FORESTS OF THE ULTRAMAFIC MOUNT GITING-GITING, SIBUYAN ISLAND, THE PHILIPPINES

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Mount Giting-Giting is an ultramafic mountain on Sibuyan Island, Romblon Province, Republic of the Philippines. It was studied along the Mayo's Peak Ridge which had rainforest from about 200m up to c.1550m. The grassland and scrub vegetation from 1550m to the summit (2050m) of Giting-Giting was not explored. The mean annual rainfall at the base of the mountain was c.2100mm which included a dry season around February and March. There was a notable increase in wind speed with altitude and there was about one hurricane (called a cyclone in the Philippines) per year. Analyses showed that the soils are acid (pH_{H_2O} 4.4–5.5), and have relatively low concentrations of Olsen extractable phosphorus (0.22–2.07μg g^{-1}), low exchangeable potassium (0.04–0.41mEq $100g^{-1}$), and relatively low (for ultramafic soils) Mg/Ca quotients (0.31–2.87) and exchangeable nickel (1.0–23.8μg g^{-1}). Coupled plots (of 0.25 or 0.04ha) were studied at altitudes from 325m to 1540m. All trees ≥10cm dbh were enumerated and structural features of the trees and smaller plants were quantified. The forests were all of fairly small stature (maximum tree height 24m) but dense (up to 2180 trees ha^{-1} in Lower Montane Forest (LMF) and up to 880 ha^{-1} in Upper Montane Forest (UMF)). While different taxa could be readily recognized, specific determinations were often impossible from the mainly sterile specimens. The LMF was species rich with up to at least 111 species of tree (≥10cm dbh) per 0.25-ha plot. There was no family clearly dominant in the two lower plots at 325m and 385m (where the *Dipterocarpaceae* were probably reduced by logging). At 770m and 860m the *Dipterocarpaceae* accounted for 12.9% and 14.7% of the basal area respectively. There was a surprisingly high representation of the *Sapotaceae* (25.9% of the basal area) at 1240m. At 1540m, the *Araucariaceae* (*Agathis* sp.) dominated one plot (37.1% of the basal area) and the *Myrtaceae* the other (72.4%).

Keywords. Floristics, tropical forests, tropical soils, ultramafic.

INTRODUCTION

The vegetation of ultramafic rocks (often called serpentine or ultrabasic rocks) has been reported as distinctive from many parts of the world (Brooks, 1987; Baker et al. 1992; Roberts & Proctor, 1992). It is often sparse or stunted and contains species which are rare or endemic or both. The explanations for these features have centred on the chemistry of the soils because they usually have potentially toxic concentrations of magnesium and nickel and are deficient in phosphorus, potassium and calcium (Proctor & Woodell, 1975). Much remains to be discovered about

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ultramafic vegetation in tropical south-east Asia but it is known to vary greatly in physiognomy and degree of species endemism (Proctor, 1992).

Ultramafic rocks occur frequently in the Philippines and examples with scrub and *Gymnostoma*-woodland have been described by Proctor et al. (1997). A good example with larger stature rainforest vegetation occurs on ultramafic rocks on Mount Giting-Giting on Sibuyan Island (Romblon Province) at 12°25′N, 122°34′E (Fig. 1). This small coastal mountain has an altitude of c.2050m and consists entirely of ultramafic rocks of the Sibuyan Formation, which are of Cretaceous to Eocene age (Bureau of Mines, 1989). The forest was studied along the Mayo's Peak Ridge which runs from north-east to south-west to reach a peak of c.1550m. Up to c.200m the forest has been destroyed and replaced by grassland and beyond that there is Lower Montane Forest (LMF, *sensu* Whitmore, 1984) in which up to c.700m there

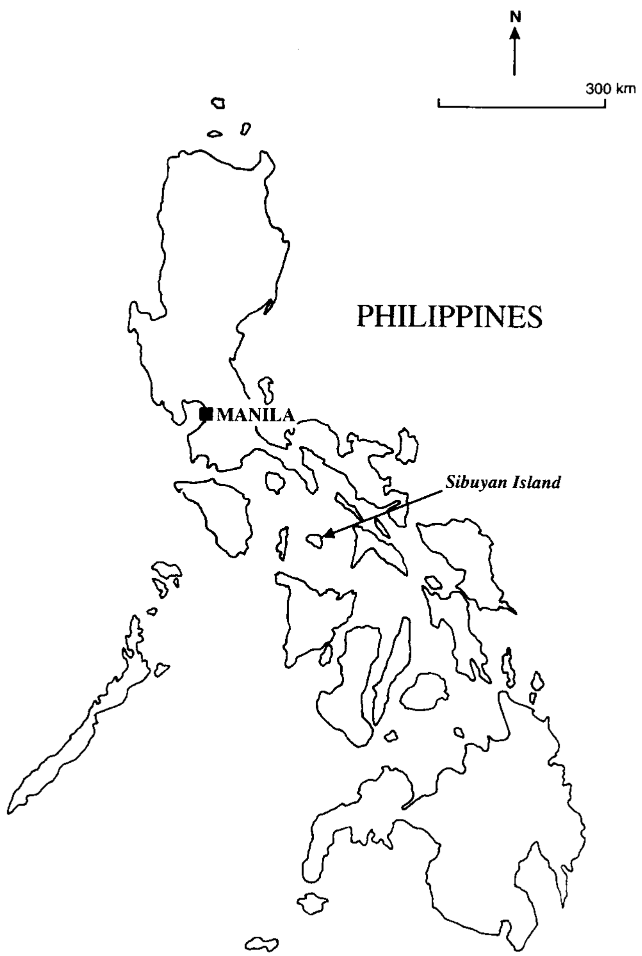

FIG. 1. The location of Sibuyan Island in the Republic of the Philippines.

has been illegal logging. The logging has removed many larger individuals of commercial trees sawn *in situ* and dragged out by carabao. There was no evidence of logging above 700m and the vegetation changed to Upper Montane Forest (UMF) at about 1000m. The forest stopped at c.1540m, to be replaced by grassland and scrub up to the summit.

The aims of this paper are to describe the forests along the Mayo's Peak Ridge and their physical environment, and to contrast them with other ultramafic sites in tropical south-east Asia to gain some insight into the causes of the differences in the ultramafic vegetation. It is hoped that the descriptions will draw attention to the need for conservation of the Giting-Giting forests which are threatened and now isolated because of widespread destruction in the surrounding areas. The field studies were made from July to September 1989 by a joint team from the National Museum of the Philippines, the Royal Botanic Garden Edinburgh and the universities of Sheffield and Stirling.

