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Plant Species Composition and Their Conspecific Association in Natural Tropical Rainforest, South Papua

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Abstract

Papua has so many wide lowland areas that cover high diversity in plant from life-forms. In contrast, there is a lack of information concerning species diversity. The objectives of the research were to describe species of plant life-forms and to analyze conspecific associations between small individuals and large individuals in natural tropical rainforest, south Papua. Then, 46 nested plots were placed systematically in natural tropical rainforest of Boven Digoel Regency, Papua. Density, frequency, dominance and importance value index (IVI) were analyzed to describe plant diversity, while detrended correspondence analysis (DCA) was to describe conspecific association between small individuals and large individuals. Results found 2040 individuals in this forest consisting 194 plant species. Those are from pteridophytes, angiosperms and gymnosperms. The plant life-forms are herbs, orchids, palms, pandans, shrubs, rattans, vines and trees in which of the plant life-forms, trees are the most abundant according to number of species. In the dominant plant species, two types of conspecific association occurred between small individuals and large individuals. Analysis of DCA revealed that there are large plant species grow along with their small individuals. Another type is that small individuals grow far from their large individuals.

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INTRODUCTION

Tropical rainforest cover abundantly species particularly flora that consists of high diversity of species (Armstrong, Shugart, & Fatoyinbo, 2011; Mesquita, Santos, Massoca, Bentos, & Williamson, 2015; Pennington, Hughes, & Moonlight, 2015). Abiotically, tropical rainforest is characterized by high moisture, rainfall and receiving sunlight. This condition results in vegetation to compete in term of space to grow and sunlight (Thomas & Baltzer, 2002). Then, vegetation has developed such strategies as responses to ecological niche. The vegetation can be divided based on diverse forms of plants (Adamson, 1939; Cain, 1950; Richards & Champion, 1954; Rikhari, Adhikari, & Rawat, 1997; Rowe & Speck, 2005) and plant major group of interest as angiosperms, gymnosperms, pterodhipytes and bryophytes (Whittaker, 1969). Therefore, various types of vegetation use strategies to outcompete among other individuals (Pinard & Putz, 1994). The plant life-forms have been described as physiognomic features (Adamson, 1939; Arnold, 1955).

The plant life-forms in tropical rainforest have been recorded (Lieberman, Lieberman, Peralta, & Hartshorn, 1996; Webb, 1959). There are perennial and annual plants grow in tropical rainforest(Du Rietz, 1931). Then, plant life-forms in tropical rainforest are found such as trees, shrubs, herbs and vines (Arbainsyah, de Iongh, Kustiawan, & de Snoo, 2014). Those can be distinguished based on stories or layer in tropical rainforest (Swaine, Whitmore, & Swaine, 1988). For an example, in tropical forest vines are found abundantly (Campbell, Magrach, & Laurance, 2015; Muthuramkumar et al., 1998; Wright, Calderón, Hernandéz, & Paton, 2004). The presence of ferns have been studied e.g. (Magrach, Rodríguez-Pérez, Campbell, & Laurance, 2014; Watkins & Cardelús, 2009). Many herbs distributed in tropical rainforest were also studied e.g. (Sanches & Válio, 2002; Willinghöfer, Cicuzza, & Kessler, 2012).

Papua is the western part of New Guinea Island that comprises high diversity of plants. In general, the plant can be grouped as forest, woodland, scrub, savanna, grassland, mixed herbaceous vegetation, pioneer vegetation, mangrove vegetation and garden (Petocz, 1989). Lowland in Papua is a wide area that cover high diversity in plant from life-form(Paijmans, 1970). Many researches have been conducted to reveal diversity based on plant species(Kuswandi, Sadono, Supriyatno, & Marsono, 2015).Some plants species have not completely identified. Therefore, some plant species have recently classified taxonomically e.g. (Heatubun, Zona, & Baker, 2014; Hughes, Barber, Heatubun, & Gagul, 2015; Maturbongs, Dransfield, & Mogea, 2015). However, there are still lack of information regarding abundance, distribution and association of the plant species that grow in natural forest. Nowadays, there are many threats, one of which is conversion of forest area to other land uses resulting in habitat loss. Hence, it is necessary now to find out related to the species diversity in natural tropical rainforest.

We formulated research questions as follows: 1. What kind of species composition based on plant life-form? and what species were dominant among them?; 2. Whether there are any association between conspecific small and large individuals of dominant species?. Thus, the aims of this research were to identify species of each plant life-forms and to describe conspecific associations between small and large individuals in natural tropical rainforest, south Papua

METHODS

Study area

Location took place in natural tropical rainforest of Boven Digoel Regency, Papua. The location is situated in 6°26'0''S - 6°30'0''S and 140°52'30''E-140°57'0'' Ebetween Muyu and Uwim Merah River in the western part and Fly River in eastern part near border of Indonesia and Papua New Guinea, while in the northern part is mountainous area of Papua and in the southern part is ex-timber concession (Figure 1). Annual mean of rainfall range from 3000 to 4000 mm and monthly rainfall is characterized as high which range from 221 to 426. This location is quite moist in which daily moisture is between 75 and 85 %. The maximum temperature on average account for 32^0 C. Location is in low land area and physiographical process have taken place here for long time. Southern part of Papua is coastal plains. Geological factor is formed dominantly by alluvium. Those factors are indicators that the southern part of Papua differs from other area in Papua (Petocz, 1989).

