Blumea 54, 2009: 119–123
www.ingentaconnect.com/content/nhn/blumea

RESEARCH ARTICLE

doi:10.3767/000651909X475473

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

H. Culmsee[1], R. Pitopang[2]

Key words

Flora Malesiana
Lore Lindu
montane forest
primary forest
rain forest
SE Asia
Sulawesi
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 m^2 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.

Published on 30 October 2009

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.

© 2009 Nationaal Herbarium Nederland

You are free to share - to copy, distribute and transmit the work, under the following conditions:
Attribution: You must attribute the work in the manner specified by the author or licensor (but not in any way that suggests that they endorse you or your use of the work).
Non-commercial: You may not use this work for commercial purposes.
No derivative works: You may not alter, transform, or build upon this work.
For any reuse or distribution, you must make clear to others the license terms of this work, which can be found at http://creativecommons.org/licenses/by-nc-nd/3.0/legalcode. Any of the above conditions can be waived if you get permission from the copyright holder. Nothing in this license impairs or restricts the author's moral rights.

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 ± 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 ≥ 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 comparability of species richness per site. Sample units were based on individual counts within the 10 × 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 ≥ 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 ≥ 10 cm.

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 ≥ 10 cm, n ha^{-1})	520	592
Stem density (trees dbh 2–9.9 cm, n ha^{-1})	1767	2653
Basal area of trees ≥ 10 cm dbh (m^2 ha^{-1})	35.4	37.1
Basal area of trees ≥ 2 cm dbh (m^2 ha^{-1})	38.8	40.9

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 ≥ 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
Aceraceae						
1 *Acer laurinum* Hassk. ex Miq.	+		+			
Annonaceae						
2 *Alphonsea javanica* Scheff.	+					
3 *Cyathocalyx acuminatus* C.B.Rob.	+					+
4 *Goniothalamus philippinensis* Merr.	+				+	
5 *Polyalthia lateriflora* King	+					
6 *Popowia pisocarpa* Endl.	+					
Apocynaceae						
7 *Alstonia spectabilis* R.Br.	+					
Aquifoliaceae						
8 *Ilex cymosa* Blume			+			+
Araliaceae						
9 *Gastonia serratifolia* (Miq.) Philipson	+		+		+	
Arecaceae (Palmae)						
10 *Areca vestiaria* Giseke	+				+	
11 *Pinanga caesia* Blume	+					+
Asteraceae (Compositae)						
12 *Vernonia arborea* Buch.-Ham.	+		+			
Burseraceae						
13 *Canarium balsamiferum* Willd.	+					
14 *Canarium trigonum* H.J.Lam			+			+
15 *Santiria apiculata* A.W.Benn.	+					+
Caprifoliaceae						
16 *Viburnum sambucinum* Reinw. ex Blume			+			
Chrysobalanaceae						
17 *Maranthes corymbosa* Blume		+				
Clusiaceae (Guttiferae)						
18 *Calophyllum* L. sp.	+		+		+	
19 *Garcinia dulcis* (Roxb.) Kunz		+				+
20 *Garcinia lateriflora* Blume	+					
21 *Garcinia* L. sp.	+					
Cyatheaceae						
22 *Cyathea celebica* Blume	+				+	
Daphniphyllaceae						
23 *Daphniphyllum papuanum* Hallier f.			+		+	
Dracaenaceae (Liliaceae)						
24 *Dracaena angustifolia* Roxb.	+				+	
Ebenaceae						
25 *Diospyros rumphii* Bakh.			+			+
Elaeocarpaceae						
26 *Elaeocarpus celebicus* Koord.			+			+
27 *Elaeocarpus culminicola* Warb.			+			+
28 *Elaeocarpus dolichostylus* Schltr.	+					
29 *Elaeocarpus erdinii* Coode			+			
30 *Elaeocarpus glaber* Blume	+				+	
31 *Elaeocarpus luteolignum* Coode			+		+	
32 *Elaeocarpus macropus* Warb. ex Knuth	+					+
33 *Elaeocarpus musseri* Coode		+	+			
34 *Elaeocarpus octopetalus* Merr.			+			+
35 *Elaeocarpus* sect. *Coilopetalum* Schltr.	+			+		
36 *Elaeocarpus* L. sp. 1			+			
37 *Elaeocarpus* L. sp. 2	+					
Escalloniaceae (Saxifragaceae)						
38 *Polyosma celebica* Schulze-Menz			+			+
39 *Polyosma integrifolia* Blume	+					
40 *Polyosma latifolia* Schltr.			+		+	
Euphorbiaceae						
41 *Acalypha* L. sp.	+					
42 *Antidesma stipulare* Blume	+					
43 *Antidesma* L. sp.	+					
44 *Aporosa lucida* (Miq.) Airy Shaw	+					+
45 *Bridelia glauca* Blume	+					+
46 *Drypetes minahassae* Pax & K.Hoffm.	+					+
47 *Glochidion lucidum* Blume	+		+			+
48 *Homalanthus populneus* Pax	+		+			
49 *Macaranga allorobinsonii* Whitmore	+		+			
50 *Macaranga waturandangii* Whitmore			+			

