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Key note

Evaluating and forecasting the influences of CDM plantations on biodiversity

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Key words: remote sensing, GIS, *Acacia mangium*, secondary forest, biodiversity, distance

Introduction

The Clean Development Mechanism (CDM) was proposed at the third meeting of the Conference of the Parties to the Convention on Climate Change (COP3) held in December 1997 as a means to meet reduction targets for greenhouse gas emissions, with the rules set at the subsequently held COP9 meeting. However, unique organisms, vegetation and ecosystems may exist in non-forest areas targeted by new CDM afforestation projects. Because CDM afforestation often targets a single large area, there has been concern about its impact on local biodiversity; Japan, as an executor of CDM afforestation projects, needs to develop scientific methods for evaluating biodiversity and other methodologies to evaluate and predict the impact of CDM afforestation on biodiversity. It is also important in CDM projects to develop silvicultural methods that aid in restoring biodiversity as a measure of restoring deteriorated rainforests, in addition to combating global warming.

Research Objectives

a) Vegetation survey, GIS and satellite data

The objective of this research was to clarify the influence of distance from natural forests on the biodiversity of surrounding secondary understory vegetation by producing forest cover maps using ground truthing data and satellite image analysis in order to evaluate differences in distance from primary forests which act as a source of seed.

b) Insects

In this study, the diversity of butterflies (which interact with plant diversity), and the diversity of dung and carrion scarabaeid beetles (which interact with mammals and provide various ecological services (Nichols et al., 2007)) were investigated and compared in CDM afforestation model study sites, including *Imperata cylindrica* grasslands, plantations of *Acacia mangium* (hereafter called *Acacia* plantations), and natural forests. Based on the results, the impact of afforestation was evaluated.

c) Parasitoid wasps

To understand the impacts of forest fires and the effects of *Acacia* plantations on forest ecosystems and biodiversity, assemblages of parasitoid wasps as an indicator group of the diversity of forest vegetation and arthropods (Hilszczański et al., 2005; Sääksjärvi et al., 2006) were compared among *Imperata* grasslands, *Acacia* plantations, secondary forests, and natural forests.

To understand the impact of landscape and vegetation factors on the function of secondary forests in supplying endemic species to plantation forests, we investigated the spatial changes in the assemblage of parasitoid wasps along a gradient from unburnt to severely burnt forest areas, using SPOT satellite images for analyzing landscape structures.

d) Mammals and birds

Whether plantations in the course of the CDM project can play a key role in conservation and restoration of species diversity may be highly dependent on plantation design at the landscape level. For example, we could establish ecological corridors which connect remaining forests as stepping stones for wildlife. Such corridors would affect tree species distributions by influencing the travel of seed-dispersing wildlife species, and thus CDM plantations could play an important role in the conservation of biodiversity. We attempted to assess species diversity both of the targeted areas and the surrounding areas to select suitable places for CDM plantations, and to develop effective monitoring methods.

Methods

a) Vegetation survey, GIS and satellite data

1) To make a base map for evaluating the landscape level biodiversity, we gathered satellite images taken in 2003 and 2005 and made a land use/cover map. A Spot 5 image taken on February 27, 2003 was used to make a ground survey map, which was classified by the unsupervised classification method. We conducted a ground survey in December 2007 and collected ground truth data, including photo images with position information.

2) A transect (length 1800 m) was established from unburnt remnant logged forest at the edge of the Sungai Wain Forest Reserve to heavily burnt forest. These forests had been burnt several times since 1997. The line plot started from S1.04.00, E116.53.18 and stretched southeast. Thirty-eight subplots (10×10 m) were set every 50 meters. Distance from the starting point was used to designate each plot.

b) Insects

1) Study sites: For butterflies and for dung and carrion scarabaeid beetles, several study sites located 10–30 km north of Balikpapan, East Kalimantan, Indonesia, were selected in grasslands, *Acacia* plantations, burnt natural forests, and intact natural forests of the Sungai Wain Forest Reserve (SWFR) and Bukit Bangkilai Reserve Forest (BBRF). Surveys were also conducted in one cattle pasture for dung and carrion scarabaeid beetles. We also conducted a study using a transect starting from an intact remnant forest free from fire to an *Acacia* plantation through burnt natural forests (called Remnant-Transect (RT)), to evaluate the function of the burnt natural forest as a corridor between the intact natural forest and the plantation.

2) Butterflies: In 2004 and 2005 we collected butterflies several times with insect nets along a transect set inside and on the edge of an intact natural forest in the SWFR, in three *Acacia* plantations, and two grasslands, over a period of 2 hours using two persons as collectors. In 2006 and 2007 we also collected butterflies along RT and totaled the number of butterflies collected every 100 m.

3) Dung and carrion scarabaeid beetles: A crush-board trap was set up by driving a plastic cup into the ground so that its opening was level with the ground. Then, two B4-size transparent plastic sheets crossing over each other were mounted on the cup, upon which a top was placed. Each cup contained a glass bottle with a perforated lid (6 holes, each 5 mm in diameter) containing propylene glycol. Human excrement (10 g) or raw fish (30 g) was used as bait. Captured insects were collected five days after trap installation. Traps were distributed along a 90-m transect at an interval of 10 m, alternating human excrement and raw fish as bait. We collected the dung and carrion scarabaeid beetles at each site over different years between 2004 and 2008 and at RT in 2007 and 2008.

c) Parasitoid wasps

Research plots were set up in *Imperata* grasslands (5 plots) formed following forest fires, *Acacia* plantations established in grasslands (5 plots), burnt secondary forests (2 plots), and unburnt natural forests (2 plots), in or near the Sungai Wain Forest Reserve, 10–30 km north of Balikpapan, East Kalimantan, Indonesia. We sampled braconid parasitoids (Yu et al., 2004) by sweep netting at each plot. Abundance, species richness, and species composition of braconids were analyzed using EstimateS and PC-ORD.

We placed plots at 100-m intervals in naturally regenerating secondary forests along the

1.1-km census line located from an unburnt forest into an area intensively burnt in 1997/98. Landscape structure around the census line was analyzed with a SPOT satellite image taken in 2003. We sampled braconid parasitoids in December 2006 and 2007. Abundance, species richness, and species composition (NMS scores) were analyzed in relation to distance from the unburnt forest and vegetation parameters with GLM.

d) Mammals and birds

As a complementary index of avian species diversity and abundance, we trapped birds in secondary forest patches using mist nets in July (non-breeding season) and December (breeding season). To clarify the relationship between forest type and habitat stability, we compared the recapture rate among plantation, secondary forests, and grassland. For mammals, we surveyed fauna using a passive infrared camera and traps in *Acacia* plantations, Macaranga forest patches, and open land in the Bukit Soeharto Education Forest, and compared biodiversity using new statistical methods that consider ecological and phylogenetic characteristics, and rarity of species.

Results and Discussion

a) Vegetation survey, GIS and satellite data

1) We found that the 2003 Spot 5 image was not an appropriate way to classify artificial plantations, because at that time, some of the plantation forests had only just been planted or were at a very young stage and were difficult to identify. We used another SPOT 5 image taken on June 19, 2005 which was able to detect most young artificial stands and made a base map for biodiversity evaluation using a supervised classification method. Mature forests covered less than 10% of our target area (about 40 km square) with 30% being secondary forests affected by fire in 1998. Artificial forests, agricultural lands, and grasslands covered 5%, 15% and 25% of the area, respectively. If we consider grasslands as candidate sites for CDM plantation, their area can be estimated as 5 times that of existing plantation forests.

Aerial photos taken in 1981, LANDSAT images taken in 1992 and 1998 and a SPOT 5 image from 2005 were used to analyze the transformation of land use/forest cover around the Sungai Wain Reserve Forest (SW) and Bukit Bangkirai Forest (BB). In 1981, mature forests occupied much of the area and SW and BB were united as a single large forest. Due to rapid development/cutting activities during the 1980s, mature forests decreased and SW and BB became connected only by a narrow corridor. A very large forest fire in 1998 affected most of these forests. Mature forest was limited to the core of the SW and BB forests by 1998, with remnant forests found around the core of SW and BB by 2005. Rapid changes in the history of the target area are an important basis on which to understand the biodiversity of these areas.

2) Species richness per 16 m^2 of each forest type was highest in low-level damaged secondary forest (61.92), followed by the Sungai Wain Forest Reserve (50.0), grassland (31.25), and high-level damaged secondary forests (26.98), and was lowest in plantation forests (19.58).
Number of species per ha that re-colonized within three years totaled only 6 species, consisting of two herbs (*Axonophus compressus* and *Scleria levis*), two ferns (*Blechnum orientale* and *Lygodium flexuosum*), one shrub (*Ficus glandulifera*), and one tree, *Macaranga hypoleuca*. The results of NMDS ordination showed plantations were still severely disturbed and far different in composition to natural forests. Vegetation distance between plots and the distance between plots were significantly correlated. Three tree species (*Cotylelobium lanceolatum*, *Pternandra coerulescens*, and *Syzygium urceolatum*) were biased to plots near natural forests, while in contrast, many ruderal species were biased to plots distant from the natural forests. Consequently, it may take a very long time to restore natural forest species by planting only *Acacia mangium* in degraded lands.

b) Insects

1) Butterflies: Species richness was highest in the intact natural forests followed by the *Acacia* plantations, and abundance was highest in the *Acacia* plantations followed by the intact natural forests. Butterfly diversity was highest in the intact natural forests. The plantations contained a large number of forest species, while the grassland had only a few of these. However, the

communities differed greatly between the intact natural forests and plantations. Based on these results, it is suggested that afforestation increases the number of species of insects and contributes to the restoration of forest species that do not inhabit the inner areas of intact natural forests. Collection along RT showed that many species in the intact natural forest also inhabited the burnt natural forest. This result suggested that, next to plantations, burnt natural forest was an important source of forest species.

2) Dung and carrion scarabaeid beetles: The number of species was highest in the intact or burnt natural forests and did not differ between plantations and grasslands. However, species common in natural forests were also present in plantations, but not in grasslands. Abundance was highest in cattle pasture, followed by natural forests, but did not differ between plantations and grasslands. A community structure analysis using NMS allocated plantations as intermediate between natural forests and grasslands. Based on these results it is suggested that while afforestation does not increase the number of species of insects, it contributes to the restoration of the community structure of natural forests. Collection along RT showed that both species richness and abundance declined in accordance with the distance from the intact natural forest. Both species richness and abundance were lower in the valley than on the ridge.

Findings in this study suggest that afforestation increases the local diversity of insects when compared with grasslands left as they are, and that CDM afforestation contributes to the increase of biodiversity. Our results are consistent with a study reporting that afforestation promoted the restoration of native tree species (Otsamo, 2000) and studies reporting that the diversity of moths and dung beetles was high in plantations (Nummelin and Hanski, 1989; Holloway et al., 1992; Chey et al., 1997; Estrada et al., 1998; Harvey et al., 2006). However, it is still considered difficult to use afforestation to restore rare forest species that are decreasing due to the loss of natural forests, since community structure was very different between natural forests and plantations.

c) Parasitoid wasps

Both abundance and species richness of braconid parasitoids markedly declined in Imperata grasslands, but increased somewhat in mature *Acacia* plantations, indicating that *Acacia* plantations in grasslands promote the recovery of arthropod diversity. DCA ordination also showed that species composition of parasitoids in *Acacia* plantations was intermediate between natural forests and grasslands, verifying that *Acacia* plantations drive the insect assemblages of grasslands to native natural forests to some degree. Recovery after plantation establishment as well as declines after forest fires were both more distinctive in parasitoids of wood borers than for those of herbivores.
Abundance and species richness of braconid parasitoids decreased exponentially with distance from unburnt forest stands in both 2006 and 2007, and species composition analyzed with NMS ordination changed along the same gradient. Parasitoids were also highly affected by species richness of canopy trees, which increased in forest remnants remaining along streams that were probably unburnt. For conservation and promotion of regional biodiversity in degraded forests areas after fires it is important to make appropriate landscape designs for CDM plantations, especially considering the location of large and small unburnt remnants and their connections, and which can be rather easily identified using satellite images.

d) Wildlife and birds

Avian diversity was poorest in grasslands, medium in plantations and richest in the secondary forests according to the complexity of forest structure. In May–July, the number of captured bird species was 7, 8, 11, 19, 21, 21 and 18 species in grasslands, immature and mature plantations, small, medium, large-size, and lightly-burnt secondary forests, respectively. The diversity indices were similar among small, medium and large-size burnt secondary forests, and lightly-burnt secondary forests, but species compositions were very different among these four forest types. The dominant species in secondary forests was *Arachnothera longirostra*. However, *Pycnonotus goiavier* was dominant in the grasslands and plantations. It was not captured so frequently in secondary forests and was never caught in the large-size and lightly-burnt secondary forests. On the other hand, the other bulbul species were caught only in large and lightly-burnt secondary forests. Bulbuls are a likely good indicator of avian diversity. The recapture rates were more than 10% in medium- and large-size burnt and lightly-burnt secondary forests, but less than 5% in small secondary forests, which were more similar to plantations and grasslands. In the medium and large-size burnt and lightly-burnt secondary forests, there may be more resident individuals probably because of abundant food availability. This suggests that small secondary forests and plantations cannot be the source of this diversity alone, although they were better than grasslands. Such habitats can contribute to maintaining avian diversity in combination with larger secondary forests. In the secondary forest, we caught 91 individuals (21 species) in the non-breeding season and 40 individuals (14 species) in the breeding season. The relationship between forest structure and avian diversity showed that the complexity of structure in the mid-layer appeared to be related to the diversity index.

Our passive infrared cameras and traps caught 23 and 8 mammalian species, respectively. The results showed that mammalian diversity was low in open land, and the primary and secondary forests showed a relatively high diversity compared to that in plantation forests. Compared to the fauna in the non-burnt forest, there was no difference in the number of medium and large-size mammalian species. However, two small species *(Lariscus insignis* and *Trichys fasciculata*) were not caught in the burnt forest, indicating these two species were vulnerable to forest fires. We also found that mammals functioning as seed dispersers still remained even after forest fire. Further, more than 78% of local people were able to distinguish three species of primates, and the results of the questionnaire showed a geographical gradient in the distribution of these species. These results assured us that information from local people was useful for monitoring mammalian fauna.

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Amount of C stored in aboveground biomass of trees of mixed dipterocarp forest of East Kalimantan and its dynamics

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Key words: tree and sapling, diameter, natural and secondary forest, mortality, growth and sequestration

Introduction

The main carbon pools in tropical forest ecosystems are the living biomass of trees and understory vegetation and the dead mass of litter, woody debris and soil organic matter. Among the dominant terrestrial forest ecosystems in Kalimantan with mineral soil, such as mixed dipterocarp forests, in terms of the amount of C stored, living biomass is more important than either dead organic matter or soil organic matter.

Living biomass provides the important function of fixing C from the atmosphere through photosynthesis and storing it in living biomass. It also becomes a source of dead organic material on the forest floor or in the peat layer through litter fall and falling logs. Thus, it is important to understand the aboveground forest biomass and its changes in quantifying the carbon stocks and fluxes of tropical forests.

The aboveground oven dry weight of living biomass in a forest can be measured directly by felling, drying and weighing all components of the living biomass (destructive methods). However, the method is not practical for a large area and it also destroys the living biomass of the forest. Hence, only a few destructive studies have been conducted to measure the total aboveground living biomass and to develop an allometric relationship between diameter and total biomass aboveground, such as: Kato et al. (1978), Yamakura et al. (1986) on mixed dipterocarp forests, Hashimoto et al. (2004) on pioneer tree species; and Miyamoto et al. (2007) on heath forest, and Ludang & Jaya (2007) on peat swamp forest in Central Kalimantan.

Many researchers estimated the aboveground biomass of forests through a general allometric relationship developed by Brown (1997). The amount of C stored in the living biomass of a forest was derived from the tree diameter and a constant C. The amount of C stored is related to the total living biomass of the forest. Total biomass varies from site to site, depending on the structure, composition and age of the forest and disturbances. The amount of C stored in living biomass changes with time, and living biomass is directly impacted by deforestation and degradation. The changes in the amount of C stored in living biomass are related to the balances between the biomass growth (due to above- and belowground biomass increment) and biomass loss (due to litter fall and fallen dead trees).

Based on the H–D allometric relationships derived from a field study, Okuda et al. (2004) estimated total above ground biomass (TAGB) as 310.3 Mg/ha in primary and 274.4 Mg/ha in logged-over mixed dipterocarp forests; this difference was significant. These values were about 10 to 12% smaller than those estimated by Kato et al. (1978), with TAGB values of 352.8 and 300.7 Mg/ha, respectively.