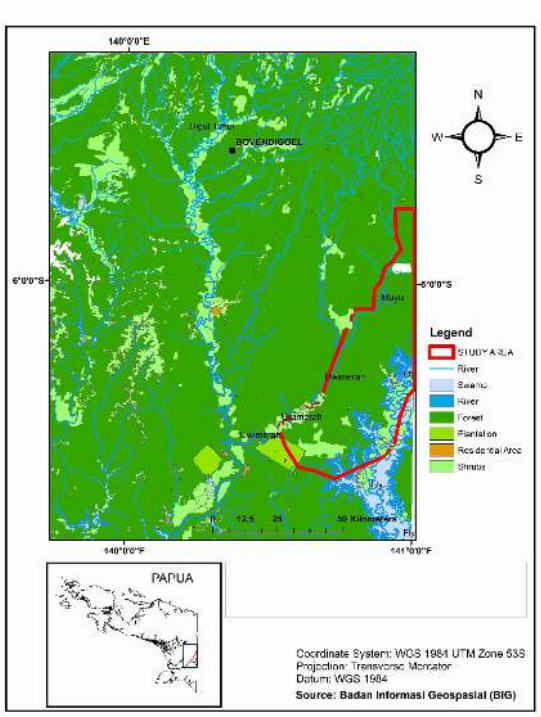


Figure 1. Location of research

Sampling

Total sampling plots in this research were 46 plots which were sampled using systematic plots. Plots were placed along transect and distance between plots was 100 m. First, plots with size set 20 m x 20 m (0.04 ha) were set for large trees and large individuals that are typified to have diameter at breast height (dbh) greater than 20 cm. Plots with size 10 m x 10 m (0.01 ha) were set for poles in which individuals are characterized to have diameter between 10 and 20 cm. Plots with size 5 m x 5 m (0.0025 ha) were set for saplings where individuals are characterized as height greater than 1.5 m and diameter less than 10 cm. Plots with size 2 m x 2 m (0.0004 ha) for seedlings where individuals are typified to have height less than 1.5 m. Then, the plots were designed and laid as nested samples (Forestry Department, 1989). .

Data collection

Plant species of pteridophytes, angiosperms and gymnosperms were taken in plots and every individual was identified according to the scientific name. Species identification was performed by two vegetation identifiers from herbarium technician. Unidentified samples were set as voucher specimens and sent to Herbarium of "*Balai Penelitian Kehutanan Manokwari*" and Herbarium Manokwariense (MAN) *Pusat Penelitian Keanekaragaman Hayati Universitas Papua* (*PPKH-UNIPA*) to be identified. Then, the validation of international scientific name of plant species and family was checked through online at http://www.theplantlist.org/; http://plants.jstor.org and www.ipni.org/ipni/. Numbers of each species in plot were documented, whereas the diameter at breast height (1.3 m) or 20 cm above buttress were tallied for poles and trees except for seedling and saplings phase (Bertault & Sist, 1997).

Data analysis

Diversity index. Shannon-Weiner diversity index was singled out as parameter and to describe distribution of each species in term of number of individuals by computing evenness (E)(Smith & Wilson, 1996; Spellerberg & Fedor, 2003). The diversity index is calculated as $H' = -\sum p_i \ln (p_i)$, where is Shannon-Weiner diversity index, is number of sample in which species *i* is present. Evenness was measured using in which S is number of species. ***Basal area (BA).*** Basal area was only performed for tree. Basal area (BA) will be computed by taking into account diameter of tree species. The computation of BA is as $BA_i = \sum {D_i}^2 \, x \, 0.7854$, , where BA_i is basal area (m^2) of tree species *i,* D_i is diameter (m) of tree species *i,* 0.7854 is π divided by 4. Then, BA per hectare where BA of tree species is divided by area of plots (m^2ha^{-1}) as density. The BA for each tree species is to describe how large the tree species dominate in location (Folega et al., 2014). ***Density.*** Density is then used to describe number of each species per hectare (ind ha^{-1}). Density was carried out for all plant life-forms. ***Frequency.*** All species of plant life-forms was described using frequency. Furthermore, number of plots where tree species *i* is present are divided by total number of sample plots. Hence, the frequency is calculated as $Fr_i = n_i / N$ where Fr_i is frequency of species *i,* n_i is number of plots in which species *i* is found, *N* is total number of sample plots. ***Importance value index (IVI).*** The important values index was performed only for trees and was calculated to figure out distribution of each tree species in term of dominance (Cottam & Curtis, 1956). The index is determined by adding relative frequency, relative density and relative dominance as $IV_i = RFr_i + RDe_i + RDo_i$, where IV_i is important value index of tree species *i,* RFr_i is Relative Frequency of tree species *i,* RDe_i is Relative Density of tree species *i,* RDo_i is Relative Dominance of tree species *i.* ***Detrended correspondence analysis (DCA).*** DCA is a multivariate statistical technique DCA(Hill & Gauch, 1980) and was applied to describe conspecific association between small individuals and large individuals.

RESULTS AND DISCUSSION

Taxonomic diversity and abundance of species

The results found 2040 individuals in this forest consisting 194 plant species. Then, those species were grouped plant life-form as ferns (7 species), herbs (11 species), orchids (3 species), palms (6 species), pandan (1 species), rattans (3 species), shrubs (26 species), trees (126 species) and vines (11 species). Of number of individuals in each plant life-form, tree is the most abundant in concession forest (65.75 %), while the least scarce plant life-form is pandan (0.98 %). Other plant life-form such as fern, herb, orchid, palm, rattan, shrub and vine are between about 2 % and 8 % distributed in this area as can be seen in Table 1.

