Ecology of Tengkwang Forests under Varying Degrees of Management in West Kalimantan

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ABSTRACT West Kalimantan has about 10 species of *Shorea* called as tengkwang whose fruits are economically useful as source of fat. The fruits were collected from natural and semi-natural forests and plantations. We made eight plots in tengkwang forests in 1991 to study the change of forests by the human activity. In Ngabang which had been the capital city of old Landak Kingdom, the king made two plantations of ca. 1 km² about 100 year ago. In tengkwang species, *S. stenoptera* was mainly planted on flat bank near river, and *S. amplexicaulis*, and *S. pinanga* was on upper slope. They reached 125 cm in DBH and 49m in height. The average diameter increment of tengkwang from 1991 to 1994 was 0.28(±0.32SD) cm/yr. Two rubber tree species, *Hevea brasiliensis* and *Palaquium gutta* were planted under the canopy of tengkwangs of flat bank and slope, respectively. The plot had 123 species of wild and cultivated trees (DBH>4.8cm) in 1 ha, and the diversity was similar to the natural tengkwang forest.

On river banks of small stream near a village Muarailai, semi-natural tengkwang forests were found. Large trees reached 186 cm in DBH. People had cut useless trees and planted useful trees such as *Hevea* and *Durio* under the canopy of tengkwang. Along the Daid River, tengkwang forest remained nearly natural condition. The forest structure was similar to semi-natural forest but no planted trees except one escaped shrub *Bullucia pentamera* introduced from Latin America. The common tengkwang, *S. stenoptera* dominated exclusively on flat river banks of sandy soil and the diversity was not so high. The other dipterocarp forest on slope had higher diversity.

Key Words: tropical rain forest / Kalimantan / Tengkwang / illipe nuts / plantation / biodiversity

Dipterocarp forests on lowland of Borneo Island have the richest tree flora in the world. The Dipterocarpaceae has 267 species on this Island of 746,305 km² (Ashton, 1982). The fruit have a variety in size and shape, and some one dispersed by gyration (or wind), non-gyration, and by water (Suzuki & Ashton, 1996). The fruit has many fat and is edible for human and wild animals. Fruits of 13 species, called as tengkwang, are of commercial significance to produce fat, and the dried illipe nuts were exported from Sarawak as early as 1908 (Soon, 1988). In West Kalimantan, there are about 10 species of tengkwang. Tengkwang produces illipe nuts of 10,640 ton in 1983 in West Kalimantan (Suzuki & Gadrinab, 1988). They were used to make fat at a factory in Pontianak, and the fat was exported to Japan *etc.* But the fruit production fluctuates greatly, and there were no fruits in 1984. De Vriese traveled in West Kalimantan from October 1860 to early of 1861 (De Vriese, 1861; Van Steenis-Kruseman, 1948-1954), and found at first the tengkwang species: *Shorea splendida* (De Vriese) Ashton, *S. stenoptera* Burck, and *S. seminis* (De Vriese) Slooten. Tengkwang forests distribute naturally in Borneo, but some of them near villages might be affected by human activities

Fig. 1. Map of study site. N, M, and D show the location of plots, in Ngabang (N-1 to -5), Muarailai (M-1 to -3), and Daid (D-1 to -4). Dot line shows the boundary of old Landak Kingdom.

Table 1. Precipitation and temperature.

Site(measured years)	Alt.	Lat.	Long.	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain fall (mm/month)																
Pontianak (1968-1991)	3m	0°09'S	109°20'E	3302	266	185	263	287	287	227	208	200	305	352	413	310
Ngabang (1931-1960)	10m	0°23'N	109°57'E	2969	281	231	267	270	240	173	184	186	244	273	330	290
Sanggau (1950-1991)	10m	0°08'N	110°36'E	3060	304	273	281	266	256	169	204	198	214	278	308	310
Serimbu (1986-1994)	80m	0°45'N	110°06'E	4470	461	254	503	425	351	255	284	251	301	409	491	487
Temperature (°C)																
Pontianak (1973-1991)	3m	0°09'S	109° 20'E	26.3	25.9	26.2	26.4	26.4	26.8	26.8	26.3	26.5	26.4	26.2	26.0	25.9

Data source: Ngabang from Sastrodimedjo *et al.* 1974, and others are from unpublished data of each station: Stasiun Meteorologi Pontianak, Dinas Pertanian at Sanggau, and district office at Serimbu.

such as selective cutting of useless trees, and planting of tengkawang in a small scale. *S. stenoptera* and *S. seminis* prefer the river banks, which are also suitable sites to establish villages. After starting the export of illipe nuts to Europe, plantation of tengkawangs have been made. A few of the plantations are now about 100 years old. In tropical areas, such old plantations were rarely found. Thus we can find now many forests in varying degrees of management; natural forests, semi-natural forests (the tengkawang grew naturally but the forest structure changed by human use), and pure plantations. Our purpose of study is to compare the forests among them and to detect the change of forest by human activity. These kinds of forests are interesting and useful for investigating the effect of human on the forests. The study will give us basic knowledge how to manage the forests.

Because illipe nuts are one of the most important forest products in West Kalimantan, several studies have been made. More than hundred years ago, the importance of tengkawang fat was reported (De Vriese, 1861; Burck, 1886). The pilot plantation of tengkawang started in 1940 at Haurbentes, Bogor (Departmen Kehutanan, 1990). Suzuki & Gadrinab (1988) have studied the fruit production in a young plantation of tengkawang. Watanabe (1996) described the economical use of illipe nuts. But the purpose of most researches are the economical uses of tengkawang, and the forests have rarely

studied from ecological view points.

