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総説　（Review Article）

Patterns of slash-and-burn land use and their effects on forest succession - Swidden-land forests in Borneo -

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Abstract

To evaluate the impact of increased numbers of pyrophytic tree species on succession and the role of pyrophytic tree stands as carbon sinks and reservoirs, the floristic composition and bioeconomics of swidden-land forests were studied in lowland and lower montane Borneo. For our survey of stand floristic composition, 218 secondary forests were chosen in 4 regions including 2 remote areas; most forests were fallowed stands. In 2 of these forests, stand biomass was estimated. The floristic composition of swidden-land forests was characterized by a lack or low density of dipterocarps and the successional ascendance of pyrophytic tree species less vulnerable to felling and fire and with high sprouting capacity such as *Schima wallichii*, *Vitex pinnata*, *Peronema canescens*, and *Vernonia arborea*. In remote areas, pioneer trees with fruiting and functioning seed dispersal mechanisms were also dominant. Dipterocarps other than *Shorea balangeran* were not found or were sparse in the fallowed land, which resulted from swidden agriculture, although dipterocarps were the most dominant species in the original vegetation of lowland and lower montane Borneo. MAI (mean annual increment) values of 3.26 and 3.61 Mg ha^{-1} $year^{-1}$ of biomass were estimated in a *Schima wallichii* fallowed stand, versus 6.46 Mg ha^{-1} $year^{-1}$ in a *Peronema canescens* stand. Equivalent MAI values were estimated in fallowed pyrophytic tree stands in South Sumatra (3.85-10.62 Mg ha^{-1} $year^{-1}$); the mean of these MAI estimates is not significantly different from the mean MAI of planted forests of non-fast-growing tree, 10.71 ± 7.18 Mg ha^{-1} $year^{-1}$ (range, 1.90-18.80) under similar climate conditions. Because a relatively few hardy tree species selected by the people of the region have replaced the original tree species in the fallowed forests, young sprouts from tree stumps of pyrophytic species may rapidly close the canopy when slash-and-burn fields are fallowed.

Key words : pyrophyte, *Schima*, pioneer, dipterocarp, biomass, mean annual increment, biodiversity

Contents

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1 Introduction

Slash-and-burn agriculture* is one of the major causes of forest degradation in the tropics and is widespread in Borneo (Kalimantan, Fig. 1) (Spencer, 1966; Kartawinata et al., 1981). In the interior of East Kalimantan Province, some secondary forests have returned to conditions similar to primary dipterocarp forest after 70 years in fallow (Okimori & Matius, 2000). In the same region, however, fallow forests of predominately pyrophytic tree species have developed simultaneously, as a result of repeated slash-and-burn agriculture (Kiyono & Hastaniah, 1994; 1996; 1997). This is swidden agriculture in the narrow sense (Whitten et al., 1987). As long as the area remains fallow, this type of forest regenerates continuously. However, pyrophytic tree species are considered to be minority or invaded trees for most original ecosystems in lowland Borneo. Increase of this species in natural forests is a sign of degradation of original ecosystems. We need pay attention to the impact of pyrophytic tree species increase on regional biodiversity. On the other hand, pyrophytic tree species may have high biomass productivity and have been a useful tree for local people utilizing such species. Their low vulnerability to fire and other physical disturbances may lessen dificulties in establishing forest on some critical land. To evaluate the impact of pyrophytic tree species increase on succession and the role of pyrophytic tree stand as carbon sink and reservoir, floristic composition and bioeconomics of swidden-land forests were studied in Borneo.

Plant specimens collected were identified at the Herbarium Bogoriense (Bogor, Indonesia). Nomenclature was Jansen et al. (1993) and Keßler & Sidiyasa (1994). Vernacular names were spelled following the Indonesian practice and Benuaq names were used in section 2, Kenyah and Lun Dayeh names in section 4, and Indonesian names in the other sections. Means are provided with "± standard deviation" in principle.

This study was conducted at first as a part of the Tropical rain forest research project of Japan International Cooperation Agency (JICA) and then completed in the research with financial support by Japan Society for the Promotion of Science Funds affiliated with the Ministry of Education, Culture, Sports, Science, and Technology, Japan. We are grateful to the participants in the projects from the Mulawarman University, Bogor Agricultural Institute, PT Musi Hutan Persada, Indonesia, Kyoto University, Forestry and Forest Products Research Institute, Japan for their cooperation for our study and the

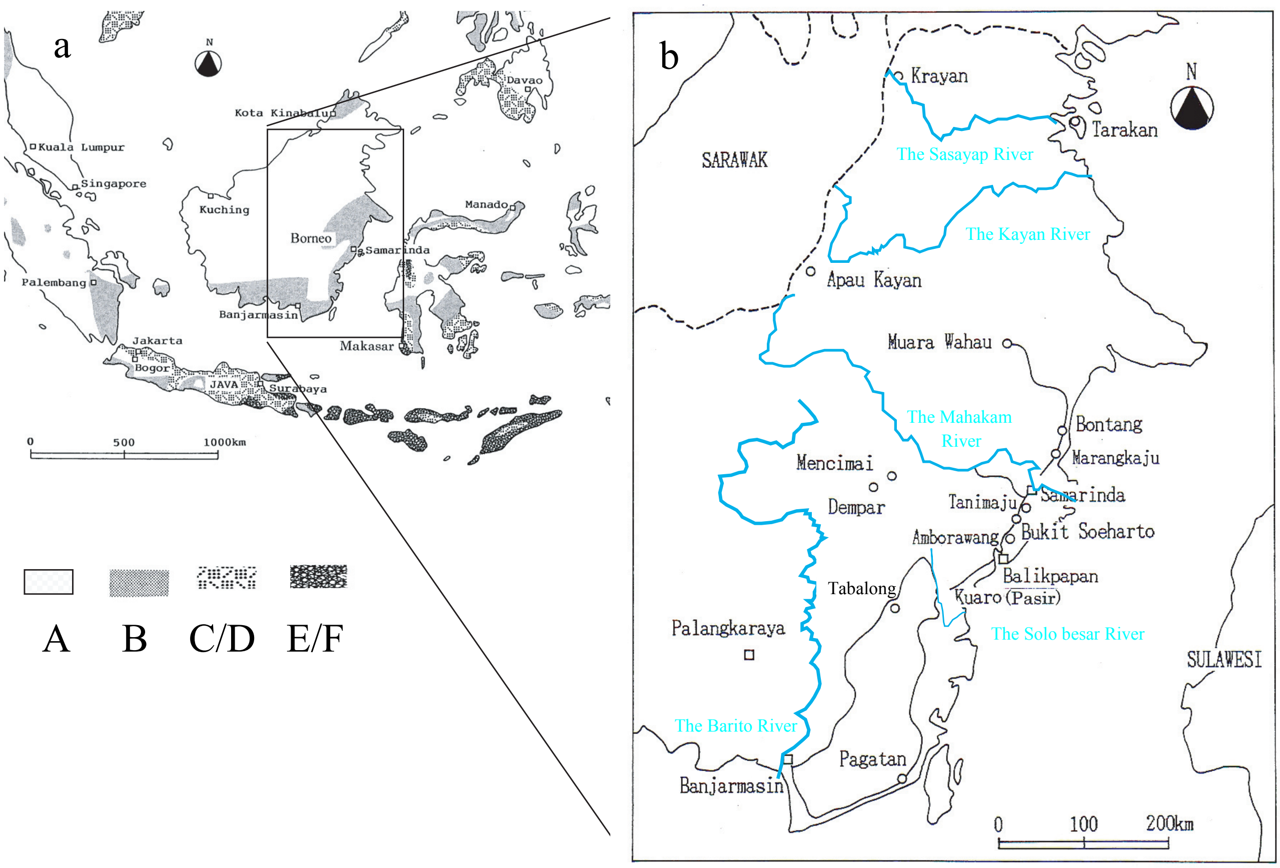

Fig. 1. Map of the rainfall types in and around Borneo (a) and the survey route followed during the present study (b).
(a) Based on the ratios of wet to dry periods (adapted from Whitmore & Burnham, 1975). A: Q < 14.3, B: 14.3 < Q <33.3, C/D: 33.3 < Q 100, E/F: 100 < Q <300. Q = (dry months/wet months) x 100. Wet month is defined as any month with over 100 mm of rain (precipitation exceeding evaporation) and dry month is any month with less than 60 mm (evaporation exceeding precipitation). Q values were calculated using wet and dry months for each year with at least 10 years' record.
(b) □Province capital or city > 100,000 people. ○Community < 50,000 people. Lines connecting cities and/or communities represent roads along which field observation was practiced by Kiyono & Hastaniah (1997) (modified from Kiyono & Hastaniah, 1997).

Demonstration study of carbon fixing forest management project (JICA) for help and provisions of unpublished data for this study. We also thank Mr. K. Morisada of Forestry and Forest Products Research Institute for his help in soil taxonomy.

* For the purposes of this paper, slash-and-burn agriculture is classified as "swidden" agriculture and shifting agriculture, as defined by Whitten et al. (1987): "Swidden agriculture, in its purest sense, is the repeated use of a patch of forest land for the cultivation of crops, and is characterized by long fallow periods between short periods of production. Shifting agriculture, on the other hand, is a particular type of swidden agriculture that encroaches upon forested areas."

2 The Mencimai Region (*Schima wallichii* forests)

2.1 Study area and method

Our study began with observations of an old settlement along the middle course of the Mahakam River. The Benuaq and Tunjung peoples live south of the Mahakam River (Fig. 1b). The village (*Desa*) of Mencimai (00° 17' S, 115° 40' E) (Fig. 1b) is one of their settlements. As of 1993, about 70 Benuaq households (300 people) lived in the village. The majority of the people are Protestant or Catholic. Each household usually has its own house in the center of the village although the people of Mencimai say that until somewhere between the 1950s to the 1970s, houses and small slash-and-burn fields were scattered in the forested land and the zone of active swidden farming was wider than at present.

The geology in and around Mencimai is characterized by sandy Tertiary deposit, while partially the soils developed on volcanic parent materials are present (Voss, 1982). The latter was classified into Ferralsols, Nitisols, and Andosols (Aksa et al., 2000) and Humic Nitosols are dominant (Food and Agriculture Organization-United Nations Educational Scientific and Cultural Organization, 1979). The topography is generally hilly, but is flat in the center of the village. The land is between 60 and 150 m above sea level. Although meteorological data are not available for Mencimai, the annual precipitation at Sekolaq Darat (8 km east of Mencimai) averaged 2789 mm and the mean monthly precipitation in September was relatively low (141 mm) from 1949 to 1962 (Transmigration area development project, 1982). Temperatures at Mencimai are slightly lower than those at Balikpapan, where the monthly mean temperature from 1961 into the 1990s was 26.6-27.3 degrees Celsius (°C) (National Astronomical Observatory, 1995).

According to the Benuaq farmers at Mencimai, the majority of swidden (slash-and-burn) agriculture proceeds as follows: First, an area of fallowed forest is cleared in May or June, before the rainy season starts. The remains of the downed vegetation are left to dry, and then are burned in August or September. The seeds of cultivated plants such as upland rice and *Zea mays* are sown after the burning (Photographs 1, 2). *Pteridium aquilinum* (*kanaau* in Benuaq name, here after [B]) and *Chromolaena odorata* (*rumput Jawa* [B]) are the major slash-and-burn field weeds, and are always weeded out of the fields. After at most three crops (and usually only one or two crops), the area is left fallow, except where perennial crops have been planted. Old forests are relatively far from the houses in the village: located at Sei Liwir, "Sawmill", and Sei Penai, respectively. Although it is difficult to know when the village was established, Benuaq elders say that they first settled their village more than 300 years ago and have practiced slash-and-burn farming. The Benuaq also say that when the people of Mencimai die, their souls return to Mount Lumut (01° 25' S, 116° 00' E, 1233 m a.s.l.) in the Pasir region about 120 km southeast of Mencimai village, and come to Mencimai while the secondary funerals are held. This anecdote may imply that the Pasir region is the place of origin of the people of Mencimai.

In September 1992, of several paths in the village, we selected 3 paths (Jl. Meluikng, Jl. Kubu, and Jl. Sungai One) and all 24 fallowed stands along the 3 paths as samples of fallowed stands in the zone of active swidden farming, which currently extends no more than about 1 hour's travel on foot from the village. We determined stand age (fallowed period) according to interviewing farmers, measured overstory height and noted dominant tree species and surface soil morphology for each stand.

