



# REINWARDTIA

A JOURNAL ON TAXONOMIC BOTANY, PLANT SOCIOLOGY AND ECOLOGY

ISSN 0034 – 365 X | E-ISSN 2337 – 8824 | Accredited 792/AU3/P2MI-LIPI/04/2016



2018 17 (2)

# REINWARDTIA

*A JOURNAL ON TAXONOMIC BOTANY, PLANT SOCIOLOGY AND ECOLOGY*

Vol. 17 (2): 87 – 154, December 18, 2018

## Chief Editor

Kartini Kramadibrata (Mycologist, Herbarium Bogoriense, Indonesia)

## Editors

Dedy Darnaedi (Taxonomist, Herbarium Bogoriense, Indonesia)

Tukirin Partomihardjo (Ecologist, Herbarium Bogoriense, Indonesia)

Joeni Setijo Rahajoe (Ecologist, Herbarium Bogoriense, Indonesia)

Marlina Ardiyani (Taxonomist, Herbarium Bogoriense, Indonesia)

Himmah Rustiami (Taxonomist, Herbarium Bogoriense, Indonesia)

Lulut Dwi Sulistyarningsih (Taxonomist, Herbarium Bogoriense, Indonesia)

Topik Hidayat (Taxonomist, Indonesia University of Education, Indonesia)

Eizi Suzuki (Ecologist, Kagoshima University, Japan)

Jun Wen (Taxonomist, Smithsonian Natural History Museum, USA)

Barry J. Conn (Taxonomist, School of Life and Environmental Sciences, The University of Sydney, Australia)

David G. Frodin (Taxonomist, Royal Botanic Gardens, Kew, United Kingdom)

Graham Egleton (Wagstaffe, NSW, Australia)

## Secretary

Ruslan Bukhori

## Layout

Liana Astuti

## Illustrators

Subari

Wahyudi Santoso

Anne Kusumawaty

Correspondence on editorial matters and subscriptions for Reinwardtia should be addressed to:

HERBARIUM BOGORIENSE, BOTANY DIVISION,

RESEARCH CENTER FOR BIOLOGY– INDONESIAN INSTITUTE OF SCIENCES

CIBINONG SCIENCE CENTER, JLN. RAYA JAKARTA – BOGOR KM 46,

CIBINONG 16911, P.O. Box 25 CIBINONG

INDONESIA

PHONE (+62) 21 8765066; Fax (+62) 21 8765062

E-MAIL: reinwardtia@mail.lipi.go.id

<http://e-journal.biologi.lipi.go.id/index.php/reinwardtia>



Cover images: *Canthiumera robusta* K.M.Wong & X.Y.Ng, *spec. nov.* Top left: leafy branch with inflorescences; note also keeled stipules. Top right: flower with tufts of pale moniliform hairs visible opposite corolla lobes. Below left: fruits. Below right: pyrenes. Photos: Ang Wee Foong (top left) and X.Y. Ng (remaining images).

**The Editors would like to thank all reviewers of volume 17(2):**

Andrew Powling, School of Biological Sciences, University of Portsmouth, Portsmouth, United Kingdom

George Argent, Royal Botanic Garden Edinburgh, Edinburgh, United Kingdom

Joan Pereira, Forest Research Centre, Sandakan, Sabah, Malaysia

Jun Yokoyama, Dept. of Biology, Faculty of Science, Yamagata University, Yamagata, Japan

Khoon Meng Wong, Singapore Botanic Gardens, Singapore

Kongkanda Chayamarit, Queen Sirikit Botanic Garden, P.O. Box 7, Mae Rim, Chiang Mai, Thailand

## TREE SPECIES DIVERSITY IN A PRISTINE MONTANE FOREST PREVIOUSLY UNTOUCHED BY HUMAN ACTIVITIES IN FOJA MOUNTAINS, PAPUA, INDONESIA

Received 06 August, 2018; accepted 04 October, 2018

### ASEP SADILI

Herbarium Bogoriense, Research Center for Biology, Indonesian Institute of Sciences (LIPI), Jln. Raya Jakarta-Bogor Km 46, Cibinong 16911, Indonesia. Email: asepsadili@gmail.com

### KUSWATA KARTAWINATA

Integrative Research Center, The Field Museum, 1400 Lake Shore Drive, Chicago, IL 60605, USA, Email: kkjak@indo.net.id

### HERWASONO SOEDJITO

Herbarium Bogoriense, Research Center for Biology, Indonesian Institute of Sciences (LIPI), Jln. Raya Jakarta-Bogor Km 46, Cibinong 16911, Indonesia. Email: herwasonosuedjito@yahoo.com

### EDY NASRIADI SAMBAS

Herbarium Bogoriense, Research Center for Biology, Indonesian Institute of Sciences (LIPI), Jln. Raya Jakarta-Bogor Km 46, Cibinong 16911, Indonesia. Email: edynas.sambas@gmail.com

### ABSTRACT

SADILI, A., KARTAWINATA, K., SOEDJITO, H. & SAMBAS, E. N. 2018. Tree species diversity in a pristine montane forest previously untouched by human activities in Foja Mountains, Papua, Indonesia. *Reinwardtia* 17(2): 133–154. — A study on structure and composition of the pristine montane forest previously untouched by human activities was conducted at the Foja Mountains in November 2008. We established a one-hectare plot divided into 100 subplots of 10 m × 10 m each. We enumerated all trees with DBH ≥ 10 cm which diameters were measured, heights were estimated and habitats were noted. We recorded 59 species, 42 genera and 27 families, comprising 693 trees with the total basal area (BA) of 41.35 m<sup>2</sup>/ha. The forest had lower species richness compared to those of lowland forests in Kalimantan, and Sumatra and montane forests in West Java. The Shannon-Wiener's diversity index was 3.22. *Nothofagus rubra* (Importance Value, IV=47.89%) and *Parinari corymbosa* (IV=40.3%) were the dominant species, constituting the basis for designating the forest as the *Nothofagus rubra* - *Parinari corymbosa* association. To date, the dominance of *N. rubra* is unique to the Foja Mountains, as elsewhere in Papua the montane forests were dominated by *N. pullei* or other species. The species-area curve indicated a minimal area of 5000 m<sup>2</sup>. On the family level Fagaceae (IV=53.23%), Chrysobalanaceae (IV=40.53%) and Myristicaceae (IV=26.43%) were dominant. Vertically the forest consisted of four strata (A–D). In each stratum *Nothofagus rubra*, *Platea latifolia*, *Parinari corymbosa* and *Myristica hollrungii* were dominant. The diameter class distribution of *Nothofagus rubra*, *Parinari corymbosa* and *Platea latifolia* led us to assume that these species were regenerating well.

**Key words:** Association, composition, Foja, montane forest, Papua, structure.

### ABSTRAK

SADILI, A. KARTAWINATA, K. SOEDJITO, H. & SAMBAS, E. N. 2018. Keanekaragaman jenis pohon di dalam hutan pegunungan yang belum terjamah kegiatan manusia di Pegunungan Foja, Papua, Indonesia. *Reinwardtia* 17(2): 133–154. — Kajian struktur dan komposisi hutan pegunungan alami yang belum terjamah manusia di hutan Pegunungan Foja dilakukan pada bulan November 2008. Kajian menggunakan petak satu hektar, yang dibagi menjadi 100 anak petak masing-masing berukuran 10 m × 10 m. Semua pohon berdiameter ≥ 10 cm diukur diameternya, ditaksir tinggi totalnya, dan dicatat habitatnya. Dari pendataan 693 individu tercatat 59 jenis, 42 marga, dan 27 suku, dengan luas bidang dasar 41,35 m<sup>2</sup>/ha. Kekayaan jenis lebih rendah dari hutan pamah Kalimantan, Sumatera, dan hutan pegunungan di Jawa Barat. Indeks keragaman *Shannon-Wiener* = 3.22. *Nothofagus rubra* dengan Nilai Kepentingan NK=47.89% dan *Parinari corymbosa* dengan NK=40.53% adalah jenis dominan dan menjadi landasan untuk menyebut tegakan hutan dalam plot sebagai asosiasi *Nothofagus rubra*-*Parinari corymbosa*. Jenis *N. rubra* merupakan jenis dominan yang unik bagi hutan Pegunungan Foja, sedangkan hutan pegunungan lain di Papua didominasi oleh *N. pullei* atau jenis lain. Kurva jenis-area menunjukkan luas 5.000 m<sup>2</sup> sebagai luas minimal. Fagaceae (NK=53.23%), Chrysobalanaceae (NK=40.53%) dan Myristicaceae (NK=26.43 %) adalah suku dominan. Secara vertikal hutan terdiri dari empat lapisan (A–D). Setiap lapisan didominasi *Nothofagus rubra*, *Platea latifolia*, *Parinari corymbosa*, dan *Myristica hollrungii*. Berdasarkan distribusi kelas diameter bagi *Nothofagus rubra*, *Parinari corymbosa* dan *Platea latifolia* adalah jenis yang regenerasinya sangat baik.

**Kata kunci:** Asosiasi, Foja, hutan pegunungan, komposisi, Papua, struktur.

## INTRODUCTION

New Guinea is the largest tropical island, covering a total area of  $\pm 900,000 \text{ km}^2$  (Polak, 2000). Politically it encompasses Indonesian New Guinea (consisting of the Papua and West Papua Provinces) to the west and Papua New Guinea to the east. Phytogeographically New Guinea belongs to the floristic region of Malesia (Steenis, 1950; Balgooy, 1976). The vegetation and climate of Papua are diverse (Hope, 1976; Pajmans, 1976; Kartikasari *et al.*, 2012). The high plant species diversity of Papua (Johns, 1993; Johns *et al.*, 2007; Kartawinata, 2013) contributes to the status of Indonesia as one of the megadiversity countries, besides Brazil and Zaire (BAPPENAS, 2003; LIPI *et al.*, 2013). It is the home and habitat of 124 endemic plant genera (Kartawinata, 2013; Steenis, 1950). The conservation areas in Papua cover 7,755,284 ha (KLHK, 2016). The Foja Mountains and the surrounding lowland forest were declared as the Foja Wildlife Refuge (*Suaka Margasatwa Foja*) by the Minister of Forestry SK No. 3028/Menhut-VII/KUH/2014 on 17 April 2014 and SK No. 3076/Menhut-VII/KUH/2014 on 23 April 2013. Along with other forest areas they were later proposed as a national park (Roberth, 2016).

Vegetation studies in Papua have been relatively fewer compared to those in Papua New Guinea. The existing results of vegetation studies in the lowland and highland of Papua have been synthesized by Johns *et al.* (2007) and Bowe *et al.* (2007). Past studies were primarily qualitative reports complementing botanical explorations, including those by Archbold *et al.* (1942), Brass (1941), Gibbs (1917), Kalkman (1963), and Lam (1945).

In Papua, Gibbs (1917) was the first botanist who classified the vegetation and recorded the flora of the Arfak Mountains. He noted the lower montane forest was dominated by *Araucaria* and *Lithocarpus*, and low mossy montane forest above 2,100 m asl was dominated by short trees of *Phyllocladus*, *Papua cedrus*, and *Dacrycarpus*. Later Lane-Poole (1925) tried to classify the vegetation of the entire New Guinea, including Papua. He identified lower montane forest zone (300–1,700 m asl), mid montane forest (1,700–2,250 m asl), mossy forest (2,250–3,350 m asl) and high montane forest (> 3,350 m asl). This classification is comparable to that of Johns *et al.* (2007).

The third Archbold expedition was undertaken in the Snow Mountains, with Mt. Jaya as the summit at the altitude of 4,886 m asl (Archbold *et al.*, 1942; Brass, 1941). Brass (1941) proposed a tentative classification of the main vegetation of New Guinea as follows: savanna and savanna forest (0–1,700 m asl); monsoon forest (0–450 m

asl), rain forest (0–2,400 m asl), mid-mountain forest (480–2,350 m asl); beech forest (850–3,100 m asl); mossy forest (1,500–3,200 m asl); sub-alpine forest (3,000–4,050 m asl); and alpine grassland (2,900 m asl–snowline), but he did not indicate the type of vegetation at the elevation of 2,400–3,000 m. Partly based on the 1919–1920 expedition to the Doorman Top, a small mountain covered by ultramafic vegetation, Lam (1945) summarized the vegetation of New Guinea but did not propose any vegetation classification based on altitudes. Johns *et al.* (2007) listed earlier expeditions by Beccari to the Arfak Mountains, Wollaston and Kloss to Mt. Jaya, Colijn in 1936, Lorentz-van Nouhuys in 1909, Herderschee in 1913, and Kalkman in 1963 in the Star Mountain.