STUDY SITE AND METHODS

Study site

We studied tengkawang forests at three sites in West Kalimantan: Ngabang, Muarailai, and Daid (Fig. 1). Table 1 shows precipitation and temperature at sites around the study area. Annual mean temperature was 26.3°C and the difference between maximum and minimum of monthly mean temperatures was 0.9°C at Pontianak, a city on the equatorial line. February, June, July and August are rather dry but these months still have precipitation more than 160mm/month. Annual precipitations at four sites were from 2969 mm/yr to 4470 mm/yr.

Vegetation survey

We made eight plots from end of July until early of October, 1991. The description of the location, and size of plots is shown in Table 2. One plot of 250 m × 50 m was made in an plantations of tengkawang about 100 years old in Ngabang. The plot was divided into 5 subplots of 50 m × 50 m, N-1 to N-5 from land side to riverside (Fig. 2.c). In two adjacent villages, Muarailai and Muaradua, we made three plots (M-1, M-2, and M-3). M-1 was in a private plantation about 20 years old. M-2 and M-3 were in semi-natural stands along a small stream in Muarailai. We made four plots (D-1 to D-4) in tengkawang and dipterocarp forests along the Daid River which is the boundary of Kecamatan (district) Serimbu, Kabupaten (prefecture) Pontianak, and Kecamatan Beduai, Kabupaten Sanggau. Forests in this area have been logged since 1984 by a logging company, P. T. Batasan. Many people are entering there through the logging roads and making shifting cultivation. Before the logging there were no roads, and local people usually used rivers for transportation.

The plots were divided into 10 m × 10 m subplots. The heights of the ground were measured along the grids, and contoured maps were made. Number tags of aluminum or plastic were put on all trees bigger than 15 cm in girth at the height of 1.3m above the ground (GBH). The GBH were measured for the tagged trees with a steel measure. In November 1993, the GBHs of trees in N-1 ~ N-5, D-1, and D-4 were remeasured, and in November 1995, those in N-1 ~ N-4 were remeasured at the third time. In 1991, the herbarium specimens were collected from them except some big trees and trees easily identified. In some plots the location of trees and height of trees were measured. Forest profile of trees bigger than 10 cm in diameter at the height of 1.3m above the ground (DBH) were drawn in a belt of 10m width. For *Shorea stenoptera*, all individuals in the plots were measured for DBH, if exist, height and the location. Height of tengkawang trees in Plot N was measured. For tengkawang species, the seedlings and saplings smaller than 15cm in GBH were tagged and measured by their height and locations in N-1 to N-4 and D-1 to D-3 in 1991, and remeasured in N-1 to N-4 and D-1 in 1993.

Soil analysis

The soil augering was carried out in at every corners of 10m × 10m subplots of D-1, D-2 and D-3 in August 1991. Eight pedons were examined in the fresh pits, and 34 soil samples were collected for physical and chemical analysis. The analyses were as follow: 1) particle size distribution (clay of less than 0.002 mm, silt of less than 0.05 mm and sand) by sedimentation method after the decomposition of organic matter with H₂O₂, 2) total carbon by Kurmis's method, 3) total nitrogen by Kjeldal's method, 4) pH in water and in 1N HCl with soil/solution ratio of 1/2.5, 5) exchangeable bases cation of Ca, Mg, K and Na in the extracts with 1N CH₃COONH₄ (pH=7) and water by the method of

Table 2. Location, size diversity, number of trees, and basal area (BA) of trees in plots. BA (m²/ha) of each species was shown for some useful genera.

Plot	N-1+2	N-3+4	N-5	M-1	M-2	M-3	D-3	D-2	D-1	D-4
Lat. (N)	0° 23'	0° 23'	0° 23'	0° 40'	0° 40'	0° 40'	0° 43'	0° 43'	0° 43'	0° 43'
Long. (E)	109° 57'	109° 57'	109° 57'	110° 22'	110° 22'	110° 22'	110° 12'	110° 12'	110° 12'	110° 12'
Alt. (m)	30	10	10	50	50	50	60	60	60	100
Area (m ²)	5000	5000	2500	300	2732	2400	4528	3133	7480	5000
Fisher's α	41.2	20.8	8.7	2.7	27.3	43.3	42.1	81.9	183.9	174.4
Morisita's β	13.9	6.8	12.2	3.8	9.4	18.5	14.3	60.9	112.8	139.0
H' (No)	5.1	4.1	3.9	2.1	4.5	5.2	4.9	6.0	7.6	7.7
H' (BA)	2.6	1.1	3.5	1.0	2.0	1.8	1.3	2.3	6.6	6.0
No. of trees	412	222	138	52	179	145	306	272	1074	1038
No. of identified trees	404	220	129	51	177	138	253	141	953	950
No. of all species	98	51	24	8	55	62	82	82	335	325
No. of dipterocarp species	5	2	1	1	2	2	3	5	16	18
Total BA (m ² /ha)	44.23	35.49	21.22	42.01	48.39	41.34	34.32	31.12	26.33	54.90
BA of each species										
<i>Shorea stenoptera</i>	6.92	30.19	0.10	32.97	37.15	30.68	27.60	8.50	3.00	
<i>S. amplexicaulis</i>	21.20									
<i>S. cf. amplexicaulis</i>										0.21
<i>S. pilosa</i>		0.00								
<i>S. pinanga?</i>	3.90	0.38							0.02	
<i>S. seminis</i>					0.43	0.04	0.03	0.28		
<i>Shorea</i> sp.(Labe)	0.67									
Other dipterocarps							0.09	0.24	3.04	18.40
<i>Hevea brasiliensis</i> ⁺⁺	0.29	1.84	1.97	6.44	1.40	0.05				
<i>Durio zibethinus</i>	0.19	0.76			0.03	0.08	0.01			
<i>D. kutejensis</i>					1.02	0.05			0.02	0.26
<i>D. griffithii</i>									0.05	
<i>Eusideroxylon zwageri</i>		0.39					0.02	0.02	0.02	
<i>Bullucia pentamera</i> ⁺	0.004						0.35	0.01	0.13	
<i>Lansium domesticum</i>	0.01	0.24			0.16	0.29				
<i>Artocarpus integer</i> [*]	0.33	0.12			0.07	0.12				0.07
<i>A. anisophyllus</i>	0.01				0.59	0.19		0.01	0.04	0.01
<i>A. dadah</i>									0.01	
<i>A. elasticus</i>				0.07	1.87	0.14	0.04			0.12
<i>A. cf. glaucus</i>	0.00	0.01			0.02		0.01			
<i>A. kemando</i>		0.02				0.26				
<i>A. rigidus</i>					0.29					0.06
<i>A. rotunda</i>	0.02									
<i>A. cf. tamaran</i>			0.21			0.11				
<i>Nephelium lappaceum</i>		0.06			0.10	0.03		0.02		
<i>N. maingayi?</i>					0.01					
<i>N. ramboutan-ake?</i>										0.06
<i>N. reticulatum</i>									0.01	
<i>N. uncinatum</i>							0.03	0.02	0.00	
<i>Palaquium gutta</i> [*]	6.25	0.01								
<i>P.</i> (small leaf)										0.01
<i>P. calophyllum</i>					0.03	0.09		0.02	0.14	0.46
<i>P. dasyphyllum</i>						0.01				
<i>P. majes</i>							0.01		0.00	0.05
<i>P. cf. oxleyanum</i>										0.14
<i>P. rostratum?</i>										0.01