A study of species richness, biomass, and net primary productivity (NPP) was then conducted from March 1993 to April 1994 in the 33-year-old fallowed stand (stand No. 10 in Table 1). *Stenochlaena palustris* (*pakuq* [B]), a climbing fern, covered the majority of the tree stems and formed a root mat 5-10 cm deep. We set one 20×20 m plot in the stand and establish twenty 0.25-m-high, 0.83-m^2 litter traps in the plot. The trapped litter was collected every 2 weeks from March 1993 to April 1994. The litter was air-dried at Mencimai and was brought to the Mulawarman University, Samarinda and weighed after drying at 85 °C in a forced-draft oven. Farmers refrained from logging and/or collecting fuel wood in the research plot from March 1993 to April 1994.

Photo. 1. Planting upland rice (*Oryza sativa*) seeds in the Mencimai region.

Photo. 2. Slash-and-burn field 2 months after planting upland rice (*Oryza sativa*) in the Mencimai region.

In all, 42 trees more than 5 cm in diameter at 1.3 m height ($D_{1.3}$) were found in the plot and identified to botanical names in March 1993 (Appendix 1). Diameters ($D_{1.3}$) and heights (H) of these trees were measured, and for 17 of the trees including the maximum and minimum class in $D_{1.3}$, diameters just below the lowest bough (D_b) were measured. In May 1994, the $D_{1.3}$ and H of the 42 trees, and the D_b values for 19 of the trees were measured; furthermore, 14, including the maximum and minimum class in $D_{1.3}$, of these 19 trees were felled to permit the measurement of the stem, branch, leaf, and other components of biomass (Appendix 2).

The biomass of each component of the trees in 1994 was estimated using the 1994 values for $D_{1.3}$, D_b, and H and equations (1) through (5), which were developed using data from the 14 trees that had been felled for destructive sampling. Only nine tallest trees were measured stem volume.

$$\text{Leaf weight} = 0.0455\, D_{1.3}^{\ 1.69} \quad (R^2 = 0.798,\ n = 14) \qquad (1)$$

$$\text{Leaf area} = 1.12\, D_{1.3}^{\ 1.36} \quad (R^2 = 0.716,\ n = 14) \qquad (2)$$

$$\text{Branch and sexual organ weight} = 0.0286\, D_{1.3}^{\ 2.41} \quad (R^2 = 0.896,\ n = 14) \qquad (3)$$

$$\text{Stem weight} = 0.0240\, (D_{1.3}^{\ 2} H)^{0.975} \quad (R^2 = 0.974,\ n = 14) \qquad (4)$$

$$\text{Stem volume} = 0.0000975\, (D_{1.3}^{\ 2} H)^{0.896} \quad (R^2 = 0.983,\ n = 9) \qquad (5)$$

The relationship between stem dry weight and $D_{1.3}^{\ 2} H$ is known to be generally stable among trees with similar wood specific gravity (Kira & Shidei, 1967). Using the same data from the destructive sampling, equations (6) through (8) were also obtained:

$$\text{Leaf weight} = 0.0360\, D_b^{\ 1.93} \quad (R^2 = 0.793,\ n = 14) \qquad (6)$$

$$\text{Leaf area} = 0.876\, D_b^{\ 1.58} \quad (R^2 = 0.735,\ n = 14) \qquad (7)$$

$$\text{Branch and sexual organ weight} = 0.0197\, D_b^{\ 2.77} \quad (R^2 = 0.900,\ n = 14) \qquad (8)$$

Also, the relationship between canopy biomass and D_b is known to be generally stable for trees at different growth stages or at different locations when their life forms and phenological stages are similar (Yamaoka, 1958; Shinozaki et al., 1964).

Tree biomass in 1993 was estimated using the 1993 values of $D_{1.3}$ and H for the 42 trees, the 1993 D_b values of 17 trees, and equations (4) and (6) through (8):

$$D_{b\ \text{in 1993}} = 1.09\, D_{1.3\ \text{in 1993}}^{\ 0.881} \quad (R^2 = 0.960,\ n = 17) \qquad (9)$$

Using equations (6) and (9):

$$\text{Leaf weight}_{\text{in 1993}} = 0.0360\, (1.09\, D_{1.3\ \text{in 1993}}^{\ 0.881})^{1.93} \qquad (10)$$

Using equations (7) and (9):

$$\text{Leaf area}_{\text{in 1993}} = 0.876\, (1.09\, D_{1.3\ \text{in 1993}}^{\ 0.881})^{1.58} \qquad (11)$$

Using equations (8) and (9):

$$\text{Branch and sexual organ weight}_{\text{in 1993}} = 0.0197\, (1.09\, D_{1.3\ \text{in 1993}}^{\ 0.881})^{2.77} \qquad (12)$$

To evaluate the overall biomass in the plot, additional materials were collected in May 1994. These included: understory plants with stem diameters of less than 5 cm in four 1×1 m plots, the climbing plants on 2 trees, and the root mat and humus in four 0.5×0.5 m plots. The amount of belowground biomass was estimated using the root-to-shoot ratio (belowground biomass/aboveground biomass presented by IPCC National Greenhouse Gas Inventories Programme (2003)) for *Schima wallichii* (0.248 ± 0.049, calculated using data in Gintings et al. (2003) and unpublished data of JICA; totally 5 trees ranging 4.8-27.6 cm in $D_{1.3}$) and the stand total aboveground biomass of the study stand. Although data on belowground biomass for forest trees are generally rarer than those for aboveground biomass, this lack of belowground data was a barrier to accurate estimates of changes in carbon stocks in the study forest. The values from the plot were then converted into values per unit area.

The NPP of the study stand between the first and second measurements was estimated using equation (13) and converted into an annual rate:

$$\text{NPP}_{\text{in 1993-1994}} = \text{Biomass}_{\text{in 1994}} - \text{Biomass}_{\text{in 1993}} + \text{Loss (Litter fall + Tree fall + Dead roots)}_{\text{in 1993-1994}} \qquad (13)$$

The amounts of understory and climbing plants were measured only in 1993 and the amounts in 1994 were assumed to be the same as those in 1993. The amount of roots that died within 1 year was estimated to be 25% of the fine root biomass in a root mat (following Kira, 1978b) although our estimate did not include the incremental death of thick roots and therefore may underestimate NPP.

2.2 Results

2.2.1 General description of fallowed stands in the Mencimai region

Table 1 provides a general description of the fallowed stands we selected, all of which lay within 1 hour's travel on foot from the village. Eighteen of 24 stands were dominated by *Schima wallichii* (*nagaaq* [B], Photo. 3). The new shoots of this species, with young, red leaves were very common in slash-and-burn fields (Photo. 4).

Schima wallichii is a member of the Camelliaceae family, which is indigenous to India through Indo-China, southern China, the Ryukyu Islands and the Bonin Islands to Thailand, Peninsula Malaysia, Sumatra, Java, Borneo, and the Philippines (Palawan) (Sosef et al., 1998). Stems of this species may reach heights of more than 40 m and diameters of 1 m. The durable wood is used locally for house construction and other purposes. It is locally dominant in lowland and lower montane areas (Whitmore & Burnham, 1975). In West Java, *Schima wallichii* is the dominant species of mature forests in the montane zone on Mt. Pangrango (3019 m a.s.l.; Yamada, 1990). In Peninsular Malaysia, this species is found mostly in the hills and montane forests up to 2000 m a.s.l., but in the northwest part of Peninsular Malaysia, it is a common lowland species and forms *Schima*-bamboo biotic climax forests (Appanah & Weinland, 1993). Symington (1943) regarded these climax forests as derived from evergreen rain forest that had been intermittently cut, grazed, cultivated, and burned and ultimately degraded to a dryer type (Whitmore & Burnham, 1975). *Schima wallichii* is only an occasional species in the primary forests of lowland Borneo; for instance, the slightly to heavily disturbed original forests in the Mulawarman University Educational Forest at Bukit Soeharto did not contain this species in 1161 sample trees more than 10 cm in $D_{1.3}$) (Matius et al., 1993). Therefore, some other factors must be responsible for the establishment of *Schima wallichii* forest in Mencimai.

Schima wallichii easily sprouts new shoots from its stumps after felling and fire (Appendix 3: modified from Kiyono & Hastaniah, 2000b). The sprouts of 4-year-old trees (de Leeuw, 1936) or trees that have reached 5 m in height can produce winged seeds that are distributed by the wind. The influence of slash-and-burn farming on *Schima wallichii* is less serious than for other species that are vulnerable to felling and fire. For this reason, and because the species provides useful products for farmers, *Schima wallichii* is likely to have benefited from the effects of repeated slash-and-burn land use and increased in abundance during fallow periods. In lowland Peninsular Malaysia, Symington (1943) described transformation of vegetation in lowland rain forest in which anthropogenic disturbances selected for pyrophytic trees, which then formed biotic climax forests. This process also may have occurred in part of lowland Borneo. *Vitex pinnata* (*kelepapaak* [B]) also occurred as a dominant species (in four stands out of 24; Table 1). The species also sprouts from its stumps after felling, or felling and fire (Appendix 3). In contrast with *Schima wallichii*, this species survives in peat swamps, and reaches heights of only 25 m and diameters of only 40 cm.

Stand ages of the 24 stands ranged from 1 to 33 years, and 15 stands out of 24 were younger than 10 years. The mean age of the 24 stands was 10.6 years, and the overstory height of such a stand was estimated at about 10 m. Since the recent farmers of Mencimai have repeatedly cleared the defined forest land in the zone of active swidden farming for the cultivation of crops, fallowed periods of slash-and-burn fields averaged out

Table 1. Fallowed stands in the Mencimai region. (modified from Kiyono & Hastaniah, 1997)

No.	Stand age [*1] (year)	Overstory height (m)	Topography	Surface soil	Dominant species
1	5	1.5	Terrace	Black	*Vitex pinnata*
2	26	8	Gentle slope	Light black	*Schima wallichii*
3	8	8	Gentle slope	Black, sand	*S. wallichii*
4	1	2	Gentle slope	Black, sand	*S. wallichii*
5	2	4	Gentle slope	Black, sand	*S. wallichii*
6	2	4	Terrace	Abund. sand	*V. pinnata*
7	3	5-7	Gentle slope	Black, sand	*S. wallichii*
8	4	9	Gentle slope	Abund. sand	*V. pinnata*
9	20	13	Gentle slope	Light black	*V. pinnata*
10	33	18	Terrace	Black, sand	*S. wallichii*
11	6	5	Gentle slope	Black	*Elaeocarpus* sp.
12	31	18	Gentle slope	Abund. sand	*S. wallichii*
13	8	9	Gentle slope	Abund. sand	*S. wallichii*
14	6	8	Gentle slope	Abund. sand	*S. wallichii*
15	20	10	Gentle slope	Black	*S. wallichii*
16	7	6	Gentle slope	Black	*S. wallichii*
17	16	10	Terrace	Black	*S. wallichii*
18	6	5	Terrace	Abund. sand	*S. wallichii*
19	12	9	Terrace	Abund. sand	*S. wallichii*
20	2	2	Terrace	Abund. sand	*S. wallichii*
21	3	3	Terrace	Abund. sand	*S. wallichii*
22	15	14	Terrace	Abund. sand	*S. wallichii*
23	15	17	Gentle slope	Abund. sand	*S. wallichii*
24	2.5	3	Gentle slope	Abund. sand	*Elaeocarpus* sp.

[*1] Stand age was determined by interviewing farmers.

10 to 11 years, or long enough for stands to reach about 10 m in overstory height. Almost all of the forests near the village, even on steep hills, were young and represented replacements for the original stands that had grown on those sites. Only trees that are useful for the production of fruits, nuts, such as *Durio zibethinus*, *Cocos nucifera*, *Mangifera* spp., and or upas (poison for poisoned arrow), *Antiaris toxicaria* (*siratn* [B]) formed old forest gardens (Photo. 5), and trees suitable for apiculture, such as *Koompassia excelsa* (*puti* [B]) (Photo. 6), have reached more than 30 m in height; these species towered above the other trees.