Table 1. Density of individual based on plant life-form

Plant life-form	Density (ind ha^{-1})	Proportion (%)
Ferns	5009	8.47
Herbs	3667	6.20
Orchids	1467	2.48
Palms	1618	2.73
Pandans	583	0.98
Shrubs	2213	3.74
Rattans	3257	5.50
Vines	2450	4.14
Trees	38901	65.75
total	59164	100

Ferns

Ferns in this area consist of 6 families and 7 species. Those families are *Blechnaceae, Cyatheaceae, Dennstaedtiaceae, Nephrolepidaceae, Pteridaceae, Pteridaceae* and *Selaginellaceae.* The most abundant species of fern is *Selaginella* sp. (3587 ind ha^{-1}), the four-moderate dominant species of fern are *Microlepia* sp., *Nephrolepis biserrata* (Sw.) Schott, *Taenitis* sp., *Adiantum* sp. where the density of each species are 326 ind ha^{-1}, 272 ind ha^{-1}, 543 ind ha^{-1}, 163 ind ha^{-1}, respectively. Those species are from *Pteridophytes* and grow as terrestrial ferns. The two-least dominant species of fern are *Blechnumorientale* L. (54 ind ha^{-1}) and *Cyathea contaminans* (Wall. ex Hook.) Copel. (63 ind ha^{-1}). Families and species of fern are presented in Table 2.

Table 2. Families and species density of fern

Family	Species	Density (ind ha^{-1})
Blechnaceae	*Blechnumorientale* L.	54
Cyatheaceae	*Cyathea contaminans* (Wall. ex Hook.) Copel.	63
Dennstaedtiaceae	*Microlepia* sp.	326
Nephrolepidaceae	*Nephrolepis biserrata* (Sw.) Schott	272
Pteridaceae	*Taenitis* sp.	543
Pteridaceae	*Adiantum* sp.	163
Selaginellaceae	*Selaginella* sp.	3587

Herbs

Herbs comprise 8 families and 11 species in which the families per each species are *Asparagaceae* (1 sp)*, Cyperaceae* (1 sp)*, Hypoxidaceae* (1 sp)*, Malvaceae* (1 sp)*, Marantaceae* (1 sp)*, Urticaceae* (1 sp)*, Xanthorrhoeaceae* (1 sp)and *Zingiberaceae* (4 spp). The most abundant species of herb is *Mapania sumatrana* (Miq.) Benth.(1630 ind ha^{-1}) followed by *Dianella ensifolia* (L.) DC. (761 ind ha^{-1}), *Molineria latifolia* (Dryand. ex W.T.Aiton) Herb. ex Kurz (326 ind ha^{-1}), *Alpinia* sp. (326 ind ha^{-1}), *Riedelia* sp. (163 ind ha^{-1}), *Dracaena angustifolia* (Medik.) Roxb. (135 ind ha^{-1}) and *Pilea* sp. (109 ind ha^{-1}) as moderate dominant species. *Pilea* sp., *Kleinhovia hospita* L., *Phrynium* sp., *Amomum aculeatum* Roxb. and *Pleuranthodium* sp.are considered as the least dominant species with density 54 ind ha^{-1}. All ferns grow as terrestrial plants. Those families and species with their densities are depicted in Table 3.

Table 3. Families and species density of herbs

Family	Species	Density (ind ha^{-1})
Asparagaceae	*Dracaena angustifolia* (Medik.) Roxb.	135
Cyperaceae	*Mapania sumatrana* (Miq.) Benth.	1630
Hypoxidaceae	*Molineria latifolia* (Dryand. ex W.T.Aiton) Herb. ex Kurz	326
Malvaceae	*Kleinhovia hospita* L.	54
Marantaceae	*Phrynium* sp.	54
Urticaceae	*Pilea* sp.	109
Xanthorrhoeaceae	*Dianella ensifolia* (L.) DC.	761
Zingiberaceae	*Alpinia* sp.	326
	Riedelia sp.	163
	Amomum aculeatum Roxb.	54
	Pleuranthodium sp.	54

Orchids

Orchids are from family *Orchidaceae* and they grow as terrestrial plants. The species of orchids are *Corymborkis veratrifolia* (Reinw.) Blume with density 1304 ind ha^{-1}, *Peristylus* sp. with density 109 ind ha^{-1} and *Calanthe* sp. with density 54 ind ha^{-1} (Table 4).

Table 4. Families and species density of orchids

Species	Density (ind ha^{-1})
Corymborkis veratrifolia (Reinw.) Blume	1304
Peristylus sp.	109
Calanthe sp.	54

Palms

Palms of family *Arecaceae* consist of 6 species where the species, ranked in descending order are as follows*Hydriastele beccariana* Burret with density 1009ind ha^{-1}, *Orania* sp. with density 326ind ha^{-1}, *Licuala* sp. with density 163ind ha^{-1}, *Orania disticha* Burret with density 57ind ha^{-1}, *Areca macrocalyx* Zipp. ex Blume with density 54ind ha^{-1} and *Sommieria leucophylla* Becc. with density 9ind ha^{-1} (Table 5).

Table 5. Families and species density of palms

Species	Density (ind ha^{-1})
Hydriastele beccariana Burret	1009
Orania sp.	326
Licuala sp.	163
Orania disticha Burret	57
Areca macrocalyx Zipp. ex Blume	54
Sommieria leucophylla Becc.	9

Pandan

Pandan or family *Pandanaceae* contains only one species, namely *Pandanus* sp. with density 583 ind ha^{-1}.