+ introduced from tropical America. * planted.

atomic absorption spectrophotometry, 6) cation exchange capacity (CEC) determined by the saturation with 1N CH₃COONH₄ (pH=7), followed by the ethanol washings and the replacement of absorbed NH₄⁺ with 1N NaCl, and measurement of NH₄ amount by spectrophotometer using Nessler's solution, and 7) available potassium and phosphorus determined by Olsen's method.

Fig. 2. Location of trees in Ngabang. a: map around Ngabang with two solid circles showing tengkawang plantations. Plot N-1 to -5 were made in the plantation near Desa raja. b: topography from the Landak River to plot. c: contour maps of the plot. Solid contours are at 1m interval and contours of broken line at 0.5 m interval are added in flat area. ●: *S. stenoptera*. □: *S. pinanga*. △: *Shorea* sp. ×: dead *Shorea*. The symbol size shows the tree size.

RESULTS

Old plantation at Ngabang

There were old plantations of tengkawang established about 100 years ago in Ngabang (Fig. 1 and Fig. 2). The city is the center of Ngabang Districts (Kecamatan), and was the capital of old Landak Kingdom which had been established as an Islam kingdom late in the fifteenth century and under the control of colonial government of Dutch in the nineteenth century (Team Penyusun Monografi Daerah Kalimantan Barat, 1976). The Kingdom had covered about four districts (Kecamatan) of today: Ngabang, Serimbu, Daid, and Pahauman. The owner of the plantation, Mr. Gusti Basuni Bdr. who was born in 1928 at Desa Raja (village of king) in Ngabang as the son of the last king, and died in 1995. According to him, his grandfather made the plantation about 100 years ago. The source of planted fruits had been originally brought from the upper part of the Landak River, where we made other plots as mentioned later. Around Ngabang there are no tengkawang trees except the plantations though it is a common tree in Sanggau, one of the main area of illipe nuts production (Soon, 1988). In Kalimantan, tengkawang trees do not distribute in coastal area (Sumadiwangsa, 1977). Tengkawang trees were rare between Pontianak and Ngabang except *Shorea macrophylla* (De Vriese) Ashton at Mandor (Fig. 1). Though illipe nuts had been collected by local people to make food fat for their home use from old time, the plantations were made to export the dried fruit to Europe. One plantation of about 100 ha was 1 km north of center of Ngabang and between the Landak River and a small stream, Emputeh (Fig. 2.a). Desa Raja and the plantation is opposite site of the Landak River. *S. stenoptera* (tengkawang tungkul) and *S. amplexicaulis* (tengkawang meje) were mainly planted though many tengkawang species were additionally planted such as *Shorea macrophylla*, *S. beccariana* Burck, *S. mecistopterix* Ridley, *S. pilosa* Ashton, and *S. pinanga* Scheff. Another plantation was along the Landak River about 7 km south of center of Ngabang. It was larger than 100

Fig. 3. Profile of trees in shadowed part of N-4 and N-3 of Fig. 2. S, *Shorea stenoptera*; A, *Shorea amplexicaulis*; T, *Tabernaemontana* (K3024); G, *Gardenia forsteriana*; M *Macaranga depressa* forma *strigosa*; E, *Eusideroxylon zwageri*; H, *Hevea brasiliensis*; D, *Dillenia* cf. *borneensis*.

ha, and there are many *Shorea amplexicaulis*, *S. pinanga* and *S. mecistopteryx* but fewer *S. stenoptera*.

Figure 2.b shows the topography between the Landak River and the plantation. The river was 49 m in width at usual water level. But floods of the river, which occurred almost every year and continued for several days, raised the water level about four meters, and the forest between river and the point of arrow in Fig. 2.b was inundated. The plot at Ngabang was 250 m $\times$ 50 m, and 4 m to 42 m higher than the usual water level. It was divided into five subplots of 50 m $\times$ 50 m from N-1 to N-5. Most part of N-1 was lower than 6 m in height inundated periodically, and tengkawang trees were not distributed. The upper flat area (N3+4) was higher than the water level by six or more meter and was rarely waterlogged. *S. stenoptera* had been planted in three rows in this area. *S. amplexicaulis* was planted on the slope (N-1+2) most frequently, though the original rows of plantation were unclear because of vigorous regeneration of small trees.