Dipterocarps other than *Shorea balangeran* (*kahoi* [B]; see Appendix 3) were rarely found in the zone of active swidden farming. Only a few *Dryobalanops beccarii* (*ngoiq* [B]), *Shorea macrophylla* (*oraai* [B]) and other dipterocarps occurred along

Appendix 1. Trees in a 20 × 20 m plot in a *Schima wallichii* stand in the Mencimai region. (modified from Kiyono & Hastaniah, 1997)

Tree No.	Species	March 1993				May 1994		
		$D_{1.3}$	D_b	Height		$D_{1.3}$	D_b	Height
				Tree	Lowest bough			Tree
		cm	cm	m	m	cm	cm	m
1	*Vitex pinnata*	14.9		14.6	7.0	15.4		10.7
2	*Schima wallichii*	10.8		13.0	8.0	12.0		10.8
3	*S. wallichii*	20.0	16.7	17.6	10.0	21.9	19.1	17.3
4	*Macaranga triloba*	11.4		10.9	9.0	11.5		12.1
5	*S. wallichii*	10.6		12.0	5.5	11.9		11.9
6	*S. wallichii*	21.6	16.4	17.7	8.0	20.8	17.5	18.0
7	*Timonius lasianthoides*	6.3	5.9	7.0	3.0	6.5	6.1	7.5
8	*S. wallichii*	15.6		14.1	8.0	15.2		14.1
9	*S. wallichii*	10.5	7.6	13.2	9.0	11.0	8.1	14.9
10	*S. wallichii*	16.5	11.9	14.2	7.9	16.7	11.9	15.9
11	*S. wallichii*	12.8	10.1	14.8	9.0	13.5	10.5	14.9
12	*Koompassia* sp.	5.7	5.5	6.0	3.0	6.2	5.2	6.7
13	*V. pinnata*	9.6		12.0	4.0	9.9		10.5
14	*S. wallichii*	15.9	11.6	16.1	8.5	16.7	10.7	18.0
15	*S. wallichii*	12.3	9.8	13.0	6.0	12.7	10.3	13.0
16	*S. wallichii*	9.3		7.5	2.0	9.7		8.0
17	*V. pinnata*	8.0		12.0	8.0	8.3		12.3
19	*S. wallichii*	7.7		10.0	5.0	8.5		11.0
20	*S. wallichii*	8.1		6.0	3.0	8.3		7.0
21	*S. wallichii*	16.8		15.7	8.0	17.5		17.0
22	*S. wallichii*	7.8		11.0	5.0	8.9		13.1
23	*Cratoxylum cochinchinense*	6.9		10.0	5.0	7.0		11.0
24	*Symplocos cochinchinensis*	9.3		12.0	2.5	9.3		13.0
25	*S. wallichii*	19.2		15.3	8.0	20.7		17.1
26	*S. wallichii*	11.3	8.5	16.1	10.0	12.9	9.1	19.0
27	*S. wallichii*	15.0	12.0	18.2	7.0	16.6	13.1	18.0
28	*S. wallichii*	16.0	12.0	17.5	11.0	17.4	12.5	19.6
29	*S. wallichii*	21.3	14.5	19.7	12.0	22.7	15.9	19.6
30	*S. wallichii*	13.2	11.4	16.0	9.0	14.6	12.6	13.6
31	*S. wallichii*	7.7	6.6	9.0	4.0	8.0	7.3	9.1
32	*Litsea* sp.	14.4		14.1	7.0	15.5	12.8	17.0
33	*S. wallichii*	12.2		11.7	7.0	12.4		12.8
34	*S. wallichii*	14.8		20.0	12.0	15.7		18.8
35	*S. wallichii*	13.9		17.7	12.0	14.5		18.8
36	*V. pinnata*	9.6		9.5	5.0	Dead		
37	*S. wallichii*	17.1	14.1	18.9	8.0	17.9	13.2	18.9
38	*Buchanania arborescens*	6.4		6.0	2.0	7.1		7.5
39	*S. wallichii*	28.9	24.4	23.0	10.0	30.1	23.1	25.2
40	*S. wallichii*	9.1		12.0	7.0	9.6		14.7
41	*S. wallichii*	21.3		22.4	11.0	22.2		23.9
42	*V. pinnata*	5.5		7.0	2.0	5.7	5.6	7.0
Mean		12.8		12.6	6.6	13.6		13.2
Basal area (m^2 ha^{-1})		15.3				16.8		

Appendix 2. Weights and dimensions of the organs of trees in a *Schima wallichii* stand in the Mencimai region. (modified from Kiyono & Hastaniah, 1997)

Tree No.	$D_{1.3}$	D_b	Tree height	Weights					Leaf area	Stem volume
				Stem	Branches		Fruits	Leaves		(Outer-bark)
					large	small				
	cm	cm	m	kg	kg	kg	kg	kg	m^2	m^3
3	21.9	19.1	17.3	174.4	51.2	8.5	1.0	10.7	104.6	0.358
6	20.8	17.5	18.0	165.7	65.2	7.4	0.9	12.6	104.5	0.328
7	6.3	6.1	7.5	6.8	4.3	0.8	+	0.8	11.5	n.a.
9	10.5	8.1	14.9	42.8	7.0	1.5	0	3.2	32.5	n.a.
10	16.7	11.9	15.9	75.9	14.0	1.8	1.1	2.3	20.1	0.168
12	5.7	5.2	6.7	6.7	1.7	1.0	0	1.8	23.5	n.a.
14	16.7	10.7	18	79.0	19.6	4.9	0.4	5.3	60.7	0.159
26	12.9	9.1	19	53.7	5.5	0.9	0.1	2.3	20.2	0.121
30	14.6	12.6	13.6	81.9	17.8	2.6	0	6.6	56.2	0.160
31	7.7	7.3	9.1	8.8	1.2	0.6	0	1.1	17.5	n.a.
32	15.5	12.8	17	78.3	13.2	3.2	0	5.1	68.0	0.165
37	17.9	13.2	18.9	109.0	32.0	2.7	0.1	8.8	72.5	0.225
39	30.1	23.1	25.2	401.8	105.0	7.7	+	9.1	80.3	0.779
42	5.7	5.6	7.0	3.1	1.7	+	0	0.6	7.4	n.a.

+: Negligible small.

Appendix 3. Interspecific variations of vulnerability to felling and/or fire events. (modified from Kiyono & Hastaniah, 2000b)

Species	$D_{1.3}$ cm	Number of individuals	% sprouted	Treatment [*1]	Vulnerability to felling and burning
Tree species					
Cotylelobium lanceolatum	30-60	5	100	F & B	Low
Shorea balangeran	10-25	12	92	F & B	Low
Dipterocarpus cornutus	30-60	3	0	F	High
Dipterocarpus humeratus	30-40	3	0	F	High
Dipterocarpus oblongifolius	50-80	21	0	F & B	High
Dipterocarpus tempehes	20-40	4	0	F & B	High
Shorea johorensis	30-100	3	0	F	High
Shorea laevis	20-75	3	0	F	High
Shorea leprosula and *S. parvifolia*	25-60	21	0	F & B	High
Shorea ovalis	20	1	0	F	High
Shorea smithiana	25	1	0	F	High
Schima wallichii	8-20	28	100	F & B	Low
Vitex pinnata	5-25	137	100	F & B	Low
Peronema canescens	11-21	46	100	F & B	Low
Nauclea sp.	7-16	13	100	F & B	Low
Artocarpus anisophyllus	6-13	23	100	F & B	Low
Vernonia arborea	7-17	42	98	F & B	Low
Eusideroxylon zwageri	44-92	26	92	F & B	Low
Macaranga gigantea	11-22	90	0	F & B	High
Macaranga triloba	10-20	14	0	F & B	High
Small-tree species					
Trema orientalis	5-10	14	0	F & B	High
Macaranga tanarius	5-13	28	7	F & B	High
Macaranga trichocarpa	2-4	112	1	F & B	High
Macaranga denticulata	6-9	38	0	F & B	High
Omalanthus populneus	4-8	14	0	F & B	High
Mallotus paniculatus	4-6	59	2	F & B	High
Fagraea racemosa	5-14	24	100	B	Low
Shrub species					
Piper aduncum	3-5	91	81	B	Low
Chromolaena odorata	1-2	129	98	B	Low
Melastoma malabathricum	1-2	62	90	B	Low
Millettia sericea	1-7	48	100	B	Low

[*1] F: felling, B: burning.

streams, in fruit-tree forests, and in some stands on fallowed land. This may represent a history of significant change in vegetation, since villagers claim that dipterocarps were formerly abundant near the village.

Gregarious dipterocarp trees mostly *Shorea parvifolia* and *Shorea leprosula* are currently found among the dominant species in the three regions with old stands that were more than 1 hour's walk from the village (Photo. 7). In these stands, where extensive tending of *Calamus* spp. (rotan [B]) is possible, the species has been cultivated. It takes 1-1.5 hours on foot, depending on the path, to reach one forest at Sei Liwir, 1.5 hours to reach another at "Sawmill", and 2.5 hours to reach the third of these stands at Sei Penai.

Since these older forests are far from the village, they are not attractive to farmers. In addition, the soils of the 3 stands contain abundant sand; developed on sandy Tertiary deposit (Voss, 1982). Soils of volcanic origin are widely distributed in and around Mencimai, and in general, these soils are more fertile than sandy soils in the tropics. The poor soil productivity appears to be an additional reason why these older forests have been left behind by farmers.

Okimori & Matius (1991) estimate that one old dipterocarp stand at Sei Liwir originated as fallowed land that had been abandoned more than 70 years earlier. The people of Mencimai say that until somewhere between the 1950s to the 1970s, the zone of active swidden farming was wider than at present, and small slash-and-burn fields were scattered in the forested land. Forests around fallowed fields might have supplied many dipterocarp seeds to regenerate the fallowed land in those days. Because dipterocarps have rarely regenerated in recently fallowed land, the old dipterocarp stand at Sei Liwir appears to be the remainder of an old fallowed stand.

2.2.2 Species richness, biomass and its mean annual increment, litter fall, and the net primary productivity of a fallowed *Schima wallichii* stand

2.2.2.1 Species richness

Only 4 species 10 cm or more in $D_{1.3}$ were recorded in the 20×20 m plot (Appendix 1). *Schima wallichii* accounted for 86 (in 1993)-87 (in 1994) % of the stand's basal area. In other stands in Mencimai, according to Baratawinata & Matius (1995), this species accounted for 59, 52, and 48% of the stand's important value in fallowed stands of 8-, 20-, and 35-year-old, respectively, in every stand of which slash-and-burn farming was repeated 3 times, while it accounted for only 6.9% in 20-year-old fallowed stand in which slash-and-burn farming was practiced only once.

2.2.2.2 Biomass and its mean annual increment

The biomass was estimated twice: at 107.8 Mg ha^{-1} in March 1993 and at 122.6 Mg ha^{-1} in May 1994 (Table 2). The humus weight was estimated at 8.9 ± 3.5 Mg ha^{-1} (n = 4) (Table 2). Mean annual increment (MAI) of the overall biomass in the plot was estimated at 3.27 Mg ha^{-1} year^{-1} (33 years stand) and

Table 2. Biomass, MAI, and the net primary production of a fallowed *Schima wallichii* stand in the Mencimai region. (modified from Kiyono & Hastaniah, 1997)

Location: lat 00° 17' S, long 115° 40' E, Mencimai, Barong Tongkok, Kutai, East Kalimantan, Indonesia		
Altitude: 125 m above sea level		
Soil: Volcanic ejecta-origin		
Vegetation: Fallowed forest of swidden agriculture		
Dominant species: *Schima wallichii* (Camelliaceae)		
Year	1993	1994
Stand age (years)	33	34
Trees (ha^{-1})	1025	1000
Tree height (m)	5.5-23	5.7-25.2
Basal area (m^{-2} ha^{-1})	15.3	16.8
Leaf area index	3.76	4.06
Stem volume (m^{-3} ha^{-1}) (outer-bark)	129.6	150
Fine roots in a root mat (Mg ha^{-1})		10.5 ± 4.7
Humus (Mg ha^{-1})		8.9 ± 3.5
Biomass (Mg ha^{-1})		
Stem wood and bark	62.47	71.22
Branches, fruits etc.	16.74 + 0.69 *1 + 1.65 *2	19.50 + 0.69 *1 + 1.65 *2
Leaves	3.65 + 0.47 *1 + 0.67 *2	4.06 + 0.47 *1 + 0.67 *2
Roots (estimate)	21.41 *3	24.37 *3
Total	107.75	122.63
Mean annual increment (MAI) (Mg ha^{-1} y^{-1})	3.27	3.61
Net primary production (Mg ha^{-1} y^{-1})		
Stem wood and bark	7.87 + 0.40 *4	
Branches, fruits etc.	2.48 + 3.74 *5	
Leaves	0.37 + 5.65 *5	
Roots (estimate)	2.68 + 2.62 *6	
Total	25.81	

*1 Lianas, *2 Understory, *3 The root-to-shoot ratio (0.248), *4 Dead trees, *5 Litter fall, *6 One quarter of fine roots in a root mat.

3.61 Mg ha^{-1} year^{-1} (34 years stand), while the current increment between March 1993 and April 1994; 14.9 Mg ha^{-1} year^{-1} was about 4 times as large as MAI values. This suggests that timber production by farmers decreased the rate of biomass increment in the research plot before we set the plot.

