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Botanizing the Laiwangi Wanggameti region reveals new records from Sumba (Indonesia), an island with poorly accessible, scattered, and outdated floristic information

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Key words

bryophytes
lowland forest
Manupeu Tanadaru Laiwangi Wanggameti National Park
submontane forest
Sumba

Abstract The Lesser Sunda Islands comprise a unique phytogeographical province within the Malesian region. The flora of Sumba, one of these islands, has been understudied and is therefore poorly known. To address this shortcoming, a botanical excursion of the Indonesian Institute of Sciences (LIPI) was conducted in 2016 at Laiwangi Wanggameti National Park in Sumba. This expedition collected data from two major types of vegetation, lowland and submontane forests from 300 – 1 225 m asl. This study documents 145 species in 49 families of vascular plants accompanied by trait data such as tree height and diameter at breast height (dbh) across elevational gradients. While the number of individual trees observed increased with elevation, the average tree diameter observed decreased. We compared our data from the Wanggameti area with data previously collected by Banilodu & Saka in a descriptive vegetation study in the early 1990s. A reevaluation of that dataset of Banilodu & Saka enabled us to correct a mischaracterization of the area as elfin forest, a classification perpetuated by a subsequent publication. The floristic work based on our data and the previous study supports the characterization of the Wanggameti area as submontane forest. In addition, we present new records for 25 spermatophytes trees and 20 bryophytes species in Sumba. We highlight that bryophytes are underrepresented in botanical surveys.

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INTRODUCTION

The island of Sumba

Sumba belongs to the Lesser Sunda Islands (LSI), a distinct biogeographic unit within the South Malesian phytogeographic region, which also includes Java and Bali (Van Steenis 1950a). This chain of islands stretches from 8°00' to 11°00'S, and from 115°00' to 132°00'E (Davis et al. 1995). Sumba (11 150 km^2) is larger than most islands in the LSI and only smaller than Timor (> 27 000 km^2), Sumbawa (15 400 km^2) and Flores (13 540 km^2) (Van Steenis 1950a).

Botanical expeditions and collection density in Lesser Sunda Islands

Thirteen botanical expeditions in Sumba were recorded between 1873 and 1950 (Van Steenis 1950b). However, only two of these expeditions resulted in publications, i.e., by Dammerman (1926) and Grevenstuk (1939). To date, there is no annotated checklist of plant species for Sumba. By contrast, checklists exist for Bali (Girmansyah et al. 2013) and Lombok (Rustiami et al. 2020), both of which have been subjects to more botanical expeditions than Sumba (Van Steenis 1950b).

Sumba has also a low collection density compared to nearby islands. Before 1950, Sumba only had 14 collected specimens per 100 km^2 slightly fewer than Sumbawa (18) and Flores (17) (Van Steenis 1950b). During the same period, however, four smaller islands within the LSI, Bali and Nusa Penida combined (5 770 km^2), Lombok (4 715 km^2), Wetar (3 500 km^2) and Sawu (440 km^2), had a substantially higher collection density per 100 km^2: 58, 74, 23 and 28, respectively (Van Steenis 1950b). Later, Van Steenis (1979) documented more collection efforts and calculated the collection density of the LSI region as a whole at 36 specimens per 100 km^2. Lastly, Kartawinata (2010) added the collection number and not the collection density until 2008 across botanical regions of Malesia but only provided resolution to the region of the whole LSI, not the individual islands.

At this moment, it is not possible to accurately estimate the collection density of Sumba due to a lack of data. Due in part to historically low density of collections, the flora of these islands, especially Sumba, is poorly understood and requires further study.

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Literature on the vegetation of Sumba

Two early articles provided a brief overview of the vegetation of Sumba, although only one of them (Grevenstuk 1939) was considered a major inventory effort by Van Steenis (1979). Grevenstuk (1939) provide brief yet informative botanical findings in the context of Sumba's general vegetation. Kalkman (1955) and Van Steenis (1979) wrote general summaries of plants in the Lesser Sunda Islands and provided a basic summary of the species encountered in Sumba. Mackinnon et al. (1982) briefly described some areas of Sumba in a feasibility study for potential reserves, providing few details on the vegetation and asserting that the mountain vegetation was an impoverished continuation of the hill forest. According to Davis et al. (1995), Sumba is in the rain shadow of Australia and receives little rain; it consequently has the most seasonal climate in Indonesia.

Banilodu & Saka (1993) conducted a study in different vegetation types over a broad range of elevations across Sumba's ecosystems. They inventoried evergreen monsoon vine forest in Katarumuru, semi-deciduous monsoon forest in Manupeu, and lowland and rain (elfin) forest at the Wanggameti summit. The study sites ranged in elevation from 100 m asl (Luku Malolo) to 1 225 m asl (Wanggameti). They found that the lowland forest was dominated by *Euphorbiaceae*, *Fabaceae*, *Meliaceae*, and *Moraceae*, with tree heights up to 30–40 m. Canopy stratification was clear in climax communities and secondary forest regrowth. Meanwhile, the mountain forest was characterised by 20–25 m tall, stunted trees with a thick accumulation of litter and high humidity that favoured epiphytes, mostly mosses. This was interpreted by them as an elfin forest, a conclusion uncritically perpetuated by Sitompul et al. (2004).

With relatively limited botanical information about Sumba, our understanding of its vegetation has not substantially increased in recent decades. A recent botanical expedition that was conducted by the Research Center for Biology, Indonesian Institute of Sciences (LIPI; now dissolved and integrated into the National Research and Innovation Agency, BRIN), provided an opportunity to meaningfully contribute to knowledge of the vegetation composition of this unique island.

MATERIALS AND METHODS

Laiwangi Wanggameti National Park, where the present study took place, has all types of vegetation found in Sumba (Direktorat Jenderal Perlindungan Hutan dan Konservasi Alam 2007). A 2018 report noted the presence of tropical (rain) forest, monsoon forest, and savannah as well as the core zone of lower montane tropical rainforest (750–1 000 m asl) (Direktorat Jendral Konservasi Sumber Daya Alam dan Ekosistem 2018). Montane tropical rain forest is typically found at 1 000–1 250 m asl.

A total of nine square plots, each of 30 × 30 m in size (0.81 Ha), were set up in the Laiwangi and Wanggameti areas at different elevations (Fig. 1). Three plots at higher elevations in Wanggameti ranged from 1 050–1 250 m asl (Table 1): at the entrance of the main trail (10°04' 42.2"S, 120°15'20.7"E), the forest trail halfway to the peak (10°05'49.8"S, 120°15'08.7"E) and on the top of Mount Wanggameti at 1 225 m asl (10°06'59.3"S, 120°14'10.0"E). We suspected that these sites were the same sites as used by Banilodu & Saka (1993). Another six plots (0.54 Ha) were established at lowland sites at Laiwangi: three plots ranging from 305–365 m asl as in Billa (9°58'51"S, 120°04'48"E), and three more at mid elevation in Praengkareha ranging from 495–585 m asl (10°02'04"S, 120°03'26"E). Each individual plot was divided into 10 × 10 m subplots, making 27 subplots in total (Fig. 2).

Within each plot, we measured the circumference and height of the trees with a girth ≥ 15 cm (diameter at breast height (dbh) 4.8 cm). The circumference at breast high was measured using measuring tape and converted into dbh for the individual trees. Tree height was initially estimated with the tangent method by measuring the angle using a Suunto clinometer and calculated based on the known distance from the observer to the target tree. In parallel, this method was compared with the estimation of tree height by comparing the known height of the field assistant to the target tree and estimated the tree height. This latter method was used after establishing its consistency with the clinometer method, which was much more time consuming.

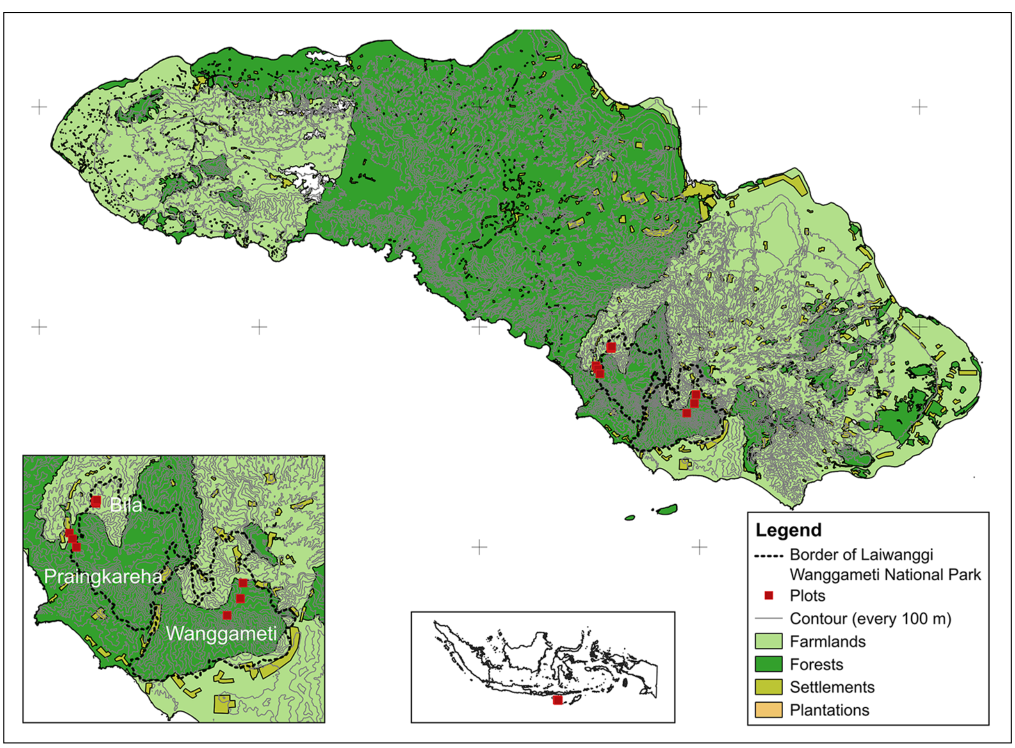

Fig. 1 The island of Sumba and the distribution of plots (red cubes) across areas in and at the vicinity of Laiwangi Wanggameti National Park, which is now merged with Manupeu Tanadaru under a single management scheme. Most of the plots were scattered distantly at the forested areas of Praengkareha and Wanggameti and the remaining farmlands of Billa, which are closely aggregated to one another. Inset map of Indonesia (black white, middle bottom).