Figure 3 shows the forest profile in the shadowed part of 10 m $\times$ 60 m of Fig. 2c, where was flat and dominated by *S. stenoptera*. This species has large leaves and thick branches. The crown had a rather flat top and was not dome-shaped as usual emergent trees of *Shorea*. The tallest tree in this plot was *S. amplexicaulis* of 49 m in height, and tallest *S. stenoptera* was 44 m. Tengkawang trees made a continuous canopy layer from 35 m to 45 m in height, and no emergent trees. The largest tree in DBH was 125 cm in *S. stenoptera*, and 117 cm in *S. amplexicaulis*. Trees distribute sparsely under the canopy because useless trees were often cut.

Fig. 4 shows the DBH distributions of main species in three parts of plot N: slope part (N-1+2), flat part (N-3 +4), and flat and low part (N-5). Table 2 shows the basal area of tengkawang species and other useful genera. The subplot nearest the river, N-5 of 50 m $\times$ 50 m part, was a secondary forest dominated by *Lagerstroemia speciosa* (L.) Pers. People often use this forest to get wood for fuel and light construction. This area is covered with water at flood, and tengkawang was not planted here. Most of *S. stenoptera* were planted on flat part of N-3+4. *S. amplexicaulis*, and *S. pinanga* (tengkawang layer) were on the slope of N-1+2. As shown in the data along the Daid river, the natural

Fig. 4. Frequency distribution of DBH in Ngabang

habitat of *S. stenoptera* is banks a few meters high along small streams. *S. amplexicaulis* and *S. pinanga* usually grow on the slope of hills. People seemed to select similar habitats to the natural ones as site of plantation. There were only a few small trees of tengkawang and other species in the flat plain, though many on the slope. Total density of trees (DBH>4.8cm) was 824/ha, 444/ha, and 552/ha in slope, flat, and low part, respectively. It might be a result of forest use. People might cut wood more often from flat area and near the river than from the slope. *S. stenoptera* had much less number of small trees than *S. amplexicaulis* (Table 3). Because people usually avoided to cut useful tengkawang trees, the poor regeneration of the former might be caused from its regeneration characteristics preferring sunny places for seedling establishment.

In this forest, some other useful trees were added after establishment of plantation, such as latex trees (*Palaquium gutta* (Hook. f.) Baillon and *Hevea brasiliensis* Muell. Arg.), wood tree (*Eusideroxylon zwageri* Teijs. et Bin.), and fruit trees (*Durio zibethinus* Murr., *Lansium domesticum* Correa, and *Artocarpus integer* (Thunb.) Merr.). On the slope, *Palaquium gutta* had been planted to produce a kind of latex called "gutta percha" in English (Hotta *et al.* 1989) or "gatah merah (red latex)" in Indonesian. Photograph 1 shows the scar on the trunk to collect the latex many years ago.

Table 3. Number and height (cm) of seedlings and saplings (GBH<15cm) of tengkawang in Ngabang (from N-1 to N-4), D-1, D-2 and D-3.

	Species	In 1991				In 1993			
		H<50cm	H>=50cm	Mean H	SD	H<50cm	H>=50cm	Mean H	SD
N	<i>S. amplexicaulis</i>	198	106	0.81	1.288	64	141	1.11	1.481
N	<i>S. stenoptera</i>	13	4	0.44	0.149	7	8	0.69	0.336
N	Other tengkawang	76	3	0.32	0.116	21	28	0.55	0.213
D-1	<i>S. stenoptera</i>	11	51	1.09	0.957	2	28	1.33	1.009
D-2	<i>S. stenoptera</i>	14	112	0.91	0.687	-	-	-	-
D-3	<i>S. stenoptera</i>	16	186	1.07	0.772	-	-	-	-

Fig. 5. Relationship between DBH and its increment of trees from N-1 to N-4 for 4.17 years. Dot and broken lines are regressions for *Shorea amplexicaulis* and *S. macrophylla*, respectively.

Photograph 1. Scar on a trunk of *Palaquium gutta* to collect latex in Tengawang plantation at Ngabang.

Fig. 6. Frequency distributions of DBH in plots of Muarailai.

Fig. 7. Profile of M-1.

Similar trees of *Palaquium* with scar of rubber collection were also found in Muarailai. But it has no commercial value now, and is not used. On the flat part, another plant of latex production, *Hevea brasiliensis*, was planted. Large trees of *Hevea* are now used to get latex. Many saplings of both species have regenerated naturally. A few trees of *Eusideroxylon zwageri* were planted but grew slowly. Several fruit trees grew in this plantation. The seeds might be dispersed when people ate the fruit there, and not planted intentionally.

Figure 5 shows the relationship between DBH and its increment (cm/yr) for observed 4.17 years.

Fig. 8. Topography and location of trees in M-2. Contours of solid and broken line are at 1m and 0.5 m intervals, respectively. ●: *S. stenoptera*. ○: *S. seminis*. ▲: *Hevea brasiliensis*. +: Other species. The symbol size shows the tree size

Fig. 9. Profile of M-2. Aa, *Artocarpus anisophyllus*; Ai, *Artocarpus integer*; D, *Durio kutejensis*; E, *Eugenia* cf. *acutangulum*; H, *Hevea brasiliensis*; K, *Koompassia excelsa*; L, *Lansium domesticum*; P, *Pentaspadon motleyi*; S, *Shorea stenoptera*; Sc, *Sterculia* cf. *cordata*; V, *Vernonia arborea*.