2.2.2.3 Litter fall and the net primary production

The total annual rate of litter production was 9.37 Mg ha^{-1} year^{-1}, of which about 60.2% (5.65 Mg ha^{-1} year^{-1}) was leaves. The *Schima wallichii* leaves fell in the plot throughout the year, but the main peak in 1993 occurred during the period from September through November. *Schima wallichii* flowers fell mostly in March-April, June, and November-December of 1993, and seed fall began 4-8 weeks after the beginning of the mass flower fall (Fig. 2). Judging by the phenological observations and heterogeneity of flower fall in the plot, the trees that shed flowers in March were not the same trees that shed flowers in May and June. After those two initial periods of flower fall, most trees in the plot shed their flowers in November and December of 1993. This suggests that some trees flowered twice, at intervals of 5 to 9 months, over a 13-month observed period. Branch fall was greatest in November and December of 1993, when a storm blew down some trees outside the plot.

Photo. 3. The appearance inside a *Schima wallichii* fallowed forest in the Mencimai region.
The stand age was 33 years when 20 litter traps were set.

Photo. 4. *Schima wallichii* sprouts in an upland rice (*Oryza sativa*) field, before weeding out *Pteridium aquilinum* in the Mencimai region.

The *Schima wallichii* stand produced seemingly less leaf litter (5.65 Mg ha^{-1} year^{-1}) than a mature forest of dipterocarps, *Koompassia* spp., and other species at the Pasoh Forest Reserve in West Malaysia; there, litter production was 7.0-7.8 Mg ha^{-1} year^{-1} (Kira, 1978 a; b; Bullock, 1981). The litter production was also less than that of a planted *Schima wallichii* forest in southern subtropical China, for which values of more than 6.3 Mg ha^{-1} year^{-1} were reported (Wu et al., 1990).

The net primary production (NPP) was estimated at 25.8 Mg ha^{-1} year^{-1}, of which 20.5 Mg ha^{-1} year^{-1} was aboveground biomass (Table 2). In contrast to the litter production, the NPP value for the Mencimai stand appeared not less than the values of mature forest at the Pasoh Forest Reserve and the values of disturbed dipterocarp forests at Bukit Soeharto in East Kalimantan. In the Pasoh forest, the NPP was 26.6-26.9 Mg ha^{-1} year^{-1}, of which 21.1-22.5 Mg ha^{-1} year^{-1} were aboveground biomass (Kira, 1978 a; b) and the NPP of aboveground biomass by Bullock (1981) was 15.4 Mg ha^{-1} year^{-1}. The NPP of disturbed dipterocarp forests at Bukit Soeharto in East Kalimantan was 14.7-17.5 Mg ha^{-1} year^{-1} (Toma et al., 2000).

3 The Pasir Region (*Peronema canescens* forests)

3.1 Study area and method

Although an accurate human geographical history of the region is not available, the Dusun people live in the Pasir region (*Kabupaten*), in southeast East Kalimantan (Lumholtzs,

Photo. 5. An old orchard of fruit, nut, and other useful trees, with natural regeneration of forest species in the Mencimai region.

1991). Kuaro town (01° 49' S, 116° 05' E) is one of their regional centers (Fig. 1b). The population of migrants from Java, Sulawesi, and other areas has gradually increased in the region. The elevations of the surveyed areas in the Pasir region ranged between 13 and 410 m. Miura (1990) described soil development in this region as follows: Mountain ridges run primarily from of north to south, with steep slopes and strong topographic relief. Karst terraces are present, and seven main groups of soils have been distinguished: serpentinized pre-Tertiary peridotite, ferruginous pre-Tertiary peridotite, felsitic pre-Tertiary mudstone, calcareous Tertiary shale, basaltic volcanic rock, Tertiary mudstone, and Tertiary limestone. According to Transmigration area development project (1982), the annual precipitation from 1958 into the 1980s averaged 2602

Photo. 6. A *Koompassia excelsa* tree with many bee hives near the Mahakam River.

Photo. 7. A *Shorea parvifolia* stand located far from a village in the Mencimai region.

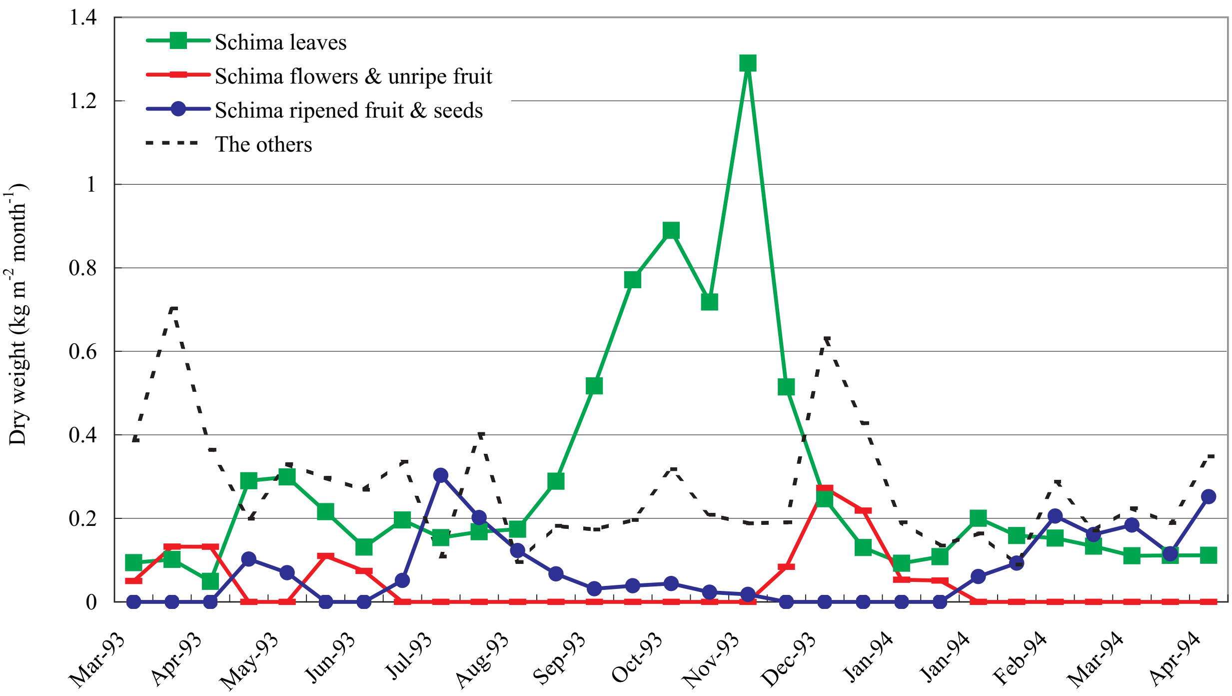

Fig. 2. Seasonal litter fall patterns in a *Schima wallichii* stand in the Mencimai region.

mm at the Tanah Grogot Rainfall Station about 10 km southeast of the forests that we studied. Although there is no annual dry season in East Kalimantan, the mean monthly precipitation from August through October is relatively lower (at 100-128 mm) than in other months (at 194-361 mm). The monthly mean temperature ranged between 23 and 27 °C.

The Dusun people speak the Dusun language, which is similar to the Benuaq language. It is difficult to ascertain when the villages of the Dusun people were established in this region. However, because the Pasir region may be the place of origin of the people of Mencimai (see 2.1), slash-and-burn farming in the Pasir region may have a longer history than in the Mencimai region, which is considered to be more than 300 years (see 2.1). The Dusun people cultivate upland rice, fruit trees, and various other species by swidden agriculture. Dusun houses are often (39 out of 80 houses in 1993) covered with strips of *Peronema canescens* (*sungkai*) bark (Photo. 8), which is usually peeled from trees greater than 40 cm in diameter. The bark lasts at least 4 years. *Peronema canescens* has many other uses for the farmers. For example, the leaves and the bark are used against fever in traditional medicine (Soerianegara & Lemmens, 1994). Pole-sized stems are used in the construction of houses, fences (Photo. 9), fence posts, ditch covers, and benches.

Peronema canescens wood forms clear growth rings (Oobayashi et al., 1992). As the appearance of its sawed wood is similar to that of teak (*Tectona grandis, jati*), *Peronema canescens* is nicknamed Sumatra teak. Natural trees of this species are distributed throughout Peninsula Malaysia, Sumatra, The Riau Archipelago, West Java, and Borneo (Soerianegara & Lemmens, 1994). *Peronema canescens* is found at some places in East Kalimantan, such as Samboja, Kota Bangun, and Mencimai. However, large-scale pure stands are mostly unknown, except in the region in and around the Pasir region (Fig. 1b). Even at Pasir, *Peronema canescens* is uncommon in primary and logged dipterocarp forests, and usually occurs gregariously in secondary forests.

According to Dusun farmers, they prefer *Peronema canescens* over *meranti merah* (an unidentified commercial species of *Shorea*) for timber. The logs of *Peronema canescens* are usually steeped in water for half a month to increase their durability before processing them. Farmers' yards and farmland are often hedged off with *Peronema canescens* cuttings. Although an accurate agricultural history of the region is not available, the people of Pasir have cultivated *Peronema canescens* around their houses and in their farm sites for some time. Multiple-use and small man-made forests of *Peronema canescens* characterize the scenery of Pasir.

Based on the descriptions provided by the slash-and-burn field holders of Dusun, the farming systems at Pasir can be categorized as swidden agriculture. Farmers usually choose old fallowed stands for slash-and-burn fields. Upland rice and such crops as *Zea mays*, *Arachis hypogaea*, *Coffea arabica*, *Musa sapientum*, *Calamus* spp., *Lansium domesticum*, *Mangifera indica*, *Mangifera* spp., or *Durio zibethinus* are planted in slash-and-burn field. Upland rice and other annual crops are cultivated for 1-3 years. The land is then fallowed except where trees useful for fruit production and other purposes had been planted; these trees are tended for 4-5 years. The fallow periods are usually 10 years or more.

In November 1993, we selected 55 young fallowed stands, 1- to 3-year-old, and 25 older fallowed stands, which had been partially cleared for new slash-and-burn fields 4-6 months before the study, along roads and paths in the Pasir region as examples of the fallowed stands in the region in our study of stand structure. We determined stand age according to interviewing farmers or number of annual rings of overstory *Peronema canescens* trees, measured overstory height, and noted dominant tree species for each stand.

In October 1992, when one of the authors first visited the *Peronema canescens* forests near Kuaro almost all the leaves of *Peronema canescens* had already fallen, unlike the leaves of other species. Thus, it was easy to detect the existence and the range of *Peronema canescens* stands. (The Dusun people say that *Peronema canescens* loses leaves for about 1 month every October; in November, the species flushes new shoots with young raspberry red leaves.) The *Peronema canescens* stands varied from forest in which it was almost the only species of large tree present, to forest in which it was clearly dominant, but was one of many species present in the stand. The extent of such *Peronema canescens* stands ranged from 1 to 20 ha.

An example of the pure stands (Site 1, Photo. 10) was selected at Mount Jelada (01° 55' S, 115° 59' E, 279 m above sea level. Geology is Pre-tertiary ultrabasic plutonic rocks (Voss, F., 1982) and dominant soils are considered Ferralic Cambisols (Food and Agriculture Organization-United Nations Educational Scientific and Cultural Organization, 1979)) in October 1992 and the study plot, which covered 20 x 55 m, was established in the stand. In all, trees at least1.3 m in height in the plot were identified to botanical names and $D_{1.3}$ and H of these trees were measured. An empirical equation based on $D_{1.3}$ (cm), H (m), and V (m^3) for *Dryobalanops* spp.: $V = 0.0000346\ D_{1.3}^2\ H$ (R^2 = 0.98, n = 104) (modified from Kiyono & Hastaniah, 1993) were used for estimates of stem volume of trees in the plot. The biomass expansion factor (BEF, aboveground biomass/stem biomass) of 1.531 ± 0.181, the root-to-shoot ratio of 0.243 ± 0.060, and the basic density (kg m^{-3}) of 487 ± 24 of *Peronema canescens*, calculated by data in Morikawa (2002) and Gintings et al. (2003), were then used to account for changes from stem volume to total biomass. The values from the plot were converted into values per unit area.

After the forest in and around the plot was unexpectedly logged by a timber merchant, trees in the plot were surveyed again in November 1993.