The present paper estimates the amount of C stored in aboveground biomass of mixed dipterocarp forest of East Kalimantan in natural and secondary forests with Brown’s equation and its changes based on the diameter.

Study sites

The studies were conducted in the Sungai Wain Nature Reserve (for natural forest), in the

Samboja area (for secondary forest), in DAS Manggar (for *Acacia mangium* 5-year-old plantation) and in Km 29 area (for *Acacia mangium* 3-year-old plantation). The Sungai Wain Nature Reserve, Samboja, DAS Manggar and Km 29 areas are respectively located at 15 km northwest, 30 km north, 12 km northeast and 29 km north of Balikpapan City, East Kalimantan, at altitudes ranging from 50 to 110 m (Fig. 1).

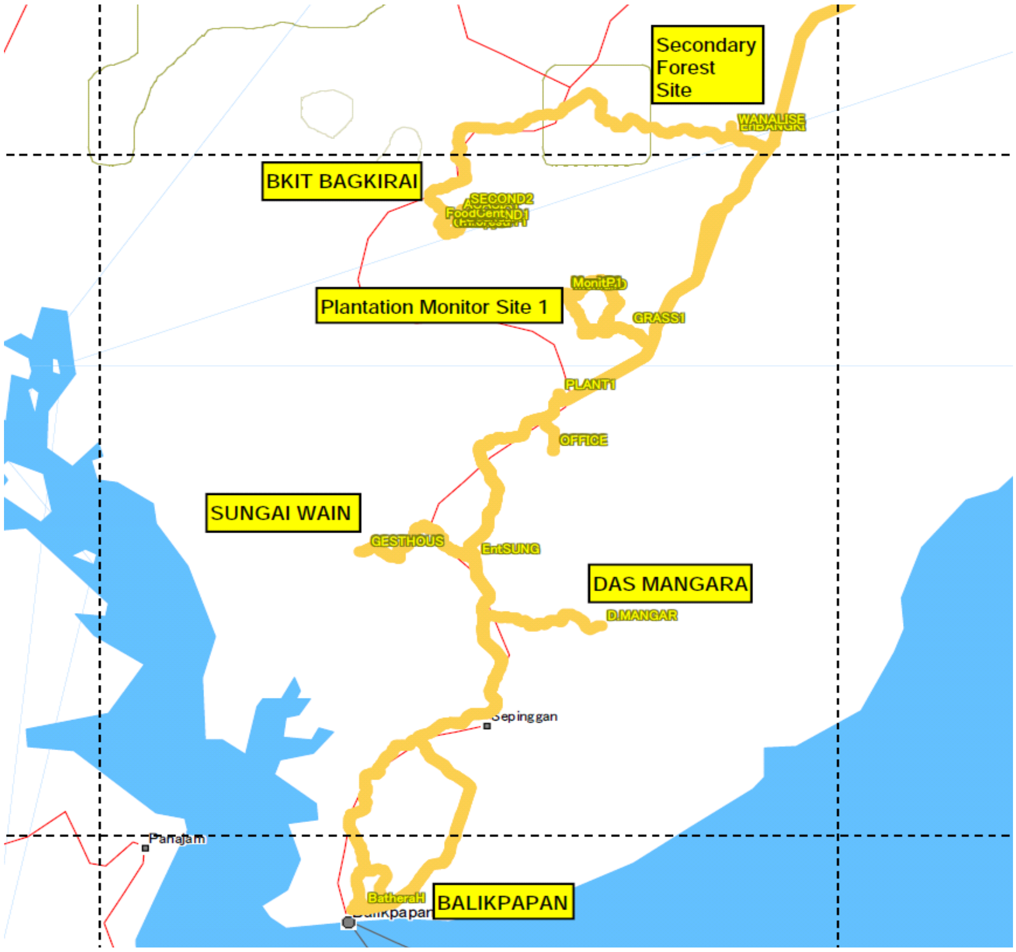

Fig. 1. Location of the study sites in East Kalimantan, Indonesia.

The Sungai Wain Nature Reserve is a typical primary lowland mixed dipterocarp forest of about 10000 ha. The forest fires of 1997/1998 destroyed about 6500 ha of the reserve, especially the perimeter areas of the reserve, whereas the central core (about 3500 ha) of the forest remained unburnt (van Nieuwstadt, 2002). The plot was established in the unburnt areas.

Originally, the forests in the Samboja area were also typical lowland mixed dipterocarp forests. However, most of these forests were burnt out during the extensive forest fires following intense long dry season periods of 1982–83 and 1997–98. After the second forest fires, the areas were left to recover naturally.

The DAS Manggar area is a 5-year-old *Acacia mangium* plantation, while the Km 29 area is a 2.5-year-old *Acacia mangium* plantation, both belonging to the company, PT Inhutani 1.

Methods

After a reconnaissance study for exploring the general condition of natural forest and secondary forest, a 1-ha plot was established in each of primary natural forest and secondary forest. The 1-ha plot of 100×100 m was divided into one hundred sub-plots of 10×10 m. Fifty sub-subplots of 5×5 m were also established systematically within the plot.

One plot was also established in each of the DAS Manggar and Km 29 plantations; however, the size of the plot in each of the *Acacia mangium* plantations was 50×100 m, with 25 sub-subplots of 5×5 m in each.

All trees with stem girth at breast height (*gbh*, or at 130 cm above the ground) of more than 15 cm within the 10×10 m sub-plots were individually numbered with aluminum tags, identified as to species according to Herbarium Bogoriense, Bogor, Indonesia, and measured for *gbh*. The diameter at breast height was also measured for all saplings with a height of more than 1.5 m but girth of less than 15 cm within the 5×5m sub-subplots.

The biomass of each tree species in primary forest and secondary forest were then estimated by Brown's (1997) allometric equation:

$$Y = a\ D\char`^{}^{b}$$

where: Y = biomass (kg dry weight)

D = tree diameter (cm)

a and *b* are constants, a = 0.19 and b = 2.37.

The biomass of the *Acacia mangium* plantation was estimated according to a general allometric equation developed by Hiratsuka et al. (2003):

$$Y = 1.876 \times 10^{-1}\ D^{1.131}$$

where: Y = biomass (kg dry weight)

D = tree diameter (cm)

The amount of C was estimated by multiplying the total biomass by a constant of 0.5.

Results and Discussion

The number of tree species with diameter of more than 5 cm, total basal area, number of individuals and five of the most prevalent species in each forest type are presented in Table 1. The number of species in natural forest of the Sungai Wain Nature Reserve (288 species) was much higher than that in secondary forest (141 species) of the *Acacia mangium* plantation. Between the two study plots of *A. mangium* plantations, the number of species in the 3-year-old plantation (15 species) was higher than that in the 5-year-old plantation (11 species).

Table 1. Top-five most prevalent species in each forest type

Forest type	**Species**	**No. of trees**	**BA m^2/ha**	**% Ind**	**% BA**
Sungai Wain natural forest	*Shorea laevis*	57	3.81	3.04	15.05
	Dipterocarpus confertus	94	3.05	5.02	12.05
	Madhuca kingiana	348	2.56	18.57	10.12
	Macaranga lowii	146	0.69	7.79	2.74
	Gironniera hirta	24	0.52	1.28	2.06
	Others 283 sp.	1205	14.68	64.30	57.98
	Total 288 sp.	**1874**	**25.33**	100.00	100.00
Wanariset secondary forest	*Eusideroxylon zwageri*	11	1.55	1.03	10.50
	Shorea parvifolia	2	1.42	0.19	9.60
	Dipterocarpus cornutus	5	1.34	0.47	9.05
	Pholidocarpus majadum	16	0.90	1.50	6.09
	Macaranga gigantea	163	0.75	15.28	5.11
	Others 141 sp.	870	8.80	81.54	59.65
	Total 146 sp.	**1067**	**14.76**	100.00	100.00
Acacia mangium 5 years old	*Acacia mangium*	445	28.07	89.36	98.48
	Artocarpus elasticus	24	0.22	4.82	0.76
	Diospyros borneensis	3	0.04	0.60	0.16
	Artocarpus glaucus	4	0.04	0.80	0.16
	Vitex pinnata	7	0.04	1.41	0.15
	Others 10 sp.	15	0.09	3.01	0.30
	Total 15 sp.	**498**	**28.51**	100.00	100.00
Acacia mangium 3 years old	*Acacia mangium*	499	5.07	69.21	48.86
	Gmelina arborea	143	3.51	19.83	33.79
	Vernonia arborea	18	0.79	2.50	7.63
	Hevea brasiliensis	39	0.76	5.41	7.33
	Mallotus paniculatus	6	0.11	0.83	1.09
	Others 6 sp.	16	0.14	2.22	1.31
	Total 11 sp.	**721**	**10.38**	100.00	100.00

The amount of C stored in aboveground biomass of trees in natural forest is higher than that in the 5-year-old *A. mangium* plantation, which is higher than that in secondary forest. However, the rate of increase of C in *A. mangium* plantation is much higher than that in secondary forest, which is higher than that in natural forest. The amount of C stored in saplings of natural forest is much higher than that in secondary forest, which is higher than that in *A. mangium* plantation. Unlike as in trees, the rate of increase of C for saplings in natural forest is much higher than that in secondary forest, especially than that in *A. mangium* plantation which tends to show a decrease (Table 2).

Table 2. Amount of C stored in aboveground biomass of trees and saplings, potential C lost due to tree mortality and relative rate of C sequestration of each forest type

No.	Subject	Secondary forest		Natural forest		A. mangium	
		2003	**2008**	**2005**	**2008**	**3 y old**	**5 y old**
1	C stored in trees (t/ha)	62.30	85.80	104.40	117.43	30.48	110.47
2	C stored in recruited trees (t/ha/y)		8.96		0.75		
3	Potential C lost due to tree mortality (t/ha/y)		12.35		1.67		
4	Net C sequestered (t/ha/y)		4.70		4.34		26.66
5	Relative rate of C increment/ year (%)		7.54		4.16		18.92
	Saplings	**2005**	**2008**	**2005**	**2008**	**3 y old**	**5 y old**
6	C stored in saplings (kg/ha)	734.43	737.33	5,503.15	6,137.46	824.42	551.11
7	C stored in recruited saplings (kg/ha)		376.48		54.24		
8	Potential C lost due to sapling mortality (kg/ha)		201.68		62.65		
9	Net C sequestered (kg/ha/y)		1.20		177.02		-91.10
10	Relative rate of C increment/ year (%)		0.16		3.22		-6.62

The C contents in natural forest (117.43 t C ha^{-1}) and secondary forest (85.8 t C ha^{-1}) of the study sites were lower compared with a range of average values for Southeast Asian forests of 175–200 t C ha^{-1} (Brown, 1997). However, the C content in *A. mangium* plantation (110.47 t C ha^{-1}) was considerably higher than that in other plantations in Indonesia (Hiratsuka et al., 2003).

Among the tree and sapling species which had more than 10 individuals within a plot, the top-five species in terms of rate of C sequestration in each forest type are presented in Table 3. The number of some species, however, decreased due to tree mortality during the study period.

Table 3. Top-five species with highest rate of C sequestration with more than 10 individuals in each plot (for the year of earlier study, refer to Table 2)

Forest type		Species	No. of individuals		C content (kg)		Growth rate per year (%)	
			Earlier study	In 2008	Earlier study	In 2008	No. of trees	C
Natural forest	Trees	*Shorea smithiana*	20	19	640.04	1,014.24	-1.67	19.49
		Alangium ridleyi	14	14	227.51	300.04	0.00	10.63
		Sindora leiocarpa	14	15	199.03	258.36	2.38	9.94
		Aglaia forbesii	14	15	95.94	122.41	2.38	9.19
		Diospyros borneensis	11	11	484.04	610.28	0.00	8.69
	Saplings	*Shorea laevis*	181	158	31.68	44.21	-4.24	13.18
		Dacryodes costata	26	25	10.96	15.10	-1.28	12.60
		Syzygium alcinae	14	13	0.65	0.88	-2.38	11.70
		Artocarpus anisophylus	15	15	7.21	9.35	0.00	9.89
		Urophyllum glabrum	12	12	3.46	4.33	0.00	8.41
Secondary forest	Trees	*Peronema canescens*	23	60	126.99	1,084.67	32.17	150.83
		Vernonia arborea	88	160	870.21	7,339.38	16.36	148.68
		Macaranga hypoleuca	13	27	92.42	652.25	21.54	121.14
		Evodia glabarata	53	63	561.75	3,557.35	3.77	106.65
		Artocarpus elasticus	45	52	428.31	2,145.81	3.11	80.20
	Saplings	*Millettia splendidissima*	54	111	3.78	11.53	52.78	102.44
		Adina minutiflora	11	11	2.13	4.13	0.00	46.99
		Peronema cansescens	13	11	3.58	4.06	-7.69	6.77
		Macaranga trichocarpa	32	19	3.89	3.81	-20.31	-0.96
		Leea indica	125	107	12.34	9.46	-7.20	-11.67
Plantation		*Acacia mangium*	499	445	6.90	55.37	-3.61	234.35

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Possibility of recovering natural forest species in *Acacia mangium* plantation forests

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Key words: *Acacia mangium*, plantation, understory vegetation, diversity, re-introduction, distance

Introduction

Drastic loss of natural tropical forests has been a global trend throughout the 20th century and is still progressing, with vast numbers of species in danger of extinction. Consequently, there is an urgent need to maintain the diversity of species which depend on natural tropical forests.

The understory vegetation layer (or herbaceous layer) is particularly important for maintaining biodiversity, since many herb and shrub species are confined to this layer, and the tall trees must pass through it during their seedling stage (Gilliam, 2007).

Monocultures of fast-growing plantations are often criticized for their lack of diversity, although there have been many reports that fast-growing plantations planted on degraded land such as Alang-alang grassland can increase the species richness and diversity of native woody species in understory (Parrotta, 1992; Kuusipalo et al., 1995; Otsamo, 2000; Otsamo, 2002).

Acacia mangium is the most popular fast-growing planting tree indigenous to Australia and is resistant to extreme environments. The nitrogen fixation ability and large amount of litter fall of A. mangium help fertilize the soil. Additionally, the dense crown can suppress light-demanding grasses and moderate the surface temperature and soil moisture. As a result, A. mangium can be used to facilitate the growth of native tree species (Otsamo, 1998). However, the potential of A. mangium as a habitat for indigenous plants remains unclear.

In this study, we examined the possibility of restoring natural forests species in A. mangium plantation forests.

Methods

Study sites: The study area was located in a hilly region alongside the road between the cities of Balikpapan and Samarinda in East Kalimantan, Indonesia.

Vegetation under Acacia plantation forests, which were planted on grasslands and were 5 to 8 years old, was compared with that of selective cut forests (Sungai Wain Forest Reserve, Selective Cut 1970), low-damage secondary forests (Wanariset, partly burnt in 1997), high-damage secondary forests (heavily burnt in 1997), and Alang-alang grasslands.

Six large plots (area: 0.25–1 ha), and 51 small plots (0.03–0.01 ha) were set around the Sungai Wain Forest Reserve. The large plots were repeatedly surveyed and the small plots were surveyed once. Small quadrats were set in each plot. The size and number of quadrats in the small plots varied (1 m2 quadrats (16 quadrats), and 4 m2 quadrats (4 quadrats)) but the area of surveyed quadrats was the same (16 m2). Large plots were divided into the same area as the small plots.

The effect of distance from seed source on the diversity of understory vegetation of secondary forests after fire was examined using a line plot. A line plot (length 1850 m) was set from the unburnt remnant logged forest at the edge of the Sungai Wain Forest Reserve to the heavily burnt forests. These forests have been burnt several times since 1997. Thirty-eight subplots (10×10 m) were set every 50 meters. The elevation of the line plot was 30–80 m. The plot includes five valleys with small rivers. The dominant forest types are burnt secondary forests with *Macaranga gigantea*, *M. trichocarpa*, *M. triloba* and *Vernonia arborea*, which are typical pioneer species in this area.

Field survey: The species, number and DBH of individual trees in each plot were recorded (tree census). The species of trees, and herbs shorter than 2 m, in each quadrat were recorded.