Shrubs

Shrubs are mostly from major group of Angiosperms where 26 species and 23 families were found in this area. Those families are *Annonaceae* (1 sp.), *Dilleniaceae* (1 sp.), *Ebenaceae* (1 sp.), *Elaeocarpaceae* (1 sp.), *Euphorbiaceae*(2 spp.), *Hypericaceae* (2 spp.), *Icacinaceae* (1 sp.), *Lamiaceae* (1 sp.), *Lauraceae*(2 spp.), *Melastomataceae* (2 spp.), *Menispermaceae* (1 sp.), *Moraceae* (2 spp.), *Myrtaceae* (2 spp.), *Polygalaceae* (1 sp.), *Primulaceae* (1 sp.), *Putranjivaceae* (2 spp.), *Salicaceae* (1 sp.), *Sapindaceae* (1 sp.), *Thymelaeaceae* (1 sp.) and *Winteraceae* (1 sp.).The species density of shrubs varied from 1 ind ha^{-1} to above 300 ind ha^{-1} in which *Uvaria* sp., *Cryptocarya palmerensis* C.K.Allen, *Diospyros vera* (Lour.) A.Chev. and *Bubbia* sp. have density greater than 200 ind ha^{-1}; *Ficus hispida* L.f., *Guioa* sp., *Alchornea* sp., *Maesa* sp. and *Phaleria octandra* (L.) Baill. Showed the density ranging from 100 ind ha^{-1} to 200 ind ha^{-1}; and *Cryptocarya* sp., *Casearia papuana* Sleumer, *Clerodendrum* sp., *Tetracera* sp., *Melastoma malabathricum* L., *Pachygone* sp., *Decaspermum parviflorum* (Lam.) A.J.Scott, *Ficus robusta* Corner, *Drypetes globosa* (Merr.) Pax & K.Hoffm., *Aceratium oppositifolium* DC.,

Mallotus paniculatus (Lam.) Müll. Arg., *Platea* sp., *Drypetes* sp., *Xanthophyllum* sp., *Astronia* sp., *Cratoxylum arborescens* (Vahl) Blume and *Decaspermum fruticosum* J.R.Forst. & G.Forst. are the least abundant species with density less than 100 ind ha^{-1} (Table 6).

Table 6. Families and species density of shrubs

Family	Species	Density (ind ha^{-1})
Annonaceae	*Uvaria* sp.	343
Dilleniaceae	*Tetracera* sp.	54
Ebenaceae	*Diospyros vera* (Lour.) A.Chev.	243
Elaeocarpaceae	*Aceratium oppositifolium* DC.	18
Euphorbiaceae	*Alchornea* sp.	109
	Mallotus paniculatus (Lam.) Müll.Arg.	11
Hypericaceae	*Cratoxylum arborescens* (Vahl) Blume	1
Icacinaceae	*Platea* sp.	9
Lamiaceae	*Clerodendrum* sp.	63
Lauraceae	*Cryptocarya* sp.	98
	Cryptocarya palmerensis C.K.Allen	272
Melastomataceae	*Astronia* sp	2
	Melastoma malabathricum L.	54
Menispermaceae	*Pachygone* sp.	54
Moraceae	*Ficus robusta* Corner	35
	Ficus hispida L.f.	117
Myrtaceae	*Decaspermum parviflorum* (Lam.) A.J.Scott	37
	Decaspermum fruticosum J.R.Forst. & G.Forst.	1
Polygalaceae	*Xanthophyllum* sp.	3
Primulaceae	*Maesa* sp.	109

Family	Species	Density (ind ha^{-1})
Putranjivaceae	*Drypetes globosa* (Merr.) Pax & K.Hoffm.	21
	Drypetes sp.	9
Salicaceae	*Casearia papuana* Sleumer	89
Sapindaceae	*Guioa* sp.	117
Thymelaeaceae	*Phaleria octandra* (L.) Baill.	109
Winteraceae	*Bubbia* sp.	235
Flagellariaceae	*Flagellaria indica* L.	272
Leguminosae	*Derris elliptica* (Wall.) Benth.	1087
Pandanaceae	*Freycinetia* sp.	335
Primulaceae	*Embelia* sp.	9
Rubiaceae	*Uncaria gambir* (Hunter) Roxb.	250
	Uncaria sp.	54
Vitaceae	*Ampelocissus* sp.	54

Rattans

Rattans from family *Arecaceae* covers 3 three species which are mentioned based on descending order in density as *Calamus* sp. with density 3030 ind ha^{-1}, *Calamus keyensis* Becc. with density 172 ind ha^{-1} and *Korthalsia* sp. with density 54 ind ha^{-1}(Table 7).

Table 7. Families and species density of rattans

Species	Density (ind ha^{-1})
Calamus sp.	3030
Calamus keyensis Becc.	172
Korthalsia sp.	54

Vines

Vines contain 1 family from Gymnosperms, namely *Gnetaceae* (1sp.) with 9 ind ha^{-1} and 7 families and 9 species from Angiosperms, namely *Araceae* (3spp.),*Flagellariaceae* (1sp.),*Leguminosae* (1sp.), *Pandanaceae* (1sp.), *Primulaceae* (1sp.), *Rubiaceae* (1sp.) and *Vitaceae* (1sp.). Species of vines with density greater than 1000 ind ha^{-1} is *Derris elliptica* (Wall.) Benth., species of vines with density below 1000 ind ha^{-1} and greater 200 ind ha^{-1} are *Freycinetia* sp., *Rhaphidophora schlechteri* K. Krause, *Flagellaria indica* L., *Uncaria gambir* (Hunter) Roxb.. Lastly, the species of vines with density less than 100 ind ha^{-1} are *Pothos scandens* L., *Scindapsus* sp., *Uncaria* sp., *Ampelocissus* sp., and *Embelia* sp. as shown in Table 8.

Table 8. Families and species density of vines

Family	Species	Density (ind ha^{-1})
Gymnosperms		
Gnetaceae	*Gnetum gnemonoides* Brongn.	9
Angiosperms		
Araceae	*Rhaphidophora schlechteri* K.Krause	272
	Pothos scandens L.	54
	Scindapsus sp.	54

The vines consist of *D. elliptica* and *Freycinetia sp.* as small vines; *F. indica* as False rattan-semi-woody climbing plant; *R. schlechteri*, *Ampelocissus sp.,Pothos scandens and Scindapsus sp.* as herbaceous vines; and *U. gambir, Embelia sp., Uncaria sp.* and *G. gnemonoides* as woody vines.

