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Impacts of Forest Fires on Tree Diversity in Tropical Rain Forest of East Kalimantan, Indonesia

By

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Key words: Forest fires, Kalimantan-Indonesia, mixed dipterocarp forest, structure and composition.

Summary

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Impacts of forest fires on the tree diversity of mixed dipterocarp forests have been studied in East Kalimantan, Indonesia. Some plots were established in Bukit Bangkirai, East Kalimantan areas in 2001. Those were a 1 ha (later 1.12 ha) plot at the natural (unburnt) forest, a 0.3 ha (later 1.01ha) plot at lightly damaged forest and a 1 ha plot at heavily damaged forest, due to the forest fires occurred in 1997-1998.

In the natural forest of Bukit Bangkirai, number of individuals, total basal areas and species number of trees of more than 10 cm in *dbh* in a 1 ha-basis were 445 trees, 25.34 m^2 and 140 species, while those in the lightly damaged forest due to forest fire in 1997-1998 were 324 trees, 13.77 m^2 and 138 species, and those in the heavily damaged forest were 147 trees, 4.80 m^2 and 56 species, respectively.

These forest fires gave great impact on the structure and composition of the mixed dipterocarp forests of studied areas. Some other impacts of forest fires such as composition changes, tree diversity lost and invasion of pioneer or secondary species as a part of early process of forest recovery were also discussed.

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Introduction

GOLDAMMER & SEIBERT 1989, 1990 have indicated the occurrence of forest fire in Sabah in 1914-1915 and in East Kalimantan in about 1914, but no detail information on the burnt areas. The oldest evidence of ancient wildfires in East Kalimantan was occurred between ca. 17,510 and ca. 350 BP. Those fires were associated with period of drought caused by ENSO complex (WINARSO 1999).

Forest fires greatly affect the conservation of biodiversity; directly by burnt out the wildlife; indirectly by changes in the habitat condition, by changes in local microclimate, and by destroying food or nutrient sources. Those impacts have been documented elsewhere (KARTAWINATA & al. 1981, RISWAN & YUSUF 1986, NGAKAN 1999, GHOZALI & TOMA 2000, MORI 2000, SIMBOLON 2000, SLIK 2004). The present paper reports the impact of the forest fires 1997-1998 on the tree diversity in tropical rain forests at Bukit Bangkirai, East Kalimantan, Indonesia.

Material and Methods

Study site

The present study was conducted in Bukit Bangkirai area, East Kalimantan, located 58 km in the northwest of Balikpapan City, East Kalimantan, with about 110m altitude (Fig. 1). Most of the areas were burnt out during the extensive forest fires following intense long dry season periods of 1982-1983 and 1997-1998. However, some areas around a hill dominated by bangkirai (a vernacular name for *Shorea laevis*, *Dipterocarpaceae*) were escaped from both extensive wildfires, and the unburnt areas were conserved and managed as a natural recreation park. Some of the burnt areas were planted with local or introducing species and the rest were left to recover naturally.

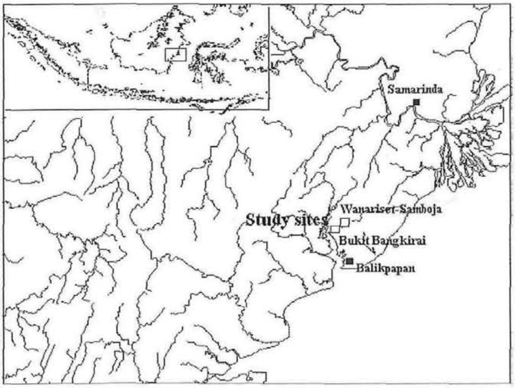


Fig. 1. Location of the study sites within the map of East Kalimantan, Indonesia.

Methods

After a reconnaissance study for exploring the general condition, forests around Bukit Bangkirai areas were determined subjectively into: control (undisturbed), lightly and heavily damaged forests due to wildfires 1997-1998. One plot was established in each of three types of forest condition. Those were: a 1 ha (100 m x 100 m) plot (later, expanded to 1.12 ha) in a natural unburnt forest (named K-plot as control); a 0.3 ha (50 m x 60 m) plot (later, expanded to 1.01 ha) at lightly damaged forest due to forest fires (named LD-plot); and a 1 ha (100 m x 100 m) plot at heavily damaged forest due to forest fires (named HD-plot). Based on the information gathered from management authority, the forests around these three studied plots were escaped from the wildfires 1982-1983 and the forest condition before wildfires 1997-1998 was relatively similar as represented by the control plot, undisturbed forest.