Analysis: We assessed the compositional characters of each stand by nonmetric multidimensional scaling (NMDS). NMDS is a method of ordination which provides views of a high-dimensional space by displaying the structure into lower dimensional plots. In this study, the distribution of stands in the n-dimensional species space (n: number of species observed) was projected to a two-dimensional plot. The Sørensen dissimilarity measure (Faith et al., 1987) with occurrence frequency of each species gave the compositional dissimilarity between stands. All the analyses were performed by R 2.5.1 with vegan package (R Development Core Team, 2007).

We tested the significance of the correlation between two dissimilarity matrices: vegetation dissimilarity of two stands, and geographic distance of the stands on the map. We used the Mantel test which evaluates the correlation between distance matrices (McCune and Grace, 2002). Pearson's product-moment correlation coefficients were calculated as indexes of the association between matrices. The significance of the statistic was evaluated by permuting rows and columns of the one dissimilarity matrix 1000 times. In the same way as the NMDS ordination, the Sørensen dissimilarity measure (Faith et al., 1987) with occurrence frequency of each species gave the compositional dissimilarity between stands.

Results and Discussion

Species richness of each forest type was highest at Wanariset (61.92), followed by the Sungai Wain Forest Reserve (50.0), grassland (31.25), high-damage secondary forests (26.98), and lowest at plantation forests (19.58) (Fig.1).

The results of NMDS ordination are presented at Fig. 2. Axis 1 shows the disturbance level. The *Acacia mangium* plantation forests are located at the upper left of the graph; they show a high disturbance level and far-different compositions to the natural forests, and were also different to the secondary forest and grasslands.

Re-introduction of natural forest species to the understory vegetation of the *Acacia mangium* plantation in 3 years was very low. The change of species density per plot (16 m^2) was 19.5 in 2005 and 20.5 in 2007. There were only six re-introduced species: two herbs (*Axonophus compressus* and *Scleria levis*), two ferns (*Blechnum orientale* and *Lygodium flexuosum*), one shrub (*Ficus glandulifera*), and one tree (*Macaranga hypoleuca*).

The vegetation distance between plots and the distance between plots were significantly correlated (Mantel test, r: 0.3463. Significance: < 0.001, Based on 1000 permutations). The results of NMDS ordination showed that the compositions of plots near natural forests were different to those of plots far from natural forests. The distance from the natural forests was correlated to the ordination axis 1. Three tree species (*Cotylelobium lanceolatum*, *Pternandra coerulescens*, and *Syzygium urceolatum*) were biased to the near natural forests, whereas many ruderal species were biased to the plots far from the natural forests.

Conclusion

The understory of plantations has low species richness and different composition to secondary forests. The input rate of new species is very low and a very long time is needed to return to a species-rich forest. The distance from seed sources can limit the recovery of natural forest species to the understory vegetation of plantation forests. Consequently, it may be difficult to restore natural forest species by planting *Acacia mangium* on degraded land.

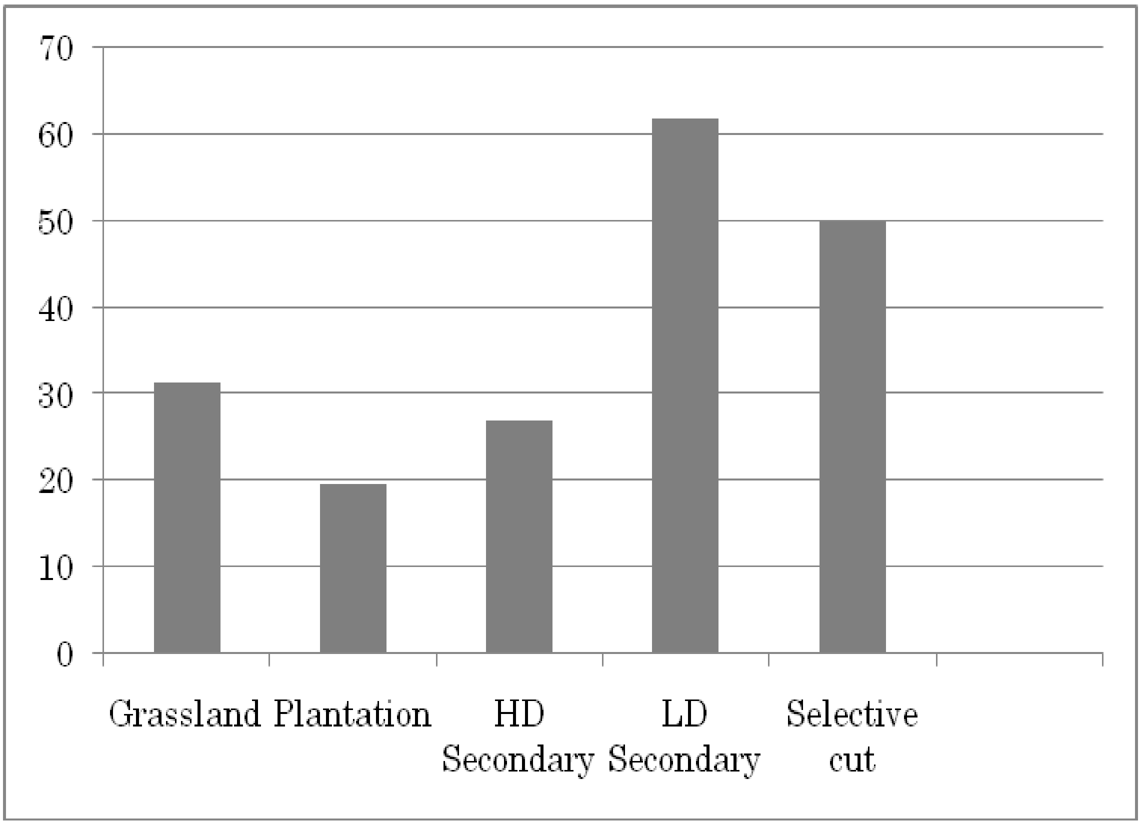

Fig. 1. Mean species richness of each type of forest.

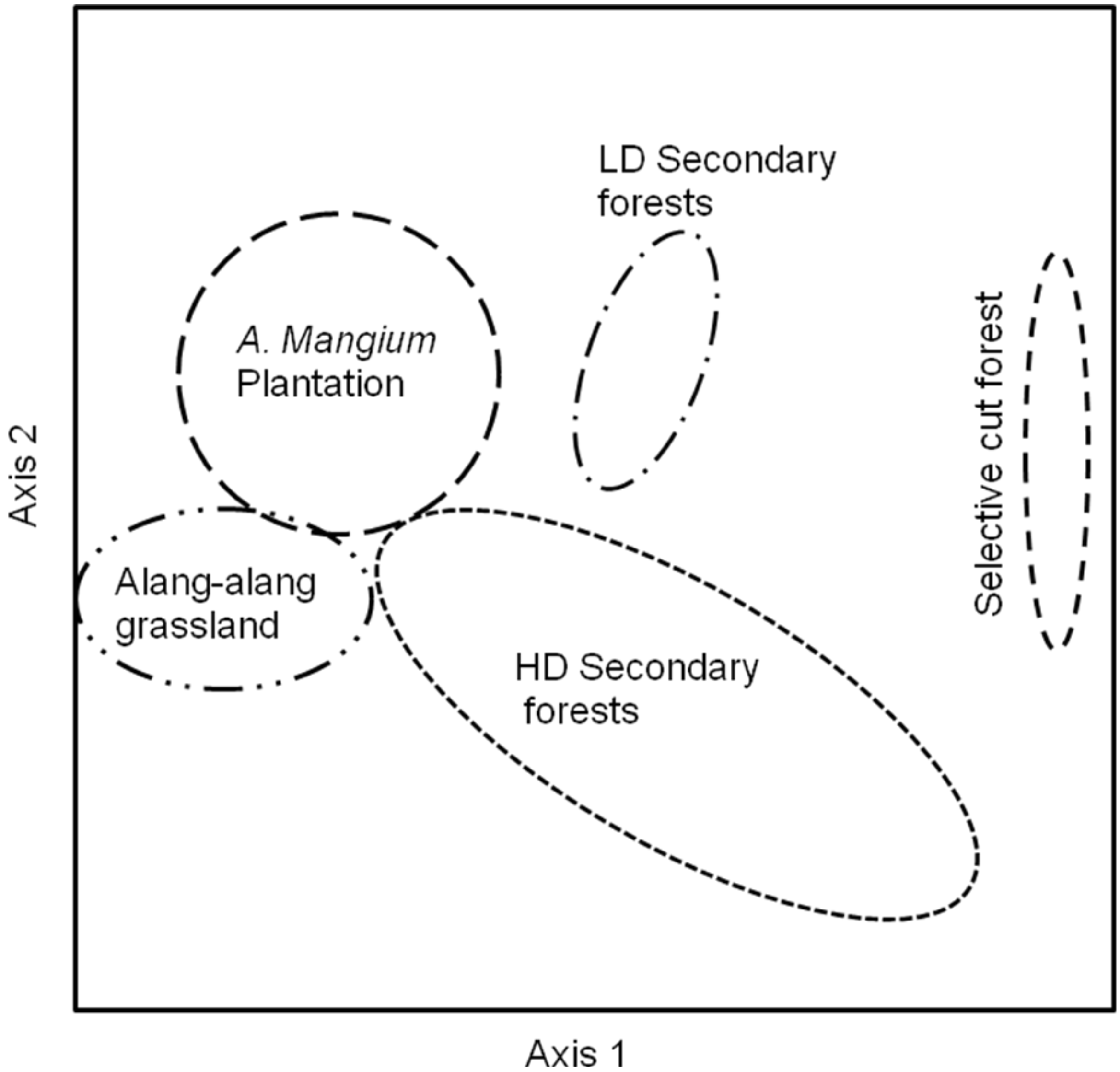

Fig. 2. Result of NMDS ordination of understory vegetation.

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Species richness and species composition of butterflies in *Imperata* grassland, *Acacia mangium* plantation and burnt and unburnt forests in East Kalimantan

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Key words: butterflies, tropical rain forest, artificial plantation, *Acacia mangium*, forest degradation, *Imperata* grassland, geographic range

Introduction

Natural forests in the tropics have been extensively degraded or transformed to grasslands due to human activity and wild fire, causing global concern about the decline of biodiversity. Artificial plantations of fast-growing exotic species, such as *Acacia mangium*, either for vegetation recovery or industrial purposes, have been established on grasslands in the last two decades, yet most biodiversity studies of tropical forests have been done in natural forests, except for studies of biodiversity in grasslands and artificial plantations by Chey et al. (1997), Maeto et al. (2008) and Nakamuta et al. (2008). In the present study, we focus on the recovery of butterfly species diversity in artificial plantations.

To clarify whether or not, and to what extent if ever, forest insects can recover in artificial plantations, we compared assemblages of butterflies in artificial plantations, ex-forest grasslands and natural forests near Balikpapan, East Kalimantan. We also studied butterfly assemblages in burnt forests, because artificial plantations are usually established on grasslands which are located next to burnt forests and, if an assemblage of forest butterflies is to be restored by reforestation of degraded land, possible colonization of forest butterfly species should be via the burnt secondary forests.

Study sites and methods

Comparison of butterfly assemblages between forest/vegetation types

Butterflies were sampled by hand-netting on a one-hour walk along a fixed sampling route in the following study sites (but see the note for Camp 1 in the Sungai Wain forest given below) representing ex-forest grassland, plantations of *A. mangium* and old grown secondary forest in December 2004, January 2005 and December 2005.

1. Inside of old grown secondary forest at Sungai Wain. The Sungai Wain Forest Reserve is a rather mature secondary forest that was logged long ago. A footpath along the Wain River (Sungai Wain) between the gate and Camp 1 in the forest was chosen as the sampling route. We also paused at Camp 1, which represents a gap in the forest, for 30 minutes for sampling.

2. Outside of old grown secondary forest at Sungai Wain. A footpath along the edge of the above-mentioned forest reserve (and a water reservoir on the other side) was chosen for sampling.

3. *Acacia mangium* plantation at Km 12. *A. mangium* was first planted in 1995 for conservation of a water reservoir, and partially replanted after a fire in 1998. A trail in the plantation and a dirt road along the edge of the plantation (and crop fields on the other side) were chosen as the sampling route.

4. <u>*Acacia mangium* plantation at Km 23.</u> *A. mangium* was planted in 1997 to enrich the vegetation coverage beside the management office of the Sungai Wain Forest Reserve. A trail in the plantation and a road along the edge of the plantation (and the office and its garden areas on the other side) were chosen as the sampling route.

5. <u>*Acacia mangium* plantation at Km 29.</u> *A. mangium* was planted in 2001 by Inhutani I (Indonesian National Forest Enterprise). A dirt road in the plantation area was chosen as the sampling route.

6. <u>*Imperata* grassland at Km 23.</u> The area is ex-forest grassland dominated by *Imperata cylindrica* with sparsely studded wild grown *A. mangium* trees (ca. 10 m height). Since there was no suitable footpath or trail in the grassland, we roughly determined a circular sampling route in the grassland.

7. <u>*Imperata* grassland at Km 29.</u> The area is ex-forest grassland dominated by *Imperata cylindrica* with scattered crop fields managed by farmers (illegal settlers). A dirt road in the grassland and several footpaths created by farmers connecting the road and the crop fields were chosen as the sampling route.

<u>Butterfly assemblage in burnt forest</u>

Butterflies were sampled by hand-netting while walking along a fixed sampling route of 1800 m in the burnt secondary forest between young *A. mangium* plantations at km 29 and a large remnant area that had survived fire or suffered little damage by fire.

Results and Discussion

More species were recorded in the plantation area than in the grassland, indicating that artificial plantations can certainly enrich butterfly species. It was also confirmed that the number of species increased with plantation age, and the increase was mainly due to increase of forest species, such as *Graphium evemon*, *Graphium sarpedon*, *Eurema hecabe*, *Euploea mulcibar*, *Cupha erymanthis*, *Athyma asura*, *Vindula dejone*, *Neptis hylas*, and *Ypthima pandocus*. Most of the forest species found in the plantation were, however, common species that are widely distributed throughout the Oriental Region or Indo-Australian Region, or even up to the Ethiopian Region, whereas the species found in the inside of unburnt Sungai Wain Forest Reserve included many interior forest species endemic to Sundaland or Borneo. Outside of Sungai Wain Forest Reserve was also rich with forest species, but lack interior species. Fewer species were recorded in the grasslands than in the *A. mangium* plantations, and species found in the grasslands were open-habitat species, such as *Papilio demoleus*, *Catopsilia pomona*, *Appias olferna*, and *Zizina otis*, or some forest species which prefer a disturbed environment or forest edge (e.g., *C. erymanthis* and *Y. pandocus*). These open-habitat species are also widely distributed throughout the Oriental Region or Indo-Australian region. *P. demoleus* and *A. olferna* are recent invaders from the Asian continent, probably benefiting from the destruction of rain forests (Matsumoto, 2002).

Many more species were found in the Sungai Wain Forest Reserve than in the plantation and grasslands, and the species found in this natural forest contained many shade-preferring interior forest species, such as *Losaria neptunus*, *Arhopalla* spp. *Neorina lowi*, *Coelites euptychioides*, *Faunius stomphax*, *Thaumantis nouredin*, *Zauxidia doubledayi*, *Cynitia* spp., *Eulaceura osteria*, etc. These species are mostly endemic to Sundaland, or several islands within or near Sundaland, or even endemic to Borneo.

Forest species found in the *Acacia* plantations were also found in the burnt forest. Moreover, the burnt forests were unexpectedly rich in *Arhopala* spp., a group of forest species found in the natural forest, but not in the plantation. Some other forest species, such as *Neorina lowi*, *Cynitia cocytina* and *E. osteria*, were found even in a heavily burnt part of the forest close to the plantation, and those species preferring a somewhat interior part of the forest, such as *Mycalesis anapita* and *Ypthima fasciata*, were found mostly in shadowy remnant areas where clumps of unburnt trees were remaining. Colonization by forest butterfly species from burnt forest to the plantation, or from the unburnt forest to the plantation via the burnt forest, seems possible.

Conclusion

In conclusion, artificial plantations can contribute considerably to the recovery of butterfly fauna, but the interior forest species would not recover, or would recover very slowly, in typical artificial plantations. Burnt forests may serve as a corridor or source of forest species colonizing the plantation.

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Preliminary study of changes in dung and carrion scarabaeid beetle diversity associated with planting of *Acacia mangium* in grasslands

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Key words: *Acacia mangium*, afforestation, CDM plantation, *Imperata cylindrica*, Scarabaeidae

Introduction

The Clean Development Mechanism (CDM) was proposed at the third meeting of the Conference of the Parties to the Convention on Biological Diversity (COP3) held in December 1997 as a means of meeting the reduction targets of greenhouse gas emissions. The rules were set at the subsequently held COP9. Because CDM afforestation often aims to plant a fast-growing tree species on grasslands, there has been concern about possible impacts on the biodiversity of local species. Consequently, scientific technologies need to be developed to evaluate the impact of CDM afforestation on biodiversity.

