STRUCTURE AND DYNAMICS OF FOREST STANDS IN GUNUNG GADUT, WEST SUMATRA

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Introduction

In this report, we describe results of the research of permanent tropical forest plots in 1987-1988. The permanent plots were established in Gunung Gadut area, about 18 km east from Padang, West Sumatra, during preceding researches (cf. Hotta, 1984, 1986). At the 1987-1988 research, it passed three to seven years after the establishment of these plots. We are going to continue research at least for 10 years, and here we sketch a brief outline of results of the research.

We express our thanks to many students of the lab of forest ecology, Department of Biology in Andalas University, for their helping every field research.

Field research in 1987-1988

The plots surveyed are listed in Table 1. Hereafter, we refer to each forest plot by the abbreviation in Table 1. Fig. 1 is the map of Gunung Gadut area showing the position of plots.

Among these plots, two 1 ha plots, PIN and GAJ, are established on the old-growth foothill forest where the effect of selection cutting of trees is not strong. AIR and GAD are on virgin forests at higher elevations, which are characteristic cloud forests, or montane evergreen oak forests, at respective elevations. PAT is the transect plot of 10 m wide and 370 m long, crossing a ridge just above PIN from a valley to another valley. An old-growth forest stand covers around the ridge (PATr), while two valley sides are secondary stands affected by clear felling some 15-20 years ago (PATv2), or by flooding, erosion and a severe selection cutting (PATv1). PBA is a 7-year-old secondary stand (clear-felled in 1980), which is located just below PIN. Further description can be seen in earlier

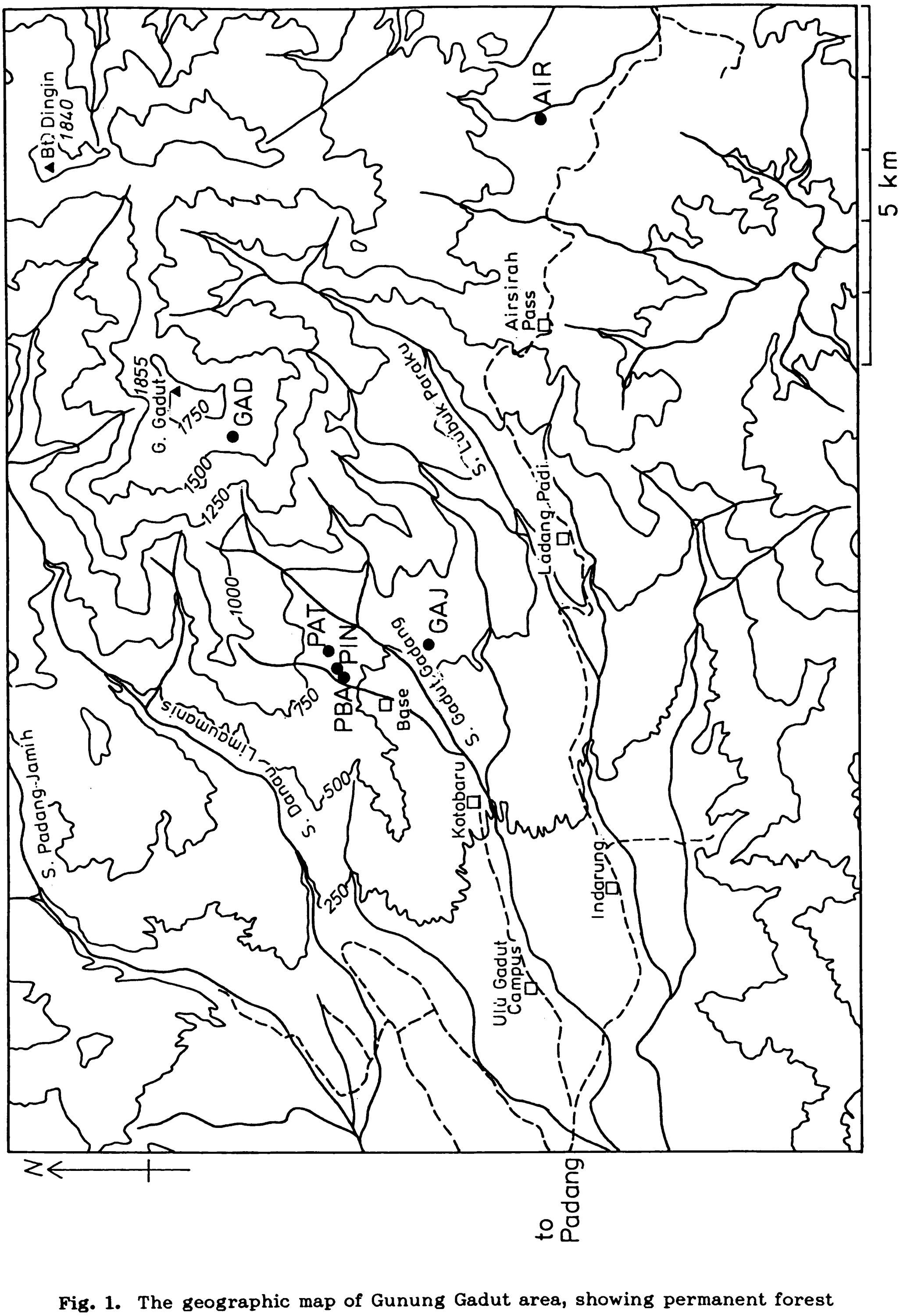

Fig. 1. The geographic map of Gunung Gadut area, showing permanent forest plots (solid circles), with contour at 250 m intervals. Distinctive points are marked by open squares, including the Ulu Gadut Campus of Andalas University and the research base of the house of field guide, Mr. Satar. Bt., Bukit (= Mount); G., Gunung (= Mount); S., Sungai (= River).

