MONTANE FOREST IN THE DUMOGA BONE NATIONAL PARK, NORTH SULAWESI

W. MILLIKEN* & J. PROCTOR†

Lower montane rainforest and upper montane forest on the slopes and summit of Gunung Sinombayuga, Dumoga Bone National Park, North Sulawesi, were described by general botanical collection and quantitative sampling. The lower montane forest was dominated by the families *Fagaceae*, *Myrtaceae*, *Icacinaceae* and *Escalloniaceae*. The upper montane forest, dominated by *Fagaceae* and *Cunoniaceae*, represented 75-year-old coppice regeneration. It was less diverse than the lower montane forest and lower in stature, with a smaller basal area per hectare and a higher proportion of multi-stemmed trees. The tree flora of the montane forest is poorly known, and rich in undescribed species.

Keywords. Coppice regeneration, diversity, Dumoga Bone, floristics, lower montane forest, Sulawesi, upper montane forest.

INTRODUCTION

The Dumoga Bone National Park, in northern Sulawesi, is a biologically important reserve with an area of about 300,000 hectares, including a tract of undisturbed lowland rainforest. The montane flora of Sulawesi, although less diverse than that of some of the larger Malesian islands (e.g. Borneo), is interesting biogeographically because its taxa appear to have arrived, by at least three routes, from both sides of Wallace's Line (Steenis, 1972; Balgooy, 1987; Whitten *et al.*, 1987). The flora of northern Sulawesi (Minahasa) appears to be most closely related to that of the Philippines (Balgooy, 1987).

The vegetation of Sulawesi has been insufficiently explored. According to Whitten *et al.* (1987), fewer botanical specimens have been collected there than in any other province of Indonesia. Wind (1984), in the management plan for the Dumoga Bone National Park, described its flora as 'poorly known'. This remains the case today, although general botanical observations, mainly of lowland vegetation, were made by the Project Wallace Expedition in 1985 (O'Donovan, 1990), and a quantitative study of the lowland forest tree flora was carried out by Whitmore & Sidiyasa (1986). These were followed in 1991 by the Linnaeus Sulawesi Expedition, a rapid and somewhat superficial botanical/ethnobotanical survey of the Park organized by Menteri Negara Riset Dan Teknologi (MENRISTEK) and Lembaga Ilmu Pengetehuan Indonesia (LIPI).

In 1991, as a follow-up to the Linnaeus Expedition, a rapid survey was made of the montane vegetation of Gunung Sinombayuga (previously known as G. Bulawa),

* Royal Botanic Garden Edinburgh, 20A Inverleith Row, Edinburgh EH3 5LR, UK.
† Department of Biological and Molecular Sciences, University of Stirling, Stirling FK9 4LA, UK.

the highest mountain in the Park (1970m). The purpose of this paper is to present the results of this survey and to discuss them in the context of the results of the aforementioned studies.

STUDY AREA

The Dumoga Bone National Park was established in 1984, and lies towards the western end of the Minahasa peninsula between the towns of Gorontalo and Kotamobagu (Fig. 1). Overviews of its physical environment are provided by Kucera (1990) and Wind (1984). The rocks in the region are mainly mid-Tertiary volcanics, and the volcanic-derived soils on the upland terrain tend to be Eutric Cambisols (Kucera, 1990). Annual rainfall in the vicinity of Toraut, at the eastern end of the park, is around 2100mm, with a seasonal peak between July and August. Gunung Sinombayuga (123°42′E, 0°28′N) lies approximately 18km from the sea near the southern boundary of the Park, in the Bolaang-Mongondow District.

METHODS

Two plots were established in a lower montane rainforest (*sensu* Whitmore, 1984) at 1500m asl on a plateau to the east of the summit of Gunung Sinombayuga, and in an upper montane forest (mossy forest) at 1970m on the summit itself (Fig. 2). These were accompanied by general description of the vegetation and general botanical collecting. The plot areas were 2250m^2 (75m × 30m) in the lower montane forest and 450m^2 (15m × 30m) in the upper montane forest.