Table 2 (cont.)

		P(T)	P(t)	B(T)	B(t)	C	CC
51	*Macaranga* Thouars sp.	+					
52	*Mallotus paniculatus* (Geiseler) Airy Shaw	+					
53	*Trigonopleura malayana* Hook.f.	+					
	Fagaceae						
54	*Castanopsis acuminatissima* (Blume) Rehder	+		+			
55	*Lithocarpus celebicus* (Miq.) Rehder	+		+			
56	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo			+		+	
57	*Lithocarpus menadoensis* (Koord.) Soepadmo			+			+
	Gesneriaceae					+	
58	*Cyrtandra fasciata* H.J.Atkins		+			+	
	Hamamelidaceae					+	
59	*Sycopsis dunnii* Hemsl.			+		+	
	Himantandraceae						
60	*Galbulimima belgraveana* (F.Muell.) Sprague	+		+			
	Icacinaceae						
61	*Platea excelsa* Blume var. *borneensis* (Heine) Sleumer	+				+	
62	*Platea latifolia* Blume			+		+	
	Juglandaceae						
63	*Engelhardtia rigida* Blume			+			
64	*Engelhardtia serrata* Blume	+		+			+
	Lauraceae						
65	*Cinnamomum polderi* Kosterm.				+		+
66	*Cinnamomum trichophyllum* Quisumb. & Merr.	+					
67	*Cryptocarya crassinerviopsis* Kosterm.	+					
68	*Cryptocarya ferrea* Blume			+			+
69	*Cryptocarya glauca* Merr.			+			+
70	*Cryptocarya laevigata* Blume	+					+
71	*Cryptocarya subvelutina* Elmer	+			+		+
72	*Endiandra rubescens* (Blume) Miq.	+					+
73	*Endiandra sulavesiana* Kosterm.			+			+
74	*Endiandra velutina* Kosterm.			+			+
75	*Lindera apoensis* Elmer	+					+
76	*Litsea accedentoides* Koord. & Valeton			+		+	
77	*Litsea elliptica* Blume	+		+			+
78	*Litsea formanii* Kosterm.	+		+			+
79	*Litsea grandis* Hook.f.			+			+
80	*Litsea timoriana* Span.	+					
81	*Neolitsea latifolia* (Blume) Moore	+					+
82	*Persea rimosa* Zoll. ex Meisn.			+			+
83	*Phoebe grandis* (Nees) Merr.	+					
	Leguminosae – Mimosoideae						
84	*Archidendron clypearia* (Jack) I.C.Nielsen	+					+
	Magnoliaceae						
85	*Magnolia liliifera* (L.) Baill. var. *liliifera*	+		+			
86	*Magnolia montana* (Blume) Figlar & Noot.		+			+	
87	*Magnolia tsiampacca* (L.) Figlar & Noot. var. *tsiampacca*	+					
	Melastomataceae						
88	*Memecylon paniculatum* Jack	+			+		+
	Meliaceae						
89	*Aglaia lancilimba* Merr.	+					+
90	*Aglaia squamulosa* King	+					
91	*Aglaia tomentosa* Teijsm. & Binn.	+					
92	*Aglaia* Lour. sp.		+				
93	*Chisocheton patens* Blume	+					+
94	*Chisocheton warburgii* Harms	+					+
95	*Dysoxylum acutangulum* Miq. subsp. *foveolatum* (Radlk.) Mabb.	+				+	
96	*Dysoxylum densiflorum* Miq.	+					
97	*Dysoxylum excelsum* Blume	+		+			
98	*Dysoxylum nutans* (Blume) Miq.	+					
99	*Dysoxylum quadrangulatum* Culmsee		+			+!	
100	*Reinwardtiodendron* Koord. sp.				+	(+)	
	Meliosmaceae (***Sabiaceae***)						
101	*Meliosma sumatrana* Walp.	+					
	Monimiaceae						
102	*Kibara* Endl. sp.		+				
103	*Levieria montana* Becc.	+		+		+	
104	*Matthaea sancta* Blume	+				+	
105	*Steganthera hirsuta* Perkins				+	+	
	Moraceae						
106	*Artocarpus lacucha* Buch.-Ham.	+				+	
107	*Artocarpus teysmannii* Miq. subsp. *teysmannii*		+				

