 23.5% (7,256,931 ha) from 2003-2008. Conversely, there are increased number of non-forest area of approximately 30% (7,252,525 ha). However, analysis of Landsat for forest cover showed the opposite result, during the period 2003 - 2009 it showed an increase in the number of natural forests at 3.5% (961 313 ha).

The difference result is probably due to the data with a resolution of 15-30 meters of Landsat land cover information is more detailed than that MODIS has a resolution of 250-500 meters. So there are some land uses, in particular estates interpreted differently between Landsat and Modis. Photo field indicates that the oil palm plantation is very dense so higher possible this would be interpreted as forest with MODIS.

When considered in detail, from 23.5% of MODIS data analysys, about 70.0% (11,793,319 ha) in the form of decline in natural forests and approximately 30.0% (4,536,388 ha) of additional forest categorized as degradation forest. While in Landsat, of 3.5%, about 7.8% (1,519,694 ha) in the form of increased to the natural forest, and a decrease in non forest degradation about 6.8% (558 381 ha) and a decrease in non-forest area of 3.7% (961 313 ha).

Tabel 4. Forest and non forest change from MODIS and Landsat data for Kalimantan area (Ha)

Landcover type	Modis 2003	Modis 2008	Landsat 2003	Landsat 2006	Landsat 2009
Forest	30,913,038	23,656,106	27,559,650	29,353,100	28,520,963
Forest change (ha and %)	(7,256,931)	(23,48)		961,313	3,49
Non Forest	22,663,931	29,916,456	26,017,269	24,223,819	25,055,956
Forest change (ha and %)	7,252,525	32,00		(961,313)	(3,69)
total	53,576,969	53,572,563	53,576,919	53,576,919	53,576,919

Satellite analysis shows the fragmentation of forests into patch area, and the perforated edge and forest core. From Landsat data, Its showed degraded forest area (patch, edge and perforated) was decrease since the year 2003-2009 approximately at 558,381 ha. While from MODIS data analysis showed that a degraded forest was increase at 1,519,694 ha.

Deforestation is a major issue in tropical countries, leading to the destruction of tropical rainforest which is a valuable resource. Currently there is no single standard definition of forest degradation although there has been a long history of forest degradation. The term forest degradation used in this study as accomodation of FAO definition is, the interrupted or exploitation forest area, except for settlement, as concluded from Darmawan et al. (2003). This degradation mainly results from the interaction of human, natural hazard (e.g. forest fire) and agriculture-related to forest.

The proportion of forest degradation area in East Kalimantan was calculated from total number of patch, edge, and perforated except for non- forest. Figure 5 - 6 and also Table 5 shows that the core forest as the representative of primary forest in Kalimantan (green in the picture) which was generated from MODIS tends to decreased from 2003 to 2009 at about 22% of forest, from 16,742,863 ha (30 %) in 2003 and only left 4,949,.544 ha (9%) in 2009 (See Table 5).

Tabel 5. Fragmentation result from Landsat and MODIS data for Kalimantan area (in Ha)

	LANDSAT			MODIS		LANDSAT	MODIS
Fragmentasi	2003 (ha)	2006 (ha)	2009 (ha)	2003 (ha)	2008 (ha)	Change	Change
Non Forest	26.017.269	24.223.819	25.055.956	22.663.931	29.916.456	(961.313)	7.252.525
Patch	608.638	604.156	862.600	2.731.681	3.656.481	253.963	924.800
Edge	5.947.419	5.649.856	5.067.263	6.430.831	7.098.019	(880.156)	667.188
Perforated	1.566.038	1.575.381	1.633.850	5.007.663	7.952.063	67.813	2.944.400
Core (<250 acres)	27.888	26.638	28.519	143.600	118.713	631	(24.888)
Core (250-500 acres	23.331	23.244	25.769	94.181	94.181	2.438	-
Core (>500 acres)	19.386.338	21.473.825	20.902.963	16.505.081	4.736.650	1.516.625	(11.768.431)
Total Area	53.576.919	53.576.919	53.576.919	53.576.969	53.572.563	-	(4.406)
Total core	19.437.556	21.523.706	20.957.250	16.742.863	4.949.544	1.519.694	(11.793.319)
Total degraded	8.122.094	7.829.394	7.563.713	14.170.175	18.706.563	(558.381)	4.536.388