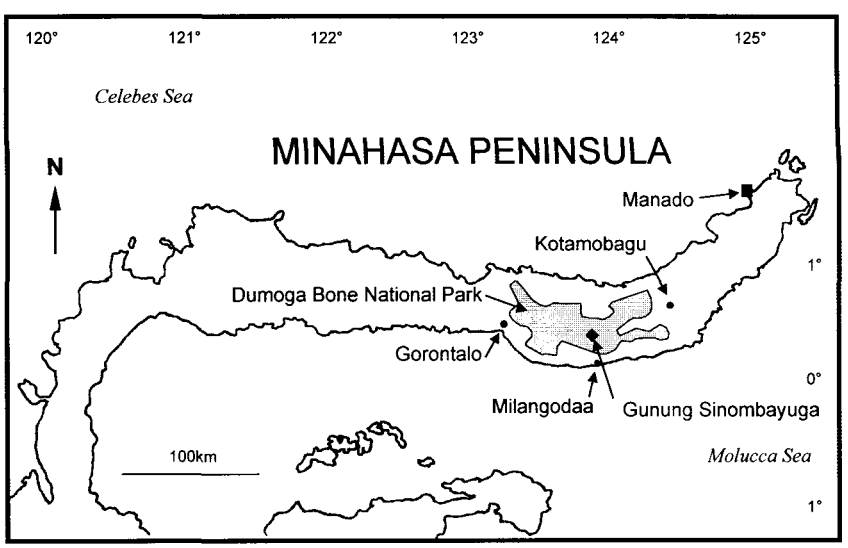

FIG. 1. Location of the study area (Gunung Sinombayuga) in North Sulawesi.

a b

FIG. 2. Two forest types on Gunung Sinombayuga, North Sulawesi: a, coppiced upper montane (moss) forest on the summit, alt. 1970m; b, lower montane forest on the ridge east of the summit, alt. 1500m.

The plots were marked out with coloured string, but not divided into subplots. Within the plots all trees of diameter at breast height (dbh) $\geqslant$10cm in the lower montane forest, or dbh $\geqslant$3.18cm ($\geqslant$10cm circumference) in the upper montane forest, were measured. The lower diameter class was used in the upper montane forest in order to obtain a more representative sample, given that most stems were less than 10cm dbh. Dimensions of their buttress/stilt roots were recorded (where present). The leaf area (mm^2) of each of the tree taxa was calculated using the formula $A = 0.67lb$, where A = area, l = length from base of lamina to base of drip tip, and b is leaf width at the widest point, and assigned to one of the size categories in the classification system of Raunkiaer (1934) modified by Webb (1959). Voucher specimens were collected and stored in 70% alcohol and subsequently dried at the Herbarium Bogoriense. Fertile vouchers are lodged in the herbaria at Kew (K), Bogor (BO), Edinburgh (E) and Leiden (L); a complete set of sterile vouchers is deposited at Kew.

RESULTS

Lower montane forest

The lower montane forest, with a canopy about 30m high and emergents to about 40m, was dominated by *Fagaceae*, *Myrtaceae* (the most species-rich tree family), *Icacinaceae* and *Escalloniaceae* (see Table 1). The majority of the trees had noticeably

TABLE 1. Representation of tree families (trees ⩾10cm dbh) in 0.225ha of lower montane forest and in 450m^2 of coppiced upper montane forest on Gunung Sinombayuga.

Family	Genera	Basal area (m^2/ha)	No. trees	No. stems	No. morphospecies
LOWER MONTANE FOREST					
Fagaceae	*Castanopsis, Lithocarpus*	19.62	19		4
Myrtaceae	*Syzygium, Eugenia*	7.16	27		6
Icacinaceae	*Platea*	6.63	15		1
Escalloniaceae	*Polyosma, Quintinia*	4.79	26		2
Podocarpaceae	*Dacrycarpus, Falcatifolium*	2.76	7		2
Oleaceae	*Chionanthus*	2.27	26		2
Elaeocarpaceae	*Elaeocarpus*	2.05	10		2
Rubiaceae	*Timonius, Canthium*	1.03	4		2
Rosaceae	*Prunus*	0.77	4		1
Theaceae	*Gordonia*	0.73	6		1
Apocynaceae	*Tabernaemontana*	0.66	3		2
Myristicaceae	*Myristica*	0.48	3		1
Lauraceae	*Actinodaphne, Cryptocarya*	0.47	2		2
Loganiaceae	*Fagraea*	0.46	1		1
Rhizophoraceae	*Carallia*	0.46	2		1
Euphorbiaceae	*Glochidion*, Indet.	0.33	5		2
Guttiferae	*Garcinia*	0.18	2		1
Sabiaceae	*Meliosma*	0.11	2		1
Actinidiaceae	*Saurauia*	0.10	1		1
Melastomataceae	*Astronia*	0.10	1		1
Sapindaceae	Indet.	0.04	1		1
Aquifoliaceae	*Ilex*	0.04	1		1
COPPICED UPPER MONTANE FOREST					
Fagaceae	*Lithocarpus*	23.00	41	64	1
Cunoniaceae	*Weinmannia*	9.44	11	21	1
Myrtaceae	*Leptospermum*	2.95	3	5	1
Euphorbiaceae	*Glochidion*	1.76	1	2	1
Daphniphyllaceae	*Daphniphyllum*	1.20	3	4	1
Theaceae	*Adinandra*	0.18	1	1	1