Two other examples of *Peronema canescens* forest were included in the study for fieldwork determining the floristic composition of the stands in November 1993. One (Site 2), with an area of about 20 ha, occurred on a limestone mountain 223 m above sea level (01° 55' 30" S, 115° 59' 15" E. The geology is Pre-tertiary ultrabasic plutonic rocks (Voss, 1982) and dominant soils are considered Ferralic Cambisols (Food and Agriculture Organization-United Nations Educational Scientific and Cultural Organization, 1979)); this site is located between Mount Jelada and Mount Sampi (01° 56' 45" S, 115° 58' 50" E, 410 m a.s.l.). Two 20 x 20 m plots were established at Site 2. Another example (Site 3) was one of 3 secondary forest areas studded with many *Peronema canescens* patches lay along the Solo besar River (01° 38' 34" S, 115° 46' 55" E. The geology is Tertiary sedimentary deposits (Voss, 1982) and dominant soils are considered Humic Acrisols (Food and Agriculture Organization-United Nations Educational Scientific and Cultural Organization, 1979)) in Muara Koman subdistrict, about 35 km northwest of Kuaro. At Site 3, research plot was not made. Fieldwork determined the floristic composition of the stands in November 1993.

3.2 Results

3.2.1 General description of fallowed stands in the Pasir region

Of the 55 young fallowed stands, 31 contained *Peronema canescens*. Along the road from Kuaro in Fig. 1b, the stands with *Peronema canescens* ranged from 01° 27' S, 116° 31' E, about 40 km northeast toward Balikpapan, to 01° 52' S, 115° 37' E, about 60km northwest toward Tabalong, and to 02° 40' S, 116° 05' E, about 160km south toward Pagatan. The ground was sometimes covered with *Chromolaena odorata* (Photo. 11). The overstory heights of the older fallowed stands ranged from 12 to 20 m and averaged 17.2 ± 3.1 m (n = 25 stands). The dominant species in these older stands were *Vitex pinnata*, *Artocarpus* spp., *Peronema canescens*, and bamboo. These species regenerate by sprouting (see Appendix 3) during the fallow period. Dipterocarps were rare in the fallowed stands we surveyed in this region.

3.2.2 Stand structure of *Peronema canescens* forests

Numerous seedlings and saplings of *Peronema canescens* were found in the *Peronema canescens* forest in the 20 x 55 m plot at Mount Jelada (Site 1). These had grown from seeds, as stump sprouts, as root sprouts, and as fragments of branches that sank into the ground when a large tree fell and that took root. In all, 96 trees greater than 1.3 m tall (Appendix 4, Fig. 3) were found in the plot in October 1992. The stand density was 873 trees per ha; tree heights ranged from 2 to 40 m, averaged 19.4

Photo. 8. A house covered with strips of *Peronema canescens* bark in the Pasir region.

Photo. 9. A junior high school fence made with *Peronema canescens* poles in the Pasir region.

Photo. 10. The appearance inside a *Peronema canescens* forest in the Pasir region.

Photo. 11. *Peronema canescens* sprouts in recently fallowed land, with a scattering of *Chromolaena odorata* shrubbery in the Pasir region.

± 9.5 m, and stem diameters ranged from 1.0 to 69.3 cm, with an average of 23.2 ± 15.9 cm. Basal area reached 53.9 m^2 ha^{-1}, which is greater than the reported values for primary forest in East and South Kalimantan (Kartawinata et al., 1981; Yamakura et al., 1986). *Peronema canescens* accounted for 93 % of the basal area and appeared in all size classes (Fig. 3). Fifteen *Peronema canescens* trees out of 46 with diameters of between 15.5 and 69.3 cm had heartwood rot (Appendix 4). Tree ages were measured using growth rings (which were regarded as annual rings (Oobayashi et al., 1992) in the present study), and ranged from 85 to 105 years for eight overstory trees. The stem volume and total biomass in the plot were estimated at 663 m^3 ha^{-1} and 613.8 Mg ha^{-1}, respectively. MAI was estimated at 6.46 Mg ha^{-1} $year^{-1}$ when stand age was considered to be 95 years.

3.2.3 Floristic composition and proposed formation of *Peronema canescens* forests

Twelve tree species (Appendix 4) with stem diameters of 10 cm or more were recorded in the plot at Site 1, but no dipterocarps were found in or around the plot. An exotic tree bean, *Archidendron pauciflorum* (*jengkol*), which was fruiting at the time of the study, was recorded in the plot, and *Garcinia celebica* (the Celebes mangosteen), which had been planted to provide fruit, was found beside the plot. This suggests that the study stand had developed on land that had been managed previously.

The floristic composition of *Peronema canescens* forests at Sites 2 and 3 were as follows: At Site 2, the following trees were found in the first 20 x 20 m plot: 2 *Durio kutejensis* (*lai*), 1 *Durio zibethinus* (*durian*), 4 *rambutan meritam* (tentatively identified as *Nephelium* sp.), 3 *Artocarpus integer* (*cempedak*), 1 *Lansium domesticum* (*langsat*), 1 *Artocarpus lanceifolius* (*keridan*), 1 *Parkia timoriana* (*petai)*, and 2 *Areca catechu* (*pinang*), a useful palm producing betel nuts and used as an ornament at traditional prayers. In the second 20 x 20 m plot, 2 *Durio kutejensis*, 1 tree tentatively identified as *Nephelium* sp., 1 *Areca catechu*, 1 *Durio zibethinus*, and 3 *Mangifera* sp. (*mangga*) trees were recorded. In addition, a grave mound with a shrub species that is used specifically in graveyards, *Codiaeum variegatum* (*puring*), was found. Some of the fruit trees had stem scars in the form of notches intended to make them flower. Dipterocarps were not found in or around the two 20 x 20 m

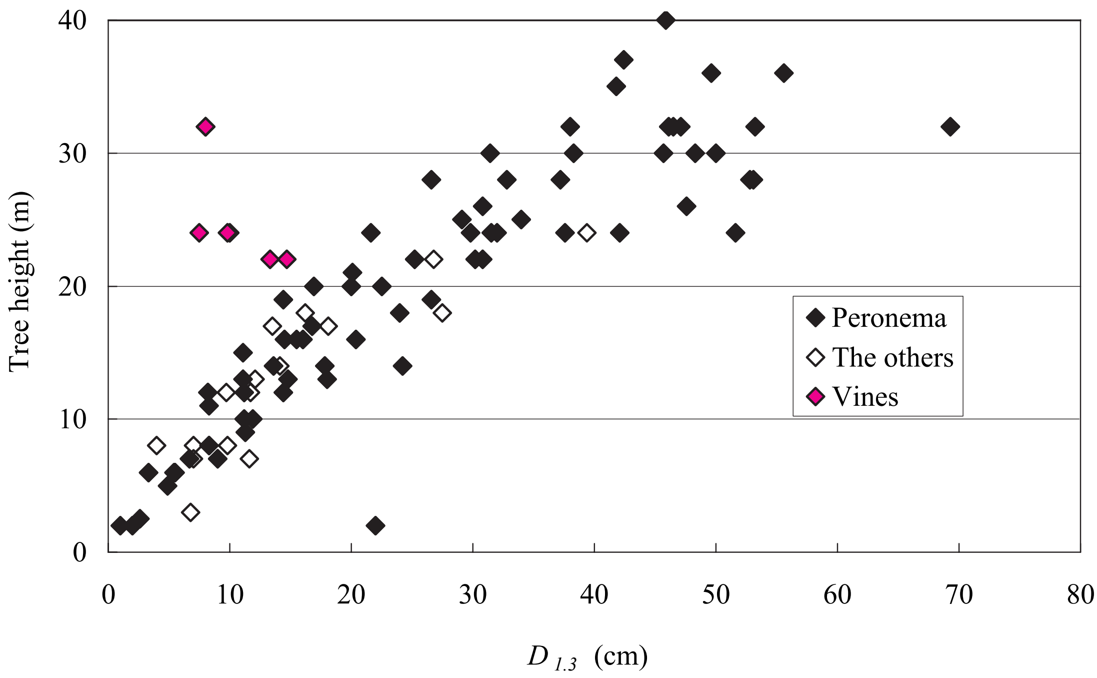

Fig. 3. The relationship between tree height and $D_{1.3}$ in trees and vines > 1.3 m tall in a 20×55 m plot in a *Peronema canescens* stand in the Pasir region. (modified from Kiyono & Hastaniah, 1997)

Appendix 4. Trees and vines > 1.3 m tall in a 20×55 m plot in a *Peronema canescens* stand in the Pasir region. (modified from Kiyono & Hastaniah, 1997)

Tree No.	Species	$D_{1.3}$ (cm)	Height: Tree (m)	Height: Lowest bough (m)	Notes
1	*Peronema canescens*	45.7	30.0	19.0	
2	*Ficus* sp.	13.3	22.0		
3	*Ficus* sp.	14.7	22.0		
4	*P. canescens*	46.5	32.0	24.0	
5	*P. canescens*	30.2	22.0	16.0	heartwood rot
6	*P. canescens*	20.1	21.0	17.0	heartwood rot
7	*P. canescens*	55.6	36.0	20.0	heartwood rot
8	*P. canescens*	16.9	20.0	10.0	heartwood rot
9	*P. canescens*	14.4	19.0	9.0	
10	*P. canescens*	42.4	37.0	18.0	heartwood rot
11	*P. canescens*	16.0	16.0	10.0	heartwood rot
12	*P. canescens*	31.4	30.0	13.0	
13	*P. canescens*	24.0	18.0	8.0	heartwood rot
14	*Barringtonia* sp.	11.6	7.0		
15	*Syzygium pycnanthum*	7.0	8.0		
16	*P. canescens*	45.9	40.0	20.0	
17	*P. canescens*	6.7	7.0		
18	*P. canescens*	41.8	35.0	22.0	
19	*P. canescens*	8.3	8.0	4.0	
20	*P. canescens*	8.3	11.0		
21	Liana sp.1	9.8	24.0		
22	Liana sp.1	10.0	24.0		
23	*P. canescens*	49.6	36.0	30.0	heartwood rot
24	Liana sp.1	7.5	24.0		
25	*P. canescens*	37.6	24.0	16.0	heartwood rot
26	*P. canescens*	38.0	32.0	24.0	
27	*P. canescens*	32.0	24.0	16.0	
28	*Ficus* sp.	8.0	32.0		
29	*Ficus* sp.	8.0	32.0		
30	*Ficus* sp.	8.0	32.0		
31	*P. canescens*	69.3	32.0	20.0	heartwood rot
32	*P. canescens*	20.4	16.0	12.0	heartwood rot
33	*P. canescens*	11.2	10.0	6.0	
34	*P. canescens*	32.8	28.0	24.0	heartwood rot
35	*P. canescens*	26.6	28.0	24.0	
36	*P. canescens*	11.9	10.0	6.0	
37	*P. canescens*	15.5	16.0	8.0	
38	*P. canescens*	46.1	32.0	26.0	
39	*Rhodamnia cinerea*	9.8	8.0		
40	*Intsia bijuga*	13.5	17.0		
41	*Archidendron pauciflorum*	18.1	17.0		*jengkol*
42	*Vitex pinnata*	39.4	24.0		
43	*P. canescens*	47.6	26.0	20.0	heartwood rot
44	*P. canescens*	17.8	14.0	8.0	
45	*P. canescens*	3.3	6.0		
46	*Diplospora singularis*	26.8	22.0		
47	*P. canescens*	48.3	30.0	20.0	
48	*D. singularis*	6.8	3.0		
49	*P. canescens*	14.8	13.0	6.0	
50	*P. canescens*	30.8	22.0	18.0	
51	*Sageraea lanceolata*	7.0	7.0		
52	*Calophyllum soulattri*	27.5	18.0		
53	*Lepisanthes fruticosa*	11.7	12.0		
54	*P. canescens*	42.1	24.0	18.0	
55	*P. canescens*	51.6	24.0	12.0	
56	*Antidesma ghaesembilla*	9.7	12.0		
57	*Cratoxylum formosum*	14.1	14.0		
58	*Eugenia* sp.	12.1	13.0		
59	*P. canescens*	37.2	28.0	22.0	
60	*P. canescens*	52.8	28.0	13.0	
61	*P. canescens*	24.2	14.0	8.0	
62	*P. canescens*	53.1	28.0	15.0	
63	*P. canescens*	22.5	20.0		
64	*P. canescens*	29.1	25.0	20.0	
65	*P. canescens*	38.3	30.0	25.0	
66	*P. canescens*	22.0	2.0		
67	*P. canescens*	18.0	13.0	6.0	
68	*R. cinerea*	5.4	6.0		
69	*R. cinerea*	16.2	18.0		
70	*R. cinerea*	4.0	8.0		
71	*P. canescens*	30.8	26.0	12.0	
72	*P. canescens*	47.1	32.0	18.0	
73	*P. canescens*	2.6	2.5		
74	*P. canescens*	9.0	7.0		
75	*P. canescens*	16.8	17.0	12.0	
76	*P. canescens*	26.6	19.0	14.0	
77	*P. canescens*	25.2	22.0	14.0	
78	*P. canescens*	21.6	24.0	9.0	
79	*P. canescens*	4.9	5.0		
80	*P. canescens*	11.3	9.0		
81	*P. canescens*	53.2	32.0	13.0	
82	*P. canescens*	50.0	30.0	12.0	
83	*P. canescens*	2.0	2.0		
84	*P. canescens*	13.6	14.0	9.0	
85	*P. canescens*	1.0	2.0		
86	*P. canescens*	11.2	12.0	6.0	
87	*P. canescens*	29.8	24.0	16.0	heartwood rot
88	*P. canescens*	11.1	15.0	11.0	
89	*P. canescens*	11.1	13.0	8.0	
90	*P. canescens*	20.0	20.0	16.0	heartwood rot
91	*P. canescens*	31.5	24.0	18.0	
92	*P. canescens*	34.0	25.0	21.0	
93	*P. canescens*	8.2	12.0	6.0	
94	*P. canescens*	5.5	6.0	4.0	
95	*P. canescens*	14.4	12.0	12.0	
96	*P. canescens*	14.5	16.0	7.0	
Mean		23.2	19.4	14.5	
Basal area (m^{-2} ha^{-1})		53.9			

plots at Site 2 although they were abundant in the logged forests between Sites 1 and 2.