Table 1. Permanent Plots in Ulu Gadut region

Plot name (Abbreviation)	Altitude (m)	Area (ha)	Established
Pinang Pinang Plot (PIN)	590-620	1.0041	Sep. 1981
Pinang Pinang Atas Transect (PAT)	570-660	0.3381	Sep. 1984
Ridge old-growth stand (PATr)*		0.1714	
SE valley secondary stand (PATv1)*		0.0631	
NW valley secondary stand (PATv2)*		0.1036	
Pinang Pinang Bawah Plot (PBA)	560	0.0880	Sep. 1984
Gajabuih Plot (GAJ)	590-635	0.9054	Dec. 1980
Airsirah Plot (AIR)	1,130	0.0961	Sep. 1980
G. Gadut Plot (GAD)	1,610	0.0883	Jan. 1983

* PATr, subplot no. 12-30 of PAT transect; PATv1, subplot no. 31-37; PATv2, subplot no. 1-11.

reports (Ogino *et al.*, 1984; Kohyama and Hotta, 1986).

During the present research, we made plot tree census between November 1987 and January 1988. Measurements of dbh (= trunk diameter at breast height) for each numbered tree are the basic data, by which we analyze dbh growth rate and mortality of plot trees. Results of the present dbh census are shown with the data of 3-year before in Appendix I. The complete records of past dbh censuses can be seen in Hotta (1986). During the present census, we corrected several errors in the former data sheets, and moved several trees to the identified fraction. The largest tree in dbh among the plots, No. 496 in GAJ (152.2 cm in 1987), was identified to be *Deplanchea bancana* of Bignoniaceae.

We carried out dbh census for trees above 8 cm in dbh for PIN, GAJ, and above 5 cm for PAT, PBA, AIR and GAD plots. We gave new numbers for the trees which grew up above these minimum sizes after the census of 3-year before (except for AIR). Collected samples for identification were labeled and stored in the herbarium of Andalas University. Distribution maps of trunks of number trees in PIN and GAJ are presented in Appendix V. Hotta (1984) presented the crown projection maps in January 1984 for PIN and GAJ. Appendix V also indicates trees died since January 1984.

During the last 2 or 3 years, many emergent and/or canopy trees of GAJ fell down and we observed a large-scale gap creation. Dead trees more than 50 cm in dbh during 1984-1987 were one *Swintonia schwenckii* (130.5 cm), four *Lithocarpus* spp. (82.4, 55.9, 55.1, and 52.1 cm), and one *Quercus gamelliflora* (69.3 cm). Fig. 2 shows the pattern of gap distribution observed by T.K. in September 1984 and in December 1987 for PIN and GAJ. The distinction between canopy gaps and closed stands is rather expedient, differing from person to person. The definition used in this research by T.K. is that gaps are parts of a forest stand marked by an opening of canopy with distinguishable gap-maker (fallen trunks, standing dead or senescent trees), which is sometimes covered by the closed foliage layer of regrowth less than 20 m in height, and that closed stands are

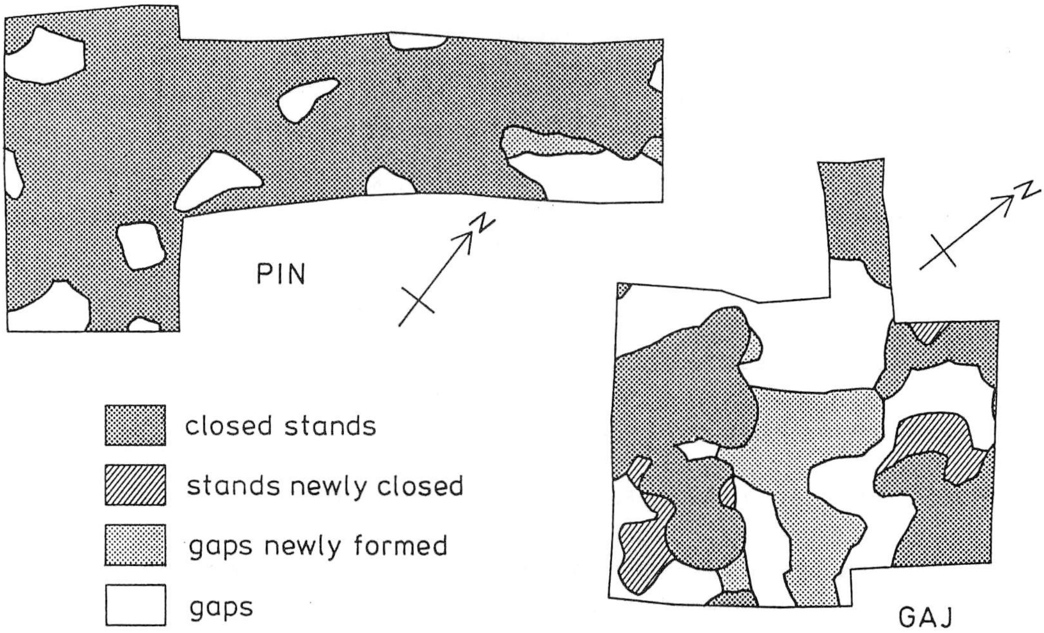

Fig. 2. Distribution of gaps and closed stands, and its change during September 1984 and December 1987, in two 1 ha plots, PIN and GAJ. The state in 1984 is reported by Kohyama and Ogino (1986).

non-gap parts of a forest stand. Gaps in this research can be divided into the gap phase and the building phase of Whitmore (1975) and closed stands correspond to the mature phase of Whitmore. To record the destruction in GAJ, M.H. sketched the profile diagram (Appendix VI-1) for the same forest stand section sketched in December 1980. In PATv1, there was a new gap formation by the fall of a tree of Sterculiaceae (69.7 cm in dbh). For the transect plot PAT, the profile diagram from the central ridge to the valley of southeast slope, including the new gap, was given in Appendix IV-2. In other plots, the death of large trees more than 50 cm in dbh resulting in a large gap formation was not observed during the period between 1984 and 1987.