Average increment of 131 tengkawang trees was $0.28(\pm 0.32 \text{ SD}) \text{ cm/yr}$. *S. stenoptera* and *S. amplexicaulis* had a positive correlations: Increment = $0.0035\text{DBH} + 0.01955$ ($r^2=0.196$) for the former and, Increment = $0.0042\text{DBH} + 0.1394$ ($r^2=0.196$) for the latter as shown in Fig. 5.c. The positive relationships were crude but significant ($P<0.01$) though other trees usually tend to have negative relationship. It means that the growth of saplings of tengkawang was suppressed by the canopy trees which were growing well. The sapling of *S. stenoptera* grew more slowly, and had less number than *S. amplexicaulis*. In other plants, only *Hevea* had significant relationship ($r^2= 0.141$, $P<0.01$). The increment of some *Hevea* trees was more than 1 cm /yr. A few saplings of *Macaranga triloba* also grew quickly. Average increment of four *E. zwageri* was $0.41 (\pm 0.081 \text{ SD}) \text{ cm/yr}$.

Semi-natural forest and plantation in Muarailai and Muaradua

In two adjacent villages, Muarailai (Kecamatan Beduai) and Muaradua (Kecamatan Kembayan) along the Ilai River, we made three plots (Fig. 6). In this area tengkawang trees seemed to distribute naturally. The villages had established in old time, local people did not know when they had established. They have collected illipe nuts since old time. The Sekayam River is about 50 m in width at Muarailai. *S. stenoptera* was mainly distributed along a small branch river, the Ilai River of several meters in width. We made one plot (M-1) in a plantation along the Sekayam River, and two plots (M-2 and M-3) along the Ilai River in 1991.

The plot M-1 was established in a small plantation of about 20 years old by a person in Muaradua. Figure 7 shows the forest profile of M-1 and topography between the river and plot. It was established on a steep slope above the road. The plantation is 40 m distant from the water of the Sekayam River and 13 m high from the usual water level. *S. stenoptera* made a canopy layer of about 20 m high, and *Hevea brasiliensis* was made a layer 12 m high. Figure 6 shows the DBH distribution in M-1. Some trees of *S. stenoptera* are bigger than 50 cm in DBH. In one year since our study, most trees in M-1 was cut or burnt to make a rice field of shifting cultivation by the owner. The village seemed to have shortage of land for shifting cultivation, and the fruit of tengkawang seemed not to be more attractive economically than shifting cultivation.

The plot M-2 was made along the Ilai River, 400 m distant from road along the Sekayam River. The trees of *S. stenoptera* were separated into two classes of DBH, bigger than 150 cm and smaller than 70 cm (Fig. 6). They were apparently older than those in plantation of Ngabang. *H. brasiliensis* and *Durio kutejensis* (Hassk.) Becc. were planted. This *Durio* with red flower and yellow fruits was commoner than usual cultivated *Durio zibethinus* with creamy white flower around Muarailai. *Durio* was also found in Daid but different species. Five species of *Artocarpus* were found in the plot. But they are different species from planted in the garden. *A. anisophyllus*, and *A. elasticus* were found in this plot and Daid. Wild species of *Artocarpus* seemed not to be planted but to be protected from cutting because of the edible fruits and useful timber. People felled down many of useless trees or peel the bark to kill. Figure 8 and 9 shows the location of trees and forest profile in M-2, respectively. *S. stenoptera* distributed on river banks from 3 to 5 m higher than river water. The height is lower than in Ngabang. But the flood water rarely inundated the site of M-2 because the river was smaller than the Landak River at Ngabang. The highest tree in M-2 was *S. stenoptera* of 44.5m. In M-3, it was also 44m. The maximum size of *S. stenoptera* seemed to be less than 50m in height and 2m in DBH, though some *Shorea* species became taller than 60 m in this area.

The plot M-3 was made along the Ilai River, 1.5 km distant from road along the Sekayam River. The topography was similar to that of M-2 and *S. stenoptera* distributed on the river bank 2-3m higher than the river water. The distribution of DBH was similar to M-2 in *S. stenoptera*, but *Hevea* and

Fig. 10. Frequency distribution of DBH in plots of Daid.

Durio became fewer (Fig. 6). We found many seedlings of *S. stenoptera* germinated in this year though no seedlings in M-2 where many people collected the fruit, and many domestic pigs fed the fruits.

Natural forests along the Daid River

Along one of branches of the Landak River, the Daid River, we made plots from D-1 to D-4. D-4 on a steep slope distant 0.5 km from the river, and other three plots bordered with the river (Fig. 10). The river ran in a little steep valley around D-1, and on a flat plain around D-2 and D-3. Fig. 10 shows the DBH distribution of some representative species and other in D-1, D-3 and D-4.

The topography of D-3 was a flat river bank a few meters higher than the water (Fig. 11). *S. stenoptera* exclusively dominated and occupied 80 % of BA of all species. Because the plot is flat, and left side of the plot has another small stream, *S. stenoptera* distributed on the whole area of the plot. Fig. 12 shows the forest profile in D-3. *S. stenoptera* made a continuous canopy about 40 m high as in M-2 and M-3. The trees in the lower stratum were not so many. As shown in DBH distribution of Fig. 10, *S. stenoptera* had big trees and also small trees. The small trees gathered in an open area where few big trees existed (Fig. 11). Data of D-2, which was located 60 m north of D-3, were omitted from the figure because the vegetations in D-2 and D-3 were similar. *S. stenoptera* was less dominant in D-2 than in D-3. It might be caused that some part of D-2 was steep slope, where other dipterocarps such as *S. leprosula*, *S. parvifolia*, and *S. scaberrima* were found.

D-1 was on river sides of Daid, but the topography was steep in most part (Fig. 13). *S. stenoptera* distributed only in small area of flat bank. The density of seedling and saplings also less than in D-2 and D-3 and they distributed only flat and open area near the river. Instead of low density of *S. stenoptera*, this plot has 16 species of dipterocarps such as, *Shorea parvifolia*, *S. parvistipulata*, *S. pauciflora*, *S. scaberrima*, *S. virescens*, *Vatica oblongifolia* and *Hopea dryobalanoides*. D-4 was on a

Fig. 11. Topography and location of trees in D-3. Contours of solid and broken line are at 1m and 0.5 m intervals, respectively. ●: *S. stenoptera*. ○: Other Dipterocarpaceae. +: *Bullucia pentamera*. The symbol size shows the tree size.