More recent vegetation studies in the Mt. Jaya area were conducted by Hope (1976) and on Mt. Trikora by Mangen (1993). Hope (1976) identified upper montane forest dominated by *Nothofagus pullei*; lower subalpine forest dominated by *Dacrycarpus compactus* and *Trochocarpus nubicola*; shrubland-grassland dominated by *Coprosma brassii* and *Deschampsia klossii*; tree-fern tussock grassland dominated by *Cyathea pseudomuelleri* and *Deschampsia klossii*; tussock grassland dominated by *Deschampsia klossii*; communities on open rocky slopes dominated by grasses, mosses and lichens, subalpine bog communities dominated by short grasses and short shrubs and alpine vegetation composed of grassland, dwarf heath scrub, moss and short scrub and tundras.

Most recent studies were conducted by Shea *et al.* (1998) in the forests within the Freeport concession area on the southern side of the Carstenz mountain around Tembapapura. They indicated *Hopea papuana*, *Lithocarpus* sp., *Symplocos cochinchinensis*, *Syzygium anomala*, *Elaeocarpus sepikensis*, *Anisoptera thurifera* and *Castanopsis acuminatissima* as common tree species. They identified a *Lithocarpus* sp., *Tristania* sp., association, *Symplocos cochinchinensis-Elaeocarpus* sp. association, *Anisoptera thurifera-Castanopsis acuminatissima* association and *Neolamarckia cadamba-Ficus* sp. association.

Polak (2000) investigated the botanical diversity and its relation to soil and geological substrata in the karst-dominated Ayawasi area (Bird's Head Peninsula), and recorded Myrtaceae, Burseraceae, and Euphorbiaceae as the most frequent families and Myrtaceae, Lauraceae, and Meliaceae as the most species-rich families. Keim *et al.* (unpublished, 2018) reported a floristic and vegetation survey around the Habbema Lake. They identified lower montane forest, upper montane forest, mossy forest, subalpine forest, subalpine scrub, subalpine grassland and tropical alpine vegetation, comprising grassland, heath

scrub and tundra. *Nothofagus brassii* and *N. pullei* characterized the upper montane forest and mossy forest. They included also a description of vegetation types beyond Lake Habbema up to Mt. Jaya, although these areas were not visited during the survey. They also recorded the occurrence of dieback in Nothofagaceae.

The Foja-Mamberamo forest (see Fig. 1) is assumed to have high species diversity, including a high number of endemic species. Floristic inventories of the forests in the Mamberamo area including the Foja Mountains around 1,000 m alt were produced by Moge (2005), Takeuchi (2007, 2009 & 2010) and Takeuchi & Arifiani (2010). Heist *et al.* (2010) studied the lowland forests and related vegetation of Kwerba, on the Foja Foothills, and recorded common canopy trees and emergents in the primary forest, including *Teijsmanniodendron bogoriense*, *T. hollrungii*, *Cleistanthus myrianthus*, *Intsia bijuga*, *Canarium maluense* and *Pometia pinnata*. In the second highest stratum they recorded *Anisoptera thurifera* subsp. *polyandra*, *Hopea novoguineensis*, *Vatica rassak*, *Pimelodendron amboinicum*, *Mastixiodendron pachyclados* and *Myristica fatua*. Sambas (2014) studied the structure and floristic composition of lowland forest stands at Hotice and Kwerba and indicated that they were mixed forests with *Teijsmanniodendron holophyllum* and *Anisoptera thurifera* as the prevalent species but not distinctly dominant. The forest communities in the two sites may be designated as *Teijsmanniodendron holophyllum*-*Anisoptera thurifera* association that may be related to the associations in the Tembagapura area described by Shea *et al.* (1998).

The montane section above 1,000 m asl remained unexplored and untouched by human activities until a team of CII (Conservation International Indonesia) field naturalists from Indonesia, USA, England, and Australia carried out an expedition in November 2008 to undertake a comprehensive biodiversity survey of the Foja Mountains. One of us (AS) took part in the expedition. It is an isolated range in a little-studied corner of the tropical world of northern Papua Province (Beehler, 2007). Until 2008 we knew nothing about the floristic composition and structure of the montane forest in the Foja Mountains. The objective of the present study was to uncover and describe quantitatively for the first time the floristic composition and structure of the forest in the Foja Mountains. The study can provide scientific data for planning necessary actions in the long-term management of the reserve. Information on vegetation structure and species composition is needed in the development and management of conservation areas.

## MATERIALS AND METHODS

### Study site

Administratively the study area in the Foja Mountains is located in the Foja Wildlife Refuge (*Suaka Margasatwa* Foja) in the Kuerba Subdistrict, Kaso District, partly Mamberamo Raya Tengah Regency and partly Waropen Regency, Papua Province. Geographically the Foja Wildlife Refuge is located at 137°54'33"–138°15'32" East and 01°29'59"–01°44'28" South. It encompasses several vegetation types ranging from lowland dryland forest, swamp forest, mixed swamp forest and lower montane forest to upper montane forest with the highest elevation of ± 2,193 m asl. A seasonally dry lake covered by herbaceous vegetation occurs within the montane forest. The forest in the reserve can be classified as a wet rain forest. The forest is a pristine primary forest, where there was no trace of previous disturbance resulting from human activities. Only natural disturbances, such as landslides on very steep slopes, may be observed in the area.

In the rainfall classification of Schmidt & Ferguson (1951) the reserve falls within the rainfall type A (perhumid climate with percentage of the number of dry months over the number of wet months,  $Q = 0-14.3\%$ ). The nearest weather station to Foja Mountains is that at Wamena with a comparable altitude of 1,803 m asl. The rainfall and temperature data were available from Climate-Data (2017) and long-term rainfall data from Boerlage (1949). We constructed a climate diagram of Walter (1973) for Wamena (Fig. 1). The data showed that the wettest season with the highest rainfall occurred in February (±224 mm) and March (±223 mm) and the driest months with the lowest rainfall happened in June (±132 mm) and July (±134 mm). The daily temperature ranged from 25°C during day time to 13.5°C at night time. The weather during the study period in November 2008 was rainy and occasionally the area was covered by thick cloud. The humidity was 95%–98% and the day-time temperature was 15°C–18°C.

Geographically the study site is located at 02°34.388' South and 138°43.049' East (Fig. 1), with an altitude of 1,710 m asl and a bird's eye view of the area is shown in Fig. 2. In general, the landscape consists of a montane forest zone on hilly topography with gentle to very steep slopes. The topography of the site where the study was undertaken was relatively flat with uneven ground surface. The soil is composed of a thin layer of humus overlying a porous greyish-brown layer, with pH of 4–4.5 and in places is swampy and peaty.

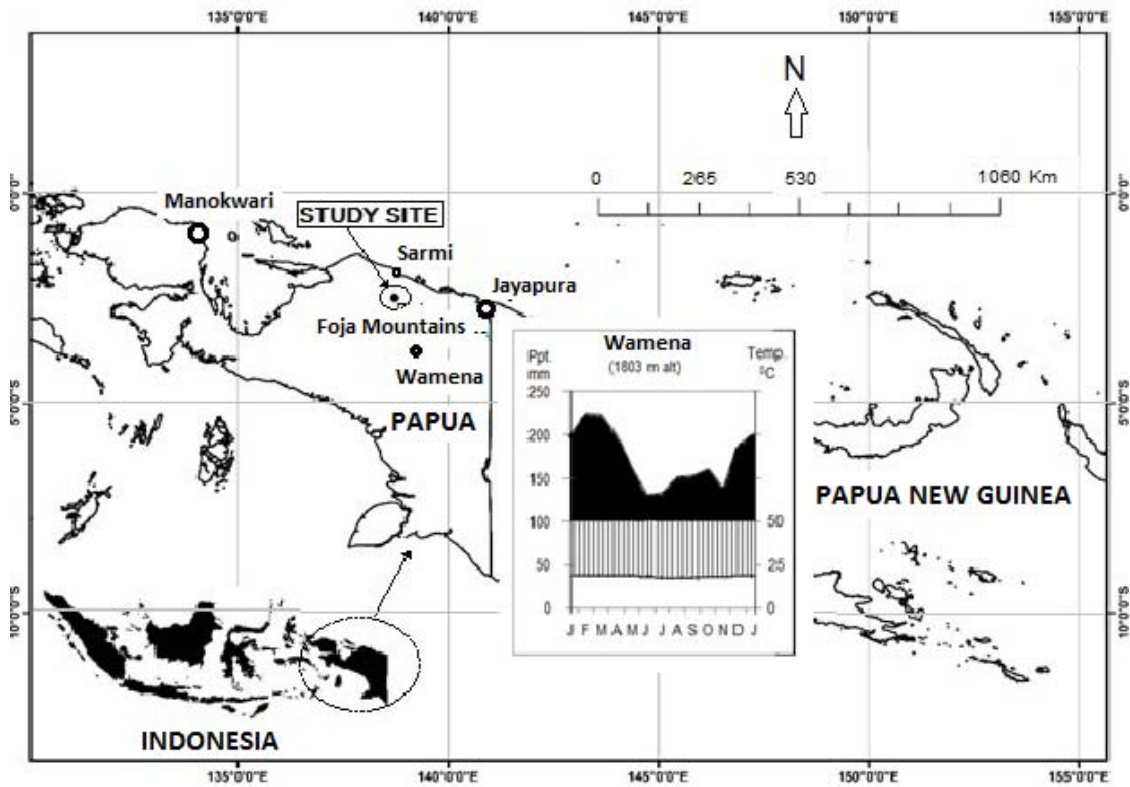


Fig. 1. Map of Papua indicating the study site at Foja Mountains, complemented with a Walter's climate diagram for Wamena, the nearest site having rainfall and temperature data. It shows that the area is everwet with mean monthly rainfall  $\geq 100$  mm.



Fig. 2. Bird's eye view of the study site in the submontane forest near a seasonally dry lake in the Foja Mountains (After Foja Mountains - Images from Tim Laman's Wildlife Photo Archive\_Page\_2 - 201 MM744070618-00922.jpg <https://goo.gl/images/iYcYiE> accessed 29 May 2017; with permission).

Geologically it consists of young tertiary rocks and sediments. The rock formation is composed of surficial sediments (alluvium, limestone and corals), sedimentary rocks, solidified rocks, tectonic (mixed) rocks and mud sediments. The area contains high mineral and energy resources, including copper and oil (Mampioer, 2009).

## Methods

Field sampling was undertaken in the forest using the plot method (Cox, 1967; Mueller-Dombois & Ellenberg, 1974). A plot of one hectare (100 m × 100 m) was established subjectively in the floristically and structurally most representative area on a relatively gentle slope of 20–30% in the most accessible area (Fig. 2). The plot size is greater than the minimal area for montane forest of Indonesia (Kartawinata, 2005) and is even acceptable for describing a tropical lowland forest (Ashton, 1965). The plot was further divided into 100 subplots of 10 m × 10 m each (Kartawinata *et al.*, 2004). Within each subplot all trees with DBH (Diameter at Breast Height) ≥ 10 cm were identified, their diameters measured and their positions recorded. Woody lianas with DBH ≥ 10 cm were treated as trees. The measurement and estimation of total height and bole height were achieved by selecting several of the tallest trees in different sections of the plot whose total and bole heights could be easily measured accurately with a Haga altimeter. The selected tallest trees were then used as the reference trees in measurements of the others. In each subplot, the percentage of canopy gaps and the projected tree crown coverage were estimated. A simulated forest profile diagram for the plot was constructed using the method of Kartawinata *et al.* (2004) by plotting in a linear row the data on tree heights and tree numbers reflecting the sequence of field recording.

Herbarium specimens for each species within the plot were collected and identified at the Herbarium Bogoriense, Research Center for Biology-LIPI, Cibinong. The identity and nomenclature of each tree species followed the *Tree flora of Indonesia: Check list for Irian Jaya* (Whitmore *et al.*, 1997), *Flora Malesiana* (Steenis *et al.*, 1948-2013) and *The Plant List* (2017).

