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Floristic Composition of Peat Swamp Forest in Mensemat-Sambas, West Kalimantan

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Abstract

The floristic composition of a 1.05 ha (70 m by 150 m) plot in an old-growth peat swamp forest was studied at Mensemat, Sambas Regency, West Kalimantan. Number of species and density of trees with more than 10 cm in diameter was 86 species and 698 trees/ha, while small tree of 2-10 cm in diameter was 100 species and 5043 trees/ha, respectively. The most abundant trees were *Blumeodendron elatriospermum* (47 trees/ha), *Cyatocalyx biovulatus* (39 trees/ha), *Blumeodendron tokbrai* (32 trees/ha), *Lithocarpus encleisacarpus* (30 trees/ha) and *Syzygium chlorantha* (30 trees/ha) with greater number of individual at smaller diameter classes. The most diverse families are Euphorbiaceae, Annonaceae and Dipterocarpaceae represented mostly by small-sized trees ranging between diameter 2-30 cm and rarely exceeding dbh 60 cm.

Key words: peat swamp forest, floristic composition, Mensemat, West Kalimantan.

Introduction

Most of the peat swamp forest around Sambas Regency; West Kalimantan has been disturbed due to land conversion and logging. Some of the disturbed peat swamp areas were drained by artificial canals and have been converted into agricultural land, such as for rubber, coffee, pineapple and other fruits plants. The fast land conversion for agricultural land was the most serious threat to the conservation of the peat swamp forest areas, including its biodiversity. Besides decreasing in forest area, converted peat swamps with their canals system have been known also degrading the remaining peat swamp forest ecosystem near by. Ibrahim and Chong (1992), in a study at a peat swamp forest of Selangor, Peninsular Malaysia, indicated that the accumulated shrinkage of the peat has caused tree roots uprooted and fallen down due to decreasing water level as an impact of drainage of the surrounding agricultural activities.

To anticipate the disappearing various important data about the peat swamp forest at this area, we carried out a study on the floristic richness of the forest. This study will be the first step for a more functionally study in the future.

Study Site and Method

The study was conducted at the primary peat swamp forest near Mensemat village, Sambas Regency, West Kalimantan in February 1993 (Fig. 1). The average annual precipitation at Sambas, about 15 km away from the study site, was 2795 mm. The highest monthly rainfall was 337 mm (recorded in December) and the lowest was 138 mm (in July).

A plot of 70 m by 150 m (1.05 ha) was established in an intact peat swamp forest near Mensemat Village (MPSF). The plot was divided into 105 subplots of 10 m by 10 m, and those trees with *DBH* of more than 10 cm were enumerated their species, measured their diameter, total height and height of the first live branch. A sub-subplot of 5 m $\times$ 5 m was systematically nested within each subplot. Those small trees with diameter 2.0-9.9 cm at 50 cm above the ground within sub-subplots were also enumerated.

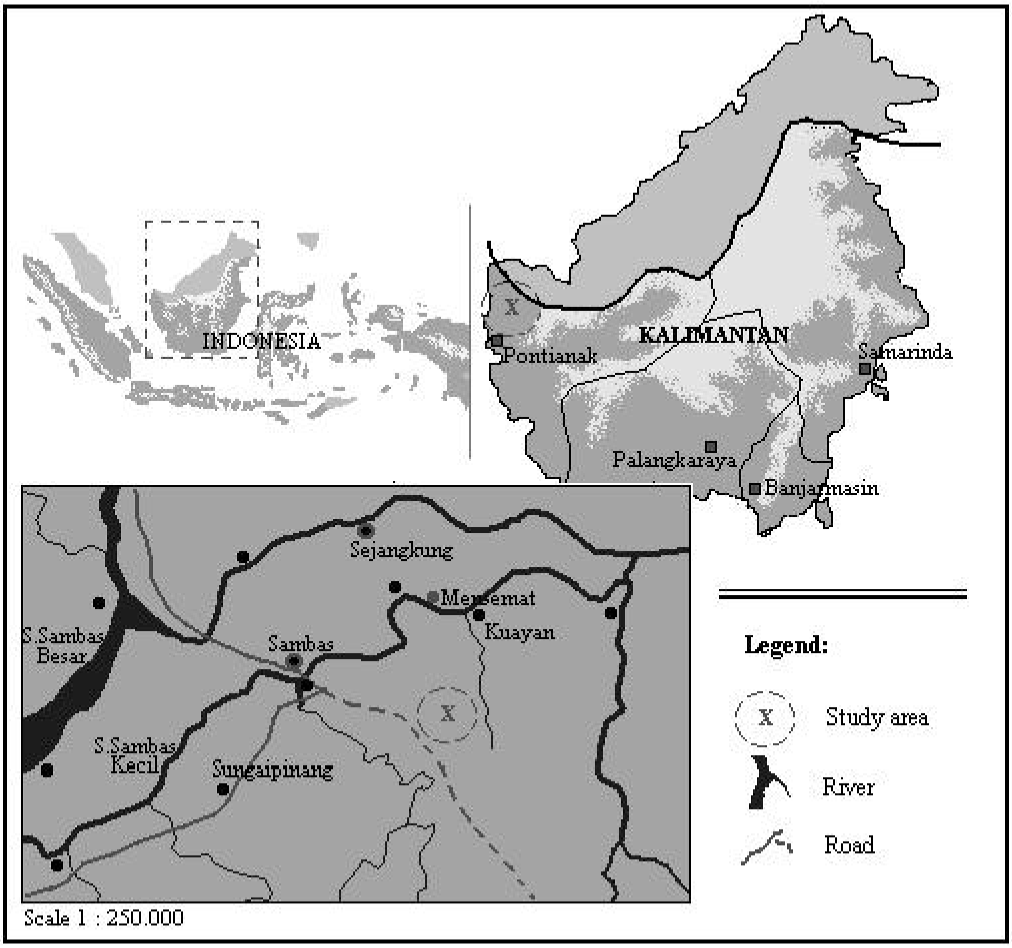

Fig. 1. Location of the study site at Mensemat, Sambas Regency, West Kalimantan

Some physical parameters of the plot were also measured during the field study. Ranges of the peat depth in plot was 2.0 - 4.0 m, pH was 3.2-3.6 and groundwater level was 30-50 cm under land surface, however the areas were flooded during the rainy season (October-December) in every years. Some chemical contents of peat sample collected from the plot were analyzed and the results were presented in Table 1.

Results and Discussion

Density and diversity

Number of species of tree more than 2 cm in diameter within the plot was 115 species belonging to 74 genera and 35 families (Table 2) and density was 5741 trees/ha. Among them tree with more than 10 cm *dbh* was 86 species (58 genera, 31 families) and the density was 698 trees/ha, while the small tree (2 - 9.9 cm diameter) was 100 species (67 genera, 33 families) and density was 5043 trees/ha.

Table 1. Quantitative data of the analytical results of the peat in the plot

Peat depth	1900 cm - 4000 cm	Exchangeable cations:	
Water content	153.8 % - 448.7 %	- Ca	2.78 – 11.04 me/100 g
pH :		- Mg	4.24 – 10.11 me/100 g
- H_2O	3.2 – 3.6	- K	0.12 – 0.80 me/100 g
- KCl	2.4 – 2.7	- Na	0.11 – 2.76 me/100 g
C-organic	51.2 % - 57.0 %	Cation Exchange Capacity	208.5 – 277.2 me/100 g
N-total	0.73 % - 1.90 %	Base Saturation	3.8% - 10.0%
C/N	29.5 % - 77.9 %	Al	1.07 – 8.69 me/100 g
P-available	3.19 % - 26.20 %	H	6.26 – 17.56 me/100 g

For comparison, Sudarmanto (1994) recorded 433 trees tree of more than 10 cm in diameter, consisted of 122 species in a 1-ha plot at the peat swamp forest of Gunung Palung National Park, West Kalimantan. In a peat swamp forest of Tanjung Puting National Park, Central Kalimantan, Mirmanto *et al.* (1999) reported 728 trees of more than 5 cm in diameter and 96 species within a 1-ha plot. Still in the Tanjung Puting National Park, Hamidi (1991) recorded 108 species in a 0.75ha-plot with density of 812 trees/ha. Saribi and Riswan (1997) recorded a tree density of peat swamp forest of Nyaru Menteng Arboretum, Central Kalimantan which was far higher i.e., 1004 trees/ha, but with less total species i.e. 64 species as conversion from a 0.5ha-plot (Table 3).

Table 2. List of tree species larger than 2 cm diameter recorded in the study plot.

No.	Species	Family	Important value (%) Trees (>10cm dbh)	Important value (%) Small trees (2-9.9cm dia.)
(1)	(2)	(3)	(4)	(5)
1.	*Aglaia aspera* [2]	Meliaceae	-	0.60
2.	*Alangium havilandii* Bloemb. [1 2]	Alangiaceae	3.34	2.27
3.	*Anaxagorea* sp. [2]	Annonaceae	-	0.23
4.	*Anisoptera marginata* Korth. [1 2]	Dipterocarpaceae	0.86	0.43
5.	*Antidesma trunciflorum* [2]	Euphorbiaceae	-	0.20
6.	*Archidendron borneensis* [2]	Fabaceae	-	0.50
7.	*Baccaurea bracteata* [1]	Euphorbiaceae	0.95	-
8.	*Beilschunicdia* sp. [2]	Lauraceae	-	0.21
9.	*Bhesa paniculata* Arn. [1 2]	Celastraceae	4.69	4.83
10.	*Blumeodendron elatriospermum* [1 2]	Euphorbiaceae	17.53	4.59
11.	*Blumeodendron tokbrai* (Bl.) J.J.Sm. [1 2]	Euphorbiaceae	12.64	8.22
12.	*Blumeodendron* sp. [1]	Euphorbiaceae	0.35	-
13.	*Brackenridgea palustris* Bartell. [1 2]	Ochnaceae	0.72	0.49
14.	*Buchanania arborescens* (Bl.) Bl. [1 2]	Anacardiaceae	0.34	0.34
15.	*Calophyllum rigidum* [1 2]	Clusiaceae	0.66	1.64
16.	*Camnosperma coriaceum* (Jack.) Hall.f. ex v. Steen.[2]	Anacardiaceae	-	0.49
17.	*Cansjera rheodii* [2]	Opiliaceae	-	0.83
18.	*Chionanthus laxiflorus* [2]	Oleaceae	-	7.76
19.	*Cratoxylum arborescens* (Vahl.) Bl. [2]	Clusiaceae	-	0.24
20.	*Cratoxylum glaucum* [1]	Clusiaceae	0.39	-
21.	*Croton oblongus* [2]	Euphorbiaceae	-	1.04

Table 2 (continued)

(1)	(2)	(3)	(4)	(5)
22.	*Cryptocarya erectinervia* [2]	Lauraceae	-	1.95
23.	*Cryptocarya zollingeriana* [1 2]	Lauraceae	0.44	11.80
24.	*Ctenolophon parvifolius* Oliver [1 2]	Ctenolophonacea	2.80	5.85
25.	*Cyathocalyx biovulatus* Boerl. [1 2]	Annonaceae	12.49	6.20
26.	*Dialium* sp. [2]	Fabaceae	-	0.21
27.	*Dillenia pulchela* [2]	Dilleniaceae	-	0.67
28.	*Diospyros bantamensis* [1 2]	Ebenaceae	2.32	9.77
29.	*Diospyros hermaproditica* [2]	Ebenaceae	-	0.22
30.	*Diospyros maingayi* Hk.f. [1 2]	Ebenaceae	0.35	0.71
31.	*Diospyros oblongus* [1 2]	Ebenaceae	1.10	0.34
32.	*Diospyros* sp. [1]	Ebenaceae	4.32	-
33.	*Dryobalanops lanceolata* [1 2]	Dipterocarpaceae	10.10	15.71
34.	*Dryobalanops rappa* [1]	Dipterocarpaceae	1.41	-
35.	*Durio graviolens* [1 2]	Bombacaceae	0.38	0.55
36.	*Dyera lowii* [1 2]	Apocynaceae	11.91	2.30
37.	*Elaeocarpus glaber* [1 2]	Elaeocarpaceae	1.00	2.22
38.	*Elaeocarpus mastersii* King. [1 2]	Elaeocarpaceae	5.58	2.52
39.	*Elaeocarpus petiolatus* [1 2]	Elaeocarpaceae	0.35	4.12
40.	*Endiandra ochracea* Kosterm. [1 2]	Lauraceae	0.72	0.23
41.	*Erycibe* sp. [2]	Convolvulaceae	-	0.65
42.	*Syzygium chlorantha* [1 2]	Myrtaceae	12.00	2.62
43.	*Syzygium jamboloides* [2]	Myrtaceae	-	6.98
44.	*Syzygium oblata* [1 2]	Myrtaceae	7.22	1.75
45.	*Syzygium sexangulata* [2]	Myrtaceae	-	15.46
46.	*Syzygium spicata* [2]	Myrtaceae	-	0.71
47.	*Syzygium* sp. 1 [2]	Myrtaceae	-	0.27
48.	*Syzygium* sp. 2 [2]	Myrtaceae	-	0.89
49.	*Syzygium* sp. 3 [1]	Myrtaceae	3.20	-
50.	*Ganua coriacea* [1]	Sapotaceae	6.23	-
51.	*Ganua motleyana* (de Vr.) Pierre ex Dubard. [1 2]	Sapotaceae	10.25	4.36
52.	*Garcinia dioica* [2]	Clusiaceae	-	0.44
53.	*Garcinia dulcis* [1 2]	Clusiaceae	0.74	1.41
54.	*Garcinia forbesii* [1 2]	Clusiaceae	0.38	2.05
55.	*Garcinia rostrata* [1]	Clusiaceae	0.58	-
56.	*Glochidion rubrum* [1 2]	Euphorbiaceae	0.35	0.77
57.	*Gluta beccarii* [1 2]	Anacardiaceae	3.74	0.52
58.	*Gonystylus bancanus* (Miq.) Kurz. [1 2]	Thymelaceae	0.40	4.55
59.	*Gymnacranthera contracta* [1]	Myristicaceae	6.71	-
60.	*Horsfieldia glabra* [1 2]	Myristicaceae	0.35	0.46
61.	*Ilex macrophylla* [1 2]	Aquifoliaceae	1.80	2.46
62.	*Jakia ornata Wall.* [1 2]	Rubiaceae	0.57	0.65
63.	*Knema cinerea* [1 2]	Myristicaceae	0.67	8.18
64.	*Koompasia malaccensis* [1]	Fabaceae	9.35	-
65.	*Lithocarpus bennettii* [1 2]	Fagaceae	2.19	1.69
66.	*Lithocarpus encleisacarpus* [1 2]	Fagaceae	10.96	14.18
67.	*Litsea gracilipes* Hook.f. [2]	Lauraceae	-	8.80
68.	*Litsea nidularis* Gamble [1 2]	Lauraceae	2.04	13.52
69.	*Litsea resinosa* Bl. [1 2]	Lauraceae	1.17	4.42
70.	*Litsea* sp. [1]	Lauraceae	0.40	-
71.	*Lophopetalum javanicum* [1 2]	Celastraceae	0.92	1.35
72.	*Macaranga caladifolia* Becc. [1 2]	Euphorbiaceae	2.79	4.00
73.	*Macaranga curtsii* [1 2]	Euphorbiaceae	6.46	1.26
74.	*Macaranga depressa* [2]	Euphorbiaceae	-	1.55
75.	*Macaranga hosei* [1 2]	Euphorbiaceae	1.35	4.85

Table 2 (continued)

(1)	(2)	(3)	(4)	(5)
76.	*Macaranga triloba* [1]	Euphorbiaceae	0.36	-
77.	*Magnolia candollii* (Blume) H.Keng1 [2]	Magnoliaceae	1.01	2.59
78.	*Mangifera longipetiolata* [1 2]	Anacardiaceae	4.20	0.41
79.	*Mezzetia havilandii* [1 2]	Annonaceae	4.17	0.57
80.	*Mezzetia parviflora* [1 2]	Annonaceae	2.82	8.65
81.	*Neoscortechinia kingii* Pax.et K.Hoffm. [1 2]	Euphorbiaceae	5.53	11.93
82.	*Nephelium maingayi* Hiern. [1 2]	Sapindaceae	5.42	8.63
83.	*Nothaphoebe cuneata* [1 2]	Lauraceae	2.55	2.36
84.	*Palaquium leiocarpum* Boerl. [1 2]	Sapotaceae	6.75	1.87
85.	*Parastemon urophyllus* (A.DC.) A.DC. [1 2]	Rosaceae	4.23	1.39
86.	*Parishia maingayi* Hk.f. [1 2]	Anacardiaceae	4.11	1.26
87.	*Parkia sumatrana* [1]	Fabaceae	0.71	-
88.	*Peltopherum* sp. [2]	Fabaceae	-	0.39
89.	*Pometia pinnata* Forst. [1 2]	Sapindaceae	1.46	2.11
90.	*Polyalthia glauca* (Hassk.) Boerl. [1 2]	Annonaceae	1.41	2.42
91.	*Polyalthia lateriflora* [1 2]	Annonaceae	1.04	0.98
92.	*Pygeum lompogum* [1]	Rosaceae	0.35	-
93.	*Randia* sp. [1 2]	Rubiaceae	1.64	0.33
94.	*Sandoricum emarginatum* Hiern. [1 2]	Meliaceae	0.39	0.64
95.	*Santiria apiculata* [1 2]	Burseraceae	0.33	3.44
96.	*Santiria laevigata* Bl. [1 2]	Burseraceae	1.73	0.20
97.	*Santiria oblongifolia* [2]	Burseraceae	-	2.30
98.	*Santiria rubiginosa* Bl. [1 2]	Burseraceae	0.49	0.21
99.	*Santiria tomentosa* Bl. [1 2]	Burseraceae	0.80	0.59
100.	Sarcotheca glauca (Hk,f.) Hall.f. [1 2]	Oxalidaceae	0.69	0.77
101.	*Shorea leprosula* [1 2]	Dipterocarpaceae	2.38	4.82
102.	*Shorea macrantha* (Brandis) Sym. [1 2]	Dipterocarpaceae	2.14	1.19
103.	*Shorea parvifolia* [1 2]	Dipterocarpaceae	7.73	1.89
104.	*Shorea* sp. [2]	Dipterocarpaceae	-	0.24
105.	*Stemonurus scorpioides* [1 2]	Icacinaceae	9.44	1.51
106.	*Tetractomia holtumii* [1 2]	Rutaceae	20.74	10.43
107.	*Tricalysia singularis* [2]	Rubiaceae	-	0.23
108.	*Tristania bakhuizeni* [1 2]	Myrtaceae	0.47	0.27
109.	*Vatica* sp. [2]	Dipterocarpaceae	-	0.21
110.	*Xanthophyllum eurhycum* [1 2]	Polygalaceae	0.37	1.68
111.	*Xanthophyllum scootechiinii* [1 2]	Polygalaceae	2.76	4.25
112.	*Xerospermum cuspidatum* [2]	Sapindaceae	-	1.86
113.	*Xerospermum laevigatum* [1 2]	Sapindaceae	3.98	6.39
114.	*Xylopia coriifolia* Ridl. [1 2]	Annonaceae	2.09	2.41
115.	*Xylopia glauca* [1]	Annonaceae	5.18	-

Note: [1] Trees (> 10 cm dbh) [2] Small trees (2 - 9.9 cm diameter)

When the species number of each study site in Table 2 presented in a figure of species number-areas relationships, it was shown that the species richness on primary forest seemed higher than have in the secondary forest (Fig. 2).

The most abundant tree (>10 cm dbh) at the plot was Blumeodendron elatriospermum (47 trees/ha), followed by Cyatocalyx biovulatus (39 trees/ha), Blumeodendron tokbrai (32 trees/ha), Lithocarpus encleisacarpus (30 trees/ha), and Syzygium chlorantha (30 trees/ha). These species are usually abundant on dbh 10 - 30 cm and rarely reached 60 cm dbh (Fig. 3). Lithocarpus encleisacarpus dominated lower layer (8 - 15 m height) while other dominant species occupied the upper layer (15 - 25 m height) of forest canopies.

Table 3. Species numbers, density and basal area of tree species (> 10 cm *dbh*) in the study site and other eleven plots of peat swamp forests in Kalimantan.

Locations	Plot size (ha)	Σ Species	Density (tree/ha)	Basal area (m^2 / ha)
MPSF	1.05	86	698	24.29
PNm	0.50	64	1004	52.40
SNm *	0.50	49	926	51.32
Pse	1.0	61	513	17.67
PSp	0.20	42	535	14.27
SSp *	0.20	31	260	6.37
PGp	1.0	122	433	28.03
PTp1	0.75	108	812	40.03
PTp2	1.0	96	728	43.01
STp *	1.0	50	1132	8.19
SBs *	0.40	32	251	15.21
Sin *	0.45	37	301	20.90

Legend: * secondary forest; MPSF from this study, PTp2 from Mirmanto *et al*. (1999), STp from Yusuf (1999), others from Saribi and Riswan (1997). MPSF: Mensemat Village, Sambas, West Kalimantan; PNm: Nyaru Menteng Arboretum, Palangkaraya, Central Kalimantan; PTp1, PTp2 and STp: Tanjung Puting National Park, Central Kalimantan; PGp: Gunung Palung National Park, West Kalimantan; PSe: Selatai, Lalang Village, Tayan Hilir, Sanggau, West Kalimantan; PSp: Sungai Pelang, South Matan Hilir, Ketapang, West Kalimantan; SSp: Sungai Pelang, South Matan Hilir, Ketapang, West Kalimantan (7 years after logging); SBs: PT Bina Samaktha II, Sampit, Central Kalimantan; SIn: PT Inhutani III, Sampit, Central Kalimantan (heavy over logged); SNm: Nyaru Menteng Arboretum, Palangkaraya, Central Kalimantan (23 years after logging).

Fig. 3 showed that 5 species which were the most abundant in plot, generally had average *dbh* per tree relatively small, although *Blumeodendron elatriospermum* and *Syzygium chlorantha* were classified as 5 species that had biggest total basal area (Table 4), only by their abundant number of individuals.

Among 86 species recorded in the plot, 30 species had individuals with *dbh* more than 30 cm, or about 8 % of total number of trees. The most abundant within these 30 species was Dyera lowii and *Koompasia malaccensis*, 6 trees/ha each. A tree diameter classes distribution (Fig. 4) showed a drastically decrease on *dbh* more than 20 cm.

The plot was established in an old forest stand and had never been opened for agriculture previously. Eight coppices in the plot were recognized as former cutting, and 43 trees were uprooting falling (most of the uprooting falling trees had *dbh* more than 20 cm). No wonder, the uprooting falling trees was one of the causes of the decreasing tree density on the large *dbh* class. But the extreme effect from peat medium, which could impede the growth of some tree species, might be another cause.

It was not known precisely what the cause of falling trees in the plot; it might be related to the process of draining water on agricultural areas surrounding the plot. The process led to lowering of the water table and hence increasing decomposition of peat, which consequently caused peat subsidence. Root systems will expose and provide poor anchorage to support heavy crowns and the trees become liable to windfalls during heavy storms (Ibrahim and Chong, 1992). Some species such as *Dyera lowii* and *Koompasia malaccensis* could grow big for they were supported by deep rooting system and big buttress.

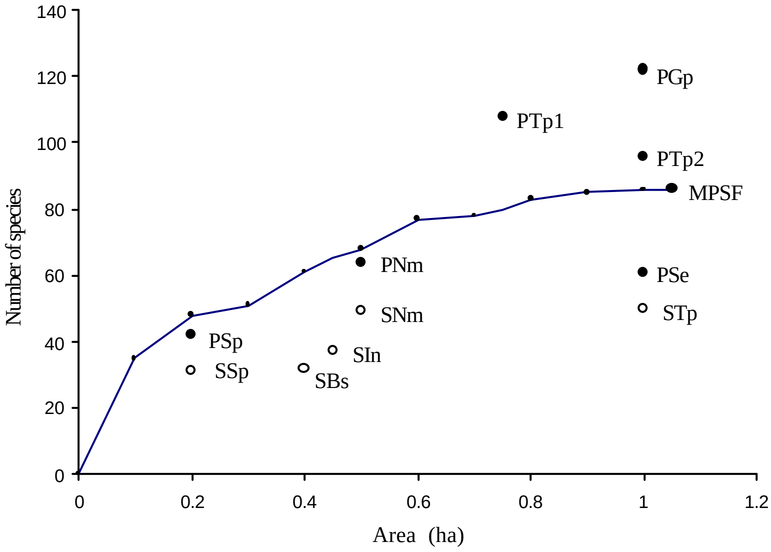

Fig. 2. Species area curve (> 10 cm *dbh*) of MPSF plot and species numbers of small plots in eleven Kalimantan peat swamp forest (Legend: see Table 3)

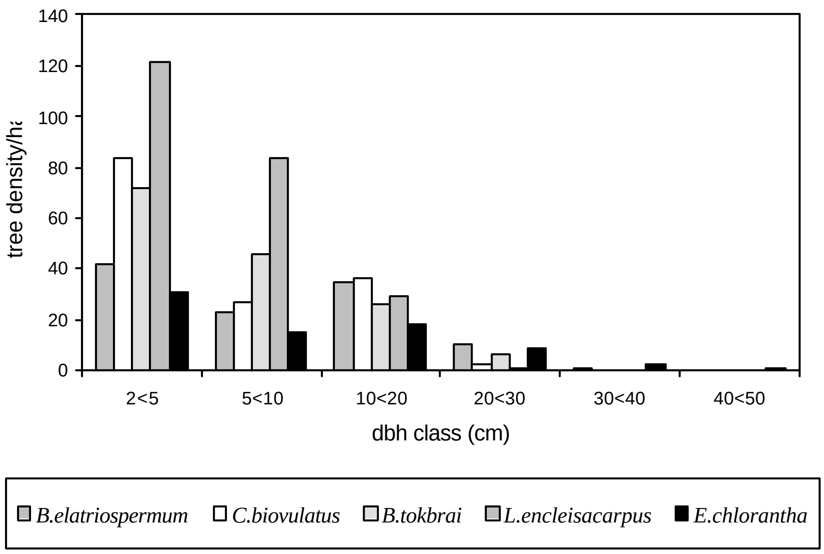

Fig. 3. Diameter class distribution of the five most abundant species in the plot

Table 4. Ten important tree species (> 10 cm *dbh*) based on greater basal area in the plot.

	Species	Basal area (m^2 /ha)	Mean of Basal area (m^2 /tree)	Density (tree /ha)
1	*Dyera lowii*	1.99	0.17	11.4
2	*Koompasia malaccensis*	1.67	0.22	7.6
3	*Blumeodendron elatriospermum*	1.16	0.02	46.7
4	*Tetractomia holtumii*	1.08	0.06	18.1
5	*Syzygium chlorantha*	0.95	0.03	30.4
6	*Syzygium oblata*	0.91	0.09	10.5
7	*Ganua motleyana*	0.89	0.13	6.7
8	*Palaquium leiocarpum*	0.76	0.06	12.4
9	*Parastemon urophyllus*	0.73	0.19	3.8
10	*Blumeodendron tokbrai*	0.68	0.02	32.4

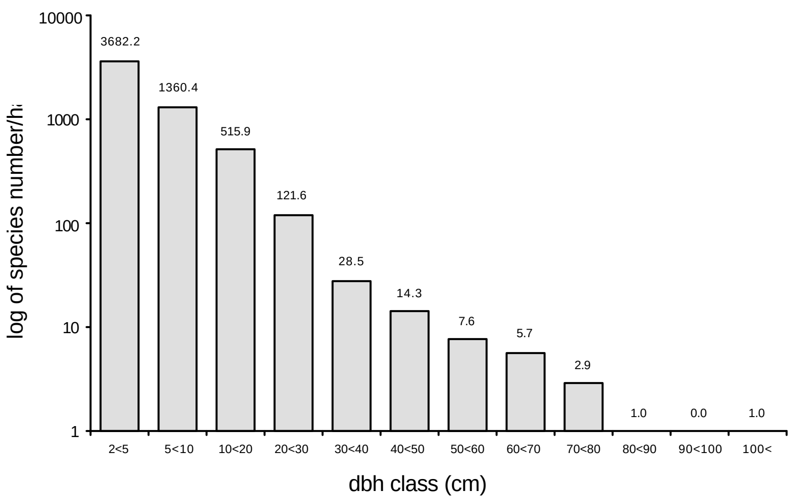

Fig. 4. Diameter class distribution of all trees more than 2 cm diameter in the plot

The family with the highest number of species in the plot was Euphorbiaceae (13 species), followed by Myrtaceae (9 species), Annonaceae, Lauraceae and Dipterocarpaceae with 8 species each. The most frequent species among Euphorbiaceae was *Blumeodendron elatriospermum*; Myrtaceae was commonly represented by *Syzygium*, and the most abundant was *Syzygium chlorantha*; Annonaceae was mostly represented by *Cyatocalyx biovulatus*; Lauraceae was represented by 5 genera but relatively small in individual number, while Dipterocarpaceae was mostly represented by *Dryobalanops lanceolata.* Euphorbiaceae has been reported as one of the biggest family in Malesia, either in peat swamp forest (Ibrahim and Chong, 1992; Mirmanto *et al*., 1993; Sambas *et al*., 1994; Sambas and Suhardjono, 1994) or in lowland Dipterocarpaceae forest (Kartawinata *et al*., 1981; Abdulhadi *et al*., 1989). The abundance of species of Myrtaceae in the study site might be related to podsol soil type under the peat layer. The similar soil type was often found on heath forest where Myrtaceae was very dominant.

The commercial timbers species of Dipterocarpaceae was represented by *Shorea leprosula, S. macrantha, S. parvifolia* and *Shorea* sp., although these 4 species were not so dominant in the study plot. Species with the highest density of small trees (2-9.9 cm *dbh*) was *Dryobalanops lanceolata* (247 trees/ha) and rank sixth for its tree with dbh more than 10 cm (of 27.6 trees/ha) (Table 5), but the biggest tree was only 24 cm *dbh*. It was not known clearly the cause of the absence of this species on bigger diameter, and also very difficult to confirm whether the ruin of falling trees were *D. lanceolata* or not. The other possibility was the stem diameter growth of *D. lanceolata* at the plot had been maximum. Anderson (1973) and Ashton (1982) did not mention that *D. lanceolata* distributes in the peat swamp forest. Also, the species is very seldom found in the peat swamp forests and hence the peat might be the limiting factor for the species to grow bigger. Other evidence that *D. lanceolata* has been grown maximum on the diameter class 20-30 cm in the plot was that generative phase has been started on the trees with *dbh* of 15 cm. This was different from other species of the same genus i.e. *Dryobalanops rappa* that was found growing bigger (Fig. 5). Ashton (1982) reported that *D. rappa* was distributed in peat swamp forests. However, this species seemed in regeneration crisis, since the tree with diameter class less than 10 cm was absence in the plot (Table 5). The explanation could be high mortality and infrequent flowering and fruiting.

Table 5. Density and basal area of Dipterocarpaceae species in the plot

Species	Small trees (2-9.9 cm *dbh*)			Trees ($\geq$ 10 cm *dbh*)		
	Density (tree /ha)	Basal area (m^2 /ha)	Mean of Basal area (m^2 /tree)	Density (tree /ha)	Basal area (m^2 /ha)	Mean of Basal area (m^2 /tree)
Anisoptera marginata Korth.	7.6	0.022	0.003	1.9	0.062	0,033
Dryobalanops lanceolata Burck	247.0	2.242	0.009	27.6	0.575	0,021
Dryobalanops rappa Becc.	0.0	0.0	0.0	2.9	0.161	0,056
Shorea leprosula Miq.	68.4	0.526	0.008	3.8	0.321	0,084
Shorea macrantha Brandis.	19.0	0.137	0.007	3.8	0.225	0,059
Shorea parvifolia Dyer	26.6	0.198	0.007	19.0	0.420	0,022
Shorea sp.	3.8	0.016	0.004	0.0	0.0	0.0
Vatica sp.	3.8	0.007	0.002	0.0	0.0	0.0

Forest regeneration

Only one gap of more than 100 m^2 was found in the plot, the size was 400 m^2, caused by uprooting tree felling and a part by formerly cutting. Based on the mosaics structures and height of canopies, the forest in the plot can be drawn into 3 growth phases i.e. gap, building and mature (Fig. 6). Bushes and trees with less than10 cm diameter and canopy less than 10 m height generally occupied the gap phase. Species occupying the gap phase area were tolerant to sunlight, such as: *Macaranga beccarii*, *Poycilospermum* sp., *Glochidion* sp., and *Uncaria* sp. Seedlings *Dryobalanops lanceolata, Blumeodendron elatriospermum*, *Gonystylus bancanus*, and *Litsea nidularis*, were also residing in the plot. Many *Macaranga* (*M. caladifolia*, *M. curtsii*, *M. hosei*, and *M. triloba*), *Lithocarpus encleisacarpus*, *Lithocarpus benettii*, *Elaeocarpus petiolatus*, *Elaeocarpus mastersii*, *Litsea nidularis* and *Litsea resinosa* were recorded to occupy the building phase forest that was slightly exposed to sunlight.

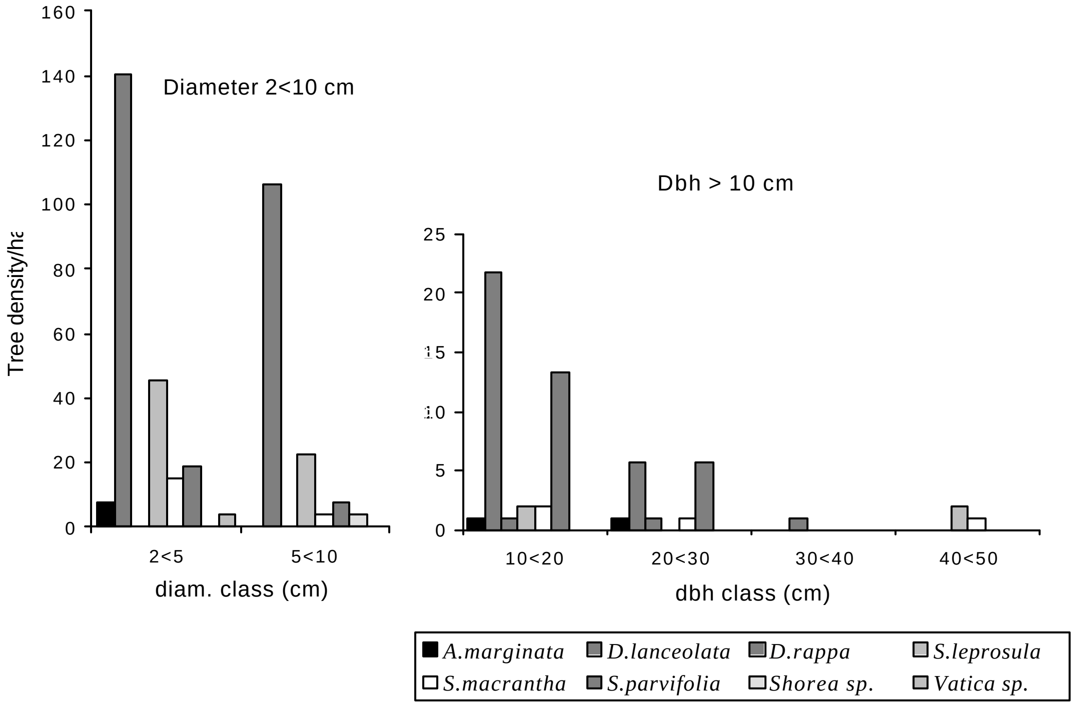

Fig. 5. Diameter class distribution of the Dipterocarpaceae species in the plot

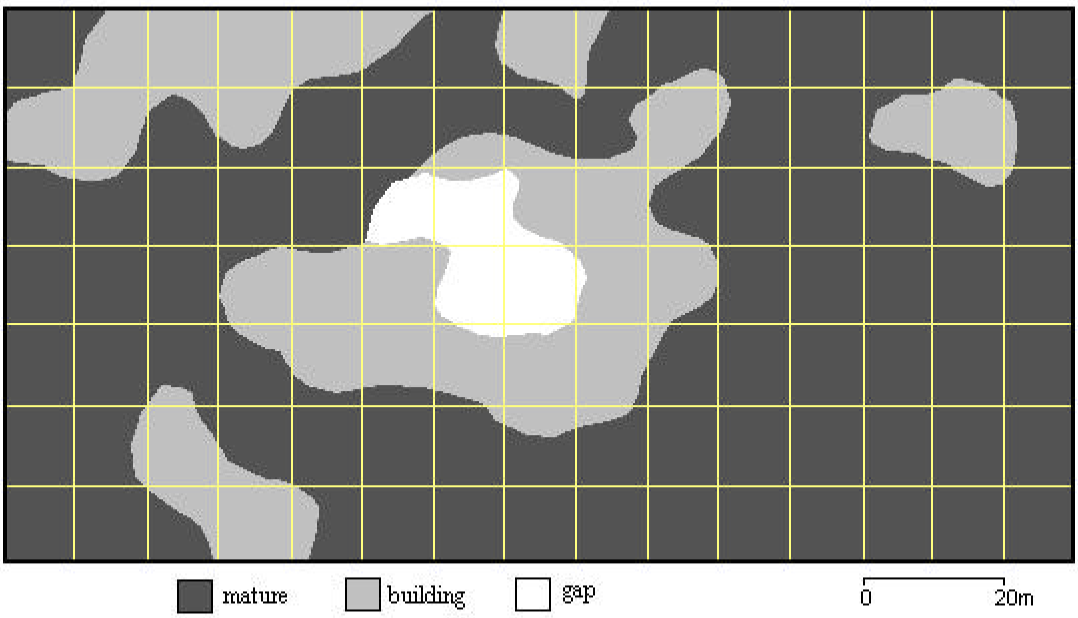

Fig. 6. The mosaic of canopy phases in the plot

Primary species that were found to occupy the building phase area were *Dryobalanops lanceolata, Blumeodendron elatriospermum, Blumeodendron tokbrai, Cyatocalyx biovulatus,* and *Syzygium chlorantha*. In building phase forest, the stratification was relatively simple with main canopy at height range 12-18 m. In mature phase forest, the stratification was continuous consisting of 4 strata i.e., stratum more than 25 m; 15-25 m; 8-15 m; and less than 8 m. The emergent trees with height reaching 45 m were mainly represented by *Koompasia malaccensis* and *Dyera lowii*.

According to species abundance and frequency of availability at each growth phase, small trees (less than 10 cm *dbh*) of *Dryobalanops lanceolata* seemed more distributed in the gaps and buildings. Although the light intensity was not measured, it is assumed that the forest floor of the gap phase was much more exposure to sunlight than of the building phase and than of the mature phase, hence the seedling of *D. lanceolata* might be tolerant to sunlight. On the contrary, seedlings and small trees of *B. elatriospermum, S. chlorantha, Cryptocarya zollingeriana, Syzygium sexangulata*, and *Litsea nidularis* prefer closed areas for their development, since they were found more abundant in the mature phase forest. Seedlings of other important species such as *B. tokbrai, Cyatocalyx biovulatus, Dyera lowii, Gonystylus bancanus*, and *Lithocarpus encleisacarpus* were distributed evenly in building and mature phase forests. However, we still need further study for confirm the ecophysiology of each species, since some other factors such as wildlife and insects, wind, human being and other mechanical factors, were also taking part in affecting the distribution of seedlings (Polunin, 1960; Richrads, 1964).

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Preliminary Study on Growth, Mortality and Recruitment of Tree Species in Peat Swamp Forest at Tanjung Puting National Park, Central Kalimantan

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Abstract

Forest trees in one-hectare permanent plot on Tanjung Puting National Park, C. Kalimantan established in 1998 were re-measured to monitor the forest dynamics. The results show that average girth increments was 0.9 cm/yr ranging from 0.4 cm/yr to 3.9 cm/yr. The highest growth rate was found on trees with diameter (DBH) between 30 and 40 cm. The number of trees with DBH greater than 4.8 cm was changed from 1998 to 1999, by death of 27 trees and recruitment of 49 trees. The total basal area changed from 40.77 m^2/ha to 41.89 m^2/ha, by loss 0.62 m^2/ha of death and 0.76 m^2/ha increases by growth, and 0.98 m^2/ha increases by recruitment. The floristic composition was nearly stable.

Key words: peat-swamp forest, mortality, recruitment, girth increment, Tanjung Puting, Kalimantan

Introduction

It was well known that peat swamp forest is the unique ecosystem but it is fragile and sensitive for development. So the extent of this forest type is dependent on the land utilization and conservation effort. According to some information, Indonesia has about 27 million hectare of peat-swamp forest that distributed in Sumatra, Kalimantan and Irian Jaya. However this wide area has been decreasing time by time, because of some human activities. Unfortunately some activities have resulted in many problems, such as land degradation and especially in biodiversity loss.

On the other hand, the knowledge of the peat-swamp forest especially for their biodiversity, ecological function and dynamics of this forest is still limited. Efforts to reclaim of the disturbed peat-swamp forest need long-term plant demographic studies. So far there has been little such long-term study where permanent plots have been laid down in the primary peat-swamp forest to study establishment, growth and mortality of tree species. The present paper is a preliminary result of long-term study in peat-swamp forest at Tanjung Puting National Park, Central Kalimantan that concern on recruitment, growth and mortality of tree species.

Study Area

The study has been made in the peat-swamp forest near camp Leaky, which is a small part of Tanjung Puting National Park. The area is belonging to Kumai district, Kotawaringin Barat, Central Kalimantan and geographically this area is situated at 2°45’45.8”S and 111°56’41.4”E. The altitude was about 20 m above sea level and located at about 230 km northeast of Palangka Raya (the capital city of Central Kalimantan).

According to Schmidt and Ferguson (1957) classification, the climate in the study area is belonging to type of A, with mean annual rainfall of 2,400 mm. The temperature varied from 25°C up to 33°C, with high (90 %) in humidity.

The vegetation here consists of some forest types, such as lowland dipterocarp forest, peat-swamp forest, heath (kerangas) forest and open area covered by grass of *Imperata cylindrica* and ferns *of Gleichenia liniaris.* The peat-swamp forest distributed in some areas as mosaic surrounded by others forest types. The condition in general was flooded and only some small area was relatively dry, with the peat layer depth varied from 1 to 3m.

Methods

A permanent plot of 100m × 100m was established in 1998 and then has been divided into 100 sub-plots of 10m × 10m. Within each sub-plot all tree with girth breast high over 15 cm were tagged, measured and identified their species. In 1999, girth of all tagged trees within one-hectare plot was re-measured in order to understand their girth increments. In addition all tagged death-trees within plot were recorded and others trees that reach up to gbh 15 cm were also measured and identified their species.

Results and Discussion

Forest structure and composition

Mirmanto *et al.* (1998) have reported the structure and floristic composition of this forest. Accordingly there are 1680 individuals of trees with dbh > 4.8 cm were recorded within one-hectare plot with total basal area of 40.77 m^2/ha. Out of all individuals most (55.7 %) of them were small size (DBH < 10 cm) and only 2.2 % with diameter greater than 50 cm, represent by *Ganua motleyana, Glutta wallichii* and *Shorea fallax*.

Within one-hectare plot 141 species of tree belonging to 84 genera and 43 families were recorded. The *Glutta wallichii, Neoscortechinia philippinensis, Gonystyllus bancanus* and *Shorea fallax* were the dominant species both in tree stage and sapling stage. The first two species (*Glutta wallichii* and *Neoscortechinia philippinensis*) were dominant for both density and basal area, whereas *Gonystyllus bancanus* and *Shorea fallax* only dominate for basal area. Another's species such as G*anua motleyana, Ptychopyxis kingii* and *Baccaurea racemosa* were dominant especially in density.

Growth rate

During one-year period almost all individual within plot increase their girth breast high (gbh), except for 32 individuals were stagnant and 19 individuals were decrease in gbh. All those 51 individuals that may have miss-measurement were excluded from calculation.