These three plots were divided into some sub-plots of 10 m x 10 m. All trees with stem diameter at breast height (*dbh,* or at 130 cm above the ground) more than 10 cm were individually numbered with aluminum tags, mapped the position in the plot, identified to species in Herbarium Bogoriense, Bogor, Indonesia, and measured *dbh*, tree height and two horizontal diameters of crown at right angles including the maximum. The canopy of trees were projected and drawn in a millimeter block. The profile diagrams of forest representing structure of the permanent plots were also drawn (see Figs. 4, 5 & 6 for details). Some data was then applied for determining the diversity index based on the Fisher's Index of diversity.

Results and Discussion

The summaries of gathered parameters of the studied plots at Bukit Bangkirai are presented in Table 1, and the dominant species based on its basal areas are presented in Table 2. A climax species, *Shorea laevis* (*Dipterocarpaceae*) was found as the biggest (145.8cm in *dbh*) and highest (59.2 m in height) tree in K-plot and this tree was the main species among the emergent species in the study area. The next most frequently-found species in K-plot were another climax emergent tree species, *Shorea pauciflora* and a late secondary species, *Madhuca kingiana* (*Sapotaceae*). The mean coverage of vertical projection of tree crown to the forest floor in each sub-plot indicated the occurrence of some layering of tree canopies. Lower canopy of K-plot was dominated by *M. kingiana* and *Lithocarpus* spp. (*Fagaceae*) associated with small trees of *S. laevis*.

Table 1. Some parameters on the forest structure of studied plots in Bukit Bangkirai area.

Subject	Plot		
	K	LD	HD
Plot size (in m)	100 by 100	60 by 50	100 by 100
Number of living trees per ha	445	324	147
Basal Area of living trees per ha (m^2)	25.34	13.77	4.80
Crown cover *DBH* ≥10cm (m^2/sub plot)	108.16	82.63	23.17
Number of species	141	138	56
Number of genus	84	79	44
Number of family	43	35	34
Fisher's Diversity Index	70.9	91.5	33.2

Table 1 implies that the wildfires in 1997-1998 burnt out more than half of trees and reduced their total basal areas, total tree crown projection, number and composition of species, genus and family. Mortal trees were observed on the whole class diameter; however there was a tendency of size dependent, where mortality is increased as tree diameter decreased (see also SLIK 2004).

Fig. 2 shows that the trunk diameter class distributions in the three plots were inverse *J*-shaped curves, which implied a good regeneration process of a dynamic steady state of climax forest (OGAWA & al. 1965). The inverse *J*-shaped curve of trunk diameter but relatively low in tree density at the lightly damaged and the heavily damaged forests implied the presence of parent trees of native primary species for forest recovery process (see also EICHHORN 2004).

Table 2. Ten top dominant species based on the total basal areas/ha in each studied plot.