We used Cox (1967) and Mueller-Dombois & Ellenberg (1974) as applied by Rahmah *et al.* (2016), Purwaningsih *et al.* (2017) and Mansur & Kartawinata (2017) for definition and calculation of density, frequency, basal area, and dominance. Density refers to the number of trees per unit area, based on counts in subplots. The number of trees per species was later calculated for the total area of the plot. The density of each species was formulated as the number of trees per hectare. The Relative Density (RD) for each species was determined as:

$$RD = \frac{\text{number of trees of a species}}{\text{total number of trees}} \times 100 \%$$

Frequency (F) refers to the number of times a species occurs in a given number of subplots in the plot and was presented as a percentage of the total number of subplots. The Relative Frequency (RF) for each species was computed as:

$$RF = \frac{\text{frequency of a species}}{\text{sum of frequency of all species}} \times 100 \%$$

Dominance for trees generally relates to stem cover, which is the same as basal area. The basal area (BA) of a tree was calculated with the formula:

$$BA = (\frac{1}{2}d)^2\pi,$$

where  $d$  = diameter,  $\pi$  = constant value (22/7 or 3.14)

The Relative Dominance (RDo) was computed as:

$$RDo = \frac{\text{dominance of a species}}{\text{dominance of all species}} \times 100 \%$$

The sum of relative density, relative frequency, and relative dominance is usually used to indicate the importance of a species in a plot and are expressed in terms of their relative values. The Importance Value (IV) was then calculated with the formula:

$$IV = RD + RF + RDo$$

and the IV of a species reaches a maximum of 300 in the plot consisting of only one tree species.

Species diversity index was calculated using the formula of *Shannon-Wiener* ( $H'$ ) based on the number of individuals as follow:

$$H' = -\sum p_i \ln p_i \quad (H' = -\sum [n_i/N] \ln [n_i/N])$$

where  $H'$  = Shannon-Wiener's species diversity index

$$p_i = n_i/N$$

$n_i$  = Number of individuals of the  $i$ th species, in which  $i = 1, 2, 3, \dots, n$

$N$  = Total number of individuals of all species.

The construction of the species-area curve was based on species data from 100 subplots nested within the plot, *i.e.* 100 m<sup>2</sup> (10 m × 10m), 400 m<sup>2</sup> (20 m × 20 m), 900 m<sup>2</sup> (30 m × 30 m), 10,000 m<sup>2</sup> (100 m × 100 m). We do not intend to specifically determine the minimal-area of sampling for the forest in the study area. The minimal area is



usually determined by constructing a species-area curve to show a full representation of species when the objective is to obtain data using a single "minimal area" plot of the community (Mueller-Dombois & Ellenberg, 1974). This approach is usually difficult to exercise in species-rich and complex tropical forests (Ashton, 1965; Mueller-Dombois & Ellenberg, 1974), such as a lowland forest of Kalimantan where there is no indication of the curve to level-off at the area of 10.5 ha (Kartawinata *et al.*, 2008).

## RESULTS

### Observations on habitat and general condition of the forest

Field observations revealed that the forest was a pristine primary forest, where there was no trace of previous disturbance resulting from human activities. Only natural disturbances, such as land slides on very steep slopes, were observed in the area. The canopy cover in each subplot was 60%–80%. In Fig. 11 the highlighted subplot 24 had a canopy cover of 30% and in the highlighted subplot 25 it was 50%. The highlighted subplots 24, 29, 30, 34 and 35 were flooded. The highlighted subplot 25 indicates the canopy cover of 50% and that the forest ground was partially flooded and covered by *Alocasia macrorrhizas* (L.) G. Don (Araceae) which reached up to  $\pm 1.5$  m tall (Fig. 3). The soil was black and not stony.

Almost all trees in the forest were blanketed with mosses from the trunk bases to the twigs, hence it can be appropriately called a mossy forest. The area was so isolated that it could be reached only by using a helicopter that could land on the dry section of the lake occurring near the study site (Fig. 1). There were open spaces, where the ground was covered by undergrowth (Fig. 4), including *Strobilanthes* sp. (Acanthaceae) on un inundated forest floor on highlighted subplots 24, 30, 34 and 35 in Fig. 11. Fallen dead trees were found on plot 50. Epiphytes on short trees were not abundant but included *Dendrobium dekokkii* J.J.Sm. which grew together with moss (*Usnea* sp.). The low herbaceous and shrubby vegetation around the lake appeared to be interesting to investigate.

The topography of the study site was undulating but in general was more or less flat. Tree distribution in the plot was in general well dispersed. The mean number of trees per subplot in subplots 2–12 was  $7 \pm 2.44$ . In Fig. 11, the topography of highlighted subplots 80, 90, 97, 98, 99 and 100 was sloping ( $45^\circ$ – $75^\circ$ ), with the mean number of trees per subplot of  $7 \pm 1.97$ .

### Species composition

In the one-hectare plot, we recorded 59 tree

species with DBH  $\geq 10$  cm, belonging to 42 genera and 27 families, with total density of 693 and total basal area of 41.36 m<sup>2</sup> (Table 1). Three trees could not be identified. *Nothofagus rubra* (IV=47.89; D=142) and *Parinari corymbosa* (IV=40.53; D=89) were the two leading dominants, hence the forest can be designated as the *Nothofagus rubra-Parinari corymbosa* association. They had a total density of 231 or 33.36% of the total in the plot and basal areas of 12.48 m<sup>2</sup> (30.17%). The other leading species, having IV >10 were *Myristica holrrungii*, *Platea latifolia* and *Lophopetalum torricellense* (Table 1). They had a total density of 374 (53.77%) and basal area of 24.37 m<sup>2</sup> (58.92%). Myrtaceae were the richest family consisting of 12 species, while each of the remaining 26 families contained less than 6 species. Shannon-Wiener's diversity index was 3.22 and the evenness index were 0.79.

The species-area curve (Fig. 5) shows that at 2,500 m<sup>2</sup> it flattens up to 10,000 m<sup>2</sup>. It is safe to designate the minimal area of 5,000 m<sup>2</sup>.

We observed also IV >5% in 11 families along with their relative values of density, frequency and dominance (Table 2). High density were recorded in Fagaceae (152 trees/ha), Chrysobalanaceae (89 trees/ha), Myristicaceae (55 trees/ha), Myrtaceae (58 trees/ha) and Icacinaceae (57 trees/ha). The lowest density (5 trees/ha) were recorded in Flacourtiaceae, Sterculiaceae, and Symplocaceae.

Species density, frequency and dominance in the plot is vary. Ten species with highest density, frequency, dominance, but they were in different orders (Table 3). *Nothofagus rubra* had the highest density, dan highest dominance (142 trees/ha and 6.50 m<sup>2</sup>/ha) and *Parinari corymbosa* with the highest frequency (F=69%), while lowest density, distribution and dominance are four species found.

High frequency was observed in Fagaceae (69%), Chrysobalanaceae (69%) and Myrtaceae (51%). The lowest frequency was observed in Symplocaceae (3%).

The highest basal area was noted in Fagaceae (7.48 m<sup>2</sup>/ha), Chrysobalanaceae (5.98 m<sup>2</sup>/ha) and Myristicaceae (4.32 m<sup>2</sup>/ha). The lowest basal area was noted in Symplocaceae (0.05 m<sup>2</sup>/ha).

High importance values (>20%) was observed in Fagaceae (53.23%), Chrysobalanaceae (40.53%), Myristicaceae (26.43%), Myrtaceae (24.08%) and Icacinaceae (22.35%). The lowest importance value was observed in Symplocaceae (4.47%).

### Structure

Horizontal and vertical distribution, size, and density of trees define forest structure (Kershaw, 1964; Mueller-Dombois & Ellenberg, 1974). The structure of forest in the plot is presented as graphs (Figs. 6, 7 & 8), simulated profile dia-



Fig. 3. *Alocasia macrorrhizos* (Araceae) reaching  $\pm 1.5$  m tall on swampy forest floor within the plot (Photo: A. Sadili, 2008).



Fig. 4. Undergrowth vegetation of mixed species on uninundated forest floor within the plot (Photo: A. Sadili, 2008).

Table 1. Density (D), frequency (F), basal area (BA) and importance value (IV) of trees  $\geq 10$  cm in the one hectare plot at the Foja Mountains, Papua. The species are arranged in descending order of IV.

No	Species	D (Tree/ ha)	F (%)	BA (m <sup>2</sup> )	IV (%)
1	<i>Nothofagus rubra</i> Steenis	142	61	6.5	47.9
2	<i>Parinari corymbosa</i> (Blume) Miq.	89	69	5.98	40.53
3	<i>Myristica hollrungii</i> Warb.	53	40	4.23	25.55
4	<i>Platea latifolia</i> Blume	57	40	2.67	22.35
5	<i>Lophopetalum torricellense</i> Loes	33	27	3.99	19.59
6	<i>Elaeocarpus culminicola</i> Warb.	13	13	1.52	8.04
7	<i>Syzygium fibrosum</i> (F.M. Bailey) T.G. Hartley & L.M.Perry	14	12	0.72	6.06
8	<i>Carallia brachiata</i> (Lour.) Merr.	14	13	0.62	6.01
9	<i>Garcinia</i> sp.	9	7	1.2	5.54
10	<i>Aporosa longicaudata</i> Kaneh. & Hatus. ex Schot.	15	13	0.35	5.5
11	<i>Timonius timon</i> (Spreng.) Merr.	7	7	1.27	5.42
12	<i>Lithocarpus</i> sp.	10	8	0.98	5.35
13	<i>Cryptocarya brassii</i> C.K.Allen	8	6	1.05	4.84
14	<i>Memecylon edule</i> Roxb.	11	11	0.45	4.78
15	<i>Calophyllum excelsum</i> Zoll. & Moritzi	11	9	0.56	4.67
16	<i>Syzygium</i> sp.	9	9	0.62	4.52
17	<i>Nephelaphyllum</i> sp.	10	9	0.5	4.38
18	<i>Cinnamomum</i> sp.	11	10	0.33	4.3
19	<i>Fagraea elliptica</i> Roxb.	6	6	0.81	3.98
20	<i>Dysoxylum</i> sp.	9	9	0.38	3.94
21	<i>Litsea timoriana</i> Span.	5	5	0.75	3.49
22	<i>Podocarpus neriifolius</i> D.Don	7	7	0.39	3.29
23	<i>Eurya</i> sp.	9	7	0.23	3.2
24	<i>Elaeocarpus oriomensis</i> Weibel	7	6	0.38	3.08
25	<i>Turpinia sphaerocarpa</i> Hassk.	10	7	0.12	3.07
26	<i>Palaquium</i> sp.	7	6	0.37	3.05
27	<i>Syzygium laqueatum</i> Merr. & L.M.Perry	9	7	0.1	2.88
28	<i>Ficus</i> sp.	6	5	0.41	2.82
29	<i>Glochidion novoguineense</i> K.Schum.	8	7	0.1	2.74
30	<i>Rapanea leucantha</i> K.Schum.	7	7	0.1	2.59
31	<i>Syzygium jambosoides</i> (Lauterb.) Merr. & L.M.Perry	8	6	0.09	2.52
33	<i>Artocarpus</i> sp.	6	6	0.17	2.43
34	<i>Chisocheton lasiocarpus</i> (Miq.) Valetton	6	6	0.06	2.16
35	<i>Calophyllum insularum</i> P.F.Stevens	2	2	0.61	2.15
36	<i>Syzygium branderhorstii</i> Lauterb.	3	3	0.43	2.05
37	<i>Madhuca</i> sp.	2	2	0.53	1.95
38	<i>Polyosma illicifolia</i> Blume	6	5	0.05	1.94
39	<i>Dacrycarpus imbricatus</i> (Blume) de Laub.	4	4	0.22	1.88
40	<i>Casearia pachyphylla</i> Gilg	5	5	0.05	1.8
41	<i>Sterculia</i> sp.	5	4	0.06	1.63
42	<i>Metrosideros</i> sp.	4	4	0.07	1.51
43	<i>Symplocos</i> sp.	5	3	0.05	1.42
44	<i>Syzygium anomalum</i> Lauterb.	3	2	0.19	1.28
45	<i>Ardisia forbesii</i> S.Moore	3	2	0.15	1.18
46	<i>Syzygium phaeostictum</i> Merr. & L.M.Perry	3	3	0.03	1.08
47	Unidentified	3	3	0.02	1.06
48	<i>Glochidion molle</i> Blume	2	2	0.05	0.79
49	<i>Syzygium claviflorum</i> (Roxb.) Wall. ex A.M.Cowan & Cowan	2	2	0.05	0.79
50	<i>Croton laevifolius</i> Blume	2	2	0.02	0.72
51	<i>Syzygium insulare</i> Hartley & L.M.Perry	1	1	0.14	0.67
52	<i>Knema</i> sp.	1	1	0.06	0.48
53	<i>Myristica fatua</i> Houtt.	1	1	0.03	0.41
54	<i>Polyosma integrifolia</i> Blume	1	1	0.03	0.41
55	<i>Syzygium platycarpum</i> (Diels) Merr. & L.M. Perry	1	1	0.02	0.38
56	<i>Antidesma</i> sp.	1	1	0.01	0.36
57	<i>Cryptocarya cordata</i> Meisn.	1	1	0.01	0.36
58	<i>Macaranga fallacina</i> Pax & K.Hoffm.	1	1	0.01	0.36
59	<i>Syzygium antisepticum</i> (Blume) Merr. & L.M.Perry	1	1	0.01	0.36