Fig. 12. Profile of D-3. Bh, *Bhesa paniculata*; Bu, *Bullucia pentamera*; C, *Cleistanthus cf. myrianthus*; H, *Horsfieldia* (WK1328); St, *Santiria tomentosa*; S, *Shorea stenoptera*.

steep slope of a small mountain, and had 18 species of Dipterocarpaceae, such as *Dryobalanops beccarii*, *Shorea laevis*, *S. leprosula*, *S. ovalis*, *S. pauciflora* and *Vatica micrantha* but no *S. stenoptera*. The forest had a high diversity (Table 2).

Soils in Daid

Table 4 shows the result of soil analysis along the Daid River. The soil had been developed from two types of sandy materials. The first (Oxic Humitropepts and Aquic Dystropepts) was derived from the weathering of sandstone in most of D-1, and some part of D-2. The topography was undulating to rolling. The second was derived from loose sand produced by overflow on the flood plain along the

Fig. 13. Topography and location of trees in D-1. Contours are at 1m intervals.

river in most area of D-3, and some parts of D-2.

Oxic Humitropepts was found on steep slope of D-1 and Aquic Dystropepts was on wet and gentle slope in D-1. Typic Dystropepts and Aquic Tropfluvents were found in flat area of D-3. The soil pH was weakly acidic or neutral (Table 4). The average clay content was 13.7 (SD=5.1)%. Soils in D-3 had higher contents of sands than that in D-1. The carbon contents were low, about 1.5 % to 1.1 %, and CEC was also low.

Distribution of useful trees

Many trees of tengkawang and *Hevea brasiliensis* were systematically planted in some forests in Ngabang and Muarailai. Tengkawang trees are native in this area, and they are planted in a large scale only at Ngabang. In Muarailai, their abundance might be increased by cutting of other species but most large trees seemed to germinate in natural. Tengkawang forest along the Daid River seemed to be in natural condition until recent. *Hevea* had been introduced from tropical south America and it is now the most important trees to make large plantation in this area. Because it can regenerate from seeds in and around the plantation, plots in Ngabang and Muarailai had many small *Hevea* trees. But the large seed without special equipment for dispersal rarely invaded natural forests. Other useful trees were also planted sporadically or often germinated from abandoned seeds after eating fruit. They were fruit trees in most case such as *Lansium domesticum*, *Nephelium* spp., *Artocarpus integer*, *Baccaurea* sp. and so on. Once they had been established in forest, they might regenerated naturally. A shrub species in Melastomataceae, *Bullucia pentamera* Naud., grew in open areas along rivers and made fruit of 3cm in diameter with many fine seeds and apple like taste. It had been introduced from tropical Latin America, and was dispersed by animals and became a common shrubs in the study area. The specimens of this species collected from Java, Sumatra, Malaysia have been stored in Leiden. Though Whitmore (1991) mentioned that very few woody species from other region had become invasive and naturalized in perhumid tropical climates, *Bullucia pentamera* was one of the exceptional successes. In *Durio* of Bombacaceae, *D. zibethinus* is economically important species and commonly planted to make orchard, and a few trees were found in forests at nearly natural condition. *D. kutejensis* with red flower is also locally planted around Muarailai.

Diversity of trees

Four diversity indices were calculated for each plot (Table 2). The first index is Fisher's α

Table 4. Physical and chemical characters of soil in the plots of Daid.

Pit No	Depth	Hori- zon	Particle size (%)			pH		Total C (%)	Total N (%)	Sorption Coef. (mg/100g)		Exchangable bases (me/100g)				CEC (me/100g)	Base Satura- tion degree (me/100g)
			Sand	Silt	Clay	H ₂ O	KCl			P ₃ O ₅	K ₃ O	Ca	Mg	K	Na		
D-1																	
1	0-13	A.1	63.8	10.9	25.3	5.9	4.6	2.41	0.075	14.49	3.52	0.16	0.24	0.23	0.18	5.72	14.16
	13-48	AB	52.2	23.0	24.8	6.5	5.2	0.82	0.039	7.43	2.57	0.49	0.52	0.17	0.18	5.06	26.87
	48-97	B	48.7	44.7	6.6	6.5	5.2	0.80	0.032	9.00	2.53	0.36	1.02	0.17	0.13	5.04	33.33
	97-133	BC	54.8	39.2	6.0	6.5	5.2	0.79	0.032	5.30	3.08	-	-	-	-	-	-
2	0-6	A.1	85.3	1.0	13.7	6.6	5.3	1.26	0.041	9.18	2.51	0.31	0.31	0.12	0.04	4.79	16.28
	6-31	AB	78.7	7.1	14.2	6.9	5.6	0.60	0.010	0.00	2.07	0.19	0.19	0.14	0.12	4.22	15.17
	31-56	B	76.0	14.6	9.4	6.7	4.4	0.54	0.010	3.06	2.06	0.22	0.22	0.13	1.24	3.04	59.54
	56-107	B _g	69.3	13.1	18.6	6.8	5.5	0.39	0.007	0.00	3.90	-	-	-	-	-	-
3	0-9	A.1	82.7	5.9	11.4	6.2	4.9	0.86	0.061	11.66	2.03	0.25	0.25	0.18	0.15	3.70	22.43
	9-22	AB	82.7	6.2	11.1	6.3	5.1	0.85	0.022	4.08	1.58	0.15	0.15	0.16	0.17	2.72	23.16
	22-42	B.1.1	89.5	2.4	8.1	6.7	4.6	0.83	0.028	0.00	1.59	0.04	0.04	0.13	0.12	2.35	14.04
	42-119	B.1.2	73.8	12.0	14.2	5.9	4.9	0.72	0.030	6.18	1.55	-	-	-	-	-	-
	119-145	RC	72.2	14.3	13.5	6.5	5.2	0.47	0.052	3.09	2.03	-	-	-	-	-	-
145-160	CB	77.0	11.5	11.5	6.7	5.5	0.39	0.015	5.51	2.54	-	-	-	-	-	-	-
D-3																	
4	0-8	A.1	80.2	6.3	13.5	6.5	5.2	0.87	0.122	8.16	3.93	0.19	0.11	0.12	2.52	3.00	101.33
	8-23	C1	88.6	3.1	8.3	6.8	5.5	0.19	0.182	3.06	5.03	0.16	0.10	0.11	1.28	1.50	110.00
	23-46	C2	60.4	19.7	19.9	6.2	4.9	0.98	0.149	11.11	5.07	0.22	0.51	0.29	0.48	8.62	17.40
	46-71	C3	77.5	9.8	12.7	6.1	8.8	0.34	0.030	9.45	3.94	-	-	-	-	-	-
	71-86	C4	87.6	0.4	12.0	5.9	4.6	0.60	0.010	9.27	3.08	-	-	-	-	-	-
	86-112	C5	73.9	9.6	16.5	6.4	5.1	0.19	0.035	12.24	3.91	-	-	-	-	-	-
5	0-26	A.1	79.9	6.7	13.4	6.3	5.0	1.48	0.111	18.36	6.03	0.12	0.22	0.17	2.15	3.09	86.08
	26-58	C1	65.3	16.0	18.7	6.7	5.4	1.44	0.037	14.42	3.56	0.14	0.10	0.09	1.19	2.24	67.86
	58-98	C2	75.6	12.4	12.0	6.7	5.5	0.78	0.087	15.60	3.93	0.17	0.10	0.10	2.24	3.37	77.45
	98-124	C3	92.1	0.6	7.3	6.9	5.6	0.78	0.016	6.12	3.06	-	-	-	-	-	-