Growth rate for some commonest tree species are shown in Table 1. The growth rate given are annual girth increments calculated for each size class. Although the girth increment had great variety among individuals in the same diameter class, but the trend still can be detected. There are tendency that trees with diameter between 30 cm and 50 cm tended grows most quickly. Almost all tree species presented in Table 1, seemed follow this pattern, except for *Baccaurea racemosa, Baccaurea motleyana* and *Campnosperma coriacea*.

Those three species together with *Ostodes macrophylla* and *Neoscortechinia philippinensis* may categorize as the under-canopy species, indicated by most of tree high were less than 20 m. On the other hand, *Glutta wallichii, Ganua motleyana* and *Ptychopyxis kingii* were belonging to main-canopy species, indicated by the maximum high may reach up to 35 m. Some emergent tree species such as *Koompasia malaccensis*, *Cratoxylum glaucum* and *Combretocarpus rotundus* was only represent a little number of individuals, so it was not enough for calculations.

Table 1. Girth increments (cm /yr) for some commonest tree species over one-year

	Diameter class (cm)								
Species	<10	-20	-30	-40	-50	-60	-70	-80	Total
Baccaurea racemosa	0.6	0.8	0.9	0.8					0.77
Baccaurea motleyana	0.5	0.8	1.0	1.2	1.0	0.9			0.82
Camnosperma coreacea	0.6	1.1	2.2	2.5	2.1	1.2	0.7	0.6	1.38
Ganua motleyana	0.4	0.8	0.9	1.1	0.7	0.6			0.75
Glutta wallichii	0.7	1.1	1.6	2.4	2.0	0.9	0.6		1.33
Neoscortechinia philippinensis	0.6	0.9	1.0	0.8	0.9				0.80
Ostodes macrophylla	0.9	1.2	0.8	0.8	0.6				0.86
Ptychopyxis kingii	0.7	0.8	2.0	2.4	2.2	0.9	0.7		1.50
Total	0.59	0.87	1.09	1.44	1.04	0.85	0.77	0.62	0.90

Highest overall growth rates among tree species presented in Table 1, were 1.5 cm /year for *Ganua motleyana* and 1.4 cm/year for *Glutta waliichii.* All those two species were main-canopy species. The overall growth rate for among main-canopy species varied from 1.3 cm/yr to 1.5 cm/yr. On the other hand, the lowest growth rate were 0.77 cm/yr for *Baccaurea racemosa* and 0.75 cm/yr for *Neoscortechinia philippinensis.* Those two species were under-canopy species, and the overall growth rate among them varied from 0.75 cm/yr to 0.86 c/yr. So, there is tendency that the main-canopy species most quickly grow than under-canopy species.

All of the main-canopy species, in this case, are characteristic for peat-swamp forest species and with a relatively high in growth rates. This demonstrates the importance of the native species to maintain the extent of the peat-swamp forest.

Mortality

The total number of tree death recorded over one year period was 27 individuals with total basal area of 0.62 m^2/ha (Table 2). It is only about 2% of total of trees and 1.5% total basal area recorded within one-hectare plot.

Highest overall death tree among tree species presented in Table 2 was 5 individuals for *Baccaurea racemosa;* 4 individuals for *Baccaurea motleyana* and *Eugenia virens;* and 2 individuals for *Aglaia ganggo*. Others 12 tree species was only represent by single individual respectively.

The interesting point from this result is that the most of death tree species were belonging to family of Euphorbiaceae (Table 3), and some of them were under-canopy species. There are big differences in mortality between main-canopy species and under-canopy species. The main-canopy species show a relatively low in mortality rates, whereas the under-canopy species have a higher rate (Table 2). This is may be because the differences in longevity between these species group. More than 70 % of death trees are under-canopy species, whereas the main-canopy death tree species only represent by about 20 %. In addition so far, there is no emergent death tree species recorded.

Table 2. Density (D= individual /ha) and basal area (BA= m^2/ha) of death-trees within plot over one year

Species	D	BA	D (%)	BA (%)
*Acronichya la*urifolia	1	0.026	3.85	4.174.17
Adinandra dumosa	1	0.022	3.85	3.533.53
Aglaia ganggo	2	0.066	7.69	10.59
Artocarpus kemando	1	0.028	3.85	4.49
Baccaurea motleyana	4	0.077	15.38	12.32
Baccaurea racemosa	5	0.036	19.23	5.76
Dialium maingayi	1	0.029	3.85	3.64
Diospyros polyalthioides	1	0.023	3.85	3.68
Dysoxylum arborescens	1	0.022	3.85	3.53
Endiandra rubescens	1	0.086	3.85	14.18
Eugenia virens	4	0.055	15.38	8.80
Ganua motleyana	1	0.038	3.85	6.08
Gymnacranthera eugeniifolia	1	0.024	3.85	3.85
Gynotroches axillris	1	0.025	3.85	4.00
Jackia ornata	1	0.037	3.85	5.92
Pimeleodendron papaveriodes	1	0.035	3.85	5.46
Total	27	0.623	100.00	100.00

Table 3. Density (D= individual /ha), basal area (BA= m^2 /ha) and number of species (NS) within plot over one-year according to family

Family	NS	D	BA	D (%)	BA (%)
Ebenaceae	1	1	0.023	3.85	3.68
Euphorbiaceae	3	10	0.148	38.46	23.54
Fabaceae	1	1	0.029	3.85	3.64
Lecythidaceae	1	1	0.037	3.85	5.92
Meliaceae	2	3	0.088	11.54	14.12
Moraceae	1	1	0.028	3.85	4.49
Myristicaccea	2	12	0.110	7.70	18.03
Myrtaceae	1	1	.0.0551	15.38	8.80
Rhizophoraceae	1	1	0.025	3.85	4.00
Rutaceae	1	1	0.026	3.85	4.17
Sapotaceae	1	1	0.038	3.85	6.08
Sapotaceae	1	1	0.022	3.85	3.53
Total	16	27	0.623	100.00	100.00

Recruitment

During one-year period, there are 49 individuals of small (< 15 cm GBH) tree were reach up to 15 cm or more in GBH (Table 4). A highest overall recruited tree was 23 individuals for *Baccaurea racemosa*, and 9 individuals for *Ardisia laevigata.* Other higher recruited tree species were *Litsea diversifolia* (4 individuals), *Polyalthia laterifolia* (3 individuals) and *Pternandra cordata* (2 individuals). The dipterocarp species, which represent by *Shorea fallax* was only one recruited tree recorded.

Out of 49-recruited tree, 36 (73.4 %) of them are under-canopy species and 11

(2.2 %) are main-canopy species. In addition there are only 2 individuals of emergent recruited trees were recorded. Most of recruited tree were always found in 1998, except for *Ardisia laevigata* and *Pternandra cordata.* Those two species were under-canopy forest and together with other under-canopy species, such as *Baccaurea racemosa* have higher rate of recruitments. On the other hand most of main canopy species have a low rate in recruitments. However two main-canopy species such as *Polyalthia laterifolia* and *Polyalthia laterifolia* have a relatively high in rate of recruitment. In addition some recruited emergent species also recorded, even though in lower rate of recruitments. This result suggests that under-canopy species have importance role in maintain of the forest ecosystem.

Table 4. Density (D= individual/ha) and basal area (BA= m^2 /ha) of recruited tree species within plot over one year

Species	D	BA	D (%)	BA (%)
Ardisia laevigata	9	0.18	18.37	18.45
Aromodendron nutans	1	0.02	2.04	2.05
Baccaurea racemosa	23	0.46	46.94	46.65
Diospyros buxifolia	1	0.02	2.04	2.05
Diospyros polyalthioides	1	0.02	2.04	2.05
Eugenia perpuncticulata	1	0.02	2.04	2.05
Eugenia virens	1	0.02	2.04	2.05
Horsfieldia glabra	1	0.02	2.04	2.05
Litsea diversifolia	4	0.08	8.16	8.20
Polyalthia laterifolia	3	0.06	6.12	6.15
Pternandra cordata	2	0.04	4.08	4.10
Shorea fallax	1	0.02	2.04	2.05
Tetramerista glabra	1	0.02	2.04	2.05
Total	49	0.98	100.00	100.00

Table 5. Density (D= individual /ha) and basal area (BA= m^2 /ha), and number of species (NS) within plot over one year according to family

Family	NS	D	BA	D (%)	BA (%)
Annonaceae	1	3	0.06	6.12	6.15
Combretaceae	1	1	0.02	2.04	2.05
Dipterocarpaceae	1	1	0.02	2.04	2.05
Ebenaceae	2	2	0.04	4.08	4.10
Euphorbiaceae	1	23	0.46	46.94	46.65
Lauraceae	1	4	0.08	8.16	8.20
Magnoliaceae	1	1	0.02	2.04	2.05
Melastomataceae	1	2	0.04	4.08	4.10
Myrsinaceae	1	9	0.18	18.37	18.45
Myristicaceae	1	2	0.04	4.08	4.10
Myrtaceae	2	1	0.02	2.04	2.05
Total	13	49	0.98	100.00	100.00

Basal area and density

During one-year period there are any changed both in density and basal area of tree within one-hectare plot (Table 6). The basal area increase from 40.77 m^2 /ha to 41.89 m^2 /ha and density increase from 1680 to 1702 individuals /ha. The tree density increase because the increase of tree density from recruitment was greater than lost of tree by death. The increase of tree density also followed by increase of basal area, because the increase of basal area of survived trees and from recruited trees were greater than the lost by death.

Table 6. Basal area (BA= m^2 /ha) and density (D= individual /ha) change of tree species within plot from 1998 to 1999

From 1998 to 1999	BA	BA (%)	D	D (%)
In 1998	40.77	100.00	1680	100.00
Loss by tree death until 1999	- 0.62	- 1.51	- 27	- 1.61
Increase by growth until 1999	0.76	1.88		
Increase by recruitment until 1999	0.98	2.40	49	2.92
In 1999	41.89	102.77	1702	101.31

The tree density change in this study was little bit higher than two others study sites (Table 7). It was resulted from the relatively lower in tree mortality and higher in tree recruitment. In total the basal area change also higher than two others study site. However the growth rate, which expressed in increase of basal area by increment, was lowest among three study sites. This is may demonstrate the characteristic of peat-swamp forest that grows on poor habitat and consequence is lower in forest growth and primary productivity.

Table 7. Basal area (BA= m^2 /ha) and density (D= individual /ha) change of trees in three study sites

	This study		G. Halimun *		Barito Ulu **	
	BA	D	BA	D	BA	D
First year	40.77	1680	39.64	995	46.87	879
Loss by tree death	- 0.62	- 27	- 0.85	- 25	- 1.02	- 18
Increase by growth	0.76		0.89		0.96	
Increase by recruitment	0.98	49	0.49	25	0.39	20
Second year	41.89	1702	40.17	995	47.20	881

*) Mean of 2 plots (Suzuki *et al.*, 1998) **) Mean of 5 plots (Mirmanto, 1996)

In general the preliminary results of this study was closer to the G. Halimun results rather than Barito Ulu. It was expected that those two study sites (this study and G. Halimun) were relatively poor habitat, which resulted in slower of some forest ecological process. However the data presented in this paper is a result from a short time period of study, so the further study must be conducted to clarify this result.

Conclusions

Based on the results presented above, there are tentative conclusions:

1. The floristic composition was nearly stable.
2. Although some tree died and others were recruited the forest seemed to be stable condition.
3. The further measurement is needed in order to monitor of the forest dynamics, and also to understand the constancy of tree growth.

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Preliminary Study on the Water Relations of Tropical Peat Land Plants

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Abstract

This paper presenting and discussing results of the preliminary experiment on water relations of tropical peat land in Central Kalimantan. The discussion is based on the result of preliminary field study in 1998. Our data were gathered from the first year of study on osmotic properties of three tree species (tumih, *Combretocarpus rotundatus*), belangeran, *Shorea balangeran* and ramin, *Gonystylus bancatus*). The results revealed that during flooding period (August 1998) those plants were still retained their positive turgor pressure. We expected that due to the flooding conditions (hence, creating anoxia/hypoxia), the cells/tissues should have collapsed, thus the points generated from pressure chamber to build Pressure-Volume (P-V) curves from each species were no longer formed ordinary shape i.e. a non linear. However, the P-V curves did not show any anomalies, thus led us to conclude that those species seems retained some ability to cope with flooding stress. Those results are discussed and projected to the future study of plant water relations in conjunction with productivity of peat land plants. The future study will be complemented with other aspects including seasonal and diurnal fluctuations of osmotic properties of plant cells/tissues, seasonal fluctuations of cellular/tissue solutes in conjunction with the osmotic properties and seasonal and diurnal fluctuations of stomatal behaviour in conjunction with plant water potential components.

Introduction

Water is one of the main phenomenon dominating the life cycle of biodiversity components in tropical peat land area in Central Kalimantan. However, the existence of water is no longer as a determinant positive factor in the life of plants in that area; instead, water has became a factor creating other problems i.e. flooding stress. *Rhizosphere* is the part of plant which undergoes most severe stress (especially during flooding phenomenon) in peat environment, creating anoxia and/or hypoxia conditions i.e. when the oxygen supply for root consumption is being reduced mainly by microorganism respiration. Anaerobic respiration may leads to the synthesis and translocation of some toxic components, and affected various processing activities within plants. One of the main factors being interfered by flooding in peat land area is the *water relations of plants*.

In a broad sense, the effect to plant water relations may have touched a number of basic biological processes within plants such as water (hence nutrient) transport, osmotic properties of cells/tissues and gas exchange between plant surface and atmosphere.

The purpose of this study is to observe the osmotic properties of tissues/cells of plants growing in the peatland area. The results may be used to interpret the adaptation ability of peatland plants to the harsh environmental conditions such as flooding, and possibly conjunctioned with their (plants) productivity.

Materials and Method

The study was held in Laboratory of the Faculty of Agriculture, The University of Palangkaraya, Palangkaraya, Central Kalimantan, Indonesia in August 1998, while the source of samples was Sebangau River area in Setia Alam site. Three local tree species were used namely tumih, *Combretocarpus rotundatus*, belangeran, *Shorea balangeran* and ramin, (*Gonystylus bancatus*). These species are known as quite dominant for this area.

The approach was made from measuring the water potential components i.e. total water potential, osmotic potential and turgor pressure of the plant tissue/cells. The samples were collected early morning by crossing over the (flooded) R. Sebangau by a small boat and (passing the remains of the old bridge over water used by the exploiters for cutting off and transported the ramins) collecting twigs of these plants. The collected samples were quickly put into a plastic bag, saturated with water to reduce transpiration, and sealed. The samples were then taken back to the laboratory with the distance about 10 km. It was need about two hours from collecting the samples until starting the measurement.

To derive total water potential (which is actually xylem water potential), a Scholander Pressure Chamber was used. A single leaf-bearing twigs or a single shoot in adequately mature (fully expanded) were selected, quickly sealed into the chamber, and high pressure nitrogen gas was released. The pressure was then applied slowly until the sap appeared on the cut end of the sample. Water potential was recorded i.e. the value of gas pressure at which the sap first appeared on the surface of the sample's cut end (Boyer, 1967; Hellkvist *et al*., 1974; Ritchie and Hinckley, 1975). This was observed by a hand-lens. The balance pressure is actually equal (but opposite in sign) to the xylem pressure potential (Hellkvist *et al*., 1974). The balance pressure when sap appeared from the cut end is a function of plant water potential (Scholander *et al*., 1965; Boyer, 1967).

Osmotic potential at full turgor ($\Psi_{\pi(100)}$) was generated from Pressure-Volume (P-V) curves, constructed by the same pressure chamber, following the steps as described by Tyree and Hammel (1972), Sinclair and Venables (1983). A P-V curve is derived from the tissue water potential isotherm, the relationship between the change of total water potential and volume of the tissue or cells within a living sample (Richter et al, 1980; Tyree and Jarvis, 1982). To construct a P-V curve, the twig was selected, cut under water (to avoid a possible air bubble blockage), the cut end placed in a container filled with water and covered with a plastic bag for rehydration to allow the tissues to reach full turgor. Tissue paper, saturated with water, was placed in the chamber to reduce the loss of water via transpiration during the P-V curve construction (Sinclair and Venables, 1983).

Due to flooding conditions, it was need only about two hours the samples to be rehydrated to achieve full turgor. After the sample was sealed into the chamber, the pressure was gradually increased. The sap extruded was collected with a pre-weighed transparent plastic tube (0.5 cm in dia. 10 cm in length) containing colored (pink) tissue paper. The difference between two respective weighing is the amount of extruded sap for that pressure increment. The cumulative weight of the extruded sap was then plotted against the reciprocal of the corresponding balance pressure to construct a P-V curve. To obtain a ψ_π value, the linear part of the P-V curve was extrapolated to reach the y-axis, where the point of intersection was the reciprocal of the initial osmotic potential.

Turgor pressure was estimated as the difference between total water potential and osmotic potential according to equation $\Psi = \Psi_\pi + \Psi_p$, where Ψ is water potential, Ψ_π is osmotic potential and Ψ_p is turgor pressure (Sutcliffe, 1979; Tyree and Jarvis, 1982; Kramer, 1983).

Results and Discussion

The results of the measurement are presented in Table 1. The total water potential of all species were nearly zero, showing that the plants are nearly fully turgid due to flooding conditions. It is clear that all the species retained their positive turgor pressure. Data in Table 1 were tested for their significance by a simple model *one way anova*.

Table 1. Results of water potential component measurements (n=3). i.e. water potential Ψ (-MPa), osmotic potential Ψ_π (-MPa) and turgor pressure Ψ_p (MPa) in 3 tree species of the Sebangau River, Central Kalimantan

Species	ψ	ψ_π	ψ_p
tumih			
C. rotundatus	0.20	1,00	0.80
	0.05	0.85	0.80
	0.05	0.76	0.71
Ā	**0.10**	**0.87**	**0.77**
balangeran			
Shorea balangeran	0.05	1.00	0.95
	0.05	1.34	1.25
	0.05	1.41	1.36
Ā	**0.05**	**1.25**	**1.20**
ramin			
Gonystylus bancatus	0.05	1.30	1.25
	0.05	1.39	1.34
	0.05	1.16	1.11
Ā	**0.05**	**1.28**	**1.51**

No significance was found between species in their water potential (Ψ). This is due to the flooding conditions where all the tissues are in very saturated with water. While it does significant for osmotic potential (Ψ_π) and turgor pressure (Ψ_p).

The Ψ_π for tumih (-0.87 MPa) indicating smaller water absorption, compared to other 2 species and possible tissue disorder due to flooding stress (less tolerant); while the Ψ_π of 2 species ramin and balangeran (-1.25 MPa and –1.28 MPa) are reasonably more negative, close to some terrestrial species when well watered. Lower negative value of Ψ_π apparently shows that more solutes may have accumulated in the tissues/cells to generate the osmotic values. We guessed that those solutes are may be some salts which have dissolved from plant parts in the peat water and transported to the cells by transpiration stream. Higher salt concentration in peat water may has led those plants to regulate their tissue osmotic values. Another possibility is that some organic solutes may have been synthesized to be rolled as "negative charge" for some excessive toxic salts translocated to the leaves.

The greater Ψ_π of a species in flooding conditions may have more productivity gaining since there would be bigger delta between Ψ and Ψ_π, thus would generate bigger Ψ_p, although Ψ_p of these species has approached to maximum as Ψ were nearly zero. Turgor pressure is usually recognized to play an important role in the maintenance of growth and leaf expansion (Drew, 1987). In other plant groups such as in grapes (Schultz and Matthews, 1993) and sunflower (Chimente and Hall, 1994), turgor could be retained may not always be associated with the continuation of growth, but rather the extension of the survival period, as there was a negative association between osmotic regulation and leaf expansion.

The results of species rank test using the LSD 5% level on the significant parameters ($\Psi_{\pi\,(100)}$ and Ψ_p) is presented in Table 2. It is clear that the values of $\Psi_{\pi\,(100)}$ in ramin and balangeran are not significantly different for each other, but they are to tumih. The same phenomenon is also shown for Ψ_p, where the two species is not significantly different each other, but they are for tumih as well.

It seems that tumih would achieve quickly wilting point as their turgor pressure are smaller compared to the other two species. Wilting in flooding conditions are due to the reduction of water absorption since the sudden increase of root resistant to saturated water in their milieu. The increase of root resistant to water transport is caused by toxicity of high CO_2 concentration (Kramer, 1983). Another reason may be due to anaerobic conditions which lead to synthesize of some toxic components such as ethanol, aldehydes and lactic acid which accumulated in the rhizosphere to cause destruction of absorption areas (Kramer, 1983). These conditions may cause disintegration in water transport, thus ilting may happen.

Table 2. Species rank on $\Psi_{\pi\,(100)}$ and Ψ_p in 3 tree species of peat land area in the Sebangau River, Central Kalimantan spillited by LSD 5% analysis. Values marked with the same letter within a column are not significantly different.

Parameter	Ranking composition	
$\Psi_{\pi\,(100)}$	ramin	1.28 [a]
	balangeran	1.25 [a]
	tumih	0.87 [b]
Ψ_p	ramin	1.23 [a]
	balangeran	1.19 [a]
	tumih	0.77 [b]

Conclusion

We expected that due to the flooding conditions (hence, creating anoxia/hypoxia), the cells/tissues should have collapsed, thus the points generated from pressure chamber to build Pressure-Volume (P-V) curves (not displayed) from each species were no longer formed ordinary shape i.e. a non linear (cf. Table 1 as well). However, no sign of wilting detected within the 3 species (i.e. when Ψ_p reached zero), due to sudden increase of root resistant which caused by decreasing of water absorption, also, the P-V curves did not show any anomalies, thus seems that these three species have shown some indications to stand in flooding conditions. These plants still retain their positive turgor pressure thus tissues/cells are active; the values of Ψ_p in balangeran and ramin even not far behind the values of some tropical "terrestrial" species when in well-watered conditions. As in puspa (*Schima wallichii*) recorded in January 1994 (rainy season) was -1.65 MPa (Naiola *et al*., 1997) and rambutan (*Naphelium lappaceum*) in August 1994 was -1.6 MPa (Naiola, unpublished data). Those have led us to conclude that those species seems to retain some abilities to cope with flooding stress.

However, we did not surely know exactly when the flooding started to cover these plants before the field reading taken, thus the duration of flood may one of the main reason. Thus future study should involve a more and regular field reading to show the realistic time of flooding phenomenon (including seasonal and diurnal fluctuations of osmotic properties of plant cells/tissues, seasonal fluctuations of cellular/tissue solutes in conjunction with the osmotic properties). Some supportive aspects are also proposed in the future study i.e. the comparisons of plant water relations aspects with the same species growing in "terrestrial" conditions, and combining the data for interpretation the productivity of plants due to flooding stress. Another proposed aspect is to study the effect of hypoxia/anoxia in the accumulation of "toxic" components in the guard cells (for example as ABA) thus influencing stomatal behavior (conductivity/resistance) in conjunction with plant water potential components during flooding in peat land.

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Checklist of Plant Species in the Peat Swamp Forests of Central Kalimantan, Indonesia

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Abstract

The present paper intends to prepare the checklist of plant species in the peat swamp forest of Central Kalimantan, Indonesia. The list was constructed mainly based on the specimens collected during the expeditions conducted at Lahei in August 1997, Tanjung Puting National Park in June 1998 and at Sebangau River areas in August 1999. More than 310 species (78 family) of plants have been listed from these areas. Some families with the most diverse species in the areas were Myrtaceae (4 genus, 35 species), Euphorbiaceae (12 genus, 29 species), Clusiaceae (2 genus, 20 species), Dipterocarapceae (3 genus, 12 species) and Myristicaceae (4 genus, 11 species). Most of the observed peat swamp forests have been disturbed due to logging, land cover conversions and forest fires. The dominant tree species in the peat swamp forest along the riverbanks of Lahei was *Semecarpus longifolius* and *Shorea balangeran*, in Tanjung Puting National Park was *Glutta wallichii* and *Neoscortechinia philippinensis*, and in Sebangau River areas was *Palaquium leicocarpum* and *Syzygium densinervium*. Those plant species encountered during the expedition were listed and some notes on the species were also given.

Introduction

Ecologically, wetland ecosystem is unique ecosystems due to its large carbon sinks (the so-called warming substance), and its high endemism of biodiversity. The peat swamp forest is the most important one among wetland ecosystems. Peat swamp ecosystem covers an area of about 400 million ha of earth surfaces, mostly in temperate areas and only 10% of them are found in tropics. It was estimated that Indonesia has about 27 million ha (distributed in Sumatra, Kalimantan (Borneo) and Irian Jaya islands), that is more than 60% of the tropical peat land resources. Recently, Indonesian peat swamp forests had been drained and converted into agricultural lands in a very spectacular rate. Unfortunately, many of them were unsuccessful, creating major land degradation and biodiversity loss while in the other hand, little is known on the natural biodiversity, natural function and values of peat swamp forests.

The unsuccessful land conversion and management of a recent project so called "one-million hectares" of peat swamp forests in Central Kalimantan for example was basically related to our poor knowledge on the peat swamp forest ecosystem of the area. The main reason was peat swamp forests in tropical countries have been little studied so far. The first comprehensive study on the peat swamp forests of Southeast Asia is the works conducted by Anderson in North Kalimantan (Sarawak and Brunei), started from 1954. He also then conducted some ecological surveys in Sumatra and Western Malaysia (Anderson, 1961, 1963, 1964, 1972, 1983). Up to the present, Anderson's works remain the substantial studies of peat swamp forest of Southeast Asia. Recently, some other studies on the diversity of plants in peat swamp forests have been reported from Peninsular

Malaysia (Ibrahim, 1997), Southern Thailand (Kaneko, 1992), West Kalimantan (Siregar and Sambas, 1999) and Central Kalimantan (Saribi and Riswan, 1997; Shepherd *et al.,* 1997; Mirmanto *et al.*, 1999; Suzuki *et al.*, 1999). The present paper intends to prepare the checklist of plant species collected from peat swamp forests in Central Kalimantan, Indonesia.

Methods

A 1-ha permanent plot (100 m by 100 m) was established on a peat swamp forest in Lahei, Central Kalimantan in August 1997 with the goal of understanding the community and population dynamics of the forest. All trees with *DBH* more than 5 cm within the plot were identified to species. In order to gather much more information on the flora of peat swamp forest in the area, an exploration was also carried out by crossing over the entire peat swamp forests around the permanent plot. By doing so the overall plant diversity in the peat swamp forest of the area would be represented. Plant species encountered from the plot and during exploration were recorded and herbarium specimens were collected, treated with alcohol, then sent to Herbarium Bogoriense, Research and Development Center for Biology-LIPI in Bogor for further identification.

The similar methods (plot establishment and exploration) were also conducted in Tanjung Puting National Park in June 1998 and in Setia Alam Jaya area of Sebangau River in August 1999. Those measured plants from plots and encountered plants during the exploration in those areas were identified and noted to construct the present checklist of plant species in peat swamp forests of Central Kalimantan. The list of tree species was also improved from the secondary data of ecological studies reported from the areas, such as Shepherd *et al.* (1997), Mirmanto *et al.* (1999) and Suzuki *et al.* (1999).

Overview on the Observed Sites

Lahei Area

The explored sites were the peat swamp forests along the banks of Mangkutup River, a branch of Kapuas River. The areas is about 3-4 km east of the recent settlement Kampung Babugus, Desa Lahei, Kecamatan Mentagai, Kabupaten Kapuas, about 2 hours by car from Palangkaraya, the capital of Central Kalimantan Province. The forests along the road from Palangkaraya to Kampung Babugus were formed up by mainly heath (*kerangas*) forest type, while peat swamps forest only about 100-500 m depths along the riverbanks. Most of the heath forests along the road have been disturbed due to slash and burn cultivation and tree extraction. During the August 1997 field study, these disturbed heath forests along the road were almost entirely burnt, while the peat-swamp forests were remaining unburned until December 1999.

Semecarpus longifolius, *Buchanania sessifolia* (Anacardiaceae) and *Shorea balangeran* (Dipterocarpaceae) mainly dominated the canopy layer of peat swamp forests along the riverbank. *Vatica oblongifolia* (Dipterocarpaceae) was also a common species, though it rarely became canopy trees. While in the heath forest near by, the common species were consisted of *Cotylelobium lanceolatum, Dryobalanops rappa* (Dipterocarpaceae) and *Palaquium leiocarpum* (Sapotaceae, also distributed in peat swamp forests). Number of species, density and basal areas of trees with diameter at breast height more than 5 cm in a 1-ha plot in the areas were 70, 1557, and 45.6 m^2, respectively (see Suzuki *et al.*, 1998 for forest structure).

Tanjung Puting National Park Area

The exploration was made in the Leakey base camp areas, the upper stream of Sekonyer River, within the area of Tanjung Puting National Park. Geographically the area was located at 2°45’45.8” S and 111°56’41.4” E latitude and, at about 20 m altitude, with the annual precipitation about 2,400 mm, daily temperature ranged from 25 to 32°C, and mean air humidity was 90 %. The vegetation along the Sekonyer River up to the Leakey base camp have been disturbed due to the forest logging, only the forests in the upper stream were remain intact. Some peat swamp forests around Kumai Village areas in the river mouth and along the Sekonyer River were burnt during the extensive 1998-forest fire in Indonesia, following the long dry season period in 1997-1998.

The vegetation along the river from Kumai Village to the observed site were gradually changes, from mangrove dominated by *Rhizophora* spp., *Bruguiera* spp., *Cerbera manghas* and *Xylocarpus granatum* in the beach, changed into pure *Nypha fruticans* forest stand behind the mangrove, were dominated by *Glutta wallichii*, *Neoscortechinia philippinensis*, *Gonystylu*and swamp or peat swamp forests in the upper stream. The peat swamp forests of the area *s bancanus* and *Shorea fallax*. Other frequently observed species in the peat swamp forests of the areas were *Ganua motleyana, Ptychopyxis kingii* and *Baccaurea racemosa*, and also other species of Euphorbiaceae, Anacardiaceae, Annonaceae and Myrtaceae. Number of species, density and basal areas of trees with diameter at breast height more than 5 cm in a 1-ha plot in the areas were 141, 1653, and 46.8 m^2, respectively (see also Mirmanto *et al*., 1999 for structure and species composition of the forest).

Sebangau River Area

The exploration was made in the peat swamp forest of the Setia Alam Jaya logging concession, about 1-3 km from the logging base camp, of Sebangau River upper water catchments areas. Most of the explored sites have been disturbed due to the selective logging. The degree of forest disturbance varies along the explored site depending on the intensity of logging. Shepherd *et al.* (1997) had reported the forest vegetation and peat characteristic of the areas. The vegetation of the areas was divided, from the river edge to the watershed, into several types, such as: riverine, mixed peat swamp, low pole, medium pole and tall interior forests. Each forest type has distinct differences in forest structure and tree species composition (see Shepherd *et al.,* 1997 for the species composition in each forest type). Number of species, density and basal areas of trees with diameter at breast height more than 5 cm within 6 plots of 0.25-ha each established in the areas were 110, 4607 trees and 43.6 m^2, or about 90-100 species, 3071 trees and 29.1 m^2 per ha, respectively. The tree density of plot in Sebangau was almost twice of the similar forest type in either Lahei or Tanjung Puting National Park areas. These figures also indicated that the Sebangau forests were much more disturbed than other two areas and the forest were mainly constructed of small trees. Some of the most common species in Sebangau study site were *Palaquium leicocarpum, Syzygium (Eugenia) densinervium, Hydnocarpus* sp.*, Xanthophyllum palembanicum* and *Shorea guiso*. Those species were found often both in upper canopy and sub-canopy layers.

Plant Species in the Peat Swamp Forests of Central Kalimantan

Checklists of the plant species collected from these three locations of peat swamp forests in Central Kalimantan are presented on the List 1. In the present paper, more than 310 species (78 family) of plants have been listed from the peat swamp forests of the areas. The most diverse families in species numbers were Myrtaceae (4 genus, 35 species), Euphorbiaceae (12 genus, 29 species), Clusiaceae (2 genus, 20 species), Dipterocarpaceae (3 genus, 12 species) and Myristicaceae (4 genus, 11 species). Notes on the species distribution and commercial values were also given in the list.

Results of our observation indicated that there are differences in the dominant tree species among observed sites (see also Mirmanto *et al.*, 1999, Suzuki *et al.*, 1999, Yusuf, 1999). The dominant species in the peat swamp forest of Lahei was *Semecarpus longifolius* and *Buchanania sessifolia* (Anacardiaceae); in Tanjung Puting National Park was *Glutta wallichii* (Anacardiaceae) and *Neoscortechinia philippinensis* (Euphorbiaceae), while in Sebangau River was *Palaquium leicocarpum* (Sapotaceae) and *Syzygium densinervium* (Myrtaceae). The differences in the dominant tree species among observed sites might be related to the degree of forest disturbance, intensity of logging, peat depth and other edaphic factors.

The present listed species from Central Kalimanatn were mainly consisted of tree plants. Number of species of some families, such as: Myrtaceae, Euphorbiaceae and Clusiaceae in the Central were much more than have in North Kalimantan. Contrarily, number of species of shrubs, herbs, epiphytes and climbers, such as Araceae, Arecaceae, Asclepiadaceae, Orchidaceae and Rubiaceae in the present list from Central were much lower than of listed from North Kalimantan. As a whole, the total number of present list were smaller than of species listed from Sarawak and Brunei (376 species; Anderson, 1963), but it does not mean that the species diversity of peat swamp forest in Central less than of in North Kalimantan (Sarawak and Brunei). The present list was resulted from a few short time expeditions to Central Kalimantan; hence, increasing the intensity and observed areas will still may increase the number of species encountered. A special attention should be paid to shrubs, herbs, epiphytes and climbers when conducting other explorations in order to represent the flora of peat swamp forests in Central Kalimantan.

In the past, almost all of the forest areas in Central Kalimantan were allocated for timber extraction using selective logging techniques. As the consequences, the present remaining peat swamp forests (including protected areas) have ever been logged at least once before. Only few areas in the remote upper stream beyond apparent limit of logging activity remain relatively undisturbed. Even up to the present, the peat swamp forests within Tanjung Puting National Park for example, are still intensively disturbed due to illegal logging makes the forests fragile to a wild forest fires. The extensive forest destruction caused by either tree extraction, slash and burn cultivation and wild forest fires were among the reasons for decreasing the present biodiversity of peat swamp forests in Central Kalimantan.

Some logged commercial timber tree species from the peat swamp forests of Central Kalimantan were *Gonystylus bancanus, Agathis borneensis*, *Lophopetalum* spp., *Camnosperma* spp. *Calophyllum rhizoporum*, *Calophyllum hosei*, *Shorea* spp. *Dipterocarpus* spp. *Dialium maingayi*, *Koompassia malaccensis*, *Sindora leiocarpa*, *Cratoxylum* spp., *Scaphium macropodum* and some other species. Those species were still observed at present in the field, however in smaller size (less than 20 cm in *DBH*) although those species may naturally grown up to more than 40 cm *DBH* in an intact peat swamp forest. *Shorea albida* is the characteristic species of the peat swamp forests of Sarawak and Brunei, and its distribution extends from Pontianak in the West to Sarawak and Brunei in the North of Kalimantan. In certain areas of Sarawak, the species may form pure stand (Anderson 1963; Yamada 1995). The species so far was not encountered during our field observation, neither in an ecological study plots at Sambas, West Kalimantan (Siregar and Sambas 1999). However, we were not sure yet whether the species not distributed in the peat swamp forests of Central Kalimantan.

As has been reported by many researchers, the diversity of tree plants in peat swamp forest areas was not as high as that of in lowland mixed dipterocarp forests. The tree diversity of peat swamp forests in some areas of Central Kalimantan was about 70, 90-100 and 141 species per 1-ha plot in Lahei, Sebangau River and Tanjung Puting National Park areas, respectively. The tree diversity of other peat swamp forest study sites were 86 species in a 1.05-ha plot at Mensemat-Sambas, West Kalimantan (Siregar and Sambas, 1999) and 61 species in a 1-ha plot at Nyaru Menteng-Palangkaraya, Central Kalimantan (Saribi and Riswan, 1977). Diversity of tree species per ha in peat swamp forest was much lower than of a mixed dipterocarp forest (270-314 species) in West Kalimantan (Suzuki, 1999). The tree diversity of peat swamp forest was about equal to that of heath forest type (70 species) in Kalimantan (Suzuki *et al.*, 1999) and to that of sub-mountain forest (115 species), but higher than tree diversity of mountain forest (45 species) of West Java area (Suzuki *et al.*, 1997). Nevertheless, we still need more study for understanding the biodiversity of peat swamp forests, and their important on maintaining carbon sink and water balance.

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List 1. Checklist of the plant species collected from peat swamp forest areas in Central Kalimantan. Numbers following family names are the number of genera (species) distributed in Sarawak and Brunei, after Anderson (1963).

Aceraceae
Acer niveum (*laurinum* Hassk.)

Anacardiaceae 7(11)
Buchanania arborescens (Bl.) Bl. The third most dominant species in the study plot of Lahei area (Suzuki *et al.* 1999), also found in Sarawak.
Camnosperma coriaceum (Jack.) Hall. f., commercial timber tree species, also in Sarawak, Malay Peninsula and Thailand.
Glutta wallichii (Hook. f.) Ding Hou. Is the first most dominant species in the study plot of Tanjung Puting National Park (Mirmanto *et al.*, 1999).
Mangifera quadrifida Jack
Parishia insignis Hook. f., also in Malay Peninsula and Thailand.
Semecarpus longifolius Bl. The second most dominant species in the study plot of Lahei area (Suzuki *et al.*, 1999).

Anisophyllaceae
Combretocarpus rotundatus (Miq.) Danser, also in Sarawak.

Annonaceae 12 (17)
Melodorum kentii (Bl.) Miq.
Mezzettia havilandii (Boerl.) Ridley
Mezzetia leptopoda (Hook. f. & Thomson) Oliv., also in Sarawak.
Phaeanthus crassipetalus
Polyalthia glauca (Hassk.) Boerl., also in Sarawak, Malay Peninsula and Thailand.
Polyalthia hypoleuca Hook. f. & Thomson, also in Sarawak and Malay Peninsula.
Polyalthia lateriflora King., also in Malay Peninsula.
Polyalthia sumatrana Miq. (Kurz.)
Xylopia caudata Hook. f. & Thomson
Xylopia fusca Maingay, also in Sarawak, Malay Peninsula and Thailand.

Apocynaceae 5(6)
Alstonia ngustiloba Wall. Very common in open area and riverside at Tanjung Puting National Park.
Alyxia reinwardtii Bl.
Chilocarpus tortulosa (Baill.) Mgf
Dyera costulata (Miq.) Hook. f.
Dyera eximia
Dyera lowii Hook. f., also in Sarawak.
Urceola brachysepala Hook. f. also in Sarawak.

Aquifoliaceae
Ilex wallichii
Ilex cymosa Bl. also in Thailand.

Araceae 9(9)
Aglaonema simplex

Araucariaceae
Agathis borneensis Warb., a commercial timber tree species, have been planted for enrichment planting.

Arecaceae 7(7)
Pinanga sp.

Asclepiadaceae 2(6)
Hoya sp.

Asteraceae
Vernonia arborea Buch.-Ham.

Bonnetiaceae
Ploiarium alternifolium (Vahl.) Melchior, also in Sarawak.

Burseraceae 2(6)
Canarium hirsutum Willd.
Dacryodes rugosa (Bl.) H. J. Lam
Santiria apiculata A. W. Benn.
Santiria griffithii (Hook. F.) Engl.
Santiria laevigata Bl., also in Malay Peninsula.
Santiria oblongifolia Bl., also in Malay Peninsula.
Santiria rubiginosa Bl., also in Sarawak and Malay Peninsula.

Casuarinaceae 1(1)
Gymnostoma sumatranum (Jungh. ex. de Vriese) L. A. S. Johnson

Celastraceae 3(4)
Bhesa paniculata Arn., also in Sarawak and Malay Peninsula.
Lophopetalum sp., a commercial timber tree species.

Clusiaceae 3(16)
Calophyllum biflorum M.R. Handerson & Wyatt Smith, a commercial timber tree species.
Calophyllum fragrans Ridley, also in Sarawak.
Calophyllum hosei Ridley, a commercial timber tree species.
Calophyllum inophyllum King, a commercial timber tree species.
Calophyllum lowii
Calophyllum rhizophorum Boerl. & Koord., commercial timber tree species, also in Sarawak.
Calophyllum sclerophyllum Vesque, a commercial timber tree species.
Calophyllum soulattri Burm. f., also in Sarawak and Malay Peninsula.
Callophyllum teysmannii Miq., a commercial timber tree species.
Calophyllum sp.
Cratoxylum arborescens (Vahl.) Bl., a commercial timber tree species.
Cratoxylum glaucum Korth., a commercial timber tree species.
Garcinia apetala
Garcinia bancana Miq., also in Malay Peninsula and Sarawak.
Garcinia cuneifolia
Garcinia cuspidata, also in Sarawak.
Garcinia dioica Bl.
Garcinia lateriflora Bl.
Garcinia maingayi Hook. F.
Garcinia mangostana L.
Garcinia penangiana
Garcinia rostrata, also in Malay Peninsula.
Garcinia vidua Ridley, also in Sarwak.

Commelinaceae
Forrestia molissima

Connaraceae 3(3)
Cnestis platantha Driff.

Cornaceae 1(1)
Mastixia trichotoma Bl.

Crypteroniaceae
Dactylocladus stenostachys Oliv., also in Sarwak.

Cucurbitaceae 1(1)
Momordia charantia L.
Trichosanthes sp.1. New species recorded from Lahei area
Trichosanthes sp.2

Cyperaceae 2(2)
Fimbristylis pauciflorum. Very common in open peat-land area and as indicator of peat-land
Hypolythrum sp. Very common in open peat-land area and as indicator of peat-land
Scleria sp.
Thoracostachyum bancanum (Miq.) Kurz, also in Sarawak.

Daphniphyllaceae
Daphniphyllum laurinum (Benth.) Baill.

Dilleniaceae 2(2)
Dillenia pulchella (Jack) Gilg., also in Sarawak, Malay Peninsula and Thailand.
Dillenia suffruticosa (Griff.) Mart. Common small tree in the open area and river side

Dipterocarpaceae 7(15)
Dipterocarpus coriaceus V. Sl., also in Sarawak.
Shorea balangeran (Korth.) Burk. The first most dominant species in the study plot of Lahei area (Suzuki *et al*., 1999).
Shorea fallax Meijer. Is the forth most dominant species in the study plot of Tanjung Puting National Park (Mirmanto *et al*., 1999).
Shorea guiso (Blanco) Bl., a commercial timber tree species.
Shorea leprosula Miq., also in Malay Peninsula.
Shorea ovalis (Korth.) Bl.
Shorea parvifolia Dyer, also common in open dry-land forest
Shorea platycarpa Helm., also in Malay Peninsula.
Shorea teysmanniana Dyer ex Brandis, also in Sarawak.
Shorea sp.
Vatica mangachopai Blanco, also in Sarwak.
Vatica rassak (Korth.) Bl.

Ebenaceae 1(4)
Diospyros buxifolia (Bl.) Hiern.
Diospyros clavipes
Diospyros dajakensis
Diospyros evena Bakh., also in Sarawak.
Diospyros fuberulata
Diospyros hermaphroditica (Zoll.) Bakh.
Diospyros maritima Bl.
*Diospyros pendula*Hasselt ex Hassk.
Diospyros polyalthoides Korth ex Hiern.
Diospyros pseudomalabarica Bakh., also in Sarawak.

Diospyros siamang Bakh., also in Malay Peninsula and Sarwak.
Diospyros sp.