pale-coloured bark and very few possessed buttress roots: of those in the plot 5% were buttressed (three *Syzygium* species, one *Lithocarpus* and one *Dacrycarpus*) and 1.5% were stilt-buttressed (*Elaeocarpus lancistipulatus* Coode and *Myristica* sp.). There were very few lianas in this forest type, and only two of the tree species (0.05%) had pinnate leaves. The leaves were predominantly in the notophyll/mesophyll category (see Table 2), which, together with the other physiognomic/structural features of this vegetation type, confirm its classification as a Lower Montane Forest as defined by Whitmore (1984).

Epiphytes were abundant, particularly on the larger trees, and consisted primarily of *Orchidaceae* (including *Eria* aff. *glabra* Schltr. and *Phreatia listrophora* Ridl.), pteridophytes (including a common myrmecophilous *Lecanopteris* species), and diverse bryophytes. All of the trees carried mosses and liverworts on their trunks, and those collected in the plot included *Ctenidium polychaetum* (Bosch & Lac.) Broth., *Hypnodendron dendroides* (Brid.) Touw., *Lepidozia ferdinandi-muelleri* Steph. (a new record for Sulawesi) and *Thysananthus aculeatus* Herz. A woody melastomataceous climber (*Medinella* cf. *rosea* Gaud.) was abundant.

In the lower understorey there were three very common species of small trees: *Camellia lanceolata* (Blume) Seem. vel aff. (*Theaceae*), *Urophyllum* sp. and *Psychotria* sp. (*Rubiaceae*). Palms were absent apart from a few rattans (*Calamus* spp.).

Thirty-eight species of trees were recorded in the plot, of which the most important (in terms of basal area) were *Castanopsis acuminatissima* (Bl.) A.DC. (*Fagaceae*; 30.7%), *Platea excelsa* Bl. *sens. lat.* (*Icacinaceae*; 12.9%) and *Polyosma celebica* Schulze-Mez *ined.* (*Escalloniaceae*; 8.5%). The most common understorey trees were *Chionanthus* spp. (*Oleaceae*) and an unidentified *Myrtaceae* (probably *Syzygium* sp.). *Agathis dammara* (Lamb.) Rich. (*Araucariaceae*) was not recorded in the plot, but several very large individuals were found at the same altitude. Details of the physical characteristics of the lower montane forest are shown in Table 3.

The ridge

The vegetation on the ridge running to the summit of Gunung Sinombayuga was essentially the same as that described above, but from 1700m to 1850–1900m a large stilt-rooted screw-pine (*Pandanus koordersii* Martelli) dominated the vegetation conspicuously. The canopy here was lower and much more open, and the small palm *Areca vestiaria* Giseke (*sens. lat.*) was common. Rattans became more abundant between here and the summit. The *Pandanus* grew only on the top of the ridge (on the steep slopes immediately to the north and south it is absent), and did not occur on the summit. This corresponds to the observation made by G. O'Donovan (Knight, 1988) that on the ridges below the neighbouring mountain Gunung Poniki the proportion of pandans was correlated with the narrowness of the ridges and the steepness of their sides.

TABLE 2. Numbers of individuals in a range of leaf size classes in a lower montane forest and a coppiced upper montane forest in the Dumoga Bone National Park. Leaf size nomenclature follows the classification system of Raunkiaer (1934) modified by Webb (1959).

		Lower montane forest		Coppiced upper montane forest			
		Trees ⩾10cm dbh		Trees ⩾10cm dbh		Trees ⩾3.18cm dbh	
Type	Area (mm^2)	% species	% trees	% species	% trees	% species	% trees
Leptophyll	<25	2.6	1.8				
Nanophyll	25–230	2.6	2.4	16.7	5.0	9.1	3.8
Microphyll	230–2000	23.7	16.1	66.6	90.0	36.4	86.1
Notophyll	2000–4500	31.6	49.4	16.7	5.0	54.6	10.1
Mesophyll	4500–18,000	36.8	29.8				
Macrophyll	18,000–16,000	2.6	0.6				

TABLE 3. Structural data for lower montane forest and coppiced upper montane forest on Gunung Sinombayuga.