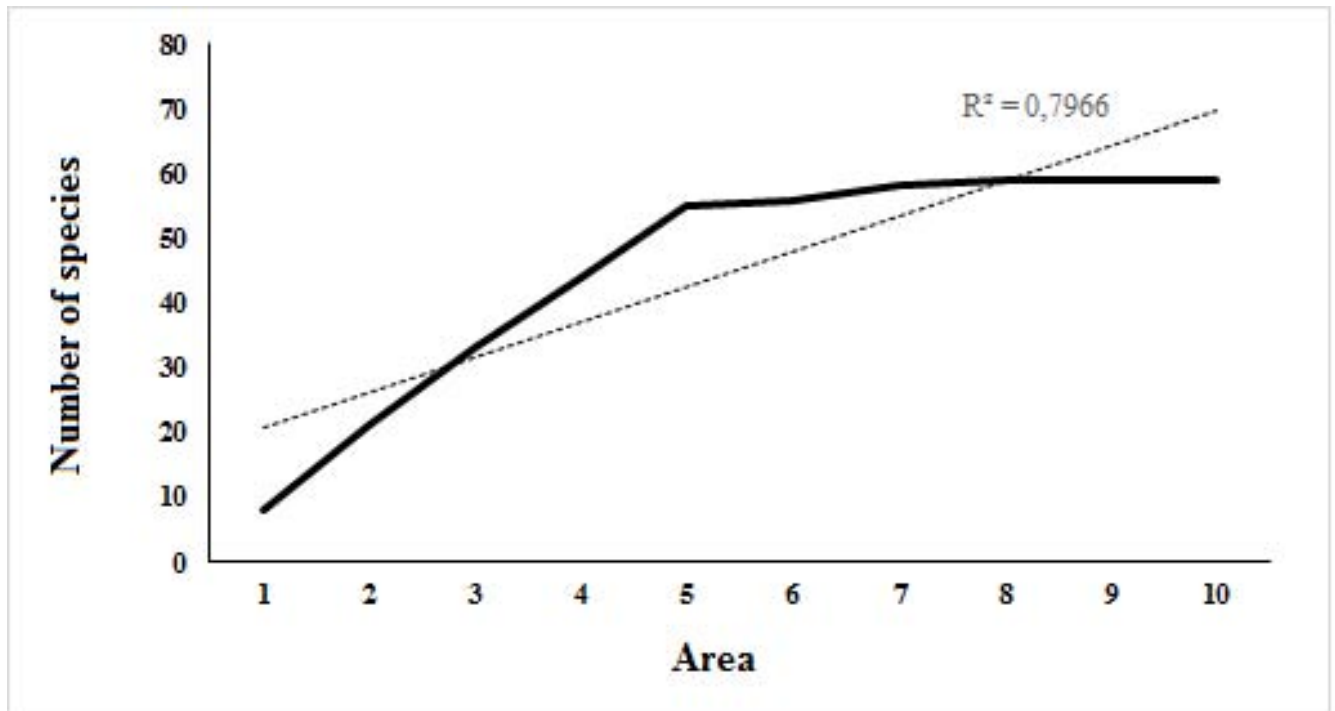


Fig. 5. Species-area curve of a one-hectare plot of forest at the Foja Mountains Papua. Area 1 = 100 m<sup>2</sup>; 2 = 400 m<sup>2</sup>; 3 = 900 m<sup>2</sup>; 4 = 1,600 m<sup>2</sup>; 5 = 2,500 m<sup>2</sup>; 6 = 3,600 m<sup>2</sup>; 7 = 4,900 m<sup>2</sup>; 8 = 6,400 m<sup>2</sup>; 9 = 8,100 m<sup>2</sup>; 10 = 10,000 m<sup>2</sup> (1 ha).

Table 2. Importance values (IV), relative density (RD), relative frequency (RF), and relative dominance (RDo) of 11 families having IV > 10% in the one-hectare plot of forest at Foja Mountains Papua.

No	Family	RD (%)	RF (%)	RDo (%)	IV
1	Fagaceae	21.93	13.22	18.08	53.23
2	Chrysobalanaceae	12.84	13.22	14.47	40.53
3	Myristicaceae	7.94	8.05	10.45	26.43
4	Myrtaceae	8.37	9.77	5.94	24.08
5	Icacinaceae	8.23	7.66	6.46	22.35
6	Celastraceae	4.76	5.17	9.64	19.57
7	Lauraceae	3.61	4.21	5.18	13.00
8	Clusiaceae	3.17	3.45	5.74	12.36
9	Meliaceae	3.90	4.98	2.47	11.35
10	Elaeocarpaceae	2.89	3.64	4.58	11.10
11	Euphorbiaceae	4.18	4.98	1.28	10.45

Table 3. Ten species with highest density, frequency, and basal area; and four species with lowest density, frequency and basal area in one-hectare plot of forest in Foja Mountains.

Species group	Species
a. Ten species with highest density (trees/ha)	<i>Nothofagus rubra</i> (142), <i>Parinari corymbosa</i> (89), <i>Platea latifolia</i> (57), <i>Myristica hollrungii</i> (53), <i>Lophopetalum torricellense</i> (33), <i>Aporosa longicaudata</i> (15), <i>Syzygium fibrosum</i> (14), <i>Carallia brachiata</i> (14), <i>Elaeocarpus culminicola</i> (13) and <i>Memecylon edule</i> (11).
b. Ten species with highest frequency (%)	<i>Parinari corymbosa</i> (69), <i>Nothofagus rubra</i> (61), <i>Platea latifolia</i> (40), <i>Myristica hollrungii</i> (40), <i>Lophopetalum torricellense</i> (27), <i>Aporosa longicaudata</i> (13), <i>Carallia brachiata</i> (13), <i>Elaeocarpus culminicola</i> (13), <i>Syzygium fibrosum</i> (12) and <i>Memecylon edule</i> (11).
c. Ten species with highest basal area (m <sup>2</sup> )	<i>Nothofagus rubra</i> (6.50), <i>Parinari corymbosa</i> (5.98), <i>Myristica hollrungii</i> (4.23), <i>Lophopetalum torricellense</i> (3.99), <i>Platea latifolia</i> (2.67), <i>Elaeocarpus culminicola</i> (1.52), <i>Timonius timon</i> (1.27), <i>Garcinia</i> sp. (1.20), <i>Cryptocarya brassii</i> (1.05) and <i>Lithocarpus</i> sp. (0.98).
d. Four species with lowest density, frequency, and basal area	<i>Antidesma</i> sp., <i>Cryptocarya caudata</i> , <i>Macaranga fallacina</i> , and <i>Syzygium antisepticum</i>

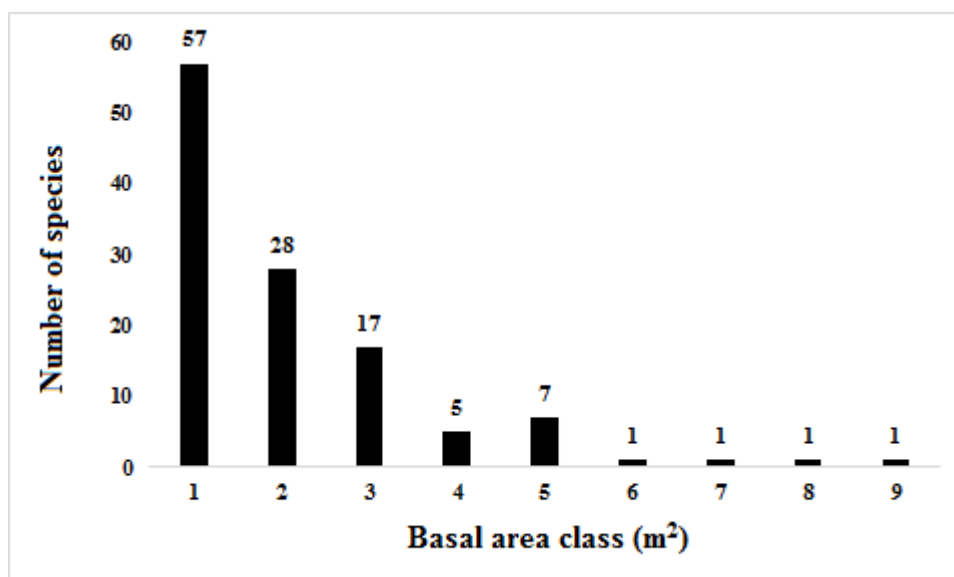


Fig. 6. The relationships between the number of species and basal area classes in the lower montane forest at Foja Mountains. Basal area class (m<sup>2</sup>): 1 = 0.01–0.09; 2 = 0.10–0.19; 3 = 0.20–0.29; 4 = 0.30–0.39; 5 = 0.40–0.49; 6 = 0.50–0.59; 7 = 0.60–0.69; 8 = 0.70–0.79.

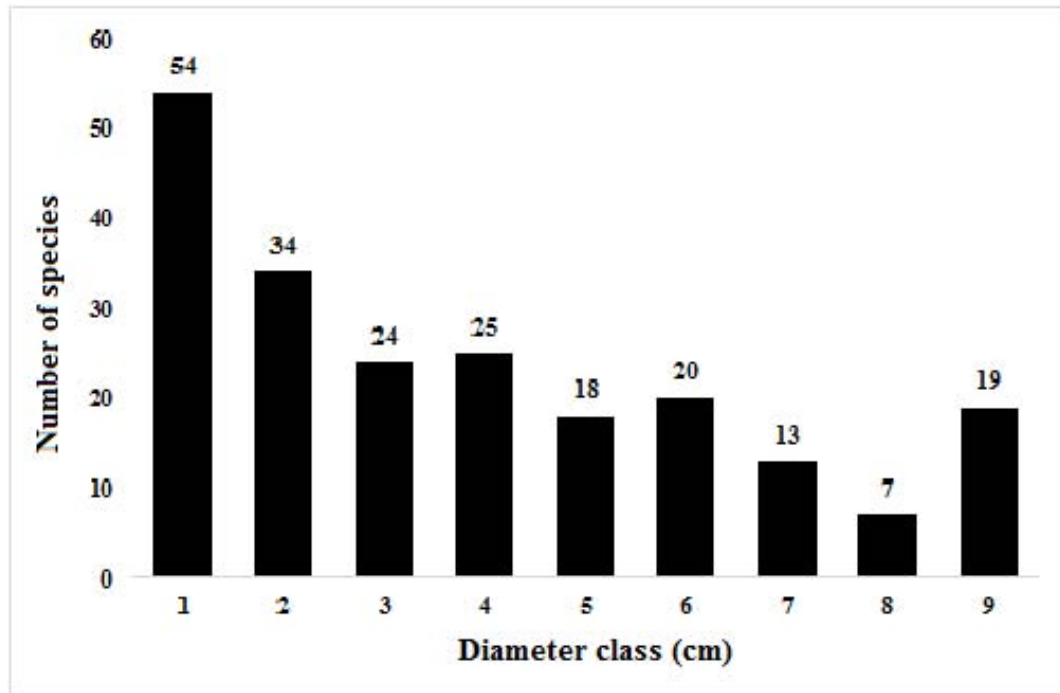


Fig. 7. The relationships between the number of species and diameter classes in the forest of Foja Mountains. The diameter classes: 1=10–14.9 cm; 2=15–19.9 cm; 3=20–24.9 cm; 4=25–29.9 cm; 5=30–34.9 cm; 6=35–39.9 cm; 7=40–44.9 cm; 8=45–49.9 cm; and 9 $\geq$ 50 cm.

grams (Fig. 9) and a photo (Fig. 10). Fig. 11 shows the map of ground distribution of all trees and Fig. 12 shows the map of ground distribution of the dominant species *Nothofagus rubra* and *Parinari corymbosa*. Density, dominance and frequency of each species vary. The total density of the entire plot was 693 trees/ha with the mean density of  $7\pm 2.46$  trees/subplot. The highest density as listed in Table 1 and Table 3a were recorded in *Nothofagus rubra* (142 trees/ha), *Parinari corymbosa* (89 trees/ha), *Platea latifolia* (57 trees/ha) and *Myristica hollrungii* (53 trees/ha). Density of one tree/ha and absolute frequency of 1% occurred in nine species including *Antidesma* sp., *Cryptocarya caudata*, *Knema* sp., *Macaranga fallacina*, *Myristica fatua*, *Polyosma integrifolia*, *Syzygium anti-septicum*, *Syzygium insulare* and *Syzygium platycarpum* (Table 1) with the mean frequency of the species being  $5\pm 1.88\%$ . The highest frequency was recorded in *Parinari corymbosa* (69%) as in Table 3b.