Trees

Trees were found belonging to mayor group of Angiosperms and Gymnosperms. The Angiosperms consist of 43 families and 123 species, namely *Anacardiaceae* (5 spp.), *Annonaceae* (7 spp.), *Apocynaceae* (2 spp.), *Araliaceae* (1 sp.), *Burseraceae* (5 spp.), *Calophyllaceae* (1 sp.), *Cannabaceae* (2 spp.), *Cardiopteridaceae* (1 sp.), *Celastraceae* (1 sp.), *Chrysobalanaceae* (2 spp.), *Clusiaceae* (8 spp.), *Combretaceae* (1 sp.), *Corynocarpaceae* (1 sp.), *Dipterocarpaceae* (5 spp.), *Ebenaceae* (1 sp.), *Elaeocarpaceae* (5 spp.), *Euphorbiaceae* (4 spp.), *Fagaceae*(1 sp.), *Gentianaceae* (1 sp.), *Lamiaceae* (1 sp.), *Lauraceae* (8 spp.), *Lecythidaceae* (1 sp.), *Leguminosae* (3 spp.), *Loganiaceae* (1 sp.), *Malvaceae* (4 spp.), *Meliaceae* (6 spp.), *Monimiaceae* (1 sp.), *Moraceae* (4 spp.), *Myristicaceae* (6 spp.), *Myrtaceae* (4 spp.), *Nyctaginaceae* (1 sp.), *Ochnaceae* (1 sp.), *Phyllanthaceae* (2 spp.), *Rhamnaceae* (1 sp.), *Rhizophoraceae* (2 spp.), *Rosaceae* (2 spp.), *Rubiaceae* (4 spp.), *Rutaceae* (4 spp.), *Salicaceae* (2 spp.), *Sapindaceae* (5 spp.), *Sapotaceae* (4 spp.), *Tetramelaceae*(1 sp.) and *Thymelaeaceae* (1 sp.). The mayor group of Gymnosperms comprise 2 families and 3 species, namely *Gnetaceae* (1 sp.) and *Podocarpaceae* (2 spp.).

Seedlings

There are 78 species of tree categorized as seedlings and then the 10-dominant species of trees are displayed based on Importance Value Index (IVI). The density of the dominant species is above 800 ind ha^{-1} (Table 9). Of the species of seedlings, *Hopea celtidifolia* Kosterm. is the densest species growing in this forest with density almost 5000 ind ha^{-1}, where *Vatica rassak* Blume and *Hopea iriana* Slooten showed density between 2000 ind ha^{-1} and 3000 ind ha^{-1}. Ten species of

dominant species were singled out and displayed in Table 9.

Saplings

Saplings contain 86 species in total and the 10-most dominant sapling of tree have been singled out based on IVI (Table 10). Density of tree saplings are greater than 100 ind ha^{-1} except for *Timonius rufescens* (Miq.) Boerl. where its density is only 78 ind ha^{-1}. The highest density of saplings is *Syzygium anomalum* Lauterb. in which number of individuals per hectare is almost 300 (Table 10).

Poles

There are 60 species of treeclassified as pole. Density of 10-most dominant poles range from 11 ind ha^{-1} to 37 ind ha^{-1} with dominance using basal area of its pole per hectare is between 0.18 m^2 ha^{-1} and 0.67 m^2 ha^{-1}.*Gymnacranthera farquhariana* (Hook & Thomson) Warb. and *Hopea celtidifolia* Kosterm.are the two-densest species of poles in which number of individuals and basal area per hectare are above 30 and 0.43 respectively (Table 11).

Large Trees

Species recorded in large trees are 76 species in which of the 10-most dominant species of large trees (Table 12), their density cover from 5 ind ha^{-1} to 23 ind ha^{-1} along with a range of dominance is from 0.54 m^2 ha^{-1} to 2.33 m^2 ha^{-1}. The high density of large tree is *Vatica rassak* Blume with about 20 ind ha^{-1} and its basal area is 2.33 m^2 ha^{-1}, whereas *Syzygium anomalum* Lauterb., *Planchonella anteridifera* (White & Francis ex Lane-Poole) H. J. Lam, *Gironniera subaequalis* Planch. and *Hopea celtidifolia* Kosterm. showed their number of individuals per hectare at least above 10 (Table 12).

Distribution and dominance of species of life-form in natural forest

The distribution of vegetation species, regardless of life-forms, is seemingly uniform since the average evenness (E) is 0.9 and its standard deviation is 0.09 for 46 plots. It suggests that most of 194 plant species, there are not species that is mainly dominant in natural forest. Another indication is that natural forest is species-mixed forest (Katovai, Katovai, Edwards, & Laurance, 2015; Mesquita et al., 2015) and species-rich area. Even though we did not take into account the Bryophytes (Mosses and liverworts), there are ferns, herbs, orchids, palms, pandans, rattans, shrubs, trees and vines as categories of life-form of plants that showed high number of species. The plant diversity can be described from understory to upper story in which they have grown symbiotically as natural forest (Givnish, 1999). It can be said that forest condition is in successional climax (Swaine et al., 1988).

In understory, the most dominant fern is *Selaginella* sp. (*Selaginellaceae*) which were found in about 25 % of natural forest (frequency is 0.24), while other ferns were only found in less than one per cent of this forest. This species is small ferns grow mostly in group (Kessler, Salazar, Homeier, & Kluge, 2014; Sharpe & Shiels, 2014; Tryon, 1971; Watkins & Cardelús, 2009). In herbs, the most dominant species is *Mapania sumatrana* (*Cyperaceae*) in which they are distributed in 22 % of this forest (frequency is 0.22). The species also grow more than 1000 ind ha^{-1}