	Lower montane forest	Coppiced upper montane forest	
	Trees ⩾10cm dbh	Trees ⩾10cm dbh	Trees ⩾3.18cm dbh
Basal area (m^2/ha)	51.3	38.5	43.6
Density (trees/ha)	747	1333	1756
Density (stems/ha)	756	2133	3645
Mean stem diam. (cm)	29.5	15	11.3
Mean no. stems/tree	1	1.6	2.1
Height of continuous canopy (m)	30	15	15

TABLE 4. Bryophyte species collected in upper montane forest on the summit of Gunung Sinombayuga.

Acroporium hermaphroditum (C. Müll.) Fleisch.	*Plagiochila frondescens* (Nees) Lindb.
Anastrophyllum squarrosum Herz.	*Plagiochilion oppositus* (Reinw., Blume & Nees) Hatt.
Bazzania paradoxa (Lac.) Steph.	*Schistochila aligera* (Nees) Jack. & Steph.
Bryum billardieri Schwaegr.	*Sphagnum junghuhnianum* Dozy & Molk.
Lepidozia cladorhiza (Reinw., Blume & Nees) Gottsche	*Spiridens reinwardtii* Nees
Meiothecium hamatum (C. Müll.) Broth.	

Upper montane forest

Towards the summit bryophytes and lichens (e.g. *Usnea*) became much thicker on the trees and the ground, eventually coating the tree trunks and branches to a depth of several centimetres. A list of the more common bryophytes collected in the summit forest is given in Table 4. The trees recorded in the plot were generally of low stature (15–20m), with the majority exhibiting multi-stemmed 'coppice regeneration' form (see Table 3). Buttress roots were not recorded. The diversity of tree species in the upper montane forest was lower than in the lower montane forest, even taking into account the differences in plot size. Only six species with stems $\geqslant$10cm dbh were collected, and twelve of dbh $\geqslant$3.18cm. As in the lower transect, *Fagaceae* dominated the plot in terms of basal area (Table 1).

One species of *Lithocarpus*, with an average of 2.4 stems/tree and a mean stem diameter of 10.8cm, represented 60% of the basal area of stems $\geqslant$10cm dbh within the plot. The second most abundant species, *Weinmannia* cf. *negrosensis* Elmer, averaged 1.8 stems per tree and represented 25% of the basal area. Only five other species possessed stems $\geqslant$10cm dbh, including *Leptospermum javanicum* Bl. (*Myrtaceae*) and *Daphniphyllum* aff. *gracile* Gage (*Daphniphyllaceae*). Of the species $\geqslant$10cm dbh, none had pinnate leaves. Neither of the dominant species were recorded in the lower montane forest, and the only tree found in both plots was a *Glochidion* species (*Euphorbiaceae*). The density of stems with diameter $\geqslant$10cm dbh in the summit plot was almost twice that of the lower plot (Table 3), but nonetheless the total basal area/ha was considerably lower.

Considering the trees $\geqslant$10cm girth ($\geqslant$3.18cm dbh), the leaves of only 45.5% of the species were microphylls or smaller, but on the basis of individual trees this increased to 89.9%. Thus although strictly speaking the forest fell short of the required 50% of species with microphylls or smaller, in all other respects it fitted the Upper Montane Forest classification of Whitmore (1984). Considering the trees $\geqslant$10cm dbh, the forest fitted this category without qualification.

There were very few shrubs or herbs in the upper montane forest, with the exception of a common species of herbaceous *Hedyotis* (*Rubiaceae*), and the density of vascular epiphytes did not appear to be higher than in the forest at 1500m. Orchids collected

on the summit included *Eria robusta* (Bl.) Lindl. and *Epiblastus masarangicus* (Kozl.) Schltr. Ferns were not frequent or diverse, although some tree ferns (*Cyathea* spp.) were present, and apart from rattans (one abundant *Calamus* species) there were few lianas. On the steep southern slope immediately below the summit were treeless patches where there had been landslides at some point in the past, and which had been colonised by brambles (*Rubus alpestris* Blume and *R. fraxinifolius* Poir.).

