



Tree diversity in sub-montane and lower montane primary rain forests in Central Sulawesi

H. Culmsee¹, R. Pitopang²

Key words

Flora Malesiana
Lore Lindu
montane forest
primary forest
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tree diversity

Abstract The tree diversity of sub-montane and lower montane primary forests is studied in plot-based inventories on two sites in Lore Lindu National Park, Central Sulawesi. Out of 166 species in total, 50 % are new records for Sulawesi (19 %) or the Central Sulawesi province (31 %). Species richness decreases with altitude. In the sub-montane forest, the highest Family Importance Values (FIV) are reached by the *Lauraceae*, *Fagaceae*, *Sapotaceae*, *Moraceae* and *Euphorbiaceae*. In the lower montane forest, the *Fagaceae* are of major importance (FIV 71.9), followed at some distance by the *Myrtaceae*, *Elaeocarpaceae* and *Lauraceae*. For each site, a group of important families is identified that is of minor importance or absent on the other site. The comparison of basal area (BA), number of species and FIV with published plot-based studies in sub-montane and lower montane primary forests in Malesia (Borneo, Sulawesi, Papua New Guinea) reveals: 1) with 35.4 and 37.1 m² ha⁻¹, the BA is comparable to that measured in Borneo and Papua New Guinea, but does not support previous findings of extremely high BA in Sulawesi forests; 2) species richness is comparable to that in Borneo and other Sulawesi forests, but lower than in Papua New Guinea; 3) decrease in diversity with altitude is in accordance with findings in Borneo; 4) in sub-montane forests, the *Lauraceae* are generally important; the Sulawesi studies are closely related to those from Papua New Guinea; 5) the lower montane forests have the *Fagaceae* and *Myrtaceae* as most important families in common.

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INTRODUCTION

A survey of plant species diversity and endemism across five major Malesian islands has indicated that the island of Sulawesi is intermediate for these measures (Roos et al. 2004). This is remarkable, because one would expect at least high endemism rates due to the isolation of the Wallacean island from the Sunda Shelf during the Quaternary period (Primack & Corlett 2006). Cannon et al. (2007) pointed out that this mediocrity might be related to the fact that collection rates on the island are among the lowest in Indonesia and to the limited taxonomic study. Hence, additional collections, especially from remote and primary forest areas in Sulawesi, are needed to further our knowledge of the island's plant diversity. Our plot-based tree inventories in primary forests of Lore Lindu National Park, Central Sulawesi, explore the species diversity of sub-montane and lower montane forests. We present a large number of new taxonomic records for Sulawesi or the Central Sulawesi province compared to the Checklist of woody plants of Sulawesi (Keßler et al. 2002).

Especially in montane forests of the Malesian tropics, detailed tree surveys are limited. Quantitative altitudinal transect studies are known from Mt Kinabalu, Borneo (Kitayama 1992, Aiba & Kitayama 1999, Aiba et al. 2005). A tree diversity study on a one-hectare-plot was carried out by Wright et al. (1997) at 900 m altitude in Papua New Guinea. In Lore Lindu National Park, Central Sulawesi, primary forests were studied at 1 100–1 200 m altitude by Kessler et al. (2005). The present study is the first to deal with the primary forest of Sulawesi at different elevations. We aim at identifying the most important tree families

in our surveyed forests as well as detecting changes in tree family composition between sub-montane and lower montane primary forest sites.

METHODS

Study area

The two primary forest study sites are located in Lore Lindu National Park, Central Sulawesi, Indonesia. Most parts of the protected area are covered by upland and montane forests on intermediate soils. The forest condition is good to old growth (Cannon et al. 2007).

The first site is situated in Pono Valley at 1 050 m altitude (S 01°29.6', E 120°03.4', GC-WGS 84). The habitat is a sub-montane old growth forest on Ferralsol (FAO 2006) developed on metamorphic rocks in a stable level terrain on a mid-slope. Pono Valley is one of the Sulawesi Throughfall Displacement Experiment test sites hosted by the collaborative research centre SFB 552 (University of Göttingen).

