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Characterizing forest reduction in Ketapang district, West Kalimantan, Indonesia

ASEP SUNJAYA ADHIKERANA[1], JITO SUGARDJITO[2,♥]

[1]Fauna and Flora International – Indonesia Programme, Jl. Harsono, R.M. No.1, Ragunan, Jakarta 12550, Indonesia
[2]Research Centre for Biology, The Indonesia Institute for Sciences, Jl. Raya Jakarta-Bogor Km. 46, Cibinong-Bogor 16911, West Java, Indonesia, Tel.: +62-21-8765056 Fax.: +62-21-8765068, ♥e-mail: jitos@cbn.net.id

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ABSTRACT

Adhikerana AS, Sugardjito J (2010) Characterizing forest reduction in Ketapang district, West Kalimantan, Indonesia. Biodiversitas 11: 46-54. We have characterized deforestation in the Ketapang district forests when we implemented the Orangutan (*Pongo pygmaeus wurmbii*) Conservation in Trans-boundary Landscape between Central and West Kalimantan provinces. For the purpose of evaluating the changes in land use and land cover in the study areas, a series of Landsat imageries have been analyzed. Each of the Landsat imagery data set for all study areas was initially classified using unsupervised classification into 13 different land-cover types. Ground truth checks were undertaken for Ketapang district forests and Sungai Puteri peat swamp forest, from which the results were used for the supervised land use classification of these two study areas. Between 1992 and 2000 there was only small conversion of primary forest into secondary forests. During this period barren land remained extensive about 30.17% of the total area of Ketapang district. Both agriculture and plantation areas substantially increased 56% and 55% respectively during 2003, while at the same time the extent of both primary and peat swamp forests were considerably reduced up to 15% and 28% respectively. The most striking conversion was from secondary forest to agricultural land and from peat swamp forest to swamp areas. A fraction of lowland forest was also converted into oil-palm plantation which was extended with considerable size into agricultural land. The patterns of land use changes detected in this study indicated a number of possible causes that trigger deforestation in this district include, the local government policy and market demand.

Key words: deforestation, habitat fragmentation, Landsat, imagery, land use.

INTRODUCTION

For more than four decades Indonesia has been relied its economic development on forest resources. In the 1980s, the forestry sector became the second highest contributor to foreign exchange in Indonesian economy after oil and gas sector (FWI/GFW 2002). In this decade, Indonesia became the biggest producer of plywood in the world. It was able to manage 75% of the world market demands. Despite the success of controlling plywood market in the world, the rainforest which is the pool of biodiversity has been reduced drastically and has changed the land use and land cover in the region. Up to 1950 Indonesia was still densely forested, but 40% of the forests existing in that year were cleared in the following 50 years. In round numbers, forest cover fell from 162 million hectares to 98 million hectares during 50 years period (FWI/GFW 2002). This phenomenon makes Indonesia belong to one of the countries with the highest tropical forest loss rate in the world. The annual rate of deforestation was at least 1.7 million hectares between 1985 and 1997, and it has been even higher at about 2 million hectares lost annually since 1997 (Scotland 2000).

Conversion, degradation, and fragmentation threaten the integrity of forested ecosystem. Holmes (2002) suggested that without any conservation measures, tropical lowland evergreen forest would be diminished by 2005 in Sumatra and after 2010 in Kalimantan due to deforestation. He estimated the rate of deforestation in Kalimantan during the period of 1985 until 1997 reaching 8.5 million hectares, with a loss of 21%, or 706,000 ha per year. Curran et al. (2004) suggested that deforestation in Kalimantan was not primarily due to local human population density, smallholder agricultural clearing, or paved roads. Kalimantan has relatively low human population density and growth rates (MacKinnon et al. 1996). However, the spontaneous interior migration which caused slash and burn cultivation can not be neglected. Kalimantan is also distinctive because of the dominance of the timber industry and the commercial value of stock of Dipterocarpaceae forests. Over the past two decades, the volume of dipterocarp timber exports from Borneo (Kalimantan, Sarawak, and Sabah) exceeded all tropical wood exports from tropical Africa and Latin America combined (ITTO 1996).

There has been no simple explanation for deforestation in Indonesia. What so ever the causes of deforestation, the reduction of forest habitats is still continuing and it is therefore, sound regional land use planning is critical to protecting lowland forest habitats from increasingly human pressures. During the implementation of "*Landscape-based Conservation of Orangutans in Trans-boundary Landscape between Central and West Kalimantan Provinces*" we were able to characterize the patterns of deforestation in the

region in order to understand at local to regional scales how changes in land use and land cover related to forest habitats reduction in the district of Ketapang, West Kalimantan.