CLIMATE

The following account of the climate is based mainly on PAGASA (1989). A mean annual rainfall of 2105mm has been recorded near sea level from Romblon (c.50km from the base of Mount Giting-Giting) for the years 1951–1985. The driest months were February and March which each had a mean rainfall of 48.3mm and the wettest October, with 323.1mm. Mean minimum temperatures were 24.3°C (range 23.3°C for January to 25.4°C for May), and mean maximum temperatures were 30.5°C (range 28.4°C for January to 32.5°C for May). The monthly mean wind speed varied from 3 to 4m s^{-1} but there were occasional (about one per year on average) hurricanes (cyclones). Between 1966 and 1986 the highest wind speed recorded was 62m s^{-1} on 3 July 1971. In 1989 a few measurements were made by the authors on Mount Giting-Giting. Rainfall from 2 August to 24 September was 399mm at 290m and 417mm at 1540m. Cloud was frequently observed at c.1000m and above, which roughly coincided with the lower limit of UMF. Soil temperatures were measured over a few minutes at 50cm depth at two altitudes in August 1989: they were 24.0°C at 315m, and 18.1°C at 1550m, indicating a lapse rate of 0.48°C per 100m. The main south ridge of Giting-Giting was markedly windy at 1550m when speeds of up to 18m s^{-1} were recorded using a hand-held anemometer (integrated over 30 seconds) at times when simultaneous records in a clearing (at 350m) showed wind speeds of less than 3m s^{-1}.

METHODS

Forest description

Paired plots of 50m × 50m were set up between 25 July 1989 and 15 August 1989 in typical examples of the logged LMF (plots 1A at 325m, 1B at 385m), the unlogged LMF (plots 2A at 770m, 2B at 860m), and the UMF (plots 3A and 3B at 1240m).

Two further plots (4A and 4B) of 25m × 25m were placed in UMF at 1540m on 8 September 1989. All the plots except 4A and 4B were on steeply sloping ground (Table 1).

The plots were surveyed and the trees ($\geq$ 10cm dbh) were enumerated. The diameters of the trees were measured at breast height (1.3m) and herbarium specimens were collected for each individual. The leaf-size class of each tree was estimated from samples of 10 mid-canopy leaves collected by tree climbers for plots 1A, 2B and 3A. Profile diagrams of trees over 6m high were drawn for 7.5m-wide strips of mature phase forest in the same three plots. The following forest features were measured by assessing a sample of 75 consecutively numbered trees (or all the trees in plots 4A and 4B): the presence or absence of buttresses; the presence or absence of lianas with a minimum dbh of 1cm; and the estimated cover of epiphytic bryophytes on the bole at 2m.

Tree identifications

There are very great difficulties identifying sterile tree specimens from poorly known regions. In this case the specimens were sorted into morphological taxa and matched with named specimens in the herbaria at the Royal Botanic Gardens of Edinburgh and Kew. The former has a set of duplicates of Elmer's March–May 1910 expedition to Mount Giting-Giting and eventually all but about 4% of the specimens from the 1989 expedition were assigned at least to family (except for plot 3B for which most of the specimens were lost).

Soil sampling and analysis

Unweathered rock samples were collected from exposures at 300m, 700m and 1500m altitude and analysed by X-ray fluorescent spectroscopy. A soil pit was dug to a

TABLE 1. The plot notation, altitude, dimensions, aspect and slope of four Lower Montane Forest (LMF) plots (1A, 1B, 2A and 2B) and four Upper Montane Forest (UMF) plots (3A, 3B, 4A and 4B) on Mount Giting-Giting, Sibuyan Island. Plot 1A was of irregular shape but contiguous.

Plot notation	Altitude (m)	Dimensions (m × m)	Aspect	Slope
1A	325	80 × 30 + 10 × 10	NE	40°
1B	385	50 × 50	NNE	40°
2A	770	50 × 50	NE	20°
2B	860	50 × 50	ENE	22°
3A	1240	50 × 50	SSW	35°
3B	1240	50 × 50	NW	23°
4A	1540	25 × 25	—	0
4B	1540	25 × 25	—	0

depth of 1m just outside the upper and lower part of each plot. The pits were described and a sample taken by trowel from each horizon between 1 and 5 September 1989. A surface sample (0–15cm) was collected from each of ten 10m × 10m subplots selected in a stratified random manner from 25 such subplots in each plot. The samples were air-dried and stored for about one month in sealed polythene bags. On their return to the UK the samples were lightly ground and sieved through a 2-mm mesh. All the analyses were carried out on samples treated in this way but subsamples were oven-dried at 105°C for a moisture correction factor. Values of pH were measured in a mixture of 10g soil with 25ml of deionized water. Loss-on-ignition was measured by burning a 5-g subsample of soil in a furnace at 375°C for 16h. Available phosphorus was extracted using the Olsen method in which 4g of soil were leached with 50ml of 0.5M sodium bicarbonate solution and analysed colorimetrically using an auto-analyser technique. Exchangeable cations were extracted from 5-g subsamples by four successive extractions with a total of 95ml 1M ammonium acetate (adjusted to pH 7 with hydrochloric acid). The cation concentrations were determined by atomic absorption spectrophotometry using an air/acetylene flame for potassium and sodium, and nitrous oxide/acetylene flame for calcium and magnesium. Cation exchange capacity was measured by the titration method.

The soil data were log transformed, analysed by a one-way analysis of variance, and the least significant difference for the plot means calculated.

RESULTS

Forests

The profile diagrams (Figures 2–5) give an impression of the overall appearance of the forests at 325m, 860m, 1240m and 1540m, and show the general reduction in canopy height with altitude. Several other features of the trees (≥ 10cm dbh) showed important trends up the mountain (Table 2). Tree density (ha^{-1}) increased from 1228 (plot 1A) and 828 (plot 1B) to very high values of 1828 (plot 2A) and 2180 (plot 2B). In the UMF tree density ranged from 256 (plot 4B) to 880 (plot 4A). Basal area ($m^2\ ha^{-1}$) in the LMF plots ranged from 36.5 (plot 1B) to 59.1 (plot 2B); in the UMF it was much less and ranged from 5.07 (plot 4B) to 16.7 (plot 4A). Tree diameter generally decreased with altitude; the largest tree at 325m had a dbh of 103cm while that at 1540m had a dbh of only 28.7 (Table 3). Tree buttressing, large woody climbers and leaf size all decreased with altitude while the cover of epiphytic bryophytes increased (Table 4).

The LMF plots were species rich and the UMF less so. As explained earlier, few floristic data are available for plot 3B. The large number of species in the LMF plots is in part a reflection of their high tree density, and the species/individual quotient ranged from 0.39 (plot 1B) to 0.18 (plot 2B). In the UMF this quotient ranged from 0.06 (plot 4A) to 0.18 (plot 3A) (Table 2). In the lower LMF plots 1A and 1B no