(Williams, 1947),

$$S = \alpha \log_e (1+N/\alpha),$$

where N and S is total number of individuals and species in plot, respectively.

The second is Morsita's β (Morisita, 1967),

$$\beta = 1/\Sigma (n(n-1)/N(N-1))$$

where n is number of individuals of each species.

The third and fourth are Shanon-Weaver function (MacArthur & MacArthur, 1961),

$$H'_{(n)} = -\Sigma (n \log_2(n)),$$

$$H'_{(BA)} = -\Sigma (BA \log_2(BA)),$$

where n and BA are relative dominance of each species in number and BA, respectively. D-1 had the highest diversity. It had a complex topography, flat and steep river banks and a few open areas logged recently. Dipterocarp forest of D-4 on steep slope had diversity similar to D-1. The plot of 5000 m² had 325 species of trees bigger than 4.8 cm in DBH. D-3 in natural forest of *S. stenoptera* had lower diversity and its Fisher's α was nearly 42. Most area in this plot was flat river bank and exclusively dominated by *S. stenoptera*. The value was similar to those in M-3 and N-1+2. M-3 seemed to be

originated from natural forest of *S. stenoptera* and modified only a little. In 1-ha from N-1 to N-4, 123 species of 634 trees ($D > 4.8\text{cm}$) was found, its diversity is much higher than natural forest in warm temperate zone. Most of the species was wild trees that might be remains of the lost natural forest. Though the lost forest might be a lowland dipterocarp forest, no Dipterocarpaceae was found except tengkawang and a tree of *Dipterocarpus crinitus* out of the plot. Dipterocarpaceae without seedbanks and the ability of vegetative reproduction might be extinct in this area though many other species survived.

DISCUSSION

Habitat preference of tengkawang species

In the tengkawang species of our study area, *Shorea stenoptera* was the most common and economically important species. It preferred sandy banks a few meter higher than the river water though it could grow on slopes if it had been planted such as plantations in M-1 (Fig. 7) or experimental forest at Haurbentes, Bogor. It became a large tree of 50 m height with light wood (Suzuki, unpublished data). It had the large leaf and fruit, and short fruit sepals. *S. seminis* preferred the same habitat with *S. stenoptera* but the former was less common. It made small fruits with short wings and is easily identified from its smaller leaves lepidote beneath. The fruits of both species with short sepals may be adapted to water dispersal (Suzuki & Ashton, 1996). *S. mecistopteryx*, *S. pinanga*, and *S. amplexicaulis* grew on mountain slopes and had long fruit sepals. Out of our study site, *S. macrophylla* grew in a kerangas forest of Mandor (Fig. 1). It had similar leaf and fruit with *S. stenoptera* but a understorey tree of 20 m height and the trunk base were usually in water.

History of use by European

De Vriese traveled in West Kalimantan from October 1860 to early of 1861 (De Vriese, 1861; Van Steenis-Kruseman, 1948-1954), and found at first the tengkawang species: *Shorea splendida* (De Vriese) Ashton, *S. stenoptera* Burck, and *S. seminis* (De Vriese) Slooten. In 1886 Burck wrote a report of Mijyak tengkawang (fat of tengkawang) based on the collection by De Vriese. At that time, the Dutch knew the economic importance of tengkawang fat from West Kalimantan where were many small kingdoms under the control of the colonial government.

After the increase of demand for illipe nuts for export, the plantations of tengkawang were made at Ngabang which was the capital city of Landak Kingdom. Sanggau is one of the most important site of illipe nuts production and in the area of the natural distribution of *S. stenoptera*. But Sanggau was another small kingdom at that time. Landak Kingdom had natural habitat of *S. stenoptera* only in remote area such as the Daid River. For the convenience of transportation of hundreds tons of illipe nuts, Ngabang might be selected as plantation site, though it was probably out of natural distribution. Before recent construction of road, the most important transportation was boat. The Landak river between Ngabang to Pontianak is enough wide to transportation by boat though the Daid river is only a small stream as shallow as 0.5 m in most part.