MATERIALS AND METHODS

Digital data

For the purpose of evaluating the changes in land use and land cover in the study areas, namely: Ketapang district, West Kalimantan, Indonesia and Sungai Puteri peat swamp forest (within the district) over 18 years (from 1989 to 2007), a series of Landsat imageries were analyzed. However, only six series of Landsat 7 ETM Path 121 Row 61 were available for the areas of Ketapang District (i.e. years of 1992, 2000, 2002, 2003, 2004 and 2005), and seven series of Landsat 5 ETM Path 121 Row 61 were available for analyzing Sungai Puteri peat swamp forest, namely those of 1989, 1990, 1999, 2000, 2002, 2005, and 2007 images. The area of Ketapang district analyzed lies within the coordinates: 0°45'00"-3°00'0" S and 108°30'0"-111°30'0"E. and that of Sungai Puteri peat swamp forest lies within the following coordinates: 1°15'00"-1°55'00"S and 109°58'00"-110°25'00"E, where rivers are the main natural barrier for this area (namely Pawan river – ca. 75 m width – in the south, and Rangkung river – ca. 5 m width – in the north) in addition to the main road from Ketapang to Sukadana. The source of digital data for Ketapang district was the Ministry of Forestry, while those of Sungai Puteri peat swamp forest was analyzed from satellite imageries.

Image pre-processing

The subset extracted from each Landsat-TM image was geometrically corrected and geo-referenced using 1:50,000 topographic maps of the study area obtained from the National Agency for Survey and Mapping of Indonesia, where image-to-image rectification was undertaken. Radiometric correction was undertaken using Envi 4.1 and ERDAS 9.1 for combining and manipulating band-widths. Later, image enhancement was carried out in order to obtain images with good quality of visual and spectral data.

Vegetation classification

Each of the Landsat imagery data set for all study areas was initially classified using Unsupervised Classification into 13 different land-cover types: Primary forest, Secondary forest, Peat swamp forest, Mangrove forest, Coastal fishery, Swamp, Savannah, Agriculture, Bushes, Plantation, Mining, Settlement, and Barren land. Two other classes were also identified, namely undetermined area and no data due to cloud coverage. Ground truth checks were undertaken for Ketapang district and more details for Sungai Puteri peat swamp forest, from which the results were used for the Supervised Landuse Classification of these two study areas. The final land use classification for Sungai Puteri peat swamp forest consists of mangrove forest, peat swamp forest, riparian forest, oil-palm plantation, settlement, agriculture and settlement, swamp area, bushes, and barren land. The extent of each land cover area was calculated directly using ArcGIS 9.2.

Patterns of landuse changes and deforestation rate

In order to establish the land cover changes that occurred within the study areas, a post classification change detection analysis of the available imageries was performed. For this purpose, two sets of information classes are available: (i) West Kalimantan province and Ketapang district comprising the data derived from 1992 to 2005.Landsat images, which are further grouped into two series of changes, namely "from 1992 to 2000 land use change" and "from 2000 to 2005 land use change". This was done to account for the impacts of forest fire occurring in 1996-1997 on the calculation of deforestation rate analyzed in this study; (ii) Sungai Puteri peat swamp forest comprising the data derived from satellite images recorded during the 1989-2007 period, which are grouped into two series of changes, namely "from 1989 to 1999 land use change" and "from 1999 to 2007 land use change" for the same reason as before. Each "from to land use change" was detected with overlapping the relevant imageries, with which the extent of any significant change from one class to another could be estimated.

Deforestation is defined as the conversion of forested areas to non-forest land use such as arable land, urban use, logged area or wasteland. Tree height and percent crown cover are the quantitative forest parameters used widely in classifying forest from non-forest areas, as well as different categories of forest classes. Deforestation rates were estimated for the whole West Kalimantan region, the area of Ketapang district, and that of Sungai Puteri peat swamp forest. The deforestation rate for West Kalimantan province and Ketapang district was estimated for the following periods: 1992 to 2000, 2000 to 2002, 2002 to 2003, 2003 to 2004, 2004 to 2005, and 2000 to 2005. Sungai Puteri peat swamp forest was estimated for the following intervals: 1989 to 1990, 1990 to 1999, 1999 to 2000, 2000 to 2002, 2002 to 2005, 2005 to 2007, 1989 to 1999, and 1999 to 2007. Two models have been applied for calculating deforestation as follows (Puyravaud 2003):

$$q = \{(A_2/A_1)^{1/(t2 - t1)}\} - 1 \quad (1)$$

$$r = [1/(t_2 - t_1)]*\ln(A_2/A_1) \quad (2)$$

where A_1 and A_2 are the forest cover at time t_1 and t_2, respectively. In these models, the rate of deforestation can be expressed as the percentage of remaining forest that is cleared per year. Equation (1) is proposed by FAO (1995) as to derive the rate of change from the Compound Interest Law, while equation (2) denotes the rate of the Compound Interest Law itself as proposed by Puyravaud (2003). Basically there are no significant differences in the calculation results between the two models, but here they are presented for the comparison purpose only.