Comparative studies among natural forests, plantations, and grasslands in tropical regions are needed to evaluate the effects of CDM plantations. However, most biodiversity studies in tropical regions have focused on natural forests; there have been few such studies on plantations and grasslands. With regard to dung and carrion scarabaeid beetles, several studies have compared their communities between natural forests and plantations in Central America, Sulawesi, north Borneo, and Africa. These studies reported that the diversity in plantations was slightly lower than that in natural forests, although most of the species found in plantations were similar to those in natural forests and those found in natural forests along rivers (Nummelin and Hanski, 1989; Estrada et al., 1998; Davis et al., 2000, 2001; Estrada and Coates-Estrada, 2002; Shahabuddin et al., 2005; Harvey et al., 2006). Other studies have also reported that the communities differed between natural forests and plantations (Davis and Philips, 2005, 2009; Gardner et al., 2008). To date, no studies have been carried out to assess insect diversity in natural forests, plantations, and grasslands located together in a tropical region. This is especially so for the grassland of *Imperata cylindrica*, where the grassland's widespread distribution in post-deforested, burnt areas of tropical Asia has not yet been studied.

Dung and carrion scarabaeid beetles are known to be a superior indicator of habitat quality and environmental change in tropical regions because they are able to inhabit various kinds of vegetation and are not associated with the distribution of particular tree species or groups, but are significantly influenced by environmental disturbance (McGeoch et al., 2002; Aguilar-Amuchastegui and Henebry, 2007). These beetles also serve important ecological functions, such as promoting rapid decomposition of dung and carcasses, as well as influencing nutrient cycling, bioturbation, plant growth enhancement, secondary seed dispersal, and parasite control (Nichols et al., 2007). Thus, higher diversity of the beetle indicates a more active, complicated forest ecosystem.

The purpose of this study was to evaluate the impact of CDM afforestation on biodiversity by examining how the diversity of the dung and carrion scarabaeid beetles in non-forest areas changed in response to afforestation. It is predicted that by conducting afforestation and allowing time to pass after afforestation, the number of plant species will increase, making the environment more complex and increasingly diverse, particularly adjacent to and within natural forests. It is also predicted that the area of plantations has a positive impact on beetle diversity, whereas their distance from natural forests, where a large number of species may inhabit, has a negative influence, as has been reported for a fragmented natural forest (Estrada et al., 1998). These hypotheses are focused on identifying and comparing the diversity among natural forests, plantations, and grasslands, and among different ages, areas, and isolating distances between plantations. Currently, there are only a few CDM-certified afforestation areas. In this study, the diversity of dung and carrion scarabaeid beetles was investigated and compared in model study sites of CDM afforestation, composed of grasslands of *I. cylindrica* and plantations of *Acacia mangium*. *A. mangium* is one of the most popular fast-growing tree species used for plantations in anthropogenic areas of tropical Asia. Based on the results of these studies, the impact of afforestation was evaluated.

This study was conducted as a joint research project between the Indonesian Institute of Science (LIPI), Tropical Forest Research Center, Mulawarman University (PPHT, UNMUL), and the Forestry and Forest Products Research Institute (FFPRI) in order to evaluate the impact of CDM afforestation on biodiversity.

Methods

Study sites

Seven *A. mangium* plantations, located 10–30 km north of Balikpapan, East Kalimantan, Indonesia, were selected as study sites because they possessed a range of forest areas including background forests, tree sizes (DBH), and trunk basal areas (Table 1). Three of them were situated beside burnt natural forests that were regrowing around a large intact forest, the Sungai Wain Forest Reserve (SWFR) (Table 1). This area has not been disturbed in the last 50 years, such as from selective logging or forest fire. The plantation age was 8 years old and 5 years old at sites 23 and 29, respectively, but was unknown for the other sites. Each plantation was paired with another study site in the *I. cylindrica* grassland next to the plantation, and each grassland site was 100–300 m away from the edge of the plantation. Surveys were also conducted in one site inside the SWFR as a control (NF in the tables). In the control site, the trap transect started from 200 m from the forest edge.

Table 1. Location of intact natural forest site (NF) and locations and characteristics of *Acacia mangium* plantation site (numbers)

Site*	Latitude	Longitude	Adjacent to Sungai Wain area**	Distance from Sungai Wain area (km)	Area including back-ground forest (ha)	Mean DBH (cm)	Trunk basal area (m^2/ha)	Trapping period in December 2006 (dd-dd)
NF	S 1˚ 08' 21	E 116˚ 50' 06						16-21
18	S 1˚ 08' 21	E 116˚ 53' 39	no	2.0	1.9	22.7	54.4	19-24
22	S 1˚ 06' 23	E 116˚ 53' 37	no	1.2	5.5	10.3	16.6	19-24
23	S 1˚ 06' 30	E 116˚ 54' 20	no	2.3	9.5	17.1	20.2	19-24
24a	S 1˚ 04' 46	E 116˚ 54' 11	yes	0	10830.7	8.7	16.0	17-22
24b	S 1˚ 05' 09	E 116˚ 54' 27	yes	0	10830.7	12.0	10.2	22-27
26	S 1˚ 05' 05	E 116˚ 55' 28	no	1.4	1.3	22.8	21.4	23-28
29	S 1˚ 03' 34	E 116˚ 55' 01	yes	0	10830.7	11.2	7.4	18-23

*Number of plantation site indicates the approximate km point of the junction accessing the plantation on the main road from Balikpapan to Samarinda. Each plantation site accompanied with another site in *Imperata cylindrical* grassland 100-300m far from the edge of the plantation.

**Sungai Wain area includes the reserve forest and its surrounding burnt natural forests and plantations.

Collection of dung and carrion scarabaeid beetles

Baited pitfall traps were used to collect beetles. A trap was set up by driving a plastic cup (8.4 cm in open diameter, 5.6 cm in minimum diameter, and 12.2 cm high) into the ground so that its opening was level with the ground surface. An upside-down plastic bowl (20 cm in diameter and 5 cm high) was placed over each trap, providing a ceiling that was approximately 20 cm over the trap. Each trap contained a 50-ml glass bottle (4.3 cm in diameter and 8.0 cm high) with a perforated lid (six holes, each 5 mm in diameter) that was baited to attract beetles. Fresh human excrement (10 g) or raw meat of jack fish (30 g) was used as bait. A cut nylon net (0.5 mm mesh) was put between the lid and the bottle to prevent attracted beetles that were small from entering the bottle. The traps also contained a 30% solution of propylene glycol to kill and preserve the collected beetles. All traps were set in the morning during the month of December 2006 and captured insects were collected five days after trap installation (Table 1). Trap periods were simultaneous between each plantation and its accompanying grassland. Ten traps were distributed along a 90-m transect at intervals of 10 m, alternating human excrement and raw fish as the attractant.

Results and Discussion

Species richness and Shannon-Wiener diversity index (H') were highest in the intact natural forest and were similar between the plantations and the grasslands (Table 2). Abundance and J' evenness index did not differ among the intact natural forest, the plantations, and the grasslands (Table 2). Biomass (total dry weight of the beetles collected) was heavier at plantations than at grasslands, but did not differ between plantations and the intact natural forest (Table 2). This was attributed to the high frequency of large-size species (e.g., *Catharsius renaudpauliani* and *Onthophagus schwaneri*) that were collected at plantations but were only rarely found in the grasslands. Many of the species found in the intact natural forest were not collected in either the plantations or grasslands. However, several species found at the intact natural forest were found in plantations, but were absent or rare in grasslands (Table 2). Moreover, Morisita's similarity index (C_λ) to the intact natural forest was higher at plantations than at grasslands (Table 2). Based on these results, it is suggested that while afforestation does not increase the number of species or individuals of dung and carrion scarabaeid beetles, it helps to restore the community structure in the intact natural forests. Our results are consistent with previous studies reporting that afforestation promoted the restoration of native dung and carrion beetle species (Nummelin and Hanski, 1989; Estrada et al., 1998; Estrada and Coates-Estrada, 2002; Shahabuddin et al., 2005; Harvey et al., 2006), and also with the studies reporting that the communities differed between natural forests and plantations (Davis and Philips, 2005, 2009; Gardner et al., 2008). However, in the present study, only one of the beetle communities in the intact natural forest was compared with those in plantations and grasslands. Further studies at other sites in the corridor separating intact natural forests and burnt natural forests are needed to better understand the composition of dung and carrion scarabaeid beetle assemblages in plantations. In particular, studies at burnt natural forests are important since deterioration of natural forests in the zones between intact forests and plantations might have a direct impact on the species composition of the beetles in plantations.

The results of analyses between the beetle communities and the characteristics of plantations showed that the plantations adjacent to the Sungai Wain area retained higher species richness and a larger number of species in common with the intact natural forest than those that were not adjacent (Table 3). Distance from the Sungai Wain area and the size of plantations was positively correlated with the number of species in common with the intact natural forest, but was negatively related to the trunk basal area of plantations (Table 3). These results suggested that plantations adjacent to the Sungai Wain area maintained a larger number of beetle species that came from the intact natural forest through the burnt natural forests. It also seems that the age and density of trees in plantations were not correlated with the dung and carrion scarabaeid beetle communities, as both the mean DBH and trunk basal area did not influence, or negatively influenced, all indices of the beetle communities. Although Estrada et al. (1998) indicated that across forest fragments the species richness and the abundance of dung and carrion beetles were positively correlated with area and negatively correlated with isolating distance, neither area nor distance affected the beetle communities in the present study.

This might be due to the small variances of isolating distances and areas of fragmented plantations (Table 1). Fragmented plantations larger than 10 ha and isolated by more than 3 km need to be studied so as to evaluate both the size and location of a plantation.

Table 2. Comparison of dung beetle community between plantation and grassland

Site	Species richness (23) P	Species richness (23) G	Abun-dance (117) P	Abun-dance (117) G	Shannon-Wiener diversity index (H') (2.55) P	Shannon-Wiener diversity index (H') (2.55) G	J' evenness index (0.81) P	J' evenness index (0.81) G	Biomass (dry weight) (g)* (8.51) P	Biomass (dry weight) (g)* (8.51) G	No. species same with NF P	No. species same with NF G	Morisita's similarity index (Cλ) to NF P	Morisita's similarity index (Cλ) to NF G
18	8	8	37	89	1.90	1.65	0.91	0.79	2.75	0.35	3	1	0.125	0.001
22	5	8	39	224	1.45	1.33	0.90	0.64	11.61	1.43	3	0	0.334	0
23	7	7	56	91	1.28	1.57	0.66	0.81	1.24	1.11	3	0	0.072	0
24a	10	9	36	102	1.77	1.65	0.77	0.75	3.49	3.43	4	1	0.205	0.037
24b	12	8	329	208	1.75	1.40	0.71	0.67	19.98	4.09	5	1	0.053	0.019
P26	7	9	46	302	1.61	1.64	0.83	0.75	6.86	4.03	2	1	0.044	0.004
P29	8	7	53	23	1.71	1.42	0.82	0.73	5.46	1.06	4	2	0.552	0.069
Wilcoxon signed rank test	P = 0.892		P = 0.176		P = 0.203		P = 0.176		P = 0.018		P = 0.017		P = 0.018	

Parenthesized numbers in the head line indicate the data at the intact natural forest site (NF).

P: *Acacia mangium* plantation. G: *Imperata cylindrica* grassland.

*Calculated from mean dry weight of each species, which was dried for 7 days at 70°C and additionally for 1 day at 105°C.

Table 3. Results of relationships between characteristics of *Acacia mangium* plantations and dung beetle community.

	Applied test	Species richness	Abun-dance	Shannon-Wiener diversity index (H')	J' even-ness index	Bio-mass	No. species same with NF	Morisita's similarity index (Cλ) to NF
Adjacent to Sungai Wain area	Mann-Whitney's *U*-test	U = 0.50 P = 0.048	NS	NS	NS	NS	U = 0.00 P = 0.026	NS
Distance from Sungai Wain area	Kendall's rank correlation	NS	NS	NS	NS	NS	τ = -0.629 P = 0.047	NS
Area including background forest	Kendall's rank correlation	NS	NS	NS	NS	NS	τ = 0.857 P = 0.007	NS
Mean DBH	Kendall's rank correlation	NS	NS	NS	NS	NS	NS	NS
Trunk basal area	Kendall's rank correlation	NS	NS	NS	NS	NS	τ = -0.688 P = 0.030	NS

NS: P > 0.05.

Conclusion

The findings of this study suggest that afforestation increases the local native diversity of dung and carrion scarabaeid beetles compared to grasslands, and that CDM afforestation therefore helps to increase local biodiversity. Nonetheless, it may be difficult to restore rare forest species that have already declined in abundance due to the loss of natural forests by past logging and fire events as the basic community structure differs so dramatically between intact natural forests and plantations. Plantations adjacent to large intact natural forests may be better able to restore native species than isolated plantations to relatively natural community assemblages of beetles.

Acknowledgements

We thank Teruo Ochi who helped to identify the specimens; Woro A. Noerdjito and co-workers of LIPI; Sugiarto and Chandra Boer and co-workers of PPHT; Agustin, Agus and co-workers of SWFR; and the people in Sungai Wain Village, who helped us to perform the field work. We also thank Robert Johns who helped improve the manuscript.

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Parasitoid diversity in changing forest landscape after fires in East Kalimantan, Indonesia

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Introduction

Our goal is to clarify the ecological implications of the landscape design of A/R CDM plantations in degraded lowland areas after repeated forest fires in the Asian tropics. To study the recovery of forest arthropods after fires, and especially the effects of *Acacia* plantations, we used parasitic wasps (hymenopteran parasitoids) as a representative of overall arthropod communities (Maleque et al., 2009), because they depend on taxonomically and ecologically diverse groups of insects (e.g., Gauld and Bolton, 1988). A high diversity of parasitoids is generally accompanied with a high diversity of herbivores (Siemann, 1998). Moreover, recent studies indicate that parasitoids are more sensitive to environmental changes than other lower trophic insects (Kruess and Tscharntke, 1994; Hilszczański et al., 2005).

We have already reported that *Acacia* plantations on *Imperata*-dominated grasslands after repeated forest fires somewhat promote the recovery of endemic species of insect parasitoids in the lowlands of East Kalimantan (Maeto et al., 2009). We are also interested in the conditions of rather weakly burnt secondary forests regenerating after fires, because they should serve as a source of endemic species for neighboring plantations. It is essential for landscape design of CDM plantations to understand the effects of distance from unburnt natural forests and other landscape and local factors on the function of such secondary forests to supply endemic species to plantation forests. We investigated the spatial changes in the assemblage of parasitoid wasps of secondary forests, as an indicator group of the general diversity of forest arthropods (Hilszczański et al., 2005; Sääksjärvi et al., 2006), along the gradient from unburnt to severely burnt secondary forests in the Sungai Wain Forest Reserve, East Kalimantan. This is a tentative summary of collaborative studies with Dr. Woro A. Noerdjito (LIPI), and Messrs. T. Igarashi and M. Takahashi (FFPRI).

Study site and method

We placed a census line from unburnt to intensively burnt secondary forests in 1997/98, which crossed two unburnt or weakly burnt remnants (Fig. 1), in the eastern edge of the Sungai Wain Forest Reserve, East Kalimantan. We conducted sampling of braconid parasitoids (Gauld and Bolton, 1988; Yu et al., 2005) at intervals of about 100 m along the census line in December 2006 and 2007. Abundance, species density, and species composition of the parasitoid wasps were analyzed together with pre-existing data from unburnt core area, *Acacia* plantations, and *Imperata* grasslands. Their regression to the distance from a large unburnt stand was analyzed, with consideration of the local effects of unburnt small remnants.

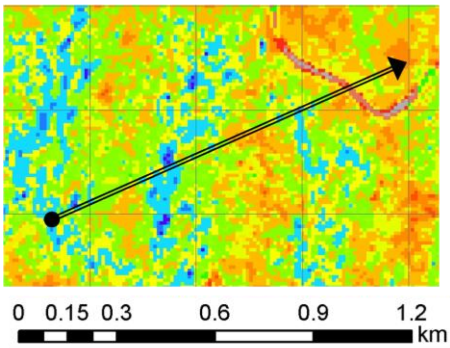

Fig. 1 SPOT image of research site in the Sungai Wain Forest Reserve.