Table 1 The range of physical environmental measurements, like elevation, soil pH, soil humidity, temperature, and humidity, of the study areas in Billa, Praengkareha and Wanggameti.

Location	Elevation (m asl)	Soil pH	Soil humidity (%)	Temperature (°C)	Humidity (%)
Billa	300–375	5.6–6.8	55–90	26.5–30.5	73–92.2
Praengkareha	480–600	6.6–7	40–80	25–30.5	77.7–93.9
Wanggameti	1020–1225	6.5–7	60–95	21–27.8	66.2–90

For each species, the average height and dbh were calculated by adding all the individual measurements and divided by the number of individuals. Comparison of species similarity between altitude was conducted using the Sørensen index (Magurran 1988).

We also collected voucher specimens of the majority of trees in the plots for identification to species or at least to genus level by TM and SJ. In addition, bryophytes were recorded and collected along the trail and around the plots during the survey. Identification to species level was conducted using Gradstein (2011) and Eddy (1988a, b) as well as comparing our collections to reference specimens at the Herbarium Bogoriense by DR and FIW. Bryophyte collections were made from ground level to around 2 m high, which was the limit of hand reach, from all available substrates such as rotten logs, trees, and rocks. All plant collections were deposited in BO. The names of all identified spermatophytes and pteridophytes in this study and in Banilodu & Saka (1993) were updated as need to presently accepted names based on Plants of the World Online (POWO continuously updated). Correspondence was established with Dr. Leonardus Banilodu, one of the authors of Banilodu & Saka (1993), to achieve clarity and avoid misinterpretation of their work.

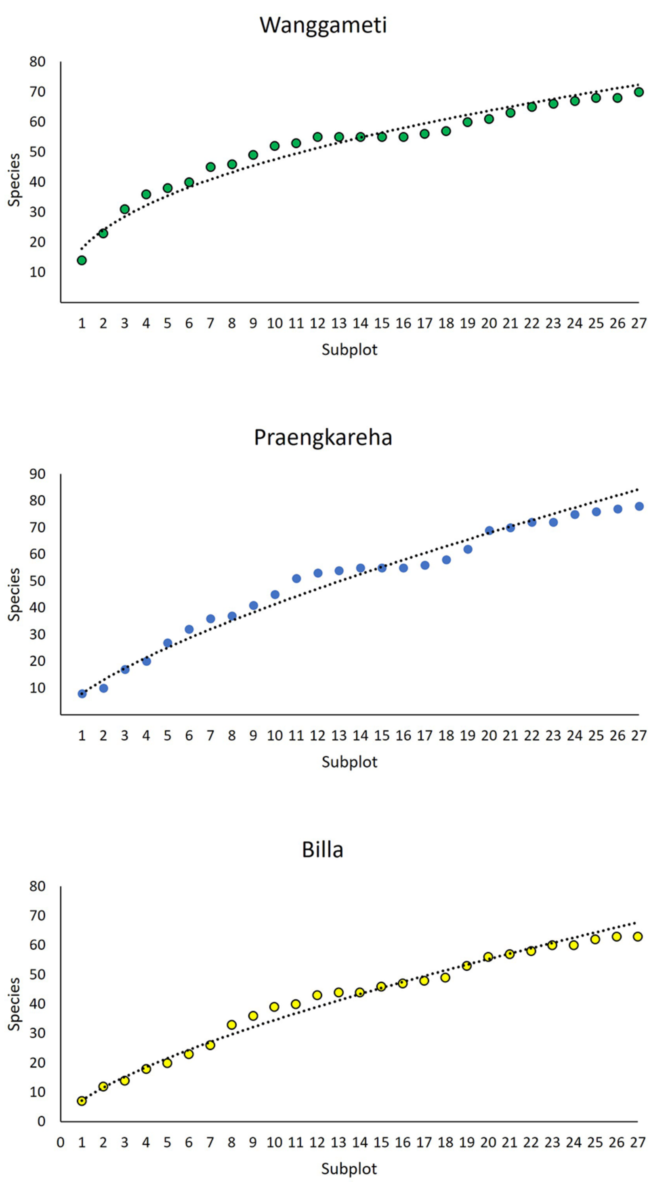

Fig. 2 Species accumulation curves based on the species in 27 subplots of Billa (bottom), Praengkareha (middle), and Wanggameti (top).

RESULTS

Vegetation across elevational gradient

Plots studied from three areas, Billa (305–365 m asl), Praengkareha (495–585 m asl) and Wanggameti (1 050–1 225 m asl), provided snapshots of two vegetation zones, lowland forest and submontane forest, across elevational gradients. All areas had their temperature and humidity recorded as shown in Table 1. The number and size of the plots were equal for the three areas, thus justifying the comparison of species diversity between them. The number of species found in the three study areas reached a plateau as indicated in species accumulation curves (Fig. 2). In total, there were 145 species of trees in 48 families including two species in two families of ferns (Table 2). Praengkareha (average elevation 540 m asl) had the highest number, 78 species in 32 families, with *Meliaceae* having the most (seven) species. Wanggameti (average elevation of 1 150 m asl) came second with 65 species in 37 families, with *Lauraceae* having the most (six) species. Billa (an average elevation of 335 m asl) had 62 species in 25 families, with *Moraceae* having the most (eight) species as seen in Fig. 3 (right bars). Families with the most species did not necessarily have the most individuals across elevations as demonstrated in Fig. 3 (left bars). In Billa, *Euphorbiaceae* had the most individuals (27), whereas in Praengkareha, *Sapindaceae* had the most (34). In Wanggameti were 75 individuals of *Rutaceae*, the most of any family in any area.

Of the 48 families, nine contributed more than five species (number within parentheses): *Rubiaceae* (11), *Moraceae* (10), *Euphorbiaceae* (9), *Lauraceae* (8), *Meliaceae* (8), *Apocynaceae* (7), *Phyllanthaceae* (6), *Anacardiaceae* (6), and *Sapindaceae* (6) as seen in Fig. 3. These represented only 18.75 % of the total families recorded but made up around 42 % of the species recorded across the plots. These families, therefore, comprise the most substantial components of Sumba's lowland and submontane vegetation.

The study areas at low elevation (Billa and Praengkareha) shared more similar species with each other than either did with the area at higher elevation (Wanggameti). Billa and Praengkareha shared more species (Sørensen index = 0.51) than Wanggameti with Billa (Sørensen index = 0.12) or Wanggameti with Praengkareha (Sørensen index = 0.19) as seen in Table 3.

In general, the number of individual trees across regions showed a positive association (either linear or non-linear) with increasing elevation (Fig. 4). Billa at the lowest elevation had 227 individuals, Praengkareha had 304 individuals, and Wanggameti at the highest elevation had the most (553)

Table 2 The list of Spermatophytes and Pteridophytes families and species across study areas (Billa, Praengkareha, and Wanggameti) plus the result of Banilodu & Saka (1993) with focus on Wanggameti. Each species is accompanied by the status of natural distribution (Sumba vs Out of Sumba) and the status of origin (Native vs Introduced).