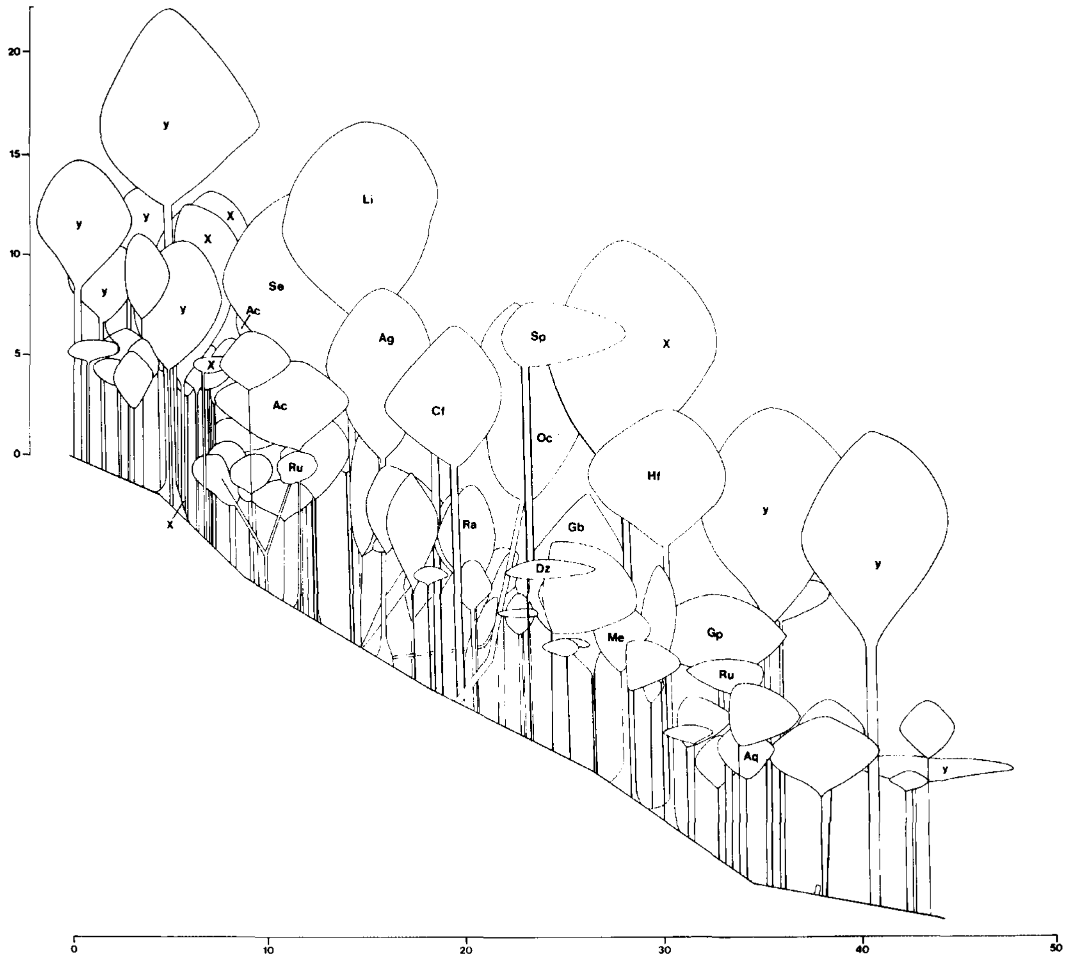

FIG. 2. Profile diagram (50m × 7.5m) of forest in plot 1A at 325m on Mount Giting-Giting, the Philippines. Trees less than 6m high are excluded. Symbols for trees over 10cm dbh: Ac, cf. *Acetiphila*; Al, *Adinandra luzonica*; Ag, *Aglaia* sp.; Aq, *Aquilaria* sp.; Cf, *Calophyllum flavocorticum*; Di, *Diospyros* sp.; Em, *Elaeocarpus* cf. *multiflorus*; Gb, *Garcinia binucao*; Gp, *Garcinia parvifolia*; Hf, *Hopea foxworthyi*; Li, *Litsea* sp.; Me, *Mallotus echinatus*; Oc, *Ochrosia* sp.; Ra, *Randia* sp.; Raa, *Randia* cf. *arborea*; Ru, *Rubiaceae* sp.; Rut, *Rutaceae* sp.; Se, *Semecarpus* sp.; Sp, *Shorea* cf. *polysperma*; X, unidentified; y, lost specimen.