RESULTS AND DISCUSSION

Land-cover changes

Ketapang District

Unfortunately the available imageries data were stained by cloud coverage and poor mosaic that made some areas

were undetermined, and yet these areas are presumed to be the spots of forest fire occurring in 1997 (Table 1). This constraint has made it impossible to predict changes in these areas. There seems to be virtual changes from "forest" to "non-forest" during the period of 1992 until 2000, but substantial changes from "forest" to "non-forest" occurred during the period of 2000 to 2005, when about 27.11% of forested areas converted into non-forested areas (Figure 1; Figure 3). During the period of 1992 to 2000 there was only very small conversion of primary forest into secondary forest; there was a slight succession from secondary forest to primary forest as well as from swampy, agriculture, plantation, settlement, and barren areas into secondary forest. During this period barren land remained extensive about 30.17% of the total area of Ketapang district (Table 2).

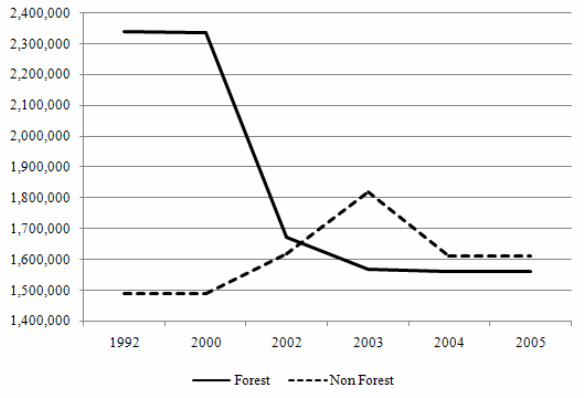

Figure 1. Changes in the extent of forest and non forest areas in Ketapang district during the period of 1992 to 2005.

Table 1. Land use of Ketapang district (ha) during the period of 1992 to 2005.

	1992	2000	2002	2003	2004	2005
Primary forest	439,573.00	439,563.00	348,264.55	294,236.73	290,553.96	292,018.00
Secondary forest	1,282,921.55	1,280,955.12	606,809.64	758,412.54	761,265.07	756,141.05
Peat swamp forest	617,189.01	617,184.52	717,390.51	513,910.97	510,349.10	511,813.03
Mangrove forest	13,405.21	12,428.40	37,555.84	32,870.24	26,282.87	32,870.93
Coastal fishery				1,537.25	1,594.24	1,594.24
Swamp	65,420.08	65,420.12	158,077.42	359,438.55	692,711.70	359,850.62
Savannah				2,291.48	2,291.51	2,291.48
Agriculture	224,527.01	224,527.27	486,051.59	752,872.63	753,599.83	753,599.80
Bushes			893,639.32	333,077.43		332,861.04
Plantation	87,346.12	87,346.23	73,774.43	114,706.91	114,737.29	114,737.26
Mining			508.80	2,706.88	2,706.93	2,706.90
Settlement	3,607.07	3,607.14	2,073.26	18,193.09	17,730.75	17,730.71
Barren land	1,108,143.36	1,108,143.10	6,214.76	237,146.94	26,835.45	26,835.41
Undetermined	139,302.40	140,803.35	130,505.01	124,431.10	455,670.23	347,770.74
No data (cloud)	130,310.86	131,757.43	211,747.10	126,779.51	16,283.32	119,791.04
Total	4,111,745.67	4,111,735.68	3,672,612.25	3,672,612.25	3,672,612.25	3,672,612.25

Source: Available GIS data for Ketapang district acquired by FFI and analysed for this study.

Table 2. Details of landuse changes (ha) in Ketapang district during the period of 1992 to 2000.

From (in 1992)	**Primary forest**	**Secondary forest**	**Peat swamp forest**	**Mangrove forest**	**Swamp**	**Agriculture**	**Plantation**	**Settlement**	**Barren land**
	439,573.00	1,280,953.88	617,184.14	13,005.21	65,420.08	224,527.01	87,346.12	3,607.07	1,107,132.78
To (in 2000)									
Primary forest	439,563.00	0.01							
Secondary forest	1.00	1,280,950.41	0.29	0.11	0.02	0.57	0.09		2.47
Peat swamp forest		0.25	617,181.62	0.16	0.43	0.44	0.04		1.30
Mangrove forest		0.01	0.14	13,004.51	0.02	0.08	0.01		0.02
Swamp		0.01	0.49	0.03	65,419.15	0.12	0.02		0.27
Agriculture		0.72	0.50	0.02	0.16	224,525.07	0.12	0.01	0.51
Plantation		0.08	0.14	0.23	0.04	0.13	87,345.67		0.21
Settlement						0.01		3,607.02	0.02
Barren Land		2.39	0.96	0.16	0.27	0.58	0.18	0.03	1,107,127.99
Total	439,564.00	1,280,953.88	617,184.14	13,005.21	65,420.08	224,527.01	87,346.12	3,607.07	1,107,132.78
To (in 2000)									
Remaining (ha)	439,563.00	1,280,950.41	617,181.62	13,004.51	65,419.15	224,525.07	87,345.67	3,607.02	1,107,127.99
Converted (ha)	1	3.47	2.52	0.71	0.94	1.93	0.46	0.04	4.80
%	0.0002	0.0003	0.0004	0.0055	0.0014	0.0009	0.0005	0.0011	0.0004

Both agriculture and plantation areas substantially increased in year 2003, and at the same time the extent of both primary and peat swamp forests reduced considerably. Further, a ground truth survey has also confirmed such a conversion. Mining activities started in 2002 has been identified in a relatively small area, but it increased substantially in the year 2003. This mining however, has taken place in secondary forests. Such mining seemed to create "savannah-like" landscape with barren land more exposed in extent.