Elaeocarpaceae
*Elaeocarpus angustifolius*Bl.
Elaeocarpus glaber Bl.
Elaeocarpus griffithii (Wight) A. Gray, also in Malay Peninsula.
Elaeocarpus longipetiolatus
Elaeocarpus mastersii King, also in Malay Peninsula.
Elaeocarpus ovalis
Elaeocarpus petiolatus (Jack) Wallich
Elaeocarpus winklerii

Euphorbiaceae 11(17)
Antidesma montanum Bl., also in Malay Peninsula.
Antidesma coriaceum Tul, also in Sarawak.
Aporosa falcifera Hook. f.
Aporosa frutescens Bl.
Aporosa lucida
Baccaurea bracteata Muell. Arg., also in Sarawak, Malay Peninsula and Thailand.
Baccaurea javanica (Bl.) Muell. Arg.
Baccaurea kunstleri King
Baccaurea macrocarpa (Miq.) Muell. Arg.
Baccaurea motleyana (Muell. Arg.) Muell. Arg.
Baccaurea racemosa (Reinw. ex Bl.) Muell. Arg.
Blumeodendron tokbrai (Bl.) J. J. Sm., also in Malay Peninsula and Sarwak.
Breynia sp.
Cnesmone sp. Edible liana, have been domesticated
Glochidion littorale
Glochidion rubrum Bl.
Glochidion superbum Baill.
Macaranga amissa Airy Shaw
Macaranga caladifolia Becc., also in Sarawak.
Macaranga conifera (Zoll.) Muell. Arg.
Macaranga puncticulata, also in Sarawak and Malay Peninsula.
Macaranga tanarius (L.) Muell. Arg.
Macaranga triloba (Bl.) Muell. Arg.
Neoscortechinia kingii (Hk. f.) Pax et K. Hoffm., also in Sarawak.
Neoscortechinia nicobarica (Hk. f.) Pax et K. Hoffm.
Neoscortechinia philippinensis (Merr.) V. Welzen. Is the second most dominant species in the study plot of Tanjung Puting National Park (Mirmanto *et al*., 1999).
Ostodes macrophylla
Pimelodendron papaverioides J. J. Smith, also in Malay Peninsula.
Ptychopyxis kingii Ridley

Fabaceae 8(8)
Adenanthera pavonina L., also in Sarawak.
Archidendron microcarpum (Benth.) Nielsen, a commercial timber tree species.
Dialium maingayi Baker
Dialium sp.
Koompassia malaccensis Maingayi ex Benth., commercial timber tree species, also in Sarawak and Malay Peninsula.
Miletia sp.
Sindora leiocarpa Backer ex K. Heyne, commercial timber tree species, also in Sarawak.

Fagaceae 2(5)
Castanopsis foxworthyi Schottky ex Winkler, also in Sarawak.
Castanopsis sp.
Lithocarpus dasystachyus (Miq.) Rehd., also in Sarawak.
Lithocarpus sp.

Flacourtiaceae 2(2)
Hydnocarpus sp.

Hypericaceae 1(2)
Cratoxylum arborescens (Vahl) Bl., commercial timber tree species, also in Malay Peninsula and Sarawak.
Cratoxylum glaucum Korth., commercial timber tree species, also in Sarawak.

Icacinaceae
Platea excelsa Bl., also in Sarawak.
*Stemonurus scorpioides*Becc.

Lauraceae 9(18)
Alseodaphne coriacea Kosterm.
Cinnamomum sintoc Bl.
Litsea accendens
Litsea euneura
Litsea paludosa
Litsea resinosa Bl., also in Malay Peninsula, Sarawak and Thailand.
Litsea rufo-fusca
Litsea turfosa Kosterm.

Lecythidaceae
Barringtonia reticulata
Barringtonia sp.

Leeaceae
*Leea indica (*Burm.f.) Merr.

Linaceae 2(2)
Ctenolophon parvifolius Oliv., also in Sarawak

Loganiaceae 1(2)
Fagraea racemosa Wall., also in Sarawak.

Loranthaceae 3(3)
Helixanthera cylindrica (Jack) Danser

Magnoliaceae 1(1)
Jasminum pubescens Willd.
Michelia sp.

Melastomataceae 4(8)
Astronia spectabilis Bl.

Meliaceae 3(3)
Aglaia rubiginosa (Hiern) Pannel, also in Malay Peninsula.
Aglaia odoratissima Bl.
Aglaia tomentosa Teijsm. & Binnend.
Dysoxylum arborescens (Bl.) Miq.
Dysoxylum densiflorum (Bl.) Miq.
Dysoxylum alliaceum (Bl.) Bl.
Sandoricum emarginatum Hiern, also in Sarawak.
Sandoricum koetjape (Burm. f.) Mern

Moraceae 3(27)
Artocarpus mangiayi Hook. f., also in Malay Peninsula.
Artocarpus sp.
Ficus deltoidea Jack
Ficus deltoidea var *intermedia*
Ficus deltoidea Jack var. *motleyana* (Miq.) Burck., also in Sarawak.
Ficus sumatrana Miq., also in Sarawak.
Ficus sundaica Bl., also in Sarawak.
Ficus sp.

Myristicaceae 4(7)
Gymnacranthera eugeniifolia Sincl., also in Malay Peninsula and Sarawak.
Horsfieldia crassifolia (Hk. f. *et* Th.) Warb., also in Malay Peninsula, Sarawak and Thailand.
Horsfieldia glabra (Bl.) Warb.
Horsfieldia subglobosa (Miq.) Warb.
Knema glauca (Bl.) Warb.
Knema intermedia (Bl.) Warb., also in Sarawak and Malay Peninsula.
Knema cinera (Poir.) Warb.
Knema laurina (Bl.) Warb.
Myristica elliptica Wall., also in Thailand.
Myristica lowiana King, also in Sarawak and Malay Peninsula.
Myristica tomentosa Thunb.

Myrsinaceae 5(11)
Ardisia laevigata
Maesa ramentacea (Roxb.) Wall
Embelia ribes Burm.

Myrtaceae 3(16)
Rhodamnia cinerea Jack
Rhodomyrtus tomentosa (Aiton) Hassk.
Syzygium aquaea Burm.
Syzygium castaneum
Syzygium caudatilimba
Syzygium cerina M.R. Henderson, also in Sarawak.
Syzygium cuprea Koord. & Valeton
Syzygium claviflora Roxb., also in Malay Peninsula.
Syzygium densinervium
Syzygium ecostulata
Syzygium fusiformes (Duthie) Merr & Perry.
Syzygium garcinifolia King.
Syzygium grandis Wight, also in Malay Peninsula and Thailand.
Syzygium havilandii Merr., also in Sarawak.
Syzygium incarnata Elm., also in Sarawak.
Syzygium jamboloides K. et V.
Syzygium leucoxylon (Korth.) Miq., also in Sarawak.
Syzygium lineata (Bl.) Duthie, also in Sarawak.
Syzygium multibracteata
Syzygium napiformis K. & V., also in Thailand.
Syzygium nemastrina M. R. Hend., also in Sarawak.
Syzygium oblata Roxb., also in Thailand.
Syzygium ochneocarpa Merr.
Syzygium opaca Poir.
Syzygium palembanica (Miq.) Merr.
Syzygium perpuncticulata
Syzygium polyantha
Syzygium spicata Lamk., also in Sarawak, Malay Peninsula and Thailand.
Syzygium subdecussata Wallich ex Duthie
Syzygium virens (Bl.) Koord. & Valeton.
Syzygium sp.
Tristania bakhuizenia Backer.
Tristania grandifolia Ridley, also in Sarawak.
Tristania obovata R. Br., also in Sarawak.
*Tristania whiteana*Griffith.

Nepenthaceae 1(5)
Nepenthes ampullaria Jack.,also in Sarawak
Nepenthes gracilis Korth., also in Sarawak.

Nepenthes mirabilis
Nepenthes rafflesiana Jack., also in Sarawak.

Ochnaceae 3(4)
Euthemis leucocarpa Jack., also in Sarawak.

Olacaceae 4(5).
Strombosia ceylanica Gardner

Oleaceae 2(4)
Chionanthus ramiflorus Roxb.

Orchidaceae 12(17)
Bulbophyllum acuminatum
Dendrobium destichophyllum
Eria pulchella
Dipodium sp.

Pandanaceae 1(4)
Pandanus sp., also in Sarawak.
Freycinetia sp., also in Sarawak.

Podocarpaceae
Dacrydium pectinatum de Lauben f.

Polygalaceae 2(4)
Xanthophyllum amoenum Chodat, also in Sarawak.
Xanthophyllum eurhynchum Miq.
Xanthophyllum obscurum A.W. Benn.
Xanthophyllum palembanicum
Xanthophyllum sp.

Proteaceae
Helicia excelsa

Rhizophoraceae 2(2)
Carallia brachiata (Lour.) Merr., also in Sarawak.
Combretocarpus rotundatus (Miq.) Dans., also in Sarawak.
Gynotroches axillaris Bl., also in Malay Peninsula and Sarawak.

Rocaceae 2(3)
Parastemon urophyllum A. DC., also in Sarawak and Malay Peninsula.
Parastemon spicatum Ridley, also in Sarawak.
Prunus arborea (Bl.) Kalkman var. *arborea*, also in Malay Peninsula.

Rubiaceae 18(22)
Gaertnera vaginans (DC) Merr.
Gardenia pterocalyx Val. , also in Sarawak.
Lucinaea montana Korth.
Psychotria laxiflora Bl.
Psychotria viridiflora Reinw.
Randia sp.
Tarrena fragrans (Bl.) Koord. And Val., also in Sarawak.
Timonius flavescens (Jack) Backer
Timonius sp.
Uncaria sp.

Rutaceae 2(3)
Acronichya laurifolia
Acronychia porteri Hook. f.
Evodia accedens Bl.

Sapindaceae 3(4)
Lepisanthes amoena (Hask.) Leenh.
Nephelium sp.
Pometia pinnata Forst., also in Sarawak.

Sapotaceae 4(12)
Ganua motleyana Pierre., also in Sarawak, Malay Peninsula and Thailand.
Madhuca sp.
Palaquium cochleariifolium P. van Royen, also in Sarawak.
Palaquium leiocarpum Boerl, also in Sarawak.
Palaquium ridleyi King & Gamble, also in Sarawak and Malay Peninsula.
Planchonella maingayi (C. B. Clarke) P. V. Royen, also in Malay Peninsula.
Planchonella obovata

Sterculiaceae 2(4)
Scaphium macropodum (Miq.) Beumee ex K. Heyne, commercial timber tree species, also in Sarawak.
Sterculia bicolor Masters, commercial timber tree species, also in Sarawak, Malay Peninsula and Thailand.

Symplocaceae
Symplocos celastrifolia Griff. ex Clarke

Tetrameristicaceae
Tetramerista glabra Miq., a commercial timber tree species.

Theaceae 2(4)
Adinandra dumosa Jack
Eurya acuminata DC
Haemocharis ovalis (Chois) O. Ktze.
Ploiarium alternifolium (Vahl) Melchior
Schima wallichii (DC) Korth.
Ternstroemia coriaceae R. Scheffer.

Ternstroemia magnifica Stapf ex Ridley, also in Sarawak.

Thymelaeaceae 2(4)
Gonystylus bancanus Miq., a commercial timber tree species. The species is the third most dominant in the study plot of Tanjung Puting National Park (Mirmanto *et al*., 1999), also in peat swamp of Sarawak and Malay Peninsula.
Wilestroemia androsaemiflora DC

Tiliaceae 2(5)
Microcos sp.

Ulmaceae
Gironniera subaequalis Planch.
Trema orientalis

Urticaceae 1(2)
Poikilospermum suaveolens (Bl.) Merr., also in Sarawak.

Verbenaceae 3(3)
Callicarpa longifolia Lam.
Vitex pinnata L.

Vitaceae
Cissus javana
Ampelocissus thyrsiflora Planch., also in Sarawak.

Ferns:
Aspleniaceae
Asplenium sp.
Trichomanes sp.

Blechnaceae
Stenoclaena palustris

Davalliaceae
Humata angustata

Hymenophyllaceae
Hymenophyllum sp.

Oleandraceae
Nephrolepis biserrata Schott.

Polypodiaceae
Platycerium sp.

Pteridaceae
Pteris sp.

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Plants Diversity of Peat Swamp Forest in Riau Province, Sumatra

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Abstract

Studies on a population density of trees in the peat swamp forest in Desa Plintung, Desa Sumber Jaya, and Desa Pulau Muda all in Riau Province Sumatra using transect line method of 1,000 × 20 m, 2,000 × 20 m, and 4,000 × 20 m respectively had been conducted. Shrubs and herbs were observed qualitatively by their present. The area is a wide flat about 10 to 20 km from east coast of Sumatra which lay at about 5-15 m above sea level. In total 131 species of plants had been recorded, namely 78 species in Desa Plintung, 75 species in Desa Sumber Jaya, and 68 species in Desa Pulau Muda. Five trees species which have high relative density 14% or more which mean the tree species consists of one to three trees per hectar are: bintangur (*Callophyllum soulattri*), balam (*Palaquium hexandrum*), meranti bako (*Shorea uliginosa*), terentang (*Camnosperma coriaceum*), and ramin (*Gonystylus macrophyllus*). Shrubs are dominated by *Cyrtostachys lakka*, *Maccaranga diepenhortii*, *Uncaria glabrata*, *Santiria laevigata*, *Eleiodoxa conferta*, *Glochidion rubrum*, and *Macaranga triloba*. Herbs are dominated by bakung hutan (*Crinum asiaticum*), paku resam (*Glechinia linearis*), *Lygodium* sp., *Nephenthes ampularia*, *Asplenium nidus*, *Nephrolepis bisserata*, *Nephrolepis exceltata,* and *Schleria laevis*.

Comparison of the tree plants of the peat swamp forest above to other observation which had been done along time ago in 1976 by Anderson in three localities in Sumatra revealed that the tree species diversity of the peat forest is very high as it is shown that from 53 trees species in the present study and 22 trees species reported by Anderson, only five tree species occur in the previous ones, the other eleven are not found in the present study. The number of tree species which occur in both peat forest in Sumatra, Borneo, and Sulawesi are also very few. Eight tree species are both occurred in Sumatra and Borneo namely Shorea uliginosa, *Gonystylus bancanus*, *Dyera lowii, Mangifera havilandii*, *Mezzettia leptopoda*, *Garcinia rostrata*, *Palaquium warsufolium*, and *P. alternifolium*. Only *Calophyllum soulattri*, *Dyospyros malabarica*, and *Livistona rotundifolia* occur in both Sumatra and Sulawesi's peat forest.

Some trees of peat swamp forest are recorded as rare plants based on the IUCN Plant Red List Categories 1994, there are *Ailanthus integrifolia* (Simaroubaceae) and *Cyrtostachys lakka*. The latter are rare in Sumatra, not threatened in Sarawak but endangered to extinct from the wild in Brunei and Singapore.

Keywords: Plant diversity, peat swamp forest, population density, conservation status

Introduction

The peat swamp forest in Indonesia is about 6.53 million ha (Riswan, 1998) distributed in Sumatra, Java, Kalimantan, Sulawesi, Moluccas, and Irian Jaya. In Riau Province of Sumatra, the size of peat swamp forest is about 383,750 ha. The swamp peat forest might cover about 40% of the main land province. However, information on the flora of the peat swamp forest so far is very few. On the other hand it is very important to understand the role of the flora and all other components of biotic and non biotic of the area before people could utilize the peat swamp forest for the need of an economic development. In fact, it has been planned that many of the swampy peat forest areas of the province will be converted to particularly an oil palm plantation. Before the execution of this conversion, it is important to considered that the conversion should give a maximum benefit in the long run particularly for the people around the area which means will result a very little damaged to the environment including to the habitat of the flora and fauna. To evaluate the existing flora and fauna, hence in this case it is important to inventory a plant population before the peat swamp forests are gone. That means a study of plant diversity is needed to be conducted.

The present study of the plant diversity of the swamp peat forest in the province was actually done in 1996 by coincidence when the authors were invited by the Ministry of Forestry to participate in a team with some related specialists to study a conservation and biodiversity in the area to examine whether there is any endangered and rare plants to be protected, what species is it belong to, how big is the population, and how do we might be protected and utilize the swampy peat forest area based on the sustainable manner.

Materials and Methods

The areas of study located at an ombrogen swamp peat forest of the Riau Province on a wide flat about 10 - 20 km from east coast of Sumatra which lay about 5 - 15 m above sea level. The peat layer is about 2.5 to 3 m deep from the surface ground. To study of the plant diversity, three observed peat swamp forest sites belonging to a forest concession area of a timber company were chosen. The temporary line transect plots were set up namely in Desa Plintung of 101°33'E - 1°12'N with a transect plot of 1,000 by 20 m, Desa Sumber Jaya of 101°47'E - 1°03'N with the transect plot of 2,000 by 20 m; and Desa Pulau Muda of 103°01'E - 0°40'S with the transect plot of 3,000 by 20 m. The transect plots were preferably followed the existing foot paths. Desa Plintung has the best quality of peat which consists of mature saphric at the above layer and hemic at the bottom layer; whilst the peat in Desa Sumber Jaya considered moderate and the peat in Desa Pulau Muda is still very young (Anonym, 1997). To facilitate during conducting the observation, the transect plot were divided into tree subplots of 10 by 10 m for tree observation, in each of the tree subplot a 5 by 5 m shrub subplot was set up to study of liana and shrub; and in each shrub subplot, a 1 by 1 m herb subplot was also set up for the study of herbs and tree seedlings. Using those plots above, the relative trees density were accounted, as well as for shrubs and herbs. Tree is the plant which have stem more than 10 cm in diameter, usually it has stem of more than 15 m tall. Shrub has a stem of 2.0-9.9 cm in diameter, and about 5-7 m tall; and herbs have mostly a fleshy stem of less than 1.9 cm and plant with up to 3 m tall. Voucher plant specimens were collected particularly for a determination in the Herbarium Bogoriense. After the specimens had been determined than the analysis of the tree plant relative density was conducted. The results had been compare to the floristic data from peat swamp forest of Sumatra (Anderson, 1976a, b), Borneo (Anderson, 1983), and Sulawesi (Anonym, 1978).

Results and Discussion

The number of tree species in Desa Plintung is 45, in Desa Sumber Jaya 28, and in Desa Pulau Muda is 25, the total number is 53 (Table 1). Based on their similarity on the present in the observed sites, the tree species may be divided on seven groups. Group 1 consisted of 15 species which were present on all of the three observed sites. The dominant species in the group were *Calophyllum soulattri* which had three trees in a

Table 1. List of number of trees from the three observed sites

	P	J	M	T
GROUP 1:				
Calophyllum soulattri	16	12	14	42
Palaquium hexandrum	12	8	1	31
Shroea uliginosa	6	7	3	16
Cannosperma coriacea	4	4	6	14
Gonystylus bancanus	5	3	4	12
Gonystylus macrophyllus	4	5	3	12
Palaquium burckii	6	4	2	12
Shorea teysmanniana	4	2	4	10
Mangifera griffithii	4	3	2	9
Diospyros maritima	2	4	2	8
Eugenia claviflora	2	2	2	6
Knema laurina	2	2	1	5
Stemonurus scorpioides	2	1	2	5
Tetramerista glabra	1	2	2	5
Litsea grandis	1	1	2	4
GROUP 2:				
Aglaia odorata	4	0	0	4
Pandanus sp.	4	0	0	4
*Garcinia rostrata**	3	0	0	3
Alseodaphne oblanceolata	2	0	0	2
Diospyros malabarica	2	0	0	2
Eugenia bankensis	2	0	0	2
Actinodaphne macrophylla	1	0	0	1
Canarium denticulatum	1	0	0	1
Dacryodes rostrata	1	0	0	1
Diospyros hermaphroditica	1	0	0	1
Drypetes sp.	1	0	0	1
Gomphia serrata	1	0	0	1
Labisia pumila	1	0	0	1
Palaquium walsurifolium	1	0	0	1
Polyalthia laterifolia	1	0	0	1
Shorea sp. 1	1	0	0	1
Shorea sp. 2	1	0	0	1
GROUP 3:				
Ailanthus integrifolia	0	2	0	2
Palaquium obovatum	0	2	0	2
Parastemon urophyllum	0	2	0	2
Diospyros sp	0	1	0	1
GROUP 4:				
Exocarpus latifolius	0	0	2	2
Glochidion zeylanicum	0	0	2	2

Table 1. Continued.

	P	J	M	T
GROUP 5:				
Dillenia excelsa	3	2	0	5
Antidesma phanerophlebium	2	1	0	3
Garcinia nigrolineata	1	2	0	3
Livistona rotundifolia	2	1	0	3
Dillenia pulchella	1	1	0	2
Elaeocarpus glaber	1	1	0	2
Xanthophyllum palembanicum	1	1	0	2
GROUP 6:				
Ficus sp. 1	5	0	4	9
Ficus sp. 2	5	0	2	7
Gymnacrantha forbesii	2	0	4	6
Acronychya porteri	1	0	1	2
Knema cinerea	1	0	1	2
Knema intermemdia	1	0	1	2
GROUP 7:				
Nothophoebe coriacea	0	2	2	4
Garcinia parviflora	0	2	1	3

Note: P = Desa Plintung, J = Desa Sumber Jaya, M = Desa Pulau Muda , T = Total tree number

hectar, followed by *Palaquium hexandrum* which had two trees in a hectar, and *Shorea uliginosa* which had one tree in a hectar. Group 2 consisted of 17 species which only occurred in Desa Plintung; the dominant species in the group was *Aglaia odorata*, the tree *Pandanus* sp., and *Garcinia rostrata*, each consisted three to four trees in the 12 ha. According to Anderson (1976b) the latter species is found as well in a heath forest in Sumatra. Group 3 consisted of four species which were only found in Desa Sumber Jaya, namely *Ailanthus integrifolia*, *Palaquium odoratum*, *Parastemon urophyllum*, and *Diospyros* sp. Group 4 consisted of two species which were only found in Desa Pulau Muda namely *Exocarpus laltifolius* and *Glochidion zeylanicum*. Group 5 consisted of seven species which occurred in both Desa Plintung and Desa Sumber Jaya. The dominant species were *Dillenia excelsa*, *Antidesma phanerophlebium*, *Garcinia nigrolineata*, and *Livistona rotundifolia*, each had three to five trees in the 12 ha. Group 6 consisted of six species which occurred in both Desa Plintung and Desa Pulau Muda; the dominant species were *Ficus* sp. 1, *Ficus* sp. 2, and *Gymnacrantha forbesii* each consisted of between six to nine trees in the 12 ha. Group 7 consisted of two species which were presented in both Desa Sumber Jaya and Desa Pulau Muda namely *Nothophoebe coriacea* and *Garcinia parviflora*. Group 1 shows thought there are similarity but species diversity in each sites are quite high particularly as show in the Group 2 where Desa Plintung had very diverse and high number of tree species. These will considered that more sites may be observed, the more diverse tree species may be expected.

Fifteen dominant tree species of the Group 1 as cited in Table 2, based on the relative density (%) may be figured as follows: *Calophyllum soulattri* (42.80), *Palaquium hexandra* (36.60), *Shorea uliginosa* (17.30), *Cannosperma coriacea* (16.70), *Gonystylus macrophyllus* (14.00), *G. bancanus* (13.75), *Palaquium burckii* (13.30), *Shorea teymaniana* (11.70), *Diospyros maritima* (10.10), *Mangifera griffithii* (8.45), *Eugenia claviflora* (6.60), *Tetramerista glabra* (5.80), *Knema laurina* (5.35), *Litsea grandis* (4.55), and *Stemonurus scorpiodes* (3.20).

The trees diameter in Desa Pintung were in general much bigger compare to the trees diameter in Desa Pulau Muda, but the total fifteen trees density (%) in Desa Pulau Muda (74.05) is much higher compare to the trees density in Desa Plintung (57.60). The bigger tree diameter in Desa Plintung may be correlated to the much mature of the peat compare to Desa Pulau Muda which has much young peat land. These evidence is supported the result of study by Rieley *et al*. (1998) which mentioned that the structure and composition of tree species is depended on the type and composition of peat layer.

The tree species showed three layers canopy, the first layer canopy of 30-40 m tall consisted of bintangur (*Calophyllum soulattri*), meranti anak (*Shorea teysmanniana*), meranti bako (*Shorea uliginosa*), and suntai (*Palaquium burckii*). The second layer canopy of 20 - 30 m tall consisted of ramin (*Gonystylus bancanus* and *G. macrophyllus*), terentang (*Cannosperma coriacea*), gerunggang (*Cratoxylum arborescens*), and kelumpang (*Litsea grandis*). The third layer canopy of 10-20 m tall consisted of kelat putih (*Eugenia claviflora*), *E. fascigiata*, manggis hutan (*Garcinia nigrolineata*), pasir-pasir (*Stemonurus scorpioides*), tengek burung (*Acronychya porteri*), *Ilex macrophylla*, and mempelam (*Mangifera griffithii*).

Table 2. List of 15 dominant trees and their relative density (%) in the observed sites

	P	J	M	T
Calophyllum soulattri	12.80	15.00	15.00	42.80
Palaquium hexandrum	9.60	12.00	15.00	36.60
Shorea uliginosa	4.80	8.75	3.75	17.30
Cannosperma coriacea	3.20	6.00	7.50	16.70
Gonystylus macrophyllus	4.00	6.25	3.75	14.00
Gonystylus bancanus	4.00	3.75	6.00	13.75
Palaquium burckii	4.80	6.00	2.50	13.30
Shorea teysmaniana	3.20	2.50	6.00	11.70
Diospyros maritima	1.60	6.00	2.50	10.10
Mangifera griffithii	3.20	3.75	2.50	8.45
Eugenia claviflora	1.60	2.50	2.50	6.60
Tetramerista glabra	0.80	2.50	2.50	5.80
Knema laurina	1.60	2.50	1.25	5.35
Litsea grandis	0.80	1.25	2.50	4.55
Stemonurus scorpioides	1.60	0.80	0.80	3.20
S	57.60	77.55	74.05	

Note: Sites P = Desa Plintung, J = Desa Sumber Jaya, M = Desa Pulau Muda,
T = Total density relative of the species (%), S = Total relative density of 15 species (%)

Compared to a previous report by Anderson (1976a) who studied in three other localities in Sumatra revealed that the trees composition is very much different. From 16 trees species mentioned by Anderson (1976a) only five species are present in our observed sites namely *Palaquium burckii*, *Shorea uliginosa*, *Gonystylus bancanus*, *Cannosperma coriacea*, and *Shorea teysmaniana*. Other 11 trees species are not present in our study. This evidence again indicates that other tree species may be expected from different places of the peat swamp forest (see Table 3). Based on the number of tree species of the study namely 53 plus 11 species as an addition of the previous study by Anderson (1976a) then the total tree number of species is become 64.

Compare to other inventory tree species of Borneo (16 species), the trees in Sumatra are very much more in number of species. So far only eight species are also found in the present study namely *Shorea uliginosa*, *Gonystylus bancanus*, *Dyera lowii*, *Mangifera havilandii*, *Palaquium walsurifolium*, *Mezzettia leptopoda*, *Garcinia rostrata*, and *Palaquium alternifolium* (Table 3). From Celebes only three species are recorded namely *Calophyllum soulattri*, *Diospyros malabarica*, and *Livistona rotundifolia*. Those number of tree species indicate that the diversity of the tree species in Sumatra is very high (64 species), followed by Borneo (eight species) and Sulawesi (three species). The small tree species diversity in Borneo and Celebes might be due to lack of published data, we believe that the species tree diversity in Borneo and Celebes will be higher than the number figured above.

Table 3a. List of tree composition in Sumatra, Borneo, and Sulawesi

	P	A	B	S
Palaquium hexandrum	+	0	0	0
Gonystylus macrophyllus	+	0	0	0
Mangifera griffithii	+	0	0	0
Palaquium burckii	+	+	0	0
Cannosperma coriacea	+	+	0	0
Shorea teysmaniana	+	+	0	0
Shorea uliginosa	+	+	+	0
Gonystylus bancanus	+	+	+	0
Diospyros malabarica	+	0	0	+
Livistona rotundifolia	+	0	0	+
Calophyllum soulattri	+	0	0	+
Garcinia rostrata	+	0	+	0
Artocarpus rigidus	0	+	0	0
Durio carinatus	0	+	0	0
Eugenia elliptica	0	+	0	0
Shorea platycarpa	0	+	0	0
Strombosia javanica	0	+	0	0
*Tristania obovata**	0	+	0	0
Dyera lowii	0	+	+	0
Mangifera havilandii	0	+	+	0
Palaquium walsurifolium	0	+	+	0
Mezzettia leptopoda	0	+	+	0
Palaquium alternifolium	0	+	+	0

P= Trees of Sumatra from the present study; A= Trees of Sumatra after Anderson (1976a), B= Trees of Borneo after Anderson (1976b), S= Trees of Celebes after Anonym (1978) and Susanto (1984).

Table 3b. List of trees composition in Sumatra, Borneo, and Sulawesi

	PA	B	S
Artocarpus rigidus	+	0	0
Cannosperma coriacea	+	0	0
Durio carinatus	+	0	0
Eugenia elliptica	+	0	0
Gonystylus macrophyllus	+	0	0
Mangifera griffithii	+	0	0
Palaquium burckii	+	0	0
Palaquium hexandrum	+	0	0
Shorea platycarpa	+	0	0
Shorea teysmaniana	+	0	0
Strombosia javanica	+	0	0
*Tristania obovata**	+	0	0
Dyera lowii	+	+	0
Garcinia rostrata	+	+	0
Gonystylus bancanus	+	+	0
Mangifera havilandii	+	+	0
Mezzettia leptopoda	+	+	0
Palaquium alternifolium	+	+	0
Palaquium walsurifolium	+	+	0
Shorea uliginosa	+	+	0
Calophyllum soulattri	+	0	+
Diospyros malabarica	+	0	+
Livistona rotundifolia	+	0	+

PA= Trees of Sumatra from the present study plus Trees of Sumatra after Anderson (1976a), B= Trees of Borneo after Anderson (1976b), S= Trees of Celebes after Anonym (1978) and Susanto (1984).

Due to the time constrain only existing shrubs and herbs were able to be accounted. In Desa Plintung 21 numbers of shrubs species were recorded, in Desa Sumber Jaya 33, and in Desa Pulau Muda 29, in total there were 58 species (Table 4).

Cyrtostachys lakka, *Macaranga diepenhorstii*, and *Uncaria glabrata* were present in all the sites; but 11 species were only found in Desa Plintung (Group 2), 14 species were only in Desa Sumber Jaya (Group 3), and 11 species were only in Desa Pulau Muda (Group 4). Four species namely *Santiria laevigata*, *Eleiodoxa conferta*, *Glochidion rubrum*, and *Macaranga triloba* were found in both in Desa Plintung and Desa Sumber Jaya (Group 5). Three species namely *Psychotria* sp.1, *Cryptocarya erectinerva*, and *Medinilla crassifolia* were found in both in Desa Plintung and Desa Pulau Muda (Group 7). The similar case was noticed for Desa Sumber Jaya and Desa Pulau Muda; 12 species were found in both Desa Sumber Jaya and Desa Pulau muda (Group 6). This evidence indicates that the diversity of shrubs was also very high.

Table 4. List of shrubs in the observed sites

	P	J	M
GROUP 1:			
Cyrtostachys lakka	+	+	+
Macaranga diepenhorstii	+	+	+
Uncaria glabrata	+	+	+
GROUP 2:			
Archidendron clyperia	+	0	0
Calamus sp. 1	+	0	0
Daemonorops sp.	+	0	0
Dissochaeta sp.	+	0	0
Korthalsia sp.	+	0	0
Myristica sp.	+	0	0
Pinanga sp.	+	0	0
Piper sp.	+	0	0
Santiria griffithii	+	0	0
Trema orientalis	+	0	0
Ziziphus angustifolius	+	0	0
GROUP 3:			
Diospyros pilosnathera	0	+	0
Cleidion spiciflorum	0	+	0
Diospyros siamang	0	+	0
Dysoxylum sp.	0	+	0
Eugenia acuminatissima	0	+	0
Eugenia fascigiata	0	+	0
Eugenia formosa	0	+	0
Eugenia jamboloides	0	+	0
Horsfieldia crassifolia	0	+	0
P. excelsa var.borneensis [1)]	0	+	0
Plectronia didyma	0	+	0
Poikilospermum suaveolens	0	+	0
Ternstroemia glabra	0	+	0
Uncaria acida	0	+	0
GROUP 4:			
Alyxia floribunda	0	0	+
Ardisia sp.	0	0	+
Blumeo. subrotundifolium	0	0	+
Calamus sp. 2	0	0	+
Pandanus sp. 2	0	0	+
Paratocarpus forbesii	0	0	+
Lecananthus erubescens	0	0	+
Garcinia forbesii	0	0	+
Psychotria sarmentosa	0	0	+
Tristania bakhuizenii	0	0	+
Tristania whitianum	0	0	+
GROUP 5:			
Santiria laevigata	+	+	0
Eleiodoxa conferta	+	+	0
Glochidion rubrum	+	+	0
Macaranga triloba	+	+	0

Table 4. (Continued).

	P	J	M
GROUP 6:			
Cratoxylum arborescens	0	+	+
Diospyros sumatrana var.[2)]	0	+	+
Eugenia densiflora	0	+	+
Eugenia lineata	0	+	+
Eugenia sp.	0	+	+
Garcinia sp.	0	+	+
Ilex cymosa	0	+	+
Ilex macrophylla	0	+	+
Planchonella obovata	0	+	+
Randia grandis	0	+	+
Ternstroemia foetida	0	+	+
Timonius wallichianus	0	+	+
GROUP 7:			
Psychotria sp. 1	+	0	+
Cryptocarya erectinervia	+	0	+
Medinilla crassifolia	+	0	+

Note : P = Plintung, J = Sumber Jaya, M = Pulau Muda
1) = *Platea excelsa* var. *borneensis* 2) = *Diospyros sumatrana* var. *decipiens*

Herbs were the smallest number of species accounted but they were very significantly and visible covered the forest ground, hence the herbs in the three sites were looked very similar. In Desa Plintung there were 13 species, in Desa Sumber Jaya 15 species, and in Desa Pulau Muda 15 species, in total there were 19 species. The nine dominant species (Group 1) occurred in the three sites namely: *Crinum asiaticum*, *Dischidia* sp., *Glechinia linearis*, *Lygodium* sp., *Nephenthes ampularis*, *Asplenium nidus*, *Nephrolepis bisserata*, *Nephrolepis exceltata*, and *Schleria laevis* (Table 5); but *Bulbophyllum macranthum* and *Dianella nemorosa* were only found in Desa Plintung (Group 2), *Bulbophyllum odoratum* was only found in Desa Sumber Jaya (Group 3), and Pandanus sp.3 was only found in Desa Pulau Muda (Group 4). *Rhaphidophora apiculata* was found both in Desa Plintung and Desa Sumber Jaya (Group 5); four species namely *Alocasia longiloba*, *Alpinia* sp., *Nepenthes rafflesiana*, and *N. reinwardtii* were found in both Desa Sumber Jaya and Desa Pulau Muda (Group 6), *Nepenthes gracilis* was found in both Desa Plintung and Desa Pulau Muda (Group 7).

In all total plant species observed in these three sites study is 131 species (Table 6) consisting of 64 trees species (including 11 species which were reported by Anderson in 1976a), 58 shrubs species including liana, and 19 herbs species. *Calophyllum soulattri* and *Palaquium hexandra* may be regarded as a tree species forest type of the sites; *Cyrtostachys lakka*, *Macaranga diepenhorstii*, and *Uncaria glabrata* for the shrubs; and *Crinum asiaticum*, *Glechinia linearis*, *Nephrolepis bisserata*, *N. exceltata*, and *Schleria laevis* may be considered for the herbs.

Table 5. List of herbs in the sites

	P	J	M
GROUP 1:			
Crinum asiaticum	+	+	+
Dischidia sp.	+	+	+
Glechinia linearis	+	+	+
Lygodium sp.	+	+	+
Nepenthes ampularia	+	+	+
Asplenium nidus	+	+	+
Nephrolepis bisserata	+	+	+
Nephrolepis exceltata	+	+	+
Schleria laevis	+	+	+
GROUP 2:			
Bulbophyllum macranthum	+	0	0
Dianella nemorosa	+	0	0
GROUP 3:			
Bulbophyllum odoratum	0	+	0
GROUP 4:			
Pandanus sp	0	0	+
GROUP 5:			
Rhaphidophora apiculata	+	+	0
GROUP 6:			
Alocasia longiloba	0	+	+
Alpinia sp.	0	+	+
Nepenthes rafflesiana	0	+	+
Nepenthes reinwardtii	0	+	+
GROUP 7:			
Nepenthes gracilis	+	0	+

Note: P = Plintung; J = Sumber Jaya; M = Pulau Muda

Regarding a forest damaged, however the forest in Desa Pulau Muda is much better protected compare to the one in Desa Plintung and Desa Sumber Jaya. The forests in Desa Plintung and Desa Sumber Jaya had much illegal trees cutting and hence had many opened areas. In around the areas of study a punak's tree (*Tetramerista glabra*) was over harvested for making a plank house, as well as ramin (*Gonystylus macrophyllus* and *G. bancanus*) as an exotic raw materials for a furniture. Even in the Tanjung Puting National Park in Central Kalimantan, this ramin was illegally over exploited (Rieley, 1998). According to local people it was said that dried barks of medang lendir (*Nothophoebe coriacea*) were exported to Taiwan as raw materials for making flammable substance to avoid mosquitos. In 1997 the fresh bark valued of Rp. 200 per kg, the dried bark valued Rp. 600 per kg.

According to World Conservation Monitoring Centre (1994), few of the plant mentioned above are necessary to be noted for their conservation status due to only found in a small population, such as the tree *Ailanthus integrifolia* (Simaroubaceae). *Gonystylus bancanus* and *G. macrophyllus* (Gonystylaceae) which they are considered over harvested for their "gaharu" and the punak tree are apparently not yet evaluated. And surprisingly *Palaquium burckii* and *P. walsurifolium* are not threatened. No shrubs above are reported in the WCMC's book as rare or endangered except small tree or shrubs of the lipstick palm or sealing wax palm *Cyrtostachys lakka* is rare in Sumatra, but reported endangered to extinct in the wild in Brunei and Singapore, and not threatened in Sarawak. For herbs, just remind that all the wild species of orchid and all pitcher plants of Nepenthes are in the very strict supervision by CITES rules. However, again according to the WCMC's book some of the pitcher plant *Nephenthes ampularia*, *N. rafflesiana*, and *N. reinwardtii* which were found there are surprisingly also not threatened. The genus *Nephenthes* is very unique plant and even interesting and beautiful for ornamental.

Table 6. List of plant species in the observed sites

Acronychya porteri	*Dissochaeta* sp.
Actinodaphne macrophylla	*Drypetes* sp.
Aglaia odorata	*Dysoxylum* sp.
Ailanthus integrifolia	*Elaeocarpus glaber*
Alocasia longiloba	*Eleiodoxa conferta*
Alpinia sp.	*Eugenia acuminatissima*
Alseodaphne oblanceolata	*Eugenia bankensis*
Alyxia floribunda	*Eugenia claviflora*
Antidesma phanerophlebium	*Eugenia densiflora*
Archidendron clyperia	*Eugenia fascigiata*
Ardisia sp.	*Eugenia formosa*
Asplenium nidus	*Eugenia jamboloides*
Blumeoden. subrotundifolium	*Eugenia lineata*
Bulbophyllum macranthum	*Eugenia* sp.
Bulbophyllum odoratum	*Exocarpus latifolius*
Calamus sp.1	*Ficus* sp. 1
Calamus sp.2	*Ficus* sp. 2
Calophyllum soulattri	*Garcinia forbesii*
Cannosperma coriacea	*Garcinia nigrolineata*
Canarium denticulatum	*Garcinia parviflora*
Cleidion spiciflorum	*Garcinia rostrata**
Cratoxylum arborescens	*Garcinia* sp.
Crinum asiaticum	*Glichenia linearis*
Cryptocarya erectinervia	*Glochidion rubrum*
Cyrtostachys lakka	*Glochidion zeylanicum*
Dacryodes rostrata	*Gomphia serrata*
Daemonorops sp.	*Gonystylus bancanus*
Dianella nemorosa	*Gonystylus macrophyllus*
Dillenia excelsa	*Gymnacrantha forbesii*
Dillenia pulchella	*Horsfieldia crassifolia*
Diospyros hermaphroditica	*Ilex cymosa*
Diospyros malabarica	*Ilex macrophylla*
Diospyros maritima	*Knema cinerea*
Diospyros pilosnathera	*Knema intermemdia*
Diospyros siamang	*Knema laurina*
Diospyros sumatrana var. *decipiens*	*Korthalsia* sp.
Diospyros sp.	*Labisia pumila*
Dischidia sp.	*Lecananthus erubescens*

Litsea grandis
Livistona rotundifolia
Lygodium sp.
Macaranga diepenhorstii
Macaranga triloba
Mangifera griffithii
Medinilla crassifolia
Myristica sp.
Nephenthes ampularia
Nephenthes gracilis
Nephenthes rafflessiana
Nephenthes reinwardtii
Nephrolepis bisserata
Nephrolepis exceltata
Nothophoebe coriacea
Palaquium burckii
Palaquium hexandrum
Palaquium obovatum var. occidentale
Palaquium walsurifolium
Pandanus tectorius var. *littoralis*
Pandanus sp.1
Pandanus sp.2
Parastemon urophyllum
Paratocarpus forbesii
Pinanga sp.
Piper sp.
Planchonella obovata
Platea excelsa var. *borneensis*
Plectronia dydyma
Poikilospermum suaveolens
Polyalthia laterifolia
Psychotria sarmentosa
Psychotria sp.
Randia grandis
Rhaphidophora apiculata
Santiria griffithii
Santiria laevigata
Schleria laevis
Shorea teymanniana
Shroea uliginosa
Shorea sp. 1
Shorea sp. 2
Stemonurus scorpioides
Ternstroemia coriacea
Ternstroemia foetida
Tetramerista glabra
Timonius wallichianus
Trema orientalis
Tristania bakhuizenii
Tristania whitianum
Uncaria acida
Uncaria glabrata
Xanthophyllum palembanicum
Ziziphus angustifolius

Conclusion

Though the floristic study above can be regarded as a preliminary, it was revealed that the plant diversity of the peat swamp forest of the Riau Province of Sumatra is quite high. In all, total plant species observed in these three sites study plus tree species studied by Anderson (1976a, b) is 131 species (Table 6) consisting of 64 trees species, 58 shrubs species including liana, and 19 herbs species. It seems that more sites will be studied, then the species plant number will be increased. To get a complete knowledge therefore a more extensive and comprehensive study on this type of forest still needed in the future, particularly to fill the gap of knowledge regarding the plant diversity which eventually may be very useful for a production of sustainable forest management. Few plant species have to be noticed due to some threats unless it may become extinct from the wild.

Acknowledgement

First of all we would like to thank Ir. Soewardi a leader of the team from the Forestry Ministry Office who offered us the job in conducted the study. P.T. Satria Perkasa Agung gave us excellent facilities and funding for conducting the study until the technical report was ready. We thank as well to Mr. Wardi and Mr. Deden Girmansyah both are our colleagues in the institute who assisted us during the field observation and did a very hardwork in identifying the plant under guidance of Mr. Ismail and Mr. Zainal Fanani.

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Initial Phase of Secondary Succession in the Exploited Peat Swamp Forest (*Shorea albida*) at Sungai Damit, Belait in Brunei Darussalam

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Abstract

Tropical forests are decreasing at the rate of 16.9 million hectares per year due mainly to clearing for agriculture and shifting cultivation. Timber harvesting results in more than 5 million hectares of tropical forest becoming degraded logged-over forests every year without any adequate managements. Processes of secondary succession provide significant information for the rehabilitation of degraded tropical forests. *Shorea albida* which established pure stands, are now to have been harvesting without plantation. The natural regeneration is the most difficult in this stand because of the long period of flowering and the extremely severe environment. Therefore, the clarification on the initial phase of vegetation recovery at the harvested site will be suggested as the feature of future forest projects at peat swamp areas.

As the results of survey, vigorous vegetation recovery was recorded for 46 months after harvesting . Among of the species, *Pandanus andersonii* and *Nephrolepis biserrata* reproducted vigorously and established their dominance. The number of species increased according to the time lapse after harvesting. 50-60 species/100 m^2 were observed for 45 months after harvesting. However, an average of 30 species was surveyed in the natural forest. Species composition was changing according to time. Natural regeneration by Dipterocarp species was very poor and only three species were observed such as *Dryobalanops rappa*, *Shorea inaequilatealis* and *S. albida*. Nevertheless, the former dominant *S. albida* was recorded at only one plot (3.1/ha). Therefore, the *S. albida* forest will be taken over by different forest types.