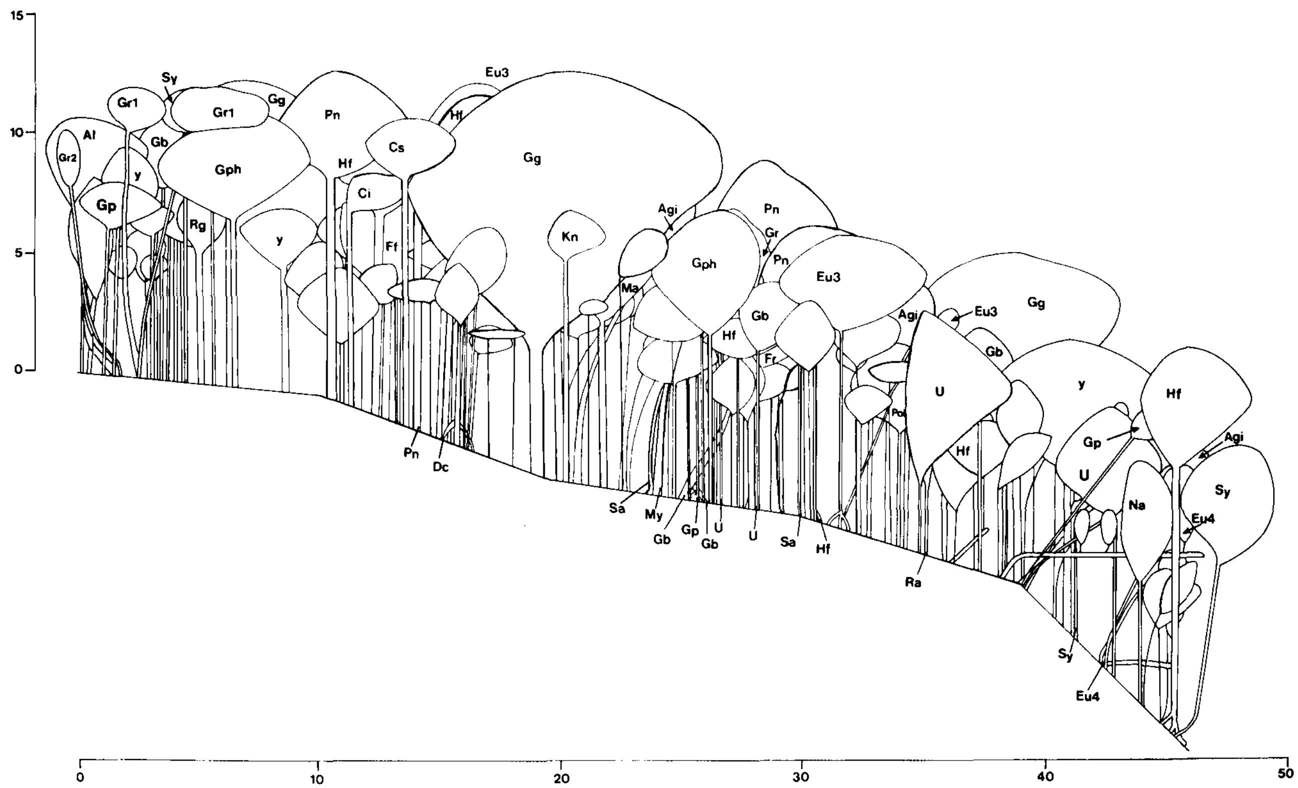

FIG. 3. Profile diagram (50m × 7.5m) of forest in plot 2B at 860m on Mount Giting-Giting, the Philippines. Trees less than 6m are excluded. Symbols for trees over 10cm dbh: Al, *Adinandra luzonica*; Agi, *Ardisia gitingensis*; Cs, *Calophyllum soulattii*; Ci, *Cinnamomum* sp.; Dc, *Diosyros castanea*; Eu3, *Eugenia* sp. '3'; Eu4, *Eugenia* sp. '4'; Ff, *Falcatifolium falciforme*; Gb, *Garcinia binucao*; Gg, *G.* cf. *gitingensis*; Gp, *G. parvifolia*; Gr, *G. rhizophoroides*; Gph, *Gonostylus philippinensis*; Gr1, *Gordonia* sp. '1'; Gr2, *Gordonia* sp. '2'; Hf, *Hopea foxworthyi*; Kn, *Knema* sp.; Ma, *Mallotus* sp; My, *Myrtaceae* sp.; Na, *Nauclea* sp.; Pn, *Planchonella* aff. *nitida*; Po, *Podocarpus* sp.; Pol, *Polyosma* sp.; Ra, *Randia* sp.; Rg, *Radermachera* cf. *gigantea*; Sa, *Sapindaceae* sp.; Sy, *Symplocos adenophylla*; U, unidentified; y, lost specimen.

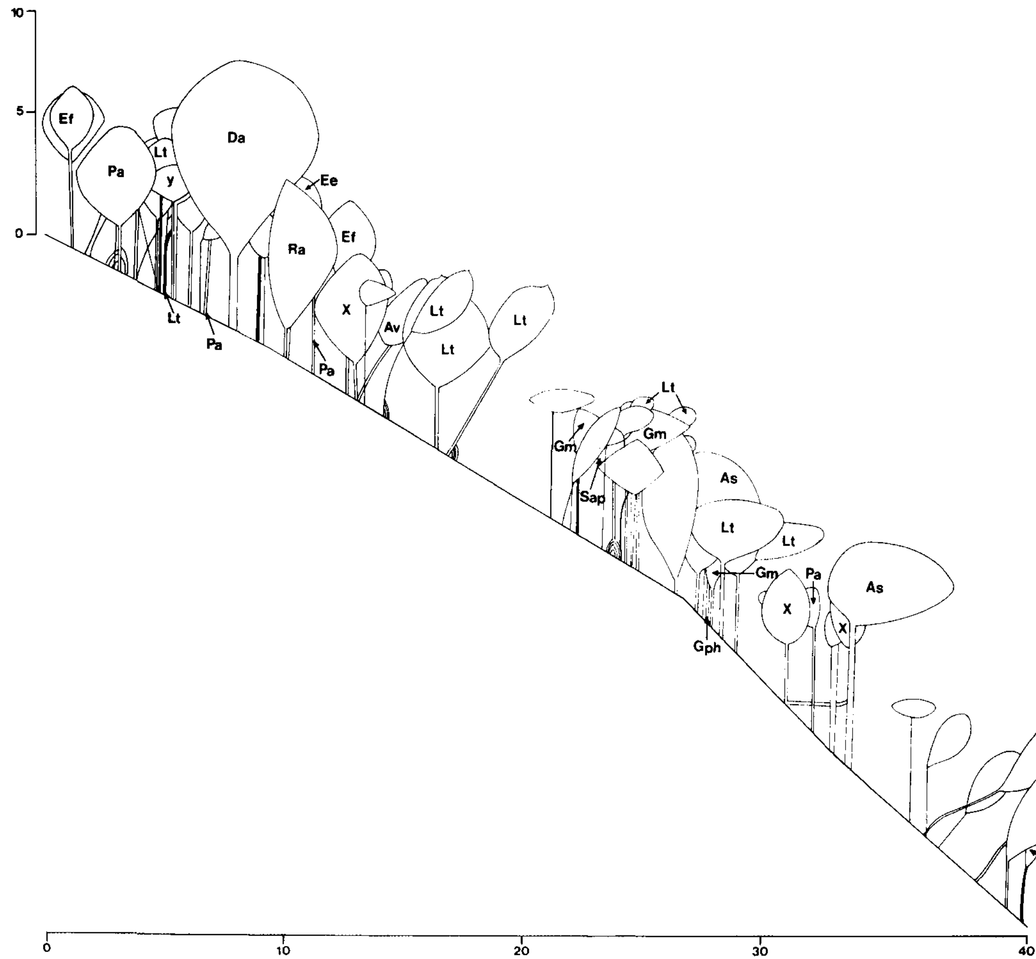

FIG. 4. Profile diagram (50m × 7.5m) of forest in plot 3A at 1240m on Mount Giting-Giting, the Philippines. Trees less than 6m are excluded. Symbols for trees over 10cm dbh: As, *Astronia lagunensis*; Av, *A. viridifolia*; Da, *Dacrydium* sp.; Ee, *Eugenia effusa*; Ef, *E. fastigiata*; Gm, *Garcinia* aff. *memecyloides*; Gph, *Gonostylus philippinensis*; Lc, *Lithocarpus* cf. *caudatifolius*; Lt, *Lithocarpus* sp.; Mg, *Melicope glabella*; Pa, *Palaquium obovatum*; Po, *Podocarpus* sp.; Pt, *Pterospermum* sp.; Ra, *Randia* sp.; Sap, *Sapotaceae* sp.; X, unidentified; y, lost specimen.

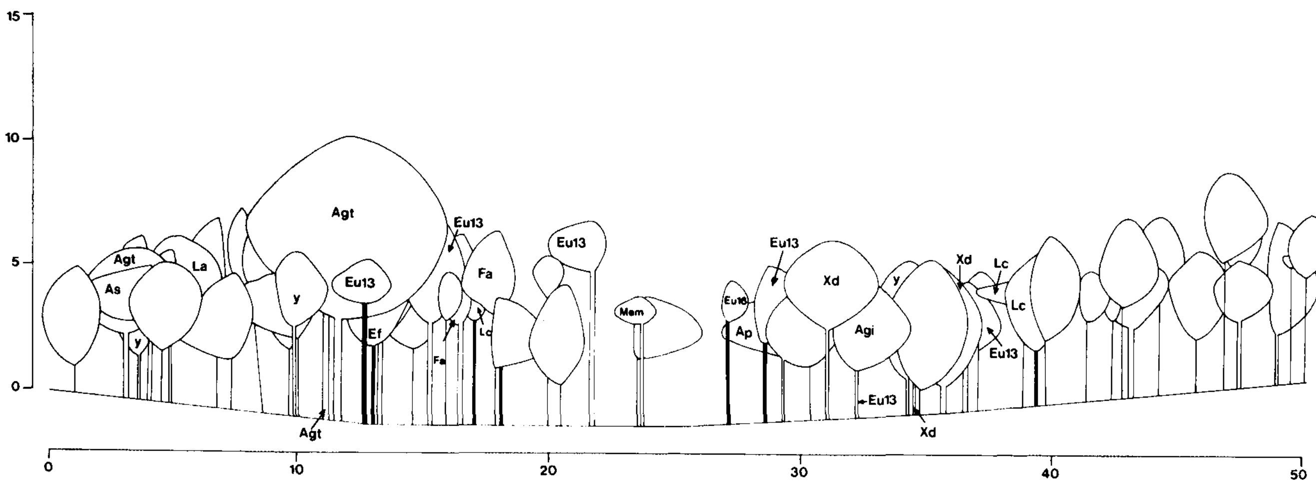

FIG. 5. Profile diagram (50m × 7.5m) of forest in plots 4A and 4B at 1540m on Mount Giting-Giting, the Philippines. Trees less than 6m are excluded. Symbols for trees over 10cm dbh: Agi, *Ardisia gitingensis*; Ap, *Ascarina philippinensis*; As, *Astronia lagunensis*; Ath, *Agathis* sp.; Ef, *Eugenia fastigiata*; Eu13, *Eugenia* sp. '13'; Eu16, *Eugenia* sp. '16'; Fn, *Fagraea negrosensis*; La, *Lauraceae* sp.; Lc, *Lithocarpus* cf. *caudatifolius*; Mem, *Memecylon* sp.; Xd, *Xanthomyrtus diplycosiifolia*; y, lost specimen.