During the period of 2000 to 2005 the primary forest remained secured, but substantial changes occurred in other land use classes (Table 3). As it has been shown here the abandoned areas might have been the new settlement areas ('transmigration" sites) which were deserted by the migrants. This is a normal case for Kalimantan, where migrants returned to their original site after the government supports no longer provide their life in a few years. The conversion of plantation area into bushes could be due to the desertion of "transmigration" areas. Substantial conversion of agricultural land to barren land could also be similar to the above mentioned case. The most striking conversion was from secondary forest to agricultural land suggesting the impact of economic development during this period, and from peat swamp forest to swamp areas might be due to peat subsidence caused by canal construction. The barren land remains extensive in 2005 suggesting that this type of land has not been managed for economic development purposes. Deforestation has always been the subject of concerns since the early 60s (SAF 1983), and it is an ongoing disturbance within human-dominated landscapes. The type, intensity, and frequency of deforestation have long been known to be attributable to the extent of human activities on the landscape (Curtis 1956; Burgess and Sharpe 1981; Zipperer et al. 1990). Settlement area changed substantially leaving only 5.80% of the original area in 2000, where it extensively changed into bushes. However, significant succession occurred from secondary forest into primary forest and from barren land into secondary forest, and additionally though in more less extensive area from other land use into secondary forest.

Sungai Puteri peat swamp forest

The main land use being concerned in this forest block is due to the fact that it is an extensive peat land with an average depth of 7 m (range: 2-15 m) with a reduction of about 35% of its size in 1989 (Table 4). The forest areas in this forest block including peat, mangrove, and riparian forests have reduced more in the period 1989 to 1999 as compared to the 1999-2007 period, whereas at the same time, non-forest areas increased substantially at the first period (1989-1999) and gradually at the second period (Figure 2, Figure 4).

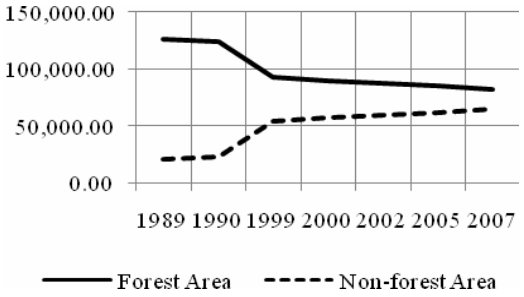

Figure 2. Changes in the extent of forest and non forest areas in the Sungai Puteri peat swamp forest blocks during the period of 1989 to 2007.

Table 3. Details of land use changes (ha) in Ketapang district during the period of 2000 to 2005.

From (in 2000)	**Primary forest**	**Secondary forest**	**Peat swamp forest**	**Mangrove forest**	**Swamp**	**Agriculture**	**Plantation**	**Settlement**	**Barren land**
	439,563.00	1,280,955.12	617,910.82	12,428.40	65,420.03	224,527.18	87,346.14	3,607.05	1,108,143.01
To (in 2005):									
Primary forest	439,563.00	287,368.95				432.96			1,556.76
Secondary forest		637,868.69	3,886.63	71.36	3.21		213.51		104,652.42
Peat swamp forest		79,367.71	358,532.54	1,167.18	6,894.29	7,584.68	1,106.17	76.97	52,814.86
Mangrove forest		6,461.21	10,447.30	6,148.47	2,416.05		29.41	28.17	307.49
Coastal fishery					214.57				
Swamp		22,730.15	116,360.79	2,521.16	28,876.69	23,076.07	7,925.02	614.74	153,155.52
Savanna		78.42	1,454.54		39.74				544.68
Agriculture		146,191.31	29,826.61	586.73	2,836.51	88,683.13	6,985.86	364.86	466,058.95
Bushes		57,371.74	44,770.65		6,529.48		40,324.10	1,919.94	144,457.66
Plantation		20,522.77	4,630.95	592.78	591.66	24,533.32	23,852.61		39,176.05
Mining		830.43	374.28		179.76				249.33
Settlement		2,082.53	1,679.97	416.97	90.09	7,081.67	183.25	209.06	5,049.77
Water Body		1,719.37	3,373.04	510.64	4,038.87		211.27	285.69	6,678.35
Barren Land		18,361.85	42,573.53	413.12	12,709.12	73,135.35	6,514.95	107.61	133,441.17
Total	439,563.00	1,280,955.12	617,910.82	12,428.40	65,420.03	224,527.18	87,346.14	3,607.05	1,108,143.01
To (in 2005):									
Remaining (ha)	150,205.36	637,868.69	358,532.54	6,148.47	28,876.69	88,683.13	23,852.61	209.06	133,441.17
%	100	49.80	58.02	49.47	44.14	39.50	27.31	5.80	12.04
Converted (ha)	0	643,086.43	259,378.28	6,279.93	36,543.34	135,844.05	63,493.54	3,397.99	974,701.84
%	0	50.20	41.98	50.53	55.86	60.50	72.69	94.20	87.96

Table 4. Land use of Sungai Puteri peat swamp forest blocks (ha) during the period of 1989 to 2007.