The second site is located in the Bariri Forest at 1 400 m altitude (S 01°39.5', E 120°10.4', GC-WGS 84). The habitat is a lower montane old growth forest on Nitisol (FAO 2006) developed on sedimentary substrate on a level plateau. A 70 m tall meteorological scaffold tower is constructed in the centre of the forest. The forest shows small-scale disturbances close-by the tower caused by the tower construction.

Field sampling

Plot-based tree inventories were carried out in the period from July to September 2006. Collections were completed in 2007.

Plot size was 40 × 60 m (0.24 ha) divided up into a 10 × 10 m grid. All trees of diameter at breast height (dbh) ≥ 10 cm were surveyed. Within the 10 × 10 m grid, 5 × 5 m-sized subplots were nested (0.06 ha). Therein, understorey trees of dbh 2–9.9 cm

¹ Department of Vegetation and Phytodiversity Analysis, Albrecht-von-Haller Institute for Plant Sciences, University of Göttingen, Untere Karspüle 2, 37073 Göttingen, Germany;

e-mail: heike.culmsee@bio.uni-goettingen.de.

² Department of Biology, Faculty of Mathematics and Natural Sciences, Tadulako University, Palu, Sulawesi Tengah 94118, Indonesia.

were additionally sampled. All trees were permanently tagged, pre-identified, their structural parameters (dbh, total height, trunk height) and their spatial position recorded. In Pono Valley six plots were installed \pm parallel to each other aligned to the Sulawesi Throughfall Displacement Experiment test plots (total area 1.44 ha). In the Bariri Forest, three plots were set up in a radial arrangement around the meteorological tower avoiding disturbed areas (total area 0.72 ha).

Tree species identification

Tree species identification was based upon about 2 000 specimens (collection numbers HC) collected from tagged trees and supplementary trees in flower or fruit. Specimens were deposited at CEB, GOET, K and L.

Tree species were identified by H. Culmsee using the collection at the National Herbarium of the Netherlands, University of Leiden branch, as reference and by specialists for *Elaeocarpaceae* (M.J.E. Coode, K), *Moraceae* (C.C. Berg, L) and *Myristicaceae* (W.J.J.O. de Wilde, L). Taxa difficult to identify to species, especially in the *Myrtaceae*, were distinguished as separate species based on morphology of vegetative characters (leaves, twigs and barks).

Tree diversity analysis

Species-level presence/absence data related to study site included all tagged trees of dbh \geq 10 cm and were complemented by supplementary species found in the understorey subplots. The assessments as new records for Sulawesi or Central Sulawesi were based on comparison with the Checklist of woody plants of Sulawesi (Keßler et al. 2002).

As the size of the sampled area varied between sites, sample-based rarefaction curves (Gotelli & Colwell 2001) were calculated using EstimateS v8.0.0 (Colwell 2006) to assess the

Table 1 Basic Pono Valley and Bariri Forest tree inventory metrics.

	Pono Valley (alt. 1 050 m)	Bariri Forest (alt. 1 400 m)
No. of tree families	42	36
No. of tree taxa	123	74
Plot size (in ha)	1.44	0.72
Stem density (trees dbh \geq 10 cm, n ha ⁻¹)	520	592
Stem density (trees dbh 2–9.9 cm, n ha ⁻¹)	1767	2653
Basal area of trees \geq 10 cm dbh (m ² ha ⁻¹)	35.4	37.1
Basal area of trees \geq 2 cm dbh (m ² ha ⁻¹)	38.8	40.9

comparability of species richness per site. Sample units were based on individual counts within the 10 \times 10 m grid, i.e. 24 samples correspond to one plot (0.24 ha). The analysis included all trees surveyed (dbh 2–9.9 cm and dbh \geq 10 cm).

On the family level, relative frequency (based on the enumeration of individuals) and basal area (based on the dbh measured) were calculated. The Family Importance Value (FIV, Mori et al. 1983) was used to assess the contribution of each family to the stand. FIV combines relative family richness (number of species), relative density (number of individuals) and relative dominance (basal area) into one value. Between-site comparison on the family level took into account trees dbh \geq 10 cm.