Traditional use of tengkawang and its effect on forest

Before the study by Dutch in middle of the 19th century, people in West Kalimantan had known the value of tengkawang and used them. They had changed the forests by cutting woods and planting of useful trees such as *Durio*, *Artocarpus*, *Lansium* and tengkawang. Even a introduced species from Latin America, *Bullucia pentamera*, spread at open sites along rivers in natural forest areas. *S.*

stenoptera prefers the habitat of flat and sandy river banks. Because these sites were also suitable place to make villages, *S. stenoptera* was easily affected by human activity. The people often changed the location of their settlements. Thus the forests, which were distant from villages of today and looked like natural ones, might be affected by people in old time. Then the *S. stenoptera* forests in Daid and Muarailai have the possibility of plantations older than the plantation at Ngabang. The canopy trees of *S. stenoptera* in Daid and Muarailai were larger than those in plantation in Ngabang and looks older than the latter. The former seemed to have germinated before the start of export in late 19th century.

But we think that the possibility of plantation before the late 19th century is very low from the following reasons. One of the reason is that the demand of illipe nuts to home use seemed to be low before the start of export, and is nearly zero today. The production of fat from tengkawang is time consuming work and is not preferred by people. According to people at Muarailai and Ngabang, the traditional way of making fat from illipe nuts of Dayak is as follow: 1) take the wings and seed coat and dry the embryo, 2) crash them, 3) put them into bamboo, 4) heating the bamboo with fire, and 5) turn the bamboo and melted fat flow down. They said also that this method was inefficient to get fat, and no one wanted to make fat after coconuts oil became available. Then the fat of tengkawang was rarely found in the village where the illipe nuts were harvested. The second reason is that the *Shorea* species make fruit only one time in several years. If people want to use the fat every day they must make a big stock at the fruiting season. The third reason is that the fat can be also made from many other *Shorea* species though *S. stenoptera* is preferred as the source because the big production of large fruit. The enough amount of nuts for the family use might be available from forests of many *Shorea* species around villages. The fourth reason is that the distribution is far from villages existed for long periods. For example Serimbu, the central village of the area of Daid River for hundreds years, had only a few trees of *S. stenoptera* though there are many river banks suitable for *S. stenoptera* growth around Serimbu. From above reasons, the value of tengkawang as the source of fat for local people was not so great to promote to make the plantation before the start of export. Therefore we consider that the tengkawang forests in Daid was natural. The *S. stenoptera* forest in Muarailai changed partly by human activity but the most big trees were germinated naturally.

Tengkawang forests of today

Tengkawang trees such as *S. stenoptera*, *S. pinanga*, and *S. amplexicaulis* can make forests of 50m in height and a large biomass. The old plantation also had rather high species diversity though the flora might be biased a little. These value are much higher than the rubber tree (*Hevea brasiliensis*) and oil palm (*Elaeis guineensis* Jacq.) plantations which are planted most frequently in West Kalimantan. And tengkawang species are native trees though rubber tree and oil palm were introduced species from Latin America and Africa, respectively. It can serve the economic benefit from the fruit, though it fruits only a time in several years. Then the tengkawang forests have the possibility to keep the forest biomass, biodiversity and economic needs. The economic value of the illipe nuts was, however, much lower than rubber plantation or shifting cultivation because of its character of rare fruiting. Then many tengkawang forests were suffered to be logged or burnt in spite of its protection by law. The tengkawang plantation of M-1 was changed into shifting cultivation in 1992, many trees in D-2 and D-3 were logged. Then we abandoned the remeasure in these plots. The old plantation in Ngabang may be sold for logging because the owner can get few benefit from the nuts. We need more strong control to protect the tengkawang forests, and also need to increase the commercial value of illipe nuts in the global market.

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山田俊弘, 梶 幹男 さまざまな管理下にある西カリマンタンのテンカワン林の生態

西カリマンタンのフタバガキ科の *Shorea* 属の中には、テンカワンと呼ばれ、果実から油脂がとれ、経済的に有用な樹種が約 10 種類ある。果実は天然林・半天然林および植林から採集されてきた。このような人間の活動によってテンカワン林がどのように変化したかを研究するために、1991 年に 8 つの調査地を設定した。かつてのランダック王国の首都であったンガバンでは、それぞれ約 1 km² のテンカワン植林が、約百年前に王家によって、ランダック川沿いに 2 つ作られた。テンカワンの代表的な種である *Shorea stenoptera* は、自然の立地に似た川の近くの平坦な堤防に、*S. amplexicaulis* と *S. pinanga* などは斜面に植えられた。それらは胸高直径 (DBH) 125 cm 樹高 49 m に達し、1991~1994 年の平均直径成長速度は 0.28 (±0.32SD) cm/年であった。パラゴム *Hevea brasiliensis* は平坦地に、昔ゴム生産に使われた *Palaquium gutta* は斜面に、テンカワン下層木として栽培されていた。1ha の調査地内に DBH 4.8 cm 以上の樹木が 123 種あり、テンカワン天然林と大差ない多様性を持っていた。

ムアライレイ村近くの小さな川沿いの堤防の上に、半自然状態の最大 DBH 186 cm に達するテンカワン林があった。元は天然林と思われるが不要な木を伐採し、パラゴムやドリアンなどをテンカワンの間に植栽していた。

ランダック川支流のダイド川沿いには、ほぼ自然状態のテンカワン林があった。森林構造は半自然林と似ているが、南米原産で逸出帰化した *Bullucia pentamera* が見られる他は栽培種はなかった。平坦な砂質自然堤防上のテンカワン天然林では、*S. stenoptera* が胸高断面積合計の 8 割を占めるので、斜面のフタバガキ天然林よりずっと多様性が低かった。