To analyze the quantitative relationship between dbh and tree height, we measured tree heights of selected trees covering the all size range of plot trees, in PBA, AIR and GAD. Tree heights were calculated by using a degree-level (Ushikata) which had an accuracy of 10 minutes. The raw data appear in Appendix II.

Stand structure and dynamics

Here we describe the stand structure from records of the latest dbh census

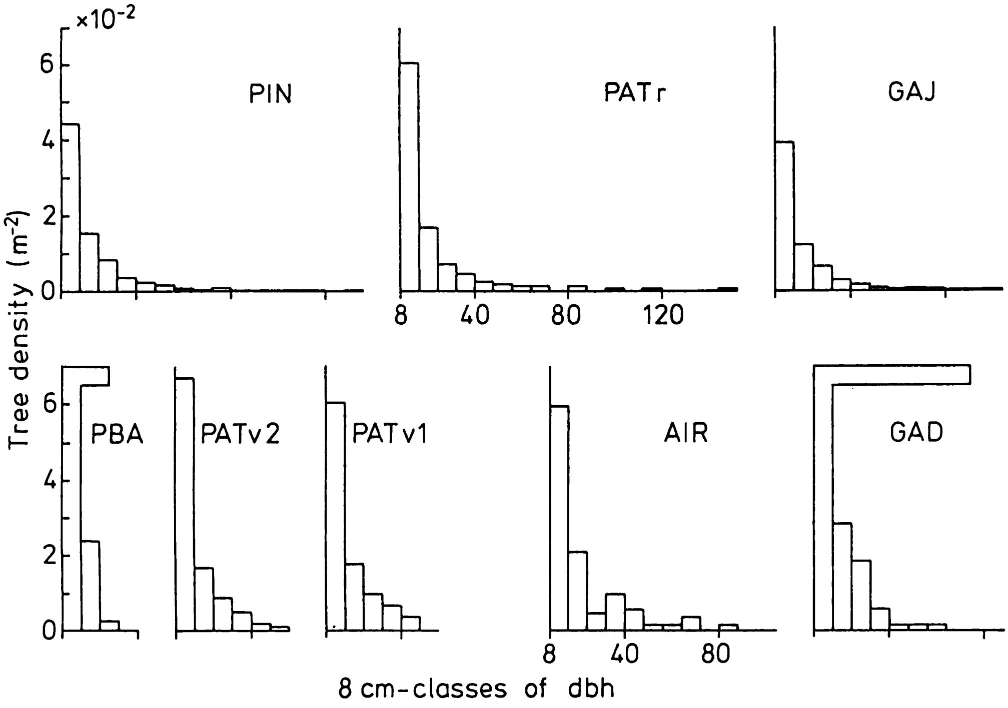

Fig. 3. Frequency distribution of dbh in 8 cm classes, for trees ≥ 8 cm dbh, in December 1987.

(November 1987–January 1988), and compare them with the dbh census carried out three years before (December 1984–January 1985). Though the date of censuses differs among plots, we refer the latest as 1987 census and that 3-year before as 1984 census. The complete original data can be seen in Appendix I. We observe trees ≥ 8 cm in dbh in the following calculation, because the minimum dbh employed in censuses differs between plots, as stated before. We make no distinction between stems of trees and those of lianas here.

Fig. 3 shows the frequency distribution of dbh in 8 cm classes in 1987. Each plot has a positively skewed distribution indicating continuous recruitment of smaller saplings. Tree density in the smallest class (8–16 cm in dbh) is larger in younger secondary stands (PBA, PATv2, PATv1), and in primary forest stands at higher elevation (AIR, GAD) than in old-growth stands of foothill forest (PIN, PATr, GAJ).

We estimate aboveground biomass as follows. Let denote dbh (cm) and tree height (m) by D and H, respectively. D-H relation of each plot is regressed by the generalized allometric function (Ogawa, 1969):

$$1/H = 1/(AD^h) + 1/H^* \tag{1}$$

where A (cm m^{-1}), H^* (m) and h (dimensionless) are regression coefficients. In a preceding report (Kohyama *et al.*, 1986), we calculated

Table 2. Coefficients of the *D-H* curve parameters of eqn (1) with the sum of square of residuals (RSS), estimated for three plots.

Plots	Sample size	$1/A$ ($cm\ m^{-1}$)	$1/H^*$ (m^{-1})	h	RSS	Max tree height (m)
PBA	37	0.621	0.0134	0.900	1.045	23.5
AIR	33	0.829	0.0321	1.273	0.689	33.8
GAD	30	1.224	0.0493	1.438	0.946	19.9

these coefficients applying the non-linear regression method which minimizes the sum of squares of residuals in terms of logarithmic H. In the 1987 research, we added tree height data for PBA, AIR and GAD. Table 2 gives estimates of coefficients for these plots, which are obtained applying the same method as before to data in Appendix II.