		P(T)	P(t)	B(T)	B(t)	C	CC
108	*Ficus aurita* Blume	+				+	
109	*Ficus calcarata* Corner		+			+	
110	*Ficus crassiramea* (Miq.) Miq.	+					+
111	*Ficus glandulifera* (Wall. ex Miq.) King				+	+	
112	*Ficus schwarzii* Koord.		+				
113	*Ficus* L. sp. (strangler)	+					
114	*Streblus glaber* (Merr.) Corner subsp. *glaber*			+			
	Myristicaceae						
115	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb. var. *zippeliana* (Miq.) R.T.A.Schouten	+				+	
116	*Horsfieldia costulata* (Miq.) Warb.	+		+			+
117	*Knema stellata* Merr. subsp. *minahassae* (Warb.) W.J.de Wilde	+				+	
118	*Myristica simiarum* A.DC. subsp. *celebica* (Miq.) W.J.de Wilde			+			+
	Myrsinaceae						
119	*Ardisia forbesii* S.Moore		+		+		
120	*Discocalyx silvestris* Holthuis		+				+
121	*Myrsine porteriana* Wall. & A.DC.				+	+	
	Myrtaceae						
122	*Myrtaceae* sp. 1				+		
123	*Myrtaceae* sp. 2	+		+			
124	*Myrtaceae* sp. 3			+			
125	*Myrtaceae* sp. 4	+					
126	*Myrtaceae* sp. 5	+		+			
127	*Myrtaceae* sp. 6	+					
128	*Myrtaceae* sp. 7	+					
129	*Myrtaceae* sp. 8	+					
130	*Myrtaceae* sp. 9	+		+			
	Oleaceae						
132	*Chionanthus celebicus* Koord.	+				+	
133	*Chionanthus polygamus* (Roxb.) Kiew	+		+			
	Pandanaceae						
134	*Pandanus* L.f. sp.	+					
	Podocarpaceae						
135	*Podocarpus neriifolius* D.Don				+		
	Proteaceae						
136	*Macadamia hildebrandii* Steenis			+			+
	Rhizophoraceae						
137	*Carallia brachiata* (Lour.) Merr.		+				
	Rosaceae						
138	*Prunus grisea* (Blume ex Müll.Berol.) Kalkman var. *grisea*	+		+			
	Rubiaceae						
139	*Diplospora* DC. sp.	+					
140	*Gardenia longifolia* Vidal	+					
141	*Hypobathrum* Blume sp.		+				
142	*Ixora longifolia* Valeton		+			+	
143	*Pavetta celebica* Bremek.		+				
144	*Porterandia celebica* Zahid	+		+			+
145	*Praravinia loconensis* Bremek.		+				+
146	*Psychotria malayana* Jack	+					+
147	*Timonius minahassae* Koord.	+					
148	*Urophyllum arboreum* Korth.				+		
	Rutaceae						
149	*Acronychia pedunculata* Miq.	+		+			+
150	*Melicope bonwickii* (F.Muell.) T.G.Hartley	+					
151	*Melicope confusa* (Merr.) T.S.Liu	+		+			+
	Sapindaceae						
154	*Guioa hirsuta* Welzen	+			+		+
155	*Harpullia cupanioides* Roxb.	+					
156	*Pometia pinnata* J.R.Forst. & G.Forst.	+					
	Sapotaceae						
157	*Palaquium luzoniense* S.Vidal	+					+
158	*Pouteria firma* (Miq.) Baehni	+		+			+
	Staphyleaceae						
159	*Turpinia sphaerocarpa* Hassk.	+					
	Sterculiaceae						
160	*Sterculia macrophylla* Vent.	+					
161	*Sterculia oblongata* R.Br.	+			+		+
	Theaceae						
162	*Adinandra celebica* Koord.			+			
163	*Camellia lanceolata* Seem.		+				
164	*Eurya acuminata* DC.	+		+			
165	*Ternstroemia* L.f. sp.			+			
	Verbenaceae						
166	*Vitex* L. sp.	+					