Introduction

Tropical forests are decreasing at the rate of 16.9 million hectares per year due mainly to clearing for agriculture and shifting cultivation. Timber harvesting results in more than 5 million hectares of tropical forest becoming degraded logged-over forests every year without any adequate management. The peat lands are widely distributed in Asia of 22.2 million ha compared with 5.2 million ha in America and 3.5 million ha in Africa. 18.2 million ha of peat exist in insular Asia (Kyuma *et al.*, 1986). Tropical peat lands constitute one of the most important areas for the land utilization in insular Asia. . Peat swamp forests in Borneo Island are commercially harvested such as timbers, Meranti (*Shorea*), Ramin (*Gonystylus*), Keruing (*Dipterocarpus*) and Tolong (*Agathis*) mainly (Kobayashi 1988). They are converted to oil palm and rubber plantations or agriculture fields, sometimes. These logged-over peat swamp forests are recognized as low values of forest resources without successful natural regeneration. Abandoned agriculture fields and plantations are also degraded such as grasslands, climber covered jungle, low valued secondary vegetation, ground subsidence of peat and accelerated peat decomposition (1994).

Therefore, the specific *Shorea albida* (Alan) forest which established the pure stand, is now to be exploited without application of Alan plantation. The natural regeneration of *S. albida* is the most difficult in this stand because of the long period of flowering and the extremely severe environment (Anderson, 1964; Funakawa *et al*., 1995). The initial phase of vegetation recovery at the harvested site is suggested as the feature of future forest projects at peat swamp areas (Kobayashi, 1994). Processes of secondary succession provides significant information for the rehabilitation of degraded tropical forests (Tilman, 1997). Initial secondary succession as the biodiversity changes was described as exponential increase which facilitation and competition process are observed (Auclair *et al*., 1971; Callaway *et al*., 1997).

Therefore, the final study target is to be decided the facilitation process or competition process at the initial vegetation recovery for the rehabilitation of degraded peat swamp forest.

Purposes of this study are:

(1) to clarify the natural forest structure at the study site (Alan Bunga) for the future forest projection.

(2) to clarify the initial phase of vegetation recovery (dominance changes, plant diversity changes, species composition changes) 1 to 46 months after forest harvesting.

(3) to clarify the recovered vegetation types as “facilitation process” or “competition process”.

(4) to discuss the possibility of the Alan forest recovery and necessity of the treatment for the rehabilitation of degraded Alan forest ecosystem.

Site Description and Methods

Site

The study site is located on the east part of Belait Peat Swamp Forest Reserve, where attains on the water pipe from Badas to Seria. Badas is relatively higher than Seria in elevation. Peat dominates over the study site, Kerangas (white silica sand) is distributed at Badas, and sand soil is composed under mixed swamp forests overlaying peat and mud clay near Seria, comparatively. The study site on the vegetation recovery after forest harvesting is located 25 km from Kuala Belait, on the side of Sungai Damit where is one of the Sungai Belait river branches in the Belait Peat Swamp Forest Reserve.

The landform of tropical peat swamp forms convex dome at this study site. Different forests types are observed from outside of dome to center such as the mixed swamp forest dominated *Dryobalanops rappa*, Alan Batu, Alan Bunga, Alan Padang and Padang Paya forest. Among of these forests, Alan forests occupy wide area and consist of pure *S. albida* stands (Ashton, 1964; Kobayashi, 1988).

According to Soil taxonomy, peat of different Alan forest types is classified into Oligotorophic Tropofibrists at this study site. Hemic material is dominated until 20-80 cm in depth and loose fibric material becomes fluid in upper horizon held by root system which appears under the ground water level (Kobayashi, 1989; Swanson *et al*., 1989).

This study site was exploited from 1 to 7 months interval at the blocks (200 m × 200 m) from 1981 to 1988.

Methods

Experimental site is shown in Fig.1. Each quadrate size is 10 m × 10 m in 200 m × 200 m where *Shorea albida* was harvested from 1 month to 46 months after harvesting for the exploited area and 15 plots were set (Fig. 1). Quadrate of 30 m × 30 m is for the natural forest. Vegetation survey was conducted on the species composition, the dominance and height of each species by Braun- Blanquet's method.

Mean diversity and total diversity were calculated using dominance value (Lloyd *et al.*, 1964; Pielou, 1975). Species composition table was made to examine relationships between the vegetation types and the following characteristics of each species.

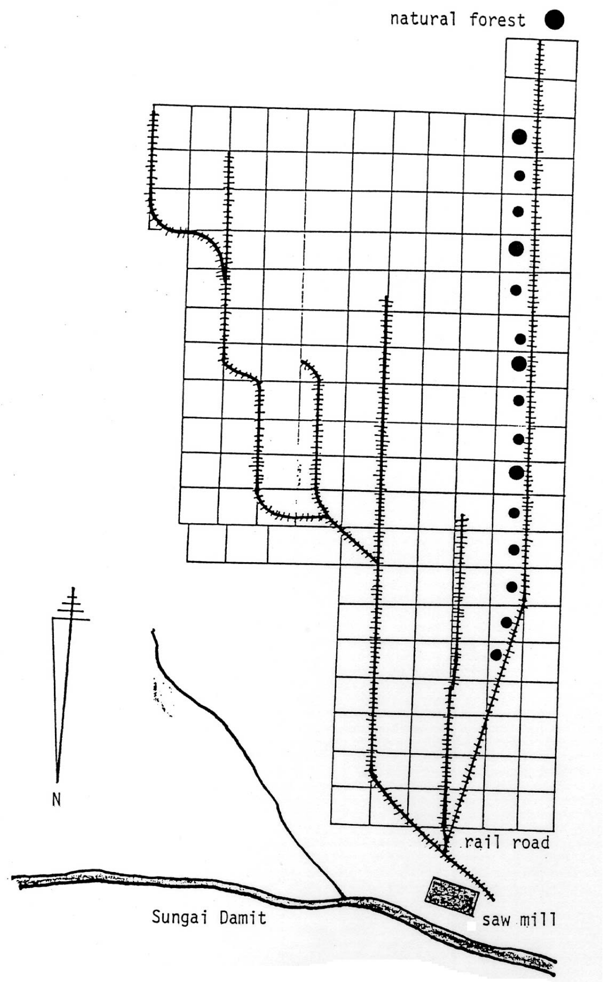

Fig. 1. Location of study site at Sungai Damit, Brunei. Quadrat represents the harvest unit and its size is about 200 m × 200 m. Dot indicates survey unit.

Results and Discussions

The structure of Alan natural forest

The structure of Alan natural forest is characterized its mono-dominance by *Shorea albida* (Alan) which is classified into three types such as Alan Batu (DBH = 87.8 cm, height = 49.0 m), Alan Bunga (DBH = 65.0 cm, height = 48.0 m) and Alan Padang

(DBH = 38.7 cm, height= 33.3 m). The experimental forest consists of 77.7/ha in density, 60.9 m 2 /ha in basal area and more than 65 cm in DBH. This forest is classified into Alan Bunga (Fig. 2). Alan Bunga forest is pure stand which is peculiar in natural tropical forest (Kobayashi, 1988). When this Alan forest is harvested, it becomes like a clear-cutting except remaining a few bad quality individuals which will be easily fallen down by wind and have difficulties to blossom (Kobayashi, 1997). The natural regeneration of Alan forest seems to be difficult, although the vegetation recovery is observed vigorously in the peat swamp forest. Therefore, *S. albida* forest must be conserved on the view of biodiversity.

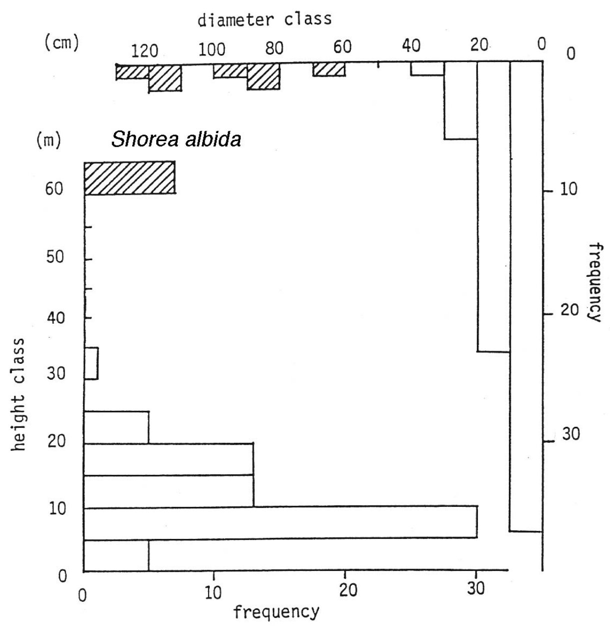

Fig. 2. Natural forest structure of *Shorea albida* at Sungai Damit, Brunei.
Quadrat size is 30 m × 30 m.

Changes of plant diversity during initial secondary succession

Vigorous vegetation recovery is observed that change of species number per 100 m^2 indicates to increase lineally as Y = 5.5 + 0.9X (R = 0.8447) according to time sequence after harvesting.”Y” is species number and “X” is month after harvesting. Maximum species number is recorded as 67 species/100 m^2 for 46 months after harvesting compared with 26 species/100 m^2 at the natural forest (Table 1). The herb and fern recover quickly at first one year and the shrub and climber become co-dominance following time. Almost herb and fern have disappeared for four years after harvesting and some shrub and climber remain until mature phase. These co-existing species play the role to be competitor and/or facilitator for secondary succession (Holmgren *et al.*, 1997; Li *et al.*, 1998). Especially, fern and climber play their rolls as competitors typically. Among of recovered species, *Pandanus andersonii* and *Nephrolepis biserrata* establish their dominance at early phase of two to four years (Fig. 3). *N. biserrata* disappears during initial phase. *P. andersonii* is expected to remain to dominate undergrowth at mature phase (Table 1).

Table 1. Changes of species composition at peat swamp forest after harvesting of *Shorea albida*, Brunei. Quadrat size is 10 m × 10 m.

	Plot no															
	E16	E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2	E0
Species no.	14	16	14	20	23	20	29	27	26	32	46	54	44	48	67	26
Months after logging	1	8	12	15	18	22	26	33	35	38	41	42	43	45	46	
Specles name																
Pandanus andersonii	+	1	2	2	1	3	3	3	5	2	4	4	3	3	3	5
Nephrolepis biserrata		2	4	4	2	5	3	3	3	4	3	4	3	1	1	
Plastris (leminding)	1	+	1	+	+	1	1	1	1	1	+	1	+		+	
Picus punctata (Moraceae)	+	+	+	2	1	2	+	3	2	1	+	1	+	+	+	
Timonius flavescens	+	1	+	+	+		2		+	1			+	3		
Symoplocos (Symoplocaceae)	+					+		1		+						
Nepenthes gracilis					1		1	+			+		1			
Poikilopernum annesenus			+						2							
Macaranga puncticulata (Euphorbiaceae: Mahang)					+					1	+					
Ilex hypoglauca	+	+	+	+	+			+					2	1		
Diospyros buxifolia	+	+				+	1							1	1	
Eugenia cerina (Myltaceae: Ubah)				2	3	+	3	1	+		3	1	4	3		
Ganua curtisii (Nyatoh)				+			1				+	1	1		+	
Lithocarpus sundaica			+	1	+			2	+	+	+	2	1	2		
Litsea cylindrocarpa (Medang)				+		1		+	+	1	2	2	+	2	2	2
Nepenthes rafflesia					1	+	+				1	1	1	3	1	
Knema						+								1	1	
Platea excelsa								1					+	2		
Polyalthia hypoleuca														2	2	
Annamonomusas (Lauraceae)														2		
Ixonanthes recticulata														3		
Tetorastigma (Vitaceae)	+		+	1	1	+	2	+	+	1	+	+		+	+	
Euphorbiaceae			1	1		2	2	2	1	3	3	2	3	+	+	+
Paederia (Rubiaceae)	+				4	1	1	1	1	1	+	3	+	+	+	+
Leucananthus (Rubiaceae)					1		+	1	1		1	1	+	+		+
Dryobalanops rappa									1			2		2		
Shorea albida																4
Gonystylus forbesii (Ramin)																2

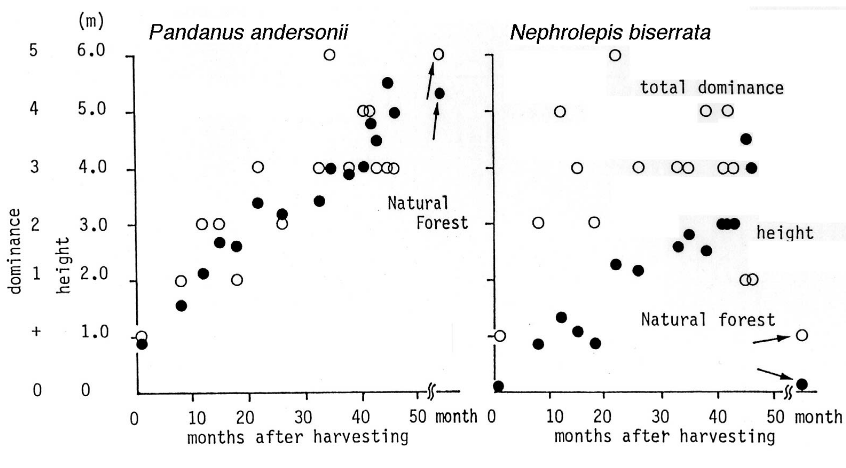

Fig3. Changes of total dominance and height in two dominant species (*Pandanus andersonii*, and *Nephrolepis biserrata*) after harvesting of *Shorea albida* forests at Peat Swamp, Sungai Damit, Brunei.

Mean and total diversity increase until 3.594 and 945.7 at 46 months after harvesting, but the natural forest indicates 2.145 in mean diversity and 502.0 in total diversity respectively (Figs. 4, 5). This change is caused by reproductive methods of each species, clear cutting like, and lack of seed sources. Secondary succession shows exponential increase at initial phase and then gradually decrease (Auclair *et al.*, 1971; Kobayashi, 1987). This study indicates same trend regarding biodiversity at the mature Alan forest.

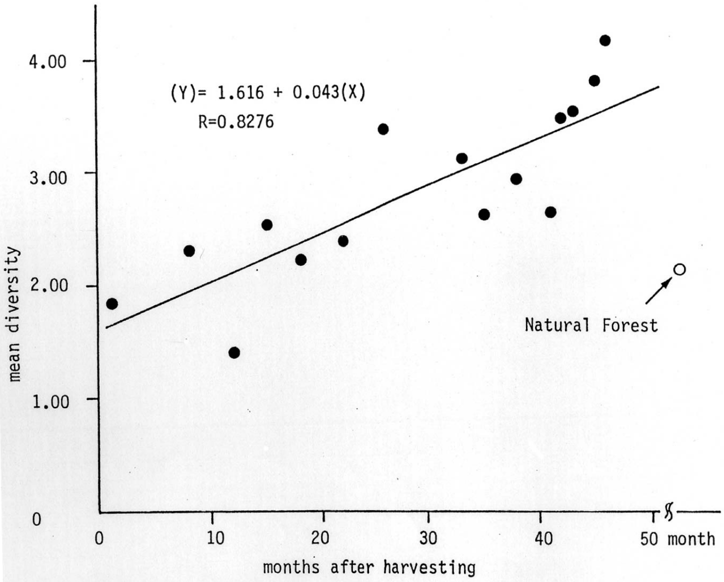

Fig4. Changes of mean diversity in Peat Swamp after harvesting of *Shorea albida* natural forests at Sungai Damit, Brunei.

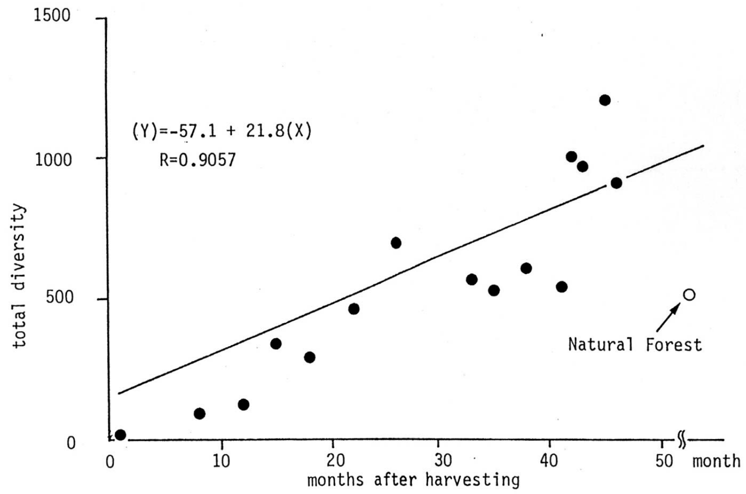

Fig5. Changes of total diversity in Peat Swamp after harvesting of *Shorea albida* natural forests at Sungai Damit, Brunei. Total diversity represents that mean diversity multiplies total dominance values.

Perspective for the forest recovery

Initial vegetation recovery is classified into Shrub, Herb, Fern and Climber types. Shrub and Herb types are considered as facilitation process and Fern and Climber types are competition process during secondary succession according to species changes, although *S. albida* forest is not expected to re-establish (Fig. 6). This perspective is recognized coupled with natural regeneration by Dipterocarp species and Ramin is very poor. Three species are observed such as *Dryobalanops rappa*, *Shorea inaequilatealis* and *S. albida* (Table 2). The former dominant *S. albida* was recorded at only one plot (3.1/ha). Therefore, the *S. albida* forest will be taken over by different forest types which are expected low value resources. If *S. albida* forest and/or high value forest is maintained, silviculture treatments such as enrichment planting, mixed plantation and accelerating methods must be applied to these logged-over peat swamp forests.

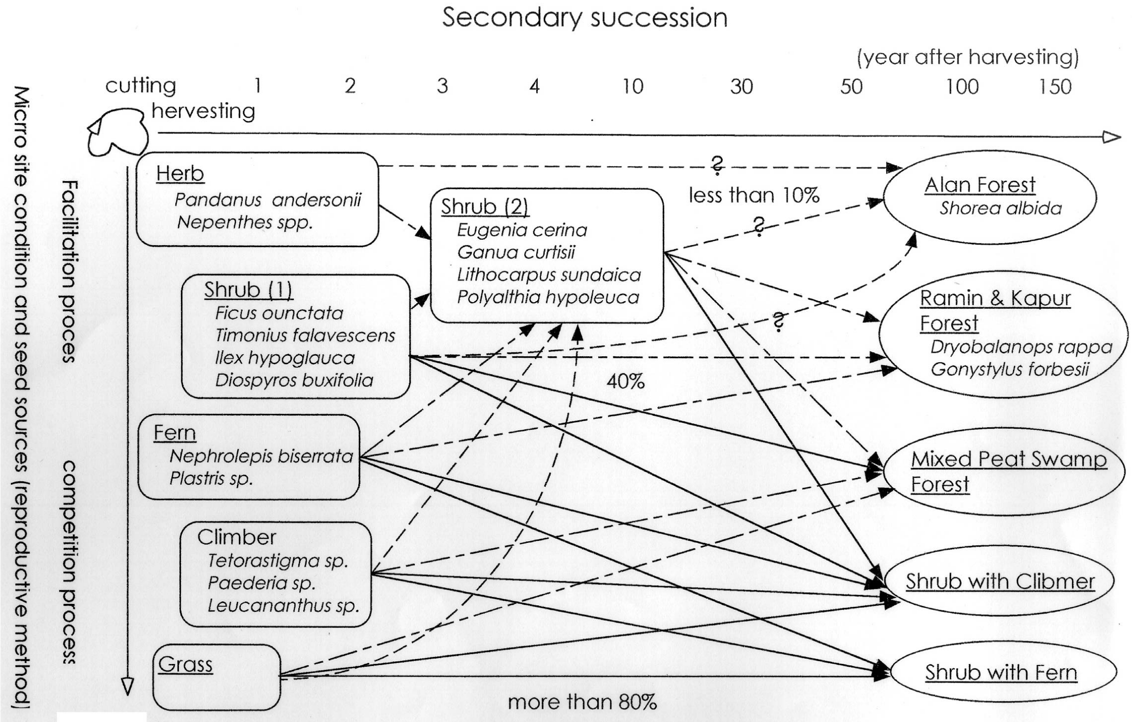

Fig. 6. Secondary succession process and projection of future forest recovery based on species composition and dominance changes at initial phase of succession.

For trying to answer against these questions, I surveyed initial vegetation recovery and have classified into undergrowth vegetation types for the predictions of species changes on a logged-over tropical peat swamp Alan forest. The influences and roles of vegetation types on the secondary succession have been discussed as the facilitation process or competition process related to environment (Holmgren *et al.*, 1997; Li *et al.*, 1998) and each interaction (Callaway *et al.*, 1997). Fern and Clibmer types indicate the composition process, because they remain same type, smallest species number and smallest recruit to the woody shrub 46 months after forest harvesting. Herb and Shrub types represent the facilitation process because of higher species number and the highest recruit to the woody shrub. Shrub and Fern types will be classified into lower criteria based on the furthermore monitoring. Even though the vegetation recovery shows the facilitation process, I can not expect the Alan forest recovery caused by lack of Alan seedlings.

Table 2. Condition of species natural regeneration of Dipterocarp speies in the Peat Swamp forest. Sungai Damit after harvesting of *Shorea albida*.

Plot no	Species	Density (/100 m^2)	Height (cm)
E16 (1)*	*Dryobalanops rappa*	0.5	39
E10 (26)	*Dryobalanops rappa*	0.2	384
	Shorea albida	0.5	20
E8 (35)	*Dryobalanops rappa*	1.0	389
E5 (42)	*Dryobalanops rappa*	3.0	570
E3 (45)	*Dryobalanops rappa*	5.0	650
E2 (46)	*Shorea inaequilatealis*	5.0	710

* Months after harvesting

Rehabilitation of this degraded tropical peat swamp forest must be initiated by the inventory study (Lee, 1979). And the recovered vegetation will be classified into facilitation and competition processes. Enrichment planting by Alan cuttings must be applied at the competitive vegetation, because Alan cuttings have been produced by special techniques to overcome some difficulties (Uchimura *et al*., 1994).

Conclusion

(1) The structure of a natural forest indicates its mono-dominance by *Shorea albida* which consists of 77.7/ha in density, 60.9 m^2/ha in basal area and more than 65 cm in DBH. Therefore, this forest became like a clear-cutting except remaining a few bad quality individuals.

(2) Vigorous vegetation recovery is recorded as 67 species/100m^2 for 46 months after harvesting compared with 26 species/100m^2 at the natural forest. Among of the species, *Pandanus andersonii* and *Nephrolepis biserrata* established their dominance and *P. andersonii* will be expected to remain to dominate undergrowth at mature phase.

(3) Mean and total diversity increase until 3.594 and 945.7 at 46 months after harvesting, but the natural forest indicates 2.145 in mean diversity and 502.0 in total diversity respectively. This change is caused by reproductive methods of each species, clear cutting like, and lack of dominant seed source.

(4) Shrub and Herb types are considered as facilitation process, and Fern and Climber types are competition process during secondary succession, although *S. albida* forest is not expected to re-establish.

(5) Natural regeneration by Dipterocarp species and Ramin is very poor. Three species are observed such as *Dryobalanops rappa*, *Shorea inaequilatealis* and *S. albida*. The former dominant *S. albida* was recorded at only one plot (3.1/ha). Therefore, the *S. albida* forest will be taken over by different forest types which are expected low value

resources. If *S. albida* forest and/or high value forest is maintained, silviculture treatments such as enrichment planting, mixed plantation and accelerating methods must be applied to these logged-over peat swamp forests.

Acknowledgement

I would like to thank Emi Ueda, FFPRI, for her help and useful comments. This study was supported by JICA technical cooperation project in Brunei Darussalam. Table2. Condition of natural regeneration of Dipterocarp species in the Peat Swamp forest, Sungai Damit after harvesting of *Shorea albida*.

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Proposed Methodology on Determination of Photosynthetic Capacity of Peatland Vegetation: Soybean as a Study Case

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Introduction

Type of vegetation/crop living in a peatland ecosystem depends on the soil and agroclimatic conditions. By observing the dominance of a certain vegetation, the level of soil fertility, and agroclimatic suitability of that vegetation can be obtained. Plant dominance is determined by the ability of plants to photosynthesize effectively and accumulate assimilate for growth.

Potosynthetic capacity, that is the potential capacity of a plant to photosynthesize at a highest rate under a certain environment, can be used as parameters showing how good the plant perform under a certain environmental conditions. Also, by comparing photosynthetic capacity of a same type of vegetation under different environmental condition give us information on the suitability of a certain location for this type of vegetation.

The poster presented here introduced the method to obtain V_{cmax} and J_{max} from gas exchange mesurement using the model of Farquhar *et al.* (l980) and Faquhar and von Caemmerer (1982), in order to be able to identify modification or acclimation in the model parameters of peatland vegetation. Examples of measurement on soybean were shown.

Methodology

Models of leaf photosynthesis

Leaf photosynthesis can be described by the equations developed by Farquhar *et al.* (l980) and Farquhar and von Caemmerer (1982). The basic assumption underlying the model is that the rate of photosynthesis is controlled by the amount of activated enzyme RuBP carboxylase-oxygenase (Rubisco), the rate of regeneration of RuBP, and the relative partial pressures of CO_2 (c_i) and O_2 at the site of CO_2 fixation. Therefore, under a given set of environmental conditions, the net CO_2-assimilation rate, A, is taken as being either the Rubisco-limited rate, A_v, or the predicted RuBP-regeneration limited rate of photosynthesis, A_j, whichever is the lower at a particular c_i (This holds for ci > Γ*). A has units of µmol m^{-2} s^{-1}.

$$A_j = \frac{J}{4}\left(\frac{c_i - \Gamma^*}{c_i + 2\Gamma^*}\right) - R_d \qquad (1)$$

$$A_v = V_{c\max}\left(\frac{c_i - \Gamma^*}{K_c\left(1 + O/K_o\right) + c_i}\right) - R_d \qquad (2)$$

$$A = \min(A_j, A_v) \tag{3}$$

where c is partial pressure of CO_2 in the leaf (µbar); Γ^* = CO_2 compensation partial pressure in the absence of dark respiration (P_a); R_d = dark respiration by the leaf which continues in the light (µmol m^{-2} s^{-1}); O = ambient partial pressure of oxygen (21%); K_c and K_o are Michaelis-Menten constants for carboxylation and oxygenation by Rubisco (P_a), respectively; V_{cmax} is the maximum rate of Rubisco activity in the leaf; and J is the actual electron transport rate (µmol m^{-2} s^{-1}).

The temperature dependence of K_c and K_o follows an Arrhenius function:

$$K_c = K_{c,25}\exp\left[\frac{E_c}{298.2R}\left(1-\frac{298.2}{(T+273)}\right)\right] \tag{4}$$

$$K_o = K_{o,25}\exp\left[\frac{E_o}{298.2R}\left(1-\frac{298.2}{(T+273)}\right)\right] \tag{5}$$

where R is the universal gas constant, 8.3144 J mol^{-1} K^{-1}, and T is temperature in °C. E_c and E_o are the apparent activation energies and the 25 subscript refers to the value at 25°C.

The effect of temperature on the CO_2 compensation point of photosynthesis in the absence of mitochondrial respiration follows the equation of von Caemmerer *et al.* (1994):

$$T^* = 36.9 + 1.88(T-25) + 0.036(T-25)^2 \tag{6}$$

The photosynthesis parameters K_c (Pa), K_o (Pa), Γ^* (Pa) and related activation energies (J mol^{-1}) for K_c and K_o at 25°C are 40.4, 24800, 3.69 and 59400, 36000, respectively (Badger and Collatz 1977; von Caemmerer *et al.* 1994).

The rate of electron transport, J, follows the equation by Farquhar and Wong (1984):

$$J = \frac{Ia_2 + J_{max} - \sqrt{(Ia_2 + J_{max})^2 - 4\Theta Ia_2 J_{max}}}{2\Theta} \tag{7}$$

where J_{max} is the maximum light-saturated rate of electron transport of the leaf (µmol m^{-2} s^{-1}), Θ is the curvature factor of the light response curve that varies from 0 (rectangular hyperbola) to 1 (two straight lines quasi Blackman). The value of Θ is usually taken as 0.7 (Evans and Farquhar, 1987), a_2 is the quantum yield of electron transport at low light and I is the light intensity incident on the leaf.

Estimation of model parameters

There are seven parameters that need to be estimated: K_c, K_o, θ, a_2, V_{cmax}, J_{max} and R_d, K_c and K_o indicate the intrinsic kinetic properties of Rubisco. They are relatively constant, varying only with temperature for all C_3 species (Berry and Björkman 1980, Jordan and Ogren 1984), and hence in this analysis the values presented by Badger and Collatz (1977) and von Caemmerer *et al*. (1994) were used. However, the values of J_{max}, V_{cmax} and R_d can vary greatly between species and growth conditions (Farquhar and von Caemmerer 1982), and hence they should be estimated for all treatments at different leaf temperatures. From the measurement of the light response curves, where the incident light ranged from 0 to 1650 µmol m^{-2} s^{-1}, R_d can be determined by extrapolation of a linear regression at the lower end of the response curve (at I = 0-150 µmol m^{-2} s^{-1}). Using this interpolated R_d along with Γ^* corrected for each temperature using Eq. (6), J was calculated from Eq. (1) and then J_{max}, a_2 were estimated by fitting the J-light curve with Eq. (7). V_{cmax} was estimated from the lower end of the c_i response curve at c_i up to around 200 µbar. Temperature dependence of K_c and K_o follows Eqs. (4) and (5).

Gas exchange measurement: soybean as an example

Rates of CO_2-assimilation of soybean leaves (grown under different CO_2 and temperatures) were measured over a wide range of CO_2 concentrations (50-900 µmol mol^{-1}), photon flux densities (0-1650 µmol m^{-2} s^{-1}) and leaf temperatures (15-35°C). Leaf to air vapour pressure difference was maintained at about 12.5 mbar. Irradiance at the leaf surface for all CO_2 exchange measurements was maintained at 1200 µmol m^{-2} s^{-1}, except during measurement of the light response curve. Each different CO_2 concentration was maintained for at least 30 min to reach a steady state gas exchange, while each light intensity was maintained for at least 20 min before the measurements were recorded. Measurements have to be made on expanded leaves of the third trifoliate (14-16 days after emergence of the leaves with emergence is defined as leaf length of 2 cm).

Results of Measurements on Soybean

CO_2 response curve, V_{cmax}

Fig. 1 shows the relationship obtained experimentally between the CO_2-assimilation rate and c_i at different measurement temperatures for plants grown at low (20/15°C) and high temperature (32/27°C) with both 350 and 700 µmol mol^{-1} CO_2 concentrations.

In general, the response curves show a typical crossing-over due to increases in the CO_2-compensation point and the RuBP-regeneration rate with increasing temperature. The response is similar to that found by Kirschbaum and Farquhar (1984) for *Eucalyptus pauciflora.*

Light-electron transport curve: J_{max}

Fig. 2 shows examples of the light response curve of electron transport for plants grown at [CO_2] of 350 µmol mol^{-1} and temperatures of 32/27°C and 20/15°C (day/night) measured at three different temperatures. The electron transport rate (J) was calculated using Eq. (1).

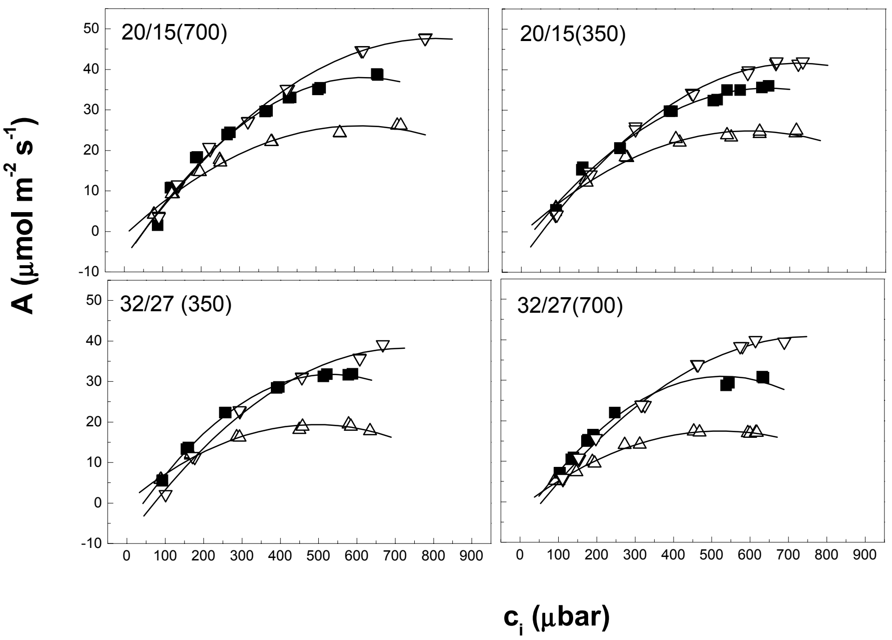

Fig. 1. Relationship between net CO_2-assimilation rate (*A*) and intercellular concentration of CO_2 (c_i) obtained at 3 temperatures (Δ: 15°C; ■: 25°C and ∇: 35°C) of soybean leaves grown at different [CO_2] and temperature. Measurement was done with light intensity of 1200 µmol m^{-2} s^{-1}. Solid lines are splines connecting the data points as a guide to the eye (June, 2000).

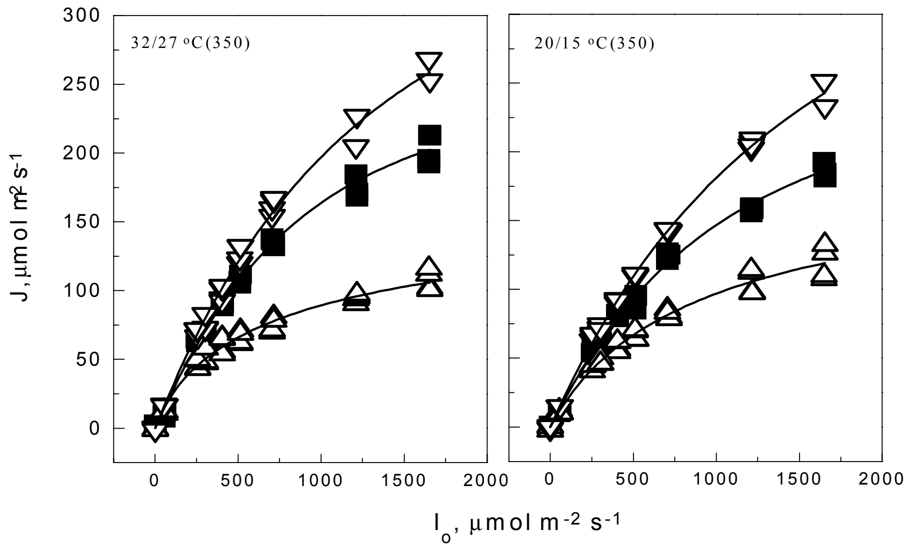

Fig. 2. Light response curves of the electron transport rate measured at three temperatures (Δ: 15°C; ■: 25°C and ∇: 35°C). Plants were grown under different conditions as indicated in the graph and measured at [CO_2] of 700 µmol mol^{-1} (June, 2000).

The temperature dependence of R_d is shown in Fig. 3. The values were obtained by fitting a linear regression to net CO_2-assimilation rate data at irradiance < 150 µmol m^{-2} s^{-1} and extrapolating to zero irradiance. Considerable variation in the values of R_d can be observed among growth conditions, but there were no significant differences. This is consistent with measurements of R_d in cotton leaves grown with elevated [CO_2] (Thomas *et al*., 1993) and in *Eucalyptus pauciflora* (Kirschbaum and Farquhar, 1984).

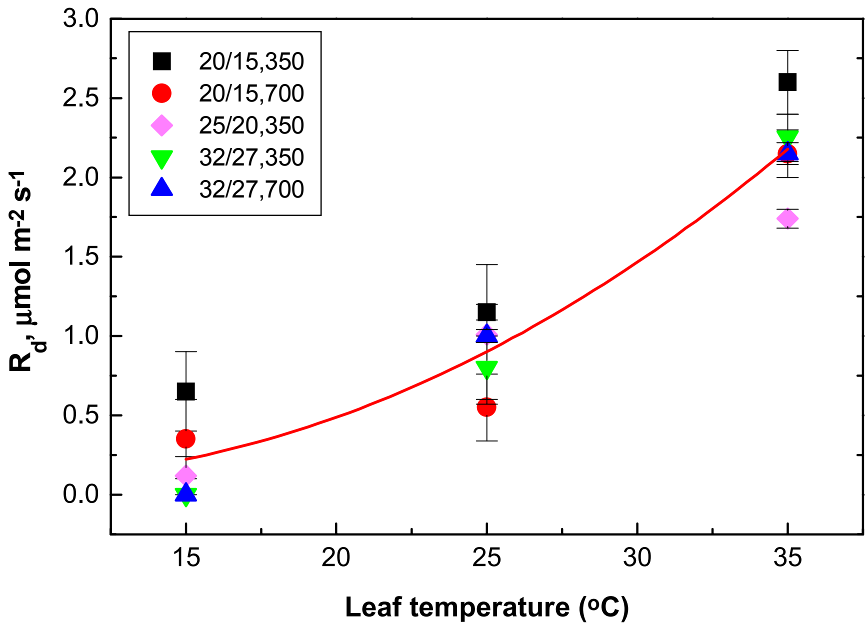

Fig. 3. Temperature dependence of R_d. The values of R_d were determined from the extrapolation of the linear regression of the A-light response curve at low light (< 150 µmol m^{-2} s^{-1}). Different symbols refer to different groups of data. The solid line is the average best fit second degree polynomial from all growth conditions: $R_d = 0.328 - 0.051\ T + 0.00299\ T^2$ (with $R^2 = 0.92$, N=15 and P <0.0001) (June, 2000).

Fitted value of V_{cmax} and J_{max}

The result as shown in Fig. 1 and Fig. 3 can then be fitted using Eqs. (1) - (7) to get the V_{cmax} and J_{max} value as seen in Table 1.

Conclusion

This methodology is very reliable and very easy to do, and it gave us an insight of the adaptability of the photosynthetic capacity of plants to environmental conditions. As the photosynthetic model is highly mechanistic, different environmental condition exposed to the plants during its growing condition can be well described by its parameters. Hence, by using this methodology, choosing suitable plants for a certain condition or studying plant performance at different environmental conditions can be conducted. Using a portable gas exchange system (for example: LICOR 6400), measurement can be conducted easily in the field.

Table 1. List of model parameters with ± standard error, for each measurement at 3 leaf temperatures and a CO_2 concentration of 700 µmol mol^{-1}. Nitrogen supply for all plants was 16 mM. Fitting of the light response curve was done using Θ = 0.7. Leaves for light response curves were different to those leaves used in CO_2 response curve measurement (June, 2000).

Growth condition day T/[CO_2]	Leaf Temperature (°C)	Fitted from light response curve, measured at 700 µmol mol^{-1} CO_2 (Eq. 2)		Fitted from CO_2 response curve, measured at light of 1200 µmol m^{-2} s^{-1} (Eq. 2).			
Parameters		a_2	J_{max}	V_{cmax}	J_{1200}	J_{max}	J_{max}/V_{cmax}
20/350	15	0.17±0.00	184±12.5	46± 3	102± 9	111	2.4
	25	0.22±0.00	261± 3.0	120±10	203± 8	251	2.1
	35	0.26±0.01	345± 3.1	230± 0	225± 5	290	1.3
20/700	15	0.16±0.02	139± 7.06	58± 8	128± 1	143	2.5
	25	0.26±0.01	301±24.5	118± 3	195± 5	238	2.0
	35	0.28±0.01	349±40.1	240± 7	258± 4	357	1.5
25/350	15	0.13±0.05	153±16.3	55± 0	113± 8	124	2.3
	25	0.22±0.01	290±31.2	118± 8	222± 4	284	2.4
	35	0.28±0.02	372± 0.2	190±10	263± 8	369	1.9
32/350	15	0.21±0.03	117± 3.4	38±10	66±21	69	1.8
	25	0.26±0.01	256±21.9	106±19	163±28	190	1.8
	35	0.28±0.01	369±28.4	170±35	203±13	251	1.5
32/700	15	0.15±0.01	133± 0.7	39± 1	85± 5	91	2.3
	25	0.21±0.01	229± 5.0	105± 5	153± 3	176	1.7
	35	0.23±0.00	369± 4.8	208± 3	230± 5	299	1.4

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Litter Decomposition Process in Two Contrastive Nutrient Limited Forest Types in Central Kalimantan

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Abstract

Litter fall and litter decomposition process in two contrastive of forest types, i.e. heath and peat swamp forest were studied in Lahei, northeast of Central Kalimantan, Indonesia, to quantify seasonality of litter fall and mineral cycling. Sampling was carried out from February 1998 to February 1999 and will be continued until March 2000.

Litter fall (t $ha^{-1}year^{-1}$) measured by litter traps, was 6.64 (total), 3.5 (leaves) and 2.6 (stem < 2cm) in heath forest. In peat swamp forest (t $ha^{-1}year^{-1}$) that was 5.3 (total), 2.9 (leaves) and 1.5 (stem < 2 cm). During rainy season, the peak of litter fall was observed in heath forest in early December, while in dry season it was occurred in July. In peat swamp forest during dry season, the peak was observed in June. The fall rate of stems with diameter ≥ 2 cm was slower than that of small stems (< 2 cm). The rate of stem ≥ 2 cm was higher in peat swamp forest than in heath forest.

The decomposition process of leaves from three dominant species in heath forest; (i) Bintangur Marutan (*Calophyllum pulcherrimum*), (ii) Belawan (*Tristania* sp.), (iii) Hangkang (*Palaquium* sp.), and three dominant species in peat swamp forest; (i) Rasak (*Vatica* cf. *rassak*), (ii) Kandorin (*Buchanania sessifolia*), and (iii) Umpa (*Gluta* cf. *laurifolia*) was monitored using litter bags. *Tristania* sp. in heath forest decomposed more rapidly than the other species, while in peat swamp forest, Kandorin (*Buchanania sessifolia*) was decomposed rapidly than others.

Introduction

Tropical forests produce large amounts of litters, such as: leaves, flowers and fruits, trash and woody fraction (Burghouts *et al.*, 1993). So far, only a few studies have been done on the litter decomposition in lowland rain forest of South-east Asia (Proctor, 1984). Studies on quantitative and qualitative aspects of the litterfall are important for the following reasons; to provide an index of production, to give information on decomposition rates, to give information on tree phenology and to quantify an important pathway in mineral cycles and to indicate efficiency of these cycles (Proctor *et al.*, 1983; Burghouts *et al.*, 1993).

Proctor *et al.* (1983) conducted a study on the litter fall of a heath forest in Gunung Mulu National Park, Malaysia and found that the weight loss of leaves in fine mesh litter bags in heath forest was higher than of in alluvial and dipterocarp forests. Leaf litter deposition and decomposition is critical pathway of organic matter and nutrient flux in tropical forest systems (Burghouts *et al.*, 1993; Wieder and Wright, 1995). The impact of trees on litter decomposition, nutrient availability and soil acidity depends on the chemical composition of litterfall and canopy leachate (Burghouts *et al.*, 1993; Vitousek and Turner 1994). Variations in decomposition rates across species and sites are correlated with environmental factors, such as: humidity, pH, amount of solar radiation reaching the forest floor (Zhang and Zak, 1995), soil organisms (Gallardo and Merino, 1993), and substrate quality (Vitousek and Turner, 1994).

This paper reports the studies on seasonal changes and the quantities of litter fall, and the estimation of decomposition rate of dominant tree species in heath and peat swamp forests.