At Site 3, many *Peronema canescens* stands with an area of 2-5 ha each were found. Trees about 25-60 cm in diameter formed the overstory in each stand. Scattered among the *Peronema canescens* stands were trees maintained for apiculture, such as *Koompassia* sp., lomoh (the local name of an unidentified species), and biwan (also unknown); these trees were 30-40 m tall and about 1 m in diameter. Some *Peronema canescens* trees had been felled so their bark could be used. Trees planted to provide fruit, such as *Durio zibethinus*, *Lansium domesticum*, *Nephelium lappaceum*, *Mangifera* sp., *Artocarpus elasticus* (*terap*), and *Dialium cochinchinense* (*keranji*), as well as an exotic plant, *Coffea arabica* (*kopi arabika*) were recorded and only 6 trees of *Shorea leprosula* and 1 *Shorea* seminis, each about 50 cm in diameter, were found during the survey of the secondary forest at Site 3.

The trees used for the production of fruit and nuts that were found in the *Peronema canescens* forests at Sites 1-3 are mostly indigenous to Pasir, but they were too abundant to have grown that way naturally; thus, their gregarious or partially regular distributions seemed to have originated artificially, as a result of planting. In addition, every stand contained exotic plants or a grave mound, and each *Peronema canescens* stand appeared to be almost even-aged. Regeneration in gaps or by other means can successfully fill in small forest gaps, but there must be other reasons for the establishment of *Peronema canescens* stands on such a large scale. For these reasons, the forests containing *Peronema canescens* trees we surveyed are believed to have been man-made.

Miura (1990) suggests that *Peronema canescens* forests in Pasir occur on soils that have developed on sites with soils that developed on limestone. However, the forests that we studied occurred not only on soils derived from limestone (Pre-tertiary ultrabasic plutonic rocks) but also soils from Tertiary sedimentary deposits. According to our observation, neither limestone nor serpentine, both of which were found in Pasir, seemed to have any special relationship with stand formation by *Peronema canescens*.

One day, a staff member of the Mulawarman University Educational Forest at Bukit Soeharto provided a possible explanation. He came from Muara Uya, in South Kalimantan, and *Peronema canescens* trees were common near his old home, where there were Dusun settlements (Lumholtzs, 1991). After migrants from Java built a new transmigration village near the Dusun settlements in 1983, however, some Dusun who disliked living together with the Javanese moved to new location 30-40 km deeper into the forest. Because the Javanese migrants believed that the Dusun people had cast a "magic" spell on their belongings before they left, the vacant houses and useful trees were abandoned and had burned during a prolonged dry spell. This information must be confirmed, but if it is true, we speculate that there were Dusun settlements in the *Peronema canescens* forests present in the study area. These Dusun had cultivated young *Peronema canescens* in and around their villages, but about 100 years ago, they moved somewhere else for unknown reasons. Their abandoned houses were lost to the forest or to fire, but the *Peronema canescens* trees, which are less vulnerable to fire (Appendix 3), grew into the large stands now present in the area. It is well known that people who practice swidden agriculture sometimes move on to other areas for various reasons (4.1, Numata, 1974; Jessup, 1981; Okushima, 1999).

4 The Apau Kayan and Krayan Regions (forests in the remote areas)

4.1 Study areas and method

The Apau Kayan region (Fig. 1b) is the remote area near the headwaters of the Kayan River, near the border with Sarawak, West Malaysia. Upland rice-based agriculture has been practiced by the Kenyah people for decades, and perhaps even more than a century. Muller (1990) reported a population of more than 30000 for the Apau Kayan region in 1954, and that the population had declined to about 5300 in 1982; this decline was likely due to a shortage of arable land near the existing villages and the high cost of commodities, which led the people to move to new areas. Most of the 1995 population of 6829, as reported by the regional government office, were members of the Kenyah people, who speak the Kenyah languages, which includes a group of related languages. The majority of the people are Protestant or Catholic. Related peoples live in the Sarawak area also. The main cash income comes from jobs in Sarawak and from collecting aloes of *Aquilaria malaccensis* (*sekow* in Kenyah language, hereafter [K]). No motor vehicles are present, but small motorboats have been available since 1994. Essential daily provisions are transported by air from the coastal cities of Samarinda and Tarakan, East Kalimantan and are carried from Sarawak, West Malaysia on the shoulders of bearers.

Eight villages, located around at 01° 42' to 01° 50' N, 114° 47' to 115° 06' E, are found in Kayan Hulu district: Long Ampung, Long Nawang, Nawang Baru, Long Payau, Long Betaoh, Long Uro, Lidung Payau, and Long Sei Barang. These were chosen in October 1994 to serve for our vegetation surveys as examples of 19 villages of the Apau Kayan. The elevations of the surveyed areas were between 590 and 875 m above sea level, a range that includes the boundary between the lowland and lower montane ecosystems, which falls at around 750 m (Whitmore & Burnham, 1975). Mountain slopes are generally gentle, but have precipices and waterfalls. The mean annual rainfall from 1917 to 1956 was 4159 mm at Long Nawang (Voss, 1982), located at 01° 47' N, 114° 54' E, the center of the Apau Kayan region.

The vegetation observed in the Apau Kayan was roughly classified into 6 types: (1) slash-and-burn fields and their fallowed stands; (2) forests conserved for logging; (3) fruit tree gardens; (4) *Ananas comosus* (*usan* [K]) plantations and their fallowed stands, which comprised *Pteridium aquilinum* (*nyaong, nya' ong*, or *buk* [K]) communities; (5) irrigated rice fields and their fallowed stands, which comprised *Scleria purpurascens* (*sisit amat* [K]) communities; and (6) riparian *Dipterocarpus oblongifolius* (*laran* [K]), trees with abundant epiphytic plants reach 20 m in height and 80 cm in diameter (Photo. 12) forests, and its secondary plant communities. The areas covered with ecosystem types 1, 2, and 6 were quite large compared with those of the other ecosystem types. *Imperata cylindrica* forms pure communities in open land on a small scale. The sedimentary basin of the area is mostly Paleocene/Pre-Tertiary Igneous and Volcanic rocks and Pre-Tertiary basement complex, while partially Tertiary sedimentary deposits (Voss, 1982). Soils of Orthic Acrisols, Dynastic Cambisols, and Humic Acrisols (Food and Agriculture Organization-United Nations Educational Scientific and Cultural Organization, 1979) are dominant. By local people, the soils were roughly divided into 3 types: (1) fertile black or chocolate-colored soils; (2) infertile yellow (and sometimes red or white) soils with abundant clay; and (3) yellow (and sometimes red) soils with some clay and abundant sand with intermediate fertility. When a choice of all these soils is available, slash-and-burn field is mostly begun on the most fertile soils, and forests are retained on the less fertile soils to produce materials for the construction of housing, bridges, and boats.

The farming systems can be categorized as swidden agriculture with relatively long fallow periods between 1 (sometimes to 2) year(s) crop-production periods. According to the chiefs or assistants of the eight villages, most households farm two types of slash-and-burn fields. One type is called *kelimung*, and represents a small slash-and-burn field located within 2 hours travel on foot from the village. Another is called *uma bio'* (Photo. 13), and represents a larger slash-and-burn field relatively far from the village (up to 4 hours distant). The people of Long Betaoh farm only the *uma bio'* type, however. Since old fallowed land is abundant within 2-8 hours travel from the village, both *kelimung* and *uma bio'* are usually established in fallowed land. One household typically sows 29 L (with a range from 15 to 55 L) of upland rice seeds in a *kelimung* and 59 L (20-80 L) in a *uma bio'*. The yields in the normal year are 55 times the volume of seeds that were sown in *kelimung* (with a range from 5 to 130) and 74 (30-140) times in *uma bio'*. Crop-production periods usually last 1 year, but extend to 2 years in *uma bio'* when the fallowed stands are sufficiently old and contain abundant tall trees. Fallow periods are 10.7 years (with a range of from 7.5 to 15 years) for *kelimung* and 13.2 (with a range of 8.5 to 19) years for *uma bio'*.

Fifty-nine young stands 1- to 2-year-old and 24 older stands (about 10-year-old) were selected as examples of fallowed stands in our survey of floristic compositions. Dominant species with a cover of at least 5% were recorded. Overstory height was measured in most stands.

Krayan subdistrict (Fig. 1b) lies in the remote area around the headwaters of the Sasayap River, in the northwestern part of East Kalimantan near the border with Sabah, West Malaysia. Both irrigated rice and upland rice-based agriculture have been practiced by the Lun Dayeh for decades and perhaps for more than a century. Most of the area's population of 8559 in 1992 (based on information from the government office) is Lun Dayeh, but this people consist of two groups: the Tana Lun' and Lun' Ba. Farming of irrigated rice is dominant for the latter people. Water buffalo (*Bos* sp.) have generally been reared in the region. The majorities of the Lun Dayeh are Protestant and speak the Lun Dayeh language. The relatives of these people live in Sabah and Sarawak and in other nearby regions. The main cash income is from jobs in West Malaysia and from salt manufacturing in Krayan, where brine pits occur in several places. Motorcycles and small motorboats have been available since 1995. Essential provisions for daily use are transported by air from Tarakan and by land from Sabah.

Seven villages (*Desa*) or groups of villages (*Lokasi*), located around at lat 03° 53'-03° 58' N, long 115° 36'-115° 48' E, were chosen in October and November 1995 as examples of 27 villages or groups of villages in Krayan for our vegetation surveys. Long Umung, Pa' Kebuan, and Pa' Betung are the villages of Tana Lun' people and Kuala Belawit, Long Api, and Long Midang are the villages of Lun' Ba people. Kampung Baru is the educational center of Krayan and most of the people who farm are teachers from other regions.

The elevations of the surveyed areas ranged between 910 and 1000 m above sea level, and this falls within the bounds of the lower montane ecosystem, which occurs at altitudes of 750-1500 m (Whitmore & Burnham, 1975). Mountain slopes are generally gentle and the relief is strong. Meteorological data for the region are not available, but the annual precipitation of the region has been estimated at 3500-4000 mm (Voss, 1982).

In the Krayan, the vegetation observed during our surveys was roughly classified into eight classes: (1) slash-and-burn fields and their fallowed stands (Photo. 14); (2) irrigated rice fields and their fallowed stands of *Rhynchospora corymbosa* (*bagong* [L]); (3) fruit tree gardens; (4) secondary riparian bamboo forests, with *Persea rimosa* (*laget labu* [L]), *Syzygium densiflorum* (*buau* [L]), and other species; (5) *Melastoma malabathricum* (*udu sikali, siang* [L]) communities in water buffalo meadows; (6) *Kerangas* (heath) vegetation; (7) *Pteridium aquilinum* (*lehuteng buda* [L]) and *Dicranopteris linearis* var. *linearis* (*lifuteng* or *lehuteng* [L]) communities near villages, where forest cover was mostly lost in a forest fire in 1982 after intensive production of firewood; and (8) forest conserved for logging. The areas occupied by ecosystem types 3 and 5 were smaller than those of the other ecosystem types. *Imperata cylindrica* was not a dominant species in open land. The sedimentary basin of this area is Tertiary sedimentary deposits (Voss, 1982). Soils of Humic Acrisols are dominant (Food and Agriculture Organization-United Nations Educational Scientific and Cultural Organization, 1979). The soils were roughly divided into 3 types by local people: (1) infertile white soils with abundant silt, (2) fertile red or chocolate-colored soils with abundant clay, and (3) yellow soils with abundant clay of intermediate fertility. *Kerangas* vegetation had become established on the first (infertile) soil type, which was not used for slash-and-burn field. When both fertile soils and soils of intermediate fertility are available, slash-and-burn field is usually established on the more fertile soils, and forests on the intermediate soils are conserved to produce firewood and materials for housing, bridges, and so on.