RESULTS

Species richness

The sub-montane forest in Pono Valley (alt. 1 050 m) accommodates 123 tree taxa assigned to 42 families. The lower montane Bariri Forest (alt. 1 400 m) is much species poorer with 74 tree taxa out of 36 families (Table 1).

Although the size of the sampled area in the Bariri Forest (0.72 ha) is only half of that in the Pono Valley (1.44 ha), the

Table 2 Species list based on plot-based tree inventories. P = Pono Valley (alt. 1 050 m); B = Bariri Forest (alt. 1 400 m); (T) = records for trees dbh \geq 10 cm; (t) = supplementary records for small trees dbh 2–9.9 cm; C = new record for Sulawesi; CC = new record for Central Sulawesi in comparison to Keßler et al. (2002); + = record; +! = new species; (+) = probably a new record.

	P(T)	P(t)	B(T)	B(t)	C	CC		P(T)	P(t)	B(T)	B(t)	C	CC
Aceraceae													
1		+		+			Daphniphyllaceae						
							23 <i>Daphniphyllum papuanum</i> Hallier f.						
Annonaceae													
2		+					Dracaenaceae (Liliaceae)						
							24 <i>Dracaena angustifolia</i> Roxb.						
3		+				+	Ebenaceae						
							25 <i>Diospyros rumphii</i> Bakh.						
4		+				+	Elaeocarpaceae						
							26 <i>Elaeocarpus celebicus</i> Koord.						
5		+				+	27 <i>Elaeocarpus culminicola</i> Warb.						
							28 <i>Elaeocarpus dolichostylus</i> Schltr.						
6		+				+	29 <i>Elaeocarpus erdinii</i> Coode						
Apocynaceae													
7		+				+	30 <i>Elaeocarpus glaber</i> Blume						
Aquifoliaceae													
8				+		+	31 <i>Elaeocarpus luteolignum</i> Coode						
Araliaceae													
9		+		+		+	32 <i>Elaeocarpus macropus</i> Warb. ex Knuth						
Arecaceae (Palmae)													
10		+				+	33 <i>Elaeocarpus musseri</i> Coode						
							34 <i>Elaeocarpus octopetalus</i> Merr.						
11		+				+	35 <i>Elaeocarpus</i> sect. <i>Collopetalum</i> Schltr.						
Asteraceae (Compositae)													
12		+		+		+	36 <i>Elaeocarpus</i> L. sp. 1						
Burseraceae													
13		+				+	37 <i>Elaeocarpus</i> L. sp. 2						
							Escalloniaceae (Saxifragaceae)						
14		+		+		+	38 <i>Polyosma celebica</i> Schulze-Menz						
							39 <i>Polyosma integrifolia</i> Blume						
15		+				+	40 <i>Polyosma latifolia</i> Schltr.						
Caprifoliaceae													
16				+			Euphorbiaceae						
Chrysobalanaceae													
17				+			41 <i>Acalypha</i> L. sp.						
Clusiaceae (Guttiferae)													
18		+		+		+	42 <i>Antidesma stipulare</i> Blume						
							43 <i>Antidesma</i> L. sp.						
19		+		+		+	44 <i>Aporosa lucida</i> (Miq.) Airy Shaw						
							45 <i>Bridelia glauca</i> Blume						
20		+		+		+	46 <i>Drypetes minahassae</i> Pax & K.Hoffm.						
							47 <i>Glochidion lucidum</i> Blume						
21		+				+	48 <i>Homalanthus populneus</i> Pax						
Cyatheaceae													
22		+				+	49 <i>Macaranga allorobinsonii</i> Whitmore						
							50 <i>Macaranga waturandangii</i> Whitmore						

Table 2 (cont.)