Methods

Study site

The study was conducted in two different types of inland forests (peat swamp and heath forests) in Lahei village, northeast of Palangkaraya, Central Kalimantan. A 1-ha permanent plot was established in each forest type in August 1998 for a population dynamics study. Suzuki *et al.*, (1998) reported that the peat swamp forest plot was dominated by Rasak (*Vatica oblongivolia*), Kandorin (*Buchanania sessilifolia*), and Umpa (*Gluta* cf. *laurifolia*); while heath forest plot was dominated by Bintangur Marutan (*Calophyllum pulcherrimum*), Belawan (*Tristaniopsis* sp.), and Hangkang (*Palaquium* sp.). The tree density of heath forest was higher than peat swamp forest, however, heath forest mainly consisted of small trees (the biggest tree diameter was 69.7 cm), while peat swamp forest consisted of larger trees (the biggest tree diameter was 100.2 cm). The highest trees were 37 m in heath forest and 38 m in peat swamp forest and number of species was 116-147 in heath forest and 73 species in peat swamp forest.

Litterfall observation

Twenty-five litter traps are installed randomly within each 1-ha permanent plot of peat swamp and heath forests. Every litter trap was circle in shape and the surface areas was 0.785 m^2. Each litter trap was placed 1m above ground level and tied up among four of 1-m long PVC poles stuck into the soil. Those trapped litter falls were collected every 2 weeks within a 12-month of study period in heath forest and only during the dry season of the same period for peat swamp forest type.

Litterfall were separated into (i) coarse leaf litterfall (leaf fraction ≥ 1 cm; LLF), (ii) leaf fraction (< 1 cm); (iii) twigs or woody litterfall (≥ 2cm diameter); reproductive parts (fruits and flowers) (Burghout *et al.*, 1993); and (iv) the materials that could not be classified either by species or element were left as "others". Those fractions were dried in an oven and weighed separately.

Litter bags experiment

Litterbags experiment was also conducted in order to study the decomposition rate of litterfalls of each dominant species and mixed litters in each forest types. Some trees with various stem diameters of each mentioned dominance species in peat swamp and heath forest plots from outside permanent plots were cut off for collecting their leaves and branches. Leaves and branches of selected cut trees were divided by species for further litterbags experiment. Leaves from forest floor of both forest types were also collected and treated as mixed litters. Leaves and small branches of each species from cut trees and from forest floor (mixed litters) were dried in air condition.

Air-dried leaves of each species and mixed litters were filled into two types of litterbags; those are nylon litterbags with the mesh size of 1 mm (coarse mesh) and of 0.35 mm (fine mesh). Each litterbag was filled up with 100 g air-dried leaf samples of each species. Two hundred litterbags (50 bags each of 4 types air-dried litters, i.e. litters of 3 dominant species and mixed litters) were distributed systematically in each 1-ha permanent plot of heath and peat swamp forest types at the end of January 1988 and let them to decompose naturally in the fields.

Litterbag of each species of coarse and fine mesh bags were then collected periodically from each forest type and the remaining leaves within each litterbag were weighed after dried in an oven at 75°C until the mass weight constant. The remaining weights of leaves were corrected using ash content by burning leaf sample in a muffle oven at 800°C over 8 h, for correction factor of litter contaminated by mineral soil (Murphy, 1998).

The rate of organic matter decomposition is calculated by using the widely applied differential equations:

$$d\,W/dt = k\,W$$

where W represents the mass of the litter (organic matter), t is expressed in day, and k is the decomposition constant (rate). The value of the decomposition constants k for particular litter was estimated by fitting the regression line $W(t) = W_0 e^{kt}$ (the integrated from the equation) putting W_0 at the t = 0 is 100% (Laskowski *et al.*, 1995).

Results

Quantity and seasonality of litter fall

The composition of litters collected from heath and peat swamp forest is shown in Table 1. Leaves constituted the majority (53 % in heath forest and 55 % in peat swamp forest) of the litterfall, and were followed by stem (38.7 % in heath forest and 27.57 % in peat swamp forest) (Table 1).

Table 1. Litter production from twenty-five 0.785 m^2 litter traps in peat swamp and heath forest. The litterfall rates are based on the summed 2-week collections for each trap.

Component	Heath forest ton ha^{-1} $year^{-1}$	Percent	Peat swamp forest ton ha^{-1} $year^{-1}$ *	Percent
Leaves ≥ 1 cm	3.51	52.87	2.93	55.25
Stem < 2 cm	2.57	38.70	1.46	27.57
Stem ≥ 2 cm	0.002	0.03	0.45	8.55
Reproductive part	0.29	4.38	0.13	2.51
Others	0.12	1.84	0.17	3.25
Leaves < 1 cm	0.15	2.19	0.15	2.87
Total	6.65	100.00	5.30	100.00

* estimated from 8-month data

The total litterfall in heath forest was higher than peat swamp forest. Each litter component (leaves, reproductive part, stem ≥ 2 cm, leaves < 1 cm and others) in heath forest was higher than peat swamp forest, while stem with diameter ≥ 2 cm was higher in peat swamp forest.

Figure 1a and 1b show seasonal variations in the total quantity of litter fall of each element in heath and peat swamp forest. In heath forest during dry period, the total amount was fluctuated markedly, with a peak in April and a major peak in July, and another peak in September. On wet period the peak began in middle October, with a major peak in early December, and another peak in January. The sampling of litterfall in peat swamp forest was done in dry season, with a peak in late April and the major peak in June, and another peak in late July.

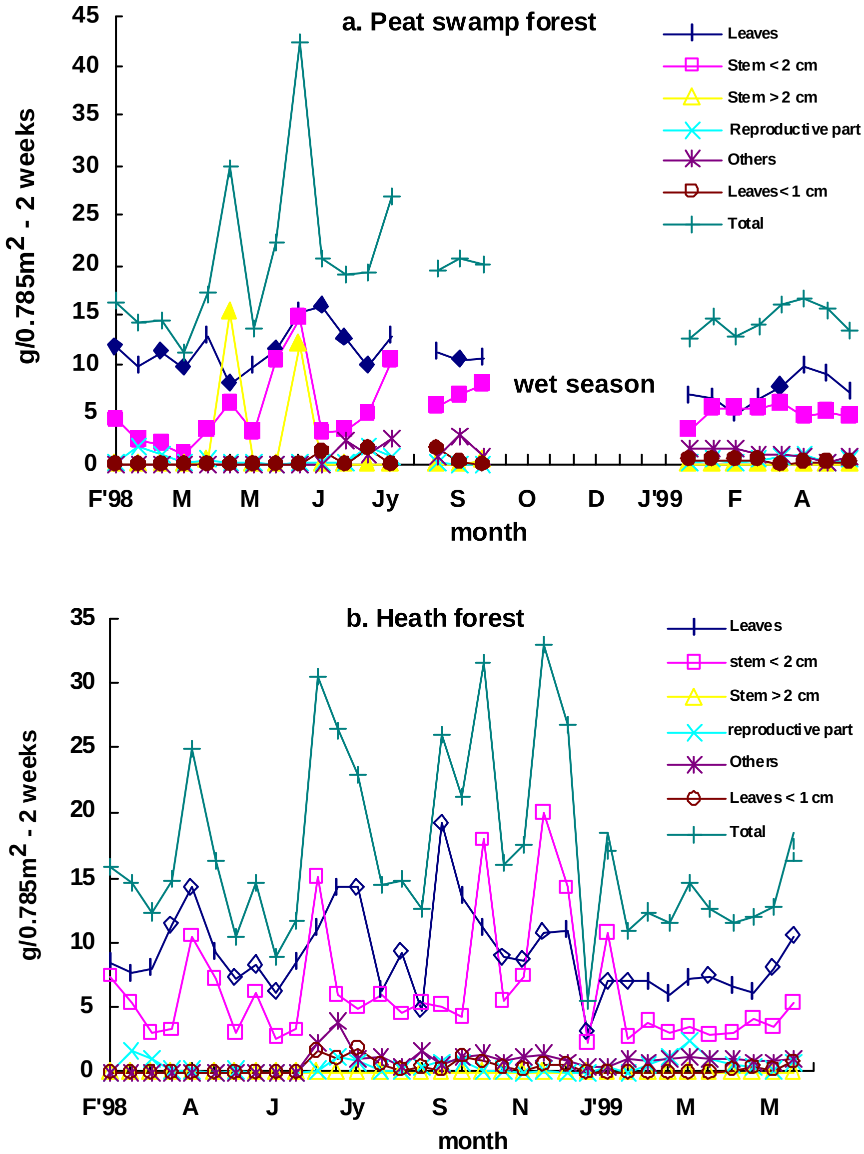

Fig. 1. Seasonal variation of litter fall in peat swamp (a) and heath forest (b).

Decomposition rate of litter

Decomposition rate and the percentage of original litter mass remaining over time for all the species in the two ecosystems is shown in Figs. 2 and 3. In peat swamp forest, the decomposition rate ranged between $k = 0.0008$ day^{-1} for *V. oblongivolia* and 0.0026 for *B. sessilifolia*, whereas in heath forest the value was higher, ranging from 0.0012 for *C. pulcherrimum* to 0.0039 for *Tristaniopsis* sp. The decomposition rate of *Tristaniopsis* sp. ($k = 0.0037$, fine mesh and $k = 0.0039$, coarse mesh) was higher than the other species (Table 2).

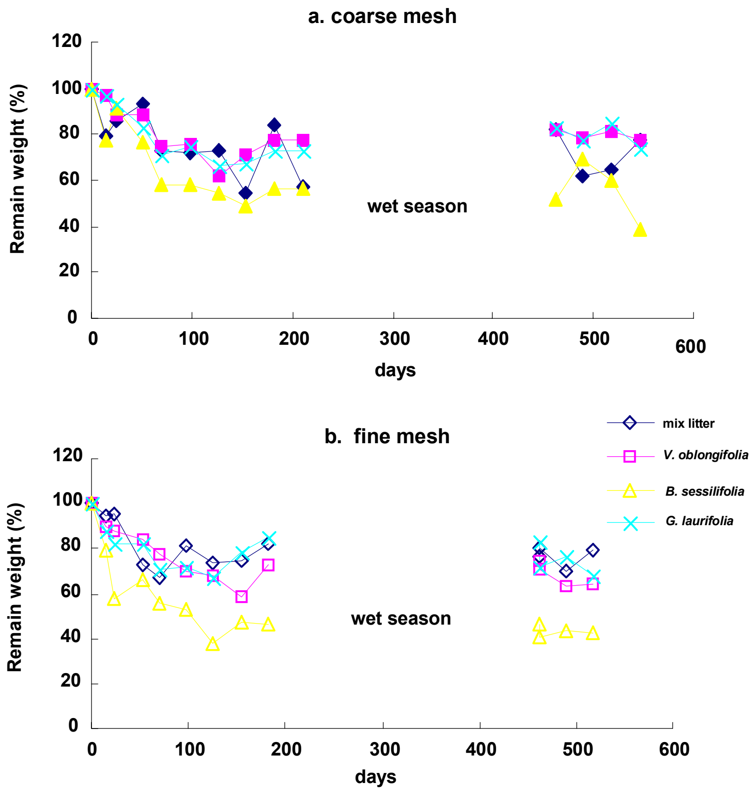

Fig. 2. Remaining weight of leaves of dominant species in various litter bags in peat swamp forest.

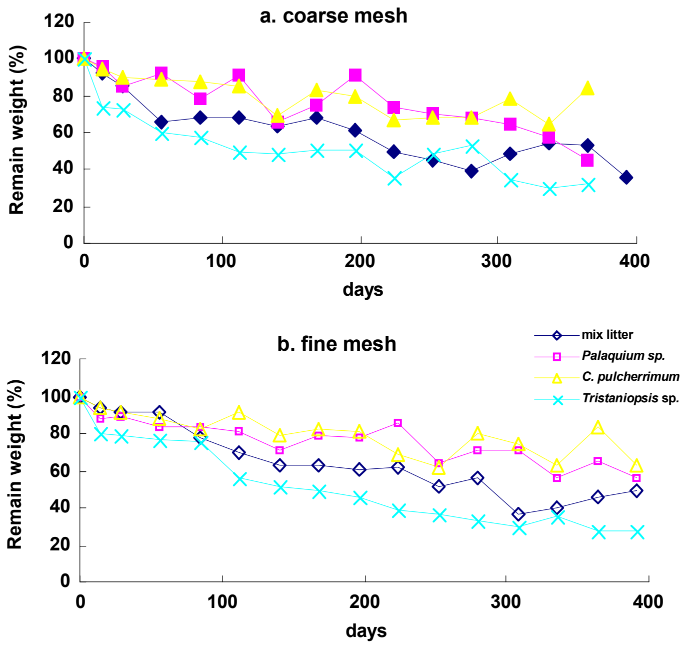

Fig. 3. Remaining weight of leaves of dominant species in various litter bags in heath forest.

In peat swamp forest, remaining mass of *B. sessilifolia* was lower than the others species. Decomposition rate of *B. sessifolia* with k = 0.0026 (fine mesh) and k = 0.002 (coarse mesh) was faster than that of *G*. cf. *laurifolia* (k = 0.0009, fine and coarse mesh), *Vatica oblongivolia* (k = 0.0012, fine mesh; k = 0.0008, coarse mesh) and mix litter (k = 0.0009, fine mesh; k = 0.0012, coarse mesh) (Table 2).

Table 2. The rate of decomposition of the dominant trees species in peat swamp and heath forest in Central Kalimantan.

Forest type	Species	decomposition rate day^{-1} (k)	
		fine mesh	coarse mesh
Peat swamp forest	*V. oblongifolia*	0.0012	0.0008
	B.sessilifolia	0.0026	0.002
	G. cf. *laurifolia*	0.0009	0.0009
	mix litter	0.0009	0.0012
Heath forest	*C. pulcherrimum*	0.0012	0.0012
	Tristaniopsis sp.	0.0037	0.0039
	Palaquium sp.	0.0017	0.0015
	mix litter	0.0027	0.0025

The decomposition rates of the dominant tree species in peat swamp and heath forest were not significantly different between fine and coarse mesh of litter-bags, except for *Tristaniopsis* sp. ($p < 0.022$) (Table 3).

The weight loss of mixed litter in fine mesh bags after 1 year was 54.4% in heath forest and 19.5% in peat swamp forest. In coarse mesh that was 45.5% in heath forest and 37.9% in peat swamp forest. The weight loss of mix litter in fine and coarse mesh in the two main study sites may be ranked in the order: heath forest > peat swamp forest. This view means that the mix litter of heath forest was decomposed more rapidly than the mix litter in peat swamp forest (Table 2).

Table 3. p-Value of litter mass lost between mesh size in peat swamp and heath forest.

	Peat swamp forest		Heath forest	
	species	p-value	species	p-value
Mass lost	*V. oblongifolia*	0.24	*Palquium* sp.	0.69
	B. sessilifolia	0.06	*C. phulcherrimum*	0.55
	G. cf. *laurifolia*	0.8	*Tristaniopsis* sp.	0.022*
	mix litter	0.38	mix litter	0.052

* Significant at P < 0.05.

Discussion

Quantity and seasonality of litter fall

The total litterfall of heath forest in Lahei (6.6 ton ha^{-1} year^{-1}) was lower than those in heath forest in Gunung Mulu National Park (9.2 ton ha^{-1} year^{-1}). The leaf litter fall was 52.9% of total litterfall in heath forest. It was smaller than those which were reported by Proctor *et al.* (1983), that leaf litter of heat forest in Gunung Mulu National Park accounted for 60.9% of total litter fall (Table 4).

Reproductive parts were higher in Gunung Mulu National Park than in Lahei, but the stem with diameter < 2 cm were higher in Lahei. The stem with the diameter ≥ 2 cm and leaves (< 1 cm) were not recorded in Gunung Mulu National Park.

Table 4. Estimated litterfall from thirty-five 0.25 m^2 litter traps in Heath forest in Gunung Mulu National Park, Sarawak (Proctor *et al.*, 1983).

Component	Heath forest	Percent
Leaves ≥ 1 cm	5.6	60.9
Stem < 2 cm	2.2	23.9
Stem ≥ 2 cm	-	-
Reproductive part	0.32	3.48
Others	1.1	12.0
Leaves < 1 cm	-	-
Total	9.2	100

The litter fall data from peat swamp forest was presented only during dry period. It was difficult to collect the litter during rainy season, because of high water level. The data was predicted from eight months observation. It should be higher than the prediction because during rainy season, the litter is expected to fall more than in dry season. This prediction was based on the litterfall data from heath forest which showed the increasing litterfall during rainy season. The leaf litter of peat swamp forest were 55.2 %, this value were lower than those in fresh water swamp in Tasek Bera Malaya, which was reported to be 78.3 % (Furtado *et al*., 1980).

This research showed a peak of total litterfall in heath forest during wet period in October and November 1998. This result was similar to litterfall in heath forest in Gunung Mulu NP, where the peak of litterfall was occurred in rainy season in April and June 1978. It might be caused of high winds contributed to the peak of litter fall. John (1973) in Ghana and Rai (1986) in Kartanataka noted higher litter fall associated with the strong wind at the beginning of the wet season. Beside that, the varied seasonal pattern of species shedding their leaves is another reason that causes the peak of litter occurred in rainy season.

Decomposition rate of litter

Weight losses of mixed litter in peat swamp forest ranged from 19.5 % $year^{-1}$ (the slowest in the fine mesh) and in heath forest 54.4% (the fastest in the fine mesh). Comparable range for *C. pulcherrimum*, are 16.2% $year^{-1}$, *Tristaniopsis* sp. 67.5-72.3% $year^{-1}$, *Palaquium* sp. 35.4-55.5% $year^{-1}$ in heath forest and for *V. oblongivolia* 21.3-29.3% $year^{-1}$, *B.sessilifolia* 30.5-59.7% $year^{-1}$, and *G.* cf. *laurifolia* 22.7-28.2% $year^{-1}$. Data from Anderson (1983) for two species of leaves and mix litters were collected from forest floor in 40 µm mesh (fine) and coarse 7-20 mm mesh bag gives a range 50-63% $year^{-1}$ in four tropical lowland forests in Sarawak, Malaysia. Edward (1977) found that for six species of leaves in 8 mm mesh bags give a range of 26-95% $year^{-1}$ (average 40% $year^{-1}$) in four montane rain forest sites in New Guinea. Tunner (1981) in four Jamaican montane rain forests, used 2 mm mesh litter bags containing fifteen species give the same range of decay rates as Edwards (1977) with a mean value of 47% year^{-1}. These results suggest that the decomposition rates of leaves in heath and peat swamp forest is lower than those in lowland tropical rain forest in Malaysia and in lower montane rain forest in New Guinea and Jamaica.

The decomposition processes in peat swamp and heath forest were not significantly different between the type of litter bags (Table 3 and Fig. 4). This result was similar to the research conducted in Gunung Mulu National Park (Anderson *et al.,* 1983). Even the decomposition rate between the type of litter bags was not significant, there was still differences in decomposition rate among the type of litter bags. The differences are largely caused by the feeding activities of invertebrate saprotrophs but include losses of large fragments due to abiotic processes (Anderson *et al.*, 1983), losses by leaching, especially in coarse mesh.

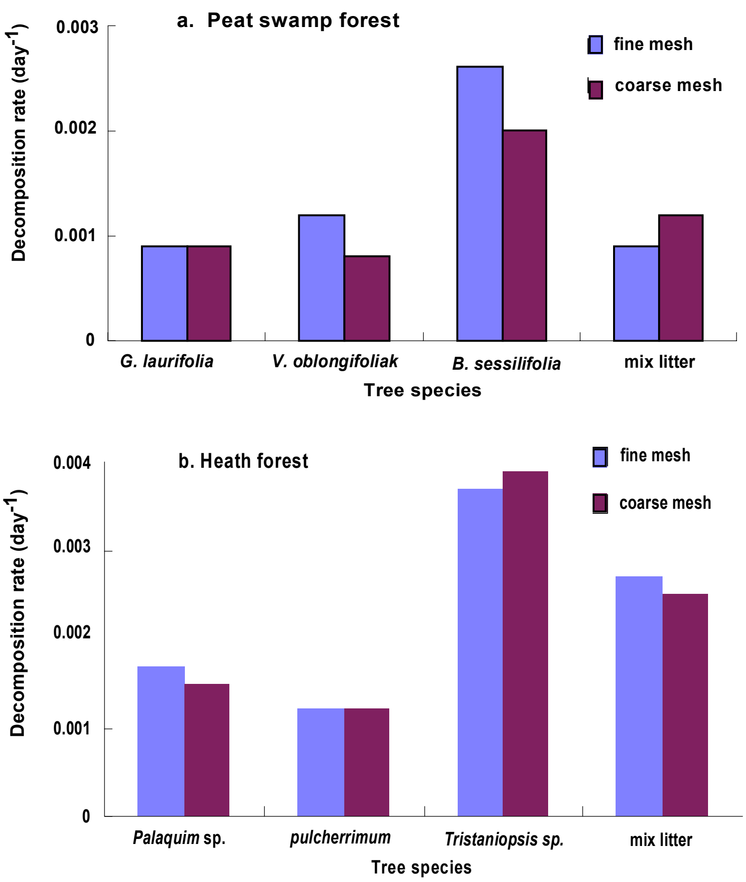

Fig. 4. Comparison between different mesh size of litter bags in peat swamp and heath forest.

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Study on Leaf Element Concentrations of Some Dominant Tree Species Grown in Peat Swamp Forest, Central Kalimantan

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Abstract

With the aim of understanding the ecological characteristics of peat swamp forest ecosystem, which paid due regard to the foliage nutritional traits under a great pressure of persistent land degradation and deforestation, a preliminary study has been carried out in Central Kalimantan. At the initial stage, 4 of 1 ha permanent plots have been established at Kalampangan Zone, Central Kalimantan. The study site covered a primary or relatively undisturbed peat swamp forest and fire-damaged areas representing the different magnitude of human interference upon them. Results of this study showed that the ranges of peat thickness, ground water level, fresh peat soil pH, EC and Eh varied greatly following the nature of the study plots. The pH of peat soil at study site was very low (pH<4). It is probably due to high organic matter constituents which producing some organic acid compounds through decomposition process under waterlogged conditions. In terms of mineral concentrations, it was observed that the mean concentration of macro-elements in plant leaves at the whole study plots following the same order as follows: N>K>Ca>Mg>P. In addition, it was also observed that in many plant studied, some micro-elements such as Fe, Mn and Zn were found below the critical levels for adequate growth. However, there were no symptoms of these nutrients disorder appeared. Among other plants studied, *Combretocarpus rotundatus* and *Eugenia* sp. tend to accumulate Al more than the others. However, most of the plants were found maintaining high concentrations of Al and Na in their leaf tissues compared to other microelements. Further studies should be addressed to know more the physiological characteristics of both *Combretocarpus rotundatus* and *Eugenia* sp. in terms of adaptation mechanisms to the poor-nutrient habitat of PSF.

Key words: Kalampangan zone, native peat swamp forest, fire-damaged area, leaf element concentrations, peat thickness, ground water level, and poor-nutrients habitat.

Introduction

Peatlands are wetland ecosystems that are characterized by the accumulation of organic matter, which is produced and deposited at a greater rate than that decomposed leading to the formation of peat. Tropical peatlands, in particular, inland and transitional peat have been recognized as nutrient-poor environment. However, natural or relatively undisturbed peatlands are covered by diverse species of peat swamp forest as climax vegetation. It is assumed that those native plants had an inherent mechanism to be tolerant to the harsh environment of the peatland ecosystems. In this poor nutrient ecosystem, there are two aspects of nutritional trait that considered to be the most essential; (1) nutrient cycle within ecosystem, and (2) nutritional characteristics of individual plants therein. To determine the nutrient cycle, it is required a fully understanding towards the magnitude of litter supply, litter decomposition, nutrient supply from soil, precipitation and river, and nutrient loss from soil. Nutrient cycling is very complicated because there are various attributes, processes and mechanisms involved. Litter decomposition, for instance, is governed by various factors such as nutrient compositions of litter, soil microbial activity, small animals, water and temperature conditions, nutrient supply by flood, sometimes fire occurrence, and other related components. Thus, it is appear that only to understand the process of litter decomposition, many factors should be viewed and analyzed.

In terms of requirement for nutrients, there is a general range in which a plant can survive, which is depending on species, tissue and age of the plant. In the case of peatland ecosystems, as it is also acknowledge occurs in tropical forest, many scientists argued that most of nutrients stored in vegetation in the form of biomass. In addition, plant species can also be recognized by way of their typical elemental compositions. Therefore, those natural plants can also be used as bio-indicator of changing environment. Since there has been very limited information available concerning the nutritional traits of plants those grown on tropical peatland ecosystems, the current study was aimed to understand clearly the nutritional traits on peatland ecosystems from ground vegetation standpoint. To this end, detailed sampling of plant compartments mainly leaves of peat swamp forest trees and associated vegetation has been carried out in Central Kalimantan, Indonesia.

This recent study is aimed to determine nutrient composition in leaf of some dominant tree species that naturally grown in peat swamp forest. Inherent nutritional characteristics of mineral elements in those tree species is also identified and elucidated.

Materials and Methods

Study site

Field investigation has been carried out in Central Kalimantan where study site and experimental plots were established. The research site comprised a primary or natural peat swamp forest and fire-damaged area of inland peat, which representing different magnitude of human interference upon them. Primary or natural peat swamp forest site was defined as a relatively undisturbed area of peat swamp forest, whereas fire-damaged area was a site that affected by massive wildfires in 1996-1997. In June 1999, 4 of 1-hectare study plots were established at Kalampangan Zone, which is located between 2°19’ to 2°21’ south latitude and 114°00’ to 114°03’ east longitude. Two of the study plots laid on deep peat and the rests two plots located on shallow peat. Using a grid system, each of the 1-ha study plots divided into 100-sub plots of 10 m × 10 m in size. 20-sub plots out of 100 then selected systematically in where sampling, all field measurements and monitoring are employed. Samplings are conducted toward leaf and bark of predominant trees and also peat soils with different depth; whereas field measurements and monitoring applied to obtain data on peat depth, peat water table, tree biomass, plant root systems, forest profile diagram, litter fall and litter decomposition. Some related and necessary instruments were installed within the selected plots. This recent report, however, is solely based on the study that was carried out on leaf element concentrations of some dominant tree species found in the study plots.

Determination of peat depth and ground water level

During the dry season of July and August 1999, peat depths and ground water levels were determined. Twenty dip-wells (2 m long) were inserted into peat soil layer on selected subplots, in where peat borings were also conducted. Along with the measurement of peat depth and ground water level, fresh peat soil pH, electric conductivity (EC) and redox-potential (Eh) were directly determined in the field after the fresh peat soil firstly squeezed and shook properly. These field determinations of pH and EC have done using a portable pH combination electrode and EC meter (TOA Electronics Ltd.), respectively. Meanwhile, redox status of tropical peat soil was determined using a portable potential meter equipped with platinum electrode and Ag/AgCl (3.3 mol/l KCl) as reference electrode, and determination was made following the different depth of peat soil layers.

Leaf samples preparation and analytical methods

Mature leaves (including shoots) of trees were collected and mixed from several plants found within selected subplots. The mature leaves were firstly washed with deionized water, dried in an oven at 80°C for 24 h, then ground and homogenized using a tungsten carbide vibrating mixer mill.

Prior to determine its total elemental concentrations, plant tissues were digested by a mixed solution of sulfuric acid - H_2O_2. N concentration was determined by the semi-micro Kjeldahl method, whereas P, K, Ca, Mg, Na, Fe, Mn, Zn, Al and Si concentrations by Inductively Coupled Plasma Atomic Emission Spectrometry (SHIMADZU ICPS-7000).

Results and Discussion

Peat depth and ground water level

Results of the peat depth and ground water level measurement are shown in Table 1, whereas its distribution at entire study plot is illustrated in Fig. 1. According to the range of peat thickness (Table 1), it seems that the peat layer in Plot 1 and Plot 2 was relatively deep than that in Plot 3 and Plot 4. Meanwhile, ground water level in entire study plots was remained high (less than 1 m from the surface), though the period of measurement was in dry season of July and August 1999. This is indicating that peat soil has a high water holding capacity and therefore it is very important as source of water particularly during the dry period. In addition, during the period of August to December 1999 it was also found that the atmospheric and below ground temperatures seem to be fluctuated over the study plots which ranged from 20.35°C– 32.91°C and 25.68°C – 27.02°C, respectively.

Table 1. Peat thickness and ground water level measured in study plots

Plot	Peat thickness, m mean (range)	Ground water level, cm mean (range)
1	4.14 (4.00 – 4.35)	45.75 (22 – 77)
2	4.79 (4.03 – 5.20)	26.88 (15 – 46)
3	4.27 (3.50 – 4.67)	53.40 (35 – 69)
4	4.11 (3.35 – 4.84)	51.25 (27 – 71)

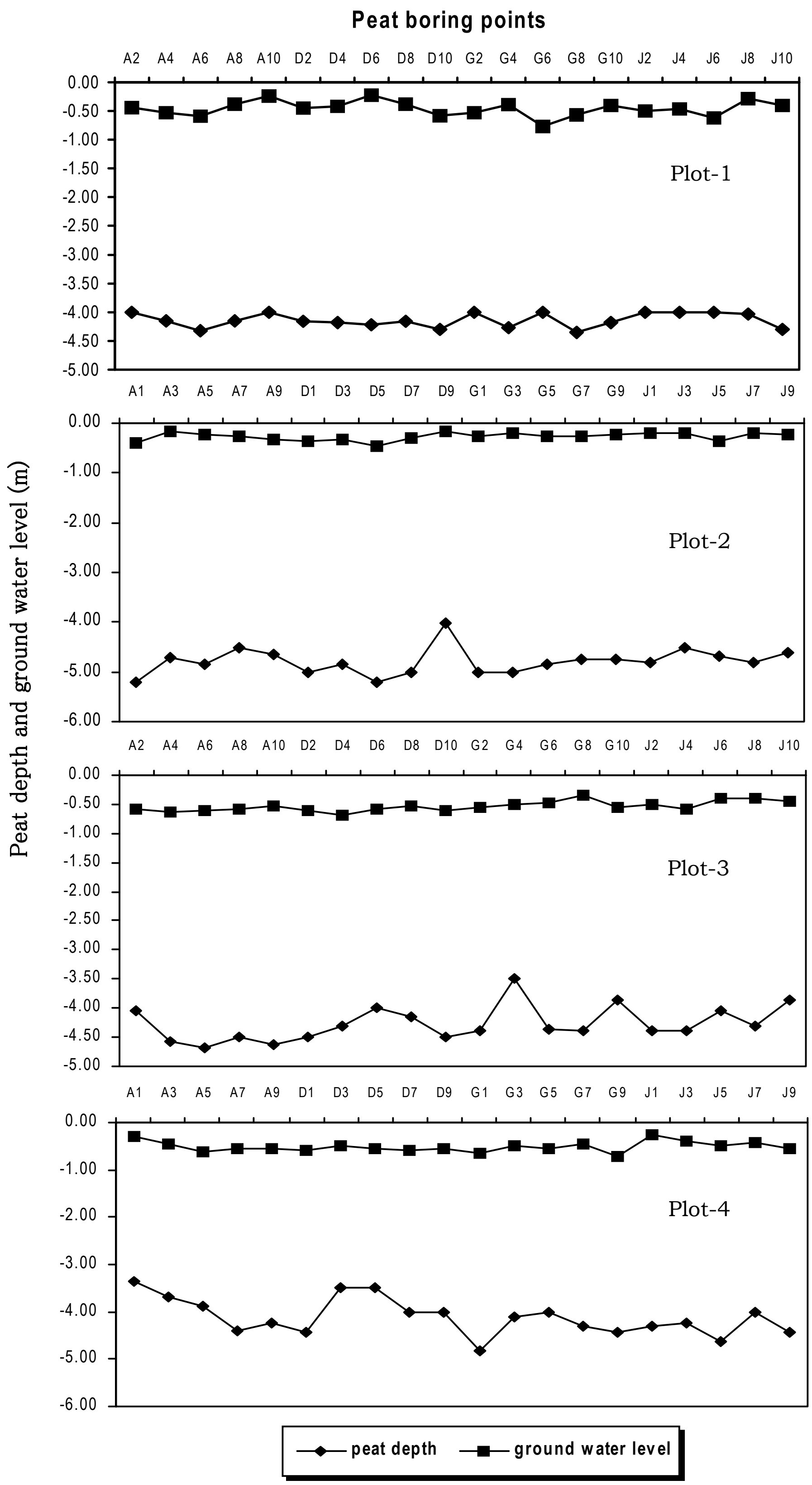

Fig. 1. Distribution of peat depth and ground water level at study plots

Fresh soil pH, electric conductivity and redox potential

Mean values and ranges of pH, EC and Eh that were measured in whole study plots presented in Table 2. However, the results reported here were mainly for the surface of peat soil layer (10 – 20 cm in depth) and subsoil layer (20–50 cm in depth). It was found that the mean range values of pH varied among the peat core depth in entire study plots. The pH in Plot 1 and 2 was relatively low compared to that in Plot 3 and 4. In contrast, the mean values of EC were high in Plot 3 and 4 compared to that in Plot 1 and 2. This is probably because the position of plot 3 and 4 near to the river of Sebangau, and may sometimes influence by flooding water. In general, there was no significant different between the mean values of fresh peat soil pH on the surface (3.09–3.31) and on subsoil (2.97–3.34) in all study plots. This is indicating that the peat soil at study site has very low pH (<4). The acid soil reactions (low pH) were also measured by Sabiham *et al*. (1997) at Bereng Bengkel site, and Shepherd *et al*. (1997) under mixed swamp forest of Sebangau. Both of these sites area adjacent to this current study site. A high organic matter constituent probably the main cause of acid reaction of the peat soils. In the whole study plots, *Combretocarpus rotundatus* was found as the abundant tree species. This tree species is assumed containing a high proportion of lignin. This lignin then undergoes decomposition through biodegradation under anaerobic conditions producing phenolic acids (Sabiham *et al*., 1997).

Table 2. pH, EC and Eh of peat soil on different core depth at study plots

Plot	Core depth, cm	Fresh soil pH mean (range)	Electric conductivity mean (range), μScm^{-1}	Redox-potential mean (range), mV
1	10 – 20	3.09 (2.92 - 3.25)	152.86 (103.10 - 254.42)	386 (349 - 422)
	20 – 50	2.97 (2.85 - 3.13)	120.36 (103.30 - 158.64)	394 (359 - 432)
2	10 – 20	3.12 (3.04 - 3.25)	73.85 (63.86 - 87.20)	355 (320 - 385)
	20 – 50	2.98 (2.89 - 3.08)	76.24 (62.94 - 82.10)	369 (332 - 399)
3	10 – 20	3.31 (3.22 - 3.41)	60.64 (51.22 - 81.42)	295 (274 - 308)
	20 – 50	3.34 (3.28 - 3.41)	55.19 (43.56 - 69.76)	297 (287 - 308)
4	10 – 20	3.17 (2.97 - 3.32)	72.08 (55.82 - 85.12)	329 (303 - 347)
	20 – 50	3.14 (3.00 - 3.25)	56.84 (50.18 - 63.86)	335 (306 - 362)

Moreover, oxidation-reduction is one of the general measures, which describes chemical status of water or soil environments. Eh is a measure of oxidized and reduced ratio of materials in solution, therefore it is strongly affected by oxygen status of the substances. In peat soils, oxygen supply from atmosphere to soil is limited by the low diffusion rates within water over the soil. This, therefore, low Eh value is commonly found in the peat soils at all study plots as shown in Table 2. However, the mean Eh values were found relatively high in Plot 1 and 2 than that in Plot 3 and 4. Soils with low Eh value affects plants not only by the inhibition of respiration due to low oxygen contents, but also by the detrimental effects of toxins which are produced under reduced condition of the soils. Data obtained from this study show that Eh values were generally decreased with the increasing depth of peat from the surface. This probably relates to the low oxygen diffusion rates within the peat and extensive oxygen consumption by the peat microorganisms on the surface layer. In addition, ground water level is also performing a strong influence to the Eh value.

Some dominant tree species of PSF found in study plots

The previous works of Anderson (1976) in Sarawak and Brunei reported that the formation of peat swamp forest is supported by lowland peat soil. This lowland peat soil is oligotrophic and recognized as ombrogenenous peat, where precipitation is the main source of nutrients (Brunig, 1973). Most peat swamp have concentric forest zones, changing from an outer uneven-canopied high forest, similar to lowland dipterocarp forest, to zones of lower height, decreased tree girth and less species richness towards the center of the swamp. Therefore, Whitmore (1990) affirmed that the peat swamp forest (PSF) formation is quite distinctive with a rather restricted flora. The PSF in Central Kalimantan is quite extensive in area, yet very little is known about their forest species composition and structure. A great loss of the PSF biodiversity is continuously occurred, since most of the dominant and commercially important tree species have been extensively logged.

As shown in Table 3 and 4, it was identified at least 21 family of trees and 4 family of shrubs under native or relatively undisturbed PSF (Plot 1 and Plot 3). Meanwhile, over fire-damaged area (Plot 2 and Plot 3) at least 18 family of trees and 4 species of ferns were identified. Under native or relatively undisturbed peat swamp forest (Plot-1 and Plot-3), woody plant density of more than 1.3 m in height, including shrub and vein species was very dense. Canopy closure was moderate and around 75%. Major tree species found in the top canopy layer were *Gonystylus bancanus*, *Calophyllum inophyllum*, *Shorea* sp., *Tetrameristra glabra*, *Combretocarpus rotundatus*, *Mangifera* sp., *Camnosperma coriaceum*, and *Eugenia* sp. In addition, family of Pandanaceae, Orchidaceae, Arecaceae, and Nephetaceae were abundantly found as the main shrub layer. There was no apparent of nutrient disorders on tree leaves. In contrast, the plots under fire-damaged area (Plot 2 and 4) had lost many canopy trees caused very sparse in canopy closure. Canopy height was about 20-25 m and the density of residual stands was very low. However, woody plant density of more than 1.3 m in height was abundant because of many seedlings and saplings regenerated naturally after the fire. Major tree species in the stand were *Palaquium* sp., *Combretocarpus rotundatus*, *Mangifera* sp., *Cratoxylum arborescens*, *Buchanania sessifolia*, *Tetrameristra glabra*, *Callophylum* sp. and *Dyera* sp. Ferns occurred very frequently as the forest floor vegetation. In general, the species composition in native or relatively undisturbed PSFs of this study was relatively poor compared to that in PSFs of Selangor and Pahang (Harun *et al*., 1999).

Mineral Concentrations in Leaves

As has widely been recognized that tropical peatland ecosystem was classified as nutrient-poor habitat, and the native plants that grown therein argued to maintaining an inherent mechanism to be adapted. In this study, mature leaves (including shoots) of tree species above 10 cm in diameter at breast height that naturally distributed in whole study plots were sampled and analyzed for their element concentrations. About 40 tree species Plot 1, 22 tree and 2 fern species from Plot 2, 29 tree species from Plot 3, and 6 tree and 2 fern species from Plot 4 were sampled analyzed. However, the results presented in Table 5 are only for some dominant species as the main part of the top canopy layer of the PSF at Kalampangan Zone, Central Kalimantan.

Table 3. Some abundant species found in native or relatively undisturbed peat swamp forest

Family	Genus-Species	Growth form
Anacardiaceae	*Buchanania sessifolia*	Tree
	Camnosperma coriaceum	Tree
	Mangifera sp.	Tree
Anisophylleaceae	*Combretocarpus rotundatus*	Tree
Annonaceae	*Polyalthia hypoleuca*	Tree
	Xylopia fusca	Tree
Apocynaceae	*Dyera costulata*	Tree
Aquifiliaceae	*Ilex macrophylla*	Tree
Burseraceae	*Santiria laevigata*	Tree
Caesalpiniaceae	*Koompasia malaccensis*	Tree
Clusiaceae	*Garcinia dioica*	Tree
Dipterocarpaceae	*Shorea blangeran*	Tree
	Shorea rugosa	Tree
	Shorea spp.	Tree
	Shorea teysmanniana	Tree
	Shorea uligonosa	Tree
	Shores retusa	Tree
	Vatica umbonata	Tree
Ebenaceae	*Diospyros oblonga*	Tree
Euphorbiaceae	*Antidesma bunius*	Tree
	Baccaurea bracteata	Tree
	Macaranga semiglobosa	Tree
	Neoscortechinia kingii	Tree
Guttiferae	*Calophyllum hosei*	Tree
	Calophyllum inuphyllum	Tree
	Calophyllum rhizophorum	Tree
	Calophyllum sclerophyllum	Tree
	Calophyllum sp. (1)	Tree
Hypericaceae	*Cratoxylum arborescens*	Tree
Lauraceae	*Alseodaphne coriacea*	Tree
	Litsea resinosa	Tree
Meliaceae	*Sondoricum emarginatum*	Tree
Myristicaceae	*Myristica lowiana*	Tree
Myrtaceae	*Eugenia havilandii*	Tree
	Eugenia lepidocarpa	Tree
	Eugenia sp. (1)	Tree
	Eugenia sp. (2)	Tree
	Eugenia sp. (3)	Tree
	Tristania maingayi	Tree
Rosaceae	*Parastemon urophyllus*	Tree
Sapotaceae	*Ganua motleyana*	Tree
	Palaquium leiocarpum	Tree
	Palaquium sp. (1)	Tree
	Palaquium sp. (2)	Tree
Theaceae	*Tetramerista glabra*	Tree
Thymelaeceae	*Gonystylus bancanus*	Tree
Pandanaceae	*Pandanus* sp.	Shrub layer
Orchidaceae	*Spathoglottis*sp.	Shrub layer
Arecaceae	*Calamus* sp.	Shrub layer
Nephentaceae	*Nepenthes* sp.	Shrub layer

Table 4. Some abundant species found in fire damaged area

Family	Genus-Species	Growth form
Anacardiaceae	*Buchanania sessifolia*	Tree
	Mangifera sp.	Tree
Anisophylleaceae	*Combretocarpus rotundatus*	Tree
Annonaceae	*Xylopia fusca*	Tree
Apocynaceae	*Dyera costulata*	Tree
Clusiaceae	*Garcinia dioica*	Tree
Dipterocarpaceae	*Shorea blangeran*	Tree
	Shorea rugosa	Tree
	Shorea teysmanniana	Tree
Ebenaceae	*Diospyros oblonga*	Tree
Euphorbiaceae	*Neoscortechinia kingii*	Tree
Fabaceae	*Dialium patens*	Tree
Guttiferae	*Calophyllum inuphyllum*	Tree
	Calophyllum sclerophyllum	Tree
	Calophyllum sp. (1)	Tree
Hypericaceae	*Cratoxylum arborescens*	Tree
Lauraceae	*Cinnamumun* sp.	Tree
	Litsea firma	Tree
Myrtaceae	*Eugenia lepidocarpa*	Tree
	Eugenia sp. (1)	Tree
Polygalaceae	*Xanthophyllum* sp.	Tree
Rosaceae	*Parastemon urophyllus*	Tree
Sapotaceae	*Palaquium leiocarpum*	Tree
	Palaquium sp. (1)	Tree
Theaceae	*Tetramerista glabra*	Tree
Thymelaeceae	*Gonystylus bancanus*	Tree
FERNS	*Lycopodium cernuum*	Shrub layer
	Stenochalena palustris	Shrub layer
	Nephrolepis biserrata	Shrub layer
	Pteridium esculentum	Shrub layer

As can be seen in Table 5, that the mineral concentrations in mature leaves of some dominant plants in all study plots were varied greatly according to the species and the site of origin. There was a similar pattern in the average concentration of macro elements of the plant species for whole study plots, as in the following order: N>K>Ca>Mg>P. In contrast, the average concentration of microelements was found similar in Plot 1 and 4, but slightly different in Plot 2 and Plot 3. In Plot 1 and 4, the order of leaf element concentrations was Na>Al>Mn>Fe>Si>Zn, whilst the following orders of Na>Mn>Al>Fe>Si>Zn and Al>Na>Mn>Fe>Si>Zn were appeared in Plot 3 and Plot 3, respectively. In this study, although some microelements such as Fe, Mn and Zn found below the critical levels for adequate growth, there were no symptoms of these nutrients disorder observed. This is denoting that the concentrations of those microelements have sufficient enough to support the plant growth in peat soils.