The relationships between species and basal areas are presented in Fig. 6 which are definitely related to those between species and diameter classes as presented in Fig. 7. Fig. 8. shows the relationships between the number of trees and diameter classes.

Total BA was  $\pm 41.36$  m<sup>2</sup>/ha and the mean was  $0.41\pm 0.29$  m<sup>2</sup>/subplot. The highest BA was recorded in *Nothofagus rubra* (6.50 m<sup>2</sup>/ha), *Parinari corymbosa* (5.98 m<sup>2</sup>/ha) and *Myristica hollrungii* (4.23 m<sup>2</sup>/ha) (Table 3c). The lowest BA (0.01 m<sup>2</sup>/ha) was recorded in *Cryptocarya caudata*, *Syzygium antisepticum*, *Antidesma* sp. and *Macaranga fallacina* (Table 1 and Table 3d).

A simulated forest profile diagram (Fig. 9) shows four strata (A, B, C & D). The mean total tree height was  $15.26\pm 5.71$  m and the mean bole height was  $9.65\pm 4.90$  m. The A stratum consisted of three emergent tree species comprising *Nothofagus rubra*, *Platea latifolia*, and *Cinnamomum* sp. The B stratum which constituted the upper canopy with the height of 20–29.9 m was composed of 169 trees (24.39%) representing 41 species (69.49%). The prevalent species, each represented by more than 10 trees included *N. rubra* (40 trees), *P. corymbosa* (20 trees), *M. hollrungii* (14 trees) and *P. latifolia* (10 trees). The C stratum with the height of 10–19.9 m formed the middle-level canopy and consisted of 408 trees (58.87%) and 51 species (86.44%). The prevalent species, each represented by more than 10 trees included *N. rubra* (88 trees), *P. corymbosa* (52 trees), *M. hollrungii* (36 trees), *P. latifolia* (30 trees), *Lophopetalum torricellense* (19 trees), and *Carallia brachiata* (12 trees). The

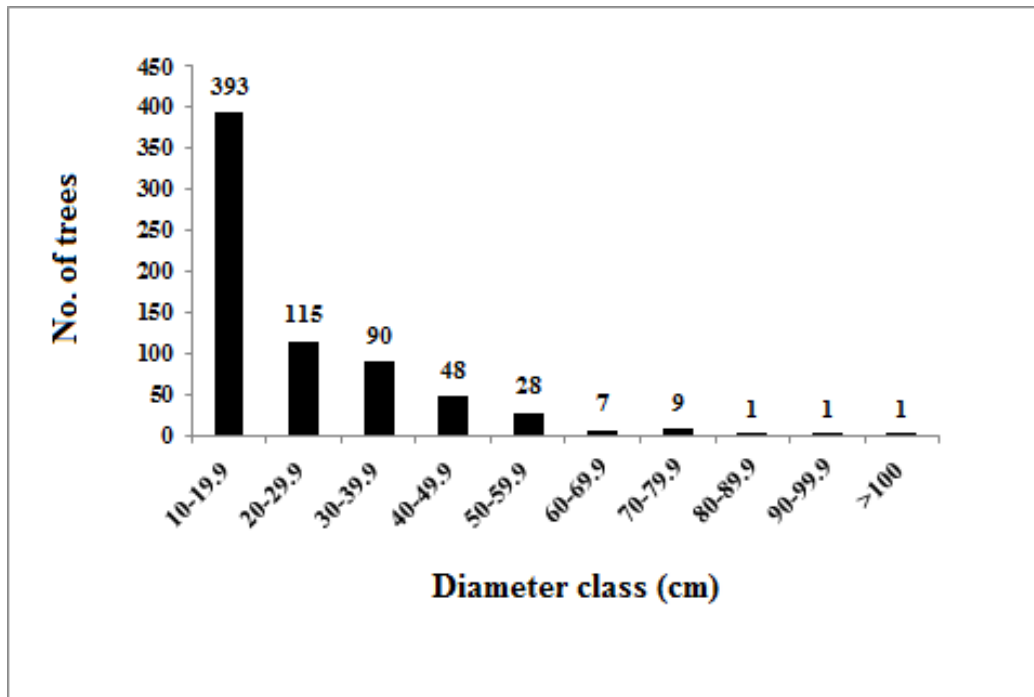


Fig. 8. The relationships between the number of trees and diameter classes in the lower montane forest at Foja Mountains.

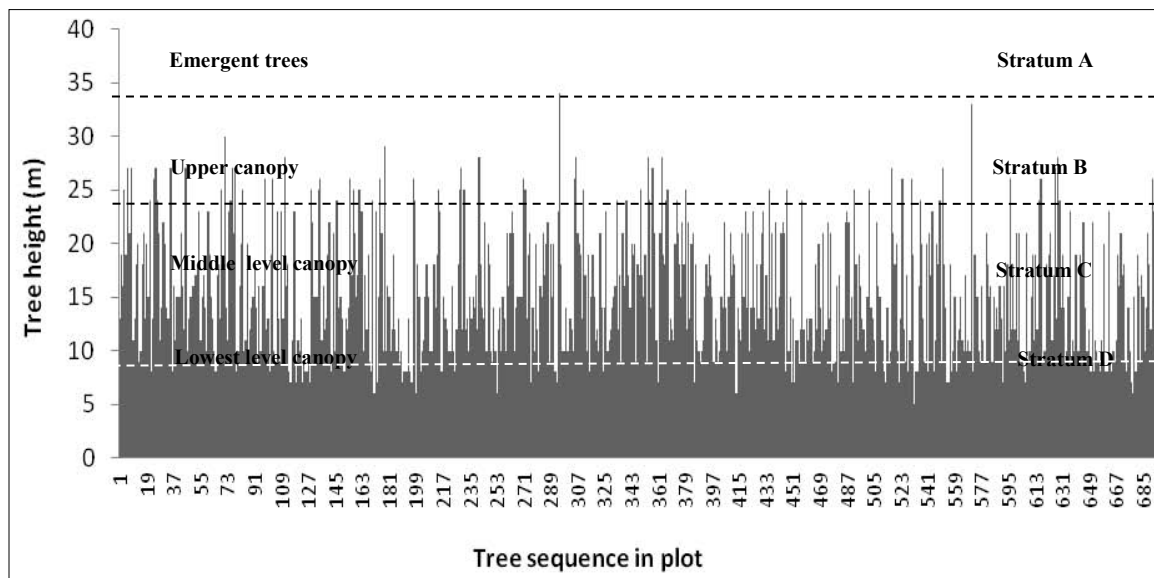


Fig. 9. A simulated forest profile diagram based on the tree height and sequential tree positions from tree no 1 in 1<sup>st</sup> subplot up to the tree no. 693 in 100<sup>th</sup> subplot in the one-hectare plot at Foja Mountains. It shows four strata: Stratum A (Emergent layer), Stratum B (Upper canopy), Stratum C (Middle level canopy) and Stratum D (Lower level canopy).



Fig. 10. The forest stand in the plot at the lower montane forest of the Foja Mountains, Papua showing dense structure with *Nothofagus rubra* and *Parinari corymbosa* as the dominant species (Photo: A. Sadili, 2008).

D stratum with height of 5-9.9 m constituted the lowest level canopy and consisted of 113 trees (16.31%) and 34 species (57.63%). The prevalent species, each represented by more than 10 trees, included *P. corymbosa* (17 trees), *P. latifolia* (16 trees) and *N. rubra* (13 trees).

### Species Regeneration

The process of species regeneration in tropical forests is complex as it depends on a variety of factors including the fortuitous formation of natural gaps (Richards, 1996; Whitmore, 1984). Regeneration may be indicated by a complete profile of size class distribution from seedlings to trees with largest diameters. Size-class distributions, however, depend on growth and mortality (Jones, 1950 cited by Richards, 1996) and may be related to site conditions as well as to the occurrence of natural or artificial disturbances in the past (Richards, 1996).

Regeneration is a mechanism of an organism to maintain and perpetuate its existence, which in a forest stand can be reflected by the number of individuals along the gradient of diameter classes and height stratification. In the present study data on seedlings and saplings (diameter <10 cm) were

not available and we recorded only trees with DBH  $\geq 10$  cm (Table 4). Based on the diameter class distribution we may assume and infer the status of regeneration of the species. In Table 4, the species were grouped according to diameter class distribution. Group 1 consisted of two species, *Lophopetalum torricellense* and *Syzygium fibrosum*. The species have been regenerating and are assumed to have reached a mature state in the forest. Group 2 consisted of species that could reach the maximum diameter of up to 79.9 cm and the density of trees in each diameter class were mostly less than nine. The most notable species in Group 2 were *Parinari corymbosa* and *Platea latifolia*. The density of these species in diameter classes of 10–20 cm to 40–50 cm was high, indicating that they were regenerating well. Other species were also regenerating but with low intensity. Group 3 consists of the species that have reached a diameter of less than 69.9 cm and they were regenerating but with low density, except for *Myristica hollrungii*. This species had a high density (51) in the diameter class of 10–19.9 cm indicating better regeneration than the other species. Group 4 contains species that reached the maximum diameters of 39.9 cm.



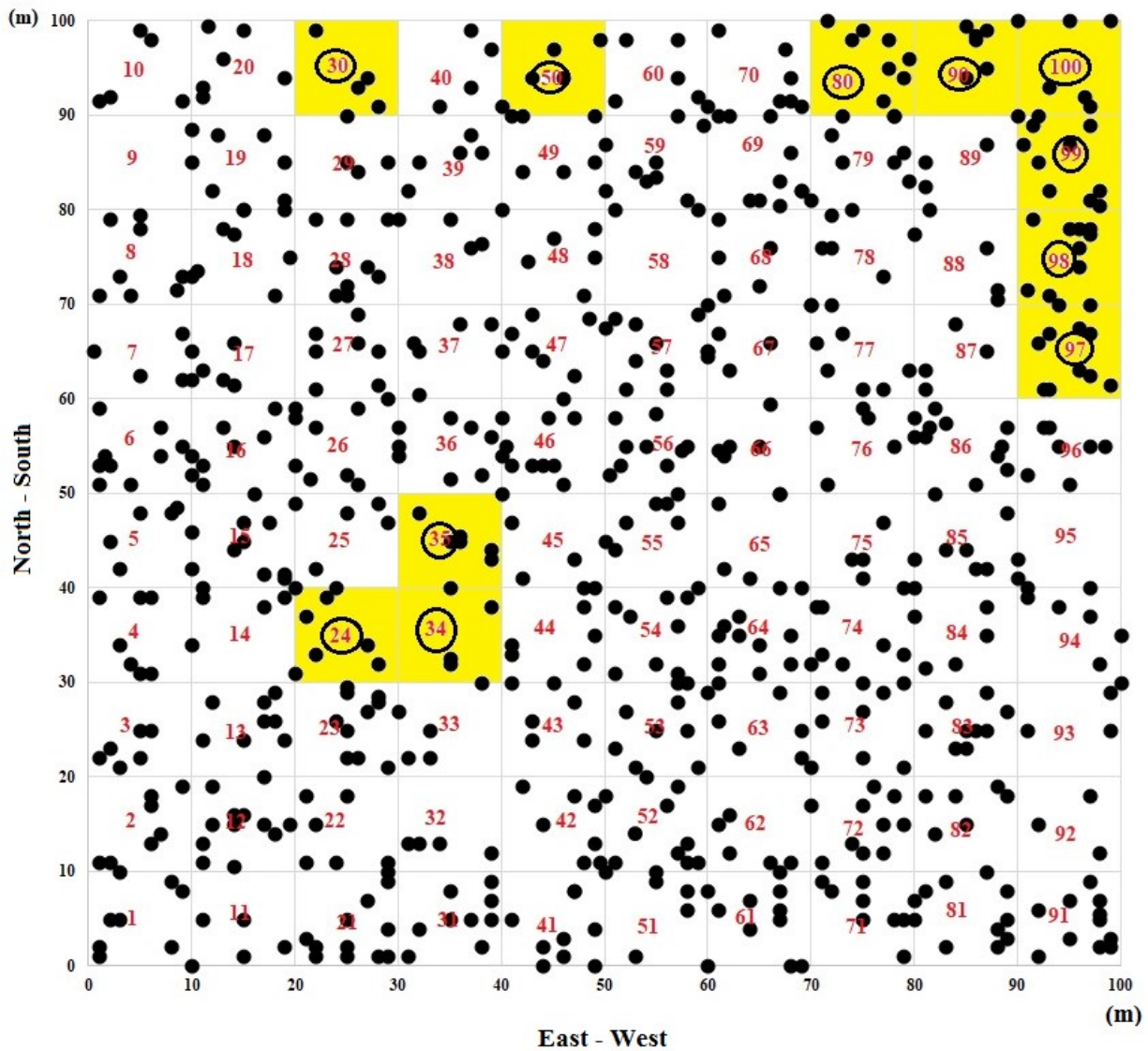


Fig. 11. The ground distribution of dense trees in the one-hectare plot in the lower montane forest of the Foja Mountains, Papua. The canopy cover in the highlighted subplot no 24 were 30% and in subplot 25 were 50%. In the highlighted subplots 24, 29, 30, 34, 35 the mean number of trees per subplot was  $7 \pm 2.44$ . On highlighted subplots 80, 90, 97, 98, 99 and 100 the topography was sloping ( $45^{\circ}$ – $75^{\circ}$ ) with the mean number of trees per subplot of  $7 \pm 1.97$ . The highlighted subplots 24, 30, 34 and 35 were open and the ground was inundated and covered with *Strobilanthes* sp. (Acanthaceae). Fallen dead trees were found on highlighted subplot 50.