A census line was drawn from unburnt to intensively burnt secondary forests, crossing two unburnt or weakly burnt remnants (courtesy of M. Takahashi).

Results and Discussion

Abundance and species density (number of morphospecies) of braconid parasitoids and their species composition (NMS ordination) in the regenerating burnt secondary forests varied widely between unburnt near-natural forests and *Acacia* plantations (Fig. 2). Abundance and species density of parasitoids decreased exponentially with the distance from a large unburnt stand both in 2006 and 2007 (Fig. 3). Also, they were highly affected and considerably increased as indicated by arrows (Fig. 3), by the presence of unburnt or weakly burnt small remnants remaining along the streams (Fig. 1).

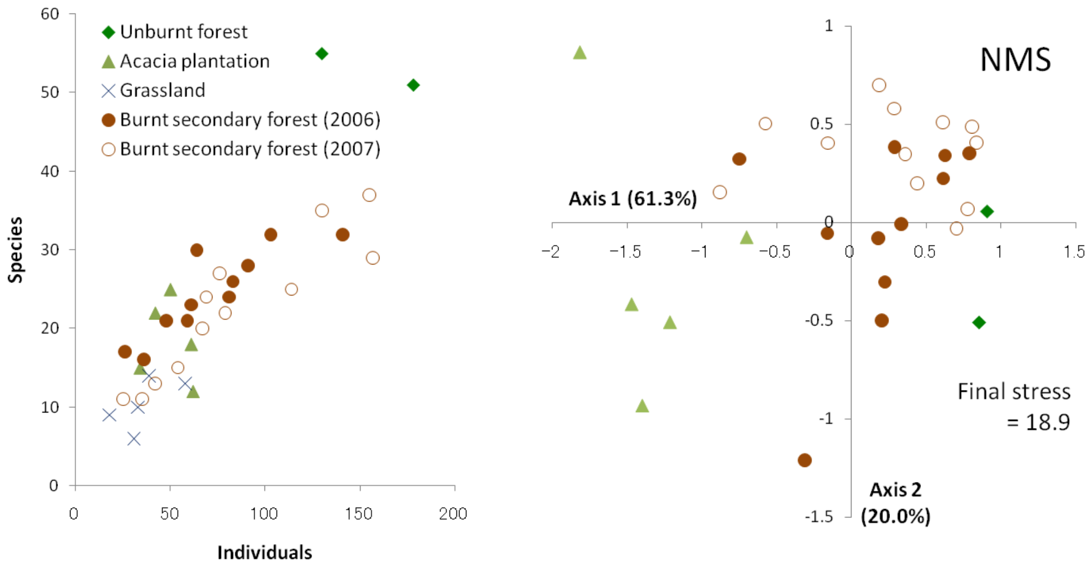

Fig. 2. Abundance and species density (left) and species composition (right) of braconid parasitoids in unburnt forests, burnt secondary forests, *Acacia* plantations, and *Imperata* grasslands.

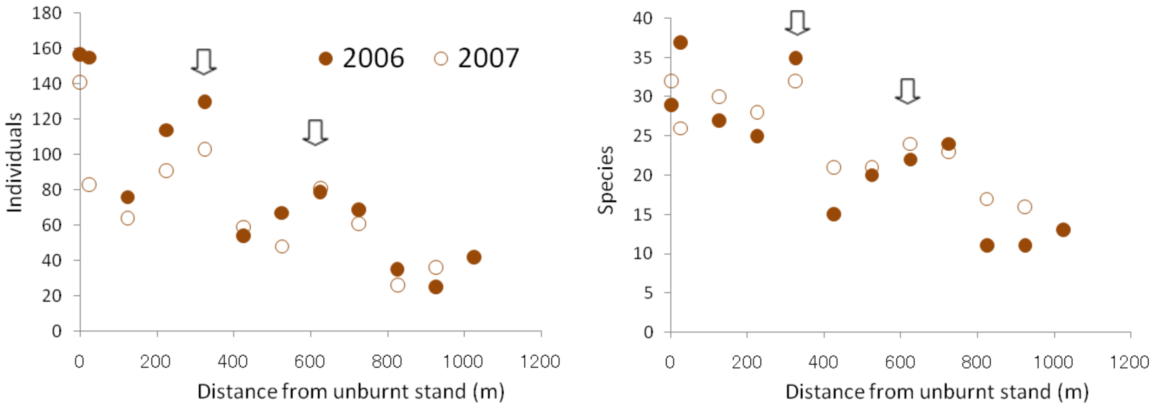

Fig. 3. Changes in abundance (left) and species density (right) of braconid parasitoids in secondary forests with distance from large unburnt stand, with local increase around unburnt or weakly burnt remnants shown by arrows (see Fig. 1).

Individuals: 2006, $y = 144.31e^{-0.001x}$, $r^2 = 0.741$; 2007, $y = 108.12e^{-0.001x}$, $r^2 = 0.604$. Species: 2006, $y = 33.421e^{-1E\text{-}03x}$, $r^2 = 0.672$; 2007, $y = 31.405e^{-6E\text{-}04x}$, $r^2 = 0.719$.

The effects of forest fires in 1997/98 on vegetation, arthropods, and thus parasitoid wasps in burnt secondary forests still remain markedly, with a sharp decrease of parasitoid wasps with distance from the large unburnt area. It should also be noted that the decline of parasitoid wasps is certainly moderated by the presence of unburnt forest remnants. Those secondary forests naturally regenerating after fires are expected to provide habitats for endemic species that will serve as the source for the recovery of biodiversity in neighboring plantation forests. It is also clear that the biodiversity of such previously burnt forests has been not only affected by the distance from large and continuous natural forests but also improved by the local presence of small unburnt remnants, which usually remain along streams. The location and size of such large and small unburnt forests can be investigated by satellite images (Fig. 1) when creating the landscape design of plantation areas in order to promote regional biodiversity in every A/R CDM plantation project.

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Evaluation of various forest conditions based on longhorn beetles (Coleoptera: Cerambycidae) as bio-indicators in East Kalimantan

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Abstract

There are many species of longhorn beetle (Coleoptera, Cerambycidae). They are one of the largest groups of woodborers and therefore typical forest-dependent insects. The species diversity of these beetles may vary with species composition and age of the trees, and stability of the forests, and thus they are a useful bio-indicator for assessing forest conditions.

We compared the assemblages of longhorn beetles among *Imperata* grassland, young and elder plantations of *Acacia mangium*, burnt secondary forest, and unburnt old secondary forest in the lowlands of East Kalimantan. Abundance of mature forest species was low in *Imperata* grassland, and somewhat increased in *Acacia mangium* plantations. The species composition of longhorn beetles in *Acacia mangium* plantations seemed intermediate stage between *Imperata* grassland and unburnt forest.

Introduction

The family Cerambycidae (Coleoptera) is one of the largest groups of wood-boring insects. Larvae of almost all species are woodborers, tunneling in the xylem of branches or stems of trees. Some of them prefer dead, decaying, and sometimes quite dry wood, but many others are injurious to living trees in natural forests, plantations, and orchards. Adult beetles feed on bark, leaves or flower pollen and/or nectar. Longhorn beetles are thus playing important roles in forest ecosystems. The diversity of longhorn beetles varies with age and species composition of trees.

About 35,000 species of longhorn beetles have been described, of which about 800 species have been reported from lowland forest in East Kalimantan (Makihara et al., 1999). Species have also been reported in many places in Java, including about 150 species from Gunung Halimun (highland forest, about 1000 m asl.) (Makihara et al., 2002); 38 species from Mt. Ciremai (highland forest 1100–1700 m. asl.) (Noerdjito, 2008); lowland (10 m. asl.); 15 species from the Banten forest plantation (W. Java) (not yet published); 13 species collected from the Bogor Botanical Garden (Noerdjito, 2008) and about 200 species distributed in other parts of Indonesia, with species being described and preserved in Museum Zoologicum Bogoriense (Makihara & Noerdjito, 2004).

Our former investigations in Bukit Suharto (Makihara et al., 1999), Sebulu Experimental Forest (Makihara et al., 2003), Bukit Bangkirai and Gunung Halimun National Park (Noerdjito et al., 2003), and Sekaroh, plantation forest in East Lombok (Noerdjito et al., 2005) indicated that longhorn beetles are useful as a bio-indicator, for their habitat preference and host specificity.

Some common species of longhorn beetles can be categorized as open habitat species that prefer to live in open areas and bore into small branches, while some others as interior forest species or mature forest species living only in primary or very mature secondary forest depending on specific host plants. These extreme groups are not found in secondary forests that are lightly disturbed.

We investigated assemblages of longhorn beetles in *Imperata* grasslands, *Acacia mangium* plantations, burnt secondary forests (hereafter burnt forest) and unburnt old secondary forests (unburnt forest) in East Kalimantan.

Materials and Methods

Study sites:

1. *Acacia mangium* plantations

9-year-old stands: 2 plots in a plantation (20 ha) at Das Manggar located 12 km north of Balikpapan.

7-year-old stands: 2 plots including one in a plantation (2 ha) which is located 23 km north of Balikpapan, and the other in a plantation (1.5 ha) at Das Manggar.

5-year-old stands: 2 plots in a plantation (800 ha) located 29 km north of Balikpapan.

2. Burnt forests: two plots at 29 km north of Balikpapan, and the other at 23 km north of Balikpapan.
3. Alang-Alang grasslands: one plot at 29 km north of Balikpapan, and the other 23 km north of Balikpapan.
4. Unburnt forest at Sungai Wain: nine plots, including three on hills, three on slopes and the other three in swamps in the Sungai Wain Forest Reserve, located 15 km north of Balikpapan.
5. Transect crossing burnt and unburnt forests: seven plots at an interval of 500 m along a transect crossing unburnt remnant and burnt forests, located between 24 km and 29 km points to the north from Balikpapan.

Field methods:

We conducted field sampling for about 3 weeks in December in 2006 for sites 1-4 and in 2007 for site 5.

The beetles were collected by "*Artocarpus* trap" as shown in Fig. 1. *Artocarpus* trap is a bait trap. It is a bundle of about 5 freshly-cut branches of *Artocarpus heterophyllus* (jackfruit), 80 cm long with many leaves, tied up and hung from a tree trunk or standing poles at 1.5 m above the ground (Fig. 1). The trap attracts longhorn beetles that need feeding for reproductive maturity. Three traps were set at each plot, and the attracted beetles were collected every 3rd days by beating method (Fig. 1), because the beetles are usually gathered by the 3rd day after setting of the trap.

Fig. 1. *Artocarpus* branch trap and beating method.

We followed categorization of indicator species by Makihara et al. (2004), in which East Kalimantan species of longhorn beetles are arranged along a spectrum of forest disturbance/maturation (Figs. 2 and 3). Nine species, *Acalolepta dispar, Acalolepta unicolor*, *Parepicedia fimbriata*, *Amechana nobilis*, *Gnoma longicollis*, *Gnoma vittaticolis*, *Metopides occipitallis*, *Ropica angusticollis* and *Ropica sparcepunctata* are indicators for mature forest, because they are found only in primary or very old secondary forests. Four species, *Epepeotes spinosus*, *Paraleprodera epiocedoides*, *Acalolepta fulvoscutellata* and *Nyctimenius ocraceovittata* are indicators for lightly disturbed forest found in lightly burnt and unburnt forests, whereas *Ropica marmorata, Xenolea tomentosa, Sciades quadriplagiatus* and *Rondibilis spinosula*, are indicators for degraded forest. In the present paper, we combined these two groups as indicator species for less disturbed forest. Four species, *Pterolophia melanura*, *Pterolophia anulitarsis*, *Epepeotes luscus* and *Acalolepta rusticatrix*, are common in all habitat types and thought to be habitat generalists.

Results and discussion

In total, we collected 54 species and 2392 individuals of Cerambycid beetles by Artocarpus traps in about 3 weeks in December 2006 from *Acacia mangium* plantations, secondary forests, grasslands, and natural and degraded forests (Table 1).

Species richness and abundance of Cerambycid beetles collected by the *Artocarpus* trap in the *Acacia mangium* plantations, secondary forests, *Imperata* grasslands and burnt and unburnt forests in and around the Sungai Wain Forest Reserve are indicated in Table 1. Based on these data, we compared composition of species and abundance of the beetles as indicators of degradation of the forests (Table 2). Ten species (*Acalolepta cariosa*, *Acalolepta dispar*, *Acalolepta unicolor*, *Cacia* (*Ipocregyes*) *newmani*, *Epepeotes spinosus*, *Gnoma longicollis*, *Nyctimenius ochraceovittata (Aurivillius)*, *Ropica angusticollis*, *Ropica sparsepunctata and Trachelophora maculosa*) may be indicators of mature forest, and five species, *Atimura bacillima*, *Rondibilis spinosula*, *Ropica marmorata*, and *Ropica piperata Xenolea tomentosa* may be indicators of degraded forest.

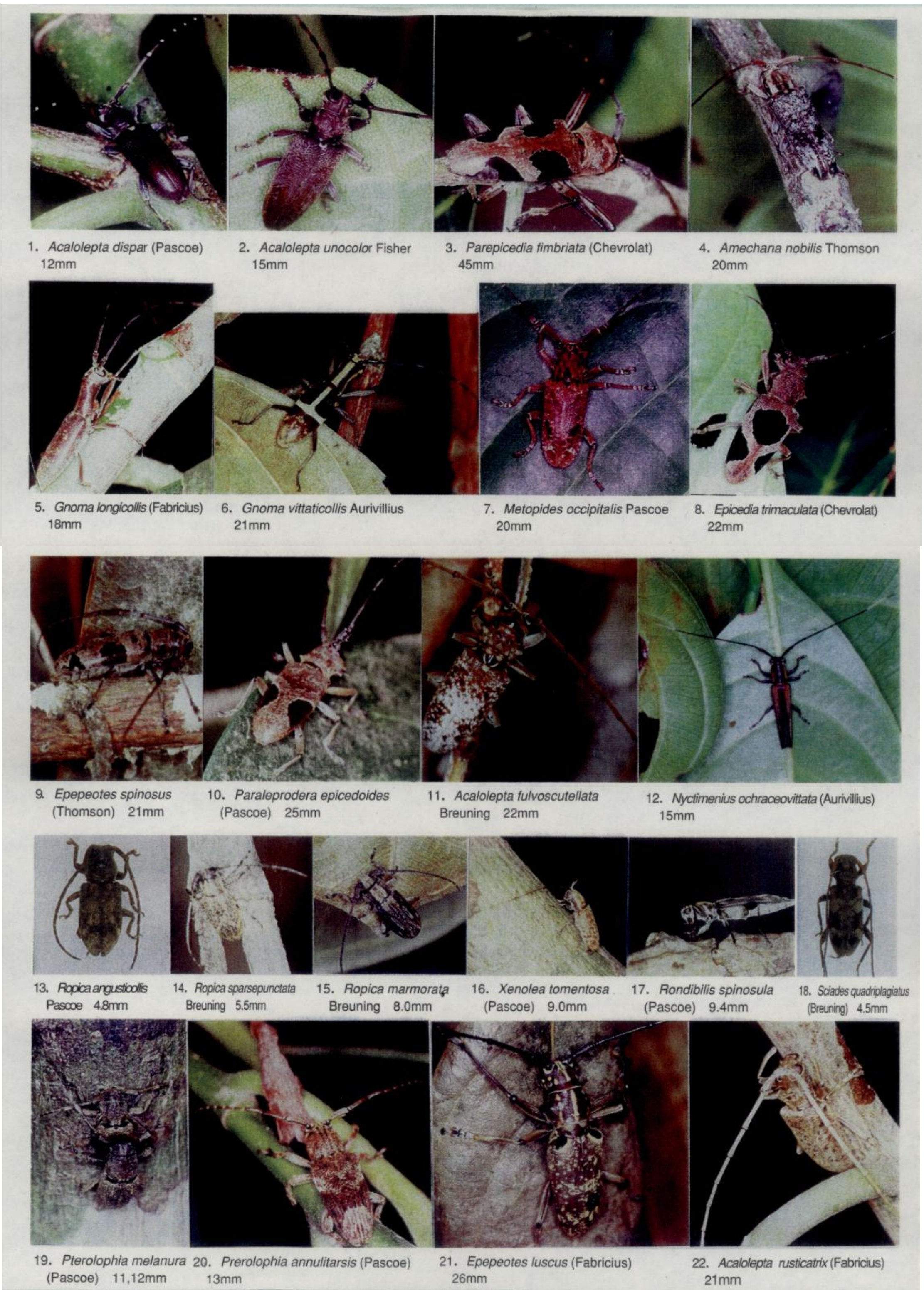

Fig. 2. Cerambycid species as bio-indicators for forests of various conditions, in East Kalimantan (Makihara et al., 2004). No. 1-7: For natural forest; No. 8: Rare species; No. 9-12: For lightly disturbed forest; 13-14: For natural forest; 15, 16: For disturbed forest; 17: For degraded forest; 19-22: Common species