Table 5. Leaf element concentrations of some dominant plant grown in peat swamp forest at Kalampangan Zone, Central Kalimantan

Species	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Al	Si
	g kg^{-1}					mg kg^{-1}					
Native-Deep Peat [Plot-1]											
Camnosperma coriaceum	12.8	0.5	8.8	5.7	5.6	589	55	192	15	121	59
Calophyllum inuphyllum	10.8	0.3	6.0	3.2	1.3	488	114	31	12	28	47
Calophyllum sclerophyllum	19.2	0.3	5.0	21.4	4.0	459	40	30	7	110	57
Diospyros oblonga	15.2	0.3	11.9	3.9	4.3	308	46	591	8	37	51
Palaquium leiocarpum	19.6	0.3	7.3	5.1	2.9	395	629	28	9	72	66
Dyera costulata	16.2	0.4	5.8	6.9	2.8	219	44	382	16	49	46
Antidesma bunius	13.0	0.1	7.6	1.8	3.7	252	54	40	26	309	88
Mangifera sp.	14.0	0.2	13.0	6.4	3.6	277	51	34	8	31	55
Ilex macrophylla	24.9	0.3	6.7	10.3	2.9	228	42	42	13	31	18
Eugenia havilandii	16.2	0.3	12.5	5.8	3.6	526	132	168	34	1	21
Shorea teysmanniana	16.8	0.3	5.4	10.7	3.5	201	68	654	13	35	35
Tetramerista glabra	10.5	0.2	8.6	4.5	1.9	697	70	27	12	28	58
Gonystylus bancanus	9.4	0.2	7.4	4.6	1.9	280	82	29	8	1	39
Combretocarpus rotundatus	14.0	0.5	7.3	5.5	2.0	373	91	826	45	7756	44
Fire Damaged Area-Deep Peat [Plot-2]											
Calophyllum inuphyllum	8.6	0.2	4.8	6.7	2.0	485	51	117	16	13	33
Calophyllum sclerophyllum	15.8	0.5	21.2	10.8	4.5	299	87	180	48	36	32
Diospyros oblonga	10.6	0.3	5.5	14.1	2.2	240	66	985	47	45	34
Eugenia lepidocarpa	9.6	0.2	12.2	10.1	1.7	218	70	23	9	55	49
Cratoxylum arborescens	15.1	0.6	9.9	6.6	1.0	327	73	520	29	14	36
Palaquium leiocarpum	12.9	0.3	16.1	6.9	2.6	406	60	25	10	38	60
Dyera costulata	17.6	0.6	14.8	7.5	2.4	378	64	224	20	8	26
Tetramerista glabra	11.8	0.3	11.3	7.7	2.8	393	96	28	9	50	44
Combretocarpus rotundatus	16.5	0.7	8.7	7.2	2.1	516	173	454	30	2084	65
Lycopodium cernuum [Fern-1]	8.1	0.5	14.4	12.7	12.1	126	95	125	25	103	60
Pteridium esculentum [Fern-2]	9.3	0.4	16.7	0.8	1.1	198	51	52	20	37	26
Native-Shallow Peat [Plot-3]											
Shorea blangeran	17.0	0.6	11.5	8.8	2.5	522	314	355	84	59	64
Calophyllum inuphyllum	10.5	0.4	11.1	10.6	3.0	706	62	72	21	57	49
Calophyllum sclerophyllum	9.6	0.4	19.0	7.9	4.9	561	64	227	38	23	25
Diospyros oblonga	17.6	0.4	16.1	7.1	2.8	469	49	448	11	40	56
Eugenia lepidocarpa	18.3	0.3	6.3	10.5	1.8	647	77	49	12	275	79
Dyera costulata	11.9	0.3	8.0	9.0	3.1	237	121	41	12	73	103
Ilex macrophylla	11.0	0.4	11.7	15.5	2.4	487	102	39	11	200	97
Shorea teysmanniana	8.0	0.3	9.2	15.0	1.4	290	93	73	14	49	33
Tristania maingayi	8.7	0.4	17.7	6.1	2.4	820	43	26	7	66	102
Tetramerista glabra	13.0	0.4	10.6	5.9	1.6	673	84	169	9	49	60
Gonystylus bancanus	8.1	0.3	17.6	5.9	2.3	471	48	23	7	63	93
Eugenia sp.	13.6	0.5	14.0	4.4	2.5	551	52	497	37	10149	30
Combretocarpus rotundatus	12.3	0.4	11.6	4.8	2.6	512	49	485	33	9751	55
Fire Damaged Area-Shallow Peat [Plot-4]											
Buchanania sessifolia	23.0	0.6	5.9	13.8	2.5	675	76	226	16	85	52
Mangifera sp.	14.6	0.5	9.0	5.6	3.0	549	104	248	24	100	41
Palaquium sp.	18.6	0.4	5.0	4.8	3.8	262	38	114	16	17	24
Tetramerista glabra	13.6	0.2	11.0	3.0	1.0	924	39	25	13	28	49
Combretocarpus rotundatus	18.2	0.5	9.7	6.6	2.4	585	79	437	46	4367	56
Lycopodium cernuum [Fern-1]	18.7	0.6	15.2	1.5	1.5	426	142	62	20	311	53
Pteridium esculentum [Fern-2]	16.1	0.3	13.0	4.8	4.1	895	118	166	20	141	47

Moreover, among other plants studied, *Combretocarpus rotundatus* and *Eugenia* sp. tend to accumulate Al more than the others. If the criteria of Al accumulator plant that introduced by Chenery and Sporne (1976) should be referred, so these native plants of PSF can be categorized as Al accumulator plants. As shown in Table 5, that the species of *Combretocarpus rotundatus* in whole study plots accumulates Al more than 1000 mg kg^{-1} in its leaf (including shoot), whereas *Eugenia* sp. was only found in Plot 3. In addition, all the plants studied were found maintaining high concentrations of Al and Na in their leaf tissues compared to the other elements as such Fe, Mn, Zn and Si. Osaki *et al*. (1998) argued that this phenomenon remained inherent to plant characteristics regardless of soil conditions as observed over native plants that grown in various adverse soils in Peninsular Thailand. Although further study need to be addressed to the adaptation mechanisms of plants that grown and survive in nutrient-poor habitat of PSF, Jordan (1991) argued that as part of the mechanisms the plant often performed a large root biomass, root concentration near surface, aerial roots, mycorrhizae, tolerance of acid soils, nutrient uptake kinetics, long life span, leaf morphology and physiology, allelopathy, nutrient translocation, efficiency of nutrient use, reproduction, silica concentration, bark, epiphylls, and drip tips. As observed in this study, the most abundant trees recorded belong to families rich in defense compounds such as latex, essential oils, resins, and tannins. In addition to these mechanisms, Berendse *et al*. (1999) concluded that plant species could increase their success in nutrient poor habitats along three different lines. First, they can maximize the acquisition of nutrients by increasing their competitive ability for soil nutrients. Second, is by changing the efficiency with which the nutrients that are present in the plant are used for carbon assimilation and subsequent growth. Third, is by increasing the length of the time period during which nutrients can be used.

Conclusions

- Based on the range of peat thickness, it was observed that Plot 1 and Plot 2 covered by deep peat than that in Plot 3 and 4. Meanwhile, ground water level in entire study plots was remained high, indicating that peat soils are considerable important as water storage, particularly during dry season. Therefore, over-drain on peatlands may lead to rapid rates of peat oxidation and decomposition. Consequently, peat subsidence may occur at a very fast rate, especially under tropical conditions.
- The peat soil at study site has very low pH (<4), this is assumed due to a high organic matter constituents which producing some organic acid compounds through decomposition process under waterlogged conditions. Whilst, the mean values of EC were remained high over the study plots nearby the Sebangau River (Plot 3 and 4). Eh values, on the other hand, were generally decreased with the increasing depth of peat from the surface layer. Perhaps, this relates to the low oxygen diffusion rates within the peat and extensive oxygen consumption by the peat microorganisms on the surface layer.
- In terms of the dominant plant species recorded from entire study plots, it was identified at least 21 family of trees and 4 family of shrubs under native or relatively undisturbed PSF (Plot 1 and Plot 3). Meanwhile, over fire-damaged area (Plot 2 and Plot 3) at least 18 family of trees and 4 species of ferns were recorded.
- The same successive order of the average concentration of macro elements in plants studied was observed in whole study plots, namely: N>K>Ca>Mg>P. On the other

hand, some microelements such as Fe, Mn and Zn were observed below the critical levels for adequate growth of the plants studied, but no symptoms of these nutrients disorder found.

- Among other plants studied, *Combretocarpus rotundatus* and *Eugenia* sp. tend to accumulate Al more than the others. However, most of the plants studied were found maintaining high concentrations of Al and Na in their leaf tissues compared to the other elements as such Fe, Mn, Zn and Si.
- Further studies should be addressed to know more the physiological characteristics of *Combretocarpus rotundatus* and *Eugenia* sp. in terms of adaptation mechanisms to poor-nutrients habitat of PSF. In addition, the possible relationships among elements measured are also requiring for further analysis and interpretation.

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Nitrogen and Carbon Cycles of Peat Swamp Forests and Surrounding Areas in Narathiwat, Thailand, Inferred from $\delta^{13}C$ and $\delta^{15}N$ Analyses

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Stable isotope analysis has been recognized as a useful tool for ecological research, especially on ecosystem structure and dynamics such as food web and nutrient dynamics in forests. In this paper we introduce briefly what kind of information a stable isotope analysis gives us and then demonstrate the results of a case study in a peat swamp ecosystem at Narathiwat, Thailand. We clarified the characteristics of nitrogen and carbon cycles in the peat swamp ecosystem and estimated the contribution of biological products at Narathiwat peat swamps as food resource for the people living in this area.

What Kind of Information Stable Isotope Analysis Gives Us?

Light elements composing organic matters, such as hydrogen, carbon, nitrogen, oxygen and sulfur, have a dominant “light isotope” with the nominal atomic weight, and one or two “heavy” isotopes with a natural abundance of a few or less than few percent (Table 1). These heavy isotopes are called stable (in some cases silent) isotopes. The nature of these isotopes is quite similar in chemical and biological reactions. But the isotopes have their own particular thermodynamic and rate constants. Consequently, variation in the isotope ratios of biogenic substances depends on the isotopic composition of reactant, metabolic pathways, and kinetic modes of reaction dynamics. Every biogenic

Table 1. Average terrestrial abundances of the stable isotopes of major elements in ecological studies.

Element	Isotope	Abundance(%)
Hydrogen	^{1}H	99.985
	^{2}H	0.015
Carbon	^{12}C	98.89
	^{13}C	1.11
Nitrogen	^{14}N	99.63
	^{15}N	0.37
Oxygen	^{16}O	99.759
	^{17}O	0.037
	^{18}O	0.204
Sulfur	^{32}S	95.00
	^{33}S	0.76
	^{34}S	4.22
	^{35}S	0.014

material, accordingly, have their own inherent isotopic composition (Wada and Hattori 1991). For instance, a human with 50 kg of body weight has 225 g of heavier isotopes (Fig.1). Human life depends on the material cycles of natural environment and its body has their own istopic pattern of light elements corresponding to its own positions in matter cycle. This is the reason why the isotopic composition of organisms provides useful information on diet analysis, identify nutrient sources and individual feeding behavior, organisms function and position in a food web. In following part we focus on carbon and nitrogen stable isotopes, which are most frequently used for ecological studies.

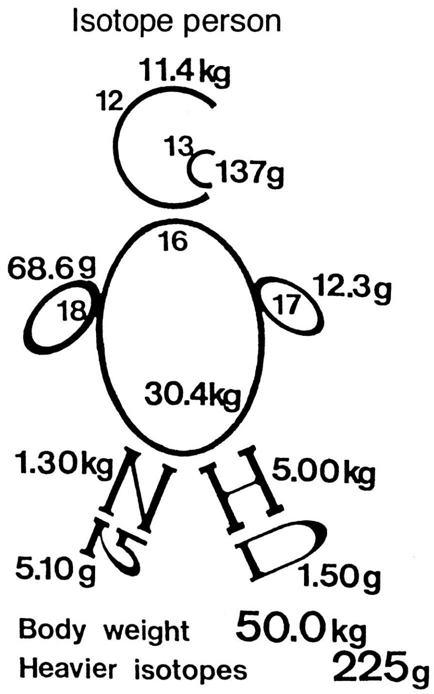

Fig. 1. Isotope person. This person explain isotope balance of light elements composing human body (adapted a brochure from the Mitsubishi Kasei Institute of Life Sciences with permission).

Natural abundance of stable isotopes is explained as the δ-notation:

$$\delta X = [(R_{sample}/R_{standard}) - 1] \times 1000,$$

where X is ^{13}C or ^{15}N and R is $^{13}C/^{12}C$ or $^{15}N/^{14}N$, respectively. Then, δ units are quoted relative to an internationally recognized standard which is set to 0 ‰. For nitrogen, the standard is atmospheric nitrogen, because this isotope pool is well homogenized across the planet's surface. For carbon, the standard is the carbonate fossil, *Bellemnitella americana*, from the Pee Dee Formation in South Carolina, U.S.A. (PDB). Since the accepted standard is limited by availability of the material except nitrogen, samples are measured against a laboratory reference materials so-called "working standard" which have been calibrated against the international standard.

$\delta^{13}C$ and $\delta^{15}N$ of an animal provide information on its diets. $\delta^{13}C$ of animals are used as an indictor of diet (DeNiro and Epstein, 1978; Rau *et al.*, 1983; Fry *et al.*, 1984) (Fig. 2). A stepwise enrichment of $\delta^{15}N$ along food chain is widely recognized among animals with an enrichment factor of 3.4 ± 1.1 ‰ (DeNiro and Epstein, 1981; Minagawa and Wada, 1984; Wada *et al.*, 1987) (Fig. 2). $\delta^{15}N$ of an animal is thus used as an indicator of trophic level of animals.

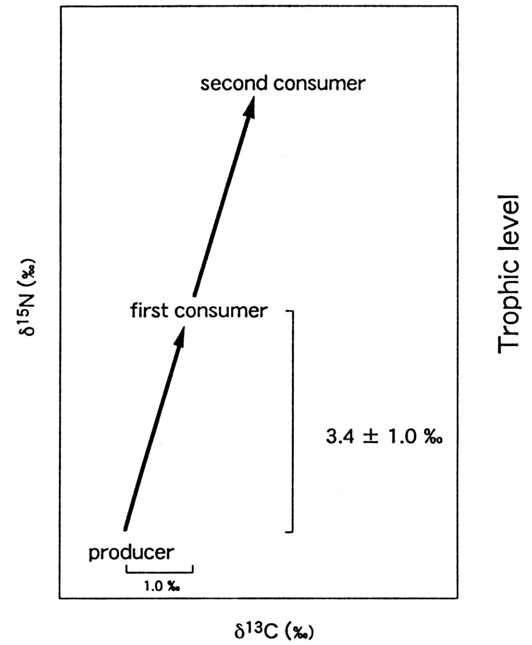

Fig. 2. Schematic $\delta^{13}C$ - $\delta^{15}N$ map of a food web. Regarding $\delta^{13}C$, the relation is only in protein chain, because during synthesyzing lipid $\delta^{13}C$ value depress dramatically.

$\delta^{13}C$ of plants is characterized according CO_2 assimilation system known as C_3, C_4 and CAM-systems: average $\delta^{13}C$ value of C3 plants is - 26 ‰ and that of C4 and CAM is ca. -14 ‰) (O'Leary 1981). The $\delta^{13}C$ becomes high in an aquatic environment where CO_2 diffusion is restricted (Sweeney *et al.*, 1978). $\delta^{15}N$ is closely correlated with forms of nitrogen uptaken by plants as well as organism's growth rate.

According to previous studies, average $\delta^{13}C$ and $\delta^{15}N$ value of terrestrial ecosystems are -25 and 6 ‰ (Fig. 3). Then, if denitrification and/or NH_3 volatilization activate in an ecosystem, light nitrogen (^{14}N) emit faster than heavier nitrogen (^{15}N). Consequently, $\delta^{15}N$ of organisms in the ecosystem reveals relatively heavy $\delta^{15}N$ value. If nitrogen fixation activate and/or inorganic nitrogen in precipitation is major nitrogen source in a ecosystem, $\delta^{15}N$ of organisms become close to 0 ‰ and/or -5 ‰, respectively, because $\delta^{15}N$ values of nitrogen in atmosphere and in precipitation are 0 ‰ and -5 ‰, respectively. In the case of $\delta^{13}C$, active photosynthesis and water stress enrich $\delta^{13}C$ value of plant leaves (Fig. 3).

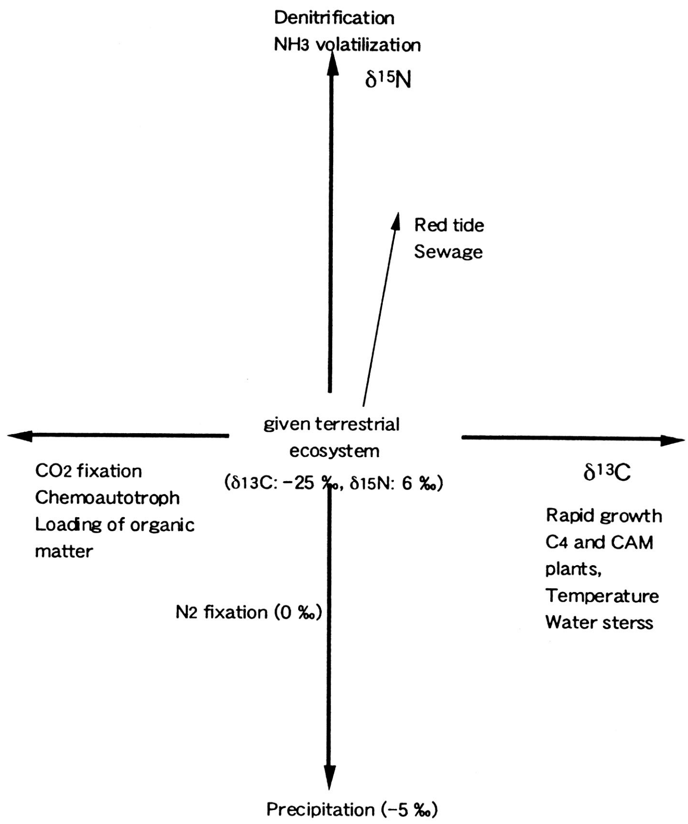

Fig. 3. Fluctuation of $\delta^{13}C$ and $\delta^{15}N$ values and factors affecting the isotope values in a terrestrial ecosystem.

The other example is isotope ratio of human scarp hair. $\delta^{13}C$ value distinguishes C_3 plants, as mentioned above. $\delta^{13}C$ and $\delta^{15}N$ values also distinguish most marine fishes, meat, and dairy products (Wada *et al.*, 1991). Since most commercial plants are cultivated in the presence of chemical fertilizers ultimately made from atmospheric nitrogen, the $\delta^{15}N$ of C_3 plants tends to overlap that of leguminous plants (ca. 0 ‰), which can fix atmospheric nitrogen biologically. Most marine fishes caught as human foods are usually carnivorous and on higher trophic positions in a food web. Hence their ^{15}N contents become relatively high (Wada *et al.*, 1991). For instance, the $\delta^{13}C$ and $\delta^{15}N$ values indicate trend of food consumed in Japan. The values of commercial foods in Japan are becoming close to those of American foods, partly because some foods, such as wheat, potato and soybeans, are imported from the U. S. In addition, assorted food for livestock cultured in Japan has been prepared by using imported materials, including corn (C_4 plant) from the U. S.

Due to these background human $\delta^{13}C$ and $\delta^{15}N$ decrease its $\delta^{15}N$ values. These effects are major reasons for the hair isotope characteristics in Indian (less than 9 ‰), Chinese, Korean, and Japanese populations (less than 11 ‰). Whereas the different usage of C_3 and C_4 plants make a large difference in the ^{13}C content of the food. $\delta^{13}C$ of human hair differentiates Europeans (ca. -20.5 ‰) from Americans (ca. -17.5 ‰), because the ultimate source of organic matter for the former depends mainly on C_3 plants, whereas the diet of the latter depends more heavily on corn.

Relationship between Natural Ecosystem and Human Foods: A Case Study in Narathiwat, Thailand

Since 1995, we conducted stable isotopic study at Narathiwat (N5^{o} 44' - 6^{o} 38', E101^{o} 12' - 102^{o} 5'), the southeast province of Thailand, to investigate carbon and nitrogen cycles in peat swamp forests and surrounding areas. Wide area of natural peat swamp forest had been destroyed to create paddy field in this province. Consequently, peat layer decreased and soil condition become acid-sulfate. Finally the destroyed area become secondary forest dominated only by *Melaleuca cauputi* and *Blechnum indicum* (Kyuma 1995). Natathiwat area is divided into hill site, alluvial plain, swamp, sandy plain, river and ground water pool (Fig.4). Various kinds of organic matters were collected mainly at the natural (ToDaeng) and secondary (Bacho) forests, and surrounding areas, then analyzed their stable isotope ratios. The ToDaeng swamp have been kept intact as a protected forest, while wide area of Bacho swamp already underwent a large scale development during 1970s to early 1980s (Kyuma 1995). In addition, we started the another research at the Narathiwat area since 1997. We collected human scarp hair and measured its carbon and nitrogen stable isotope ratios to evaluate the contribution of biological products from natural ecosystem as food resource for local people in Narathiwat area.

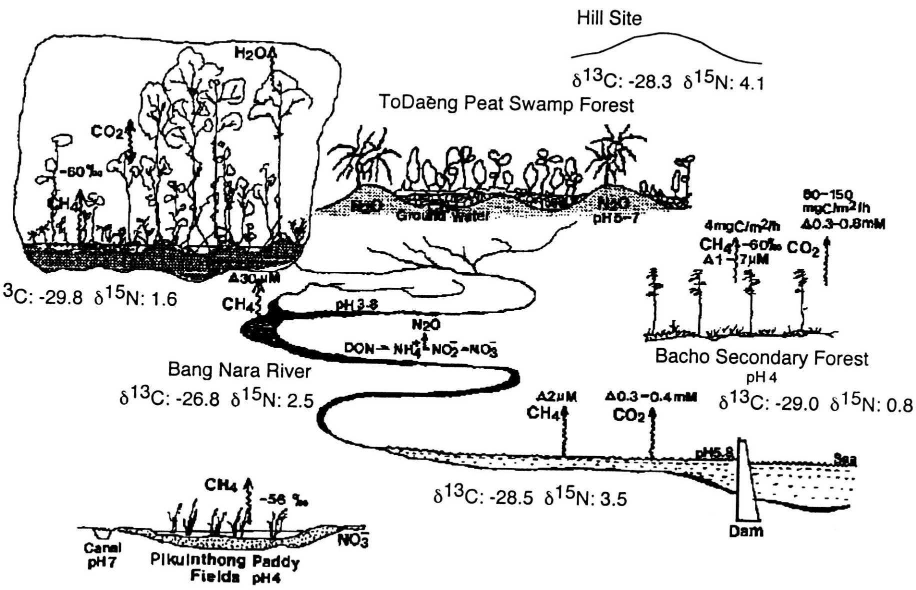

Fig. 4. ^{13}C and ^{15}N of sediments at Narathiwat watershed.

The results are summarized as follows.

1) $\delta^{15}N$ values suggested that inorganic nitrogen in precipitation is major source for organisms at the forests and surrounding area at Narathiwat (Fig. 5). The effect of nitrogen fixation and NH_3 volatilization was low in the area due to low pH (4-5) of the swamp water. Higher nitrogen isotope ratio at ToDaeng natural forest ($\delta^{15}N$; ca. 2 ‰) suggested that denitrification activity was higher at ToDaeng than at Bacho secondary forest (ca. -5 - 0 ‰) (Fig.5).

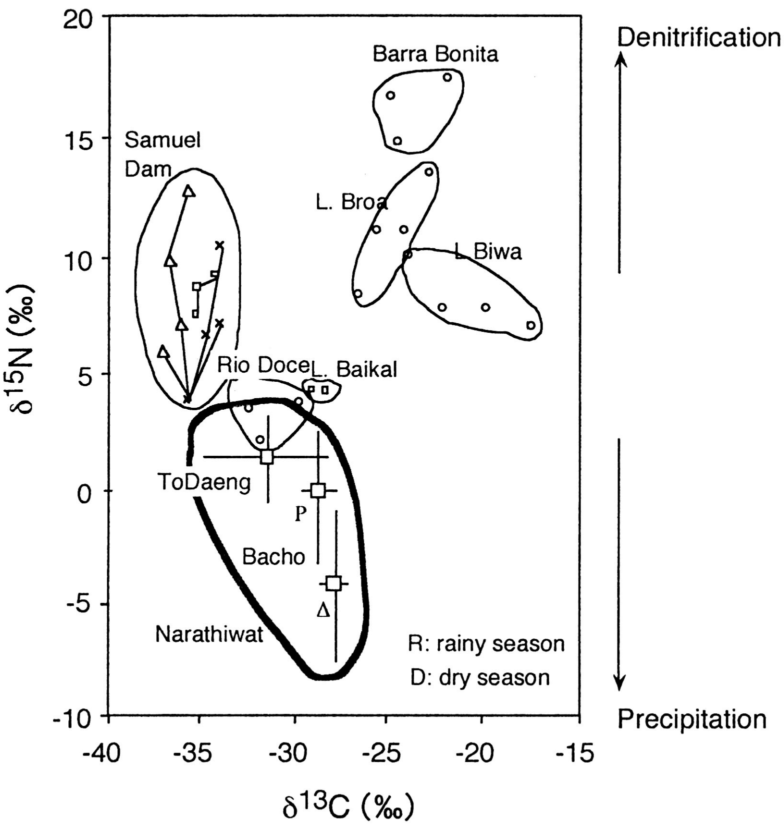

Fig. 5. Summary of $\delta^{13}C$ and $\delta^{15}N$ values of plant leaves collected at Narathiwat area and organic matters in various kinds of lacustrine ecosystems. Possible factors affecting isotope ratios of respective ecosystems are as follows: Barra Bonita: sewage water, L. Bira: allochthonous inputs of terrestrial plants from upper region, L. Biwa: denitrification, Samuel Dam: inflowing organic matter from upper region, Rio Doce: Steady state, L. Baikal: oxygen rich water, Narathiwat: precipitation.

2) Photosynthetic activity is higher at secondary forest ($\delta^{13}C$; ca. -28 ‰) than at natural forest (ca. -32 ‰) (Fig.5). Fluctuation of $\delta^{13}C$ at ToDaeng natural forest was affected primary by vertical depression of right intensity (Hanba *et al.*, 1996) and also plant species diversity. Vertical depression of $\delta^{13}C$ of plant leaves correlated

with light intensity under no water stress. This pattern is widely observed in various kinds of forests (Hanba *et al.*, 1996). On the contrary the fluctuation at Bacho secondary forest was rather affected by difference of photosynthetic activity depend on leaf longevity, because species composition of plants was simple as mentioned above.

3) $\delta^{15}N$ in soil organic matter at ToDaeng was lower than that at other tropical forest possibly due to lower turnover rate of nitrogen compared with other tropical forests (Fig. 6). That is, the swamp is under depletion of available nitrogen because of low mineralization of the peat materials. Assimilation of inorganic nitrogen with low $\delta^{15}N$ that enters the system by atmospheric precipitation most probably caused the low $\delta^{15}N$ in primary produced organic matters. The $\delta^{15}N$ of organic matters in the Bacho swamp (reclaimed) are lower than those in the ToDaeng swamp (virgin) (Fig. 5). The difference probably reflected that N-availability (size of inorganic-N pool) was enlarged during dry season because of increased mineralization under aerobic condition (not water-logged).

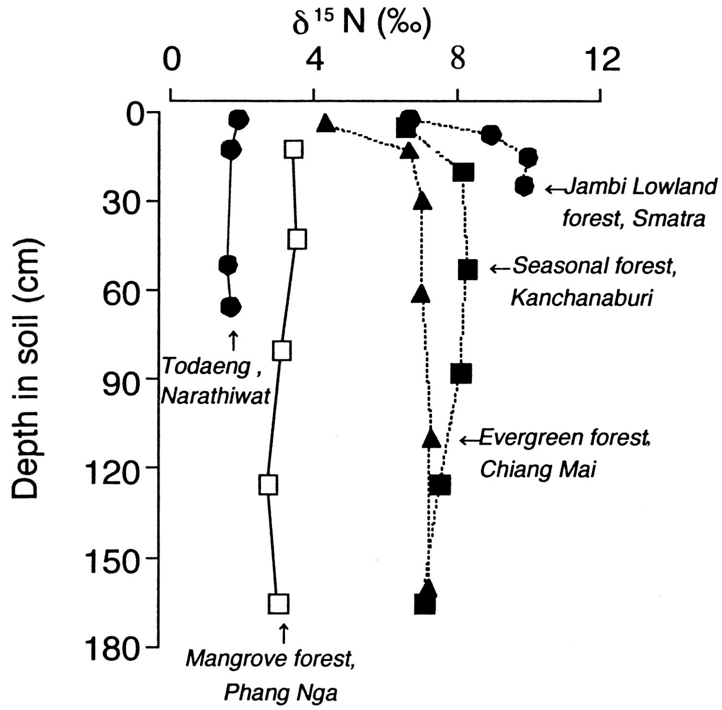

Fig. 6. Vertical profile of ^{15}N of soil organic matter at different types of tropical forests.

4) Isotope values of human hair ($\delta^{13}C$; ca. -19 ‰, $\delta^{15}N$; 10.6 ‰) suggested that food resources for people in Narathiwat and surrounding area were not only products in the Narathiwat ecosystem but also those imported from other areas (Fig. 7).

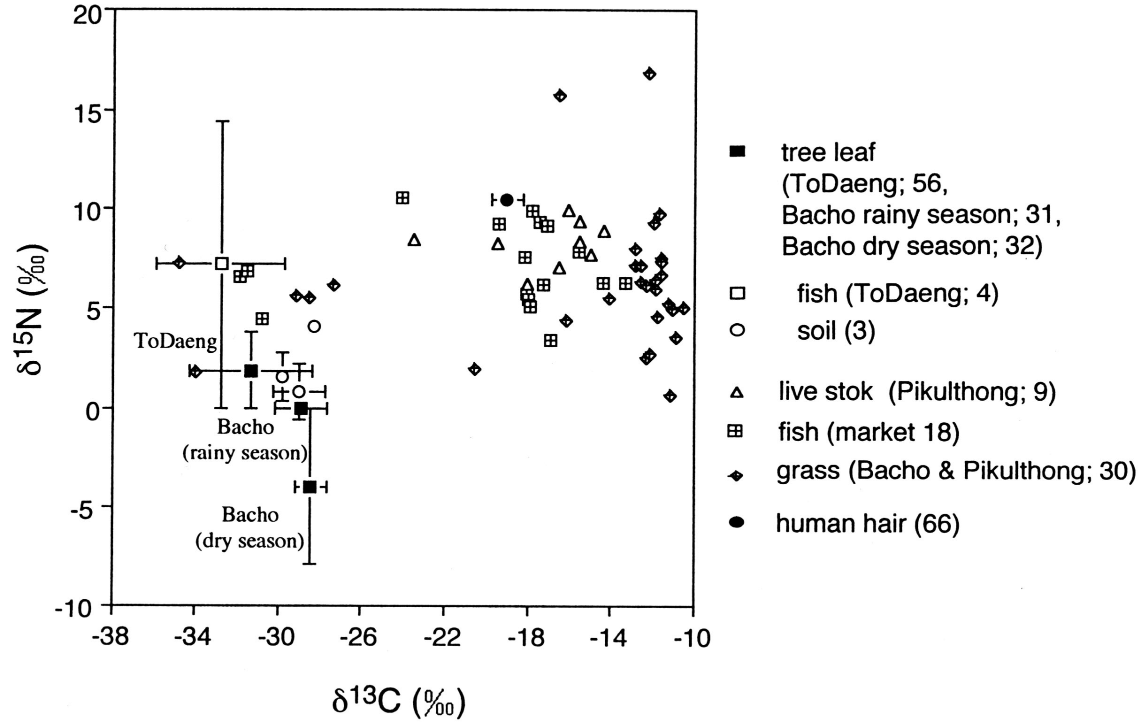

Fig. 7. $\delta^{13}C$ and $\delta^{15}N$ of human scarp hair and orgnic materials at Narathiwat.
Number of samples is shown in parenthesis.

Stable isotope studies at Narathiwat mentioned above were conducted as a part of the research programme of "Creative Basic Research Studies on Development of Sustainable Biomass Production Techniques" by Ministry of Education, Science and Culture, Japan".

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Mangrove Litter-Fall Studies at the PT Freeport Indonesia Project Area

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Abstract

Litter traps were used to estimate litter-fall production in two mangrove communities in the Ajkwa estuary; part of the PT Freeport Indonesia project area. The two communities studied included *Bruguiera gymnorrhiza - Camptostemon schultzii - Rhizophora apiculata* (Site 1) and *B. cylindrica - R. apiculata* (Site 2). The period of study was from February 16, 1998 to October 27, 1998 for Site 1 and February 25, 1998 to December 12, 1998 for Site 2. Total annual litter-fall for Site 1 and Site 2 was estimated at 800.78 g/(m^2 year) and 744.35 g/(m^2 year), respectively. For both communities, litter-fall consisted of leaves (61.5% of total litter production at Site 1 and 51.8% at Site 2), reproductive parts (20.5% at Site 1 and 11.1% at Site 2) and twigs (18.0% at Site 1 and 37.1% at Site 2). The monthly rate of total litter production at Site 1 displayed two peaks during the study period (a major peak in March and a minor one in October) while Site 2 showed only a single peak in February. Monthly rates of production for both leaf and twig litters at both sites peaked only once during the study period while rates of litter production from plant reproductive parts peaked twice. In both communities, the rate of twig litter production coincided with litter production from reproductive parts. During the sampling period, litter-fall rates varied substantially but were not significantly correlated with rainfall. However, the rate of twig litter production in both communities was significantly correlated with wind velocity.

Key words: Ajkwa estuary, community, litter-fall, litter trap, mangrove, rate of litter-fall, reproductive parts, twig.

1. Introduction

Organic material covering forest floors, commonly referred to as litter, is primarily composed of dead plant parts (including leaves, twigs and reproductive parts). Litter production is defined as the weight of all dead material (of both plant and animal origin) deposited on a given unit area of soil surface within a specified time period (Chapman, 1986). Estimations of abundance and composition of litter-fall are important to the study of nutrient cycling (Proctor, 1984), primary production (Ovington, 1962) and the structure and function of the ecosystem (Gaur and Pandey, 1978). Therefore, the study of quantitative aspects of litter-fall continues to be an important part of forest ecology (Proctor, 1984). However, rates of forest litter production around the world vary widely due to differences in community structure, stand age, geographical situation (altitude), and seasonal climatic changes (Tanner, 1980).

Mangrove swamps are thought to be highly productive communities (Lugo and Snedaker, 1974) and are recognized as an important source of detritus to marine and estuarine ecosystems (Snedaker, 1978) supporting a variety of aquatic organism (Odum and Heald, 1972). Snedaker (1978) also reported that litter-fall produced in mangroves enters the estuarine system, where it forms the basis for a complex food web. Despite the likely importance of mangrove litter-fall to the aquatic ecosystem, little information exists regarding productivity in Indonesia (Soemodihardjo and Soerianegara, 1989).

The island of Irian Jaya contains one of the largest expanses of unmodified mangrove forests in the world. However, no recent data on the productivity of mangroves in this region have been published. The intention of this study was to provide baseline data on the input of organic matter from the mangrove communities into the surrounding coastal ecosystem; specifically to estimate monthly productivity and composition of litter-fall from mangroves in the Ajkwa river estuary within the PT. Freeport Indonesia (PTFI) project area.

2. Description of Study Area

2.1 PT Freeport Indonesia (PTFI) Project Area

The Contract of Work (COW) signed between the Government of Indonesia (GOI) and PTFI in 1991, granted PTFI two working areas defined as:

a. Contract of Work Mining Area (COW A). This area is approximately 100 km^2 and is the location of most mining activities. Activities include exploration, open-pit, and underground mining, ore processing (at the mill site) and mine overburden disposal.

b. Contract of Work Project Area (COW B). This area of approximately 2,890 km^2 connects the mining area in the north of the Arafura Sea in the south. Supporting facilities and infrastructure including Tembagapura, Ridge Camp, Kuala Kencana, Amamapare Port, Timika Airport and other areas situated in the COW Project Area.

PTFI Contract of Work Area (Mining Area and Project Area) is in the Mimika Baru District of the Mimika Administrative Regency.

2.2 Environment of Research Location

Climate

Fig. 1 presents monthly rainfall and temperature data collected in the study area from January to December, 1998.

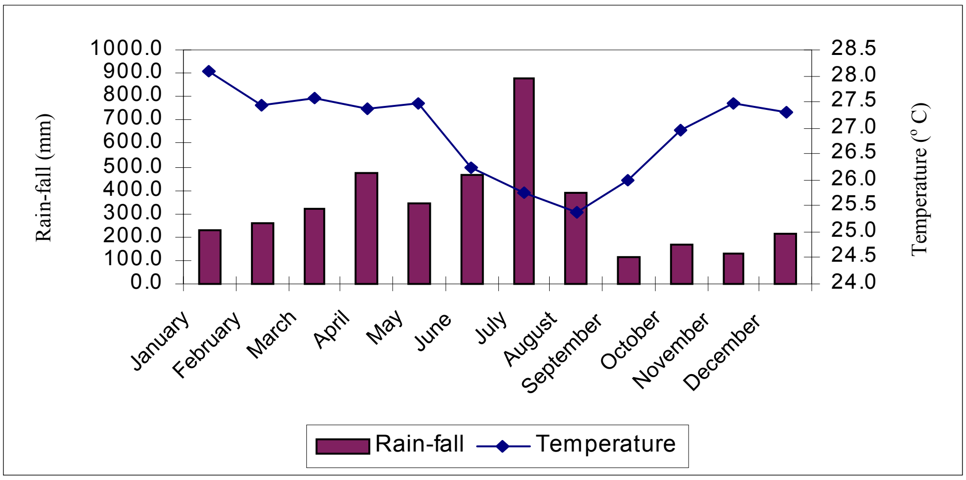


Fig. 1. Total monthly rainfall and mean monthly temperatures, PTFI Project Area, January to December, 1998.

The total annual rainfall in the study area was approximately 3,980.1 mm. Total monthly rainfall ranged from 114.0 mm in September to 876.5 mm in July. The Schmidt and Ferguson System (1951) classifies this climate as Type A (no dry month throughout the year). The mean monthly air temperature in this area ranged from 25.4ºC in August to 28.1ºC in February and mean monthly humidity ranged from 80% to 91%. Average monthly wind velocity in this area ranged from 2.02 m s^{-1}. in October and July, to 2.58 m s^{-1}. in December.

Soil
The sites used for this study are situated within the Kajapah Land System and consist of inter-tidal swamps of mangrove and Nypa palm. Soils consist of recent fine alluvium (marine) or peat and are classified as Sulfaquents and Sulfihemists according to the USDA Great Soil Group System (USDA, 1975). Sulfaquents are permanently saturated, unweathered soils that become strongly acidified upon aeration. The soil texture is peat.

Geology
The regional geology of the PT Freeport Area consists of both older sedimentary rocks and recent sedimentary material. This material is composed of rocks from the Buru formation consisting mainly of calcareous mudstone, shale, limestone, conglomerate, and occasionally beds of lignite coal. The material ranges from unconsolidated to relatively consolidated. This geological unit is usually found in gently sloping hills, however, in cleared areas with steep slopes the material is unstable and susceptible to landslides.

Fanglomerate and alluvial deposits are also found within the study area. Fanglomerate is a combination of conglomerate, sand and mud and is spread across the Timika lowlands and surrounding areas. The area stretching south to the coast is formed by alluvial and swamp deposits consisting of mud, sand, silt, peat and organic matter. This formation is largely unconsolidated with high permeability.

2.3 Vegetation
Preliminary research conducted by Ellison (1997), reported five mangrove communities in the Ajkwa estuary:

(1) **Seaward pioneer community (*Avicennia – Sonneratia* association)** - This community is located at lower elevations on accreting mud banks and inner bends of rivers. Community species include *Avicennia marina*, *A. officinalis*, *A. eucalyptifolia* and *Sonneratia caseolaris*;

(2) ***Rhizophora stylosa – Bruguiera gymnorrhiza* community** – This community grows in the south of the main Ajkwa estuary and on outer bends of rivers. Additionally, *R. apiculata* and *R. mucronata* may also occur in this community;

(3) ***Bruguiera – Rhizophora – Xylocarpus* community** – This community is generally found at higher elevations on the inner bends of rivers. Within the study area, this community is located mainly in the north of the main Ajkwa estuary. Species identified in this community include *R. stylosa*, *R. mucronata*, *B. cylindrica*, *B. parviflora* and *X. mekongensis*;

(4) ***Nypa fruticans* community** – This community is found on accreting banks (raised-land building by sedimentation) in northern mangrove areas; and

(5) **Mixed mangrove forest community** – This community grows in brackish water

and consists of *R. apiculata, Heritiera littoralis, X. granatum, Pandanus* sp. and *N. fruticans*.

In general, the Ajkwa estuary is dominated by the *Bruguiera – Rhizophora – Xylocarpus* community, however, the *R. stylosa – B. gymnorrhiza* community dominates the composition of the Minajerwy estuary.

3. Literature Review

Litter is defined as dead organic matter (of both plant and animal origin) overlying the forest floor. The rate of litter production can be defined as the weight of organic materials deposited on a given unit area of soil surface within a standard period of time (Chapman, 1986). The use of litter-fall traps is the most widely accepted method of measuring litter production (Newbould, 1967).

Pool *et al.* (1975) and Twilley *et al.* (1986) reported that mangroves with greater tidal activity and water turn-over generally have higher litter-fall rates than mangroves in stagnant water areas. Odum (1980) described the tides as an energy subsidy stimulating the net primary production of the intertidal wetlands. Similarly, Wharton and Brinson (1979) suggested that the water movement provides not only a source of silts and clays, but also a supply of nutrients and aeration for optimal growth.

Annual litter-fall rates of some mangrove forests are presented in Table 1. Generally, annual litter-fall rates in tropical mangrove forests are higher than that of sub-tropical mangroves. This difference may be attributable to differences in vegetation structure (Othman, 1989), climatic factors (Proctor, 1984), forest growth phase and soil fertility (Schaik and Mirmanto, 1985) and tidal activity and hydrologic condition (Twilley *et al.*, 1986). Maximum leaf-fall coinciding with periods of high rainfall is uncommon in the tropics, although periods of high litter-fall usually coincide with either high or low precipitation (Proctor *et al.*, 1983). The underlying factors causing seasonality in mangrove litter production appear to be complex. There is, however, little available evidence documenting the causes, although climatic factors have been suggested by some studies (Pool *et al.*, 1975; Sasekumar and Loi, 1983; Williams *et al.*, 1981). Seasonality in the phenological cycle of mangroves may be the result of a combination of many factors including environmental parameters, tree physiology and the ecological aspects of pollination and propagule dispersal (Duke *et al.,* 1984).

4. Methodology

4.1 Location and Time Period of Research

This study was conducted at two sites (Site 1 and Site 2) within mangrove communities of the Ajkwa estuary in the PTFI COW area (Figure 4.1). In 1998, permanent plots were constructed at the 2 sites for estimating the abundance and production rate of litter-fall. Litter was collected from February 16, 1998 until October 27, 1998 at Site 1 and from February 25, 1998 until December 12, 1998 at Site 2.

4.2 Sample Plots

At each sample site, two sample plots of 100 m × 100 m were established in a prominent mangrove forest in the study area. Furthermore, in each community, two permanent plots were established which were completely divided into sub-plots of 20 m × 20 m.