No.	Species	Family	Wanggameti (B & S)	Wanggameti LIPI	Praengkareha LIPI	Billa LIPI	Natural distribution	Native/Introduced
1	*Buchanania arborescens* (Blume) Blume	*Anacardiaceae*	–	–	1	–	Sumba	Native
2	*Buchanania* sp.	*Anacardiaceae*	–	–	1	–	Sumba	Native
3	*Gluta renghas* L.	*Anacardiaceae*	1	–	–	–	Out of Sumba	–
4	*Mangifera gedebe* Miq.	*Anacardiaceae*	1	–	–	–	Out of Sumba	–
5	*Mangifera indica* L.	*Anacardiaceae*	–	–	–	1	Sumba	Introduced
6	*Pentaspadon motleyi* Hook.f.	*Anacardiaceae*	–	–	–	1	Out of Sumba	–
7	*Rhus taitensis* Guill.	*Anacardiaceae*	–	1	1	1	Sumba	Native
8	*Spondias mombin* L.	*Anacardiaceae*	–	–	–	1	Out of Sumba	–
9	*Alstonia macrophylla* Wall. ex G.Don	*Apocynaceae*	–	1	1	1	Out of Sumba	–
10	*Alstonia scholaris* (L.) R.Br.	*Apocynaceae*	–	–	1	–	Sumba	Native
11	*Tabernaemontana macrocarpa* Jack	*Apocynaceae*	1	–	1	1	Out of Sumba	–
12	*Tabernaemontana* sp.	*Apocynaceae*	–	–	1	–	Sumba	Native
13	*Tabernaemontana sphaerocarpa* Blume	*Apocynaceae*	–	1	1	1	Sumba	Native
14	*Voacanga foetida* (Blume) Rolfe	*Apocynaceae*	–	–	–	1	Out of Sumba	–
15	*Wrightia pubescens* R.Br.	*Apocynaceae*	–	–	1	1	Sumba	Native
16	*Ilex cymosa* Blume	*Aquifoliaceae*	–	1	–	–	Out of Sumba	–
17	*Heptapleurum rigidum* (Blume) Hassk.	*Araliaceae*	–	1	–	–	Out of Sumba	–
18	*Areca catechu* L.	*Arecaceae*	–	–	–	1	Sumba	Introduced
19	*Calamus javensis* Blume	*Arecaceae*	1	–	–	–	Out of Sumba	–
20	*Calamus melanochaetes* (Blume) Miq.	*Arecaceae*	1	–	–	–	Sumba	Native
21	*Caryota mitis* Lour.	*Arecaceae*	–	–	–	1	Sumba	Native
22	*Caryota* sp.	*Arecaceae*	–	–	–	1	Sumba	Native
23	*Pinanga densiflora* Becc.	*Arecaceae*	1	–	–	–	Out of Sumba	–
24	*Asplenium nidus* L.	*Aspleniaceae*	1	–	–	–	Sumba	Native
25	*Bidens* sp.	*Asteraceae*	1	–	–	–	Out of Sumba	–
26	*Canarium asperum* Benth.	*Burseraceae*	–	1	–	1	Sumba	Native
27	*Canarium oleosum* (Lam.) Engl.	*Burseraceae*	1	–	–	–	Sumba	Native
28	*Canarium* sp.	*Burseraceae*	–	–	1	1	Sumba	Native
29	*Lonicera* sp.	*Caprifoliaceae*	1	–	–	–	–	–
30	*Euonymus indicus* B.Heyne ex Wall.	*Celastraceae*	–	1	–	–	Sumba	Native
31	*Calophyllum soulattri* Burm.f.	*Clusiaceae*	1	1	1	–	Sumba	Native
32	*Garcinia dulcis* (Roxb.) Kurz	*Clusiaceae*	–	1	–	–	Sumba	Native
33	*Garcinia* sp.	*Clusiaceae*	–	–	1	–	Sumba	Native
34	*Terminalia bellirica* (Gaertn.) Roxb.	*Combretaceae*	–	1	–	–	Sumba	Native
35	*Terminalia* sp.	*Combretaceae*	–	–	1	1	Sumba	Native
36	*Alangium chinense* (Lour.) Harms	*Cornaceae*	1	–	–	–	Sumba	Native
37	*Alangium rotundifolium* (Hassk.) Bloemb.	*Cornaceae*	–	1	1	1	Sumba	Native
38	*Pterophylla fraxinea* D.Don	*Cunoniaceae*	–	1	–	–	Sumba	Native
39	*Sphaeropteris glauca* (Blume) R.M.Tryon	*Cyatheaceae*	1	1	–	–	Sumba	Native
40	*Cyperus* sp.	*Cyperaceae*	1	–	–	–	Sumba	Native
41	*Daphniphyllum glaucescens* Blume	*Daphniphyllaceae*	–	1	–	–	Sumba	Native
42	*Elaeocarpus angustifolius* Blume	*Elaeocarpaceae*	–	1	1	–	Sumba	Native
43	*Elaeocarpus floribundus* Blume	*Elaeocarpaceae*	–	1	–	–	Sumba	Native
44	*Elaeocarpus petiolatus* (Jack) Wall.	*Elaeocarpaceae*	–	–	1	–	Sumba	Native
45	*Elaeocarpus* sp.	*Elaeocarpaceae*	–	1	1	–	Sumba	Native
46	*Polyosma* sp.	*Escalloniaceae*	1	–	–	–	Sumba	Native
47	*Balakata baccata* (Roxb.) Esser	*Euphorbiaceae*	–	1	–	–	Out of Sumba	–
48	*Claoxylon* sp.	*Euphorbiaceae*	–	–	–	1	Sumba	Native
49	*Cleidion javanicum* Blume	*Euphorbiaceae*	1	–	–	–	Sumba	Native
50	*Cleistanthus oblongifolius* (Roxb.) Müll.Arg.	*Euphorbiaceae*	–	–	1	1	Sumba	Native
51	*Glochidion rubrum* Blume	*Euphorbiaceae*	–	–	1	1	Sumba	Native
52	*Hancea penangensis* (Müll.Arg.) S.E.C.Sierra, Kulju & Welzen	*Euphorbiaceae*	–	–	1	–	Sumba	Native
53	*Homalanthus* sp.	*Euphorbiaceae*	–	–	1	1	Sumba	Native

Table 2 (cont.)

No.	Species	Family	Wanggameti (B & S)	Wanggameti LIPI	Praengkareha LIPI	Billa LIPI	Natural distribution	Native/Introduced
54	*Macaranga involucrata* Baill	*Euphorbiaceae*	1	–	–	–	Out of Sumba	–
55	*Mallotus peltatus* (Geiseler) Müll.Arg.	*Euphorbiaceae*	–	–	–	1	Sumba	Native
56	*Mallotus philippensis* (Lam.) Müll.Arg.	*Euphorbiaceae*	–	1	–	1	Sumba	Native
57	*Albizia tomentella* Miq.	*Fabaceae*	–	–	1	1	Sumba	Native
58	*Canavalia* sp.	*Fabaceae*	1	–	–	–	Sumba	Native
59	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	*Fabaceae*	1	–	–	–	Sumba	Introduced
60	*Lithocarpus rotundatus* (Blume) A.Camus	*Fagaceae*	1	–	–	–	Out of Sumba	–
61	*Flacourtia rukam* Zoll. & Moritzi	*Flacourtiaceae*	–	–	1	–	Sumba	Native
62	*Engelhardia serrata* Blume	*Juglandaceae*	–	–	1	–	Out of Sumba	–
63	*Engelhardia spicata* Blume	*Juglandaceae*	1	1	–	–	Sumba	Native
64	*Vitex* sp.	*Lamiaceae*	–	–	1	1	Sumba	Native
65	*Actinodaphne macrophylla* (Blume) Nees	*Lauraceae*	–	1	–	–	Out of Sumba	–
66	*Cinnamomum burmanni* (Nees & T.Nees) Blume	*Lauraceae*	–	1	1	–	Sumba	Native
67	*Cinnamomum verum* J.Presl	*Lauraceae*	1	–	–	–	Out of Sumba	–
68	*Cryptocarya ferrea* Blume	*Lauraceae*	–	1	–	–	Sumba	Native
69	*Cryptocarya triplinervis* R.Br.	*Lauraceae*	–	1	1	–	Out of Sumba	–
70	*Dehaasia incrassata* (Jack) Nees	*Lauraceae*	–	–	1	1	Out of Sumba	–
71	*Litsea elliptica* Blume	*Lauraceae*	–	1	1	–	Out of Sumba	–
72	*Litsea timoriana* Span.	*Lauraceae*	–	1	1	–	Sumba	Native
73	*Payena leerii* (Teijsm. & Binn.) Kurz	*Lauraceae*	–	–	1	–	Out of Sumba	–
74	*Geniostoma rupestre* J.R.Forst. & G.Forst.	*Loganiaceae*	1	–	–	–	Sumba	Native
75	*Lagerstoemia* sp.	*Lythraceae*	–	1	–	–	Sumba	Native
76	*Magnolia liliifera* (L.) Baill.	*Magnoliaceae*	–	1	–	–	Sumba	Native
77	*Kleinhovia hospita* L.	*Malvaceae*	–	–	–	1	Sumba	Native
78	*Melochia umbellata* (Houtt.) Stapf	*Malvaceae*	1	–	–	–	Sumba	Native
79	*Pterospermum diversifolium* Blume	*Malvaceae*	–	–	1	1	Sumba	Native
80	*Pterygota horsfieldii* (R.Br.) Kosterm.	*Malvaceae*	–	–	1	1	Out of Sumba	–
81	*Sterculia* sp.	*Malvaceae*	1	–	1	1	Sumba	Native
82	*Angiopteris evecta* (G.Forst.) Hoffm.	*Marattiaceae*	1	–	–	–	Out of Sumba	–
83	*Memecylon edule* Roxb	*Melastomataceae*	1	–	–	–	Out of Sumba	–
84	*Aglaia edulis* (Roxb.) Wall.	*Meliaceae*	–	–	1	1	Sumba	Native
85	*Aglaia elaeagnoidea* (A.Juss.) Benth.	*Meliaceae*	–	1	–	–	Sumba	Native
86	*Aglaia odoratissima* Blume	*Meliaceae*	–	–	1	–	Sumba	Native
87	*Aglaia* sp.	*Meliaceae*	1	–	–	–	Sumba	Native
88	*Chisocheton ceramicus* Miq.	*Meliaceae*	–	1	1	–	Out of Sumba	–
89	*Chisocheton* sp.	*Meliaceae*	1	–	1	1	Sumba	Native
90	*Dysoxylum parasiticum* (Osbeck) Kosterm.	*Meliaceae*	1	–	1	–	Sumba	Native
91	*Dysoxylum* sp.	*Meliaceae*	–	–	1	1	Sumba	Native
92	*Epicharis parasitica* (Osbeck) Mabb.	*Meliaceae*	–	–	1	–	Sumba	Native
93	*Toona sureni* (Blume) Merr.	*Meliaceae*	1	–	–	–	Sumba	Native
94	*Artocarpus* sp.	*Moraceae*	–	–	1	–	Sumba	Native
95	*Ficus ampelos* Burm.f.	*Moraceae*	–	–	1	1	Sumba	Native
96	*Ficus callosa* Willd.	*Moraceae*	–	–	–	1	Sumba	Native
97	*Ficus depressa* Blume	*Moraceae*	–	–	–	1	Sumba	Native
98	*Ficus drupacea* Thunb.	*Moraceae*	1	–	–	–	Sumba	Native
99	*Ficus magnoliifolia* Blume	*Moraceae*	–	–	1	–	Sumba	Native
100	*Ficus sinuata* Thunb.	*Moraceae*	–	–	–	1	Sumba	Native
101	*Ficus* sp.	*Moraceae*	–	–	–	1	Sumba	Native
102	*Ficus* sp. 1	*Moraceae*	–	–	–	1	Sumba	Native
103	*Ficus* sp. 2	*Moraceae*	–	–	–	1	Sumba	Native
104	*Ficus variegata* Blume	*Moraceae*	1	–	–	1	Sumba	Native
105	*Streblus asper* Lour.	*Moraceae*	1	–	–	–	Sumba	Native
106	*Myrica javanica* Blume	*Myricaceae*	–	1	–	–	Sumba	Native
107	*Myristica fatua* Houtt.	*Myristicaceae*	–	–	1	1	Out of Sumba	–

Table 2 (cont.)