Landuse	1989	1990	1999	2000	2002	2005	2007
Mangrove forest	221.01	244.12	131.50	174.46	145.62	132.09	132.09
Peat swamp forest	125,760.12	123,725.10	91,928.74	88,850.65	86,553.60	84,301.97	81,512.68
Riparian forest	317.11	317.13	345.32	297.36	298.66	283.49	251.15
Oil-palm plantation	-	-	-	-	-	394.03	5,077.35
Settlement	256.10	219.01	383.83	195.61	342.31	244.25	244.07
Agriculture and Settlement	16,582.01	17,817.13	50,756.18	50,410.78	53,279.77	55,734.58	53,169.67
Swamp	-	-	501.32	491.96	-	58.25	246.36
Bushes	1,445.14	2,249.09	263.45	4,329.09	2,264.52	947.43	1,072.24
Barren land	2,568.16	2,578.07	2,839.32	2,399.74	4,265.19	5,053.56	5,444.05
Total	147,149.65	147,149.65	147,149.65	147,149.65	147,149.66	147,149.65	147,149.65

Table 5. Details of land use changes (ha) in Sungai Puteri peat swamp forest blocks during the period of 1989 to 1999.

From (in 1989)	**Peat swamp forest**	**Mangrove forest**	**Riparian forest**	**Agriculture**	**Agriculture and Settlement**	**Bushes**	**Settlement**	**Barren land**
	128,262.35	**221.48**	**315.65**	**16,305.08**	**210.84**	**1,639.63**	**249.09**	**2,568.13**
To (in 1999):								
Peat swamp forest	90,606.41	-	-	825.55	13.14	364.36	2.30	117.16
Mangrove forest	-	128.35	-	-	-	-	-	-
Riparian forest	54.22	-	291.11	-	-	-	-	-
Swamp	414.53	-	-	-	-	-	-	43.28
Agriculture	36,171.60	93.12	24.54	15,220.62	11.88	1,275.27	128.08	106.66
Agriculture and Settlement	102.19	-	-	5.42	185.82	-	-	-
Bushes	263.46	-	-	-	-	-	-	-
Settlement		-	-	-	-	-	118.72	-
Barren land	649.95	-	-	253.48	-	-	-	2,301.02
Total	128,262.35	221.48	315.65	16,305.08	210.84	1,639.63	249.09	2,568.13
To (in 2007):								
Remaining (ha)	90,606.41	128.354	291.105	15,220.624	185.823	0.000	118.716	2,301.022
%	70.64	57.95	92.23	93.35	88.14	0.00	47.66	89.60
Converted (ha)	37,655.94	93.12	24.54	1,084.45	25.01	1,639.63	130.37	267.10
%	29.36	42.05	7.77	6.65	11.86	100.00	52.34	10.40

Table 6. Details of land use changes (ha) in Sungai Puteri peat swamp forest blocks during the period of 1999 to 2007.

From (in 1999):	**Peat swamp forest**	**Mangrove forest**	**Riparian forest**	**Swamp**	**Agriculture**	**Agriculture and Settlement**	**Bushes**	**Settlement**	**Barren land**
	91,928.85	130.50	345.32	501.32	52,909.43	293.19	263.46	383.84	2,939.32
To (in 2007):									
Peat swamp forest	81,093.58	-	-	70.98	760.44	12.98	-	20.90	47.07
Mangrove forest	-	89.99		-	41.87	-	-	-	-
Riparian forest	0.02	-	253.11	-	0.62	-	-	-	-
Swamp	7.06			158.90		-	-	-	81.28
Agriculture	8,182.30	40.51	50.65	67.65	45,427.42	0.01	248.33	131.81	104.93
Agriculture and Settlement	33.93	-	-	-	1.78	280.21	-	-	-
Bushes	651.47	-	-	202.07	132.43	-	15.13	40.94	-
Oil-palm plantation	437.42	-	-	-	4,628.41	-	-	-	-
Settlement	9.00	-	-	-	50.22	-	-	190.19	-
Barren land	1,514.06	-	41.57	1.72	1,866.24	-	-	-	2,706.04
Total	91,928.85	130.50	345.32	501.32	52,909.43	293.19	263.46	383.84	2,939.32
To (in 2007):									
Remaining (ha)	81,093.58	89.985	253.105	158.896	45,427.423	280.207	15.127	190.194	2,706.043
%	88.21	68.96	73.30	31.70	85.86	95.57	5.74	49.55	92.06
Converted (ha)	10,835.27	40.51	92.22	342.43	7,482.01	12.98	248.33	193.65	233.28
%	11.79	31.04	26.70	68.30	14.14	4.43	94.26	50.45	7.94