Table 1. Litter production in mangrove forest communities throughout the world.

No Location and mangrove community	Litter fall component (g m^{-2} $year^{-1}$)					Reference
	Leaf	Reproductive organs (flower, fruit, etc.)	Woody materials (twig and bark)	Others	Total	
1. Ohura Bay, Okinawa, Japan						Hardiwinoto
Kandelia candel	305.14 (43.2)	203.21 (28.8)	165.05 (23.4)	32.59 (4.6)	705.99	*et al*. (1989)
K. candel-Bruguiera gymnorrhiza	689.90 (64.3)	227.70 (21.2)	121.30 (11.3)	34.97 (3.2)	1,073.87	
B. gymnorrhiza	566.60 (73.3)	101.10 (13.1)	83.88 (10.8)	21.25 (2.7)	772.80	
Mean	520.54 (61.2)	177.33 (20.8)	123.41 (14.5)	29.60 (3.5)	850.88	
2. Iriomote Island, Okinawa						Kishimoto *et*
Rhizophora mucronata	279 (75.6)	76.6 (20.8)	12.9 (3.5)	0.2 (0.1)	368.7	*al*. (1987)
R. mucronata-Bruguiera gymnorrhiza	512.3 (38.7)	196.7 (26.4)	31.6 (4.2)	5.3 (0.7)	745.9	
B. gymnorrhiza	572.8 (65.3)	197.4 (22.5)	89.9 (10.2)	17.7 (2.0)	877.8	
Mean	454.7 (68.5)	156.9 (23.6)	44.8 (6.7)	7.7 (1.2)	664.1	
3. Middle Harbour, Australia						Goulter and
Avicennia marina	458.2 (79)	-	-	121.8^{+} (21)	580	Allaway (1979)
4. Hinchinbrook Island, Australia						Duke *et al*.
Rhizophora apiculata-R. lamarckii-R. stylosa	551.15 (57.6)	240.90 (25.2)	94.90 (9.9)	69.35 (7.3)	956.30	(1981)
Ceriops tagal	417.56 (58.1)	69.35 (9.6)	56.94 (7.9)	175.20 (24.4)	719.05	
Bruguiera gymnorrhiza	393.00 (49.4)	240.90 (30.3)	99.77 (12.5)	62.05 (7.8)	795.72	
Avicennia spp.	600.43 (75.1)	12.78 (1.6)	67.53 (8.5)	118.63 (14.8)	799.37	
B. parviflora	401.50 (40.5)	361.35 (36.4)	96.73 (9.7)	133.23 (13.4)	992.81	
Sonneratia alba	386.90 (48.8)	167.90 (21.2)	116.80 (14.8)	120.45 (15.2)	792.05	
Mean	458.42 (54.4)	182.20 (21.6)	88.78 (10.6)	113.15 (13.4)	842.55	
5. New Zealand						Woodroffe
Avicennia marina (tall mangrove)	562 (69.4)	100 (12.3)	148 (18.3)	-	810	(1982)
A. marina (low mangrove)	272 (74.5)	9 (2.5)	84 (23.0)	-	365	
Mean	417 (71)	54.5 (9.3)	116 (19.7)	-	587.5	
6. Motupore Island, Papua New Guinea						Leach and
Rhizophora stylosa	1,162 (81.3)	-	-	268^{+} (18.7)	1,430	Burgin (1985)
7. Phuket island, Thailand						Christensen
Rhizophora apiculata	670	NM	NM	NM	670	(1978)
8. Fort Myers, SW Florida, USA						Twilley *et al*.
Avicennia germinans	209 (59.5)	142 (40.5)	-	-	351	(1986)
A.germinans-Rhizophora mangle Laguncularia racemosa	547 (63)	321 (37)	-	-	868	
Mean	378 (62)	231.5 (38)	-	-	609.5	
9. Rookery Bay, SW Florida, USA						Twilley *et al*.
Avicennia germinans	355 (70.4)	149 (29.6)	-	-	504	(1986)
A. germinans-Rhizophora mangle - Laguncularia racemosa	575 (76.6)	176 (23.4)	-	-	751	
Mean	465 (74.1)	162.5 (25.9)	-	-	627.5	
10. Mgeny estuary, South Africa						Steinke and
Bruguiera gymnorrhiza	582.18 (67.44)	253.67 (29.39)	27.38 (3.17)	-	863.23	Charles
Avicennia marina	434.35 (60.71)	158.78 (22.20)	122.28 (17.09)	-	715.41	(1984)
Mean	508.27 (64.39)	206.22 (26.13)	74.83 (9.48)	-	789.32	
11. Tabasco, Mexico						Lopez-
Avicennia germinans	509.99 (83)	49.16 (8)	55.30 (9)	-	614.45	Portillo and Ezeurra (1985)
12. Malay Peninsula						Sasekumar
Avicennia	569.40 (40.9)	536.55 (38.6)	244.55 (17.6)	40.15 (2.9)	1,390.65	and Loi
Sonneratia	956.30 (66.8)	138.70 (9.7)	270.10 (18.9)	65.70 (4.6)	1,430.80	(1983)
Rhizophora	1,080.40 (71)	129.94 (8.6)	248.20 (16.3)	62.05 (4.1)	1,520.59	
Mean	868.70 (60)	268.40 (18.5)	254.28 (17.6)	55.97 (3.9)	4,447.35	
13. Matang, Malaysia						Gong *et al*.
Rhizophora apiculata						(1984)
5-year-old	618 (88.8)	9 (1.3)	69 (9.9)	-	696	
10-year-old	809 (82.0)	2 (0.2)	176 (17.8)	-	987	
15-year-old	802 (80.0)	46 (4.6)	154 (15.4)	-	1,002	
20-year-old	808 (78.5)	109 (10.6)	112 (10.9)	-	1,029	
25-year-old	844 (74.1)	185 (16.2)	111 (9.7)	-	1,140	
Virgin Jungle Reserve	576 (75.5)	124 (16.2)	63 (8.3)	-	763	
Mean	742.8 (79.3)	79.2 (8.5)	114.2 (12.2)	-	936.2	

Table 1. (Continued)

No	Location and mangrove community	Litter fall component (g m^{-2} yr^{-1})					Reference
		Leaf	Reproductive organs (flower, fruit, etc.)	Woody materials (twig and bark)	Others	Total	
13.	Matang, Malaysia						Gong *et al.* (1984)
	Rhizophora apiculata						
	5-year-old	618 (88.8)	9 (1.3)	69 (9.9)	-	696	
	10-year-old	809 (82.0)	2 (0.2)	176 (17.8)	-	987	
	15-year-old	802 (80.0)	46 (4.6)	154 (15.4)	-	1,002	
	20-year-old	808 (78.5)	109 (10.6)	112 (10.9)	-	1,029	
	25-year-old	844 (74.1)	185 (16.2)	111 (9.7)	-	1,140	
	Virgin Jungle Reserve	576 (75.5)	124 (16.2)	63 (8.3)	-	763	
	Mean	742.8 (79.3)	79.2 (8.5)	114.2 (12.2)	-	936.2	
14.	Sarawak, Malaysia						Othman (1989)
	Rhizophora mucronata-R. apiculata	449 (78.5)	-	-	123+ (21.5)	572	
15.	Pamanukan, West Java, Indonesia						Al Rasyid (1989)
	Rhizophora mucronata	623.42	NM	NM	NM	623.42	
	Avicennia spp.	635.19	NM	NM	NM	635.19	
	Mean	629.31	NM	NM	NM	629.31	
16.	Muara Angke, Jakarta, Indonesia						Sukardjo (1989)
	Avicennia marina-A. alba	614.04 (36.9)	572.20 (34.3)	479.15 (28.8)	-	1,665.39	
	A. marina-Rhizophora mucronata	515.79 (36.9)	480.64 (34.3)	402.48 (28.8)	-	1,398.91	
	R. mucronata-R. apiculata	182.27 (36.9)	169.85 (34.4)	142.23 (28.8)	-	494.35	
	Mean	437.37 (36.9)	407.56 (34.3)	341.29 (28.8)	-	1,186.22	
17.	Tanjung Apar,East Kalimantan, Indonesia						Sukardjo (unpublished report)
	Rhizophora apiculata-Avicennia marina	766.82 (36.9)	714.41 (34.3)	598.51 (28.8)	-	2,079.74	
	A. officinalis-A. marina	1,062.67 (36.9)	990.25 (34.3)	829.23 (28.8)	-	2,882.15	
	Ceriops tagal-R. apiculata	1,018.99 (36.9)	895.42 (32.4)	849.28 (30.7)	-	2,763.69	
	Mean	949.49 (36.9)	866.69 (33.6)	759.01 (29.5)	-	2,575.19	
18.	Tritih, Cilacap, Indonesia						Suwarno (1985)
	Rhizophora mucronata (6-year-old)	658.32 (81)	28.08 (3.5)	-	126.36+ (15.5)	812.76	
19.	Saleh River, South Sumatera, Indonesia						Soerianegara *et al.* (1985)
	Sonneratia spp.	-	-	-	-	622.40	
	Sonneratia-Avicennia	-	-	-	-	1,255.51	
	Avicennia spp.	-	-	-	-	689.85	
	Rhizophora spp.	-	-	-	-	1,023.83	
	Bruguiera spp.	-	-	-	-	1,177.86	
	Mean	-	-	-	-	953.89	
20.	Tiris Indramayu, West Java, Indonesia						Sukardjo (unpublished report)
	Rhizophora apiculata-R. mucronata	525.31 (40.70)	337.81 (26.18)	427.38 (33.12)	-	1,290.50	
21.	Talidendang Besar, East Sumatra, Indonesia						Kusmana *et al.* (1998)
	Bruguiera parviflora	758.75 (59.89)	263.57 (20.8)	52.00 (4.11)	192.62 (15.2)	1,266.94	
	B. sexangula	704.16 (55.47)	309.03 (24.34)	67.13 (5.29)	189.16 (14.9)	1,269.48	
	B. sexangula-Nypa fruticans	707.16 (64.53)	181.60 (16.58)	53.04 (4.84)	153.98 (14.05)	1,095.78	
	Mean	723.36 (59.75)	251.40 (20.76)	57.39 (4.74)	178.59 (14.75)	1,210.74	

Note: + = micellaneous including woody materials and reproductive organs
- = not reported
NM = not measured
Values in brackets indicate percentage of total litter

4.3 Measured Parameters

Parameters measured for this study included the diameters of trees greater than 10 cm as well as the production of litter from various tree components.

4.4 Data Collection Procedure

Tree diameters were measured 10 cm above the highest prop roots for *Rhizophora* spp. and 10 cm above the buttress or 1.3 m above ground level (diameter at breast height, DBH) for all other species.

Litter production was measured by collection in litter-fall traps as described by Newbould (1967). For this study, 13 litter traps (opening 0.50 m^2; depth-0.50 m), were suspended within each plot in the studied mangrove community. Traps were made from nylon mesh cloth (1 mm mesh size) and were suspended from tree branches above high-high tide. All materials accumulated in the traps were collected once per week during the sampling period.

4.5 Data Analysis

Estimates of litter-fall rates of various tree components were calculated using standard statistical procedures (Sokal and Rohlf, 1986). To analyse the effect of rainfall on litter-fall, individual litter components (leaves, reproduction organs, stems) and total litter in each month were correlated with monthly total rainfall. As effects of rainfall may not be immediate, monthly mean rates of litter-fall were also correlated with monthly rainfall for previous months using time-lag correlation.

5. Results and Discussion

5.1 Forest Composition and Structure

Mangrove forest species composition and structure of research Site 1 is presented in Table 2.

Table 2. Mangrove species composition and structure of Site 1.

No.	Plot	Species	N (No./ha)	BA (m^2/ha)	IVI (%)
1.	Plot 1	*Avicennia marina*	1	0.11	2.10
		Bruguiera cylindrica	1	0.03	1.87
		Bruguiera gymnorrhiza	235	17.31	145.34
		Camptostemon schultzii	91	7.03	74.90
		Rhizophora apiculata	47	8.85	70.69
		Rhizophora mucronata	5	0.25	
		Total	380	33.58	
2.	Plot 2	*Bruguiera gymnorrhiza*	242	16.53	160.17
		Camptostemon schultzii	83	7.00	79.87
		Rhizophora apiculata	42	5.46	57.42
		Xylocarpus australiasicus	3	0.06	2.55
		Total	370	29.06	

Note : IVI = Importance Value Index
N = Density
BA = Basal Area

Based on data in Table 2, mangroves in Site 1 can be categorized as *B. gymnorrhiza – C. schultzii – R. apiculata* community. Seven species of mangrove trees were recorded within both sample plots. *B. gymnorrhiza, C. schlutzii* and *R. apiculata* were considered dominant species while the other four species were minor contributors to the mangrove community. In this community, *B. gymnorrhiza* was the most dominant species with an IVI of 145.34% and 160.17% for plots 1 and 2, respectively. Densities for this species were measured at 235 and 242 trees/ha at the two plots with basal areas of 17.31 m^2/ha and 16.53 m^2/ha.

The total density and basal area of trees measured in Plots 1 and 2 ranged from 370 (Plot 2) to 380 (Plot 1) trees/ha and 29.06 (Plot 2) to 33.58 (Plot 1) m^2/ha, respectively. Consequently, major trees species comprised approximately 98% of both total density and basal area of the stand in this community. Physiognomically, the stand was formed by trees with a diameter ranging from 7.42 to 84.3 cm and a height of 5.17 m to 52.55 m forming a one continuous canopy layer.

Forest species composition and structure of research Site 2 are presented in Table 3.

Table 3. Mangrove species composition and structure of Site 2.

No.	Plot	Species	N (No./ha)	BA (m^2/ha)	IVI (%)
1.	Plot 1	*Avicennia marina*	11	0.62	14.99
		Bruguiera cylindrica	322	11.20	134.30
		Bruguiera gymnorrhiza	1	0.04	1.48
		Ceriops tagal	1	0.01	1.37
		Diospyros maritima	6	0.14	5.12
		Rhizophora apiculata	188	9.47	103.20
		Rhizophora mucronata	5	0.13	6.03
		Xylocarpus australirsicus	1	0.01	1.37
		Xylocarpus granatum	34	1.25	32.13
		Total	569	22.87	
2.	Plot 2	*Avicennia marina*	1	0.12	1.93
		Bruguiera cylindrica	211	8.64	103.09
		Bruguiera gymnorrhiza	1	0.03	1.59
		Diospyros maritima	6	0.13	8.54
		Heritiera littoralis	7	0.09	8.18
		Rhizophora apiculata	311	16.98	152.44
		Xylocarpus granatum	26	0.42	24.62
		Total	563	26.41	

Note : IVI = Importance Value Index
N = Density
BA = Basal Area

The data in Table 3 suggests that the Site 2 mangrove community can be categorized as *Bruguiera cylindrica – Rhizophora apiculata* community. Total densities of trees in this community were estimated at 569 trees/ha (Plot 1) and 563 trees/ha (Plot 2). Basal areas were calculated at 22.87 m^2/ha (Plot 1) and 26.41 m^2/ha (Plot 2). A total of ten tree species were recorded in the sample plots. Among them, *B. cylindrica* and *R. apiculata* comprised more than 90% of the total stand density and basal area in this community. The average diameter and height of trees in both plots were 15.87 cm (range = 9.6 cm to 87.9 cm) and 22.65 m (range = 4.88 m to 56.56 m), respectively. The mangrove community in Site 2 was comprised of more tree species than Site 1. Site 2 contained denser stands of trees with smaller diameters than Site 1. Mangroves in Site 1 are frequently subjected to tides providing a continuous supply of silts, clays and nutrients as well as aeration for optimal tree growth. Stands in this community produced trees with larger diameters than at Site 2 owing to the tides functioning as an energy subsidy and stimulating net primary production of the intertidal wetlands (Odum, 1980). In terms of species richness, our results support Kusmana *et al.* (1998) who suggested that species richness in mangrove forest communities increases with distance inland from the coast due to decreasing salinity.

Compared to mangrove forests in other locations in Indonesia (Table 4), mangrove communities in the study area are similar to the mangrove forests in Simpang Ulim – Aceh (Al Rasyid, 1983), Halmahera - Maluku (Komiyama *et al.*, 1988), Banyuasin - South Sumatra (Yamada and Sukardjo, 1980), Tanjung Kasam – Riau (Sukardjo, unpublished report).

Table 4. Community types of some mangrove forests in Java and other islands in Indonesia.

No	Location	Community type	Species richness	Reference
A	**Java Island**			
1	Cilacap	*Aegiceres corniculatus - Ficus retusa* *Avicennia alba - Sonneratia alba* *Rhizophora mucronata - Bruguiera cylindrica*	14	Marsono (1989)
2	Ujung Karawang	*Avicennia marina - Aegiceras corniculatus*	9	Djaja *et al.* (1984)
3	Indramayu	*Avicennia marina - Avicennia alba*	9	Sukardjo (1980)
4	Pulau Rambut	*Rhizophora mucronata - Rhizophora stylosa* *Rhizophora mucronata* *Scyphyphora hydrophyllacea - Lumnitzera racemosa*	13	Kartawinata and Waluyo (1977)
5	Pulau Dua	*Rhizophora stylosa - Rhizophora apiculata*	12	Buadi (1979)
6	Baluran	*Rhizophora stylosa - Rhizophora apiculata*	16	Indiarto *et al.* (1987)
7	Grajagan	*Rhizophora apiculata - Avicennia* spp.	14	Sukardjo, unpublished report
8	Muara Angke	*Avicennia alba - Avicennia marina* *Avicennia marina - Rhizophora mucronata*	11	Kusmana (1983)
B	**Other Indonesian Islands**			
1	Kangean Isles	*Rhizophora stylosa* *Rhizophora apiculata* *Ceriops tagal*	12	Soemodihardjo, unpublished report
2	Tanjung Apar (East Kalimantan)	*Rhizophora apiculata - Avicennia alba* *Avicennia officinalis - Avicennia alba* *Ceriops tagal - Rhizophora apiculata*	13	Sukardjo, unpublished report
3	Tanjung Kasam (Riau)	*Xylocarpus granatus - Lumnitzera racemosa* *Rhizophora apiculata - Xylocarpus granatus*	12	Sukardjo, unpublished report
4	Way Sekampung (lampung)	*Avicennia* spp *Hibiscus tiliaceus - Pongamia pinnata*	14	Sukardjo (1979)
5	Banyuasin (South Sumatera)	*Avicennia alba* *Rhizophora apiculata* *Bruguiera gymnorrhiza - Rhizophora apiculata*	9	Yamada and Sukardjo (1980)
6	Tanjung Bungin (South Sumatera)	*Rhizophora apiculata - Nypa fruticans* *Nypa fruticans - Rhizophora apiculata*	9	Sukardjo *et al.* (1984)
7	Talidendang Besar (Riau)	*Bruguiera parviflora* *B. sexangula* *B. sexangula - Nypa fruticans*	8	Kusmana and Watanabe (1991c)
8	Gaung and Mandah Rivers (Riau)	*Rhizophora apiculata - R. mucronata* *Bruguiera parviflora - B. sexangula* *Aegiceras corniculatus - Nypa fruticans*	7	Al Rasyid (1984)
9	Central Sulawesi			Darnaedi and Budiman (1984)
	- Ranu	*Rhizophora apiculata - Ceriops tagal*	3	
	- Lapangga	*Rhizophora apiculata - Ceriops tagal*	8	
	- Matube	*Rhizophora mucronata*	3	
	- Morowali	*Rhizophora apiculata*	5	
10	Halmahera (Maluku)	*Sonneratia alba* *Bruguiera gymnorrhiza - Xylocarpus granatus* *Rhizophora apiculata - Bruguiera gymnorrhiza* *Nypa fruticans - Rhizophora stylosa*	14	Komiyama *et al.* (1988)
11	Bone-bone (South Sulawesi)	*Sonneratia alba - Rhizophora apiculata* *Rhizophora mucronata* *Bruguiera gymnorrhiza*	20	Ahmad (1989)
12	Simpang Ulim (Aceh)	*Rhizophora apiculata - Bruguiera gymnorrhiza*	8	Al Rasyid (1983)

Values for species richness pertain to tree species.

Table 5 shows the density of trees with diameters greater than 10 cm as well as the species richness of trees in some virgin mangrove forests in Indonesia. Compared to mangrove forests in other regions, communities within the study area showed high species richness, similar to mangroves in Halmahera - Maluku. However, other studies of mangrove species in Irian Jaya have shown more species of mangroves than are found in our study area. For example, Prawiroatmodjo (unpublished report) recorded 14 species of mangroves in Teluk Bintuni - Irian Jaya. In terms of density, mangrove forests in the study area are most similar to mangrove communities in Halmahera – Maluku and Talidendang Besar – Riau.

Table 5. Densities and Species Richness Indices of trees with diameters greater than 10 cm for some virgin Indonesian mangrove forests.

No.	Location	Density (ind./ha)	Species richness	Reference
1.	Tanjung Bungin, South Sumatera	162 - 288	9	Sukardjo and Kartawinata, 1979
2.	Banyuasin, South Sumatera	187 - 448	9	Yamada and Sukardjo, 1980
3.	Gaung and Mandah Rivers, Riau	333	7	Al Rasyid, 1984
4.	Tanjung Apar, East Kalimantan	80 - 528	13	Sukardjo, unpublished report
5.	Irian Jaya	144 - 255	14	Prawiroatmodjo, unpublished data
6.	Central Sulawesi	210 - 422	10	Darnaedi and Budiman, 1984
7.	Halmahera, Maluku	206 - 586	14	Komiyama *et al*. (1988a)
8.	Talidendang Besar, Riau	364 - 592	8	Kusmana *et al*. (1992a)

5.2 Litter Production and its Components

Table 6 shows estimated annual litter production in mangrove communities in the study area.

Table 6. Estimated annual litter production of tree components in mangrove communities in the PTFI study area.

Site	Mangrove Community	Litter Components (g/(m^2 year))			
		Leaf	Reproductive Part	Twig	Total
1	*Bruguiera gymnorrhiza - Comptostemon schultzii - Rhizophora apiculata* community	492.61 ± 95.47 (CV = 58.14 %)	164.28 ± 31.63 (CV = 57.76 %)	143.89 ± 68.35 (CV = 142.50 %)	800.78 ± 121.15 (CV = 45.39 %)
	%	61.5	20.5	18.0	100
2	*Bruguiera cylindrica - Rhizophora apiculata* community	385.66 ± 59.59 (CV = 51.25 %)	82.91 ± 31.24 (CV = 124.99 %)	275.78 ± 160.45 (CV = 192.96 %)	744.35 ± 195.42 (CV = 78.76 %)
	%	51.8	11.1	37.1	100

Note: Value show average (x) ± SE
CV = Coefficient of Variance

Annual litter production was estimated at 800.78 g/(m^2 year) from mangroves of Site 1 and 744.35 g/(m^2 year) from Site 2. At both sites, the leaves comprised more than 50% to the total litter. Monthly total litter production in both communities was highly variable (CV = 45 % to 79 %). It should also be noted that twig litter comprised a substantial proportion of total litter-fall production at Site 2.

Annual litter-fall production from Site 1 is higher than in Site 2. These results support the findings of Pool *et al*. (1975), Twilley *et al*. (1986) and Kusmana *et al*. (1998). Who reported that mangroves exposed to greater tidal activity and water turnover generally show higher litter-fall rates than mangroves in areas with stagnant water. Odum (1980) suggests that tides may function as an energy subsidy, stimulating production in intertidal wetlands. Tides have also been shown to provide silts and clays, as well as a supply of nutrients and aeration for optimal growth of mangroves (Wharton and Brinson, 1979).

Annual litter-fall rates in the study area lie within ranges previously reported for other mangrove populations (Table 1). Litter-fall rates in both study sites were lower than for similar mangrove communities in Hinchinbrook Island - Australia (Duke *et al*., 1981), Saleh River - South Sumatera (Soerianegara *et al*., 1985), and Talidendang Besar - Riau (Kusmana *et al*., 1998). However, rates were higher than for mangrove communities studied in Iriomote island - Okinawa (Kishimoto *et al*., 1987). Differences in the abundance of mangrove litter-fall in these regions, may be attributable to differences in vegetation composition and structure (Othman, 1989), climatic factors (Proctor, 1984), the phase of forest growth and soil fertility (Schaik and Mirmanto, 1985) as well as tidal activity and hydrologic condition (Twilley *et al*., 1986).

5.3 Litter-fall Rate Pattern

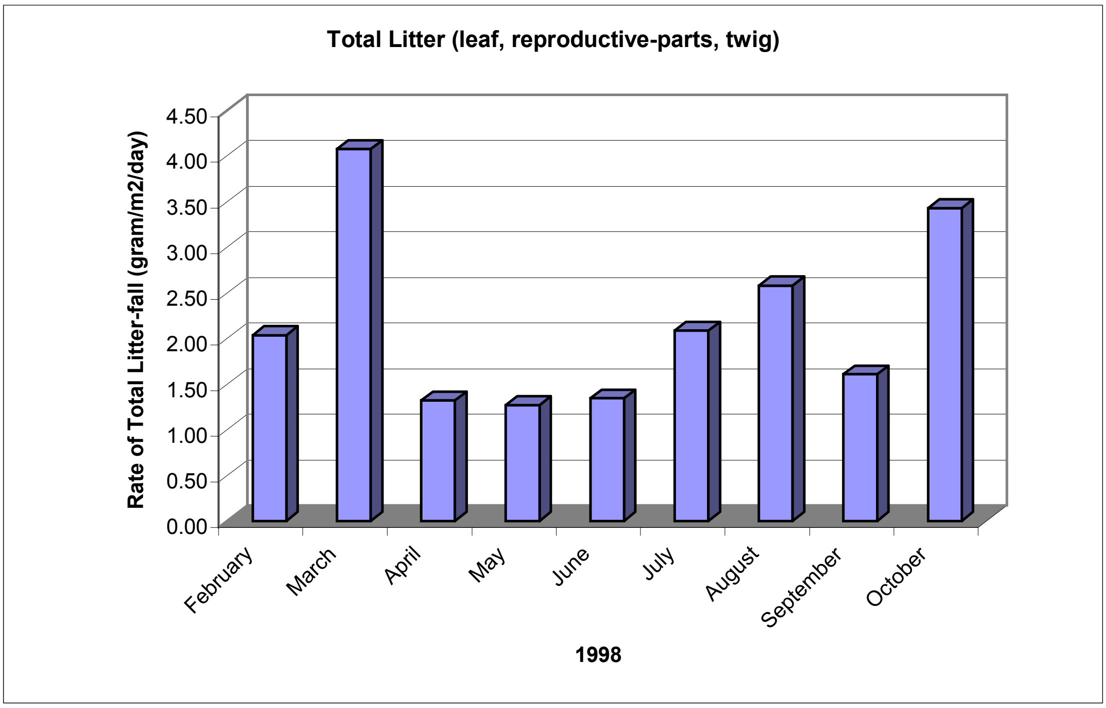
Rate of total litter-fall

Fig. 2 shows monthly rates of total litter-fall in Site 1 and Site 2 mangrove communities. Total monthly litter-fall during the sampling period ranged from 1.27 g/(m^2 d) to 4.07 g/(m^2 d) in Site 1 and 0.65 g/(m^2 d) to 6.35 g/(m^2 d) in Site 2.

In Site 1, the monthly rate of total litter-fall was highest in March although a smaller peak was observed in October (Figure 2). However, in Site 2 the monthly rate of total litter-fall showed a single in February. There was no significant correlation between rainfall and rate of total litter-fall in both mangrove communities in the study area ($r < 0.05$, $n = 26$, $p > 0.05$). Our results support other tropical studies, suggesting that maximum litter-fall coincides with both high and low periods of precipitation (Proctor *et al*., 1983).

The difference in litter-fall rate between Site 1 and Site 2 may be the result of differences in vegetation composition and structure, tree physiological processes or tidal activity as reported by Othman (1989) and Twilley *et al*. (1986).

(A)



(B)

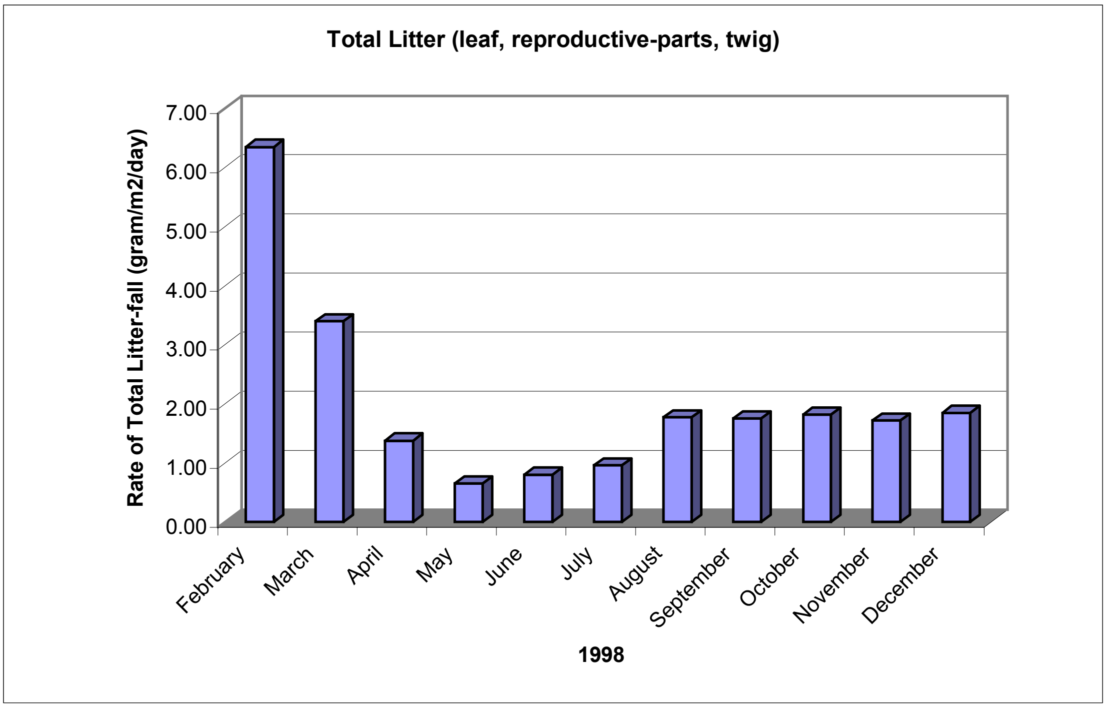
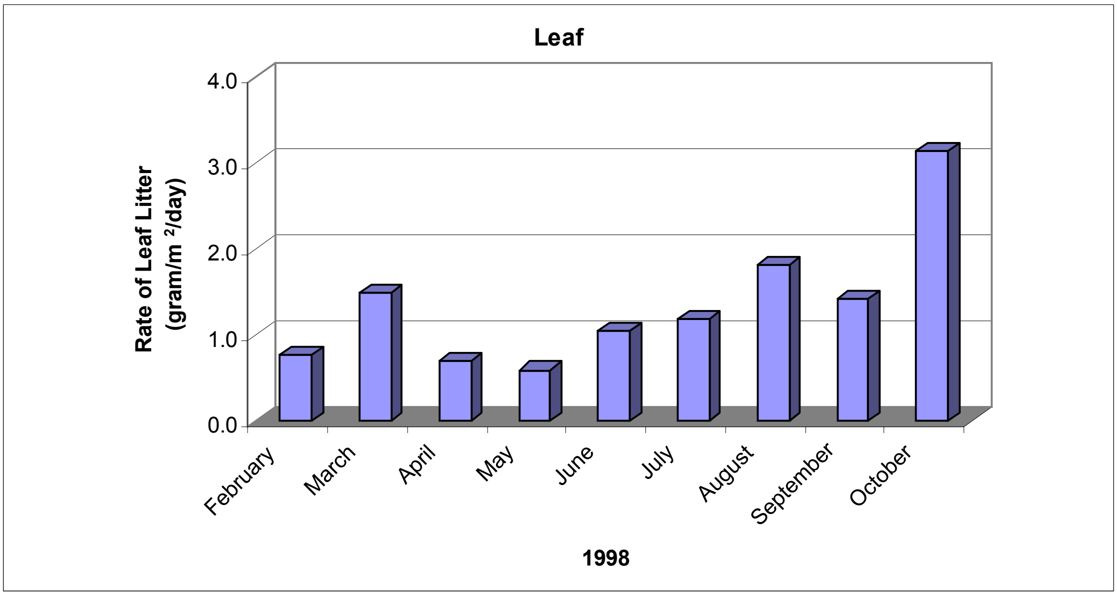


Fig. 2. Monthly rates of litter-fall for mangrove communities in research Site 1 (A) and Site 2 (B), PTFI Project Area, 1998

Rate of leaf litter production

Fig. 3 shows monthly rates of leaf litter production in mangrove communities in Site 1 and Site 2. The monthly rates ranged from 0.59 g/(m^2 d) (May) to 3.14 g/(m^2 d) (October) and 0.34 g/(m^2 d) (May) to 1.85 g/(m^2 d) (December) in the mangrove communities in Site 1 and Site 2, respectively. Both communities showed a general increase in monthly leaf production through the end of sample collection.

(A)



(B)

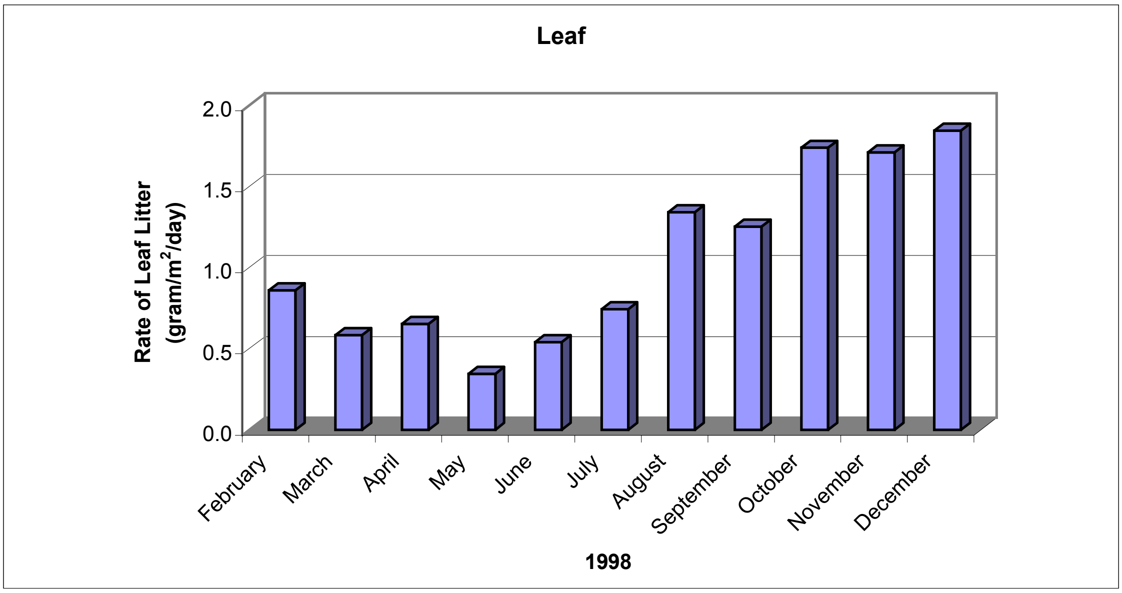


Fig. 3. The rate pattern of leaf litter of mangrove community in research Site 1 (A) and Site 2 (B)

As with previous studies conducted on litter-fall (Table 1), leaves were the major component of litter; therefore, the observed pattern of litter-fall production is attributable primarily to leaf litter. Monthly rates of leaf litter production varied widely throughout the collection period (CV > 50%) and no significant correlation existed between rainfall and rate of leaf litter-fall in both mangrove communities in the study area ($r < 0.60$, $n = 26$, $p > 0.05$). This result suggests that maximum leaf litter production coinciding with periods of high rainfall is not common in the tropics, although peaks in leaf-fall production have been shown to coincide with either low or high rainfall (Proctor *et al*., 1983).

Although the density of mangroves in Site 1 is lower than in Site 2, Site 1 produces higher amounts of leaf litter. Possible reasons for this discrepancy are: (1) mangrove community in Site 1 consists of trees with larger diameters than Site 2; (2) the mangrove community in Site 1 may produce more new leaves as an adaptation to high salinity conditions due to frequent inundation from tidal action; and (3) the exposure to tides at Site 1 possibly produces more optimal growth conditions.

Compared to other similar mangrove communities, the annual rate of leaf litter production in the PTFI study area is less than for mangroves in Talidendang Besar – Riau (Kusmana *et al*., 1998). However, the rate is higher than for mangrove communities in Hinchinbrook island – Australia (Duke *et al*., 1981) and Iriomote island – Okinawa (Kishimoto *et al*., 1987). These differences may be attributable to differences in vegetation composition, climatic factors, tidal activity and hydrologic condition (Lugo and Snedaker, 1974; Twilley *et al*., 1986).

Rate of reproductive parts litter

Fig. 4 shows the monthly rates of litter production from plants reproductive parts in the study area.

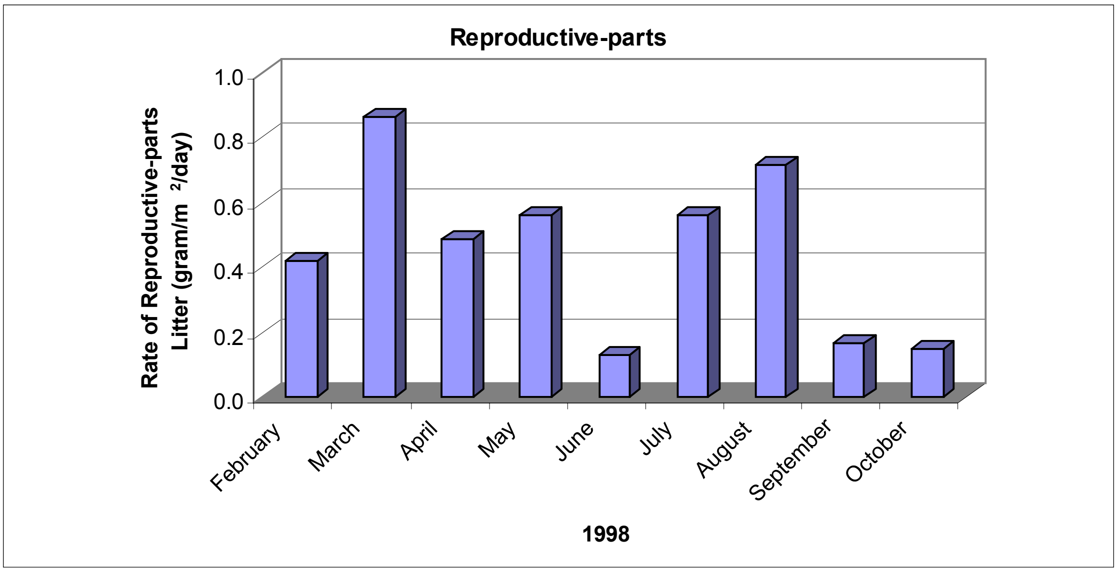
The monthly rate of litter production from plant reproductive parts ranged from 0.13 g/(m^2 d) (June) to 0.71 g/(m^2 d) (August) for Site 1 and from 0.15 g/(m^2 d) (June) to 0.99 g/(m^2 d) (February) for Site 2.

Litter production from plant reproductive parts peaked in March at Site 1 and February at Site 2. Smaller peaks were observed in August at Site 1 and in September at Site 2. Production between February and October from mangrove reproductive parts showed the same general trend as leaf litter production. Our data support the findings of Duke *et al*. (1984) who reported a relationship between leaf litter and litter production from plant reproductive parts for mangroves in north-eastern of Australia. Other research on mangroves has suggested that the relationship between leaf litter and litter from plant reproductive parts may be influenced by the phenological cycles of mangroves (Duke *et al*., 1984).

Production of litter from reproductive parts in the study area varied considerably between months (CV = 58% to 125%). However, no significant correlation ($r < 0.40$, $n = 26$, $p > 0.05$) existed between the rate of production of litter from reproductive parts and rainfall.

Compared to similar mangrove communities in other regions, the rate of production of litter from mangrove reproductive parts in the study area is less than from mangrove communities in Hinchinbrook Island, Australia (Duke *et al.*, 1981). This difference in production is possibly the result of differences in forest structure, climate or habitat condition.

(A)



(B)

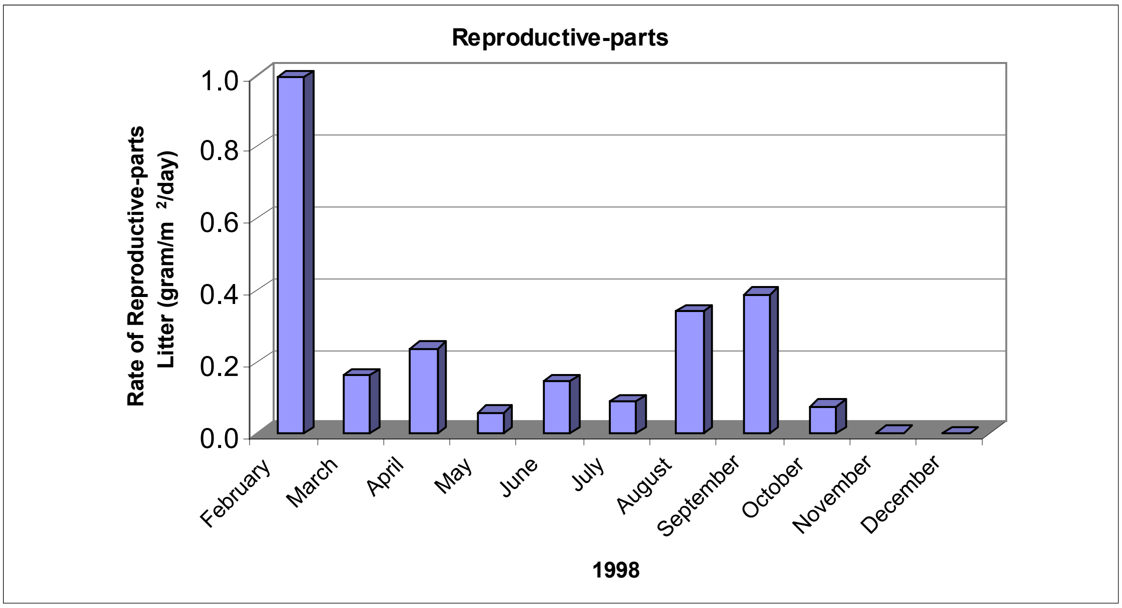


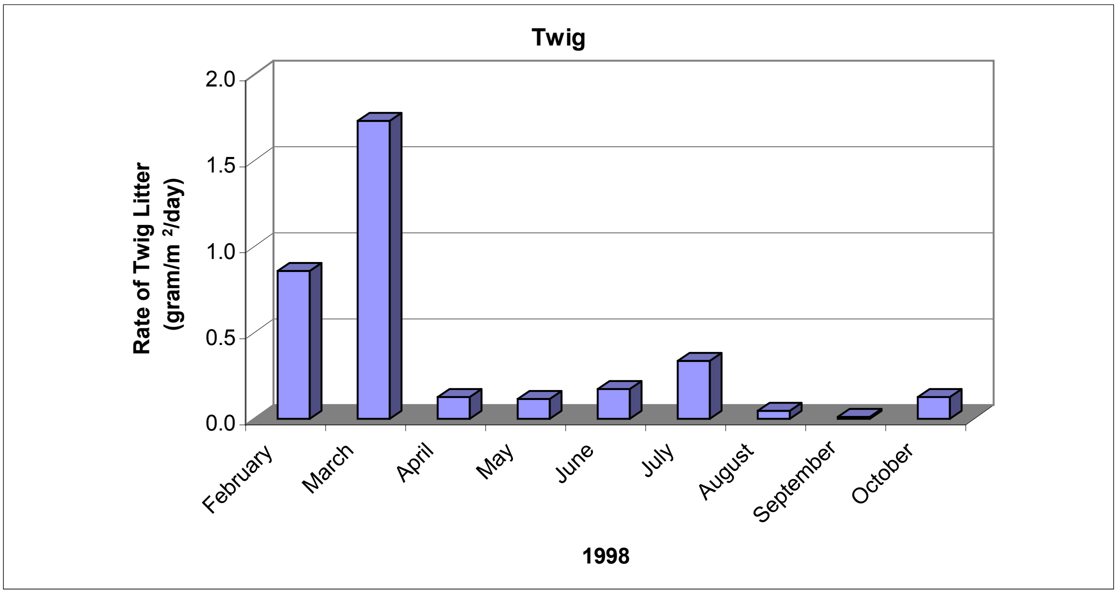
Fig. 4. The rate pattern of reproductive part litter of mangrove community in the research Site 1 (A) and Site 2 (B)

Rate of twig litter production

Twig litter rates for mangroves in the study area ranged from 0.12 g/(m^2 d) (September) to 1.73 g/(m^2 d) (March) at Site 1 and from 0.00 g/(m^2 d) (October and December) to 4.49 g/(m^2 d) (February) at Site 2. Monthly production of twig litter peaked in March at Site 1 and in February at Site 2 (Fig. 5).