	P(T)	P(t)	B(T)	B(t)	C	CC		P(T)	P(t)	B(T)	B(t)	C	CC
51 <i>Macaranga Thouars</i> sp.		+					108 <i>Ficus aurita</i> Blume	+				+	
52 <i>Mallotus paniculatus</i> (Geiseler) Airy Shaw		+					109 <i>Ficus calcarata</i> Corner		+				+
53 <i>Trigonopleura malayana</i> Hook.f.		+					110 <i>Ficus crassiramea</i> (Miq.) Miq.	+					+
Fagaceae							111 <i>Ficus glandulifera</i> (Wall. ex Miq.) King					+	+
54 <i>Castanopsis acuminatissima</i> (Blume) Rehder		+	+				112 <i>Ficus schwarzii</i> Koord.		+				
55 <i>Lithocarpus celebicus</i> (Miq.) Rehder		+	+				113 <i>Ficus</i> L. sp. (strangler)	+					
56 <i>Lithocarpus elegans</i> (Blume) Hatus. ex Soepadmo				+	+		114 <i>Streblus glaber</i> (Merr.) Corner subsp. <i>glaber</i>				+		
57 <i>Lithocarpus menadoensis</i> (Koord.) Soepadmo				+		+	Myristicaceae						
Gesneriaceae					+		115 <i>Gymnacranthera farquhariana</i> (Hook.f. & Thomson) Warb. var. <i>zippeliana</i> (Miq.) R.T.A.Schouten	+				+	
58 <i>Cyrtandra fasciata</i> H.J. Atkins		+			+		116 <i>Horsfieldia costulata</i> (Miq.) Warb.	+		+			+
Hamamelidaceae					+		117 <i>Knema stellata</i> Merr. subsp. <i>minahassae</i> (Warb.) W.J.de Wilde					+	
59 <i>Sycopsis dunnii</i> Hemsl.			+		+		118 <i>Myristica simiarum</i> A.DC. subsp. <i>celebica</i> (Miq.) W.J.de Wilde	+					+
Himantandraceae							Myrsinaceae						
60 <i>Galbulimima belgraveana</i> (F.Muell.) Sprague	+		+				119 <i>Ardisia forbesii</i> S.Moore		+		+		
Icacinaceae							120 <i>Discocalyx silvestris</i> Holthuis		+				+
61 <i>Platea excelsa</i> Blume var. <i>borneensis</i> (Heine) Sleumer		+			+		121 <i>Myrsine porteriana</i> Wall. & A.DC.					+	+
62 <i>Platea latifolia</i> Blume			+		+		Myrtaceae						
Juglandaceae							122 <i>Myrtaceae</i> sp. 1						+
63 <i>Engelhardtia rigida</i> Blume			+				123 <i>Myrtaceae</i> sp. 2	+		+			
64 <i>Engelhardtia serrata</i> Blume	+		+		+		124 <i>Myrtaceae</i> sp. 3				+		
Lauraceae							125 <i>Myrtaceae</i> sp. 4	+					
65 <i>Cinnamomum polderi</i> Kosterm.				+	+		126 <i>Myrtaceae</i> sp. 5	+		+			
66 <i>Cinnamomum trichophyllum</i> Quisumb. & Merr.	+						127 <i>Myrtaceae</i> sp. 6	+					
67 <i>Cryptocarya crassinerviopsis</i> Kosterm.	+						128 <i>Myrtaceae</i> sp. 7	+					
68 <i>Cryptocarya ferrea</i> Blume			+		+		129 <i>Myrtaceae</i> sp. 8	+					
69 <i>Cryptocarya glauca</i> Merr.			+		+		130 <i>Myrtaceae</i> sp. 9	+		+			
70 <i>Cryptocarya laevigata</i> Blume	+				+		Oleaceae						
71 <i>Cryptocarya subvelutina</i> Elmer	+			+	+		132 <i>Chionanthus celebicus</i> Koord.	+					+
72 <i>Endiandra rubescens</i> (Blume) Miq.	+				+		133 <i>Chionanthus polygamus</i> (Roxb.) Kiew	+		+			
73 <i>Endiandra sulavesiana</i> Kosterm.			+		+		Pandanaceae						
74 <i>Endiandra velutina</i> Kosterm.			+		+		134 <i>Pandanus</i> L.f. sp.	+					
75 <i>Lindera apoensis</i> Elmer	+				+		Podocarpaceae						
76 <i>Litsea accedentoides</i> Koord. & Valetton			+		+		135 <i>Podocarpus neriifolius</i> D.Don					+	
77 <i>Litsea elliptica</i> Blume	+		+		+		Proteaceae						
78 <i>Litsea formanii</i> Kosterm.	+		+		+		136 <i>Macadamia hildebrandii</i> Steenis				+		+