TABLE 2. The tree density (≥ 10cm dbh), basal area, and number of species in eight plots on Mount Giting-Giting, Sibuyan Island.

Plot	Density (ha^{-1})	Basal area ($m^2\ ha^{-1}$)	No. of species per plot	No. of species per individual
1A	1228	54.8	100	0.33
1B	828	36.5	80	0.39
2A	1828	49.1	111	0.24
2B	2180	59.1	98	0.18
3A	868	15.6	38	0.18
3B	756	15.1	—	—
4A	880	16.7	13	0.059
4B	256	5.07	7	0.11

TABLE 3. The percentages of trees (≥ 10cm dbh) in a range of diameter classes on eight plots on Mount Giting-Giting, Sibuyan Island.

	Diameter class (cm)							
Plot	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90*
1A	45.2	33.3	12.5	4.3	1.7	1.3	0.6	—
1B	43.8	32.2	15.9	4.3	2.4	—	—	1.0
2A	50.7	25.2	6.9	1.3	0.4	—	—	—
2B	65.6	25.0	7.0	1.7	0.7	—	—	—
3A	83.4	14.3	1.8	0.5	—	—	—	—
3B	78.3	16.9	3.7	0.5	0.5	—	—	—
4A	83.6	16.4	—	—	—	—	—	—
4B	87.5	12.5	—	—	—	—	—	—

* Plot 1A had in addition one tree of 103cm dbh. Plot 1B had a tree of 98.6cm dbh.

family was clearly dominant (Table 5). The upper LMF plots 2A and 2B had four families with 10% or more of the basal area: the *Clusiaceae* with 11.8% in plot 2A and 14.6% in plot 2B; the *Dipterocarpaceae* with 12.9% and 14.7%; the *Podocarpaceae* with 10% and 11%; the *Sapotaceae* with 13.0% and 16.9%. The UMF in plot 3A had as leading families the *Fagaceae* (21.7% of the basal area), the *Podocarpaceae* (15.2%) and the *Sapotaceae* (25.9%). Of the highest UMF plots, 4A had the *Araucariaceae* (37.1%), *Myrsinaceae* (11.8%) and *Myrtaceae* (16.1%), while 4B had the *Fagaceae* (10.8%) and *Myrtaceae* (72.4%), as leading families. A full list of the identified taxa for each plot is given in the Appendix.

Rocks and soils

The rocks at the three altitudes had a similar chemical composition and are typical ultramafics (Table 6).

TABLE 4. The percentage of the first 75 trees (≥10cm dbh) enumerated in plots 1A–3B and all enumerated trees in plots 4A and 4B with: buttresses ≥50cm high; woody climbers ≥1cm diameter; microphyllous (230–2000mm^2) or smaller leaves; a bryophytic epiphyte cover at 2m above the ground of ≥50%.

Plot	Trees with buttresses (%)	Trees with woody climbers (%)	Trees with microphylls or smaller leaves (%)	Trees with epiphytic bryophytes (≥50% cover) (%)
1A	21.3	33.3	5.7	4
1B	24.0	26.7	—	4
2A	12.0	29.3	—	9.3
2B	17.3	15.7	27.8	10.7
3A	9.3	5.2	55.1	24
3B	9.3	4.7	—	33.3
4A & 4B	0	2.0	—	49.3

The soil profiles had a poor horizon definition and appeared to be mainly brown to yellow-brown inceptisols (United States Department of Agriculture Soil Taxonomy 7th Approximation). They were usually freely drained and had a high proportion of silt, and were often rocky with many stones. Soil pits reached to at least 1m depth except near plots 4A and 4B where weathering bedrock occurred at 82cm. All the soils had darker surface horizons and there was a marked trend to increasing soil organic matter with altitude. There was a thin layer of mor humus in the plots at 1240m and above. Drainage was locally poor in the highest plots and there was a small area of deep organic soil in plot 4B. Thomas & Proctor (1997) have described the soil fauna. The chemical analyses of the 0–15cm depth samples (Table 7) show several important features. In general the samples were acid and the pH decreased with altitude except for the highest plots where there was a reversal of the trend. The highest plot was relatively calcareous and had by far the lowest Mg/Ca quotient. Loss-on-ignition showed a trend to increase with altitude. There was a general increase in concentrations of extractable phosphorus and potassium but a decrease in nickel with altitude.

DISCUSSION

Forest structure

The part of Mount Giting-Giting investigated did not have the ultramafic scrub or *Gymnostoma*-woodland reported for south-east Asian ultramafics on Mount Bloomfield (at 170–200m altitude) in Palawan in the Philippines (Proctor et al., 1997) and on Mount Piapi (at <500m altitude) in the Talaud Islands of Indonesia (Lam, 1927; Proctor et al., 1994). The vegetation above 1550m on Giting-Giting was grassland and scrub but requires detailed investigation to determine its causes

TABLE 5. The percentage contribution of plant families to the tree (≥ 10cm dbh) basal area in seven plots at a range of altitudes on Mount Giting-Giting, Sibuyan Island.