No	Species	Family	Basal area (m^2/ha)		
			K	LD	HD
1	*Castanopsis oviformis* Soepadmo	*Fagaceae*		0.12	0.22
2	*Cotylelobium melanoxylon* (Hook.f.) Pierre.	*Dipterocarpaceae*	1.76		
3	*Dehaasia corynantha* Kosterm.	*Lauraceae*	0.01	0.02	0.26
4	*Dipterocarpus confertus* Sloot.	*Dipterocarpaceae*	1.30	0.04	
5	*Durio acutifolius* (Mast.) Kost.	*Bombacaceae*	0.08	0.17	0.27
6	*Durio lanceolatus* Mast.	*Bombacaceae*	0.54	0.02	
7	*Hopea mengarawan* Miq.	*Dipterocarpaceae*	0.06	0.53	
8	*Koompassia malaccensis* Maing.	*Leguminosae*	0.36	0.71	0.05
9	*Macaranga gigantea* Muell-Arg.	*Euphorbiaceae*		0.33	0.44
10	*Madhuca kingiana* (Brace.) H.J.L.	*Sapotaceae*	0.78	1.25	0.05
11	*Mallotus paniculatus* (Lmk.) M.A	*Euphorbiaceae*			0.11
12	*Ochanostachys amentacea* Mast.	*Olacaceae*	0.06	0.38	0.09
13	*Quercus subsericea* A. Camus.	*Fagaceae*			0.48
14	*Scaphium macropodum* (Miq.) Beumee	*Sterculiaceae*	0.15	0.26	0.13
15	*Schima wallichii* (DC.) Korth.	*Theaceae*	0.03	0.08	0.17
16	*Scorodocarpus borneensis* Becc.	*Olacaceae*	0.08	0.53	0.17
17	*Shorea laevis* Ridl.	*Dipterocarpaceae*	7.54	0.07	0.05
18	*Shorea ovalis* (Korth.) Bl.	*Dipterocarpaceae*	0.18	0.11	0.16
19	*Shorea parvifolia* Dyer	*Dipterocarpaceae*	0.02	1.17	0.40
20	*Shorea pauciflora* King	*Dipterocarpaceae*	1.14	0.07	
21	*Shorea rubra* Ashton	*Dipterocarpaceae*	0.32		
22	*Shorea smithiana* Sym.	*Dipterocarpaceae*	1.03	0.71	
23	*Syzygium incarnatum* (Elm.) Merr. & Perry.	*Myrtaceae*		0.28	0.27
24	*Xantophyllum stipitatum* Benn.	*Polygalaceae*	0.56	0.15	

The forest fires occurred in 1997-1998 decreased about 46-81 % of total basal areas. The great losses of tree density and total tree basal areas implied the great damages on the structure of forest as figured in the vertical projection of tree canopies (Fig. 3) and profile diagrams of studied plots (Figs. 4, 5 and 6). The figures show a discontinuous coverage of tree canopies with very large gaps. As compared with K-plot with the closed canopy, the forest floor was more exposed to the sunlight in the LD-plot, and almost entirely exposed to in HD-plot, due to the destruction of canopies by forest fire (Fig. 3). The remnant tree canopy coverage in HD-plot existed mainly in the lower part of the plots, while trees in the ridge parts of the hill were very much exposed to sunlight, since almost trees in the areas were burnt out.

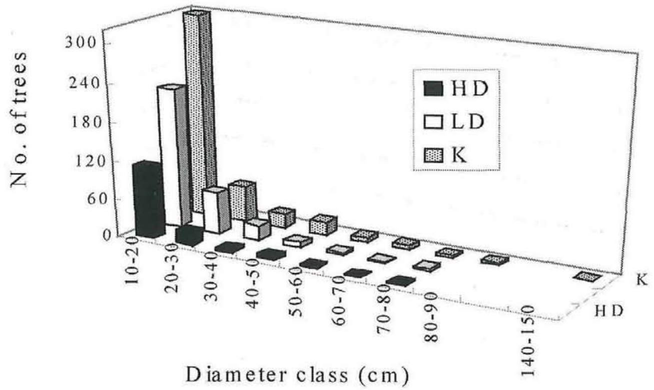
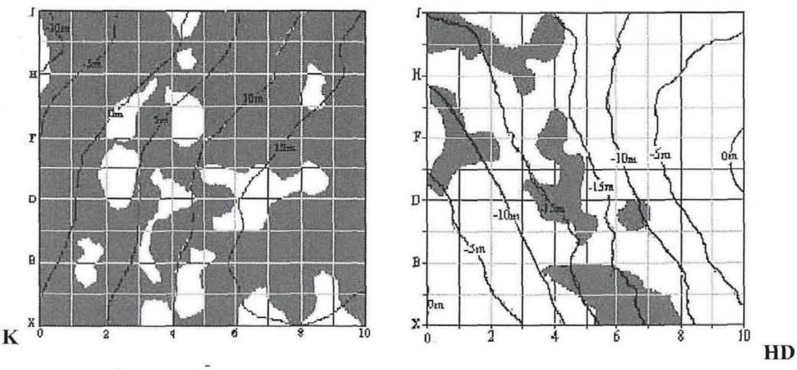


Fig. 2. Trunk diameter class distribution of living trees in the study plots at Bukit Bangkirai.