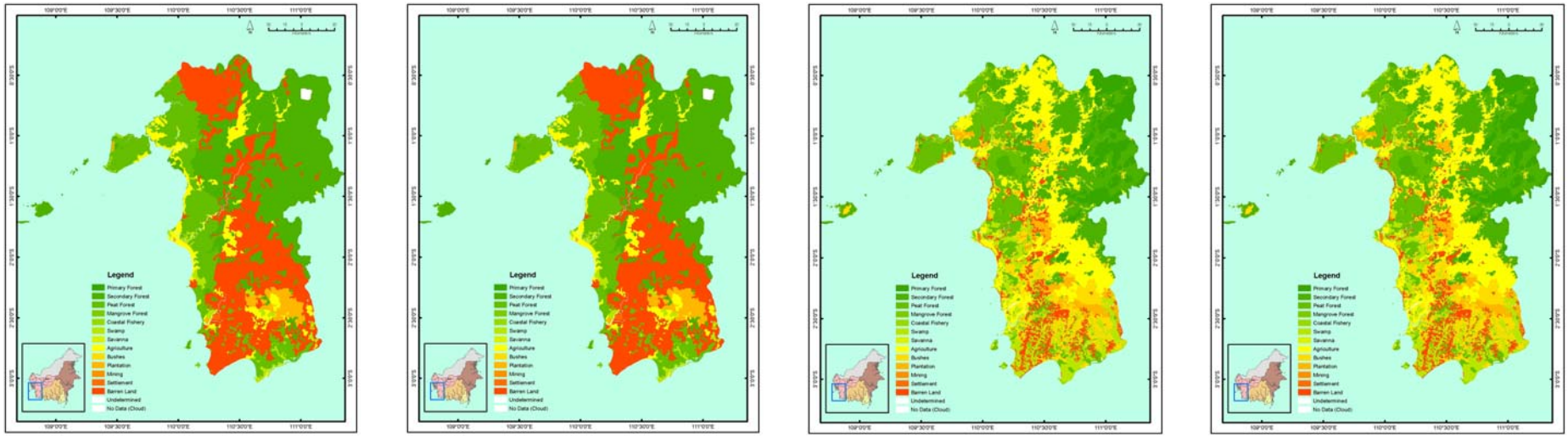

Figure 3. Cumulative of forest reduction and land use changes in Ketapang district excluding Sungai Puteri forest block during the period of 1992 and 2005. Forest and nonforest classifications are based on a Landsat Thematic Mapper time series 1992, 2000, 2002, 2003, 2004, and 2005.

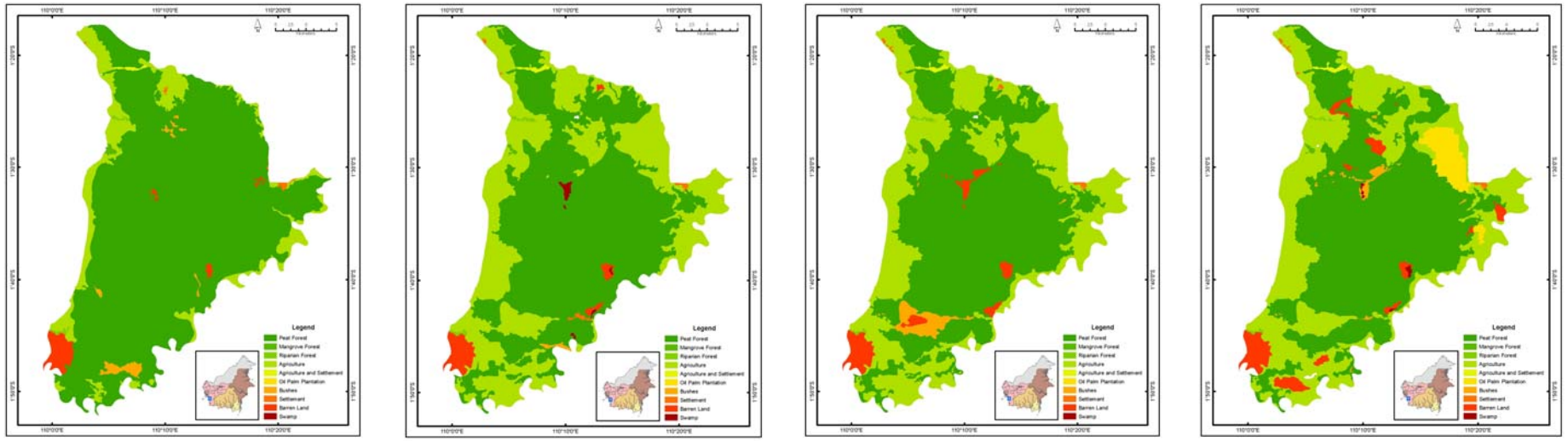

Figure 4. Cumulative of forest reduction and land use changes in Sungai Puteri peat swamp forest block during the period of 1989 and 2007. Forest and nonforest classifications are based on a Landsat Thematic Mapper time series 1989, 1990, 1999, 2000, 2002, 2005, and 2007. Classifications are shown for 1989, 1999, and 2007.