79 <i>Litsea grandis</i> Hook.f.			+		+		Rhizophoraceae						
80 <i>Litsea timoriana</i> Span.	+				+		137 <i>Carallia brachiata</i> (Lour.) Merr.		+				
81 <i>Neolitsea latifolia</i> (Blume) Moore	+				+		Rosaceae						
82 <i>Persea rimosa</i> Zoll. ex Meisn.			+		+		138 <i>Prunus grisea</i> (Blume ex Müll.Berol.) Kalkman var. <i>grisea</i>	+		+			
83 <i>Phoebe grandis</i> (Nees) Merr.	+				+		Rubiaceae						
Leguminosae – Mimosoideae							139 <i>Diplospora</i> DC. sp.	+					
84 <i>Archidendron clypearia</i> (Jack) I.C.Nielsen	+				+		140 <i>Gardenia longifolia</i> Vidal	+					
Magnoliaceae							141 <i>Hypobathrum</i> Blume sp.		+				
85 <i>Magnolia liliifera</i> (L.) Baill. var. <i>liliifera</i>	+		+				142 <i>Ixora longifolia</i> Valetton		+			+	
86 <i>Magnolia montana</i> (Blume) Figlar & Noot.		+			+		143 <i>Pavetta celebica</i> Bremek.		+				
87 <i>Magnolia tsiampacca</i> (L.) Figlar & Noot. var. <i>tsiampacca</i>	+						144 <i>Porterandia celebica</i> Zahid	+		+			+
Melastomataceae							145 <i>Praravinia loconensis</i> Bremek.		+				+
88 <i>Memecylon paniculatum</i> Jack	+		+		+		146 <i>Psychotria malayana</i> Jack	+					+
Meliaceae							147 <i>Timonius minahassae</i> Koord.	+					
89 <i>Aglaiia lancilimba</i> Merr.	+				+		148 <i>Urophyllum arboreum</i> Korth.				+		
90 <i>Aglaiia squamulosa</i> King	+						Rutaceae						
91 <i>Aglaiia tomentosa</i> Teijsm. & Binn.	+						149 <i>Acronychia pedunculata</i> Miq.	+		+			+
92 <i>Aglaiia</i> Lour. sp.		+					150 <i>Melicope bonwickii</i> (F.Muell.) T.G.Hartley	+					
93 <i>Chisocheton patens</i> Blume	+				+		151 <i>Melicope confusa</i> (Merr.) T.S.Liu	+		+			+
94 <i>Chisocheton warburgii</i> Harms	+				+		Sapindaceae						
95 <i>Dysoxylum acutangulum</i> Miq. subsp. <i>foveolatum</i> (Radlk.) Mabb.	+				+		154 <i>Guioa hirsuta</i> Welzen	+			+		+
96 <i>Dysoxylum densiflorum</i> Miq.	+						155 <i>Harpullia cupanioides</i> Roxb.	+					
97 <i>Dysoxylum excelsum</i> Blume	+		+				156 <i>Pometia pinnata</i> J.R.Forst. & G.Forst.	+					
98 <i>Dysoxylum nutans</i> (Blume) Miq.	+						Sapotaceae						
99 <i>Dysoxylum quadrangulatum</i> Culmsee		+			+		157 <i>Palaquium luzoniense</i> S.Vidal	+					+
100 <i>Reinwardtiodendron</i> Koord. sp.				+	(+)		158 <i>Pouteria firma</i> (Miq.) Baehni	+		+			+
Meliosmaceae (Sabiaceae)							Staphyleaceae						
101 <i>Meliosma sumatrana</i> Walp.	+						159 <i>Turpinia sphaerocarpa</i> Hassk.	+					
Monimiaceae							Sterculiaceae						
102 <i>Kibara</i> Endl. sp.		+					160 <i>Sterculia macrophylla</i> Vent.	+					
103 <i>Levieria montana</i> Becc.	+		+		+		161 <i>Sterculia oblongata</i> R.Br.	+			+		+
104 <i>Matthaea sancta</i> Blume	+				+		Theaceae						
105 <i>Steghanthera hirsuta</i> Perkins				+	+		162 <i>Adinandra celebica</i> Koord.				+		
Moraceae							163 <i>Camellia lanceolata</i> Seem.		+				
106 <i>Artocarpus lacucha</i> Buch.-Ham.	+				+		164 <i>Eurya acuminata</i> DC.	+		+			
107 <i>Artocarpus teysmannii</i> Miq. subsp. <i>teysmannii</i>		+					165 <i>Ternstroemia</i> L.f. sp.				+		
							Verbenaceae						
							166 <i>Vitex</i> L. sp.	+					