DISCUSSION

Only 17% of the trees in the upper montane forest and 18% in the lower montane forest on Gunung Sinombayuga have been identified to species. This is partly because a large proportion of the specimens were infertile, but mainly because many of the trees collected there are highly likely to be undescribed species. This is illustrated by the *Elaeocarpus* specimens collected in the Dumoga Bone park during the present study – one of the few parts of the collection to have been studied in depth by a specialist. Of the five species collected at altitudes over 1000m, three have since been described by Coode (1995) as new species (*E. gambutanus* Coode, *E. lancistipulatus* Coode and *E. linnaei* Coode), one as a new subspecies (*E. teysmanni* Koord. & Val. subsp. *domatiferus* Coode), and one (fruiting) specimen has yet to be described or identified.

The multi-stemmed, slender and low stature of the trees in the summit forest is the result of coppice regeneration after clear-felling by a Dutch survey team in 1916 (JTDNI, 1917). This appears to have been the last time that the top of the mountain was visited prior to the present study. The remains of the trigonometrical point were still identifiable. O'Donovan (1990) described similar multiple-stemmed upper montane forest at the summit of the neighbouring Gunung Poniki and Gunung Muajat, which were surveyed at around the same time as G. Sinombayuga.

The diversity of the lower montane forest is lower than that of the lowland forest surveyed at Toraut (also in the Dumoga Bone Park) by Whitmore & Sidiyasa (1986). These authors described the forest as 'depauperate' in the context of Malesian lowland vegetation, with only 109 tree species $\geqslant$10cm dbh in one hectare. From the species/area curve provided in their paper one would predict about 50 species from an area of 0.225ha (i.e. the size of the plot of lower montane forest surveyed during the present study, in which 38 species were recorded).

The structure of the coppiced upper montane forest on Gunung Sinombayuga provides an interesting measure of the rate of regeneration of this vegetation type over a known period (75 years). However, it also confuses any structural comparison which might be made with other montane forests, or the use of physiognomic characteristics for its classification into an altitudinal vegetation type. Its species composition, e.g. the importance of *Weinmannia* and the presence of *Leptospermum* and *Daphniphyllum*, is reasonably typical of Southeast Asian upper montane forests. However, in the descriptions of the upper montane flora of a number of Sulawesi

mountains made by Whitten *et al.* (1987), the dominant trees on or near the summits were generally gymnosperms (e.g. *Phyllocladus*, *Dacrydium*, *Dacrycarpus*).

The composition and diversity on the summit of Gunung Sinombayuga are likely to have been altered by the coppicing process, which may have eliminated groups such as the gymnosperms which tend not to regenerate well from stumps (Pancel, 1993). Edwards *et al.* (1993) on Gunung Binaya, Seram, found much of the upper montane forest on this mountain to be dominated by gymnosperms (*Phyllocladus* and *Dacrycarpus*), but in one plot at 2400m they found a forest which appears to correspond to our upper montane forest on the summit of Gunung Sinombayuga. In this vegetation there was an unusually high occurrence of multi-stemmed broad-leaved trees (1352 stems/ha $\geqslant$10cm dbh), an absence of large conifers (the only gymnosperms present were small and appeared to have regenerated from seed relatively recently), and a number of large *Phyllocladus* stumps. The multi-stemmed nature and reduced gymnosperm presence in this plot were attributed to an historical catastrophic fire; a hypothesis supported by the presence of trace charcoal in the soil. It is not known whether the Dutch surveyors burned the top of Gunung Sinombayuga after they clear-felled it, but if they did this may account to some degree for the similarity.

ACKNOWLEDGEMENTS

Assistance received from the staff of PHPA (Kosingolan and Jakarta), LIPI (Bogor), UDBK (Kotamobagu); the Natural History Museum (London), DINAS Kehutanan (Manado), the Edinburgh Centre for Tropical Forests and the people of Doluduo, Milangodaa and Negerilama is gratefully acknowledged. Josephine Camus, Arifin Bonde, Harun Bonde, Ahmad Da'wa, Said Alwi and Hansye Hamid are particularly thanked for their help and companionship in the field. The research was funded by the British Council. Dedi Darnaedi and Soetikno Atmowidjojo were helpful in obtaining permission. The late Alan Eddy is acknowledged for his bryophyte identifications, and David Henley for his kind help with the Dutch colonial records.

REFERENCES

BALGOOY, M. M. J. VAN. (1987). A plant geographical analysis of Sulawesi. In: Whitmore, T. C. (ed.) *Oxford Monographs on Biogeography 4. Biogeographical Evolution of the Malay Archipelago*, pp. 94–102. Oxford: Clarendon Press.