	Plot						
	1A	1B	2A	2B	3A	4A	4B
Anacardiaceae	0.5	1.2	0.6	—	—	—	—
Annonaceae	0.5	0.1	4.3	—	—	—	—
Apocynaceae	3.1	3.2	2.9	1.0	—	—	—
Aquifoliaceae	1.2	—	0.4	—	—	—	—
Araliaceae	0.1	0.3	0.4	0.8	—	—	—
Araucariaceae	1.5	—	—	—	—	37.1	—
Barringtoniaceae	0.2	—	—	0.1	—	—	—
Bignoniaceae	1.3	—	0.2	0.5	0.3	—	—
Burseraceae	0.3	0.4	0.7	0.3	—	—	—
Celastraceae	—	—	—	0.1	—	—	—
Chloranthaceae	—	—	—	—	—	—	4.7
Clusiaceae	9.4	5.5	11.8	14.6	5.9	—	—
Combretaceae	1.0	0.7	0.5	0.4	—	—	—
Cunoniaceae	—	—	—	0.1	—	—	—
Dichapetalaceae	—	0.4	0.5	—	—	—	—
Dilleniaceae	2.0	—	0.4	—	—	—	—
Dipterocarpaceae	6.7	1.5	12.9	14.7	—	—	—
Ebenaceae	1.4	6.8	—	0.6	—	—	—
Elaeagnaceae	—	—	—	0.6	—	—	—
Elaeocarpaceae	2.2	3.3	—	—	—	—	—
Erythroxylaceae	0.9	0.2	—	—	—	—	—
Escalloniaceae	—	—	1.6	0.5	—	—	—
Euphorbiaceae	6.0	4.9	1.6	0.8	—	—	—
Fagaceae	0.1	2.8	1.4	2.1	21.7	4.4	10.8
Flacourtiaceae	0.2	0.5	—	—	—	—	—
Lauraceae	3.3	7.6	3.2	0.2	0.2	2.0	—
Leguminosae	—	2.1	0.2	—	—	—	—
Magnoliaceae	0.4	0.1	1.0	0.2	—	—	—
Melastomataceae	—	—	0.4	0.1	7.5	3.9	—
Meliaceae	5.3	6.2	0.3	0.2	—	—	—
Memecylaceae	—	—	0.2	—	0.3	0.9	—
Moraceae	1.7	—	—	—	—	—	—
Myristicaceae	1.2	2.0	—	1.1	—	—	—
Myrsinaceae	0.4	1.8	1.4	4.0	0.2	11.8	8.5
Myrtaceae	1.4	0.8	7.7	9.3	1.6	16.1	72.4
Naucleaceae	1.2	0.6	0.4	0.1	—	—	—
Oleaceae	—	—	—	0.1	—	—	—
Podocarpaceae	0.6	—	10.0	11.0	15.2	—	—
Potaliaceae	0.1	—	0.1	0.2	0.3	4.6	—
Rhizophoraceae	0.1	—	—	—	0.4	—	—
Rosaceae	—	0.6	0.4	0.1	—	—	—
Rubiaceae	7.6	1.5	0.5	1.6	1.8	5.0	—
Rutaceae	0.5	2.8	0.3	0.3	0.5	—	—
Sapindaceae	1.0	0.1	0.3	1.1	—	—	—

TABLE 5. *(Continued)*.

Sapotaceae	5.5	6.9	13.0	16.9	25.9	—	—
Sterculiaceae	—	—	0.8	—	5.1	—	—
Strychnaceae	0.1	—	—	—	—	—	—
Symplocaceae	0.3	0.6	4.6	4.0	0.3	—	—
Theaceae	0.3	1.1	1.3	2.0	0.3	—	—
Thymelaeaceae	0.2	5.7	2.7	3.7	0.3	—	—
Tiliaceae	0.2	8.4	—	—	—	—	—
Ulmaceae	—	—	—	0.1	—	—	—
Vitaceae	1.6	2.0	—	—	—	—	—
Unidentified	28.7	17.7	12.0	6.9	12.2	14.3	3.6

TABLE 6. The percentage chemical composition of rocks collected from exposures at three altitudes on Mount Giting-Giting.

	Altitude (m)		
Element	300	700	1500
Si	21.7	21.1	21.0
Ti	0.01	0.01	0.02
Al	0.83	0.59	1.43
Fe	15.8	17.4	16.3
Mn	0.12	0.13	0.12
Mg	17.8	17.5	17.5
Ca	0.53	0.38	0.51
Na	trace	trace	trace
K	trace	trace	trace
P	trace	trace	trace
Co	0.01	0.01	0.01
Cr	0.28	0.29	0.21
Ni	0.23	0.24	0.25
O	42.7	42.3	42.7

and affinities. Rainforest, which to some extent resembles that on Mount Giting-Giting, has been described from Mount Silam, Sabah, Malaysia (Proctor et al., 1988).

The LMF on the lower parts of Giting-Giting is notably less tall than the Lowland Evergreen Rain Forest *sensu* Whitmore (1984) at a similar altitude on Silam. For example in the Giting-Giting LMF plot 1A at 325m (Fig. 2) the tallest measured tree was 24m while in a plot at 330m on Silam, Proctor et al. (1988) recorded trees up to 45m. The illegal logging probably contributed to the reduced forest stature on Giting-Giting by removing the tallest trees judging from the size

TABLE 7. Mean values of soil pH, loss-on-ignition and exchangeable cations in 15-cm deep samples collected from each of eight plots on Mount Giting-Giting, the Philippines. Values are expressed on an oven-dry (105°C) basis where appropriate. $n = 10$. Within each row of values plot differences were highly significant ($P < 0.001$). The least significant difference (LSD; $P < 0.01$) for individual plot values is given in parentheses.

	Plot								
	1A	1B	2A	2B	3A	3B	4A	4B	LSD
pH_{H_2O} (log units)	5.5	5.5	5.2	5.0	4.4	4.6	5.3	5.0	(0.40)
LOI (%)	12.2	13.6	11.7	15.0	22.3	25.7	17.6	30.9	(8.20)
P_{Olsen} ($\mu g\ g^{-1}$)	0.41	0.57	0.22	0.44	0.80	0.97	1.98	2.07	(1.25)
K (mEq 100 g^{-1})	0.04	0.14	0.10	0.15	0.37	0.27	0.31	0.41	(0.18)
Ca (mEq 100 g^{-1})	0.51	1.81	0.70	1.11	0.99	0.96	2.63	3.36	(1.35)
Mg (mEq 100 g^{-1})	1.37	3.64	1.36	1.19	1.31	0.80	0.75	1.09	(1.42)
Mg/Ca	2.87	1.91	2.53	1.56	1.73	1.58	0.31	0.38	(1.31)
Ni ($\mu g\ g^{-1}$)	12.4	23.8	6.3	4.5	2.1	1.8	1.0	1.7	(8.9)

of some of the remaining stumps. However, the lower LMF on Giting-Giting had a greater density, basal area and species richness than forest at a similar altitude on Silam (Proctor et al., 1988). For example the trees at 325m on Giting-Giting had a density of 1228 ha^{-1}, a basal area of 54.8m^2 ha^{-1} and included at least 100 species in the 0.25-ha plot (Table 2). For Silam, the forest at 330m had 633 trees ha^{-1}, a basal area of 46.2m^2 ha^{-1}, and 85 species in a 0.4-ha plot.

The LMF between 770m and 900m on Giting-Giting was also less tall than the LMF forests at a similar altitude on Mount Silam. In plot 2B at 860m the highest measured tree was 13.4m (Fig. 3); in the plot at 870m on Silam the highest tree was 16m. Moreover the forest differed greatly in appearance. The LMF forest at 870m on Silam is a classic cloud forest on soils with much surface organic matter (Proctor et al., 1988; Bruijnzeel et al., 1993) while the LMF forest at this altitude on Giting-Giting is below the zone of frequent cloud and on soils with much less organic matter. Among the more important contrasts of the Silam 870m plot with that at 860m on Giting-Giting are (Silam values first): lower basal area, 26.7m^2 ha^{-1} vs 59.1m^2 ha^{-1}; lower density, 1596 trees ha^{-1} vs 2180; smaller diameter trees, 9.3% $\geq$20cm dbh (none >30cm) vs 34.4% $\geq$20cm dbh (largest 60cm dbh); fewer buttressed trees, 1.9% vs 17.3%; and much higher bryophyte cover, 62.9% of trees (with $\geq$50% bryophyte cover on the boles) vs 10.7%. The trees at 870m on Silam had many more prop roots but these were not quantified. On Giting-Giting above c.1000m, roughly the lower limit of the cloud cap, the vegetation was UMF, a formation which did not occur on Gunung Silam.