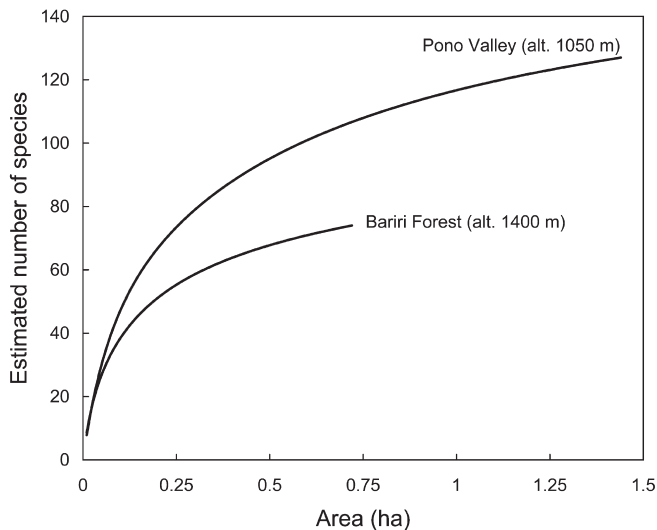


Fig. 1 Sample-based rarefaction curves for Pono Valley (alt. 1 050 m) and Bariri Forest (alt. 1 400 m).

difference in species richness is not an artefact. The sample-based rarefaction curve (Fig. 1) shows that already at half of the effectively sampled area in the Bariri Forest the curve starts rising slowly. If the curve is extrapolated, it reaches ± 85 taxa at 1.44 ha. In contrast, the number of species is expected to exceed 100 already at 0.72 ha in Pono Valley.

The combined Pono Valley and Bariri Forest species list (Table 2) comprises a total of 166 taxa assigned to 49 families. Less than 1 % of the sampled trees remained unidentified. At Pono Valley, the trees of dbh ≥ 10 cm include 104 taxa with an additional 19 supplementary species found among the trees of dbh 2–9.9 cm. The Bariri Forest comprises 60 tree species of dbh ≥ 10 cm with 14 taxa additionally found among the trees of dbh 2–9.9 cm. The two sites have 33 species in common. The highest number of species is found in *Lauraceae* (19 spp.), *Euphorbiaceae* (13 spp.), *Elaeocarpaceae* (12 spp.), *Meliaceae* (12 spp.), *Rubiaceae* (10 spp.), *Moraceae* (9 spp.) and *Myrtaceae* (9 spp.).

A total of 50 % are found to be new records, with 19 % as new records for Sulawesi (32 spp.) and 31 % as new to Central

Sulawesi (51 spp.). The new records for Sulawesi include on family level the *Gesneriaceae* and the *Hamamelidaceae*. Tree ferns are explicitly not included in the checklist (Keßler et al. 2002), but are included in the present list. One new species was described based on the collections from Pono Valley (Culmsee 2008).