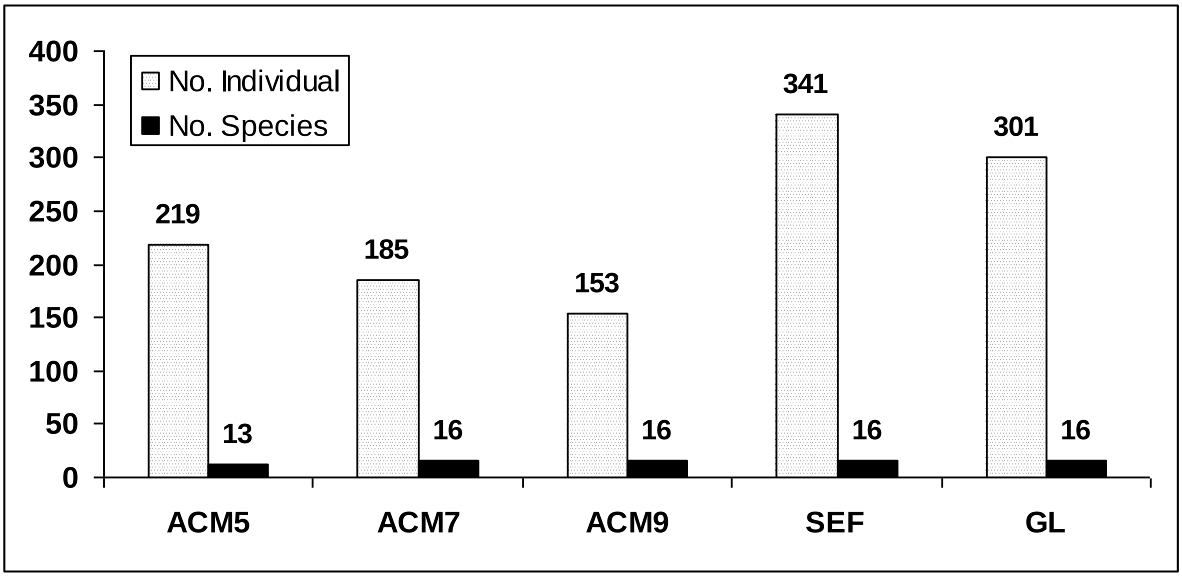

Fig. 3. Species and individuals number of cerambycid beetles collected by *Artocarpus* trap in *Acacia mangium* plantations (5, 7 and 9 years old), burnt secondary forests (SEF) and grasslands (GL) at 29 km from Balikpapan, East Kalimantan.

Figure 3 compares number of species and number of individuals of cerambycid beetles collected by *Artocarpus* trap in *Acacia mangium* plantations, burnt secondary forests and grasslands at 29 km from Balikpapan. The number of species collected from the 7- and 9-year-old *Acacia mangium* plantations, secondary forests and grasslands were the same, but collected species were different (Table 1). Based on the cerambycid species composition in the 7- and 9-year-old *Acacia* plantations, the cerambycid assemblages of the plantation may include both species common in grasslands and those of native forests to some degree.

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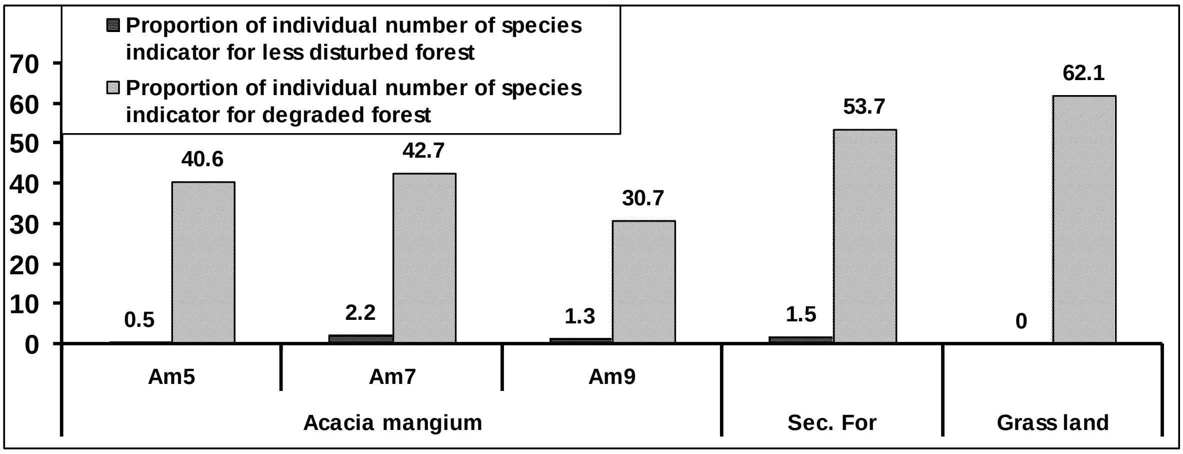

Fig. 4. Proportion of individuals (%) of indicator species for less disturbed forests (those mature forest and lightly disturbed forest combined) and degraded forests in *Acacia mangium* plantation, burnt secondary forest and grassland at km 29, Balikpapan, East Kalimantan.

The species composition and individual numbers of cerambycid beetles along the transect crossing burnt and unburnt forests are shown in Fig. 5. A generalist, *Pterolophia annulitarsis*, and an indicator of degraded forest, *Xenolea tomentosa* were very abundant at the 1000 m and 1500 m sampling plots (Table 1 and Fig. 5). The surroundings of 1000 m to 1500 m plots were a burnt area with young pioneer trees and many fallen logs. The numbers of species at these plots were fewer than at 500 m (Fig. 5).

The proportion of indicator species for less disturbed forest (those mature forest and lightly disturbed forest combined) declined near the forest edge (Pos II) and toward the other end of the transect, disappearing at 2000m and 3000 m plots, and only one individual of *Ropica sparsepunctata* (indicator of less disturbed forest) was found at 2500 m (Fig. 6).

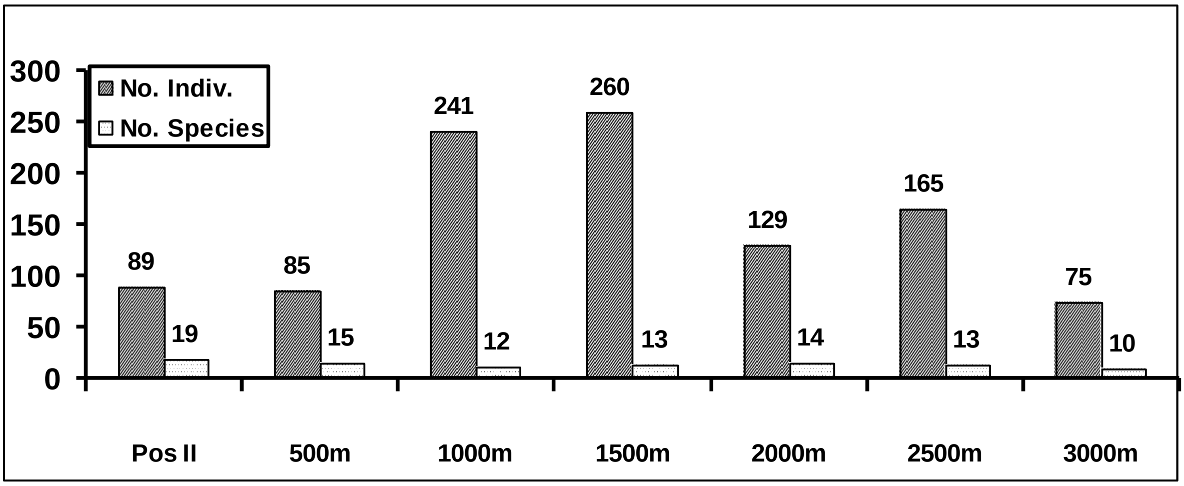

Fig. 5. Number of species and number of individuals of cerambycid beetles collected along a transect crossing burnt and unburnt forests between Km 24–29, Balikpapan, East Kalimantan.

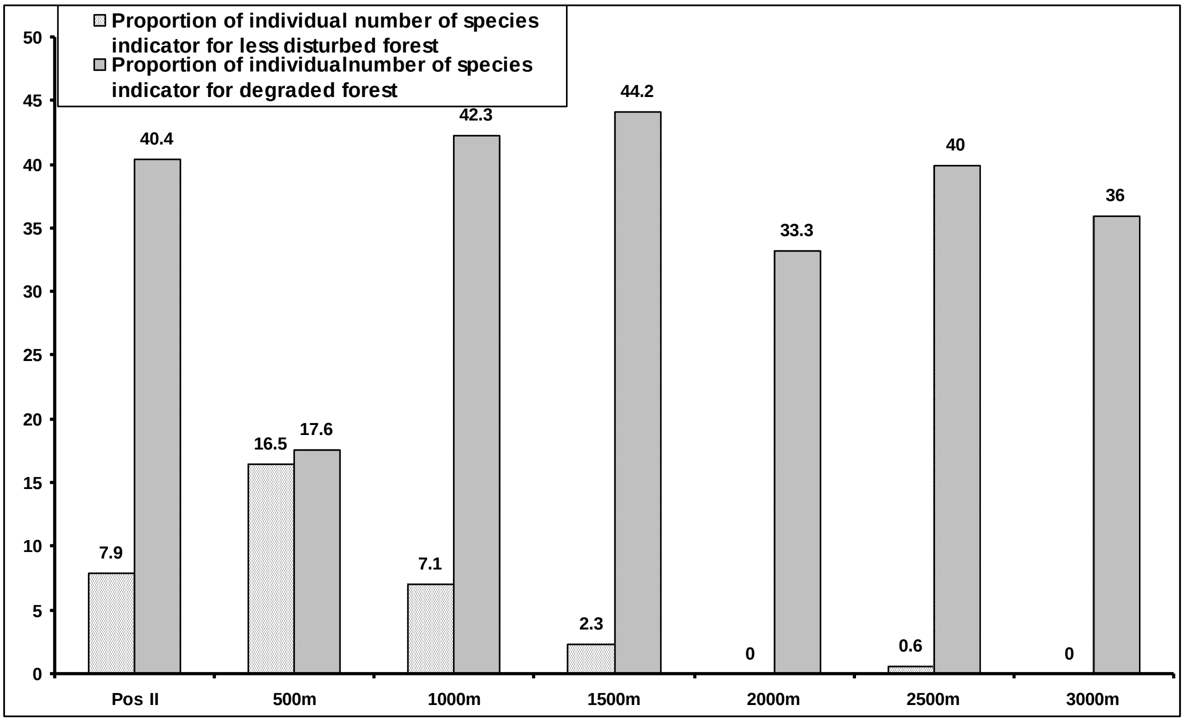

Fig. 6. Proportion (%) of individuals of species indicators for less disturbed forest and those for degraded forests along the transect between Km 24–29, Balikpapan, East Kalimantan.

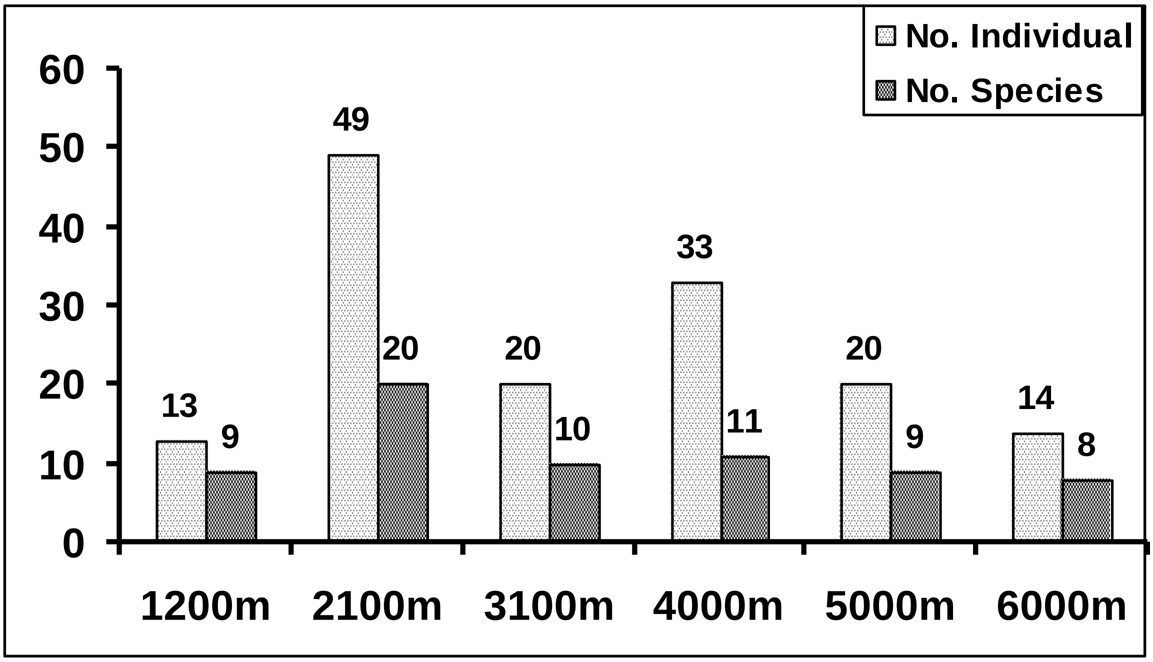

Fig. 7. Number of species and number of individuals of Cerambycid beetles collected in Sungai Wain Forest Reserve, Balikpapan, East Kalimantan.

Figure 7 shows number of species and number of individuals of Cerambycid beetles collected in Sungai Wain Forest Reserve. The conditions around the 2100 m plot seemed to be suitable for many longhorn beetles, as indicated by the highest species richness and abundance. Large forest species that prefer deep inside of the forest, such as *Gnoma longicolis*, *Epepeotes spinosus, Acalolepta dispar* and *Acalolepta unicolor,* were collected at this plot (Table 1).

Proportion of individuals of indicator species for less disturbed forest was highest at the 1200 m plot and decreased toward the 3100 m plot. In contrast, the proportion of individuals of indicator species for degraded forest increased toward the 3100 m plot, indicating disturbed conditions around the 3100 m plot. Based on the diversity of longhorn beetles collected by *Artocarpus* traps, the best site of the Sungai Wain Natural Forest is 5000–6000 distant from the entrance near the water reservoir.

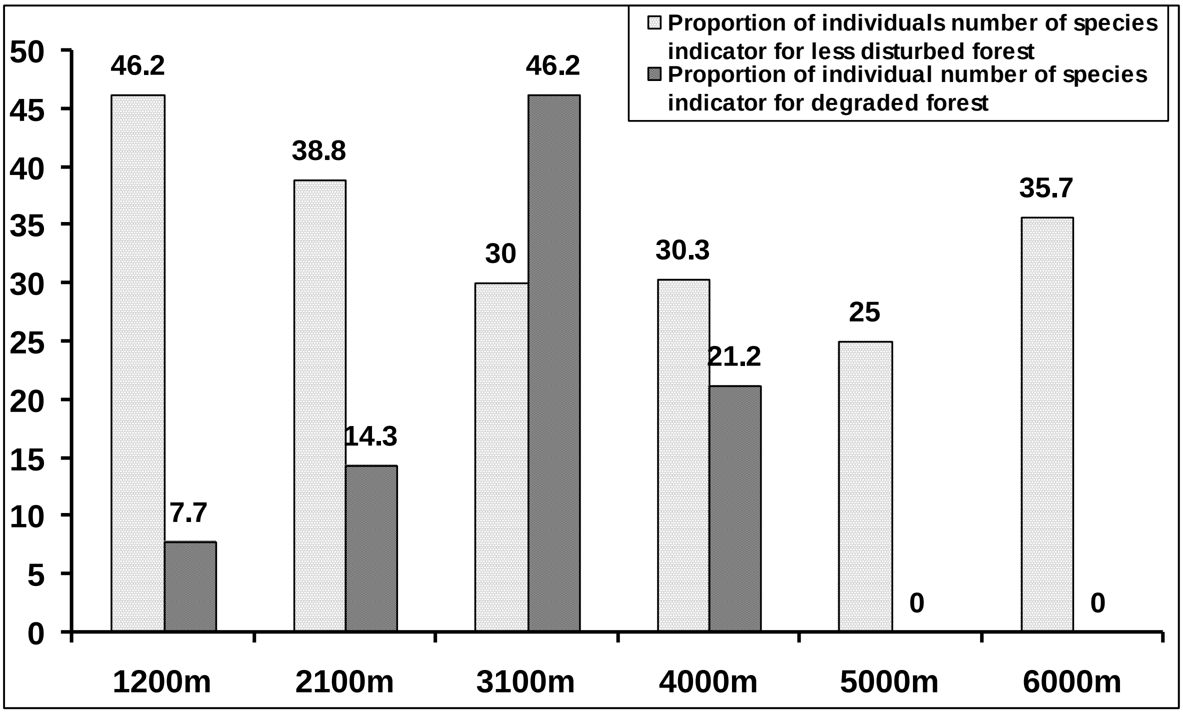

Fig. 8. Proportion (%) of individuals number of species for less disturbed (good) and degraded forest in Sungai Wain Natural Forest, Balikpapan East Kalimantan.