The farming systems can be categorized as swidden agriculture with relatively short fallow periods between short crop-production periods. According to the chiefs or assistants of the 7 villages, most Tana Lun' households and some Lun' Ba households have slash-and-burn fields. The latter people sometimes cultivate only vegetables in the slash-and-burn fields. The field is usually established in fallowed slash-and-burn field located within 3 hours travel on foot from the village. One Tana Lun' household usually sows 163 L (with a range of from 40 to 320 L) of upland rice seeds, and the yields are 17.1 (with a range from 7 to 40) times the volume of seeds that was sown. For slash-and-burn field holders of the Lun' Ba at Kuala Belawit, the corresponding figures are 40-160 L and yields of 8-20 times the volume of seeds that were sown. Crop-production periods average 1 year in most cases, with fallow periods of 6.8 (3-10) years.

Seventeen young stands 1- to 2-year-old and 11 older stands partially cleared for new slash-and-burn field 4-6 months before the study were chosen as examples of fallowed stands for our survey of stand floristic composition. Dominant species with a cover of at least 5% were recorded. Overstory height was measured in every stand.

4.2 General description of fallowed stands in the Apau Kayan and Krayan regions

In the Apau Kayan, most of the older fallowed stands had been partially cleared to produce new slash-and-burn field 3-5 months before the survey. Their overstory heights were 15.3 ± 3.1 m (n = 20 stands). A small tree from the family Euphorbiaceae, *Macaranga denticulata* (*bine* or *bene* [K]), occurred as a dominant species in 45 of 59 young fallowed stands. In the older fallowed stands, *Vernonia arborea* (*belebu*, *melabu*, or *melebu* [K]) and *Vitex pinnata* (*merang jekkou* or *temaha* [K]) were the most dominant species; both occurred as dominant species in 13 of 24 stands. Other species were occasionally or locally dominant; these included *Nauclea* sp. (*tebalut jella* [K]) on stony ground, *Blumea balsamifera* (*empung anak* [K]) in fallowed *uma bio'*, as well as *Ilex*

Photo. 12. A riparian forest in the Apau Kayan region.

Photo. 13. A larger slash-and-burn field (*uma bio'*) in the Apau Kayan region.

Photo. 14. A fallowed slash-and-burn field with abundant small tree pioneers in the Krayan region.

cissoidea (*ngelidan*, *lengidan* [K]), *Omalanthus populneus* (*kelepela* [K]), *Artocarpus* sp., bamboo, and *Schima wallichii* (*tow* [K]). Only 8 species were recorded for the 100 trees with diameters of at least 10 cm in a *Vitex pinnata* stand. *Macaranga denticulata* and *Omalanthus populneus* are small trees and *Ilex cissoidea* is a tall tree species. These species are pioneers and become fertile during the fallow periods; for example, *Macaranga denticulata* produces seeds by 8 years. *Vernonia arborea*, *Vitex pinnata*, *Nauclea* sp., *Artocarpus* sp., and *Schima wallichii* easily sprout from stumps after felling, or felling and fire (Appendix 3). Only a few dipterocarp trees were found in some fallowed stands of *uma bio'* on the red or yellow soils, but dipterocarps were not found on the black or chocolate-colored soils or in *kelimung*.

The Apau Kayan has more pioneer tree and small tree species in land fallowed after slash-and-burn agriculture than occur in lowlands, but most of the dominant tree species are common to both regions. Exotic plants were rare. *Passiflora foetida* from Brazil was collected at Long Ampung, a possible corridor for aerial dissemination of seeds into the Apau Kayan from lowland areas. Exotic species common in lowland areas, such as *Chromolaena odorata*, *Piper aduncum*, and *Solanum jamaisense* were not found in our survey.

In Krayan, the overstory heights of the old stands averaged 13.2 ± 5.6 m (n = 11 stands). *Vernonia arborea* (*byubu* or *biyubu* [K]) was the most dominant species of the old fallowed stands; it occurred as a dominant species in 7 of 11 stands. *Mallotus paniculatus* (*likad* [K]), *Trema orientalis* (*bita nung* [K]), and *Alphitonia incana* (*beranong* [K]) occurred as dominant species in 15, 12, and 10 of the 17 young fallowed stands, respectively. Other species were occasionally or locally dominant in young and/or old fallowed stands, including *Mussaenda frondosa* (*anur* [K]), *Schima wallichii* (*sebebuwong* [K]), *Castanopsis* sp. (*fidawi* [K]), and *Macaranga denticulata* (*kayu minir* [K]). *Mallotus paniculatus*, *Alphitonia incana*, *Macaranga denticulata*, and *Trema orientalis* are pioneer tree or small and become fertile during the fallow periods; for example, *Mallotus paniculatus* produces seeds by the time it is 4 m tall or 6-year-old. *Vernonia arborea*, *Mussaenda frondosa*, *Schima wallichii*, and *Castanopsis* sp. can sprout new shoots from stumps after felling, or felling and fire. Dipterocarps were not found in any fallowed land that we surveyed.

Although some plant species that were probably of exotic origin were collected in Long Midang, a likely pathway for immigration of new species from Sabah, exotic plants common in lowland areas, such as *Passiflora foetida*, *Chromolaena odorata*, *Piper aduncum*, and *Solanum jamaisense* were not found in our survey.

The Apau Kayan was an area whose population moved elsewhere, and a small number of the remaining people practice swidden farming with relatively long fallow, 10.7 or 13.2 years on average, and short crop-production periods. The people of Krayan practice swidden agriculture with relatively short fallow, 6.8 years on average, and short crop-production periods. In both areas, no perennial cash crop requires the use of slash-and-burn field. Pioneers immediately become established in young fallowed land, and are replaced as dominant species within several years by trees less vulnerable to felling and fire. Dipterocarps represent an important group of natural vegetation at the elevations found in the Apau Kayan and Krayan regions (Whitmore & Burnham, 1975). However, only few or no dipterocarps were found in fallowed land that we surveyed. The group of dipterocarps was found in the conserved forests. In the Apau Kayan, *Dipterocarpus oblongifolius* (*laran*) has formed riparian forests. *Shorea leprosula* (*meranti maro* [K]), with *Agathis* sp. and *Gonystylus bancanus* (*merang* [K]), both of which produce valuable wood, was found in the conserved forests. In Krayan, *merit* [L] (an unidentified species in the family Dipterocarpaceae), with other trees that produce valuable wood, such as *Eugenia* sp. or *Syzygium* sp. (*belibakan* [L]), *Litsea firma* (*betelau* [L]), *Agathis* sp. (*tumu* [L]), was found in the conserved forests, in which trees in the Fagaceae and Lauraceae families, such as *salad lengurung* [L] (an unidentified species in the family Fagaceae) and *Schima wallichii*, were locally dominant.

5 Discussion

5.1 Floristic composition of swidden-land forests

As described in 2.2.1, dipterocarps other than *Shorea balangeran* were not found or were sparse in the fallowed land that resulted from swidden agriculture (Table 3). Although dipterocarps were the most dominant species in the original vegetation of both lowland and lower montane Borneo (Whitmore & Burnham, 1975), dipterocarps seem to have difficulty surviving in swidden-land forests.

There are at least 3 possible reasons for the lack or low density of dipterocarps in swidden-land forests. First, dipterocarp seeds have short viability periods (at most 3 months) even under laboratory conditions (Permono, 1993); in addition, the seeds have a maximum dispersal distance of only 30 m from mother trees (Tamari & Jacalne, 1984). Therefore, dipterocarp seeds are not likely to reach the center of a square 1-ha slash-and-burn field, and mean field area can be about 2 ha (calculated from Table 2.3 in Kiyono & Hastaniah, 1997; Finegan & Nasi, 2004). Second, many dipterocarps in lowland and lower montane Borneo rarely sprout new shoots from stumps after felling or burning (Appendix 3). Third, most dipterocarps bear fruit only after the trees have grown large and do not bear fruit continuously (e.g. Kiyono & Hastaniah, 2000a). Therefore, the shorter the crop-production cycle used in swidden agriculture, the more difficult it is for dipterocarps to persist in fallowed land.

Okimori & Matius (1991) investigated *Shorea parvifolia* regeneration at Mencimai and emphasized the possibility of regeneration in swidden-land forest. However, that possibility may have been emphasized too strongly. This may have been the case long ago, when mature-phase forest were cleared for slash-and-burn fields in the Mencimai region, as *Shorea parvifolia* trees might have remained near enough to the fallowed land to serve as mother trees. However, this is no longer the case. As mentioned in 2.1, people tend to own the slash-and-burn fields only near the center of villages, where the land rarely contains *Shorea parvifolia* mother trees. Old fallowed stands do not necessarily contain dipterocarps, and the majority of young fallowed stands rarely contain them.

If we compare the reproductive characteristics of pyrophytic trees with those of dipterocarps, pyrophytic trees appear to be more adaptable under disturbance regimes of slash-and-burn farming. Although reproductive information is incomplete for most pyrophytic tree species, *Schima wallichii*, *Peronema canescens*, *Vitex pinnata*, and *Vernonia arborea* start fruiting at earlier stages, disperse seeds further, and more easily sprout new shoots from their stumps after felling and fire than do dipterocarps. *Schima wallichii* seeds do not have long viability periods (Kiyono, 1996), but this species flowers at intervals of 5-9 months (see 2.2.2.3) and sprouts of 4-year-old trees (de Leeuw, 1936) or trees that have reached 5 m in height can produce winged wind-dispersed seeds. *Peronema canescens* starts its annual flowering when trees are about 5 m high, at an age of approximately 5 years in Java, and its seeds are dispersed by wind and water (Soerianegara & Lemmens, 1994). *Vitex pinnata* flowers throughout the year (Corner, 1988). Its seeds in pulpy fruit ripening black are dispersed by animals and birds. *Vernonia arborea* flowers generally during the dry spell (in Peninsular Malaysia, Corner, 1988) and produces wind-dispersed seeds with fluff. These last 2 species have wider ranges of seed dispersion than *Schima wallichii* and *Peronema canescens*. In addition, many pyrophytic tree species live for decades or more once they have become established.

Trees derived from buried seeds are one of the dominant groups that become established on the disturbed land in tropical primary forests (Bazzaz, 1984) and the ascendance of pioneer tree species with fruiting and functioning seed dispersal mechanisms is one of the main features of fallowed stands (Finegan & Nasi, 2004). Tall pioneer trees and small trees derived from buried seeds are less abundant in Mencimai (see 2.2.1) and Pasir (see 3.2.1) than in the Apau Kayan and Krayan (see 4.2, Photograph 14). However, the dominant species in the later stages of succession, pyrophytic trees, are similar in every region. There are at least 2 possible explanations for the difference in density of pioneer trees among the regions. First, the dominant pioneer trees and small trees derived from buried seeds in the study areas were *Macaranga* spp., *Mallotus paniculatus*, *Omalanthus populneus*, and *Trema* spp. These species are usually highly vulnerable to felling and burning (Appendix 3). It appears that the longer slash-and-burn practices are repeated in an area, the less such pioneers regenerate. As mentioned in 2.1 and 3.1, Mencimai and Pasir are believed to have histories of more than 300 years of slash-and-burn agriculture, whereas in the Apau Kayan and Krayan regions the practice likely goes back decades or centuries (see 4.1). Second, the difference in density of pioneer trees may be related to ingress of the fern *Pteridium aquilinum* and the exotic shrub *Chromolaena odorata* in fallowed land in the Mencimai and Pasir regions (Photographs 4, 11). *Chromolaena odorata*, whose seeds are dispersed by wind, was first recorded in the 1940's in Kalimantan (Monk et al., 1997). Where pioneer tree species, including those that only develop into small tree, failed to dominate the fallowed land, *Chromolaena odorata* became dominant (Matius et al., 1994; Kiyono & Hastaniah, 1999). Once they become predominant, *Chromolaena odorata* (Appendix 3) and *Pteridium aquilinum* are very fire-resistant and survive repeated slash-and-burn. The abundance of these 2 species in the Mencimai and Pasir regions may have suppressed pioneers and decreased biodiversity of fallowed land. In the Apau Kayan and Krayan regions, however, *Chromolaena odorata* was not observed in our survey and *Pteridium aquilinum* thickets were limited to abandoned *Ananas comosus* plantations and other open sites near villages. The combination of repeated slash-and-burn practices and an increase in hardy

Table 3. Swidden agriculture and fallowed stands in Borneo. (modified from Kiyono & Hastaniah, 1997)

Location	Ethnic group	Crop-production periods [*1]	Fallow periods [*1]	Overstory height when felled	Major trees in fallowed stands	Dipterocarps
		year	year	m		
Mencimai	Benuaq	2(3)	10-11	10.0	*Schima wallichii, Vitex pinnata*	Lack or few
Pasir	Dusun	1-3	10 or more	17.2	*V. pinnata, Artocarpus* spp., *Peronema canescens,* bamboo	Few
Apau Kayan	Kenyah	1(2)	10.7 (*kelimung*), 13.2 (*uma bio'*)	15.3	*Macaranga denticulata, Vernonia arborea, V. pinnata*	Lack or a few
Krayan	Lun Dayeh	1	6.8	13.2	*Mallotus paniculatus, Trema orientalis, Alphitonia incana, V. arborea*	Lack

[*1] The crop-production and fallow periods at Pasir district, the Apau Kayan, and Krayan subdistrict were obtained by interviewing farmers and other residents.

shrub and fern species appears to have inhibited the regeneration of the pioneer tree and small tree species on fallowed land.