Here, we employ two published allometric relationships between D^2H and tree weight. One is obtained in a warm-temperate evergreen oak forest stand in southern Japan by Nagano (1978):

$$D_{0.1} = 0.941D + 0.734 \quad \text{and}$$
$$W = 0.0303D_{0.1}^2H, \tag{2}$$

where $D_{0.1}$ (cm) is the trunk diameter of a tree measured at 1/10 of the tree height and W (kg) is the aboveground dry weight of a tree. The other is reported from a tropical lowland Dipterocarp forest in East Kalimantan by Yamakura *et al.* (1986):

$$W_s = 0.02903(D^2H)^{0.9813},$$
$$W_b = 0.1192W_s^{\ 1.059} \quad \text{and}$$
$$W_l = 0.09146(W_s + W_b)^{0.7266}, \tag{3}$$

where W_s, W_b and W_l (kg) are dry weights of trunk stem, branch stem and leaves of a tree, respectively, and $W = W_s + W_b + W_l$. Our study plots are located in tropical foothill forest and tropical montane oak forest, and they correspond to intermediate forest types between the tropical lowland forest and the warm-temperate evergreen oak forest. So, we calculate biomass estimates using eqns (2) and (3). We find that two biomass estimates are quite similar to each other. We have that [estimate by eqn (3)] = 1.02 [estimate by eqn (2)] - 0.12, for 8 plot types at two times 1984 and 1987, with the correlation coefficient of 0.999999.

Table 3 shows the basal area and the aboveground biomass estimated by eqn (2) in 1984 and 1987. The basal area and the aboveground biomass increased during 1984-1987 except for two plots. In GAJ and PATv1, remarkable new gap creation as stated before resulted in the decrease of basal area and biomass. The increment of basal area and biomass by the recruitment of saplings was not so large as compared with the increment by

Table 3. Biomass dynamics in Ulu Gadut Plots 1984-1987; biomass is estimated by *D-H* curve regression and eqn (2).

Plot	in 1984	in 1987	*G* *	*D* *	*I* *	*E* *
(1) Basal area (cm^2 m^{-2})						
PIN	36.48	38.98	2.33	0.38	0.54	0.01
GAJ	30.66	29.03	2.63	4.92	0.66	0.00
PATr	56.14	60.35	4.62	0.86	0.48	0.03
PATv1	30.74	27.28	4.13	8.16	0.57	0.00
PATv2	21.82	26.09	3.90	0.48	0.85	0.00
PBA	8.77	15.24	4.56	0.42	2.34	0.00
AIR	52.59	54.87	3.34	1.29	0.22	0.00
GAD	38.71	41.60	2.34	0.96	1.57	0.06
(2) Aboveground biomass (kg m^{-2})						
PIN	38.04	40.52	2.50	0.27	0.25	0.00
GAJ	33.84	30.85	3.08	6.32	0.24	0.00
PATr	59.81	65.14	5.74	0.58	0.19	0.01
PATv1	22.06	18.78	3.30	6.83	0.25	0.00
PATv2	14.50	17.69	3.07	0.24	0.37	0.00
PBA	4.64	8.99	3.58	0.18	0.95	0.00
AIR	45.45	47.58	3.10	1.08	0.10	0.00
GAD	21.95	23.63	1.46	0.54	0.79	0.02

* *G*, increment of basal area/biomass by growth of surviving trees during 1984-1987; *D*, decrease by death of trees during 1984-1987; *I*, increment by immigration of trees to the class $\geq$ 8 cm dbh during 1984-1987; *E*, decrease by emigration of trees to the class $<$ 8 cm dbh during 1984-1987. Total change during 3 years is $G + I - D - E$.

the individual tree growth. An exceptionally high rate of recruitment was observed in PBA corresponding to the vigorous recovery of vegetation in this young stand. A high recruitment rate in GAD is artificial one as a large tree had been missed to be numbered until 1987.

The mortality of trees fluctuates year by year, whereas the growth rate of surviving trees is rather stable. The ratio of growth in biomass of surviving trees divided by the biomass in 1984 is 0.022–0.032 $year^{-1}$ for old-growth stands (cf. Table 3). The reverse of this ratio (31–45 years) corresponds to a rough estimate of the rotation time of stand biomass in steady-state forest stands. This ratio is remarkably larger in secondary stands (0.050 in PATv1, 0.071 in PATv2, and 0.357 $year^{-1}$ in the youngest PBA).

Fig. 4 shows the size-specific growth rate and the size-specific death rate of trees, calculated for 2^n octave classes of dbh: 8–16 cm, 16–32 cm, 32–64 cm, 64–128 cm. In old-growth stands of foothill forest (PIN, GAJ, PATr), as well as in those of montane oak forest (AIR, GAD), the relative growth rate in dbh (RDGR, $year^{-1}$) decreases with size. There are no dif-