Community composition

The sub-montane and the lower montane forests have ten important tree families in common (based on FIV, Table 3). In Pono Valley, the *Lauraceae* have the highest importance (FIV = 30.2), closely followed by the *Fagaceae*, *Sapotaceae*, *Moraceae* and *Euphorbiaceae*. In the Bariri Forest, the *Fagaceae* are by far the most dominant family (FIV = 71.9). They are followed by the *Myrtaceae*, *Elaeocarpaceae* and *Lauraceae*.

The families *Juglandaceae*, *Oleaceae* and *Theaceae* have high importance in the lower montane forest, but their importance is low in the sub-montane forest. In contrast, the *Asteraceae*, *Meliaceae*, *Myristicaceae*, *Rubiaceae* and *Rutaceae* are important families in the sub-montane forest, but their importance decreases considerably in the lower montane forest. The *Annonaceae*, *Cyatheaceae* and *Dracaenaceae* are present in the sub-montane forest, but they are absent in the lower montane forest.

DISCUSSION

The large number of new records of tree species for the island of Sulawesi or its Central province is remarkable, in particular as the Lore Lindu National Park is among the parts of Sulawesi for which the largest plant collections are available (Cannon et al. 2007). For the whole island, the plant collection density is one of the lowest in Malesia (Roos et al. 2004), with 25 per 100 km². Furthermore, only few plant collections are available from the quite extensive forests in good or old-growth conditions in other parts of Sulawesi (Cannon et al. 2007). That leads to the assumption that the relative number of new records or even new species could potentially be even higher in primary forests of other, less investigated parts of Sulawesi.

Compared to plot-based studies at similar altitudes in Malesia (Table 4), the plots in the present study are less species

Table 3 Family Importance Value (FIV; R: within-site ranking of families sorted by FIV), number of species (# sp), relative frequency in % (Rel FQ) and basal area (BA ha⁻¹) for the most important tree families (FIV ≥ 5.0) at Pono Valley (alt. 1 050 m) and Bariri Forest (alt. 1 400 m) based on trees dbh ≥ 10 cm.

Pono Valley					Bariri Forest						
R	Family	FIV	# sp	Rel FQ	BA ha ⁻¹	R	Family	FIV	# sp	Rel FQ	BA ha ⁻¹
2	<i>Fagaceae</i>	29.9	2	8.9	6.8	1	<i>Fagaceae</i>	71.9	5	15.9	17.8
1	<i>Lauraceae</i>	30.2	11	11.4	3.2	4	<i>Lauraceae</i>	23.3	9	5.7	1.2
7	<i>Myrtaceae</i>	15.1	7	5.3	1.2	2	<i>Myrtaceae</i>	27.4	5	12.0	2.8
3	<i>Sapotaceae</i>	26.4	2	8.0	5.9	9	<i>Sapotaceae</i>	10.8	1	3.1	2.3
10	<i>Elaeocarpaceae</i>	9.8	5	2.5	1.0	3	<i>Elaeocarpaceae</i>	26.5	7	10.7	1.8
5	<i>Euphorbiaceae</i>	21.1	12	7.0	1.1	7	<i>Euphorbiaceae</i>	11.4	4	4.2	0.3
4	<i>Moraceae</i>	22.3	4	1.0	6.2	12	<i>Moraceae</i>	5.7	1	2.9	0.5
13	<i>Burseraceae</i>	8.4	2	3.7	1.0	5	<i>Burseraceae</i>	18.0	1	5.5	4.0
12	<i>Icacinaceae</i>	9.2	1	5.4	1.0	10	<i>Icacinaceae</i>	9.0	1	4.7	1.0
17	<i>Clusiaceae</i>	5.5	4	0.7	0.4	8	<i>Clusiaceae</i>	11.3	1	6.3	1.3
28	<i>Oleaceae</i>	2.4	2	0.4	0.1	6	<i>Oleaceae</i>	17.3	1	12.5	1.2
30	<i>Juglandaceae</i>	2.2	1	0.4	0.3	13	<i>Juglandaceae</i>	5.4	2	1.6	0.3
38	<i>Theaceae</i>	1.4	1	0.3	< 0.1	11	<i>Theaceae</i>	6.1	3	1.0	0.1
8	<i>Meliaceae</i>	15.9	9	4.8	1.0	27	<i>Meliaceae</i>	2.2	1	0.5	< 0.1
8	<i>Myristicaceae</i>	10.9	3	6.1	0.7	14	<i>Myristicaceae</i>	4.9	2	0.8	0.4
11	<i>Rubiaceae</i>	9.7	7	2.6	0.3	17	<i>Rubiaceae</i>	3.8	1	1.6	0.2
14	<i>Rutaceae</i>	6.6	3	2.9	0.3	16	<i>Rutaceae</i>	3.9	2	0.5	0.1
15	<i>Asteraceae</i>	6.0	1	2.9	0.8	30	<i>Asteraceae</i>	2.0	1	0.3	0.1
9	<i>Annonaceae</i>	9.9	5	3.8	0.6						
16	<i>Dracaenaceae</i>	5.6	1	3.5	0.4						
18	<i>Cyatheaceae</i>	5.4	1	3.7	0.3						