Figure 4 shows the relationships between the number of trees at least 10 cm in diameter and the number of species in disturbed dipterocarp forests (Matius et al., 1993) and swidden-land forests of *Schima wallichii*, *Peronema canescens*, and *Vitex pinnata* (this study) in Borneo. The swidden-land forests contain fewer tree species than dipterocarp forests that experienced light or medium disturbance (logged and burned), in which many original lowland tree species remained. Dipterocarps and many other original forest species appear to have been lost in the fallowed stands. According to Bratawinata & Matius (1995), in a 20-year-old 0.25-ha fallows area the number of tree species with $D_{1.3} > 5$ cm was less in the stand in which slash-and-burn farming was performed 3 times (34 species) than in the stand in which it was practiced only once (48 species). Thus, the more often that slash-and-burn agriculture is repeated, the fewer the tree species that exist in the fallowed stand. The low species richness in fallowed land seems to have resulted from a decrease in the abundance of species vulnerable to slash-and-burn farming and an increase in the abundance of hardy species. This increase in hardy species, in turn, may have resulted from a long cycle of slash-and-burn agriculture over a period of decades or even centuries and shows the importance of adaptability to disturbances by slash-and-burn farming, especially sprouting capability as a regeneration mechanism.

In conclusion, the floristic composition of swidden-land forests appears to be characterized by a lack or low density of dipterocarps (and probably many other original forest species) and the ascendance of tree species less vulnerable to felling and fire, such as *Schima wallichii*, *Vitex pinnata*, *Peronema canescens*, or *Vernonia arborea*. Such hardy forest species can be consciously or unconsciously maintained in land affected by swidden agriculture in the surveyed areas, though we did not fined many primary forest species in swidden-land forests.

5.2 Bioeconomics of swidden-land forests

A relatively small number of hardy tree species selected by the people of the region have replaced the original tree species in the forests, and young sprouts from tree stumps of hardy species may rapidly close the canopy when slash-and-burn fields are fallowed. Because these trees are usually long-lived, the potential for carbon accumulation in this type of forest is high in the long term if no forest fires occur (Kiyono et al., 2003). Generally speaking, MAI values are small when a stand is in the initial stages, become large after canopy closure, and then drop to smaller values in the mature stages (e.g. Nishikawa et al. 1996). We estimated MAI values of 3.26 (33 years) and 3.61 (34 years) Mg ha^{-1} year^{-1} and current increment of 14.88 Mg ha^{-1} year^{-1} (33-34 years) of biomass in a *Schima wallichii* fallowed stand in Mencimai and a MAI value of 6.46 Mg ha^{-1} year^{-1} in a *Peronema canescens* stand (95 years) probably established on abandoned settlement and cropland in Pasir. MAI estimates were obtained in fallowed pyrophytic tree stands under similar climatic conditions (mean annual rainfall 2000-3000 mm) in South Sumatra (JICA, unpublished data): 3.85 Mg ha^{-1}

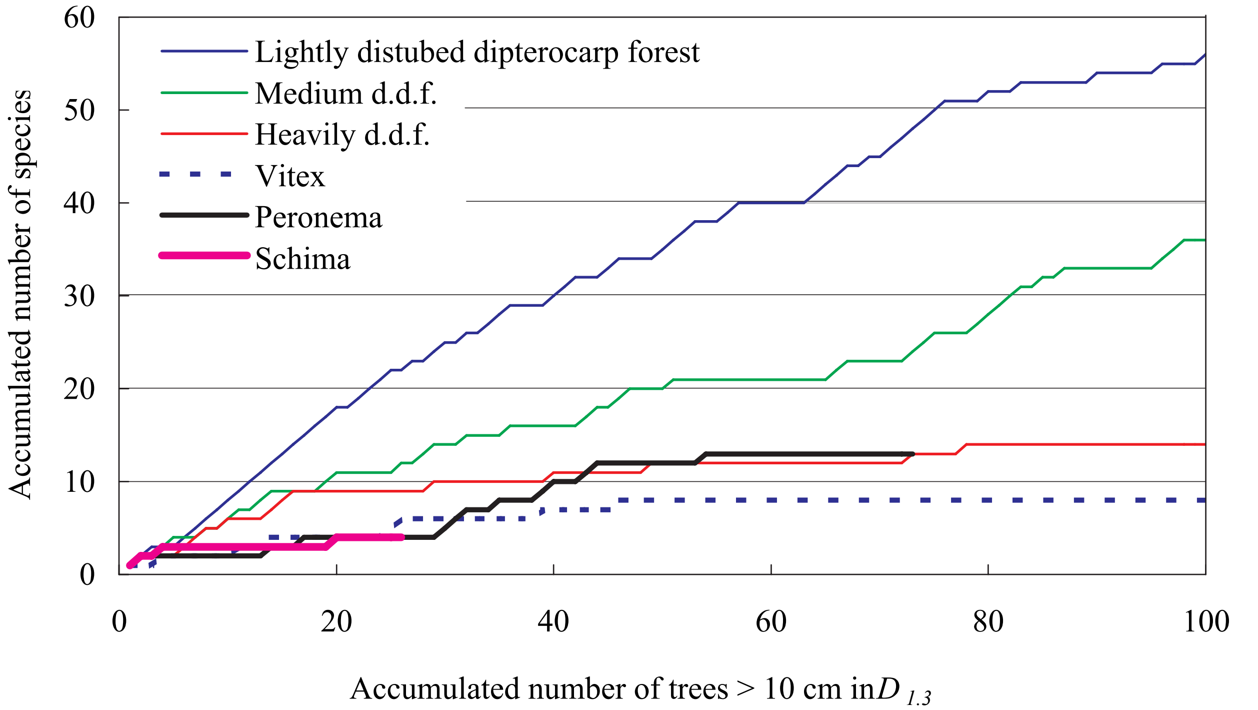

Fig. 4. Species richness of disturbed dipterocarp forests and swidden-land forests in Borneo.
Lightly, medium, and heavily disturbed dipterocarp forests (Bukit Soeharto): Matius et al. (1993); *Schima wallichii* (Mencimai), *Peronema canescens* (Pasir), *Vitex pinnata* (Apau Kayan): Kiyono & Hastaniah (1997).

year^{-1} in a 2-year-old stand (the most dominant species was *Commersonia bartramia*), 10.62 Mg ha^{-1} year^{-1} in a 4-year-old stand (*Schima wallichii*), and 8.38 Mg ha^{-1} year^{-1} in a 6-year-old stand (*Aporusa aurita*). The Mencimai stand had relatively small MAI. However, considering the large current increment of biomass in the stand (14.88 Mg ha^{-1} year^{-1}), logging or collection of fuel wood by local people must have decreased the stand's MAI value. The MAI values of swidden-land forests (range, 3.85-10.62 Mg ha^{-1} year^{-1}; average, 6.03 ± 3.00 Mg ha^{-1} year^{-1} in six 2- to 95-year-old stands) were not significantly less than MAI values of planted forests of non-fast-growing trees such as *Peronema canescens* and Swietenia mahagoni (range, 1.90-18.80 Mg ha^{-1} year^{-1}; average, 10.71 ± 7.18 Mg ha^{-1} year^{-1} in seven 10- to 25-year-old stands; P = 0.154; Morikawa, 2002; Matsune, 2003; Gintings et al., 2003) under similar climatic conditions (mean annual rainfall 2000-3000 mm) in Sumatra and Borneo. According to the general characteristics of MAI values, the MAI of the planted 10- to 25-year-old forests might be higher than the MAI of fallowed forests with a wider range of stand ages. We did not find significant differences between them in this study, however, suggesting that the MAI of swidden-land forests is equivalent to planted forests of similar species. However, the extent to which regional and other environmental conditions affected the difference is unknown. In this respect, the comparison of MAI between swidden-land forests and planted forests in the tropics needs further consideration.

The fertility of the soil used for swidden agriculture by the Tunjung people near Mencimai recovers after a fallow period of 5 to 8 years (Ruhiyat & Lahjie, 1992). Thus, the 10- to 11-year average fallow period estimated in Mencimai should not threaten soil productivity in land used for swidden agriculture. We only roughly estimate the generally proper fallow period required for nutrient build-up in fallow land ecosystems because this period depends on various factors such as soils, cropping periods, and crop species. Because both the bioeconomic potential and the floristic composition of the forests are considered to be nearly stable in land affected by swidden agriculture in the surveyed areas, although we did not find many primary forest species in swidden-land forests, we think this form of forest exploitation is an acceptable practice.

6 Conclusions

(1) The floristic composition of swidden-land forests in lowland and lower montane Borneo appears to be characterized by a lack or low density of dipterocarps (and probably many other original forest species also) and the successional ascendance of pyrophytic tree species less vulnerable to felling and fire, such as *Schima wallichii*, *Vitex pinnata*, *Peronema canescens*, and *Vernonia arborea*.

(2) Estimates of MAI (mean annual increment) of biomass in swidden-land forests were not significantly different from those of planted forest of non-fast-growing trees. However, the comparison of MAI between fallowed pyrophytic tree stands and planted forests requires further investigation.

(3) In the surveyed areas, both the floristic composition and the bioeconomic potential of the forests appear to be nearly stable in land used for swidden agriculture. We conclude that this approach to agriculture is an acceptable one.

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焼畑農業の方法とそれが植生遷移に及ぼす影響 －ボルネオ島の伝統的焼畑の場合－

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要旨

ボルネオ島の低地や山地帯下部で、耐火性樹木の増加の影響やそれが優占する森林の炭素固定機能を評価するため、焼畑休閑地の森林の種構成やバイオマスを調査した。都市から隔離された 2 地域を含む 4 つの地域で、合計 218 の二次林を主として焼畑休閑林の例として選び、種構成などを調べ、そのうちの 2 林分で林分バイオマスを推定した。休閑地の森林には伐採されたり焼かれたりしても切り株から萌芽する *Schima wallichii*、*Vitex pinnata*、*Peronema canescens*、*Vernonia arborea* といった樹木が多かった。隔離地域では早熟のパイオニア樹種も多かった。もともとの林を優占していたフタバガキ科樹木は少なく、*Shorea balangeran* 以外はほとんど見られなかった。*Schima wallichii* の休閑林のバイオマス総平均成長量（MAI）は 3.26、3.61 Mg ha^{-1} year^{-1}、*Peronema canescens* 林では 6.46 Mg ha^{-1} year^{-1} であった。南スマトラの焼畑休閑林でも 3.85 ～ 10.62 Mg ha^{-1} year^{-1} の MAI が計測されており、今後さらなる調査は必要であるが、これらの平均値 6.03 ± 3.00 Mg ha^{-1} year^{-1} は、同様の気候下にある非早生樹の植林地の MAI 平均値 10.71 ± 7.18 Mg ha^{-1} year^{-1}(1.90 ～ 18.80) とくらべて異なるとは言えなかった。森林を焼畑に利用することを通して、もともとの林の多様な樹種から比較的少数の生育旺盛な耐火性樹種が選抜されているので、焼畑が休閑されるとそうした樹種がすみやかに林を形成していると考えられる。

キーワード： パイロファイト、スキーマ属、パイオニア植物、フタバガキ科、バイオマス、総平均成長量、生物多様性

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