No.	Species	Family	Wanggameti (B & S)	Wanggameti LIPI	Praengkareha LIPI	Billa LIPI	Natural distribution	Native/Introduced
108	*Myristica guatteriifolia* A.DC.	*Myristicaceae*	1	–	–	–	Sumba	Native
109	*Myristica teysmannii* Miq.	*Myristicaceae*	1	–	–	–	Out of Sumba	–
110	*Decaspermum* sp.	*Myrtaceae*	1	–	1	–	Sumba	Native
111	*Syzygium acuminatissimum* (Blume) DC.	*Myrtaceae*	–	1	–	–	Sumba	Native
112	*Syzygium antisepticum* (Blume) Merr. & L.M.Perry	*Myrtaceae*	–	1	–	–	Sumba	Native
113	*Syzygium cerasiforme* (Blume) Merr. & L.M.Perry	*Myrtaceae*	–	1	–	–	Sumba	Native
114	*Syzygium* sp.	*Myrtaceae*	–	1	–	–	Sumba	Native
115	*Ceodes umbellifera* J.R.Forst. & G.Forst.	*Nyctaginaceae*	–	–	1	1	Sumba	Native
116	*Chionanthus ramiflorus* Roxb.	*Oleaceae*	–	1	1	1	Sumba	Native
117	*Jasminum multiflorum* (Burm.f.) Andrews	*Oleaceae*	–	1	–	–	Sumba	Introduced
118	*Champereia manillana* (Blume) Merr.	*Opiliaceae*	–	–	1	1	Sumba	Native
119	*Calanthe triplicata* (Willemet) Ames	*Orchidaceae*	1	–	–	–	Sumba	Native
120	*Pandanus* sp.	*Pandanaceae*	1	–	–	–	Sumba	Native
121	*Pandanus tectorius* Parkinson ex Du Roi	*Pandanaceae*	1	–	–	–	Sumba	Native
122	*Ternstroemia elongata* (Korth.) Koord.	*Pentaphylacaceae*	–	1	–	–	Out of Sumba	–
123	*Trigonopleura malayana* Hook.f.	*Peraceae*	–	1	–	–	Out of Sumba	–
124	*Antidesma montanum* Blume	*Phyllanthaceae*	–	–	1	1	Sumba	Native
125	*Antidesma pyrifolium* Müll.Arg.	*Phyllanthaceae*	–	1	–	–	Out of Sumba	–
126	*Breynia cernua* (Poir.) Müll.Arg.	*Phyllanthaceae*	1	1	–	–	Sumba	Native
127	*Bridelia ovata* Decne.	*Phyllanthaceae*	–	–	1	–	Sumba	Native
128	*Bridelia* sp.	*Phyllanthaceae*	–	–	1	–	Sumba	Native
129	*Glochidion philippicum* (Cav.) C.B.Rob.	*Phyllanthaceae*	–	1	–	–	Sumba	Native
130	*Glochidion* sp.	*Phyllanthaceae*	–	–	–	1	Sumba	Native
131	*Piper* sp.	*Piperaceae*	1	–	–	–	Sumba	Native
132	*Pittosporum moluccanum* (Lam.) Miq.	*Pittosporaceae*	–	1	1	1	Sumba	Native
133	*Pittosporum* sp	*Pittosporaceae*	–	–	1	–	Sumba	Native
134	*Dacrycarpus imbricatus* (Blume) de Laub.	*Podocarpaceae*	–	1	–	–	Sumba	Native
135	*Podocarpus neriifolius* D.Don	*Podocarpaceae*	–	1	–	–	Out of Sumba	–
136	*Podocarpus rumphii* Blume	*Podocarpaceae*	–	1	–	–	Sumba	Native
137	*Drynaria quercifolia* (L.) J.Sm.	*Polypodiaceae*	1	–	–	–	Sumba	Native
138	*Ardisia javanica* A.DC.	*Primulaceae*	–	1	–	–	Sumba	Native
139	*Maesa* sp.	*Primulaceae*	–	1	–	–	Sumba	Native
140	*Myrsine hasseltii* Blume ex Scheff.	*Primulaceae*	–	1	–	–	Sumba	Native
141	*Helicia serrata* (R.Br.) Blume	*Proteaceae*	–	1	–	–	Sumba	Native
142	*Helicia* sp.	*Proteaceae*	1	–	–	–	Sumba	Native
143	*Drypetes neglecta* (Koord.) Pax & K.Hoffm.	*Putranjivaceae*	–	1	–	–	Sumba	Native
144	*Drypetes ovalis* (J.J.Sm. ex Koord. & Valeton) Pax & K.Hoffm.	*Putranjivaceae*	1	1	–	–	Sumba	Native
145	*Prunus arborea* (Blume) Kalkman	*Rosaceae*	–	1	1	–	Sumba	Native
146	*Coffea canephora* Pierre ex A.Froehner	*Rubiaceae*	–	–	–	1	Sumba	Introduced
147	*Eumachia leptothyrsa* (Miq.) Barrabé, C.M.Taylor & Razafim.	*Rubiaceae*	–	1	–	–	Sumba	Native
148	*Hymenodictyon orixense* (Roxb.) Mabb.	*Rubiaceae*	–	–	–	1	Out of Sumba	–
149	*Ixora javanica* (Blume) DC.	*Rubiaceae*	–	–	1	–	Out of Sumba	–
150	*Ixora paludosa* (Blume) Kurz	*Rubiaceae*	–	–	1	1	Sumba	Native
151	*Lasianthus laevigatus* Blume	*Rubiaceae*	–	–	1	–	Out of Sumba	–
152	*Nauclea orientalis* (L.) L.	*Rubiaceae*	–	–	–	1	Sumba	Native
153	*Neonauclea excelsa* (Blume) Merr.	*Rubiaceae*	1	–	–	–	Sumba	Native
154	*Pavetta montana* Reinw.ex Blume	*Rubiaceae*	–	–	1	–	Sumba	Native
155	*Psychotria sarmentosa* Blume	*Rubiaceae*	–	1	–	–	Sumba	Native
156	*Wendlandia burkillii* Cowan	*Rubiaceae*	–	–	1	–	Sumba	Native
157	*Wendlandia densiflora* (Blume) DC.	*Rubiaceae*	–	1	–	1	Sumba	Native
158	*Melicope* sp.	*Rutaceae*	–	–	1	–	Sumba	Native
159	*Micromelum minutum* (G.Forst.) Wight & Arn.	*Rutaceae*	–	1	1	–	Out of Sumba	–
160	*Zanthoxylum ovalifolium* Wight	*Rutaceae*	–	1	–	–	Sumba	Native
161	*Exocarpos latifolius* R.Br.	*Santalaceae*	1	–	–	–	Sumba	Native

Table 2 (cont.)

No.	Species	Family	Wanggameti (B & S)	Wanggameti LIPI	Praengkareha LIPI	Billa LIPI	Natural distribution	Native/Introduced
162	*Allophylus cobbe* (L.) Forsyth f.	*Sapindaceae*	–	–	1	1	Sumba	Native
163	*Harpullia arborea* (Blanco) Radlk.	*Sapindaceae*	–	–	1	1	Sumba	Native
164	*Mischocarpus sundaicus* Blume	*Sapindaceae*	–	1	1	–	Sumba	Native
165	*Pometia pinnata* J.R.Forst. & G.Forst.	*Sapindaceae*	–	–	1	1	Sumba	Native
166	*Sapindaceae*	*Sapindaceae*	–	–	–	1	–	–
167	*Schleichera oleosa* (Lour.) Oken	*Sapindaceae*	–	–	1	1	Sumba	Native
168	*Palaquium amboinense* Burck	*Sapotaceae*	–	1	1	–	Sumba	Native
169	*Palaquium obovatum* (Griff.) Engl.	*Sapotaceae*	1	1	–	–	Sumba	Native
170	*Palaquium obtusifolium* Burck	*Sapotaceae*	1	1	–	–	Sumba	Native
171	*Palaquium* sp.	*Sapotaceae*	–	–	1	–	Sumba	Native
172	*Planchonella obovata* (R.Br.) Pierre	*Sapotaceae*	–	1	1	1	Sumba	Native
173	*Gomphandra* sp.	*Stemonuraceae*	–	–	1	–	Sumba	Native
174	*Symplocos* sp.	*Symplocaceae*	–	–	1	1	Sumba	Native
175	*Tetrameles nudiflora* R.Br.	*Tetramelaceae*	–	1	1	1	Sumba	Native
176	*Wikstroemia* sp.	*Thymelaeaceae*	1	–	–	–	Sumba	Native
177	*Debregeasia longifolia* (Burm.f.) Wedd.	*Urticaceae*	1	–	–	–	Sumba	Native
178	*Dendrocnide peltata* (Blume) Miq.	*Urticaceae*	1	–	–	–	Sumba	Native
179	*Dendrocnide* sp.	*Urticaceae*	–	–	1	–	Sumba	Native
180	*Dendrocnide stimulans* (L.f.) Chew	*Urticaceae*	–	–	1	–	Sumba	Native
181	*Oreocnide rubescens* (Blume) Miq.	*Urticaceae*	–	1	1	1	Sumba	Native
182	*Pilea* sp.	*Urticaceae*	–	–	1	–	Sumba	Native
183	*Viburnum sambucinum* Reinw. ex Blume	*Viburnaceae*	–	1	–	–	Sumba	Native
184	*Leea rubra* Blume	*Vitaceae*	–	–	–	1	Sumba	Native
		Total species	52	64	78	62		

individual trees. Dbh followed the opposite pattern, with the largest average (20.48 cm) at the lowest elevation, Billa, gradually decreasing as elevation increased, with an average dbh at Praengkareha and Wanggameti of 14.96 cm and 12.67 cm, respectively.

Each elevation had its own most frequently recorded trees, such as 16 individuals of unidentified species of *Caryota* (*Arecaceae*) in Billa, 18 individuals of *Cleistanthus oblongifolius* (Roxb.) Müll.Arg. (*Phyllanthaceae*) in Praengkareha, and 53 individuals of *Micromelum minutum* (G.Forst.) Wight & Arn. (*Rutaceae*) in Wanggameti. There were nine species in eight families that occurred across the whole gradient, *Alangium rotundifolium* (Hassk.) Bloemb. (*Cornaceae*), *Alstonia macrophylla* Wall. ex G.Don and *Tabernaemontana sphaerocarpa* Blume (*Apocynaceae*), *Chionanthus ramiflorus* Roxb. (*Oleaceae*), *Oreocnide rubescens* (Blume) Miq. (*Urticaceae*), *Pittosporum moluccanum* (Lam.) Miq. (*Pittosporaceae*), *Planchonella obovata* (R.Br.) Pierre (*Sapotaceae*), *Rhus taitensis* Guill. (*Anacardiaceae*), and *Tetrameles nudiflora* R.Br. (*Tetramelaceae*). These species could be studied to investigate morphological changes within species along an elevational gradient.