It seems likely that the principal determinants of the forest structural contrasts are Giting-Giting's higher altitude cloud cap, its frequency of strong winds including hurricanes, and the occurrence of illegal logging below 700m.

Floristics

The substantial representation of the *Euphorbiaceae* in the lower plots on Giting-Giting probably reflects the lack of value of their timber in these logged forests or their rapid response to gaps created by the logging or both. The family was much less common in plots 2A and 2B and was absent from the UMF. The low representation of the dipterocarps in plots 1A and 1B probably reflects their removal by logging. The dipterocarps were well represented in plot 2A (770m) and 2B (860m) and hence ascended higher than on Mount Silam where they were not recorded from above 700m (Proctor et al., 1988). On Giting-Giting they were not recorded from plot 3A (1240m) and above. Only three species of *Dipterocarpaceae* were recorded from Giting-Giting: *Hopea foxworthyi* (which accounted for the great majority of the individuals), *Shorea* cf. *polysperma*, and a single individual of an unidentified *Shorea* species. A large number of dipterocarp species were recorded from Gunung Silam.

Ultramafic areas are often rich in endemic species (Proctor & Woodell, 1975) and this is well illustrated in the tropical island of New Caledonia where about half of the ultramafic forest species (excluding epiphytes) are endemic to the ultramafics (Proctor, 1992). Much less endemism has been reported elsewhere in south-east Asia and for example only two tree species on Gunung Silam were endemic to ultramafics in Sabah (Proctor et al., 1988). It is impossible to say much about the endemism of the trees on Giting-Giting since many could not be identified to species and little is known of the distributions of those that were. Certainly, most of the common trees on Sibuyan Island occur elsewhere in the Philippines.

Soil analyses

The soil analytical data (Table 7) show none of the extreme values which occur under some stunted rainforests on ultramafic soils. For example on Mount Piapi, Indonesia (Proctor et al., 1994) and on Mount Bloomfield, the Philippines (Proctor et al., 1997) there are surface soils with Mg/Ca quotients as high as 37 (Piapi) and exchangeable nickel as high as $46 \mu g\ g^{-1}$ (Bloomfield). The soils on Giting-Giting are relatively deep though stony, and pits were dug in several places to depths of 1m (only 82cm near plots 4A and 4B). By contrast the soils depths on much of Piapi and Bloomfield are much less, and Bruijnzeel (1990) has suggested that drought in the shallow soils is a major cause of forest stunting on ultramafics, perhaps in association with fire (Proctor et al., 1997). Overall the soils on Giting-Giting are similar to those on Mount Silam, Sabah (Proctor et al., 1988) in their moderate nickel concentrations, Mg/Ca quotients and soil depths. Silam, like Giting-Giting, lacks stunted lowland forest, and the smallest stature forest at both sites is associated with altitudinal effects including an accumulation of soil-surface organic matter.

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APPENDIX

The tree (≥ 10cm diameter) taxa (identified to at least family level) and their number of individuals recorded from eight plots (described in the text) on Mount Giting-Giting on Sibuyan Island, Republic of the Philippines. Most of the specimens for plot 3B had been lost.

	1A	1B	2A	2B	3A	3B	4A	4B
ANACARDIACEAE								
Anacardiaceae sp. 1		2						
Buchanania aff. *sessilifolia* Bl.			2					
Semecarpus sp. 1	1							
ANNONACEAE								
Annonaceae sp. 1	5	1	21					
APOCYNACEAE								
Alstonia parvifolia Merr.	4		3	5		1		
Ochrosia cf. *apoensis* Elm.	2	5	6	1				
Ochrosia sp. 2	2							
AQUIFOLIACEAE								
Ilex cymosa Bl.	4							
ARALIACEAE								
Araliaceae sp. 1			1	7		2		
Arthrophyllum	1	2	1					
ARAUCARIACEAE								
Agathis sp. 1	4						15	
BIGNONIACEAE								
Radermachera cf. *gigantea* (Bl.) Miq.	3		1	4	2			
BURSERACEAE								
Canarium cf. *asperum* Benth.	4	3	6	2				
CELASTRACEAE								
Bhesa paniculata Arn.				1				
CHLORANTHACEAE								
Ascarina philippinensis C.B. Rob.								1
CLUSIACEAE								
Calophyllum flavocortica Elm.	7	1	7				1	
Calophyllum cf. *pulgarensis* Elm.	1		3	6				
Calophyllum pulcherimum Elm.	1	1	2					
Calophyllum soulattri "Burm." ex F. Mull.	2		3	1				
Calophyllum sp. 2		1						
Calophyllum sp. 6			2					
Garcinia binucao Choisy	11	4	28	21				
Garcinia cf. *gitingensis* Elm.	3		2	15				

	1A	1B	2A	2B	3A	3B	4A	4B
Garcinia aff. *memecyloides* Ridl.	1			9	18	5		
Garcinia cf. *merguensis* Miq.	5		5		2		2	
Garcinia cf. *parvifolia* Miq.	4		1	3				
Garcinia rhizophoroides Elm.	3	1	6	2				
Garcinia sp. 1	1	1	5	4				
Garcinia sp. 3	1	1						
Garcinia sp. 4				1				
Garcinia sp. 5		1	1					
Garcinia sp. 6			5					
Garcinia sp. 7			1					
Mesua sp. 2			1	1				
COMBRETACEAE								
Terminalia nitens Presl.	1		1	2				
CUNONIACEAE								
Weinmannia negrosensis Elm.				1				
DICHAPETALACEAE								
Dichapetalum sp. 1		1	2					
DILLENIACEAE								
Dillenia sp. 1	3		3					
DIPTEROCARPACEAE								
Hopea foxworthyi Elm.	7	5	43	54				
Shorea cf. *polysperma* Merr.	8	1	1					
Shorea sp. 2	1							
EBEANACEAE								
Diospyros castanea (Craib) R.A. Fletcher				6				
Diospyros sp. 2	1		1					
ELAEAGNACEAE								
Elaeagnus sp. 1				4				
ELAEOCARPACEAE								
Elaeocarpus cf. *multiflorus* (Turcz.) F. Vill.	5	5						
ERYTHROXYLACEAE								
Erythroxylum sp. 1								
EUPHORBIACEAE								
Actephila sp. 1	13	9						
Euphorbiaceae sp. 1	1							
Euphorbiaceae sp. 2	2	3						
Euphorbiaceae sp. 3	2							
Euphorbiaceae sp. 4	2		2					
Euphorbiaceae sp. 5	1							
Euphorbiaceae sp. 6		2						
Euphorbiaceae sp. 7			2	3				
Euphorbiaceae sp. 8			2					
Mallotus echinatus Elm.	18	8						
Mallotus sp. 2	1			2				
Mallotus sp. 3		4						
Mallotus sp. 4		2						