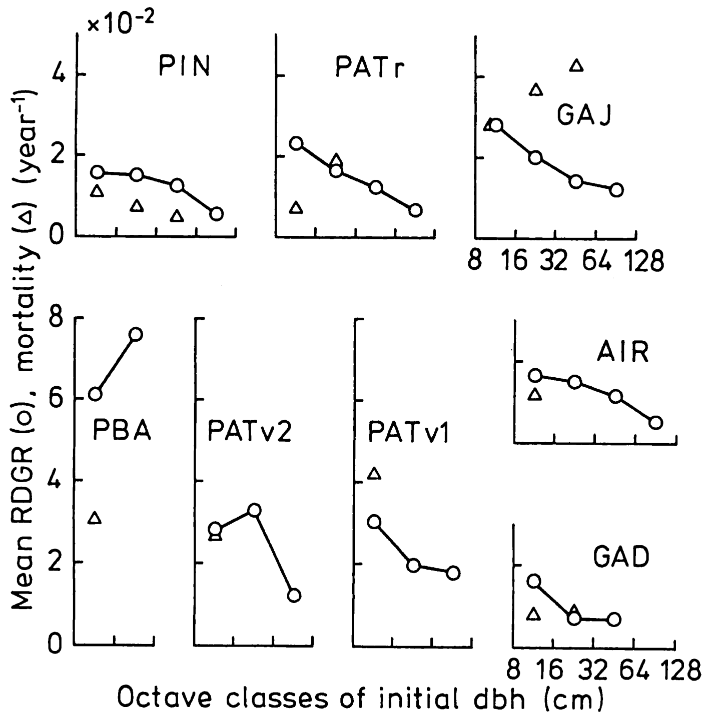

Fig. 4. Mortality and mean growth rate of dbh (RDGR) during December 1984-December 1987, in each of 2^n octave dbh classes in permanent plots. Mortality is estimated for more than 40 trees.

ference in RDGR pattern between forest types in these stable forests. Relatively higher RDGR in GAJ corresponds to higher mortality (higher rate of gap creation) in it, as suggested by Kohyama and Ogino (1986). RDGR is fairly higher in secondary stands of foothill forest (PIN, PATv2, PATv1).

Tree community structure

One of us, M.H., has been identifying plot trees. Though the identification is not yet completed, we can describe an outline of tree communities in each permanent plot. The list of species composition expressed by the number of plot trees is given in Appendix III. To compare tree communities with each other, we analyze here plot trees $\geq$ 8 cm in dbh. Trees belonging to the same genus are treated to be the same species when only their genera are known. Table 4 shows the species list of each plot in sequence of the sum of basal area. It is a distinctive characteristic of species composition that not only in montane oak forest stands but also in old-growth foothill forest stands species of Fagaceae (*Castanopsis* spp., *Lithocarpus* spp. and *Quercus* spp.) appear with a high basal area ratio. Abundant emergent and canopy-layer species in the old-growth foothill forest, such as *Swintonia schwenckii*, *Canarium denticulatum*, *Nephelium*

Table 4-1. Species list of PIN for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Swintonia schwenckii	15	4.699	*Quercus* sp.	4	0.076
Lithocarpus sp.	21	3.151	*Nephelium mutabilis* cf.	1	0.075
Palaquium sp.	48	1.844	*Shorea* sp.	2	0.074
Syzygium sp.	39	1.467	*Planchonia valida*	2	0.069
Canarium denticulatum	4	1.463	*Flacourtia* sp.	2	0.068
Nephelium juglandifolium	17	1.338	*Ganua motleyana*	1	0.068
Quercus gemelliflora	6	1.290	*Mallotus paniculatus*	4	0.067
Castanopsis rhamnifolia	6	0.893	*Memecylon laurinum*	5	0.066
Calophyllum sp.	3	0.829	*Bauhinia* sp.	4	0.061
Mastixia trichotoma	19	0.786	*Artocarpus* sp.	3	0.054
Macaranga hypoleuca	9	0.770	*Vitex gamosepala*	3	0.054
Dysoxylum sp.	18	0.745	*Sterculia* sp.	2	0.053
Phyllanthus indicus cf.	22	0.726	*Pometia* sp.	6	0.052
Grewia florida	26	0.660	*Willughbia apiculata*	5	0.051
Canarium sp.	7	0.627	*Xanthophyllum* sp.	3	0.046
Durio griffithii	9	0.552	*Anthocephallus indicus*	4	0.044
Lithocarpus conocarpum	1	0.550	*Pithecellobium microcarpum*	3	0.040
Lithocarpus platycarpus	2	0.546	*Villebrunea rubescens*	3	0.035
Styrax serrulatum	14	0.446	*Sterculia longifolia*	3	0.034
Artocarpus glauca	7	0.410	*Talauma* sp.	2	0.027
Hopea mengarawan	8	0.377	*Trema orientalis*	1	0.027
Macaranga triloba	12	0.367	*Artabotrys gracilis*	3	0.026
Schima wallichii	5	0.348	*Uncaria* sp.	2	0.024
Ficus sp.	19	0.341	*Quercus lineata*	1	0.024
Castanopsis sp.	4	0.302	*Spondias* sp. cf.	2	0.022
Parashorea lucida cf.	9	0.284	*Macaranga denticulata*	2	0.022
Nephelium sp.	7	0.279	*Cryptocorya zollingeriana*	1	0.020
Hopea sp. cf.	4	0.247	*Pithecellobium* sp. cf.	1	0.020
Platea excelsa	7	0.237	*Lithocarpus ewyckii* cf.	1	0.019
Evodia latifolia	2	0.234	*Ficus miquerii*	2	0.018
Shorea sumatrana	12	0.227	*Apolosa* sp. cf.	2	0.018
Mallotus subpeltatus	15	0.213	*Aglaea dookoo*	1	0.018
Macaranga pruinosa	4	0.204	*Ficus ribes*	2	0.017
Styrax paralleloneurum	7	0.201	*Knema cinerea*	2	0.016
Anisophyllea sp.	1	0.193	*Knema laurina*	1	0.015
Litsea sp.	10	0.188	*Spathostemon javensis* cf.	1	0.014
Sandricum koetjape	10	0.188	*Garcinia dioica*	2	0.014
Urophyllum macrophyllum	10	0.180	*Laportea stimulans*	2	0.013
Litsea cubeba	2	0.154	*Tarenna* sp.	1	0.013
Diospyros sp.	9	0.151	*Apolosa frutescens* cf.	1	0.012
Knema hookeriana	3	0.150	*Mallotus* sp.	2	0.012
Blumeodendron tokbrai	1	0.150	*Xanthophyllum rufum*	1	0.012
Eurya acuminata	8	0.147	*Memecylon* sp.	1	0.011
Knema sp.	6	0.133	*Litsea lanceolata*	1	0.010
Gonystylus forbesii	9	0.129	*Cyathea* sp.	1	0.010
Sterculia cuspidata	7	0.115	*Elaeocarpus* sp.	1	0.010
Phoebe sp.	2	0.098	*Vatica* sp. cf.	1	0.009
Pternandra caerulescens	6	0.092	*Grewia* sp.	1	0.008
Trema angustifolia	4	0.081	*Artabotrys* sp. cf.	1	0.008
Lithocarpus sundaicus cf.	1	0.077	*Randia* sp.	1	0.008