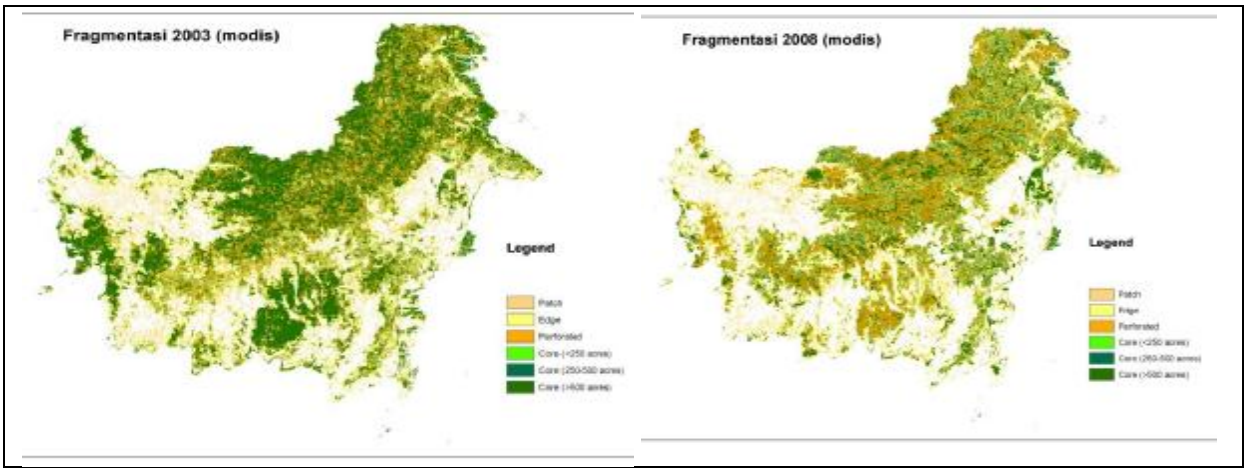

Figure 5. Fragmentation of Kalimantan using MODIS data

The results of field checks on June 17-20 2011 showed that adaptation REDD in East Kalimantan communities scattered in the degraded forest (Patch, Perforated and Edge). Therefore, It is estimated that around 35% of east Kalimantan area was actually categorized as forest degradation area, and only 12 %

is considered as natural forest . As for Eask Kalimantan, its appears that there has been an increase in degraded forest by 15% during the period 2003-2009 detected using Landsat data and about 7% detected with MODIS (Tables 6 and 7). Therefore, It is estimated that around 35% of east Kalimantan forest area was actually categorized as forest degradation area, and only 12 % is considered as natural forest in 2009. Response Action Plan (NAP) REDD implementation in the form of land use to optimize the utilization of land use: agriculture, oil palm plantations, mining, land use and forest degradation.