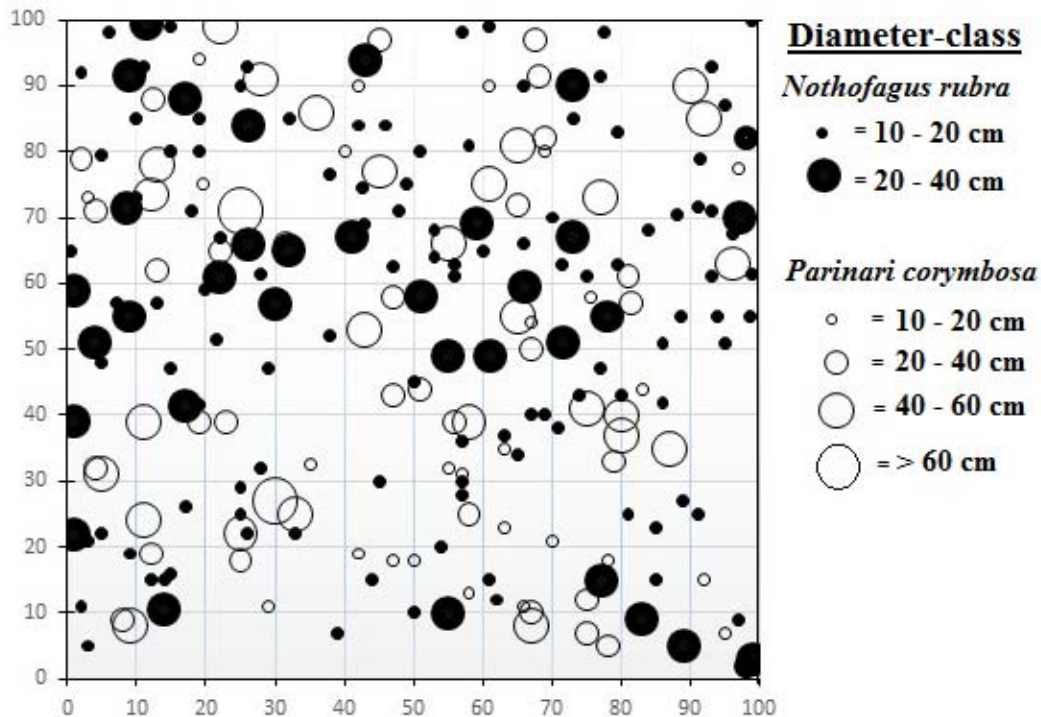


Fig. 12. Distribution of the two dominant species (*Nothofagus rubra* and *Parinari corymbosa*) in the one-hectare plot in the lower montane forest of Foja Mountains, Papua.

Except for *Nothofagus rubra*, they are regenerating but with low density. *Nothofagus rubra*, the dominant species in the plot was regenerating well as indicated by high density in the diameter classes of 10–19.9 cm and 20–29.9 cm. Group 5 represents species present only in the diameter class 10–19.9 cm with low density. They consisted of small trees and shrubs. Group 6 contains species that were not present in the 10–19.9 cm diameter class indicating no regeneration and will perhaps disappear from the plot in the future.

## DISCUSSION

In the classification schemes of Johns *et al.* (2007) and Kartawinata (2013), the forest at the Foja Mountains definitely belongs to the lower montane forest. In the Foja Mountains, *Nothofagus rubra* was dominant in the forests with dry to swampy habitats. It is one of the tallest trees but not the largest in the forest. Johns *et al.* (2007) and Shea *et al.* (1998), however, did not indicate that *N. rubra* was a dominant species in their accounts of montane forests of Papua. The forest at Foja Mountains was designated as the *Nothofagus rubra*-*Parinari corymbosa* association.

*Nothofagus* in New Guinea is represented by 13 species (Soepadmo, 1972). They constitute important species that can dominate montane

forests at 850–2,980 m asl, with varying distribution (Johns *et al.*, 2007; Paijmans, 1976; Soepadmo, 1972), *N. flaviramea*, *N. starkenborghii*, *N. rubra*, *N. carri*, and *N. crenata* occur at 900–2,200 m asl, *N. brassii*, *N. perryi* and *N. grandis* are abundant at 1,500–2,500 m asl while *N. pullei* spreads up to >2,800 m asl. They form communities with different species combinations. At 2,300 m asl *Nothofagus* spp. often grow in association with *Castanopsis acuminatissima* or *Lithocarpus*. At high elevation *Nothofagus* spp. grow together with *Phyllocladus hypophyllus* and are associated with *Dacrydium* and *Papuacedrus* in wet and cold habitats. On a wider range Soepadmo (1972) noted that *N. rubra* occurs in New Guinea, but primarily in Papua, on very poor boggy and shrubby heathlands at 1,800 m asl, boggy forest on exposed ridges or summits up to 2,150 m asl, in stunted open *Dacrydium* forest at 850 m asl and in mossy forest at 950–2,850 m asl such as in Habbema (Brass, 1941; Keim *et al.* unpublished, 2018). It was further recorded as a common species often abundant on the Arfak Mountains and Wissel Lake and a dominant species in *Castanopsis* forest on the Cyclop Mountains (Johns *et al.*, 2007).

Dieback occurs in Nothofagaceae, especially *Nothofagus brassii* and *N. pullei* in Habbema (Keim *et al.*, unpublished, 2018), but there was no

Table 4. Diameter class distribution of species with density &gt; 10 reflecting the regeneration status of the forest.

Species	Diameter class (cm.)									
	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-99.9	> 100
GROUP 1										
<i>Lophopetalum torricellense</i>	9	4	8	3	5	2		1		1
<i>Syzygium fibrosum</i>	4	3	2	2	1		1		1	
GROUP 2										
<i>Parinari corymbosa</i>	29	13	18	18	9		2			
<i>Platea latifolia</i>	15	13	15	9	3	1	1			
<i>Carallia brachiata</i>	7	2	3			1	1			
<i>Calophyllum excelsum</i>	6	1	2		1		1			
<i>Artocarpus</i> sp.	2	1	2				1			
<i>Cryptocarya brassii</i>	1	1	1	2	2		1			
<i>Syzygium leptanthum</i>	1						1			
GROUP 3										
<i>Myristica hollrungii</i>	51	1			1					
<i>Memecylon edule</i>	9	2			1					
<i>Nephelaphyllum</i> sp.	7	2			1					
<i>Aporosa longicaudata</i>	6	4	3	1	1					
<i>Timonius timon</i>	5	1		1						
<i>Polyosma illicifolia</i>	5			1						
<i>Garcinia</i> sp.	5	2		2						
<i>Rapanea leucantha</i>	4	1	1			1				
<i>Rapanea leucantha</i>	4	1	1			1				
<i>Lithocarpus</i> sp.	4	3	2			1				
<i>Rapanea leucantha</i>	4	1	1			1				
<i>Ficus</i> sp.	3	1		1	1					
<i>Symplocos</i> sp.	3			1	1					
<i>Syzygium jambosoides</i>	3		2	3						
<i>Casearia pachyphylla</i>	2		1	1		1				
GROUP 4										
<i>Nothofagus rubra</i>	109	27	6							
<i>Elaeocarpus culminicola</i>	11	1	1							
<i>Syzygium laqueatum</i>	5	2	1							
<i>Syzygium</i> sp.	5	3	1							
<i>Turpinia sphaerocarpa</i>	5	4	1							





Fig. 13. Bird's eye view of the montane forest on more or less flat topography at the Foja Mountains (After Laman, with permission).

indication of occurrence on *N. rubra* in the Foja Mountains. Dieback is "an episodic event characterized by premature, progressive loss of tree and stand vigour and health over a given period without obvious evidence of a single clearly identifiable causal factor such as physical disturbance or attack by an aggressive disease or insect" (Ciesla & Donaubaue, 1994). It is a part of forest dynamics involving complex interaction between physical and biotic factors and is initiated by sudden trigger, including drought, flood and wind (Mueller-Dombois, 1983 & 1986).

The species richness [*i.e.* number of species in a sampling unit (McCune & Grace, 2002)] and tree density in the forest of the Foja Mountains were lower than in several lowland forests of Papua, Sulawesi, Kalimantan and Sumatra and in the lower montane forest in Java (Fig. 13). Tree density in the present study was comparable to those in the montane forests in Wamena, Papua and in Gede-Pangrango National Park in Java. The situation supports the contention that species richness decreases as the elevation increases (Richards 1996; Whitmore, 1984).

It is clear that the forest under investigation had low species richness. The Shannon-Wiener's diversity index  $H' = 3.22$ , which in the criteria of Barbour *et al.* (1987) can approach a high value of 4. This is comparable to that of the lower mon-

tane forest at the Gede-Pangrango National Park, West Java, where the diversity index  $H' = 3.39$  (Zuhri & Mutaqin, 2011). It is much higher than that of the lower montane forest at Ceremai National Park which has a diversity index  $H' = 2.66$  (Purwaningsih & Yusuf, 2008). Species richness in the Foja Mountains is the poorest compared to those in various forests elsewhere (Fig. 13).

The species-area relationship is essential in ecology (Plotkin *et al.*, 2000). It can be used to estimate species extinction due to habitat loss (May *et al.*, 1995; Pimm & Raven, 2000) and to appraise species diversity patterns in different forest types (Ashton, 1965). The curve is plotted to show species richness in relation to increasing size of the area (Mueller-Dombois & Ellenberg, 1974) within the plot. In the present study, the minimal area could be identified as 5,000 m<sup>2</sup>. It was not, however, specifically intended to establish the minimal sampling area with the objective to obtain data using a single "minimal area" plot of the community (Mueller-Dombois & Ellenberg, 1974). In general, this approach is difficult to apply in species-rich and complex tropical forests (Ashton, 1965; Mueller-Dombois & Ellenberg, 1974), such as those of Sumatra and Kalimantan (Kartawinata *et al.*, 2008), where there is no indication of levelling-off of the curve at the area of 10.5 ha.

A dominant species utilizes a habitat efficiently and maximally compared to others (Smith, 1977). Species with high IV are more stable in terms of their persistence in growing and developing. In this context tree species with IV >10% in the study plot will have better chances to grow and survive. They include *Nothofagus rubra*, *Parinari corymbosa*, *Myristica hollrungii*, *Platea latifolia* and *Lophopetalum torricellense* (Table 1).

A species is considered rare if, on the average, it has one or fewer stems per hectare (Hubbell & Foster, 1986). Therefore, the nine species (15.25% of the total) having a density of one/ha and frequency of 1% listed in Table 1 can be definitely considered rare. They were rare locally in the Foja Mountains but were not necessarily rare in terms of IUCN criteria. They were *Antidesma* sp., *Cryptocarya caudata*, *Knema* sp., *Macaranga fallacina*, *Myristica fatua*, *Syzygium antisepticum*, *S. platycarpum*, *S. insulare* and *Polyosma integrifolia*.

Structure and composition of the Foja Mountains forest consisted of different species living naturally as the results of adaptation to the biotic and abiotic environment (Hutchinson *et al.*, 1999). Topographic differences may affect not only the number of species and density but also species grouping to form a floristic composition of the forest, as affirmed by Whitmore (1984) who stated that forest variations are related to terrain, topography and degree of natural disturbance. In the present study, differences in topography did not appear to affect the overall tree distribution as indicated by all the subplots being equally filled up by trees (Fig. 11). The existence of gaps allowed light to reach the forest floor that stimulates the germination of buried seeds of primary as well as secondary forest species (Hartshorn, 1980; Whitmore, 1984). Therefore, the species composition of a forest stand consists of both primary and secondary or successional species with their proportion depending on the degree of disturbance. Such mixture was evident at the Foja Mountains forest, although the proportion of the primary forest species was much greater than that of the secondary forest species because gaps are not too common. The secondary forest species filling up the gaps was small in number, which included *Aporosa longicaudata*, *Croton laevifolius*, *Glochidion molle*, *G. novoguineense* and *Macaranga fallacina* (Johns *et al.*, 2007; Whitmore, 1984).