	1A	1B	2A	2B	3A	3B	4A	4B
FAGACEAE								
Castanopsis sp. 1	1							
Fagaceae sp. 1			1					
Castanopsis sp. 2		4						
Lithocarpus caudatifolius (Merr.) Reld.			1	1	11		3	2
Lithocarpus sp. 2			2		35			
Lithocarpus sp. 3			1	2				
Lithocarpus sp. 4				4				
Lithocarpus sp. 5			2					
FLACOURTIACEAE								
Scolopia sp. 1	2	3						
GROSSULARIACEAE								
Polyosma sp. 1	2	3						
LAURACEAE								
Beilschmeidia sp. 1	1	2	5	1				
Beilschmeidia sp. 2			1					
Cinnamomum sp. 1	2	3	2	1				
Cinnamomum sp. 2			4					
Lauraceae sp. 1	4		2	1				
Lauraceae sp. 2			1					
Lauraceae sp. 5		1						
Lauraceae sp. 6			1					
Lauraceae sp. 7					1			
Litsea sp. 1		2						
Litsea sp. 2	3		1					
LECYTHIDACEAE								
Barringtonia sp. 1	1		1					
Barringtonia sp. 3	1							
LEGUMINOSAE								
Forida sp. 1		2						
Leguminosae sp. 1		3	2					
LOGANIACEAE								
Fagraea negrosensis Elm.			1	2	1		3	
Fagraea racemosa Jack	2							
Strychnos cf. *columbrina* Bl.	1							
MAGNOLIACEAE								
Talauma gitingensis Elm.			8	3				
Magnoliaceae sp. 2	1	1						
Magnoliaceae sp. 3	2							
MELIACEAE								
Aglaia aff. *rubescens* (Hiern.) C.M. Pannell	1							
Aglaia sp. 1	12	4						
Aglaia sp. 2			1					
Aglaia sp. 3	1	1					1	
Meliaceae sp. 1			2	2				
Meliaceae sp. 2	2							
Meliaceae sp. 3		1						

	1A	1B	2A	2B	3A	3B	4A	4B
MELASTOMATACEAE								
Astronia acuminatissima Merr.			1					
Astronia gitingensis Elm.				1	2			
Astronia lagunensis var. *lagunensis* Merr.								
Astronia viridifolia Elm.					17		3	
Memecylon sp. 1					1			
Memecylon sp. 2			1					
Memecylon sp. 3							1	
MORACEAE								
Artocarpus sp. 1	1							
Ficus sumatrana Miq.	1							
Ficus sp. 2	1							
MYRSINACEAE								
Ardisia gitingensis Elm.			5	20	2		6	1
Ardisia sp. 2		1						
Myrsinaceae sp. 1		1	2	1				
Rapanea sp. 1	2	4		1				
MYRISTICACEAE								
Knema sp. 1		4						
Knema sp. 2			1	7				
MYRTACEAE								
Eugenia effusa A. Gray			2	2	1			
Eugenia fastigiata Koord. & Valet.	1		1	8	3	1	1	
Eugenia sp. 1			3	4				
Eugenia sp. 3			8	11				
Eugenia sp. 4	1		3	2				
Eugenia sp. 7			1					
Eugenia sp. 8		1						
Eugenia sp. 9	1		1					
Eugenia sp. 10		1						
Eugenia sp. 13						2	8	5
Eugenia sp. 14		2	1					
Eugenia sp. 15				2				
Eugenia sp. 16					1		1	2
Eugenia sp. 17	3		4					
Myrtaceae sp. 1		1						
Myrtaceae sp. 2			1					
Myrtaceae sp. 4	2		1	1				
Myrtaceae sp. 5						2		
Myrtaceae sp. 7				2				
Xanthomyrtus diplycosiifolia (C.B. Rob.) Merr.				1		1	1	3
OLEACEAE								
Chionanthus sp. 1								
PODOCARPACEAE								
Dacrydium sp. 1								

	1A	1B	2A	2B	3A	3B	4A	4B
Falcatifolium falciforme (Parl.) de Laub.			21	25		1		
Podocarpus sp. 1	2		12	21	1		2	
RHIZOPHORACEAE								
Pellacalyx sp. 1	1				2			
ROSACEAE								
Prunus grisea (Bl. ex. C. Müll) Kalkm.		3	1					
Prunus sp. 2				1				
Rosaceae sp. 1			1					
RUBIACEAE								
Nauclea sp. 1	1							
Nauclea sp. 2	1		1					
Randia cf. *arborea* Elm.	10	3			2			
Randia sp. 2	5	2	5	19	4	3	1	
Rubiaceae sp. 1	5	3						
Rubiaceae sp. 3							4	
Rubiaceae sp. 4	1							
RUTACEAE								
Melicope glabella T. Hartley				1	2	1		
Rutaceae sp. 1		12	2	1				
Rutaceae sp. 2		1						
SAPINDACEAE								
Guioa salicifolia Radlk.	1							
Lepisathes sp. 1		1						
Sapindaceae sp. 3	4		7	12				
SAPOTACEAE								
Palaquium obovatum Engl. var. *orientale* H.J. Lam		2	1	7	45			
Planchonella firma (Miq.) Dubard		4	3	7		1		
Planchonella aff. *nitida* Dubard	6		29	51				
Planchonella sp. 3			5	15	3			
Planchonella sp. 4			1	4	3			
Sapotaceae sp. 1	1	2	5	1				
Sapotaceae sp. 2	4	4	1					
Sapotaceae sp. 3	4			2		1		
Sapotaceae sp. 4				1	5			
Sapotaceae sp. 5			2	5				
Sapotaceae sp. 6		1	3	3				
Sapotaceae sp. 7			1	1	1			
Sapotaceae sp. 9		3	3		2	1		
Sapotaceae sp. 10	1							
Sapotaceae sp. 11		1						
Sapotaceae sp. 12				2				
Sapotaceae sp. 13		2	1					
STERCULIACEAE								
Pterospermum sp. 1			1		12			

	1A	1B	2A	2B	3A	3B	4A	4B
SYMPLOCACEAE								
Symplocos adenophylla (Wall.) ex G. Don	2	1	23	32		1		
Symplocos cf. *cochinchinensis* S. Moore		2						
Symplocos sp. 3	1							
Symplocos sp. 4					1	1		
TILIACEAE								
Tiliaceae sp. 1	1	1						
THEACEAE								
Adinandra luzonica Merr.	3		2	10				
Gordonia sp. 1		1	5	4		1		
Gordonia sp. 2				2	1			
Gordonia sp. 3		1						
Ternstroemia toquian (Blanco) Fern.-Vill.				1				
Theaceae sp. 1			2	1				
THYMELAEACEAE								
Aquilaria sp. 1	3	1	5	2				
Gonostylus philippinensis Elm.			3	13				
Thymeleaceae sp. 1			2	2				
ULMACEAE								
Gironniera celtidifolia Gaud.				1				
VITACEAE								
Vitaceae sp. 1	2	4						