New distribution ranges, unrevised families, and unidentified taxa

We found 25 species across the families of spermatophytes listed in Table 2 that were previously not recorded in Sumba according to the Flora Malesiana Series I. These new records indicate wider distributions than those previously known (Soepadmo 1972, Hou 1978, Adema et al. 1994, De Wilde 2000, Middleton 2007, Van Welzen continuously updated) for the following species: *Anacardiaceae* (*Pentaspadon motleyi* Hook.f., *Spondias mombin* L.), *Apocynaceae* (*Alstonia macrophylla* Wall. ex G.Don, *Tabernaemontana macrocarpa* Jack, *Voacanga foetida* (Blume) Rolfe), *Aquifoliaceae* (*Ilex cymosa* Blume), *Araliaceae* (*Heptapleurum rigidum* (Blume) Hassk.), *Euphorbiaceae* (*Balakata baccata* (Roxb.) Esser, *Hancea penangensis* (Müll.Arg.) S.E.C.Sierra, Kulju & Welzen), *Juglandaceae* (*Engelhardia serrata* Blume), *Lauraceae* (*Actinodaphne macrophylla* (Blume) Nees, *Cryptocarya triplinervis* R.Br., *Dehaasia incrassata* (Jack) Nees, *Litsea elliptica* Blume, *Payena leerii* (Teijsm. & Binn.) Kurz), *Malvaceae* (*Pterygota horsfieldii* (R.Br.) Kosterm.), *Meliaceae* (*Chisocheton ceramicus* Miq.), *Myristicaceae* (*Myristica fatua* Houtt.), *Pentaphyllaceae* (*Ternstroemia elongata* (Korth.) Koord.), *Peraceae* (*Trigonopleura malayana* Hook.f.), *Phyllanthaceae* (*Antidesma pyrifolium* Müll. Arg.), *Podocarpaceae* (*Podocarpus neriifolius* D.Don), and *Rubiaceae* (*Hymenodictyon orixense* (Roxb.) Mabb., *Ixora javanica* (Blume) DC., *Lasianthus laevigatus* Blume). These novel and extended distribution ranges likely represent the previous absence of available specimens from Sumba. This highlights the need for more collecting on under-studied islands.

In addition, there are species of *Apocynaceae*, *Araliaceae*, *Aquifoliaceae*, *Arecaceae*, *Lauraceae*, *Malvaceae*, *Marratiaceae*, *Rubiaceae*, and *Rutaceae* (Table 2) that are lacking taxonomic information, because their taxo A nested-intensity design for surveying plant diversity. Aspen Bibliography Paper 225 nomic revisions for the Flora Malesiana have not yet been completed. Thus, we cannot confidently determine the native or introduced status of these species in Sumba.

There are 30 unidentified species in 22 families that are identified only to generic level and in one case to family (*Sapindaceae*) because they were sterile during collection. The family with the most unidentified (4) species is *Moraceae*, and three of these belong to the genus *Ficus*. Most of these unidentified species were found in Praengkareha (21) followed by Billa (16) and Wanggameti (4).

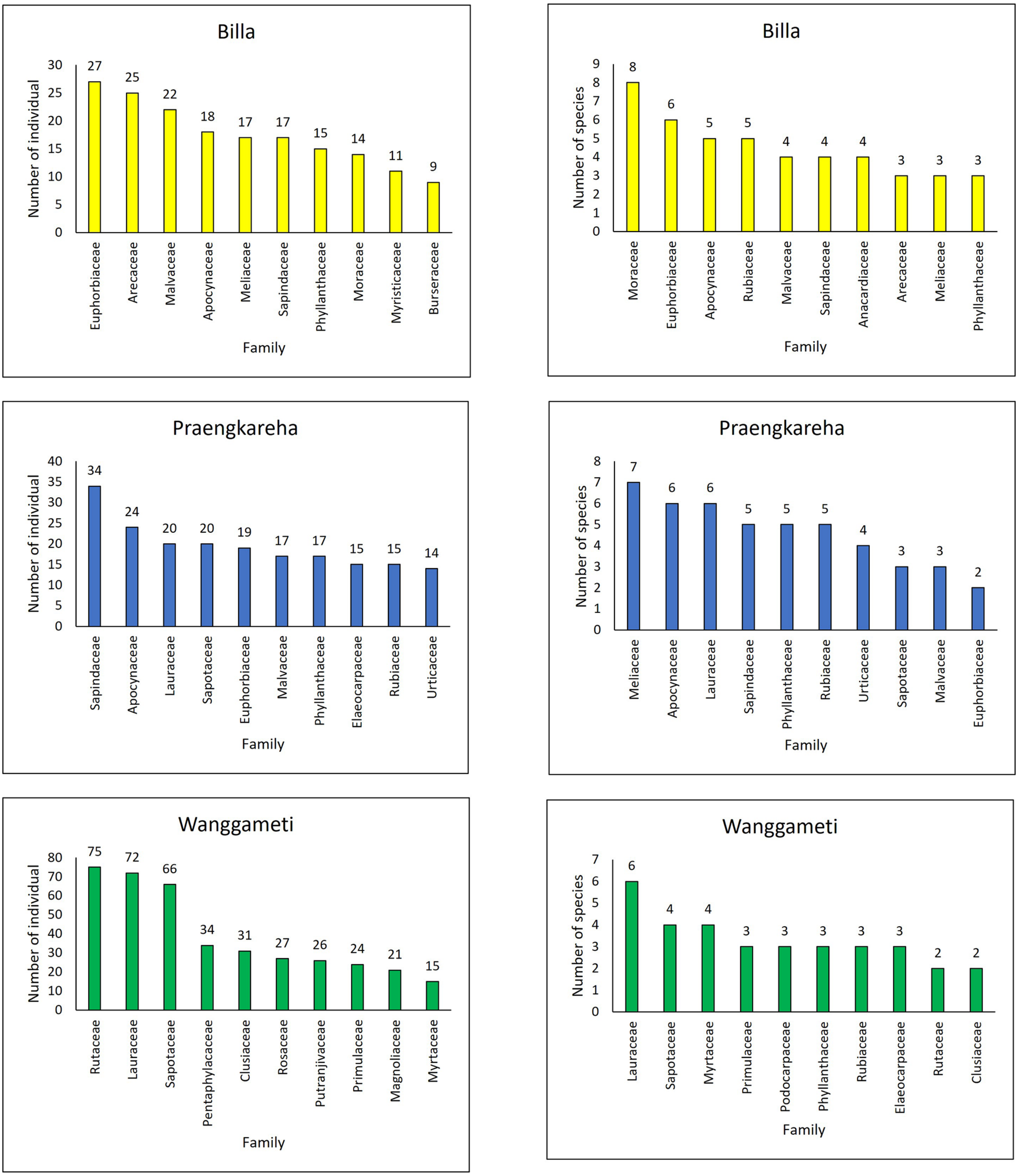

Fig. 3 Left: Ten families with the most individual trees in Billa (top), Praengkareha (middle) and Wanggameti (bottom). Right: ten families with the most species in Billa (top), Praengkareha (middle) and Wanggameti (bottom).

Bryophytes

Our excursion recorded 25 families of bryophytes containing 49 genera and 68 species (Table 3). The highest number of bryophyte species (53) was recorded at the highest elevation (Wanggameti, > 1 000 m asl), whereas the lower elevation sites (Billa and Praengkareha, < 1 000 m asl) combined had only 20 species. The number of moss familes, genera, and species were twice as high as those of liverworts. Mosses consisted of 47 species in 33 genera in 17 families, and the liverworts consisted of 21 species in 16 genera in 8 families.

The submontane forest of Wanggameti harboured 36 species of mosses, whereas the lowland forests of Billa and Praengkareha had 16 species. Four species occurred in both lowland and submontane forest. Liverworts exhibited the same pattern, with only five species in the lowland forest and 17 species in the submontane forest; two species occurred across the entire elevational range.

DISCUSSION

Patterns and reassessment of the lowland and submontane vegetation

The total number of tree species found in Billa, Praengkareha, and Wanggameti (145 species within 1.35 Ha) was much higher than in other studies such as in Central Java (81 species in more than 20 Ha) (Marliana & Rühe 2014). However, it is much

Table 3 The list of Bryophytes – with the absence of hornworts – found in the botanical excursion arranged based on groups, family, and species. The species of mosses outnumbers the liverworts. Majority of species are found at the higher altitude alone (Wanggameti) than two areas of the lowland (BIlla and Praengkareha) combined. Some of the mosses and liverworts species have broad altitudinal range.