Table 9. The 10-dominant species of seedlings

Species	Density (ind ha-1)	Frequency	IVI (%)
Hopea celtidifolia Kosterm.	4946	0.30	12.23
Vatica rassak Blume	3098	0.35	9.28
Lasianthus sp.	2337	0.43	8.77
Hopea iriana Slooten	3424	0.24	8.76
Syzygium anomalum Lauterb.	1739	0.43	7.67
Calophyllumcaudatum Kaneh. & Hatus.	2337	0.24	6.76
Blumeodendron tokbrai (Blume) Kurz	978	0.28	4.71
Prunus arborea (Blume) Kalkman	924	0.22	3.94
Parastemon versteeghii Merr. & L.M.Perry	1413	0.09	3.49
Planchonella anteridifera (C.T.White & W.D.Francis ex Lane-Poole) H.J.Lam	815	0.17	3.29

Table 10. The 10-dominant species of saplings

Species	Density (ind ha-1)	Frequency	I VI (%)
Syzygium anomalum Lauterb.	278	0.46	12.57
Canarium asperum Benth.	174	0.33	8.39
Vatica rassak Blume	165	0.30	7.90
Gymnacranthera farquhariana (Hook.f. & Thomson) Warb.	157	0.24	6.84
Hopea iriana Slooten	148	0.22	6.35
Calophyllum caudatum Kaneh. & Hatus.	130	0.22	5.94
Hopea celtidifolia Kosterm.	104	0.20	5.03
Blumeodendron tokbrai (Blume) Kurz	104	0.17	4.75
Planchonella anteridifera (C.T.White & W.D.Francis ex Lane-Poole) H.J.Lam	104	0.15	4.47
Timonius rufescens (Miq.) Boerl.	78	0.17	4.13

Table 11. The 10-dominant species of poles

Species	Density (ind ha-1)	Dominance (m^2ha^{-1})	Frequency	IVI (%)
Gymnacranthera farquhariana (Hook.f. & Thomson) Warb.	37	0.67	0.30	27.04
Hopea celtidifolia Kosterm.	33	0.43	0.22	20.06
Gironniera subaequalis Planch.	24	0.39	0.17	16.29
Pimelodendron amboinicum Hassk.	17	0.40	0.17	14.87
Syzygium anomalum Lauterb.	22	0.29	0.20	14.82
Blumeodendron tokbrai (Blume) Kurz	22	0.30	0.17	14.45
Hopea iriana Slooten	20	0.29	0.15	13.17
Melicope elleryana (F. Muell.) T.G. Hartley	15	0.18	0.13	9.80
Planchonella anteridifera (C.T.White & W.D.Francis ex Lane-Poole) H.J.Lam	13	0.18	0.13	9.34
Virola surinamensis (Rol. ex Rottb.) Warb.	11	0.20	0.11	8.53

(Table 3). This herb is morphologically like pandan. The second-most dominant species is *Alpinia* sp. (*Zingiberaceae*) that are present in 13 % of this forest (frequency is 0.13). The species is typical of understory plants in tropical forest and grow as perennial herbs (Cicuzza et al., 2013; Folega et al., 2014). Other species herbs were only found lower than one per cent of this forest. Orchids found in natural forest were terrestrial plants in which *Corymborkis veratrifolia* is the most dominant species with distribution 15 % of this forest (frequency is 0.15), whereas the two-other species showed the distribution less than one per cent in this forest.

Those ferns, herbs and orchids have short time to reach reproductive stage, resulting in producing new individuals. Hence, those life-forms can grow abundantly in understory of natural forest compared to other species of their life-form. Species of palms recorded in this forest vary in size that is from small plants to large plants. Especially, *Hydriastele beccariana*is the most dominant species of palm in small plant. This species is distributed about 30 % of this forest (frequency is 0.35). This species grow either as solitary palm or assembly palm (Baker & Loo, 2004). Regeneration of *Hydriastele beccariana* can be from germination of its seed (Wang & Augspurger, 2006) produced by mature individual and can also reproduce new individuals through suckering. The suckers can grow from small individuals (Frangi & Lugo, 1998). This is as result of how this palm can grow more abundant than some palms. There is only one species of pandan found in this forest, namely *Pandanus* sp. that is distributed only more or less one per cent of this forest (frequency is 0.11). Of the tree rattan species, *Calamus* sp. is the most dominant rattan. In contrast, this species was only found rarely in only maximum about one per cent of this forest. This species is not distributed widely, but this species tend to grow in assemblage as the density about 3000 ind ha^{-1}. The

Table 12. The 10-dominant species of trees

Species	Density (ind ha-1)	Dominance (m2 / ha)	Frequency	IVI (%)
Vatica rassak Blume	23	2.33	0.54	31.91
Syzygium anomalum Lauterb.	11	1.18	0.39	17.82
Planchonella anteridifera (C.T.White & W.D.Francis ex Lane-Poole) H.J.Lam	12	0.80	0.28	14.43
Gironniera subaequalis Planch.	10	0.67	0.37	14.24
Hopea iriana Slooten	9	1.06	0.28	14.20
Rhodomyrtus sp.	7	1.27	0.26	13.88
Hopea celtidifolia Kosterm.	10	0.85	0.28	13.64
Melicope elleryana (F. Muell.) T.G. Hartley	9	0.54	0.24	10.79
Gymnacranthera farquhariana (Hook.f. & Thomson) Warb.	8	0.58	0.26	10.76
Pometia acuminata Radlk.	5	0.54	0.20	8.20

stem of rattans can grow in any direction with hundreds of meters long as long as the stem can reach sunlight by using leaf-climbers as morphological support (Tomlinson et al., 2001) There are many types of vines, one of which is *Derris elliptica*where this species is the most dominant vine categorized as small plant (H. Zhu, 2008). This species was found in 30 % of this forest (frequency is 0.3). The density is more or less 1000 ind ha^{-1} and mostly this species is as creeping plant rather than climbing plant. Two other species, namely *Freycinetia* sp. and *Flagellaria indica* were found only in more or less one per cent of this forest. The rest species of vine were only found less than one per cent of this forest. In trees, the most dominant species of seedling is *Hopea celtidifolia* (IVI=12.23 %).