In details, peat swamp forests seemed to be subject for conversion to agriculture, and subsistence agriculture. These conversions have been accompanied by small settlement which are identified as "agriculture and settlement" in the table. Further, it was followed by settlement and later to oil-palm plantation. During the period of 1989 to 1999, the conversion of peat swamp forest into agriculture area was considerably extensive, almost 28% of its original size in 1989. However, there were more than 1,000 ha of non-forest areas, especially agriculture, bushes, settlement and barren land, re-established into peat swamp forests (Table 5).

During the period of 1999 to 2007, conversion of peat swamp forest into agricultural land remained substantial although it was much lower compared to previous period but, a fraction of this forest was also converted into oil-palm plantation. The oil-palm plantation was even extended with considerable size came from agricultural land and peat swamp forest (Table 6). Barren land was also increased and it is formed from a more varied land use. The intensity of peat swamp forest converted into barren land was quite significant during this period, and the field survey confirmed that most of which were abandoned agriculture. At the same time, a number of land use types also re-established peat swamp forest, namely swamp, agriculture, agriculture and settlement, settlement, and barren land, with a total of about 900 ha, of which were abandoned land.

The striking changes of settlement, agriculture, and plantation areas into bushes and barren land in Ketapang district could have been due to migrant desertion. Sunderlin and Resosudarmo (1996) described two types of migrants, namely "regular" who receive full government assistance, whereas the "spontaneous" one who receive partial or did not receive at all of government assistance. They suggested that forest cover removal for the migrant settlement site has been the direct effect of regular migrants. Dick (1991) has been assessed that spontaneous migrants could be the single most important cause of forests degradation, although, Sunderlin and Resosudarmo (1996) suggested that it might not be necessarily the case. The desertion of migrant resettlement sites in Ketapang district could always happen due to insufficient incomes that force the migrants move to other sites which is posing another land pressure on other forested land. Further, Cernea and Schmidt-Soltau (2003) showed that forcing resettlement, i.e. "transmigration", could push people to face impoverishment risks such as landlessness, joblessness, homelessness, marginalization, food insecurity, increased morbidity and mortality, loss of access to common property, and social disarticulation. The migrant people in Ketapang district might have been exposed to such risks that made them move away from their designated sites. On the other hand, barren land both in Ketapang district and Sungai Puteri peat swamp forest blocks remains extensive without any assessment on economic benefits. Such barren land is certainly prone to wild fire during the dry season and it can be attributable to people perception or skill to utilize marginal land. As Zube (1987) pointed out that land use patterns could be perceived in many perspectives, where they could indicate landscape function, economic opportunity, and environmental amenities, and each with different value orientation. Estate plantation companies could perceive such barren land as less economic opportunity since its conversion into plantation might need considerable investment to recover the land. At the same time, the local people could have the same perception with different reasoning, for example they do not know how to recover the barren into arable land. When such under-skilled local people are not assisted to gain more capacity in technological skill, the barren land would always extent in the future. This indicates that capacity development for people living in surrounding forest habitat is urgently needed. O'Connor et al. (2003) indicated that socio-economic and political conditions influence the effectiveness of conservation interventions, and therefore, improvement of local people capacity will certainly need appropriate socio-economic and political will in sustaining the environmental conservation. Mikkelson et al. (2007) also suggest that inequality of economic opportunity could induce biodiversity loss through a number of devastating human activities. In Kalimantan, concession-based timber extraction, plantation establishment, and weak institutions have resulted in highly fragmented and degraded forests (Ross 2000) and one of the main impacts is habitat fragmentation. Forest habitat fragmentation is considered by many to be the most important threat to biological diversity, and is the primary cause of the present biodiversity extinction crisis (Wilcox and Murphy 1985; Laurance et al. 2003; Wilcove et al. 1986).

Rate of deforestation

Tables 7a and 7b have shown the rate of deforestation both in the Ketapang district excluding Sungai Puteri and in the Sungai Puteri block of forest alone respectively. Despite forest fire disaster in 1997, there was virtually lack of deforestation in Ketapang district during the period of 1992 to 2000. Deforestation was significantly increased from 2000 to 2003, then it slowed down from 2003 to 2005 (Table 7). In average, the deforestation rate in Ketapang district during the period of 2000 to 2005 was 3.93% per year. When we compared to the whole area of Ketapang district, deforestation in Sungai Puteri peat swamp forest blocks was low. In 2000-2002 it was only 1.31% contrasting to 6.14% for Ketapang district. In average the annual deforestation rate in Sungai Puteri during the period of 1989 to 2007 was 2.41%.