No.	Group	Family	Species	Submontane forest	Lowland forest	Note
1	Musci	*Bartramiaceae*	*Philonotis bartramioides* (Griff.) Griff & Buck.	–	1	Windadri & Rosalina 2020
2	Musci	*Brachytheciceae*	*Rhynchostegium celebicum* (Sande Lac.) A.Jaeger	–	1	Windadri & Rosalina 2020
3	Musci	*Calymperaceae*	*Calymperes afzelii* Sw.	–	1	Windadri & Rosalina 2020
4	Musci	*Calymperaceae*	*Leucophanes massartii* Ren & Card	1	–	Species confirmed in this study
5	Musci	*Calymperaceae*	*Mitthyridium flavum* (Müll.Hal.) H.Rob.	1	–	Windadri & Rosalina 2020
6	Musci	*Calymperaceae*	*Syrrhopodon aristifolius* Mitt.	1	–	Windadri & Rosalina 2020
7	Musci	*Dicranaceae*	*Leucoloma mittenii* M.Fleisch.	1	–	Windadri & Rosalina 2020
8	Musci	*Dicranaceae*	*Leucobryum candidum* (P.Beauv.) Wils.	1	–	Windadri & Rosalina 2020
9	Musci	*Dicranaceae*	*Leucobryum juniperoideum* (Brid.) Müll.Hal.	1	–	Windadri & Rosalina 2020
10	Musci	*Dicranaceae*	*Leucolloma molle* (C.Mull.) Mitt.	1	–	Species confirmed in this study
11	Musci	*Fissidentaceae*	*Fissidens perpusillus* Wils. ex Mitt.	1	–	Species confirmed in this study
12	Musci	*Fissidentaceae*	*Fissidens robinsonii* Broth.	1	1	Species confirmed in this study
13	Musci	*Hypnaceae*	*Isopterygium bancanum* (Sande Lac.) A.Jaeger	–	1	Species confirmed in this study
14	Musci	*Hypnaceae*	*Ectropothecium monumentorum* (Duby) A.Jaeger	1	–	Windadri & Rosalina 2020
15	Musci	*Hypnaceae*	*Ectropothecium buitenzorgii* (Bel.) A.Jaeger.	1	–	Species confirmed in this study
16	Musci	*Hypnaceae*	*Ectropothecium dealbatum* (Reinw. & Hornsch.) A.Jaeger	1	–	Windadri & Rosalina 2020
17	Musci	*Hypnaceae*	*Ectropothecium falciforme* (Dozy & Molk.) A.Jaeger	–	1	Windadri & Rosalina 2020
18	Musci	*Hypnaceae*	*Ectropothecium ichnotocladum* (Müll.Hal.) A.Jaeger	–	1	Windadri & Rosalina 2020
19	Musci	*Hypnaceae*	*Isopterygium minutirameum* (C.Mull.) A.Jaeger	1	–	Species confirmed in this study
20	Musci	*Hypnaceae*	*Isopterygium textori* (Lac.) Mitt.	1	–	Species confirmed in this study
21	Musci	*Hypnaceae*	*Taxiphyllum taxirameum* Mitt.	1	–	Species confirmed in this study
22	Musci	*Meteoriaceae*	*Aerobryopsis wallichii* (Brid.) M.Fleisch.	1	–	Windadri & Rosalina 2020
23	Musci	*Meteoriaceae*	*Barbella enervis* (Mitt.) Fleisch.	1	–	Species confirmed in this study
24	Musci	*Meteoriaceae*	*Barbella pendula* (Sull.) Fleisch.	1	–	Species confirmed in this study
25	Musci	*Meteoriaceae*	*Floribundaria floribunda* (Doz. & Molk.) Fleisch.	1	–	Species confirmed in this study
26	Musci	*Meteoriaceae*	*Floribundaria pseudofloribunda* Fleisch.	1	–	Species confirmed in this study
27	Musci	*Meteoriaceae*	*Meteorium helmintocladum* (C.Mull.) Fleisch.	1	–	Species confirmed in this study
28	Musci	*Meteoriaceae*	*Meteorium polytrichum* Dozy & Molk.	1	–	Windadri & Rosalina 2020
29	Musci	*Neckeraceae*	*Himantocladium loriforme* (Bosch & Sande Lac.) M.Fleisch	1	–	Windadri & Rosalina 2020
30	Musci	*Neckeraceae*	*Himantocladium plumula* (Nees) M.Fleisch.	1	1	Windadri & Rosalina 2020
31	Musci	*Neckeraceae*	*Homaliodendron flabellatum* (Smith.) Fleisch.	1	–	Species confirmed in this study
32	Musci	*Neckeraceae*	*Neckeropsis gracilenta* (Sande Lac.) M.Fleisch.	1	–	Windadri & Rosalina 2020
33	Musci	*Neckeraceae*	*Neckeropsis lepineana* (Nees.) M.Fleisch.	1	–	Windadri & Rosalina 2020
34	Musci	*Octoblepharaceae*	*Octoblepharum albidum* Hedw.	1	–	Windadri & Rosalina 2020
35	Musci	*Octoblepharaceae*	Octoblepharum albidum Hedw.	–	1	Windadri & Rosalina 2020
36	Musci	*Phyllogoniaceae*	*Orthorrhynchium phyllogonioides* (Sull.) E.G.Britt.	1	–	Species confirmed in this study
37	Musci	*Polytrichaceae*	*Pogonatum neesii* (Müll.Hal.) Dozy	1	–	Windadri & Rosalina 2020
38	Musci	*Pottiaceae*	*Barbula consanguinea* (Thw. & Mitt.) A.Jaeger	–	1	Species confirmed in this study
39	Musci	*Pottiaceae*	*Barbula convoluta* Hedw.	–	1	Species confirmed in this study
40	Musci	*Pterobryaceae*	*Calyptothecium crispulum* (Sande Lac.) Broth.	1	–	Windadri & Rosalina 2020
41	Musci	*Pterobryaceae*	*Endotrichella elegans* (Dozy & Molk.) M.Fleisch.	1	–	Windadri & Rosalina 2020
42	Musci	*Pterobryaceae*	*Pterobryopsis crassicaulis* (Müll.Hal.) M.Fleisch.	1	–	Windadri & Rosalina 2020
43	Musci	*Rhizogoniaceae*	*Pyrrhobryum spiniforme* Hedw.	1	1	Windadri & Rosalina 2020
44	Musci	*Sematophyllaceae*	*Taxithelium kerianum* (Broth.) M.Fleisch.	–	1	Windadri & Rosalina 2020
45	Musci	*Sematophyllaceae*	*Taxithelium vernieri* (Duby) Besch.	–	1	Windadri & Rosalina 2020
46	Musci	*Sematophyllaceae*	*Trichosteleum elegantissimum* M.Fleisch.	1	–	Species confirmed in this study
47	Musci	*Splachnaceae*	*Tayloria borneensis* Dix.	–	1	Species confirmed in this study
48	Musci	*Thuidiaceae*	*Thuidium plumulosum* (Dozy & Molk.) Dozy & Molk.	1	–	Windadri & Rosalina 2020
49	Liverwort	*Aneuraceae*	*Riccardia crenulata* Shiffner	–	1	Haerida et al. 2020
50	Liverwort	*Frullaniaceae*	*Frullania apiculata* (Reinw., Blume & Nees) Dumort.	1	–	Haerida et al. 2020
51	Liverwort	*Frullaniaceae*	*Frullania nodulosa* (Reinw., Nees & Blume) Nees	1	–	First Liverworts collection in Sumba
52	Liverwort	*Frullaniaceae*	*Frullania moniliata* (Reinw., Blume & Nees) Mont.	1	–	Haerida et al. 2020
53	Liverwort	*Geocalycaceae*	*Heteroscyphus coalitus* (Hook.) Schiffn.	1	1	Haerida et al. 2020
54	Liverwort	*Lejeuneaceae*	*Ceratolejeunea* cf. *papuliflora* Steph.	1	–	Haerida et al. 2020
55	Liverwort	*Lejeuneaceae*	*Cheilolejeunea ceylanica* (Gottsche) R.M.Schust. & Kachroo	1	–	Haerida et al. 2020
56	Liverwort	*Lejeuneaceae*	*Cheilolejeunea trapezia* (Nees) Mizut	–	1	Haerida et al. 2020
57	Liverwort	*Lejeuneaceae*	*Drepanolejeunea levicornua* Steph.	–		Haerida et al. 2020
58	Liverwort	*Lejeuneaceae*	*Drepanolejeunea vesiculosa* (Mitt.) Steph.	1	–	Haerida et al. 2020
59	Liverwort	*Lejeuneaceae*	*Lejeunea alata* Gottsche	1	–	Haerida et al. 2020
60	Liverwort	*Lejeuneaceae*	*Leptolejeunea elliptica* (Lehm. & Lindenb.) Schiffn.	–	1	Haerida et al. 2020
61	Liverwort	*Lejeuneaceae*	*Lopholejeunea nigricans* (Lindenb.) Steph.	1	–	Haerida et al. 2020
62	Liverwort	*Lejeuneaceae*	*Mastigolejeunea humilis* (Gottsche) Schiffn.	1	–	Haerida et al. 2020
63	Liverwort	*Lejeuneaceae*	*Mastigolejeunea ligulata* (Lehm. & Lindenb.) Schiffn.	1	–	Haerida et al. 2020
64	Liverwort	*Lejeuneaceae*	*Ptychanthus striatus* (Lehm. & Lindenb.) Nees	1	–	Haerida et al. 2020
65	Liverwort	*Lejeuneaceae*	*Spruceanthus polymorphus* (Sande Lac.) Verd.	1	–	Haerida et al. 2020
66	Liverwort	*Lepidoziaceae*	*Bazzania longicaulis* (Sande Lac.) Schiffn.	1	–	Haerida et al. 2020
67	Liverwort	*Metzgeriaceae*	*Metzgeria consanguinea* Schiffn.	1	–	Haerida et al. 2020
68	Liverwort	*Plagiochilaceae*	*Plagiochila teysmannii* Sande Lac	1	1	Haerida et al. 2020
69	Liverwort	*Radulaceae*	*Radula javanica* Gottsche	1	–	Haerida et al. 2020
			Total species	53	20	

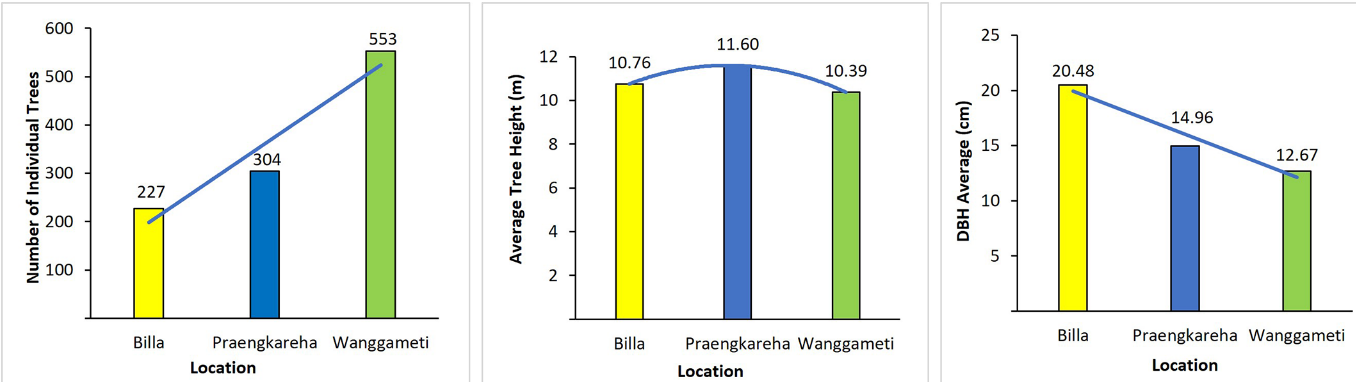

Fig. 4 The number of individuals, average tree height, and average dbh of trees in Billa (yellow), Praengkareha (blue), and Wanggameti (green).

lower than in Kalimantan (205 tree species within 1 Ha) (Sheil et al. 2010), in Jambi (Sumatra) 724 tree species within 8 Ha (Rembold et al. 2017), and in Sulawesi (c. 150 species in 1 Ha) (Kessler et al. 2005). The total number of tree species in our study area can be considered a good estimation because the species accumulation curves (Fig. 2) reached a plateau. Hence, additional plots will likely detect few new species (Barnett & Stohlgren 2003). Our study area comprises lowland and highland forest areas, similar to the study in Sulawesi, while other studies, those in Java and Lombok, were conducted in highland areas only, and those in Sumatra and Kalimantan were done in lowland areas only. Elevation affects the number of species found, determined mostly by increasing diurnal temperature variability and rainfall seasonality and a decreasing minimum temperature (Ashton 2017).