In term of distribution, species of seedlings with distribution about 30 % in this forest are *Hopea celtidifolia* (frequency is 0.3)*, Vatica rassak* (frequency is 0.35)*, Lasianthus* sp. (frequency is 0.43) and *Syzygium anomalum* (frequency is 0.43), while for species of saplings are *Syzygiumanomalum* (frequency is 0.46, IVI=12.57 %), *Canariumasperum* (frequency is 0.33, IVI=8.39 %) and *Vatica rassak* (frequency is 0.30, IVI=7.9 %). Besides the dominant species of seedlings and saplings are present in a third of this forest, they are found to grow in high-abundance compared to the rest of species. This is assumingly as a result of availability of parent trees in supplying seeds (Giles et al., 2004; Goodale, Berlyn, Gregoire, Tennakoon, & Ashton, 2014; Pérez-Méndez, Jordano, & Valido, 2015).

In upper story, there are species of the palms like *Hydriastele beccariana* and *Orania disticha*, pandan (*Pandanus* sp.), shrubs such as *Astronia* sp., *Mallotus paniculatus*, *Xanthophyllum* sp., *Decaspermum parviflorum, Drypetes globosa, Aceratium oppositifolium, Cratoxylumarborescens* and*Decaspermum fruticosum* can grow as large individuals, even though they are distributed rarely with only found in less than one per cent of this forest. Some of them can emerge from understory layer such as palms (Baker & Loo, 2004). In trees, there are species of poles, namely *Gymnacranthera farquhariana* (frequency is 0.3; IVI=27.04 %) and *Hopea celtidifolia* (frequency is 0.22; IVI=20.06 %) distribution at least 20 % of this forest, whereas species of large trees, namely *Vatica rassak* (frequency is 0.54; IVI=31.91 %), *Syzygium anomalum* (frequency is 0.39, IVI=17.82 %), *Planchonella anteridifera*(frequency is 0.28, IVI=14.43 %), *Gironniera subaequalis*(frequency is 0.37, IVI14.24 %), *H. iriana* (frequency is 0.28, IVI=14.20 %) and *Hopea celtidifolia* (frequency is 0.28, IVI=13.64 %) distributed at least about 30 % of this forest. Particularly, *Vatica rassak* is the most dominant species in upper story since this species is not only found in about 50 % of this forest, but also its Importance Value Index (IVI) is 31.91 %. A similar result was also shown by other research that genera of *Vatica*, *Syzygium* and *Hopea* grow dominantly in this forest (Gandhi et al., 2014).

Conspecific association between small individuals and large individuals among dominant plant species

There are 19 species selected as dominant species and each species consists of small individuals as juveniles and large individuals as mature individuals. Then, those were analysed using of DCA are presented in Figure 2 and Table 13.

Table 13. Summary of detrended correspondence analysis (DCA)

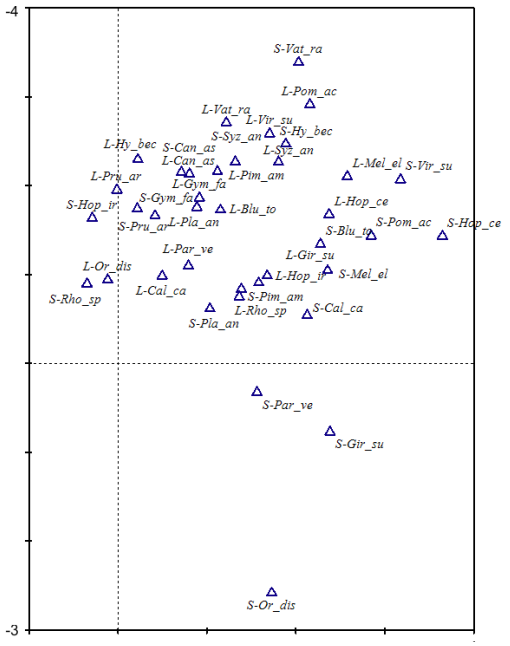
Axes		1	2	Total inertia
Eigenvalues	:	0.71	0.37	4.50
Lengths of gradient	:	3.63	3.27	
Percentage variance of species data	:	15.80	8.28	
Cumulative percentage variance of species data	:	15.80	24.07	

Total inertia of DCA is 4.5 where eigen values for first axes and second axes are 0.71 and 0.37 respectively. Percentage variance of species data are 15.8 % (axes 1) and 8.28 % (axes 2), then cumulated percentage of the-two axes is 24.07 % to explain variation of the species distributed in graph of DCA. Based on DCA analysis (Figure 1), association between small and large plant for each dominant species can be grouped as three groups. First group consists of species with small and large plants such as *Vatica rassak, Hydriastele beccariana, Syzygium anomalum, Canarium asperum, Gymnacranthera farquhariana* and *Prunus arborea;* species with only small plants such as *Hopea iriana* and *Rhodomyrtus* sp.; species only large plants such as *Blumeodendron tokbrai, Calophyllum caudatum, Oraniadisticha, Parastemon versteeghii, Pimelodendron amboinicum, Planchonella anteridifera, Pometia acuminata* and *Virola surinamensis.* Second group comprises species with small and large plants such as *Melicope elleryana, Hopea celtidifolia* and *Gironniera subaequalis*; species with only small plants like *Blumeodendron tokbrai*, *Calophyllum caudatum*, *Orania disticha*, *Parastemon versteeghii*, *Pimelodendron amboinicum, Planchonella anteridifera, Pometia* acuminate and *Virola surinamensis;* species with only large plants such as *Hopea iriana*and *Rhodomyrtus* sp. The third group contains *Gironniera subaequalis*, *Orania disticha* and *Parastemon versteeghii* in which they are small plants.