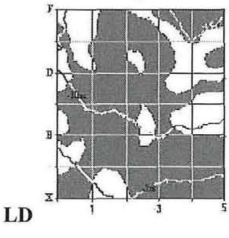


Fig. 3. Contour line and gap distribution in natural unburnt forest K-plot (upper left), heavily damaged forest HD-plot (upper right) and lightly damaged forest LD-plot (left) due to forest fires. White areas are gaps and gray areas are the projection of canopy coverage of trees with DBH of more than 10 cm).

Forest profiles of Fig. 4 showed the emergent trees in unburnt K-plot were *S. laevis* and *Dipterocarpus confertus*, while upper canopy layer with about 35 m height was *S. laevis* associated with *D. confertus* and *Koompassia malaccensis* (*Leguminosae* in Fig. 5). Although the emergent trees in the lightly damaged forest

(LD-plot) were also primary climax species *K. malaccensis* and *S. pauciflora*, the density of tree canopies at the upper layer in LD-plot was less than that in unburnt K-plot. The tree canopies were not continuous in some parts of the plot, and there was no one species with very abundant over others. Other species in upper canopy layer of LD-plot with more than 25 m height were *Payena lucida* (*Sapotaceae*), *Shorea smithiana* and *Bhesa paniculata* (*Celastraceae*). In HD-plot (Fig. 6), the main canopy was almost consisted of pioneer, secondary and light demanding tree species such as *Macaranga gigantea* (*Euphorbiaceae*) ranged from 5-8 m in height, which grown after forest fires. The emergent trees were *Gironniera nervosa* (*Urticaceae*), *Dehaasia* sp. (*Lauraceae*), *Scaphium macropodum* (*Sterculiaceae*), *Archidendron ellipticum* (*Leguminosae*) and *Scorodocarpus borneensis* (*Olacaceae*) escaped from fires. The severe impact of fires on the forest in these areas, as have been shown in the profile diagrams, might be due to the fires not only at the ground surface but also at the canopy level. BROWN & DAVIS 1973 reported that fires in canopies were greatly burnt out the trees and fires may easily extend from an individual tree to another. Mortality of big trees in LD- and HD- plots might be related to the severe fires at the canopies of forests.

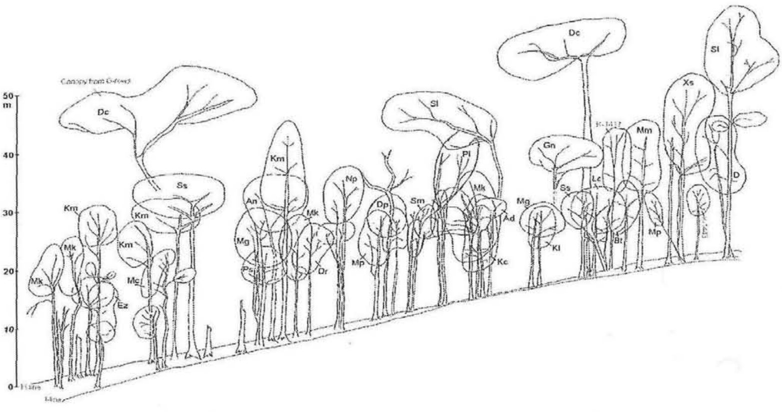


Fig. 4. Profile diagram of K-plot, presented by I1 to I10 rows: (Ad - *Artocarpus dadah;* An - *Artocarpus nitidus;* Ae - *Atuna excelsa;* Bt - *Blumeodendron tokbrai;* D - *Dacryodes rostrata;* Dr - *Dacryodes rugosa;* Dp - *Dialium platysepalum;* Dc - *Dipterocarpus confertus;* Ez - *Eusideroxylon zwageri;* Gn - *Gironniera nervosa;* Kc - *Knema cinerea;* Kl - *Knema latifolia;* Km - *Koompassia malaccensis;* Lc - *Lithocarpus conocarpus;* Mg - *Macaranga glaberrimus;* Mk - *Madhuca kingiana;* Mp - *Mallotus penangensis;* Mc - *Microcos crassifolia;* Mm - *Monocarpia marginalis;* Np - *Neoscortechinia philippinensis* ; Pl - *Payena lucida;* Ps - *Polyalthia sumatrana;* Sm - *Scaphium macropodum;* Sl - *Shorea laevis* ; Ss - *Shorea smithiana* ; Sa - *Syzygium acutangulum;* Xs - *Xantophyllum stipitatum*).