There has been no simple explanation for ongoing deforestation in Indonesia. It was suggested that unsynchronized government policies, institutional arrangement and market demands are being the main triggers of deforestation (Adhikerana 2002). The rate of deforestation has been enhanced by the change of government policy towards decentralization implemented in 2001 which allows local district to issue small logging parcel leases of 1 km^2. This has resulted in the virtually uncontrolled harvest of remaining accessible lowland forests. Further, widespread oil palm plantation establishment is also converting lowland forest. In this study, a substantial development activities including

agriculture, plantation, and mining in Ketapang district during the period of 2000 to 2005 were majority took place in both secondary and peat swamp forests. A similar case was also found in Sungai Puteri peat swamp forest blocks, where agriculture, settlement, and oil-palm plantation took place mostly in the peat swamp forests although, this peat swamp forest is not allowed to be converted in accordance to the Presidential Decree No 32/1990. Despite the average depth of this peat swamp forest is 7 meters there has been a significant conversion in the extent of peat swamp forest in this area. However,, to some extent such a significant changes of land cover might have been attributed to forest fire occurring in 1997 and this was confirmed during the ground truth where forest fire spots are now become barren land and swamp areas. This might be due to the fact that Kalimantan's rainforests are driven by El Nino Southern Oscillation events. When forest fragmentation and deforestation increased it could transforms El Nino from regenerative to a high destructive phenomenon, one that triggers droughts and wild fires with increasing frequency and intensity, disrupts fruting of dipterocarp trees, interrupts wildlife reproductive cycles, and erodes the basis for rural livelihoods (Curran et al. 1999). Further, forest habitat fragmentation has been shown to induce changing in the primate behavior (Stickler 2004). In Kalimantan recently, orangutan has been found to raid the timber industrial plantation area in order to feed the cambrium of *Acacia mangium*, the tree species planted for pulp and paper industries. This phenomenon has never been seen when the forests habitat still intact and unlogged. This suggests resource and habitat limitation have constrained the species well-being.

Table 7. Deforestation rate in Ketapang District (in Ketapang district forests excluding Sungai Puteri, and in Sungai Puteri Peat-forest blocks).

From	To	Interval (years)	*q (%)*	*r (%)*
Ketapang district				
1992	2000	8	0.01	0.01
2000	2002	2	6.14	6.34
2002	2003	1	6.33	6.54
2003	2004	1	0.28	0.28
2004	2005	1	0.14	0.14
2000	2005	5	3.85	3.93
Sungai Puteri peat swamp forest				
1989	1990	1	1.59	1.61
1990	1999	9	3.24	3.29
1999	2000	1	3.34	3.39
2000	2002	2	1.31	1.32
2002	2005	3	0.88	0.89
2005	2007	2	1.68	1.69
1989	1999	10	3.08	3.12
1999	2007	7	1.50	1.51
1989	2007	18	2.38	2.41

The Ketapang district forests are well known for being the home of orangutan, the endangered great ape species. A newly discovered orangutan population in Sungai Puteri peat swamp forest blocks could be used as a tool to protect this peat swamp forest as the habitat of orangutan. Unfortunately, people are commonly view peat swamp forest as naturally unproductive. That is why the majority of peat swamp forests suffer from land use conversion. The ecological functions of peat swamp forest as carbon store and geological source of organic rock are mainly neglected, and especially deforestation towards peat swamp forest is confirmed to have a severe impact on the global atmosphere. The tropical deforestation would releases 1.5 billion tonnes of carbon each year into the atmosphere (CSIRO 2007). A report suggested that tropical deforestation, including both the permanent conversion of forests to croplands and pastures, and the temporary or partial removal of forests for shifting cultivation and selective logging, is estimated to have released on the order of 1-2 PgC/year or 15% to 35% of annual fossil fuel emissions during the 1990s (Moutinho and Schwartzman 2005). Therefore, the avoided deforestation scheme is now gaining more concerns from the global communities, which actually presents an alternative economic development for the local people through carbon trade mechanism, such as the Reducing Emission from Deforestation and Forest Degradation (REDD). While protecting the peat swamp forest habitat for orangutan population in Sungai Puteri, it could also gain an invaluable benefit from the REDD initiative. It was predicted that Long Term Carbon Accumulation Rate (LORCA) in this peat swamp forest may probably fall between 0.4 and 0.8 t C/ha per year. (Anshari et al. 2009). However, it is not sure whether this peat swamp forest would survive or not under the present disturbances related to global climate change and economic development program.

CONCLUSIONS

This study shows that the rate of deforestation in Ketapang district of West Kalimantan remarkably increased during the period of 2000 to 2004 reaching to 6.54%. Although it was slowing down during 2004 to 2005, the average rate from 2000 to 2005 was 3.39% per year. Despite the high rate of deforestation in Indonesia as a whole which reached 1.08 million hectares during 2000-2005, or even that in Kalimantan with 1.23 million hectares, the extent of deforestation in Ketapang district was merely 74,590 ha per year. The patterns of land use changes detected in this study indicated a number of possible causes of deforestation in this district. The local government policy and market demand could be those of so many triggers of deforestation, in addition to impoverishment risks experienced by the local people, especially the migrants. Deforestation patterns in the study areas have created forest fragmentation, from which the structural change of landscape can increase the probability of natural disturbance and of exposure of the species diversity and wildlife population to deterioration. Appropriate forest conservation measures combined with pro-poor development, through for example REDD scheme, will certainly help lessen the human pressures on the lowland forests in this district as well as the peat swamp forest blocks of Sungai Puteri.

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