Table 4-1, continued (PIN)

Species	No.	BA*	Species	No.	BA*
Dehasia sumatrana cf.	1	0.008	*Aglaea tomentosa*	1	0.005
Gonyotalamus sp. cf.	1	0.007	*Macaranga* sp.	1	0.005
Alstonia angustifolia	1	0.007	*Nyssa javanica*	1	0.005
Memecylon costatum	1	0.007	*Canarium serratum* cf.	1	0.005
Uvaria sp.	1	0.007	*Cinnamomum* sp.	1	0.005
Shorea multiflora cf.	1	0.006	(not determined)	177	7.380
Fissistigma sp.	1	0.006	Total	791	38.974
Santiria sp.	1	0.005			

Table 4-2. Species list of GAJ for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Deplanchea bancana	1	2.009	*Mallotus paniculatus*	4	0.150
Swintonia schwenckii	13	1.838	*Gironniera subaequalis*	6	0.137
Canarium sp.	8	1.596	*Urophyllum macrophyllum*	9	0.122
Lithocarpus sp.	12	1.573	*Mastixia trichotoma*	3	0.119
Syzygium sp.	40	1.516	*Knema cinerea*	5	0.112
Shorea sp.	7	1.352	*Phoebe* sp.	4	0.093
Litsea sp.	21	0.893	*Macaranga denticulata*	8	0.092
Shorea sumatrana	25	0.841	*Ryparosa caesia*	1	0.091
Palaquium sp.	21	0.815	*Dysoxylum* sp.	6	0.088
Styrax paralleloneurum	9	0.665	*Macaranga hypoleuca*	3	0.087
Planchonia valida	4	0.650	*Evodia latifolia*	1	0.087
Quercus gemelliflora	3	0.644	*Vatica* sp. cf.	1	0.086
Phyllanthus indicus cf.	22	0.629	*Sterculia* sp.	3	0.082
Nephelium juglandifolium	6	0.590	*Baccaurea* sp. cf.	1	0.080
Litsea cubeba	15	0.540	*Polyalthea* sp.	4	0.072
Pithecellobium microcarpum	18	0.458	*Knema hookeriana*	1	0.066
Timonius wallichianus	13	0.449	*Uvaria* sp.	2	0.056
Durio griffithii	8	0.433	*Aglaea* sp.	3	0.053
Lithocarpus sundaicus	2	0.424	*Santiria* sp.	4	0.052
Villebrunea rubescens	26	0.391	*Mallotus subpeltatus*	4	0.048
Lithocarpus ewyckii cf.	1	0.364	*Ellipanthus tomentosus*	5	0.047
Gonystylus forbesii	13	0.359	*Ficus* sp.	5	0.045
Ficus ribes	12	0.317	*Knema* sp.	2	0.044
Diospyros sp.	9	0.310	*Planchonia* sp.	1	0.042
Tristania bakhuizeni	1	0.262	*Platea excelsa*	2	0.042
Canarium denticulatum	7	0.249	*Pternandra caerulescens*	3	0.042
Anisophyllea sp.	8	0.248	*Pithecellobium* sp.	1	0.037
Nephelium sp.	2	0.246	*Cinnamomum verum*	2	0.033
Schima wallichii	2	0.236	*Flacourtia rukam* cf.	2	0.032
Hopea mengarawan	6	0.222	*Phyllanthus* sp.	1	0.029
Grewia florida	7	0.201	*Garcinia dioica*	1	0.028
Macaranga triloba	11	0.187	*Calophyllum* sp.	1	0.028
Castanopsis rhamnifolia	1	0.186	*Memecylon* sp.	1	0.027
Trema angustifolia	6	0.182	*Podocarpus neriifolius*	1	0.027
Castanopsis lucida cf.	1	0.182	*Neesia* sp. cf.	1	0.024
Laportea stimulans	14	0.166	*Aglaea tomentosa*	2	0.024

Table 4-2, continued (GAJ)