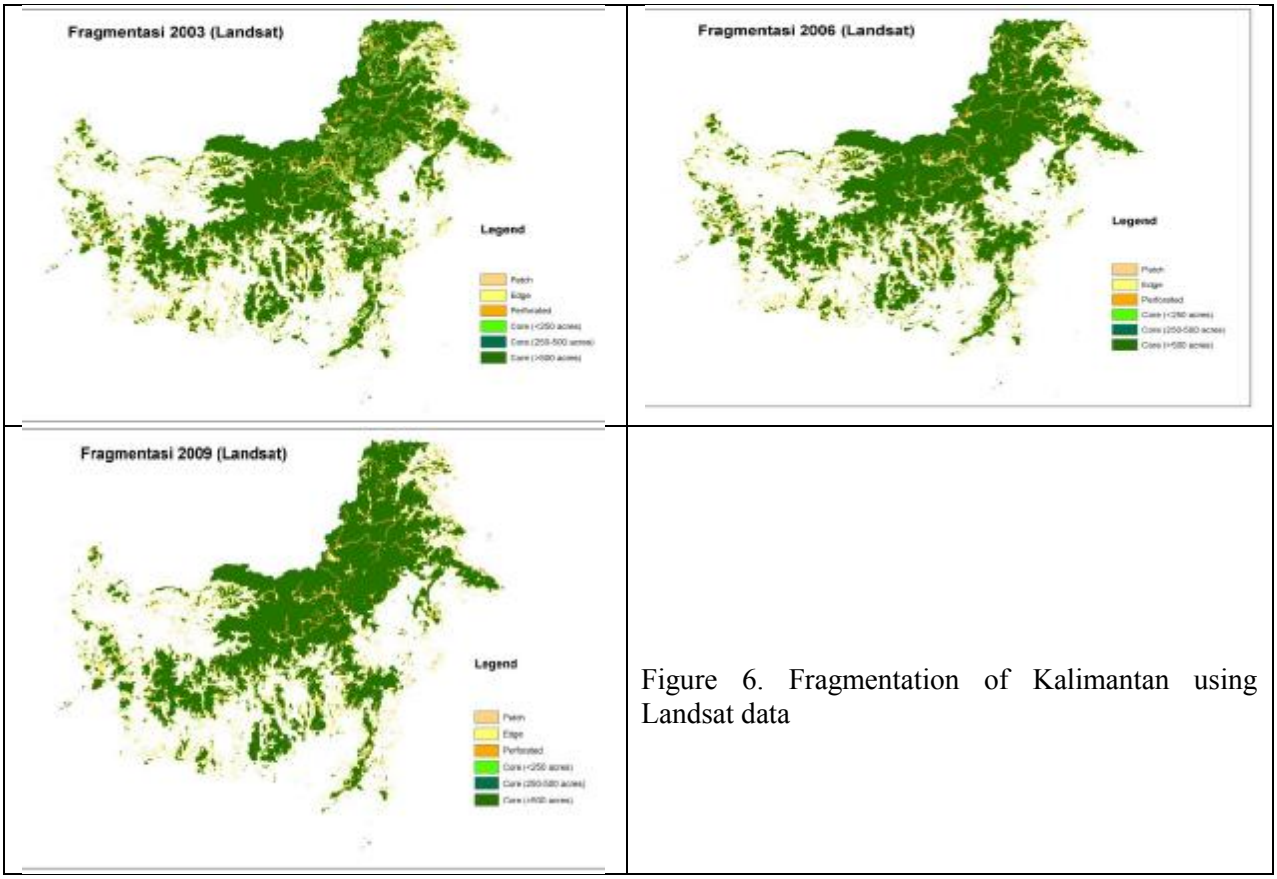

Figure 6. Fragmentation of Kalimantan using Landsat data

Table 6. Fragmentation result of east kalimantan (in Ha)

Fragmentasi	2003	2006	2009	2003	2008
Non Forest	8,315,544	6,741,606	6,669,638	7,137,281	10,175,238
Patch	155,344	131,381	258,163	883,250	1,244,313
Edge	2,152,788	1,647,488	1,422,463	2,018,125	2,639,900
Perforated	721,406	765,550	850,544	2,629,994	3,170,269
Core (<250 acres)	10,644	8,456	8,306	52,138	43,513
Core (250-500 acres)	7,613	6,388	7,756	29,106	29,350
Core (>500 acres)	8,270,806	10,333,275	10,417,275	6,886,444	2,325,475
Total Area	**19,634,144**	**19,634,144**	**19,634,144**	**19,636,338**	**19,628,056**

Table 7. Percentage of forest, non forest and degraded forest in East Kalimantan

	MODIS (%)		LANDSAT (%)		
	2003	2009	2003	2006	2009
Non forest	36,35	51,84	42,35	34,34	33,97
Degraded forest	28,17	35,94	15,43	12,96	33,97
Forest	35,48	12,22	42,22	52,70	53,14