Conclusion

A total of 54 species and 2392 individuals of longhorn beetles were collected by *Artocarpus* trap for about 3 weeks in December 2006. Ten species (*Acalolepta cariosa*, *Acalolepta dispar*, *Acalolepta unicolor*, *Cacia* (*Ipocregyes*) *newmani*, *Epepeotes spinosus*, *Gnoma longicollis*, *Nyctimenius ochraceovittata (Aurivillius)*, *Ropica angusticollis*, *Ropica sparsepunctata and Trachelophora maculosa*) were considered to be indicators for less disturbed forest, and five species, *Atimura bacillima*, *Rondibilis spinosula*, *Ropica marmorata*, *Ropica piperata* and *Xenolea tomentosa*, indicators for degraded forest.

The indicator species for less disturbed forest, which were in *Imperata* grassland, but they were somewhat abundant in *Acacia mangium* plantations. The species composition of the beetles in *Acacia mangium* plantations seemed to be intermediate between *Imperata* grassland and old secondary forest. In other words, the long horn beetle fauna was recovering in the plantation to some degree. Plantations on grassland may serve to increase the diversity of longhorn beetles, and it is better than leaving the grassland as it is.

The assemblage of longhorn beetles in the Sungai Wain Forest Reserve, was rich with indicator species for less disturbed forest, and their proportion was the highest at 5000–6000 m plots, indicating that the natural forest conditions around these plots were best conserved.

Acknowledgements

We thank the officers of the Sungai Wain Forest Reserve and Bukit Bangkirai Forest Reserve for their support during our research. Special thanks are due to Mr. Yan for his assistance with finding *Artocarpus* branches and setting the traps and also to Ms Yan for providing delicious food during our stay in Sungai Wain.

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Evaluation of the status of avian diversity in three typical habitats: grassland, *Acacia mangium* plantation and secondary forest in East Kalimantan

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Abstract

In order to evaluate the role of CDM plantations in the conservation of biodiversity, we studied the status of avian diversity in three different habitats: grassland, *Acacia mangium* plantation and secondary forest. The study was conducted by the mark and capture method. Avian diversity was assessed by species composition and diversity indices. The results showed that avian diversity was the poorest in grasslands, medium in plantations and richest in secondary forests depending on the complexity of forest structure. However, plantations alone cannot maintain local avian diversity. Plantation areas could be corridors for birds among fragmented habitats.

Key words: avian diversity, mark and recapture, plantation, secondary forest

Introduction

It has not been confirmed yet whether plantations as part of the CDM project can assist the conservation and restoration of species diversity, which may be highly dependent on the plantation design at the landscape level. For example, it may be possible to establish ecological corridors that connect remaining forests as stepping stones. Such corridors would facilitate the migration of seed dispersal birds and accelerate the succession of secondary forests, in which case CDM plantations would play an important role in the conservation of biodiversity.

Kalimantan Island used to be mainly forested and was home to approximately 523 bird species (Sukmantoro et al., 2007), with endemic birds accounting for about 10% of this number. The forested area has, however, decreased in recent decades, because of excessive deforestation (MacKinnon et al., 1993; Lambert & Collar, 2002) and fire (van Balen & Slik, 2004). This situation may be affecting biodiversity, and the avifauna of the island may have been damaged in terms of the number of individuals and species. Monoculture plantations of *Acacia mangium* have recently been established in various parts of Indonesia including Kalimantan, and there is a possibility that such new habitats may help to maintain the avifauna. On the other hand, secondary forests exist around plantation areas and settlement areas, and these habitats might also play an important role in maintaining avian diversity at the regional level.

In order to assess avian diversity, the composition and diversity of avian species were estimated for several types of habitat in the lowlands, namely, grasslands, plantations and secondary forests. Based on the results, the relationship between avian diversity and environmental factors were generalized and suitable methods for maintaining diversity at the regional level are suggested.

Methods

Study sites:

Our fieldworks were conducted at the grasslands, immature and mature plantations of *Acacia mangium*, small, medium and large-size burnt secondary forests, and lightly-burnt secondary forests between 2004 and 2009. These study sites were near the Sungai Wain Forest Reserve in Balikpapan (01°03′01.2″–01°10′00.1″ S and 116°53′21.2″–116°55′27.2″ E), aside from large-size burnt secondary forests in the Bukit Soeharto Education Forest of Mulawarman University (01°51′12.2″–01°51′15.0″ S and 117°01′34.8″–117°01′35.9″ E).

Estimation of avian diversity:

In order to assess the species composition, birds were captured by mist nets at the above-mentioned habitats and marked with numbered bird rings. Four study sites were selected in each habitat, and a series of five mist nets was set in each site. The mist net surveys were conducted from 7:00 AM to 17:00 PM. The surveys were conducted at the same sites both in May–July and November–January. The diversity index and recapture rate for the two seasons were calculated for each habitat. Tree heights and vegetation cover rates for each layer were recorded for each study site in order to estimate the relationship between avian diversity and forest structure.

Results and Discussion

Avian diversity was the poorest in grasslands, medium in the plantations and richest in the secondary forests according to the complexity of forest structure. In May–July, the number of captured bird species was 7, 8, 11, 19, 21, 21 and 18 species at the grasslands, immature and mature plantations, small, medium, large-size, and lightly-burnt secondary forests, respectively. The diversity indices were similar among the four kinds: small, medium and large-size burnt secondary forests, and lightly-burnt secondary forests, but the species compositions were very different among them. The dominant species in the secondary forests was Little Spiderhunter (*Arachnothera longirostra*). However, Yellow-vented Bulbul (*Pycnonotus goiavier*) was dominant in the grasslands and plantations. It was not captured so frequently in the secondary forests and was never caught in the large-size and lightly-burnt secondary forests. On the other hand, other bulbul species were caught only at large and lightly-burnt secondary forests. Bulbuls are considered to be a good indicator of avian diversity.

The recapture rate was more than 10% at the medium and large-size burnt and lightly-burnt secondary forests, but was less than 5% at small secondary forests, which was similar to that at plantations and grasslands. In the medium and large-size burnt and lightly-burnt secondary forests, there may have been more resident individuals because of the abundance of food. This suggests that small secondary forests and plantations alone cannot be the source of diversity, though they were more effective than grasslands. Such habitats can help maintain diversity in combination with larger secondary forests.

Conclusion

The results of this study suggest that plantations alone cannot increase local avian diversity. Although small secondary forests can maintain higher avian diversity, they cannot be the source population because of their small capacity. In order to maintain avian diversity at the regional level, larger secondary forests are required to maintain various species of resident birds. Small secondary forests, however, can act as stepping stones for bird species if they are located in degraded areas. Plantation areas might serve as corridors for birds among fragmented habitats. Although the ideal situation would be to maintain large natural forests with complex structures, this is not realistic. A realistic countermeasure is to establish secondary forests of various sizes among plantations and grasslands. The optimal distribution of secondary forests should be examined in a future study.

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A mammalian faunal survey in different forest types in East Kalimantan, Indonesia

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Key words: Borneo, family composition, human disturbances, lowland rainforest

Introduction

To determine the effects of human activities on wildlife, a mammalian faunal survey with camera traps was carried out in some remnants of lowland tropical rainforest and other forest habitats in East Kalimantan, Indonesia. There are approximately 221 mammal species in Borneo Island (Payne et al., 2005), of which 93 species are Chiroptera and therefore the remaining 128 species are non-volant species. Yasuma (1994) reported 133 species of mammals from East Kalimantan, including Chiroptera 44 spp., Rodentia 36 spp., Carnivora 20 spp., Primates 11 spp., Scandentia 7 spp., Artiodactyla 7 spp., and others 8 spp. As we concentrated on non-volant species of lowland habitats in East Kalimantan, this study focused on 89 species. In this report, we compare the family composition of mammals among different forest habitats based on the results of camera trapping, and discuss the effects of human activities on the distribution of predator and prey species.

Methods

Study sites:

We chose two lowland forests as research areas: Sungai Wain Forest Reserve (SW; 1°8’S, 116°50’E) and Bukit Soeharto Research and Education Forest (BS; 0°51’S, 117°01’E), which are separated by a distance of about 40 km. Up to the mid 20th century these two isolated forests belonged to a vast undisturbed tropical rainforest, and therefore the dissimilarity of mammalian fauna between them was expected to be the result of human disturbances in the last 50 years. One forest type was chosen in SW; SW-1: an old tropical rainforest habitat, which has never been burnt by forest fires, located in the core area of the forest reserve. Four forest types were chosen in BS; BS-1: a regenerating tropical rainforest habitat which was lightly burnt twice in 1982/83 and in 1997/98 during severe drought periods; BS-2: a regenerating forest habitat mostly dominated by pioneer trees of *Macaranga* spp., which was severely burnt in 1982/83 and in 1997/98; BS-3: a young plantation of *Acacia mangium* planted after a forest fire in 1997/98; and BS-4: an open habitat with only grasses and small trees (< 1 m height). The forest fire of 1997/98 and its effects on the forest ecosystem in East Kalimantan were described in detail by Guhardja et al. (2000).

Camera trap:

A camera trap study was conducted sequentially in the five forest types from March 2005 to May 2007. We employed a camera trap with an infrared motion sensor (SensorCamera Fieldnote I, Marif Co. Ltd., Iwakuni, Japan), which is able to detect and photograph mammals of various sizes from small to large (Yasuda, 2004). A 2-km camera-trap line was established in SW-1, and ten camera traps were set at intervals of 200 m. Two 1-km camera-trap lines were established in BS-1, a 1-km camera-trap line was established in BS-2 and BS-3, and five camera traps were set in each camera-trap line at the same spatial design. Two camera traps were set in BS-4, because of the limited area. Sliced bananas and raw shrimps were placed on the forest floor as bait. Each camera trap was fixed on a tree stem at the height of 1.0–1.2 m with an angle of depression. As the length of a camera trap session varied from five days to eight days in a month, the photo data of the first five days were used for the analysis. The camera trap study in one forest type was terminated when the species accumulation curve became saturated. As some small mammal species (Rodentia and Scandentia) are difficult to identify from images taken by camera traps, we described them at the genus or higher levels.

Results and Discussion

Species richness:

The number of mammal species recorded by camera traps varied among forest types, in the order of SW-1 > BS-1 > BS-2 > BS-3 > BS-4. The family composition between SW-1 and BS-1 was more similar than those of the other combinations of habitat (Fig. 1). Species richness of civets and ungulates were high in both study areas. Sambar (*Rusa unicolor*), bearded pig (*Sus barbatus*), and Malayan sun bear (*Helarctos malayanus*) were the largest mammals recorded in the survey and were present in both study areas. There was no evidence of the existence of the Sumatran rhinoceros (*Dicerorhinus sumatrensis*) and banteng (*Bos javanicus*) in this study.

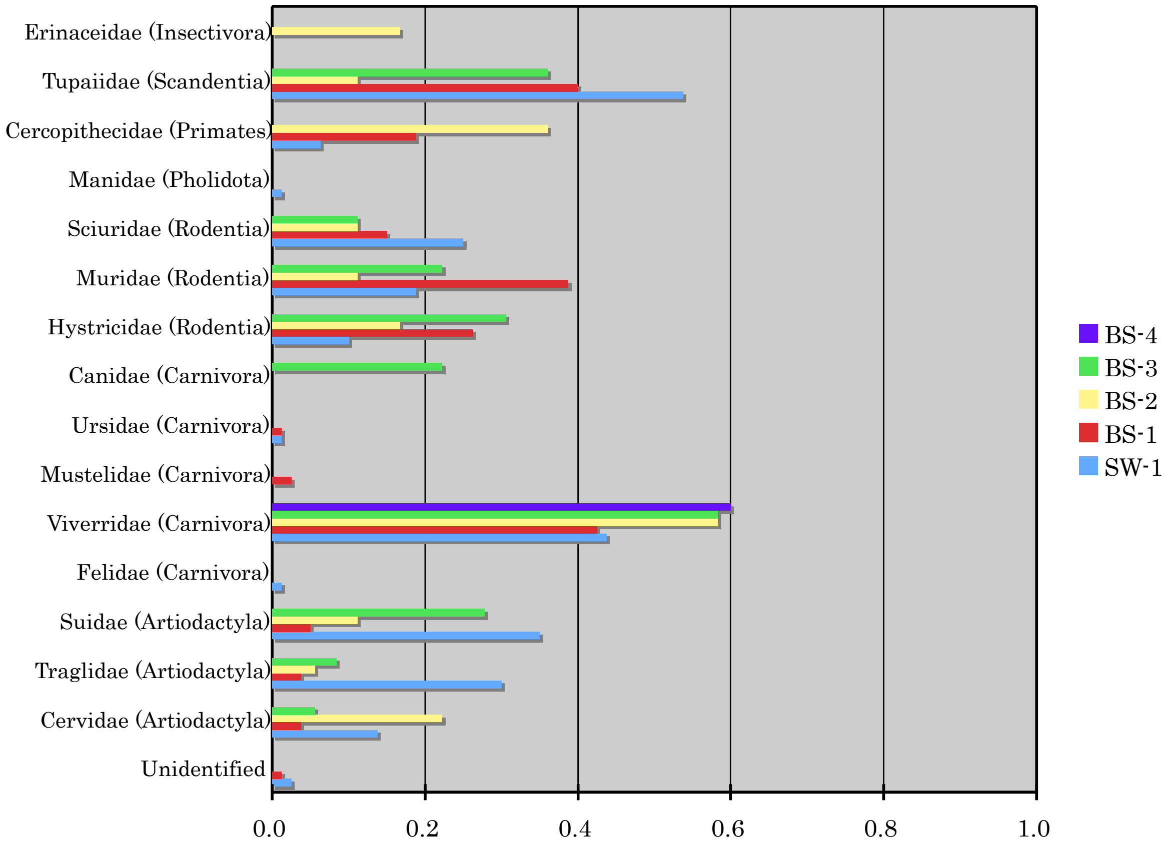

Fig. 1 Family composition of mammals recorded by camera traps on the forest floor. Frequency per study effort (unit: camera-session) on average at the family level is shown.

Predators:

There are five species of felid in Borneo Island: *Neofelis diardi*, *Pardofelis marmorata*, *Pardofelis badia*, *Prionailurus planiceps*, and *Prionailurus bengalensis*. The first four species are listed as EN or VU in the IUCN Red List (IUCN, 2009), and all five species are subject to international trade restrictions under the CITES appendices. In this survey, including the whole photo data, we obtained some photographs of *Pardofelis badia* from SW-1 and *Prionailurus bengalensis* from BS-3 (Yasuda et al., 2007). *Pardofelis badia* is one of the world's least known felids endemic to Borneo. This cat is historically only known from a few widely scattered locations except the province of South Kalimantan and southern East Kalimantan (Corbet & Hill, 1992; Meijaard, 1997). Our finding that *Pardofelis badia* inhabits the Sungai Wain Forest Reserve is thought to be the first record of this species in southern East Kalimantan. Even if widely distributed, the low population densities of *Pardofelis badia* and the ongoing fragmentation of its range imply that the species' survival is seriously threatened. On the other hand, *Prionailurus bengalensis* is known to inhabit plantations and gardens as well as forests (Payne et al., 2005). The *Prionailurus bengalensis* photographed in BS-3 suggests that the cat utilizes *Acacia mangium* plantations to some extent, though species richness and abundance of small mammals appeared to be less in the habitat.