Table 4 Number of species (# sp), basal area (BA) and top-3 families in this study compared to primary forest plots in Malesia available from literature (CEL = Sulawesi, BOR = Borneo, PNG = Papua New Guinea). Considered are trees of dbh \geq 10 cm. The ranking of the top-3 families are based on Family Importance Value (FIV) for CEL Pono, CEL Bariri, CEL LLNP and PNG, respectively relative basal area (%) for BOR 07N and BOR 17N.

Site	BOR 07N	PNG	CEL Pono	CEL LLNP	CEL Bariri	BOR 17N
Reference	Aiba & Kitayama (1999)	Wright et al. (1997)	this study	Kessler et al. (2005)	this study	Aiba & Kitayama (1999)
Altitude (m)	700	900	1 050	1 100–1 200	1 400	1 700
# sp	148	228	104	c. 150	60	84
BA (m ² ha ⁻¹)	34.0	37.1	35.4	139.8	37.1	36.4
Top-3 families	<i>Dipterocarpaceae</i> <i>Ixonanthaceae</i> <i>Lauraceae</i>	<i>Lauraceae</i> <i>Myristicaceae</i> <i>Moraceae</i>	<i>Lauraceae</i> <i>Fagaceae</i> <i>Sapotaceae</i>	<i>Meliaceae</i> <i>Moraceae</i> <i>Lauraceae</i>	<i>Fagaceae</i> <i>Myrtaceae</i> <i>Elaeocarpaceae</i>	<i>Myrtaceae</i> <i>Fagaceae</i> <i>Podocarpaceae</i>

rich. But with about double the number of species compared to Pono Valley, only the one-hectare-plot from Papua New Guinea (Wright et al. 1997) is truly exceptional. The difference is considered to be caused by the history of the Papua New Guinean flora (Primack & Corlett 2006, Wright et al. 1997). The decrease in number of species with higher elevation in the Bariri Forest compared to Pono Valley is in accordance with the results from the Mt Kinabalu altitudinal transect study (Aiba & Kitayama 1999). The basal area recorded for both the Pono Valley and the Bariri Forest is in accordance with data from all sites except the study of Kessler et al. (2005) where a basal area was recorded that was more than three times as high as in other studies.

In terms of the top-3 families, all sub-montane forests have the *Lauraceae* as important family in common. However, the overall dominant *Dipterocarpaceae* of the Bornean sub-montane forest are not represented in the studies east of Wallace's line. In the composition of the top-10 most important families (FIV), the forest site surveyed by Kessler et al. (2005) seems to be more similar to the Papua New Guinean forest (Wright et al. 1997) than to the Pono Valley forest. The lower montane Bariri Forest and the Bornean forest at 1 700 m altitude are best comparable in having their two most important families in common, the *Fagaceae* and the *Myrtaceae*.

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