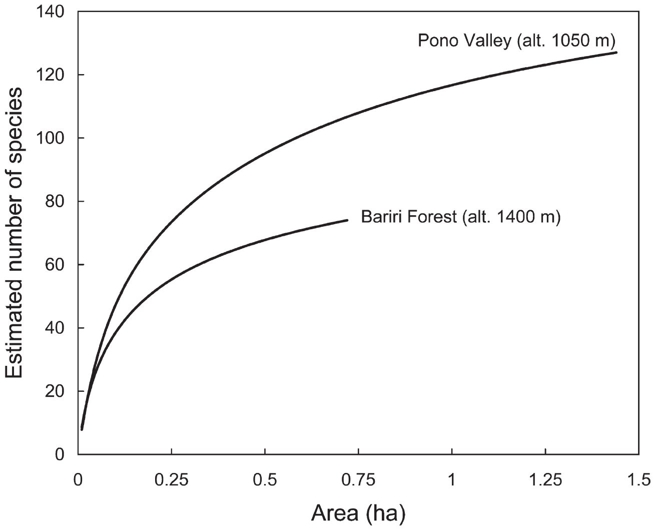

Fig. 1 Sample-based rarefaction curves for Pono Valley (alt. 1 050 m) and Bariri Forest (alt. 1 400 m).

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 ≥ 10cm.

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

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*.

Acknowledgements Field-work was kindly supported by the Collaborative Research Centre SFB 552 at the University of Göttingen, funded by the German Research Foundation (DFG). The visit to the National Herbarium of the Netherlands, University of Leiden branch was facilitated by courtesy of EU-SYNTHESYS grant NL-TAF 3317. H. Culmsee wants to thank specialists for their help in plant identification and discussions on difficult taxa, at Kew: M.J.E. Coode, and at Leiden: C.C. Berg, W.J.J.O. de Wilde, M.M.J. van Balgooy, P.C. van Welzen, D.J. Mabberley, P.J.A. Keßler, F. Adema, H.P. Nooteboom and W. Vink.

REFERENCES

Aiba S, Kitayama K. 1999. Structure, composition and species diversity in an altitude-substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. Plant Ecology 140: 139–157.

Aiba S, Takyu M, Kitayama K. 2005. Dynamics, productivity and species richness of tropical rainforests along elevational and edaphic gradients on Mount Kinabalu, Borneo. Ecological Research 20: 279–286.

Cannon CH, Summers M, Harting JR, Keßler PJA. 2007. Developing conservation priorities based on forest type, condition, and threats in a poorly known ecoregion: Sulawesi, Indonesia. Biotropica 39: 747–759.

Colwell RK. 2006. EstimateS: Statistical estimation of species richness and shared species from samples software and user's guide, v8. http://viceroy.eeb.uconn.edu/estimates.

Culmsee H. 2008. Dysoxylum quadrangulatum, and notes on Meliaceae in Sulawesi. Blumea 53: 602–606.

FAO. 2006. World reference base for soil resources 2006. A framework for international classification, correlation and communication. World Soil Resources Reports 103.

Gotelli NJ, Colwell RK. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379–391.

Kessler M, Keßler PJA, Gradstein SR, Bach K, Schmull M, Pitopang R. 2005. Tree diversity in primary forest and different land use systems in Central Sulawesi, Indonesia. Biodiversity and Conservation 14: 547–560.

Keßler PJA, Bos M, Sierra Daza SEC, Kop A, Willemse LPM, Pitopang R, Gradstein SR. 2002. Checklist of woody plants of Sulawesi, Indonesia. Blumea Supplement 14: 1–160.

Kitayama K. 1992. An altitudinal transect study of the vegetation on Mount Kinabalu, Borneo. Vegetatio 102: 149–171.

Mori SA, Boom BM, De Carvalho A, Dos Santos TS. 1983. Southern Bahian moist forests. The Botanical Review 49: 155–232.

Primack R, Corlett R. 2006. Tropical rain forests. An ecological and biogeographical comparison. Blackwell Publishing, USA.

Roos MC, Keßler PJA, Gradstein SR, Baas P. 2004. Species diversity and endemism of five major Malesian islands: diversity–area relationships. Journal of Biogeography 31: 1893–1908.

Wright DD, Jessen JH, Burke P, Gomez de Silva Garza H. 1997. Tree and liana enumeration and diversity on a one-hectare plot in Papua New Guinea. Biotropica 29: 250–260.