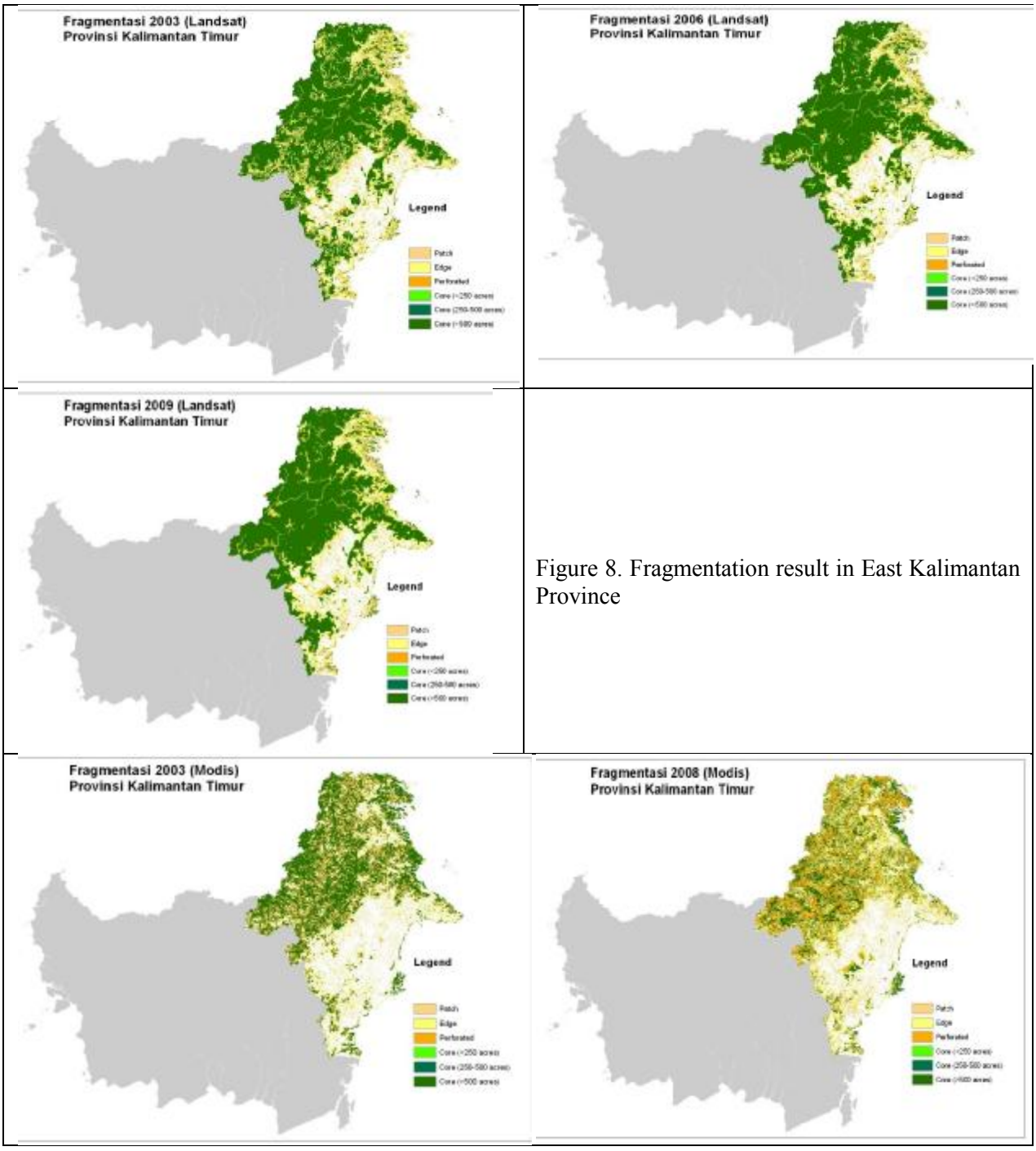

Figure 8. Fragmentation result in East Kalimantan Province

Conclusion and Recommendation

This study elaborated two remote sensing data, MODIS and Landsat TM+ for understanding inter-annual forest degradation dynamic of tropical rain forest based land cover change, examining fragmentation metrics, and assessing and evaluating Borneo land cover map. The potential of multi temporal Landsat data to monitor land cover change was also examined as the main important source for further data analysis such as degradation detection.

Through this study, it is showed that Modis and Landsat data potential for forest degradation studies. Although, results of these Landsat and MODIS for forest degradation are look inversely each other as due to differences in resolution and interpretation of the type of landcover class. It is highly recommended for regional detection area such east Kalimantan province, landsat data is suitable than MODIS. However for global or continental region, Moderate data such as MODIS is good enough for forest detection.

In general, a decline in forest area in east Kalimantan province aproximately of 35% for 2003 to 2009. Jika situasi berkembang seperti apa adanya maka diperkirakan dalam waktu 20 tahun maka hutan di wilayah Kalimantan timur akan habis. Oleh karena itu perlu dialkukan langkah-lanhkah dan kebijakan pengendalian keadaan tersebut dan program REDD diharap dapat memacu daerah untuk aktif berpartisipasi mengurangi besarnya degradasi hutan di wilayah kalimantan timur

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