## CONCLUSION

The account presented here is the first quantitative description ever made of the untouched superb and pristine lower montane forest in the isolated Foja Mountains in Papua, Indonesia. The one-hectare plot could be perceived as a representative sample of the

surrounding forests as the minimal area was reached at 0.5 ha. Structurally and floristically the forest in the plot was an established and well developed mature undisturbed forest with heterogeneous species composition consisting mainly of primary forest species.

Heterogeneity was reflected by the majority of the species having low frequency (<10%) and absolute density (<10 trees/ha), although species richness was low. The dominance of *Nothofagus rubra* signifies the status of this forest should be considered to be a variant of the lower montane and mid-montane forests of Papua dominated by *Nothofagus pullei*.

Allowing the pristine forest to remain undisturbed by human activities and permitting only natural disturbances and natural successions to take place will maintain the high value of the forest. It is one way to manage science-based conservation and management of the Foja Mountains. It should be supported by further research on the vegetation over a wider area in the reserve, including forests with low stature and bogs around the seasonally dry lake, as well as in the Mamberamo region.

Because of its uniqueness, the forest at the Foja Mountains should unquestionably at all costs be conserved with total protection to maintain the integrity and originality of the forests and prevent disturbances by human activities.

## ACKNOWLEDGEMENTS

We would like to thank Prof. Jatna Supriatna, President of the Conservation International Indonesia (CII) for allowing one of us (AS) to participate in the CII expedition to the Foja Mountains undertaken in November 2005. We are very grateful to Mr. Tim Laman for allowing us to use his copyrighted photographs of the Foja Mountains to complement the article. Gratitude goes also to field staff of the Foja Wildlife Refuge: Mr. Bernat and Mr. Paulus who assisted us in the field. Appreciation also goes to Dr. Ary P. Keim (Botany), Dr. Hari Sutrisno, M. H. Sinaga and Suparno (Zoology) of the Research Center for Biology-LIPI, for their cooperation during the field work and to CII officers in Jakarta (Ms. Iraningrum) and Mr. Yance (Papua) for assistance and facilities that made participation in the expedition possible.

## REFERENCES

- ARCHBOLD, R., RAND, A. L. & BRASS, L. J. 1942. Results of the Archbold expeditions. No. 41. Summary of the 1938–1939 New Guinea expedition. *Bulletin of the American Museum*

- of Natural History* 73: 201–288.
- ASHTON, P. S. 1965. Some problems arising in the sampling of mixed rain forest communities for floristic studies. In: Symposium on Ecological Research in Humid Tropics Vegetation (1963). 235–240. Government of Sarawak and UNESCO Science Cooperation Office for SE Asia. Tokyo Press Co. Ltd. Itabashi. Tokyo. 376 p.
- BALGOOY, M. M. J. VAN. 1976. Phytogeography. In: PAIJMANS, K. (Ed.) *New Guinea Vegetation*. Australian National University Press. Canberra. Pp. 1–22.
- BAPPENAS. 2003. *Strategi dan Rencana Aksi Keanekaragaman Hayati Indonesia 2003-2020. IBSAP*. Dokumen Nasional. Jakarta.
- BARBOUR, M. G., BURK, J. H. & PITTS, W. P. 1987. *Terrestrial Plant Ecology*. The Benjamin/Cumming Publishing Company Ins. California.
- BEEHLER, B. M. 2007. The Foja Mountains of Indonesia: Exploring the lost world. *Action bio-science*, Pp. 1–7.
- BOERLAGE, H. P. 1949. *Regenval in Indonesië (Rainfall in Indonesia)*. Meteorologische en Geophysische Dienst. Koninklijk Magnetisch en Meteorologisch Observatorium te Batavia. Verhandelingen 37: 134.
- BOWE, M., STRONACH, N. & BARTOLO, R. 2007. Grassland and savanna ecosystems of the Trans-Fly, Southern Papua. In: MARSHALL, A. J. & BEEHLER, B.M. (Eds.). *The Ecology of Papua. Part II*. Periplus Edition. Hongkong. Pp. 1054–1063.
- BRASS, L. J. 1941. The 1938–1939 expedition to the Snow Mountains, Netherlands New Guinea. *Journal of the Arnold Arboretum* 22: 271–342.
- CIESLA, W. M. & DONAUBAUER, E. 1994. *Decline and Dieback of Trees and Forests – A global review*. FAO Forestry Paper 20. FAO. Rome.
- CLIMATE-DATA.ORG 2017. Climate: Tembagapura. <https://en.climate-data.org/location/55120/https://id.climate-data.org/location/600468>. Accessed on 9 May 2017.
- COLIJN, A. H. 1936. The Carstensz massif. *Alpine Journal* 49:177–189. [https://www.alpinejournal.org.uk/Contents/Contents\\_1937\\_files/AJ49%20177.189%20Colijn%20Carstensz%20Massif.pdf](https://www.alpinejournal.org.uk/Contents/Contents_1937_files/AJ49%20177.189%20Colijn%20Carstensz%20Massif.pdf). Accessed on 28 Feb.2018.
- COX, G. W. 1967. *Laboratory Manual of General Ecology*. Second Edition. Butterworths. Crown. Iowa.
- GIBBS, L. S. 1917. *A Contribution to the Phytogeography and Flora of the Arfak Mountains*. Taylor & Francis. London. <http://papuaweb.org/dlib/bk/gibbs/1917.html>.
- HARTSHON, G. S. 1980. Neotropical forest dynamic. *Biotropica* 12 (2): 23–30.
- HEIST, M. VAN., SHEILL, D., RACHMAN, I., GUSBAGER, P., RAWEYAI, C. O. & YOTENI, H. S. M. 2010. The forests and related vegetation of Kwerba on the Foja Foothills, Mamberamo, Papua (Indonesian New Guinea). *Blumea* 55: 153–161.
- HOPE, G. S. 1976. Vegetation. In: HOPE, G. S., PETERSON, J. A., ALLISON, I. & RADOCK, U. (Eds.). *The Equatorial Glaciers of New Guinea*. Balkema. Rotterdam. Pp. 113–172.
- HUBBELL, S. & FOSTER, R. 1986. Commonness and rarity in a neotropical forest: implications for tropical tree conservation. In: SOULE, M. (Ed.). *Conservation Biology: The Science of Scarcity and Diversity*. Sinauer Assoc. Inc. Sunderland. MA.
- HUTCHINSON, T. F., BOERNER, R. E. J., IVERSON, L. R., SUTHERLAND, S. & SUTHERLAND, E. K. 1999. Landscape patterns of understory composition and richness across a moisture and nitrogen mineralization gradient in Ohio (USA) Quercus forests. *Plant Ecology* 144: 177–189.
- JOHNS, R. J. 1993. Biodiversity and conservation on the native flora of Papua New Guinea. In: ALCORN, J. B. (Ed.). *Papua New Guinea Conservation Needs Assessment*. Biodiversity Support Program. Washington. D.C. Pp. 15–75.
- JOHNS, R. J., SHEA, G. A., VINK, W. & PURADYATMIKA, P. 2007. Coastal vegetation of Papua; Lowland swamp and peat vegetation of Papua; Lowland vegetation of Papua; Heath vegetation of Papua; Mountain vegetation of Papua; Subalpine and alpine vegetation of Papua. In: MARSHALL, A. J. & BEEHLER, B. M. (Eds.). *The Ecology of Papua. Part II*. Periplus Edition. Hongkong. Pp. 901–908; 910–944; 945–961; 962–978; 977–1024; 1025–1053.
- KALKMAN, C. 1963. Description of vegetation types in the Star Mountains region. West New Guinea. *Nova Guinea Botany* 15: 247–261.
- KARTAWINATA, K. 2005. Six decades of natural vegetation studies in Indonesia. In: SOEMODIHARDJO, S. & SASTRAPRADJA, S. D. (Eds.). *Six Decades of Science and Scientists in Indonesia*. Naturindo. Bogor. Pp. 95–140.
- KARTAWINATA, K. 2013. *Diversitas Ekosistem Alami Indonesia (Ungkapan singkat dengan sajian foto dan gambar)*. LIPI Press & Yayasan Pustaka Obor Indonesia. Jakarta.
- KARTAWINATA, K., SAMSOEDIN, I., HERIYANTO, M. & AFRIASTINI, J. J. 2004. A tree species inventory in a one-hectare plot at the Batang Gadis National Park. North Sumatra. Indonesia. *Reinwardtia* 12 (2): 145–157.
- KARTAWINATA, K., PURWANINGSIH, PARTOMIHARDJO, T., YUSUF, R., ABDULHADI, R. & RISWAN, S. 2008. Floristics and structure of a lowland dipterocarp forest at

- Wanariset Samboja. East Kalimantan. Indonesia. *Reinwardtia* 12 (4): 301–323.
- KARTIKASARI, S. N., MARSHALL, A. J. & BEEHLER, B. M. 2012. *Ekologi Papua*. Yayasan Pustaka Obor Indonesia & Conservation International. Jakarta.
- KEIM, A. P., KARTAWINATA, K., & EFENDY, O. 2018. Biodiversitas terkini Danau Habbema, Papua. Unpublished.
- KERSHAW, K. A. 1964. *Quantitative and Dynamic Ecology*. Edward Arnold Publishing Co. Ltd. London.
- KLHK (Kementerian Lingkungan Hidup dan Kehutanan). 2016. *Statistik Kehutanan Tahun 2016*. Kementerian Lingkungan Hidup dan Kehutanan. Jakarta.
- LAM, H. J. 1945. Fragmenta Papuana 1–7. Translated by L. M. Perry. *Sargentia* 5: 1–196. [http://awsassets.panda.org/downloads/prentice\\_hope\\_climate\\_papua\\_2006.pdf](http://awsassets.panda.org/downloads/prentice_hope_climate_papua_2006.pdf)
- LAMAN, T. 2009. Explore Foja Mountains, Mountains Papua and more! <https://www.pinterest.com/pin>. Accessed 30 January 2017.
- LANE-POOLE, C. E. 1925. *The Forest Resources of the Territories of Papua and New Guinea*. Govt. Printer. Melbourne.
- LIPI (Lembaga Ilmu Pengetahuan Indonesia), KPPN (Kementerian Perencanaan Pembangunan Nasional) & KRT (Kementrian Riset dan Teknologi). 2013. *Bioresources Pembangunan Ekonomi Hijau*. LIPI Press. Jakarta.
- MCCUNE, B. & GRACE, J. B. 2002. *Analysis of Ecological Communities. MJM Software Design*. Glenden Beach. Oregon.
- MAMPIOPER, D. A. 2009. Suaka Margasatwa Mamberamo Foja. Rawan Perburuan Liar dan Pembangunan. <http://tabloidjubi.com>. Accessed 17 January 2017.
- MANGEN, J. M. 1993. Ecology and vegetation of Mt. Trikora, New Guinea (Irian Jaya/Indonesia). *Travaux Scientifiques du Musée National d'Histoire Naturelle de Luxembourg* 21:1–216.
- MANSUR, M. & KARTAWINATA, K. 2017. Phytosociology of a lower montane forest on Mt. Batulanteh, Sumbawa, Indonesia. *Reinwardtia* 16 (2): 77–92.
- MAY, R. J., LAWTON, J. & STORK, N. 1995. *Extinction rates*. In: LAWTON, J. & MAY, R. (Eds.). Oxford. University Press. Oxford. Pp: 1–24.
- MOGEA, J. P. 2005. Palm in the Foja Mountain, Upper Mamberamo River, Sarmi District, Papua, Indonesia. *Rapid Assessment Program*. (Field-trip Report).
- MUELLER-DOMBOIS, D. 1983. Canopy dieback and successional process in Pacific forests. *Pacific Science* 37: 317–325.
- MUELLER-DOMBOIS, D. 1986. Perspective for etiology of stand level dieback. *Annual Review of Ecology and Systematics* 17: 221–241.
- MUELLER-DUMBOIS, D. & ELLENBERG, H. 1974. *Aim and Methods of Vegetation Ecology*. John Willey Toronto.
- PAIJMANS, K. 1970. An analysis of four tropical rain forest sites in New Guinea. *Journal of Ecology* 58: 77–101.
- PAIJMANS, K. 1976. *New Guinea Vegetation*. Australian National University Press. Canberra.
- PARTOMIHARDJO, T. 1991. Analisis vegetasi hutan sekitar Air Garam, Jayawijaya. In: WITJAKSONO, MARWOTO, R. M. & SUPARDIYONO, E. K. (Eds.). Prosiding Seminar Hasil Penelitian dan Pengembangan Sumber Daya Hayati 1990/1991. Puslitbang Biologi-LIPI, Bogor. Pp. 15–23.
- PIMM, S. & RAVEN, P. 2000. Extinction by numbers. *Nature* 403: 843–845.
- PLOTKIN, J. B., POTTS, M. D., LESLIE, A. N., MANOKARAN, N., LAFRANKIE, J. & ASHTON, P. S. 2000. Species-area curves, spatial aggregation, and habitat specialization in tropical forests. *J. Theor. Biol.* 207: 81–99.
- POLAK, M. 2000. The botanical diversity in the Ayawasi area, Irian Jaya, Indonesia. *Biodiversity and Conservation* 9: 1345–1375.
- PURWANINGSIH & YUSUF, R. 2008. Analisis vegetasi hutan pegunungan di Taman Nasional Gunung Ceremai, Majalengka, Jawa Barat. *Jurnal Biologi Indonesia* 4(5): 385–399.
- PURWANINGSIH, POLOSAKAN, R. & YUSUF, R. 2017. Phytosociological studies of the montane forest on the south slope of Mt. Wilis, East Java, Indonesia. *Reinwardtia* 16 (1): 31–45.
- RAHMAH, KARTAWINATA, K., NISYAWATI, WARDHANA, W. & NURDIN, E. 2016. Tree species diversity in the lowland forest of the core zone of the Bukit Duabelas National Park, Jambi, Indonesia. *Reinwardtia* 15 (1): 11–26.
- RICHARDS, P. W. 1996. *The Tropical Rain Forest: An Ecological Study*. 2nd edition. Cambridge University Press. Cambridge. UK.
- ROBERTH, 2016. Mamberamo Foja Diusul Jadi Taman Nasional. <http://www.wartaplus.com>. Accessed on 17 January 2017.
- SAMBAS, E. N. 2014. Komposisi jenis pohon pada hutan pamah Mamberamo, Papua. In: MEGANTARA, E.N., SUPRIATUN T., ROSSIANA, N., HUSODO, T., MIRANTI, M., WULANDARI, A. P., DEWI, T. K. P., SYARIF, S., SANTOSA, P. & ANNISA (Eds.). Prosiding Seminar Nasional IV Jurusan Biologi -FMIPA, Universitas Padjadjaran. Pp. 234–244.
- SCHMIDT, F. H. & FERGUSON, J. H. 1951. *Rainfall Types Based on Wet and Dry Period Ratios for Indonesia with Western New Guinea*. Verhandelingen Djawatan Meteorologi dan Geofisika. Djakarta.