Within our study area, we also observed another pattern in the number of species. Billa had a lower species number when compared to Wanggameti. This phenomenon occurs likely because of the impact of human activities. Several domesticated species were recorded at Billa such as *Areca catechu* L., *Mangifera indica* L., and *Coffea canephora* Pierre ex A.Froehner. These economic species evidently were introduced to this island (POWO continuously updated) and cultivated in farmland as seen in Fig. 1. We also noted the presence of foraging cattle around the plot locations in Billa.

All study areas have a similar species compositions to some degree. Apart from nine common species, listed above, there were many species present in two out of three areas. Billa and Praengkareha, both in the lowlands, shared more than 30 species in common. The high species similarity (Sørensen index = 0.51) observed in these two areas was likely due to the low elevational gap, around 100 m, between these locations, reflecting similar vegetation zones. In contrast, Praengkareha and Wanggameti have a larger average elevational gap (500 m) and shared only 19 species. Moreover, Billa and Wanggameti, with an even larger elevational gap (700 m), shared a lower number of species (12). Lower similarity in species composition (Sørensen index = 0.27 and 0.19, respectively) indicates different vegetation zones, reflecting a decrease in environmental similarity due to topography or climate (Nekola & White 1999). Furthermore, along elevational gradients in the tropics the environmental conditions that shape the ecosystems are also varied, such as humidity and rainfall increases from lowland rainforests to cloud forests and elfin forests, but in contrast a decrease in nutrient availability (Givnish 1999).

The effect of elevation on average tree height, average dbh and the number of individuals of nine species occurring across all areas were compared to one another as seen in the Appendix. The elevational patterns in these three different parameters were not consistent between species, e.g., as elevation increased, two species, *Chionanthus ramiflorus* and *Tabernaemontana sphaerocarpa* exhibited an increase in average tree height, while *Tetrameles nudiflora*, *Pittosporum moluccanum* and *Alstonia macrophylla* demonstrated the opposite effect. Dbh also showed opposing patterns for some species. *Tabernaemontana macrocarpa* and *Chionanthus ramiflorus* exhibited a larger dbh with increasing elevation, in contrast to *Alstonia macrophylla*. Broader field surveys with more species covered can potentially expose more patterns and deliver a more comprehensive botanical picture of this island.

The observable patterns across elevational gradients are summarized as follows. Praengkareha at the middle elevation had the tallest tree average record (11.60 m), followed by Billa (10.76 m) and Wanggameti (10.39 m). To some degree, this is in line with Lieberman et al. (1996), who found that average canopy height, as well as the species diversity, reached their maxima at intermediate elevation. They stated that lower diversity at higher elevation was presumably the result of difficult environmental conditions, which constrained the species pool, something we unfortunately cannot test with our data, which showed lower species richness at lower altitude due to the impact of human interferences (see above).

Dbh had the highest average at Billa, the lowest elevation, with 20.48 cm, followed by Praengkareha (14.96 cm) and Wanggameti (12.67 cm). A similar situation was reported by Aiba & Kitayama (1999) on Mount Kinabalu, Borneo, where the dbh was slightly higher at lower altitudes (up to 700 m asl), reaching 120 cm, whereas at higher altitudes (above 1700 m asl) the maximum dbh was 80 cm for both ultramafic and non-ultramafic substrates. One possible explanation might be nutrient deficiency and water availability in higher elevations (Aiba & Kitayama 1999). On Mount Kinabalu, in-situ nitrogen availability was found to decrease with altitude (Kitayama et al. 1998). Similarly, the hydraulic conductance of stems is limited (Cavelier 1996), and occasional droughts (Kitayama 1996) are also known to occur at high altitudes (Aiba & Kitayama 1999). Our result, however, contrasts with Lieberman et al. (1996) who found dbh to be relatively constant both at low altitude (100 m asl) and higher altitude (up to 1500 m asl). The results of Lieberman et al. (1996) were attributed to past catastrophic disturbances such as volcanic eruptions in their study area.

Comparative assessment of Wanggameti peak between this study and Banilodu & Saka (1993)

Our dataset for Wanggameti, 64 species in 37 plant families of spermatophytes and pteridophytes, allows comparison with the data of Banilodu & Saka (1993), who recorded 52 tree species and 37 ferns species. The principal difference between the two studies is that Banilodu & Saka (1993) had a 2.5 times larger total plot area than we did, 2400 m^2 vs 900 m^2. However, species accumulation in plots between the two studies only showed five families and seven species in common, which is lower than expected, raising concerns regarding the utility of this comparative assessment and warranting a careful examination of their dataset.

Our assessment of both datasets did not support the presence of elfin forest sensu Schimper (1903): a miniature evergreen forest with a homogeneous canopy and without emergent trees. It is populated by dwarf crooked trees with bent branches, short, gnarled, often horizontal stems. This reflects an architecture adapted to withstand strong wind (Schimper 1903, Van Steenis et al. 1972, Whitmore 1990). Our findings (previous section and Table 2) support the presence of submontane forest based on the species encountered and tree height. A critical examination of the Banilodu & Saka (1993) dataset also suggests the occurrence of submontane forest at Wanggameti summit. The elfin forest habit was absent at the Wanggameti summit according to their dataset.

In addition, *Ericaceae*, a typical dominant family in elfin vegetation in Malesia that is mentioned in Schimper (1903) and Van Steenis et al. (1972), was found near the summit in our study. *Vaccinium varingiifolium* (Blume) Miq. did not show domination, which is in contrast with Grevenstuk (1939), who reported the common presence of *Vaccinium* at the highest points in Sumba. If his observation was true, then the peak had experienced a significant vegetation change. We also found species unique to high altitude that characterise submontane vegetation according to Van Steenis et al. (1972): *Ardisia javanica* A.DC., *Dacrycarpus imbricatus* (Blume) de Laub., *Daphniphyllum glaucescens* Blume, *Engelhardia serrata* Blume, *Helicia serrata* (R.Br.) Blume, *Myrica javanica* Blume, *Oreocnide rubescens* (Blume) Miq., *Podocarpus neriifolius* D.Don, and *Wendlandia densiflora* (Blume) DC.

The characterization of elfin forest by Banilodu & Saka (1993) is apparently the result of a translation error. The report on the vegetation of Sumba (Banilodu & Saka 1993) was written in two languages, Bahasa (Indonesian) and English. In Bahasa, the native language of the authors, the report mentions the presence of *lumut* (moss) and *awan* (cloud) forest and never mentions elfin forest. In the English version, however, the moss forest was translated into elfin forest multiple times by the translators. Multiple names such as cloud forest, moss forest and elfin forest are often applied to Tropical Cloud Montane Forest (Hamilton et al. 1995). Different assigned names reflect different yet often overlapping physical situations like frequent mossy and cloudy situations at higher elevation, which likely caused the above confusion as different terms were considered synonymous.

It is unfortunate that the term elfin forest for the Wanggameti top circulated in other literature, likely copied from Banilodu & Saka, but dedicated to non-botanical research, e.g., Sitompul et al. (2004). Furthermore, we treated eleven species recorded in Banilodu & Saka (1993) (Fig. 2), that were previously unknown for Sumba, with the status 'Out of Sumba', because we cannot check the accuracy of the identifications owing to the absence of specimens in their study.

Bryophytes at Wanggameti

The presence of mosses and liverworts, but no record of hornworts, characterizes the diversity of the bryoflora of Sumba at the moment. Both mosses and liverworts were found growing on stems, trunks, soil, decaying wood, roots of trees, and rocks according to Windadri & Rosalina (2020), published three decades after a comprehensive account of LSI mosses by Touw (1992). Species richness was more pronounced (53 species) at higher elevation (Wanggameti) than at lower elevation (Billa and Praengkareha) with 20 species similar to those mentioned in Richards (1984, 1988), Frahm & Gradstein (1991) and Bruun et al. (2006). However, our result contrasts with that of Acebey et al. (2003), which found a higher bryoflora diversity at lower elevations due to increased habitat complexity, while Iskandar et al. (2020) found that the middle elevation had the highest richness.

The number of species of liverworts was lower in lowland than submontane forest. This is in contrast to a study in Rio de Janeiro by Santos (2011) who found a higher species richness of liverworts at lower elevations and a higher species richness of mosses at higher elevations. Two families of mosses, *Hypnaceae* and *Meteoriaceae*, had more species than the rest of the listed families. *Hypnaceae* had the highest number of (nine) species, agreeing with the result of Gradstein & Pocs (1989). This family had six species exclusively found in submontane forest and the remaining three are in the lowland areas. *Meteoriaceae* had a high number (seven) of species, which is congruent with results of Acebey et al. (2003). This family was exclusively found in submontane forest, and most of the species found (six) were new records. Other exclusively submontane families recorded were *Dicranaceae*, *Pterobryaceae,* and *Thuidiaceae*. In the lowland forest there were several families exclusively observed there, such as *Bartramiaceae*, *Pottiaceae*, and *Splachnaceae*. After species identification by DR and FIW, twenty new species records were added when compared to the previous list of Windadri & Rosalina (2020), resulting in a total of 48 moss species in Sumba.