Species	No.	BA*	Species	No.	BA*
Artabotrys sp. cf.	2	0.024	*Uncaria* sp.	1	0.009
Polyosma integrifolia	1	0.023	*Memecylon laurinum*	1	0.009
Styrax serrulatum	2	0.022	*Gymnacranthera paniculata*	1	0.009
Ficus miquerii	2	0.022	*Anthocephallus indicus*	1	0.007
Myristica sp.	2	0.020	*Mitrephora* sp.	1	0.007
Wrightia laevis	1	0.020	*Dracaena elliptica* cf.	1	0.007
Eurya acuminata	2	0.020	*Euonymus* sp.	1	0.007
Popowia sp.	1	0.020	*Dialium* sp. cf.	1	0.007
Artocarpus glauca	1	0.019	*Arthrophyllum* sp.	1	0.006
Blumeodendron sp.	1	0.017	*Carallia* sp. cf.	1	0.006
Cinnamomum sp.	2	0.016	*Trigonostemon* sp.	1	0.006
Vitex gamosepala	2	0.015	*Neuclea* sp.	1	0.006
Ardisia sp.	2	0.014	*Mallotus* sp. cf.	1	0.006
Elaeocarpus sp.	1	0.014	*Artabotrys gracilis*	1	0.006
Schefflera sp.	1	0.012	*Xanthophyllum* sp.	1	0.005
Pometia sp.	1	0.011	(not determined)	77	4.026
Milletia sp. cf.	1	0.010	Total	596	29.024

Table 4-3. Species list of PATr for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Shorea sp.	3	9.646	*Villebrunea rubescens*	2	0.253
Dysoxylum sp.	9	8.197	*Cyathocalyx* sp.	1	0.229
Quercus sp.	1	6.219	*Litsea* sp.	3	0.179
Lithocarpus sp.	1	3.279	*Platea excelsa*	3	0.170
Nephelium sp.	5	3.062	*Mallotus subpeltatus*	2	0.156
Quercus lineata	4	2.928	*Carallia* sp. cf.	1	0.155
Santiria sp.	2	2.227	*Shorea sumatrana*	3	0.150
Canarium sp.	3	2.140	*Oncosperma* sp.	1	0.143
Phyllanthus indicus cf.	9	1.519	*Swintonia schwenckii*	1	0.096
Planchonia sp.	2	1.429	*Vitex gamosepala*	1	0.092
Syzygium sp.	9	1.353	*Alstonia* sp.	1	0.077
Palaquium sp.	9	1.270	*Urophyllum* sp.	1	0.075
Artocarpus sp.	1	0.965	*Polyosma integrifolia*	1	0.057
Quercus gemelliflora	2	0.890	*Pithecellobium microcarpum*	1	0.054
Diospyros sp.	10	0.886	*Ellipanthus tomentosus*	1	0.049
Gonystylus forbesii	1	0.883	*Urophyllum macrophyllum*	1	0.044
Sterculia sp.	5	0.848	*Styrax serrulatum*	1	0.041
Hopea mengarawan	3	0.775	*Pternandra caerulescens*	1	0.041
Ficus sp.	10	0.724	*Phyllanthus* sp.	1	0.036
Nyssa sp.	1	0.617	*Grewia florida*	1	0.033
Parashorea lucida	1	0.526	*Ficus ribes*	1	0.033
Xanthophyllum sp.	3	0.502	*Timonius wallichianus*	1	0.033
Durio griffithii	1	0.366	*Macaranga pruinosa* cf.	1	0.031
Laportea stimulans	2	0.347	*Aglaea* sp.	1	0.031
Macaranga denticulata	1	0.297	(not determined)	31	5.889
Macaranga triloba	2	0.286	Total	163	60.349

Table 4-4. Species list of PATv1 for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Cyathocalyx sp.	3	2.973	*Flacourtia* sp.	1	0.347
Erythrina sp.	5	2.241	*Ficus ribes*	1	0.276
Syzygium sp.	3	1.963	*Urophyllum macrophyllum*	2	0.213
Macaranga hypoleuca	1	1.778	*Saurauia* sp.	1	0.185
Vitex gamosepala	6	1.612	*Aglaea* sp. cf.	1	0.179
Macaranga pruinosa	1	1.388	*Tabernaemontana* sp.	1	0.142
Ficus sp.	4	1.269	*Canarium* sp.	1	0.124
Myristica sp.	2	0.814	*Palaquium* sp.	1	0.121
Dysoxylum sp.	3	0.772	*Ellipanthus tomentosus*	1	0.098
Laportea stimulans	2	0.605	*Castanopsis* sp. cf.	1	0.081
Villebrunea rubescens	2	0.390	(not determined)	16	9.346
Piper aduncum	2	0.350	Total	61	27.278

Table 4-5. Species list of PATv2 for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Mallotus sp.	9	5.664	*Myristica* sp.	1	0.373
Anthocephallus indicus	8	2.148	*Macaranga* sp.	1	0.363
Artocarpus sp.	2	1.890	*Dysoxylum* sp.	2	0.303
Elaeocarpus sp.	9	1.446	*Sterculia* sp.	3	0.280
Styrax serrulatum	3	1.193	*Trema angustifolia*	2	0.186
Erythrina sp.	1	0.950	*Piper aduncum*	2	0.153
Mallotus paniculatus	2	0.903	*Pternandra caerulescens*	1	0.148
Ficus sp.	6	0.871	*Tabernaemontana* sp.	1	0.144
Macaranga triloba	4	0.730	*Pometia* sp.	2	0.114
Macaranga hypoleuca	2	0.703	*Grewia florida*	1	0.065
Villebrunea rubescens	9	0.631	*Claoxylon longifolium*	1	0.064
Symplocos sp.	2	0.433	(not determined)	20	5.522
Laportea stimulans	7	0.416	Total	103	26.090
Ficus ribes	2	0.384			