Prey:

Most of the prey species from small to large were recorded both in SW and in BS, except two species of terrestrial rodents (*Lariscus insignis* and *Trichys fasciculata*). These two species were common in small mammal communities in unburnt forests (SW-1; see also Yasuda et al., 2003), while absent from regenerating forests and *Acacia mangium* plantations after forest fires (BS-1, BS-2, BS-3, and BS-4). The Bukit Soeharto forest has suffered large-scale forest fires twice, once in 1982/83 and again in 1997/98. Between the two forest fires, Yasuma and Alikodra (1992) carried out an intensive survey of mammals in the forest and reported 66 species from 22 families of 9 orders, including *Lariscus insignis* and *Trichys fasciculata*. These imply that the two terrestrial rodents were eliminated by the second forest fire, probably because they are more fragile to forest fires than other mammal species.

Conclusion

Our findings imply that afforestation increases the local diversity of mammals compared to grassland, and that CDM afforestation helps to increase mammalian biodiversity. A naturally regenerating forest dominated by pioneer trees showed higher species richness of mammals than an *Acacia mangium* plantation, suggesting that CDM afforestation should employ domestic tree species. To decrease the effects of habitat loss on mammalian predators and prey caused by human disturbances including forest fires and land-use change, connecting natural forest remnants by green corridors should be considered when planning CDM afforestation projects.

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Disturbance and recovery of forest patch

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Key words: disturbance, forest recovery, land cover change, fragmentation, Leaf Area Index, hemispherical view

Introduction

Factors that contribute to wildlife extinction are forest habitat conversion and fragmentation (Pattanavibool & Dearden, 2002; Christiansen & Pitter, 1997; Kattan, Lopes and Giraldo, 1994). Both factors involve disturbances such forest fire, agricultural expansion, forest plantation, settlement development and infrastructure development. The recovery of a fragmented forest or forest patch depends on the magnitude and frequency of disturbance: large, frequent disturbances will have a bigger impact on recovery than small, infrequent disturbances. This study aimed to clarify the disturbance and recovery process by using Landsat satellite data coupled with field data and high resolution (QuickBird & Ikonos) data.

Methods

Study area

The study area is situated at the Sungai Wain Forest Reserve and Bukit Bangkirai and the surrounding areas (Fig. 1).

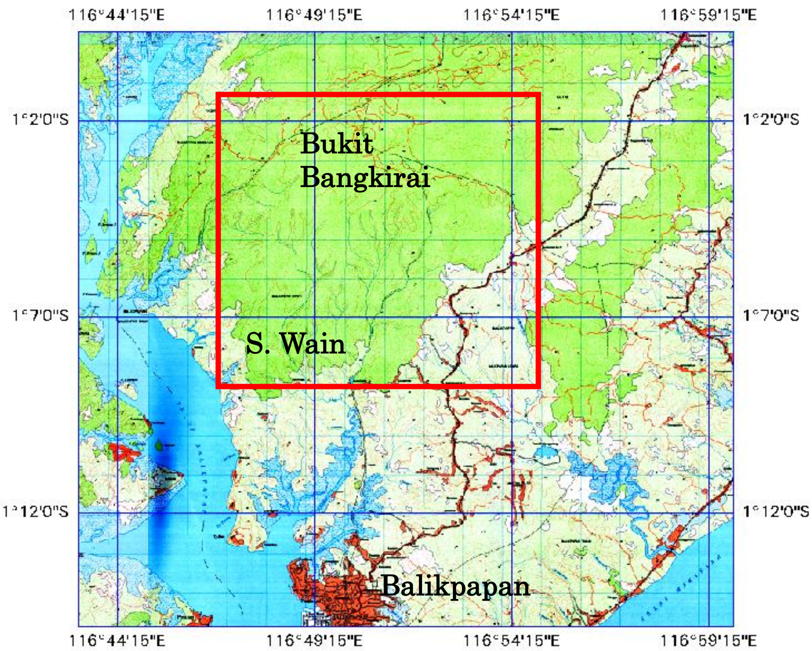

Fig. 1. Study area.

Materials

The data utilized were aerial photos taken in November 1981, and Landsat data acquired on 11

February 1992, 26 January 1998, 11 February 1998, 11 December 1998, 13 January 2002, and 8 March 2007.

Flow of research

The disturbance and recovery process during the research period (1981–2007) was analyzed based on classification of aerial photos and Landsat satellite images. As a reference, QuickBird & Ikonos images were used as well as ground truth data. The next step was to perform supervised classification, and spatial analysis to produce a disturbance and recovery map of the area. Further analysis on the vegetation diversity of the surrounding patch with regard to LAI was performed (Fig. 2). The transect line of vegetation inventory is presented in Fig. 3.

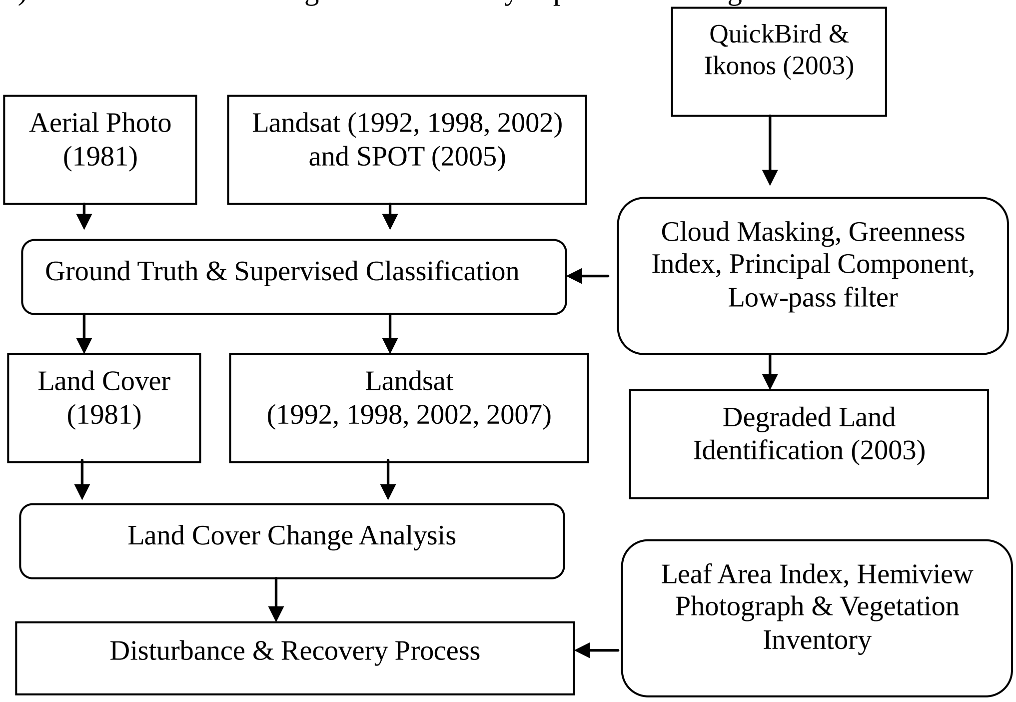

Fig. 2. Flow chart of study.

Fig. 3. Vegetation inventory.

The inventory was intended to collect information on the number of species along the transect and hemispherical view. The transect line was situated across remnant forest and recovery forest (Fig. 3).

Results and Discussion

a. Deforestation

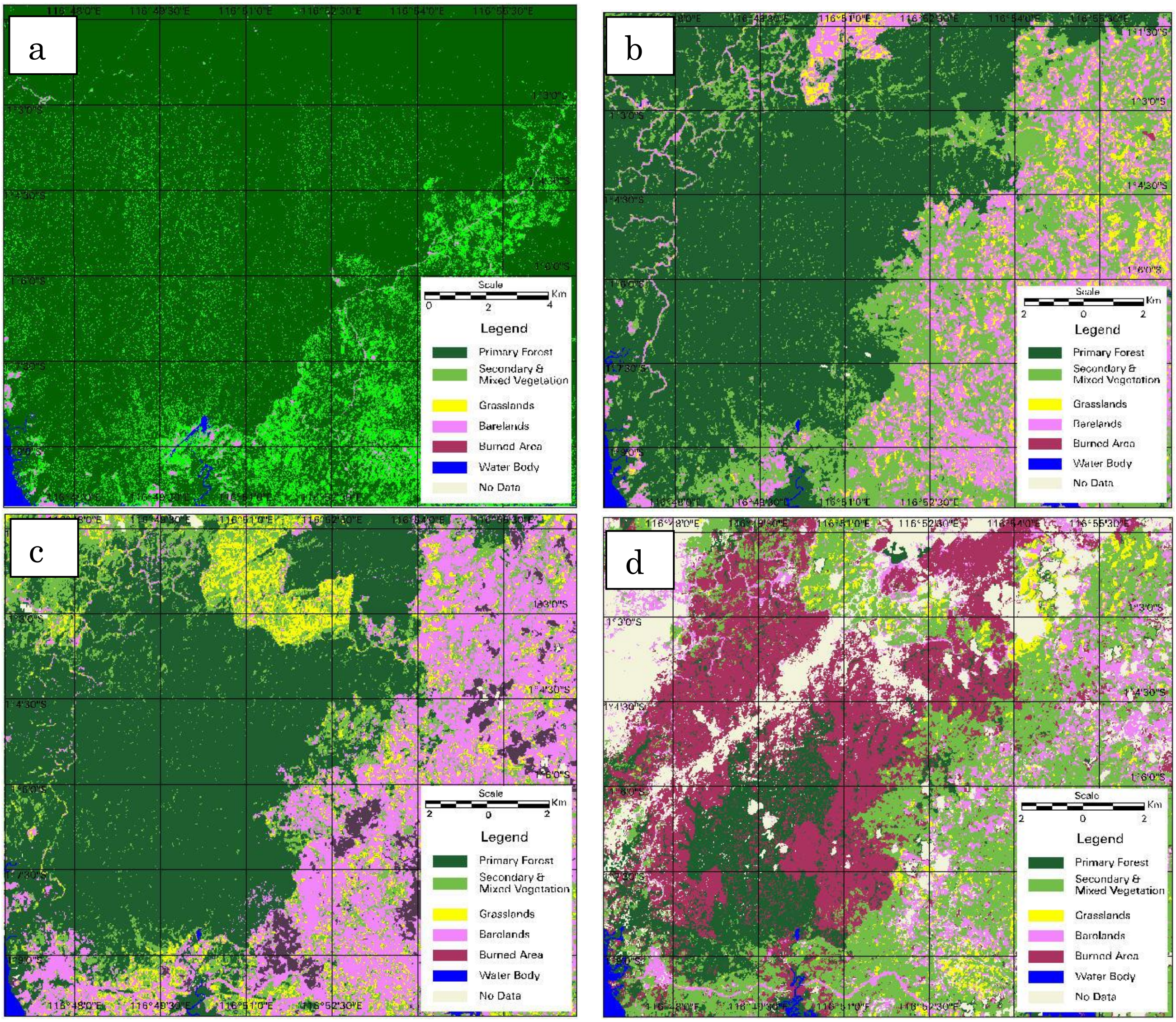

Fig. 4. Land cover in (a) 1981, (b) 1992, (c) February 1992, and (d) December 1998.

In 1981 most of the area was dominated by primary forest, but was fragmented by plantation forests and agricultural expansion. In December 1998 during the El Niño period, huge fires struck and devastated most of the remnant forest. As a result, primary forests were reduced and fragmented (Fig. 4). In comparison with SPOT data in 2005, the process of recovery appears to be very slow; this is probably due to: (a) no seeds left in the soil after the forest fire, or (b) no agent to disperse the seeds (Fig. 5).

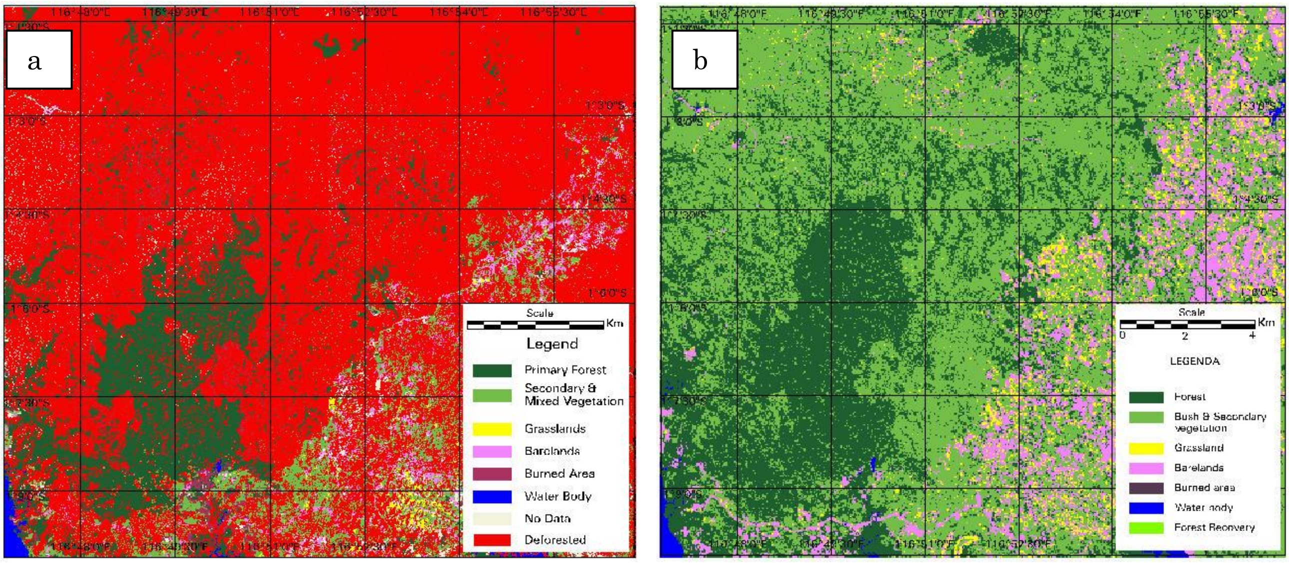

Fig. 5. (a) Deforested area from 1981 to 1998, (b) Recovery area from 1998 to 2005.

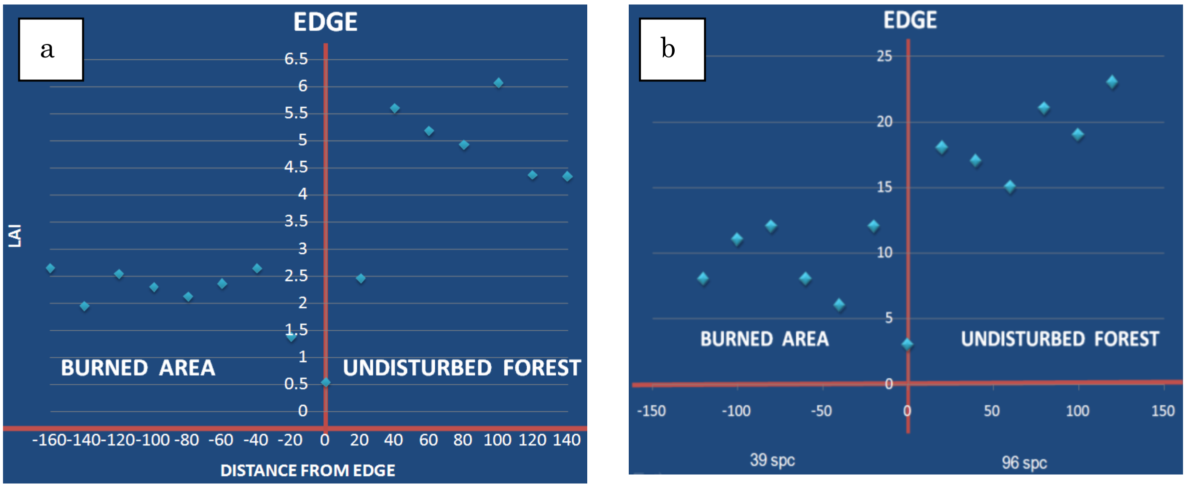

Fig. 6. (a) LAI derived from hemispherical view, (b) Species diversity.

Field data inventory analysis of the burnt forest patch area in 2008 showed that LAI derived from hemispherical view photographs (Fig. 6a) and species diversity were lower than those of the remnant forest (undisturbed forest) (Fig. 6b). This result suggests that enrichment planting is urgently needed to speed up the recovery of the burnt areas.

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