On the tree plant diversity, the forest fires reduced the number of species, genus and families about 2 to 60 %, 6 to 48 % and 19 to 21 %, respectively from the sub-plot survey at LD-plot and HD-plot relative to K-plot. The species in the unburnt forest mainly consisted of climax tree species, while in heavily damaged forest was mainly consisted of pioneer, secondary species such as *M. gigantea* with lower class diameter grown after fires (Table 2, see also GHOZALI & TOMA 2000). Some species were relatively large in total basal areas, such as *Quercus subsericea* and *Shorea parvifolia* in HD-plot, although the species was represented by only single individual with relative large of trunk diameter that escaped from fires. The lightly damaged forest was dominated by *Madhuca kingiana* (*Sapotaceae*), a shade tolerant species that was commonly found in a forest of late succession stage (building phase). Some climax species with relatively large in total basal areas were also existed in LD-plot, but the species represented by only single individual with relatively large in trunk diameter, which might also be escaped from forest fires. Those escaped trees may due to the structure of tree stem, such as: diameter, stem bark and stem gravity (HARMON 1984) and its micro habitat.

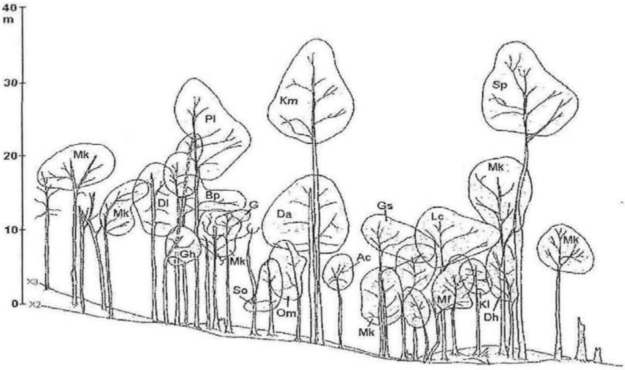


Fig. 5. Profile diagram of LD-plot, presented by A3 to F3 rows: (Ac - *Ardisia copelandii;* Bp - *Bhesa paniculata;* Dl - *Drypetes kikir;* Da - *Durio acutifolius;* Dh - *Dysoxylum hexandrum;* G - *Gironniera* sp.; Gh - *Gironniera hirta;* Gs - *Gironniera subaequalis;* Kl - *Knema latericea.* var. *latericea;* Km - *Koompassia malaccensis;* Lc - *Lithocarpus cantleyanus;* Mk - *Madhuca kingiana*; Mf - *Melanochyla fulvinervis;* Om - *Ostodes macrophylla;* Pl - *Payena lucida;* So - *Shorea ovalis;* Sp - *Shorea pauciflora*).

Our researches at Bukit Bangkirai showed obviously that the forest fires impacted on many biological and ecological status of tropical rain forest in East Kalimantan. Forest recovery process might be affected by not only the fire burning itself but also the environmental changes after fires in the area. More precise and long-term monitoring researches are necessary to understand the recovery processes of forest from fires and to manage the healthy and valuable forest.

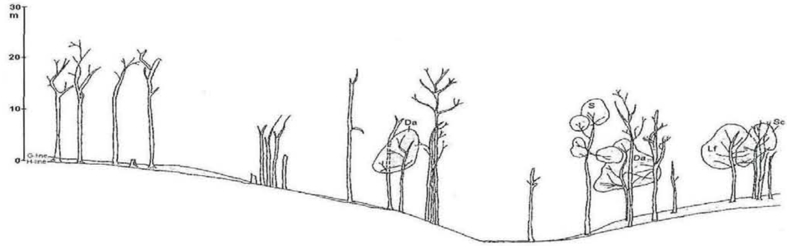


Fig. 6. Profile diagram of HD-plot, presented by H1 to H10 rows: (Da - *Durio acutifolius;* S - *Shorea* sp.; Lf - *Litsea firma;* Sc - *Syzygium caudatilimba*).

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