There are two kinds of pattern of association between small and large plants in tropical rainforest. The association describe an effect of neighbourhood whether same species or different species (Giles et al., 2004). First, small and large plants grow close together in an area where seedlings and saplings of plants are commonly found near their large plants. It indicates that seeds are produced and are dropped by large trees (Mesquita et al., 2015; Zambrano, Coates, & Howe, 2014). Those seeds mainly germinate around large trees as their parent trees. In this case, we found that *Vatica rassak, Hydriastele beccariana, Syzygium anomalum, Canarium asperum, Gymnacranthera farquhariana* and *Prunus arborea* as association of first group and another second group are *Melicope elleryana, Hopea celtidifolia* and *Gironniera subaequalis*. Seeds of those species are observably not as feed of animals. Therefore, the seeds are not dispersed by animals. Besides that, the seed size like *Vatica rassak* is big, resulting in the seeds are fallen directly below parent trees (Y. Zhu et al., 2015). During research, we also observed that the seeds of those species were near their large trees.

Secondly, there are also group of plants in which small plants are not associated with large plants. The small plants tend to grow far from their large plants such as found in first group, second group and third group. Species such as-*Hopea iriana, Rhodomyrtus* sp., *Blumeodendron tokbrai, Calophyllum caudatum, Orania disticha, Parastemon versteeghii, Pimelodendron amboinicum, Planchonella anteridifera, Pometiaacuminate, Virola surinamensis*and *Gironniera subaequalis* showed the distance between small and large plants, showing a negative dependence to parent trees (Pérez-Méndez et al., 2015). Those small individuals are not beneath their large trees. For that reason, the small plants were distributed separately with large plants as shown in DCA result (Figure 1). In the field of tropical forest, the small plants rarely grow below their large plants as parent trees, or in some cases the small individuals are absent (Baldeck et al., 2013). We also noted that it is also very infrequent to see fruits or seeds of those species near their large plants. That is probably because of that the presence of animals such as birds, bats, and rodents feeding the fruits. Other study showed that the presence of rodents in tropical forest will contribute in recruitments of plants and its distribution (Velho, Isvaran, & Datta, 2012). Then, the animals play a crucial role in seed dispersals of those species (Chapman & Chapman, 1995). Besides that, the seed size is small, bringing about the seeds are easier to be dispersed by the animals (Seidler & Plotkin, 2006; Theimer, Gehring, Green, Connell, & Theimer, 2016). Probably, there are other reasons to explain the phenomena like allelopathic potential in inhibiting growth of other plants including their young individuals (Cummings, Parker, & Gilbert, 2012; Ladwig, Meiners, Pisula, & Lang, 2013; Silva Matos & Belinato, 2010; Zhang & Fu, 2009), but we did not observe during research. Hence, more details of discussion are not presented in this paper.

Finally, results of this study give a contribution of plant diversity in natural tropical rain



Blu_to	*Blumeodendron tokbrai* (Blume) Kurz
Cal_ca	*Calophyllum caudatum* Kaneh. & Hatus.
Can_as	*Canarium asperum* Benth.
Gir_su	*Gironniera subaequalis* Planch.
Gym_fa	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb.
Hop_ce	*Hopea celtidifolia* Kosterm.
Hop_ir	*Hopea iriana* Slooten
Hy_bec	*Hydriastele beccariana* Burret
Mel_el	*Melicope elleryana* (F. Muell.) T.G. Hartley
Or_dis	*Orania disticha* Burret
Par_ve	*Parastemon versteeghii* Merr. & L.M.Perry
Pim_am	*Pimelodendron amboinicum* Hassk.
Pla_an	*Planchonella anteridifera* (C.T.White & W.D.Francis ex Lane-Poole) H.J.Lam
Pom_ac	*Pometia acuminata* Radlk.
Pru_ar	*Prunus arborea* (Blume) Kalkman
Rho_sp.	*Rhodomyrtus* sp.
Syz_an	*Syzygium anomalum* Lauterb.
Vat_ra	*Vatica rassak* Blume
Vir_su	*Virola surinamensis* (Rol. ex Rottb.) Warb.

Figure 2. Detrended correspondence analysis (DCA) to analyze association of small plants and large plants of each species. Letter before dash (-) S stands for small plant and L stands for large plant. Distribution of individuals in the graph show association where if they are closer, meaning that the associations are strong and vice versa.

forest which from pteridophytes, angiosperms and gymnosperms. The densities of each species can be used as population condition in natural rainforest. Those information of plant diversity can be specifically used as future researches on how local people utilize them such as medicinal plants e.g. (Abdullah & Mustikaningtyas, 2010; Irawan, Fitmawati, & Herman, 2013). Therefore, conservation and management programs can be supported by using this information. Moreover, there are number of species have not been identified where in this research species were taxonomically named as "sp.". This condition reveals that future researches especially regarding taxonomic topics are needed to uncover plant biodiversity taxonomically in natural tropical forest.

The conspecific association has discovered that in forest the small individuals are not consistently present and grow along with the large individuals. In some cases, small individuals as juvenile phase are missing even though the mature individuals are present.

CONCLUSIONS

There are species found from pteridophytes, angiosperms and gymnosperms that were grouped as herbs, orchids, palms, pandans, shrubs, rattans, vines and trees. Trees are the most abundant according to number of species. In the, dominant plant species, two types of conspecific association occurred between small individuals and large individuals. Analysis of DCA revealed that there are large plant species grow along with their small individuals like *Vatica rassak, Hydriastele beccariana, Syzygium anomalum, Canarium asperum, Gymnacranthera farquhariana* and *Prunus arborea*. Another type is that small individuals grow far from their large individuals such as *Blumeodendron tokbrai*, *Calophyllum caudatum*, *Orania disticha*, *Parastemon versteeghii*, *Pimelodendron amboinicum, Planchonella anteridifera, Pometia acuminata* and *Virola surinamensis*.

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