- SHEA, G. A., MARTINDALE, D., PURADY-ATMIKA, P. & MANDESSY, A. 1998. *Biodiversity Surveys in the PT Freeport Indonesia Contract of Work Mining and Project Area, Irian Jaya, Indonesia*. P.T. Freeport. Indonesia.
- SIREGAR, M. 2001. Pengaruh topografi terhadap vegetasi hutan pada formasi Wainukendi, Cagar Alam Supiori, Irian Jaya. *Ekologi Indonesia* 3 (1): 22–33.
- SMITH, R. L. 1977. *Element of Ecology*. New York: Harper & Row Publisher.
- SOEPADMO, E. 1972. Fagaceae. *Flora Malesiana* I. 7: 265–403.
- STEENIS, C. G. G. J. VAN. 1950. The delimitation of Malaysia and its main plant geographic divisions. In: STEENIS, C. G. G. J. VAN (General Editor) *Flora Malesiana* Ser. I. Volume I. Noordhoff-Kolff. N.V. Djakarta. Pp. lxxi–lxxv.
- STEENIS, C. G. G. J. VAN, KALKMAN, C., KIRKUP, D. W., NOTEBOOM, H. P., WILDE, W. J. J. O. DE., SAW, L. G., STEVENS, P. F., COODE, M. J. E. & WELZEN, P. C. VAN (Eds.). 1948-2013. *Flora Malaesiana*. Series I. Volumes 4–21. Foundation Flora Malesiana. Leiden.
- TAKEUCHI, W. 2007. Introduction to the flora of Papua. In: MARSHALL, A. J. & BEEHLER, M. B. (Eds.). *The Ecology of Papua. The Ecology of Indonesia Series*. Vol. 6. Periplus Editions (HK) Ltd. Hong Kong. Pp. 269–302.
- TAKEUCHI, W. 2009. New taxa from the Mamberamo River of Papua Province, Indonesia: *Ardisia lammersiana* (Myrsinaceae) and *Psychotria leptothyrsa* var. *defretesiana* (Rubiaceae). *Harvard Papers in Botany* 14(2): 173–181.
- TAKEUCHI, W. 2010. A floristic reconnaissance of montane environments in the Foja Mts. of Papua Province, Indonesia. *Harvard Papers in Botany* 15(1): 11–25.
- TAKEUCHI, W. & ARIFIANI, D. 2010. A synopsis of new plant distributional records from the Foja Mountains of Papua Province, Indonesia. *Harvard Papers in Botany* 15(1): 41–50.
- THE PLANT LIST. 2017. *The Plant List: A working list of all known plant species Version 1.1 (September 2013)*. <http://www.theplantlist.org>. Accessed on 30 February 2017.
- YAMADA, I. 1975. Forest ecological studies of the montane forest of Mt. Pangrango. West Java. I. Stratification and floristic composition of the montane rain forest near Cibodas. *South East Asia Studies* 13 (3): 402–426.
- WALTER, H. 1973. *Vegetation of the Earth*. (English edition). The English Universities Press. London.
- WHITMORE, T. C. & SIDYASA, K. 1986. Composition and structure of a lowland rain forest at Toraut, northern Sulawesi. *Kew Bulletin* 41: 747–756.
- WHITMORE, T. C., TANTRA, I. G. M. & SUTISNA, U. 1997. *Tree Flora of Indonesia. Check List for Irian Jaya*. Forest Research and Development Centre. Bogor.
- WHITMORE, T. C. 1984. *Tropical Rain Forest of the Far East*. (2<sup>ed</sup>). Clarendon University Press. Oxford.
- ZUHRI, M & MUTAQIN, Z. 2011. Perubahan komposisi vegetasi dan struktur pohon pada plot Meijer (1959-2009) di Gunung Gede, Jawa Barat. *Buletin Kebun Raya* 14 (1): 37–45.

## INSTRUCTION TO AUTHORS

**Scope.** *Reinwardtia* is a scientific regular journal on plant taxonomy, plant ecology and ethnobotany published in June and December. Manuscript intended for a publication should be written in English.

**Titles.** Titles should be brief, informative and followed by author's name and mailing address in one-paragraphed.

**Abstract.** English abstract followed by Indonesian abstract of not more than 250 words. Keywords should be given below each abstract.

**Manuscript.** Manuscript is original paper and represent an article which has not been published in any other journal or proceedings. The manuscript of no more than 36 pages by using Times New Roman 11, MS Word for Windows of A4 with double spacing, submitted to the editor through Reinwardtia online journal system and <reinwardtia@mail.lipi.go.id>. New paragraph should be indented in by 5 characters. For the style of presentation, authors should follow the latest issue of Reinwardtia very closely. Author(s) should send the preferred running title of the article submitted. Every manuscript will be sent to two blind reviewers.

**Identification key.** Taxonomic identification key should be prepared using the aligned couplet type.

**Nomenclature.** Strict adherence to the International Code of Nomenclature is observed, so that taxonomic and nomenclatural novelties should be clearly shown. English description for new taxon proposed should be provided and the herbaria where the type specimens area deposited should be presented. Name of taxon in taxonomic treatment should be presented in the long form that is name of taxon, author's name, year of publication, abbreviated journal or book title, volume, number and page.

**Map/line drawing illustration/photograph.** Map, line drawing illustration, or photograph preferably should be prepared in landscape presentation to occupy two columns. Illustration must be submitted as original art accompanying, but separated from the manuscript. The illustration should be saved in JPG or GIF format at least 350 pixels. Legends or illustration must be submitted separately at the end of the manuscript.

**References.** Bibliography, list of literature cited or references follow the Harvard system as the following examples.

- Journal : KRAENZLIN, F. 1913. *Cyrtandraceae* novae Philippinenses I. *Philipp. J. Sci.* 8: 163–179.  
MAYER, V., MOLLER, M., PERRET, M. & WEBER, A. 2003. Phylogenetic position and generic differentiation of *Epithemateae* (Gesneriaceae) inferred from plastid DNA sequence data. *American J. Bot.* 90: 321–329.
- Proceedings : TEMU, S. T. 1995. Peranan tumbuhan dan ternak dalam upacara adat “Djoka Dju” pada suku Lio, Ende, Flores, Nusa Tenggara Timur. In: NASUTION, E. (Ed.). *Prosiding Seminar dan Lokakarya Nasional Etnobotani II*. LIPI & Perpustakaan Nasional: 263–268. (In Indonesian).  
SIMBOLON, H. & MIRMANTO, E. 2000. Checklist of plant species in the peat swamp forests of Central Kalimantan, Indonesia. In: IWAKUMA, T., INOUE, T., KOHYAMA, T., OSAKI, M., SIMBOLON, H., TACHIBANA, H., TAKAHASHI, H., TANAKA, N., YABE, K. (Eds.). *Proceedings of the International Symposium on: Tropical Peatlands*. Pp.179 – 190.
- Book : RIDLEY, H. N. 1923. *Flora of the Malay Peninsula* 2. L. Reeve & Co. Ltd, London.
- Part of Book : BENTHAM, G. 1876. *Gesneriaceae*. In: BENTHAM, G. & HOOKER, J. D. *Genera Plantarum* 2. Lovell Reeve & Co., London. Pp. 990–1025.
- Thesis : BAIRD, L. 2002. *A Grammar of Kéo: An Austronesian Language of East Nusantara*. Australian National University, Canberra. [PhD. Thesis].
- Website : <http://www.nationaalherbarium.nl/fmcollectors/k/KostermansAJGH.html>. (Accessed 15 February 2012).



## **Reinwardtia**

Published by Herbarium Bogoriense, Botany Division, Research Center for Biology,  
Indonesian Institute of Sciences

Address: Jln. Raya Jakarta-Bogor Km. 46 Cibinong 16911, P.O. Box 25 Cibinong

Telp. (+ 62) 21 8765066; Fax (+62) 21 8765062

Email: reinwardtia@mail.lipi.go.id

### ***REINWARDTIA* Author Agreement Form**

Title of article :

Name of Author(s) :

I/We hereby declare that:

- My/Our manuscript was based on my/our original work.
- It was not published or submitted to other journal for publication.
- I/we agree to publish my/our manuscript and the copyright of this article is owned by Reinwardtia.
- We have obtained written permission from copyright owners for any excerpts from copyrighted works that are included and have credited the sources in our article.

Author signature (s)

Date

---

Name



LAODE ALHAMD. Ecological study of the arrowroot (*Tacca leontopetaloides* (L.) Kuntze) at Karimunjawa National Park (KNP), Central Java ..... 87

YASPER MICHAEL MAMBRASAR & PRIMA W. K. HUTABARAT. *Rhododendron meagaili*, a new species of *Rhododendron* subgenus *Vireya* (Ericaceae) from Papua, Indonesia ..... 97

K. M. WONG, RIDHA MAHYUNI, XIN YI NG & LOUISE NEO. Flora of Singapore Precursors, 8. Systematy of the new Southeast Asian genera *Canthiumera* and *Dibridsonia* (Rubiaceae: *Vanguerieae*), with notes on plant architecture and reproductive ecology ..... 101

ANDREW POWLING. An assessment of present plant diversity on the Natewa Peninsula, Vanua Levu, Fiji ..... 125

ASEP SADILI, KUSWATA KARTAWINATA, HERWASONO SOEDJITO & EDY NASRIADI SAMBAS. Tree species diversity in a pristine montane forest previously untouched by human activities in Foja Mountains, Papua, Indonesia ..... 133

Reinwardtia is a LIPI accredited Journal (792/AU3/P2MI-LIPI/04/2016)

<http://e-journal.biologi.lipi.go.id/index.php/reinwardtia>

Herbarium Bogoriense  
Botany Division  
Research Center for Biology – Indonesian Institute of Sciences  
Cibinong Science Center  
Jln. Raya Jakarta – Bogor, Km 46  
Cibinong 16911, P.O. Box 25 Cibinong  
Indonesia