Twenty species of liverworts were newly recorded for Sumba by Haerida et al. (2020) after only a single species collected by Teijsmann in 1926. *Lejeunaceae* accounts for more than half of the total species count and is found both in lowland and submontane forests. This family had the highest number of (12) species, similar to the finding by Dos Santos et al. (2017) at Parana, Brazil. The remaining documented families each only had a single or three species in Sumba (Table 4). *Frullaniaceae*, *Lepidoziaceae*, *Metzgeriaceae*, and *Radulaceae* were exclusively found in the submontane forest. However, new sampling might reveal more species, perhaps even at lower altitudes.

There were several bryophytes specimens identified only at the generic level (not shown here), indicating that species richness may be even higher. The absence of national and regional checklists, floras, and digital online databases for Indonesia was mentioned by Geffert et al. (2013). This means that substantial information on the diversity of Indonesian bryoflora is lacking, despite the potentially high number of species present. A recent study covering the whole LSI by Nadhifah et al. (2021) concluded that Sumba is only second to Bali within the LSI in species richness of liverworts and hornworts (the group that we did not encounter during our excursion). The accumulation of new records in this study indicates that the number of liverworts species reported for Sumba is likely an underestimation, as the survey in 2016 only covered a minor portion of Sumba's vegetation. Further study on bryophytes from different areas in this island will be essential to provide a more comprehensive picture of the bryoflora in Sumba.

CONCLUSIONS

This investigation provides updated records for two types of vegetation at different elevations in Sumba, lowland and submontane forest. The number of individual trees showed a positive association with increasing elevation across regions. Average tree height, however, was not associated with increased elevation.

In addition, this study also identified a mischaracterization of a vegetation type in the past. Future studies are advised to use correct and clearly defined terminology in order to provide an accurate floristic picture of Sumba as well as other areas. This study also added new records for 25 species of Spermatophytes that previously were not known to Sumba.

Last but not least, the Wanggameti area, with its high humidity, stable and relatively low temperature, is inhabited by a rich bryoflora. Low or no variability in environmental factors in the submontane forest may allow for more bryophyte species to thrive there than in the lowland areas. The current list comprises 20 new records of bryophytes for Sumba. This, however, does not reflect the total species level diversity, as it covers only a portion of vegetation in Sumba, and some specimens still await identification to the species level.

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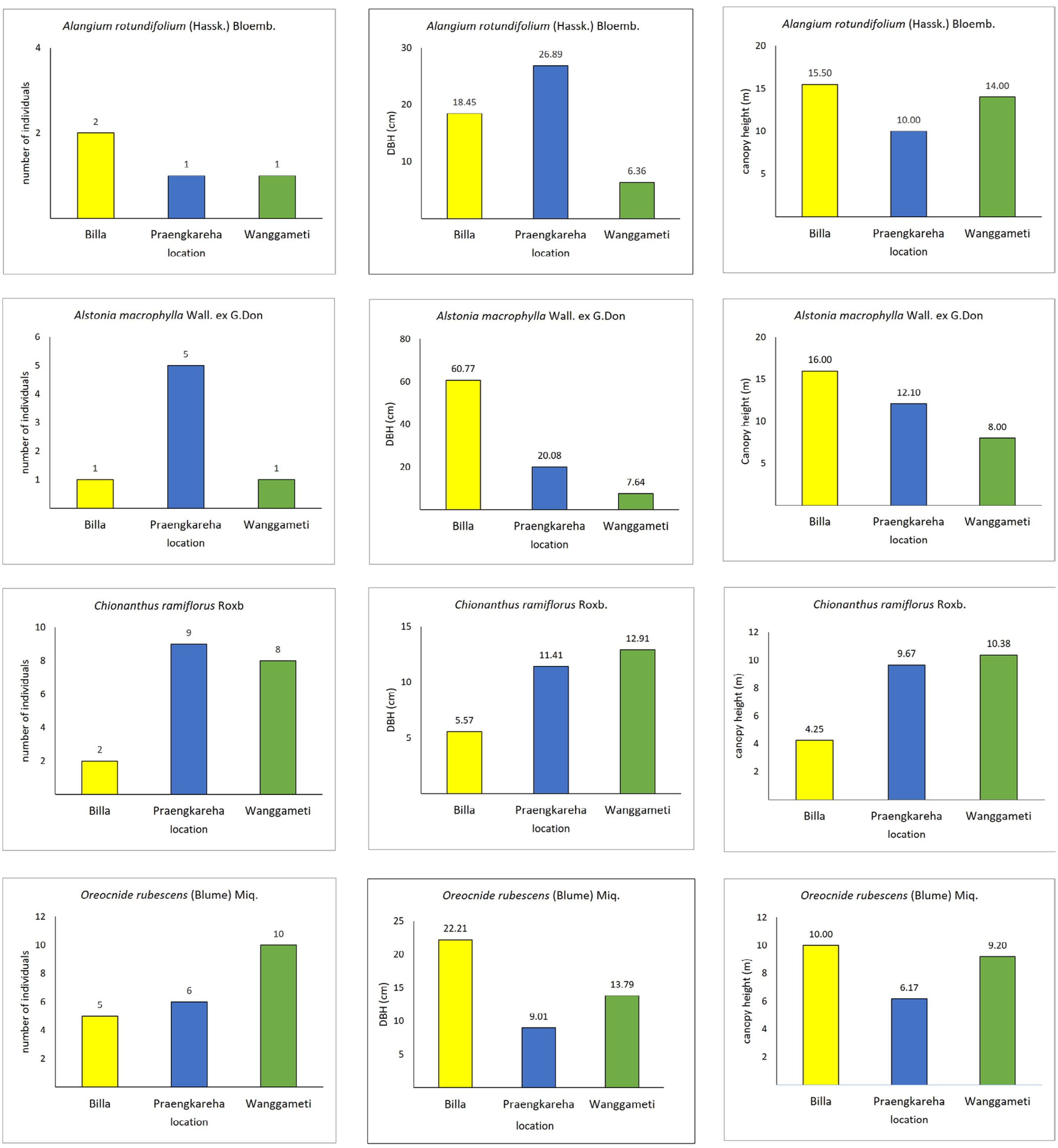
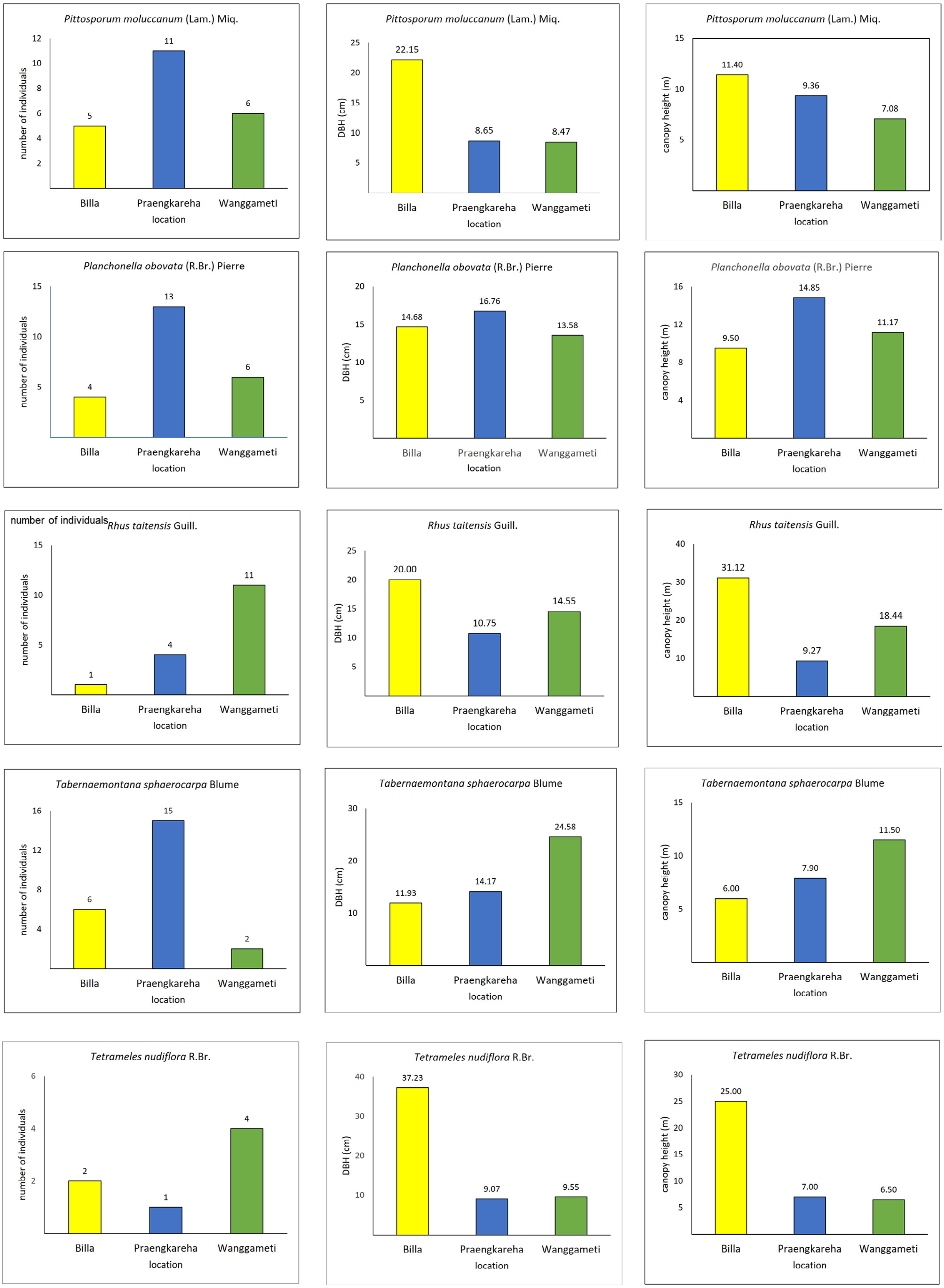


Appendix Nine species occurring in all three areas (Bila: yellow; Praengkareha: blue, and Wanggameti: green) with their number of individual trees (left), average of diameter at breast height (dbh) (cm, middle) and average tree height (m, right).



Appendix (cont.)