COODE, M. J. E. (1995). *Elaeocarpus* in the Flora Malesiana area – *E. kraengensis* and ten new species from Sulawesi. *Kew Bull.* 50: 267–294.

EDWARDS, I. D., PROCTOR, J. & RISWAN, S. (1993). Rain forest types in the Manusela National Park. In: EDWARDS, I. D., MACDONALD, A. A. & PROCTOR, J. (eds) *Natural History of Seram*, pp. 63–74. Andover: Intercept.

JTDNI (1917). *Jaarverslag van den Topographischen Dienst in Nederlandsch-Indië over 1916*. Batavia: Topographische Inrichting.

KNIGHT, W. J. (1988). *Report. Project Wallace Commemorative Expedition to North Sulawesi, January–December 1985*. London: Royal Entomological Society.

KUCERA, K. P. (1990). The physiography of the Dumoga-Bone region, North Sulawesi: climate, topography, geology, soils and generalised forest mapping. In: Knight,

W. J. & Holloway, J. D. (eds) *Insects and the Rainforests of Southeast Asia (Wallacea)*, pp. 107–128. London: Royal Entomological Society.
O'DONOVAN, G. (1990). Vegetation patterns in the Dumoga-Bone National Park, Sulawesi. In: KNIGHT, W. J. & HOLLOWAY, J. D. (eds) *Insects and the Rainforests of Southeast Asia (Wallacea)*, pp. 129–143. London: Royal Entomological Society.
PANCEL. L. (1993). Nursery management. In: Pancel, L. (ed.) *Tropical Forestry Handbook*, pp. 461–514. Berlin: Springer-Verlag.
RAUNKIAER, C. (1934). *The Life-Forms of Plants and Statistical Plant Geography*. Oxford: Clarendon Press.
STEENIS, C. G. G. J. VAN. (1972). *The Mountain Flora of Java*. Leiden: Brill.
WEBB, L. J. (1959). A physiognomic classification of Australian rainforests. *J. Ecol.* 47: 551–570.
WHITMORE, T. C. (1984). *Tropical Rain Forests of the Far East*. 2nd edition. Oxford: Oxford University Press.
WHITMORE, T. C. & SIDIYASA, K. (1986). Composition and structure of a lowland rain forest at Toraut, northern Sulawesi. *Kew Bull.* 41: 747–756.
WHITTEN, A. J., MUSTAFA, M. & HENDERSON, G. S. (1987). *The Ecology of Sulawesi*. Yogyakarta: Gadjah Mada University Press.
WIND, J. (1984). *Management Plan 1984–1989 Dumoga Bone National Park*. Bogor: Directorate General of Forest Protection & Nature Conservation (PHPA).

Received 26 May 1999; accepted with revision 28 June 1999

APPENDIX

Tree species* recorded in lower montane forest (LMF) and coppiced upper montane forest (UMF) on Gunung Sinombayuga.

Species	Family	Plot
Castanopsis acuminatissima (Bl.) A.DC.	*Fagaceae*	LMF
Dacrycarpus cf. *steupii* (Wasscher) de Laubenf.	*Podocarpaceae*	LMF
Daphniphyllum aff. *gracile* Gage	*Daphniphyllaceae*	UMF
Elaeocarpus lancistipulatus Coode	*Elaeocarpaceae*	LMF
Elaeocarpus teysmanni Koord. & Val. ssp. *domatiferus* Coode	*Elaeocarpaceae*	LMF
Fagraea cf. *longiflora* Merr.	*Loganiaceae*	LMF
Falcatifolium cf. *papuanum* de Laubenf.	*Podocarpaceae*	LMF
Gordonia cf. *excelsa* Bl.	*Theaceae*	LMF
Ilex cf. *glomerata* King	*Aquifoliaceae*	LMF
Leptospermum javanicum Bl.	*Myrtaceae*	UMF
Meliosma pinnata (Roxb.) Walp.	*Meliosmaceae*	LMF
Platea excelsa Bl. (*sens. lat.*)	*Icacinaceae*	LMF
Polyosma celebica Schulze-Menz ined.	*Escalloniaceae*	LMF
Prunus arborea (Bl.) Kalkm.	*Rosaceae*	LMF
Saurauia spadicea Bl.	*Actinidiaceae*	LMF
Weinmannia cf. *negrosensis* Elmer	*Cunoniaceae*	UMF

* Identified beyond generic level.