Monthly production of twig litter showed a similar trend to litter production from reproductive parts suggesting that flower–fall may stimulate the shedding of twigs possibly due to decreasing physiological function of the twig after living flower buds are shed. This supports the results of Lopez-Partillo and Ezcurra (1985) and Kusmana *et al*. (1998), who reported marked seasonal patterns of woody litter production in mangrove forests in Tabasco, Mexico and Talidendang Besar-Riau, respectively.

(A)



(B)

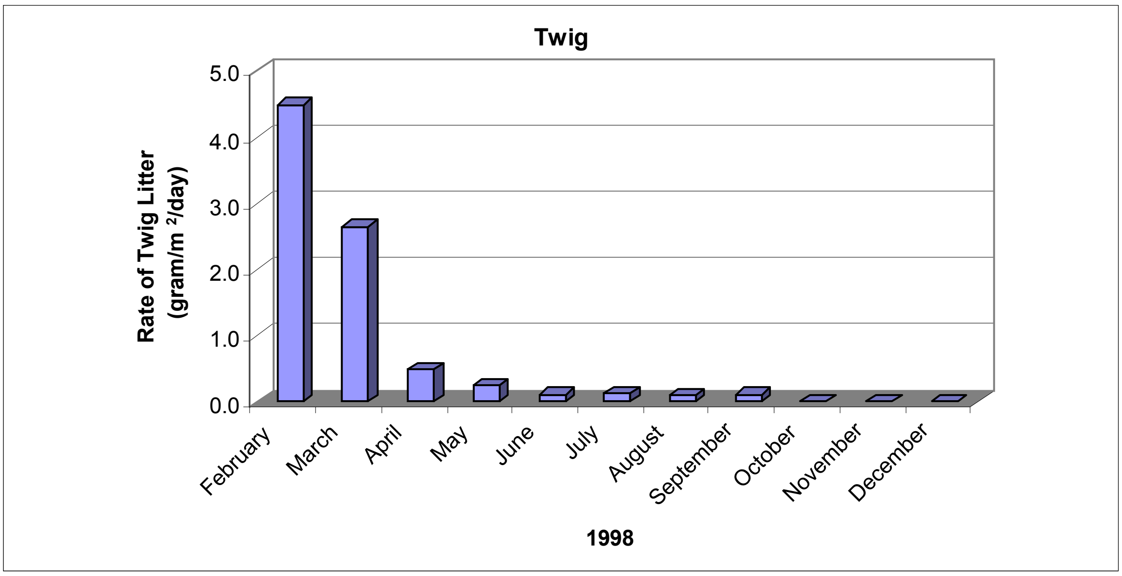


Fig. 5. The rate pattern of twig litter of mangrove community in the research Site 1 (A) and Site 2 (B)

During the litter collection period, the rate of twig litter production varied considerably (CV = 143% to 193%). Production rates were significantly correlated ($r = 0.70$, $n = 26$, $p = 0.05$) to wind velocity, but not to rainfall ($r < 0.30$, $n = 26$, $p > 0.05$). Higher wind velocity may be responsible for higher rates of twig litter production at Site 2 than Site 1 because mangrove at site 2 grow in the rather higher ground level and hence that is frequently subjected to strong wind.

The mangrove communities examined for this study have much higher twig litter rates than do other studied mangrove forests around the world (Table 1). This may be attributable to differences in vegetation composition and structure, phenological processes in relation to habitat condition, or climatic factors (wind velocity).

6. Conclusion

The total annual litterfall for site 1 and site 2 was estimated at 800.78 g/(m^2 year) and 744.35 g/(m^2 year), respectively. The monthly rate of total litter production at site 1 displayed two peaks during the study period (a major peak in March and a minor one in October) while Site 2 showed only a single peak in February. Monthly rates of production for both leaf and twig litters at both sites peaked only one during the study period while rates of litter production from plant reproductive parts peaked twice. During the sampling period, litter-fall rates varied substantially but were not significantly correlated with rainfall.

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Vegetation Analysis of Suaq Balimbing Peat Swamp Forest, Gunung Leuser National Park-South Aceh

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Abstract

Vegetation study was conducted in 1.6 ha plot of peat swamp forest at the Suaq Balimbing Research Station, in order to understand the forest structure and floristic composition. Within 1.6-ha plot, 44 species of trees and sapling belonging to 35 genera and 25 families were recorded. The *Gluta renghas* (rengas) was the most abundant tree species, followed by *Shorea palembanica* (meranti rawa), *Parinarium corymbosum* (resak), *Sandoricum emarginatum* (puin), *Garcinia celebica* (sigabu), *Eugenia sexangulata* (jambu), *Horsfieldia crassifolia* (bidarah), *Mangifera longipetiolata* (mangga hutan) and *Litsea gracilipes* (medang baru). On the other hand, for small tree (sapling) the *Garcinia celebica* was the most dominate among others species. The tree density was 806 /ha and most (80 %) of them were small trees (diameter <30cm). There are three canopy layers and most (60 %) of trees occupied stratum C (10-20 m high), and others 35 % and 5 % occupied stratum B (20-30 m high) and A (30-40 m high) respectively.

Introduction

Gunung Leuser National Park (TNGL), which has been established in May 9, 1928, is the biggest conservation areas in Sumatra Island (Anonyms, 1994). The area (792,675 ha) administratively belongs to two provinces that are North Sumatra and Aceh. Provinces. Some forest type covers the park and one particular forest type is peat swamp forest can be found in Kluwet District, South Aceh. A research station called the Suaq Balimbing Research Station has been established in this area in order to orangutan rehabilitation.

Although the area has declared as a research station, but forest destructions is still continuing and have resulted in some disturbed forest. Some parts of this area have changed to secondary growth and open areas that covered by grasses of Cyperaceae. This situation threatens the existence of orangutan because their habitat and sources of food such as *Mangifera petiolata, Tetramerista glabra, Sandoricum emarginatum, Garcinia celebica* and *Neesia altissima* might be decreasing in the future. So far little is known about the data and information on peat swamp forest vegetation of this area. The paper presented the results of the first step on ecological study of Suaq Balimbing peat swamp forest with special attention in the forest structure and floristic composition.

Study site

Suaq Balimbing Research Station is a part of the Gunung Leuser National Park, which is located at South Kluet District, South Aceh. Geographically the Suaq Balimbing situated on 3º04’ N and 97º25’E, with altitude of 15-20 m above sea level. The topography in general was plain except for several area was hilly. An alphabetically tract system was made within almost whole area in order to make easier for orangutan observation. For that reason a broad-trail 2 km long, from the camp to South direction has been made. The main vegetation type in this area is flooded peat swamp forest, which overgrown by small buttresses-trees such as Myrtaceae, Clusiaceae and Anacardiaceae.

Methods

A 1.6-ha (160m × 100m) permanent plot has been established in the Suaq Balimbing peat swamp forest, and was then divided into 160 sub-plots of 10mx10m. All trees (DBH > 10 cm) within each subplot were numbered with aluminium tag, measured and estimated their height. In addition another sub-plot of 5m × 5m has been made within each sub-plot of 10m × 10m, for sapling (2-10 cm) enumeration. The voucher specimens for each species were collected for further identification.

Results and discussion

Species composition

In the 1.6-ha plot 44 species of tree (32) and sapling (40), which belong to 35 genera and 25 families were recorded (Table 1). The forest here is very poor in species compare to other peat swamp forest (Table 2). This is may related to the unfavorable habitat condition such as poor-nutrient soil and flooded.

Table 1. Density and basal area per hectare in research plot of Suaq Balimbing forest.

	Density Ind./ha	Basal area (m^2 /ha)	Number of species	Number of genera	Number of families
Trees	806	44.43	32	26	18
Sapling	3188	3.87	40	25	19
Total	3994	48.30	44	35	25

Table 2. Number of species, density and basal area of some peat swamp forest in Indonesia

Location	Plot size (ha)	Number of species	Density (tree /ha)	Basal area (m^2/ha)	Sources
Suaq Balimbing (Aceh)	1.6	32	806	44.43	-
Mansemat (Kalbar)	1.05	86	698	24.29	Siregar, 1999
Selatai (Kalbar)	1.0	61	513	17.67	Sambas, 1994
G.Palung (Kalbar)	1.0	122	433	28.03	Soedarmanto, 1994
Tj. Puting (Kalteng)	1.0	96	728	43.01	Mirmanto, 1999
Kuala Kampar (Riau)	0.24	28	-	-	Mansur, 1999
Kwalian (Riau)	0.24	33	-	-	Anonym, 1996

Out of 18 families recorded, 5 of them were the most common families with family importance value (FIV) of greater than 20.0 (Table 3). The Anacardiaceae and Clusiaceae were dominant in terms of number of individuals, whereas Dipterocarpaceae and Meliaceae in basal area. On the other hand, the Lauraceae together with Anacardiaceae were dominant in terms of number of species.

Tabel 3. Number of species (NS), number of individual (D), basal area (BA= cm^2 /ha) and importance value of family in Suaq Balimbing forest plot

Family	NS	D	BA	FIV
Anacardiaceae	3	236.25	174332.70	77.93
Dipterocarpaceae	1	73.13	74151.50	28.89
Clusiaceae	2	90.00	25415.06	23.14
Lauraceae	3	77.51	15698.65	22.53
Meliaceae	2	53.76	34424.70	20.67
Rosaceae	1	72.50	33891.21	19.75
Myrtaceae	2	76.26	15940.80	19.30
Myristicaceae	2	40.63	23742.90	16.64
Theaceae	1	21.25	17683.72	9.74
Apocynaceae	1	24.38	14678.21	9.45
Dilleniaceae	1	26.25	9054.31	8.42
Sterculiaceae	2	2.50	413.59	6.65
Rubiaceae	2	1.88	254.03	6.54
jangkang	1	3.13	2758.22	4.13
sp-1	1	1.25	384.48	3.37
Icacinaceae	1	1.25	203.93	3.33
sp-3	1	0.63	441.79	3.30
Moraceae	1	0.63	306.80	3.27
sp.4	1	0.63	216.48	3.25
Euphorbiaceae	1	0.63	141.86	3.24
Fabaceae	1	0.63	107.52	3.23
sp-2	1	0.63	76.70	3.22

Some 9 tree species in the forest plot were recorded with importance value of greater than 10.0 (Table 4). *Glutta renghas* (IV=79.15) was the most dominant tree species followed by *Shorea palembanica* (IV=36.27), *Parinarium corymbosum* (IV=25.91), *Sandoricum emarginatum* (IV=22.14), *Eugenia sexangulata* (IV=22.12), *Garcinia celebica* (IV=22.01), *Horsfieldia crassifolia* (15.94), and *Litsea gracilipes* (IV=12.29). The success of *Glutta renghas* to dominate forest here may be due to its potency to adapt in the unsuitable environment. This species was found in almost all the sub-plots, indicated by frequency value of 86.25%.

Processes of succession in this forest have been going well, indicated by some dominant tree species having a good regeneration on the sapling. The most dominant sapling species were *Garcinia celebica*, *Glutta renghas, Eugenia sexangula, Mangifera longipetiolata* and *Shorea palembanica* (Table 5). The *Garcinia celebica* is under canopy species, which usually with unpredictable flowering season. In addition some under canopy species were able to germinate their seed under close canopy condition (cf. Denslow, 1980). *Glutta renghas, Eugenia sexangulata, Mangifera longipetiolata* and *Shorea palembanica* on the other hand, were flowering season species and need small gap for their seed germination. Whitmore (1982) mentioned that the development of plant from seed to seedling and sapling is an important factor during regeneration of tropical rain forest.

Tabel 4. The density (D= trees/ha), basal area (BA= cm^2/ha) and importance value (IV) of tree species in Suaq Balimbing forest plot

No	Family	Species	D	F	BA	IV
1.	Anacardiaceae	*Gluta renghas*	213.75	86.25	158944.71	79.15
2.	Dipterocarpaceae	*Shorea palembanica*	73.13	53.75	74151.50	36.27
3.	Rosaceae	*Parinarium corymbosum*	72.50	47.50	33891.21	25.91
4.	Meliaceae	*Sandoricum emarginatum*	53.13	40.00	34346.77	22.14
5.	Myrtaceae	*Eugenia sexangulata*	75.63	46.88	15877.01	22.12
6.	Clusiaceae	*Garcinia celebica*	67.50	45.63	20964.98	22.01
7.	Myristicaceae	*Horsfieldia crassifolia*	37.50	31.25	23023.16	15.94
8.	Lauraceae	*Litsea gracilipes*	46.25	23.75	8475.29	12.29
9.	Apocynaceae	*Alstonia spatulata*	24.38	20.63	14678.21	10.36
10.	Anacardiaceae	*Mangifera longipetiolata*	21.25	18.13	15016.64	9.56
11.	Theaceae	*Tetramerista glabra*	21.25	15.00	17683.72	9.55
12.	Dilleniaceae	*Dillenia puchella*	26.25	21.25	9054.31	9.45
13.	Clusiaceae	*Garcinia dioica*	22.50	18.75	4450.08	7.46
14.	Lauraceae	*Phoebe lanceolata*	20.63	16.88	3625.88	6.67
15.	Lauraceae	*Cryptocarya crassinervia*	10.63	9.38	3597.48	3.96
16.	Jangkang	Jangkang	3.13	3.13	2758.22	1.62
17.	Myristicaceae	*Myristica* sp.	3.13	2.50	719.74	1.04
18.	Anacardiaceae	*Campnosperma coriacea*	1.25	1.25	371.35	0.48
19.	Sterculiaceae	*Sterculia oblongata*	1.25	1.25	210.34	0.45
20.	Icacinaceae	*Platea excelsa*	1.25	1.25	203.93	0.45
21.	Sp-1	sp-1	1.25	0.63	384.48	0.36
22.	Sterculiaceae	*Sterculia rubiginosa*	1.25	0.63	203.25	0.32
23.	Rubiaceae	*Adina minutiflora*	1.25	0.63	143.58	0.31
24.	Sp-3	sp-3	0.63	0.63	441.79	0.30
25.	Moraceae	*Ficus xyllophylla*	0.63	0.63	306.80	0.27
26.	Sp.4	sp.4	0.63	0.63	216.48	0.25
27.	Euphorbiaceae	*Macaranga diepenhorstii*	0.63	0.63	141.86	0.23
28.	Rubiaceae	*Gardenia anysophylla*	0.63	0.63	110.45	0.22
29.	Fabaceae	*Diallium patens*	0.63	0.63	107.52	0.22
30.	Meliaceae	*Disoxyllum* sp.	0.63	0.63	77.93	0.22
31.	Sp-2	sp-2	0.63	0.63	76.70	0.22
32.	Myrtaceae	*Eugenia lineata*	0.63	0.63	63.79	0.21

Forest structure

Within the 1.6-ha plot, 1290 trees (DBH > 10 cm) were recorded or the tree density was 806 trees /ha with basal area of 44.43 m^2/ha. These values were relatively higher than other peat swamp forests (Table 2), suggesting that some of trees were bigger in size. Out of all the trees recorded, 20 % of them with diameter of > 30 cm and represent of them were *Gluta renghas* (23%), *Shorea palembanica* (37%) and *Parinarium corymbosum* (24%).

The tree diameter distribution showed that 80 % of total tree recorded had diameter of less than 30 cm, similar to the common phenomenon in the tropical forests, which has been always experienced as their dynamic process (Ogawa *et al*., 1965). Diameter distribution of some prominent species show that only *Gluta renghas* which is evenly distributed and with higher proportion in all the diameter classes. It could be expected that the species would remain dominant in the future, if there is no forest disturbance any more.

Tabel 5. The density (D= sapling /ha), basal area (BA= m^2 /ha) and importance value of sapling species in Suaq Balimbing forest plot

No	Species	Family	BA/HA	F	D/HA	IV
1.	*Garcinia celebica*	Clusiaceae	6393.97	103	613	49.43
2.	*Gluta renghas*	Anacardiaceae	7483.80	82	443	44.12
3.	*Eugenia sexangulata*	Myrtaceae	4882.37	96	403	37.99
4.	*Mangifera longipetiolata*	Anacardiaceae	2554.82	72	280	24.94
5.	*Shorea palembanica*	Dipterocarpaceae	3312.00	62	223	23.76
6.	*Dillenia puchella*	Dilleniaceae	1257.34	39	148	13.05
7.	*Parinarium corymbosum*	Rosaceae	1533.80	31	110	11.53
8.	*Gynotroches* sp.	Rhizophoraceae	1278.86	19	148	10.46
9.	*Tetrameristra glabra*	Theaceae	1512.40	21	95	9.68
10.	*Phoebe lanceolata*	Lauraceae	1355.26	23	75	8.91
11.	*Eugenia cuprea*	Myrtaceae	730.38	27	105	8.76
12.	*Litsea gracilipes*	Lauraceae	863.98	21	65	7.06
13.	*Cryptocarya* sp.	Lauraceae	591.86	23	65	6.62
14.	*Gardenia* sp.	Rubiaceae	603.97	19	70	6.28
15.	*Horsfieldia crassifolia*	Myristicaceae	800.79	18	55	6.18
16.	gar.2	Clusiaceae	892.70	13	35	5.13
17.	*Sterculia oblongata*	Sterculiaceae	401.97	18	53	5.07
18.	*Sandoricum emarginatum*	Meliaceae	552.41	14	45	4.70
19.	*Glochidion rubrum*	Euphorbiaceae	401.81	12	30	3.57
20.	*Alstonia spatulata*	Apocynaceae	365.09	9	23	2.84
21.	Gar.3	Clusiaceae	112.92	6	15	1.56
22.	*Dialium patens*	Fabaceae	132.05	3	18	1.29
23.	Undet		92.64	3	8	0.87
24.	Undet		52.86	2	5	0.56
25.	*Macaranga triloba*	Euphorbiaceae	125.66	1	3	0.54
26.	Undet		31.91	2	5	0.50
27.	*Platea excelsa*	Icacinaceae	27.82	2	5	0.49
28.	Undet		18.24	2	5	0.47
29.	*Ficus* sp.1	Moraceae	17.36	2	5	0.47
30.	Undet		64.50	1	5	0.46
31.	Undet		88.14	1	3	0.44
32.	Undet	Araliaceae	55.15	1	3	0.35
33.	Undet		34.64	1	3	0.30
34.	Undet		11.31	1	3	0.24
35.	Undet		10.39	1	3	0.24
36.	*Polyalthia sumatrana*	Annonaceae	9.50	1	3	0.24
37.	*Xylopia ferruginea*	Annonaceae	9.50	1	3	0.24
38.	*Semecarpus longifolius*	Anacardiaceae	7.85	1	3	0.23
39.	Undet		7.85	1	3	0.23
40.	Undet		7.85	1	3	0.23

Tree height analysis have resulted in 3 canopy layers, i.e. lower layer (stratum C) occupied by 60% trees with heights of 10-20 m; stratum B (20-30 m) occupied by 35% of trees; and stratum A occupied by only 5% trees with heights of 30-40 m (Fig. 1). The emergent trees represented by *Shorea palembanica* and *Parinarium corymbosum* reach up to 35 m, whereas *Gluta renghas* was dominant in stratum B.

Table 6 shows that there are 11 groups of species, and most (37.5 %) of them aggregated on sub-plot 20. This group consisted of prominent species i.e. *Gluta renghas, Litsea gracilipes, Parinarium corymbosum, Shorea palembanica* and *Eugenia sexangulata,* having similar distribution in each sub-plot. It can be expected that those species may have the same pattern in adaptation on the habitat. On the other hand some species such as *Cryptocarya crassinervia, Sterculia oblongata, Sterculia rubiginosa* and *Platea excelsa* were limited in distribution.

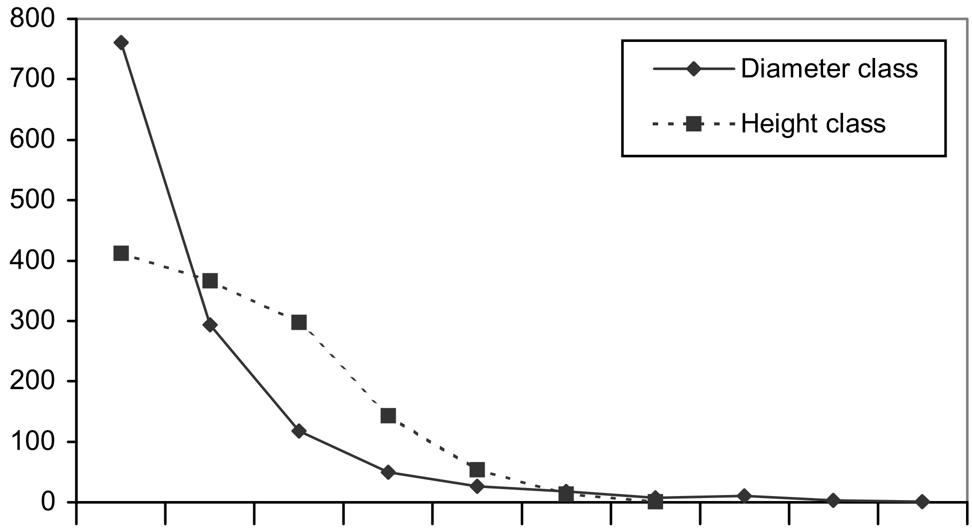

Fig. 1. Number of individuals in each diameter and height classes in Suaq Balimbing peat swamp forest, South Aceh

Conclusions

Peat swamp forest in Suaq Balimbing Research Station could be said that it was poor in plant species. Out of all the tree species recorded *Gluta renghas* would be suggested to dominate in this area in the future. The human disturbances would decrease the width of the forest area or accelerate deforestation; therefore law enforcement and forest control must be intensified.

Table 6. Species Grouping in sub-plot at Suaq Balimbing, South Aceh

Species	Sub-plot																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Gluta renghas	17	12	21	28	16	17	12	20	28	15	11	11	12	20	10	24	16	19	19	14
Litsea gracilipes		1	2	1	2	7	1			3	10	8	2	8	1	5	4	5	7	7
Parinarium corymbosum	6	6	5	6	7	3	9	6	2	7	5	1	6	2	12	8	4	5	9	7
Shorea palembanica	5	7	8	6	8	4	2	5	7	4	4	12	4	7	6	5	6	7	4	6
Eugenia sexangulata	8	3	2	3	8	11	5	6	4	13	7	8	6	10	7	5	3	5	2	5
Alstonia spatulata		4	1	2	1	1		1	1	3	1	4	1	4	4	3	1	2	1	4
Dillenia puchella	1	4	1	2	2		3	5	3		4		4	2	1	2	2	1	1	4
Garcinia celebica	2	5	1	5	9	5	5	8	5	10	5	6	2	3	11	6	4	12	2	2
Sandoricum emarginatum	5	1	7	6		7	3	6	3	3	7	3	2	7	5	1	6	3	8	2
Jangkang													2		1	1				1
Dehaasia				1					3		1	4	2			1	2			1
Phoebe lanceolata	1			2	3	1	1	2	2	1	1	2	4	2	1	1	4	1	3	1
Horsfieldia crassifolia	5	3	4	5	5	4	5	2	2	2	5	1	2	4	1	2		4	4	
Garcinia dioica	1	4		3		1	2	1	1	7	1	2	2	4	2	2	1		2	
Myristica sp.															2			2	1	
Mangifera longipetiolata		2		1			3	3	2	4	5	2	1	2	3	2	2	2		
Adina minutiflora																		2		
Tetrameristra glabra		1		2	5	3	1	2	1		3	2	4		1	6	1	2		
Macaranga diepenhorstii																		1		
undet-3															1					
undet-4															1					
undet-5															1					
Campnosperma coriacea					1									1						
undet-2														1						
Cryptocarya crassinervia			1									1								
Sterculia oblongata						1	1													
Sterculia rubiginosa					2															
Ficus xyllophylla				1																
Gardenia anysophylla				1																
undet-1				1																
Platea excelsa	1		1																	
Diallium patens	1																			
Disoxyllum sp.	1																			
Eugenia lineata	1																			

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Primary Production of a Heath (Kerangas) Forest in Lahei, Central Kalimantan

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Abstract

We examined primary production of a heath forest, which establish on highly acidic and nutrient-poor sandy soil, in central Kalimantan. Biomass of two 1-ha plots was around 200 - 250 t/ha. Relative growth rate (RGR) of stand biomass and net production was considerably lower during 1997-1998 than during 1998 - 1999, indicating that low rain fall and hours of sunlight caused by El Nino strongly affect the productivity of the heath forest. Turn over time defined as a reciprocal of RGR of stand biomass were greatly shorter than that of a mixed dipterocarp forest in west Kalimantan. Nutrient-poor soil was likely to be related to these characteristics of the heath forest.

Introduction

Kerangas forests are one of the most distinctive formation in Central Kalimantan, which occurs on highly acidic- and nutrient-poor sandy soils. Previous studies reported flora, soil characteristics and secondary succession about these forests. However, little is known about primary productivity and architectural characteristics of the forests so far. We attempted to reveal those characteristics of kerangas forests in terms of biomass, biomass allocation, growth and turn over by cutting various sized trees and using allometric relations between various pair of plant dimensions.

From 1997 to 1998, drought and haze pollution by El Nino occurred over Kalimantan. We examined the effect of insufficient rain fall and sunlight on primary productivity of the heath forest comparing primary production for El Nino period with that for non-El Nino period.

The present research addressed following questions: 1) What is the factors determining the productivity of the heath forest? 2) Are there any effects of El Nino on the productivity of the heath forest?

Study Site and Method

We carried out field survey in the area about 3-4 km east from Kampung Babugus, Desa Lahei, Kacamatan Metagai, Kabupaten Kapuas. This area is characterized by peat swamp forests and kerangas forests. We established two 1-ha plots in this area (one in a kerangas forest (P1) and another in a peat swamp forest (P2)) in August 1997, and one more plot in heath forest (P4) in January 1998. In the heath forest, main tree species were *Cotylelobium lanceolatum*, *Shorea teysmanniana*, *Shorea platycarpa* (Dipterocarpaceae), *Calophyllum* spp. (Guttiferae), *Engelhardia serrata* (Juglandaceae), *Eugenia* cf.*klosii*, *Tristania obovata* (Myrtaceae) (Table 1). To observe annual growth of the forest, we measured girth at breast height (g.b.h.) for all trees with more than 15 cm g.b.h. in one kerangas plot (P4). For calculating parameters of allometric equations to estimate primary production, we carried out clear felling in one of the subplots (10 m × 10 m) in P1. We cut various sized trees (from saplings with 4 m high to adults with 30 m high), then, measured and weighed above ground parts of these sample trees divided into three fractions (trunks, branches and leaves). In order to calculate dry weight of each sample tree, we collected small samples to be dried at 80°C in electric oven.

Table 1. Number and basal area (BA) of main species of a 1-ha plot (P1) in a heath (kerangas) forest. Only species with more than or equal to 2.0% in BA were shown except *Agathis borneensis*.

Species (Local name)	Family	Number of individuals	BA (m^2)	%
Cotylelobium lanceolatum	Dipterocarpaceae	108	4.4	14.6
Shorea teysmanniana	Dipterocarpaceae	58	1.9	6.3
Calophyllum sp 1. (bingtangor)	Guttiferae	180	1.9	6.2
Shorea platycarpa	Dipterocarpaceae	43	1.3	4.2
Engeihardia serliata	Juglandaceae	12	1.1	3.6
Eugenia cf. *klosii*	Myrtaceae	79	0.9	3.1
Tristania obovata	Myrtaceae	55	0.9	2.9
Hopea gnffithui	Dipterocarpaceae	163	0.9	2.8
Sindora leiocarpa	Legumlnosae	77	0.8	2.7
Vatica umbonata	Dipterocarpaceae	14	0.8	2.6
Garcinia rostrata	Guttiferae	87	0.7	2.4
Calophyllum pulcherrimum	Guttiferae	91	0.7	2.4
Calophyllum sp2. (kupple naga)	Guttiferae	6	0.6	2.0
Agathis borneensis	Araucariaceae	18	0.4 (1.3)†	1.3
Others		1142	13.1	42.9
Total		2133	305	100.0

† Sum of BA of living trees and stumps previously felled was shown in parentheses.

Results

Size distribution pattern of the heath forest

Fig. 1 shows d.b.h. size class distribution of the heath forest and the mixed dipterocarp forest stands. Every distribution showed a reversed -J shaped pattern. Frequency of small sized trees up to 20 cm was higher in the heath forest than in the mixed dipterocarp forest. No individuals was found in the d.b.h. class more than 70 cm in the heath forest, while trees distributed up to 158 cm in the mixed dipterocarp forest.

Architectural characteristics of the kerangas forest in allometry

We employed expanded allometric equation to describe the Diameter - Height (DH) relationship of trees:

$$1/H = 1/AD + 1/H^* \qquad (1)$$

where A and H* are regression constants. This relation is an asymptote to projected maximum tree height H^*. Maximum tree height (H^*) in the heath forest was short compared with that in the mixed dipterocarp forest. In small sized trees up to 10 cm in diameter at breast height (d.b.h.), however, trees in the heath forest were taller than those in the mixed dipterocarp forest. In fact, most tree species in the heath forest had slender trunks.

We employed simple allometric equation to describe the relations between the other pairs of tree dimensions (e.g. trunk dry weight - branch dry weight):

$$Y = aX^b \qquad (2)\text{-a}$$

in log scale, the relations are shown by linear lines:

$$\ln Y = \ln a + b \ln X \qquad (2)\text{-b}$$

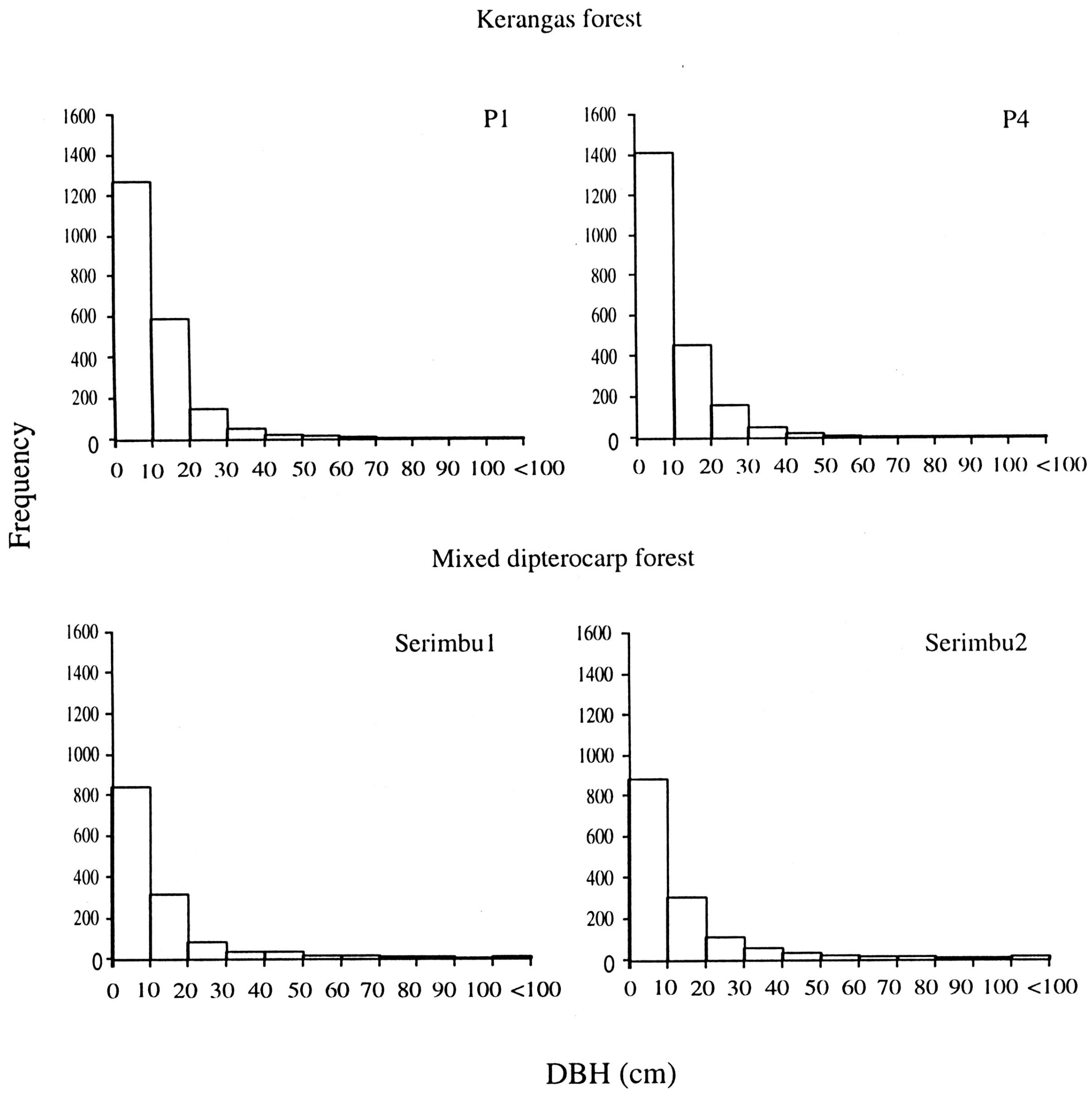

Fig. 1. Frequency distribution of DBH (≥5 cm) of trees in 1-ha plots in the heath forest and the mixed dipterocarp forest.

where a and b are regression constants. In leaf dry weight (Wl) - stem and branch dry weight (Wsb) relation and leaf area (Al) - crown area (Ac) relation, significant differences were shown between the heath forest and the mixed dipterocarp forest in the regression constant b, which correspond to a slope of linear regression line in equation (2)-b ($p < 0.005$). Whereas in Al - Wl relation, significant difference was shown in elevation ($p < 0.001$).

Primary production of the heath forest

Stand biomass of the heath forest was around 200 - 250 t/ha. These values were equivalent to a half of those of the mixed dipterocarp forests. We adopted a reciprocal of relative growth rate (RGR) of the stand biomass as a turn over time. The turn over time of two 1-ha plots during 1998-1999 were around a quarter of that of the mixed dipterocarp forest.

The effect of El Nino on the productivity of the heath forest

There were remarkable differences in RGR of stand biomass and net production between before and after August 1998 both in P1 and P4. Especially in P1, RGR during 1997-1998 showed negative value. Significant difference in relative growth rate of d.b.h. (RDGR) was not found between two plots and in time-plot interaction, but within time (i.e., El-Nino year vs. non-El Nino year).

Discussion

From the present result, it was obvious that the heath forest had lower biomass, shorter turn over time than the mixed dipterocarp forest. These characteristics of the heath forest appear to be partly due to unique DH relation and size distribution biased to small sized trees. Although occur in the same tropical lowland area as mixed dipterocarp forest, heath forests have slender trunks and short maximum tree height (around 30 m). These physiognomic features and productivity of the heath forest appear to be related to nutrient poor soil environment.

During 1997 to early 1998, rainfall was considerably lower than usual. Especially in 1997, only 2/3 of usual annual rainfall was recorded. In addition to that, hours of sunlight were remarkably short from July to September 1997 due to smoke by forest fire. Significant difference in RDGR between El Nino year and non-El Nino year indicates that insufficiency of rainfall and hours of sunlight during El Nino period strongly affected the growth of the heath forest stands. Further studies are needed to precisely evaluate the effect of El Nino on the forest productivity.

Appendix 1. Demensions and plant mass of samples in a heath forest in Central Kalimantan, Indonesia.

No	D0 (cm)	D0.1(cm)	D (cm)	Db (cm)	H (m)	Hl (m)	Ws (kg)	Wb (kg)	Wl (kg)	W (kg)	Ac (m^2)	Al (m^2)
1	5.16	4.84	4.49	2.74	10.11	7.8	6.03	1.12	0.46	7.61	6.60	4.19
2	4.07	3.53	3.79	3.44	8.5	8.5	3.36	1.17	0.52	5.05	4.78	5.32
3	5.98	4.33	4.20	2.39	7.45	5.92	4.95	0.77	0.15	5.87	2.64	2.56
4	4.84	4.30	4.39	2.93	7.68	5.63	3.86	0.55	0.25	4.66	2.83	1.85
5	4.36	3.53	3.41	2.45	8.4	5.75	3.57	0.57	0.21	4.35	5.28	1.30
6	5.57	4.42	4.42	3.95	7.79	3.9	5.23	2.15	0.57	7.95	8.28	5.49
7	4.39	3.72	3.50	3.06	6.2	3.15	1.89	0.47	0.45	2.80	5.30	3.42
8	2.86	2.42	2.36	2.29	6.93	2.5	1.41	0.21	0.15	1.78	3.60	1.42
9	3.88	3.28	3.21	2.80	7.9	4.01	2.81	0.60	0.32	3.73	2.47	2.62
10	3.85	3.37	3.28	1.24	9.5	8.35	2.65	0.11	0.08	2.84	2.01	0.63
11	3.72	2.67	2.51	2.20	6.85	3.54	1.69	0.30	0.18	2.17	1.94	1.78
12	7.19	5.09	4.87	3.18	6.7	5.53	5.04	0.79	0.39	6.22	4.15	1.93
13	7.48	6.43	6.40	3.25	10.82	8.1	12.41	2.19	0.30	14.90	3.28	2.72
14	11.14	9.80	9.80	8.56	13.66	5.5	35.18	17.00	4.95	57.13	19.79	26.28
15	8.09	6.91	6.97	5.73	13.7	7.57	24.13	5.14	1.01	30.28	11.88	5.92
16	6.24	5.09	4.97	3.12	7.1	4.95	4.24	0.88	0.90	6.02	3.80	5.99
17	8.21	7.67	7.67	5.83	13.6	7	23.60	4.50	1.62	29.72	6.33	12.29
18	8.85	8.82	9.14	5.92	12.17	8	24.28	4.14	2.18	30.60	5.73	8.39
19	10.15	*	8.66	5.12	14.78	9.85	26.71	2.23	1.04	29.98	3.58	4.95
20	9.49	*	8.94	7.29	13.01	6.34	30.89	12.06	1.92	44.87	13.43	10.33
21	7.00	6.33	6.24	4.04	10.53	7.2	11.15	1.16	0.09	12.39	3.64	0.73
22	9.52	8.37	8.37	7.00	13	8.3	34.89	11.62	3.80	50.31	14.18	21.34
23	10.92	10.12	9.61	7.19	14.44	9.25	38.67	10.79	2.50	51.96	12.37	15.53
24	11.11	9.01	9.26	6.56	14.75	7.7	32.56	6.45	1.63	40.64	4.18	11.49
25	9.17	7.67	7.64	4.11	16.26	10.2	25.73	1.95	1.03	28.71	8.34	7.18
26	12.61	9.87	9.93	8.94	15.6	7.25	53.17	17.68	6.09	76.93	10.41	40.73
27	8.18	6.53	6.33	4.46	11.6	5.53	15.51	3.22	0.90	19.62	7.79	8.24
28	*	10.22	10.31	12.03	16.1	8.5	72.70	17.32	3.80	93.82	19.35	24.12
29	8.34	6.81	7.29	5.35	11.1	7.3	21.55	2.46	0.44	24.44	6.13	3.82
30	6.49	5.86	5.92	4.71	10.6	5.5	11.13	1.99	0.50	13.63	11.04	5.25
31	7.10	5.89	5.70	3.12	9.75	*	11.40	0.54	0.07	12.01	3.53	0.61
32	6.24	5.16	5.47	3.53	8.75	5.8	7.60	0.94	0.45	9.00	4.15	3.75
33	6.24	5.09	5.03	2.74	7.15	*	7.47	0.04	0.02	7.53	1.51	0.12
34	5.06	4.77	4.74	2.39	11.2	8.1	6.04	0.24	0.12	6.40	3.29	1.18
35	5.09	4.33	4.49	3.85	10.6	6.4	7.12	0.96	0.43	8.51	4.34	3.91
36	4.39	2.83	2.83	2.51	8.3	3.12	2.08	0.67	0.33	3.08	4.14	3.16
37	6.24	5.19	5.19	4.17	10.8	6.4	9.97	2.02	0.82	12.82	4.32	6.37
38	3.50	2.99	3.06	2.10	7.45	5.05	2.24	0.44	0.32	2.99	3.14	3.29
39	4.36	3.82	3.60	2.93	10.13	5.8	4.65	0.59	0.27	5.52	2.72	2.78
40	5.00	4.46	4.65	1.59	9.95	*	4.33	0.10	0.05	4.47	0.71	0.54
41	4.20	3.72	3.69	2.32	9.35	7.1	2.06	0.27	0.07	2.39	2.76	0.64
42	5.09	4.46	4.17	3.09	9.18	6.1	2.97	0.18	0.05	3.21	1.53	0.43
43	5.32	4.62	4.65	2.07	8.95	7.6	5.50	0.10	0.04	5.65	1.30	0.31
44	4.04	3.34	3.28	1.94	7.7	4.8	2.47	0.04	0.05	2.55	0.33	0.37
45	3.66	3.06	3.06	2.58	5.45	3.95	1.41	0.28	0.28	1.97	3.30	2.52
46	21.14	15.02	15.34	11.71	17.7	10	84.96	16.04	9.73	110.72	16.96	41.42
47	4.39	4.11	4.14	2.83	9	6.35	5.58	1.07	0.27	6.92	5.72	1.49
48	3.37	3.09	3.02	*	6.7	3.45	2.04	0.64	0.28	2.96	4.10	2.38
49	21.29	18.24	19.10	14.51	21.5	*	200.73	32.17	9.36	242.26	23.00	60.91
50	3.57	2.90	2.93	2.80	8.25	3	2.39	0.57	0.24	3.21	*	2.23
51	6.62	5.03	4.93	3.66	8.1	*	4.37	1.43	0.58	6.38	2.00	3.05
52	4.30	3.47	3.31	2.04	7.35	4.5	2.37	0.07	0.04	2.49	1.26	0.40
53	26.36	23.71	25.27	17.00	20.3	14.1	251.31	45.04	6.01	302.35	39.47	48.50
54	4.20	3.72	3.57	3.37	6.5	2.3	2.28	0.76	0.32	3.36	3.28	2.10
55	4.07	4.07	3.63	2.39	8.55	5.75	2.90	0.26	0.01	3.17	1.63	0.11
56	36.61	30.69	32.59	28.49	27.6	20	817.11	226.86	20.88	1064.85	37.92	108.80
57	43.23	34.19	37.15	28.17	27.8	22	936.06	280.99	12.03	1229.09	62.58	61.93
58	26.26	21.14	21.77	17.09	20.73	11.3	176.96	53.17	19.26	249.40	39.03	85.63
59	36.13	27.09	30.18	18.75	22.1	16.85	505.47	69.37	12.66	587.50	25.51	57.28

Abbreviations: D0, stem diameter at the ground level: D0.1, stem diameter at 1/10 of the tree height; D, stem diameter at breast height; Db, stem diameter at the lowest living branch; H, tree height; Hl, height of the lowest living branch; Ws, stem dry weight; Wb, branch dry weight; Wl, leaf dry weight; W, aboveground total weight; Ac, crown area; Al, total leaf area; *, No available record