Table 4-6. Species list of PBA for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Vernonia arborea	21	4.623	*Macaranga gigantea*	1	0.104
Mallotus paniculatus	12	2.378	*Palaquium* sp.	1	0.092
Trema orientalis	3	1.781	*Ficus* sp.	1	0.082
Macaranga sp.	4	1.056	*Saurauia* sp.	1	0.080
Elaeocarpus sp.	3	0.906	*Trema angustifolia*	1	0.072
Villebrunea rubescens	9	0.684	*Nephelium* sp.	1	0.070
Styrax serrulatum	4	0.331	*Knema* sp.	1	0.070
Macaranga denticulata	3	0.290	*Macaranga hypoleuca*	1	0.069
Sapium sebiferum	2	0.288	*Dysoxylum* sp.	1	0.062
Urophyllum macrophyllum	3	0.225	*Coffia arabica*	1	0.060
Erythrina sp.	2	0.213	*Ficus ribes*	1	0.057
Breynia sp.	2	0.174	(not determined)	10	1.338
Macaranga triloba	2	0.120	Total	91	15.236

Table 4-7. Species list of AIR for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Quercus lineata	5	8.702	*Neesia altissima*	1	0.176
Schima wallichii	2	6.265	*Litsea cubeba*	1	0.160
Tristania bakhuizeni	4	4.257	*Knema* sp.	1	0.151
Palaquium sp.	6	3.929	*Canarium* sp.	2	0.127
Syzygium sp.	11	1.826	*Aglaea* sp.	2	0.122
Lithocarpus ewyckii	1	1.327	*Castanopsis* sp.	1	0.119
Cinnamomum javanicum	6	0.843	*Pithecellobium* sp.	1	0.088
Litsea sp.	3	0.523	*Magnolia* sp. cf.	1	0.080
Polyalthea sp.	2	0.509	*Timonius wallichianus*	1	0.078
Lithocarpus sp.	1	0.436	*Cyathocalyx* sp. cf.	1	0.070
Polyosma sp.	3	0.387	*Semecarpus heterophyllus* cf.	1	0.061
Adinandra dumosa	2	0.338	*Ficus* sp.	1	0.057
Weinmannia blumei	1	0.336	*Xanthophyllum* sp.	1	0.053
Elaeocarpus stipularis	2	0.260	(not determined)	35	23.130
Cinnamomum sp.	1	0.225	Total	101	54.866
Macaranga javanica	1	0.219			

Table 4-8. Species list of GAD for trees ≥ 8 cm dbh.

Species	No.	BA*	Species	No.	BA*
Lithocarpus elegans cf.	11	4.685	*Memecylon ovatum* cf.	2	0.418
Tristania bakhuizeni	16	4.289	*Chrysophyllum malayanum*	1	0.338
Canarium sp. cf.	2	2.031	*Ilex* sp.	1	0.304
Syzygium sp.	8	1.211	*Myrica javanica* cf.	1	0.257
Lithocarpus sp. cf.	2	1.193	*Polyosma* sp.	1	0.251
Anneslea fragrans	9	1.163	*Bucklandia tricuspis*	1	0.152
Podocarpus neriifolius	6	1.120	*Memecylon laurinum*	1	0.150
Disepalum platypetalum	3	0.909	*Cinnamomum* sp.	1	0.113
Litsea sp.	1	0.805	*Talauma* sp.	1	0.080
Ellipanthus tomentosus	5	0.665	*Neolitsea* sp.	1	0.076
Weinmannia blumei	3	0.634	*Garcinia* sp.	1	0.065
Macaranga javanica	5	0.548	(not determined)	56	19.140
Platea excelsa	1	0.533	Total	143	41.601
Elaeocarpus sp.	3	0.459			

* BA = sum of trunk basal area ($cm^2\ m^{-2}$) for each species.

Table 5. Species diversity in Ulu Gadut forest plots

	PIN	GAJ	PATr	PATv1	PATv2	PBA	AIR	GAD
Total no. of trees	791	596	163	61	103	91	101	143
No. of identified trees	614	519	132	45	83	81	66	87
No. of identified species	113	104	50	22	25	24	29	25
Simpson's index	42.8	40.9	30.0	22.0	17.6	9.5	19.0	13.1

juglandifolium, *Shorea sumatrana*, *Hopea mengarawan*, *Lithocarpus* spp. and *Quercus* spp. are disappeared in secondary foothill stands, where pioneer species, such as *Macaranga* spp., *Mallotus* spp., *Vernonia arborea*, *Villebrunea rubescence* and *Laportea stimulans*, take the place of them.

Table 5 shows the number of trees/species and the Simpson's index of species diversity (Simpson, 1949). The Simpson's index of diversity as the unbiased estimate for the finite community is expressed by $[S^2 - S]/[S_2 - S]$, where S and S_2 are the sum of number of trees and the sum of square of number of trees for every species, respectively. In Table 5, we can find clear tendencies that (1) tree species diversity is richest in old-growth stands of foothill forest (PIN, GAJ, PATr) among our permanent plots, that (2) it increases with aging of secondary stands in the same forest type (PBA -> PATv2 -> PATv1 -> PIN, GAJ, PATr), and that (3) it decreases with elevation in old-growth forest stands (PIN, GAJ, PATr -> AIR -> GAD).

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