Heterospecific and conspecific associations of trees in lowland tropical forest of New Guinea

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Abstract. Murdjoko A, Jitmau MM, Djitmau DA, Siburiyan RH, Ungirwala A, Wanma AO, Mardiyadi Z, Rumatora A, Moffe WY, Sineri AS, Fatem SM, Worabai D, May NL, Tokede MJ, Warmetan H, Wanggai CB, Wanma JF, Sirami EV, Paembonan JB, Unenor E, Kuswandi R, Lekito M, Khayati L, Benu NMH, Tambing J, Saragh ASB. 2020. Heterospecific and conspecific associations of trees in lowland tropical forest of New Guinea. Biodiversitas 21: 4405-4418. The vegetation in the tropical rainforest of New Guinea consists of a large number of species that interact with each other within and among species. While several studies have attempted to reveal the diversity of flora of New Guinea, little is known about plant communities that develop associations. This study aimed to investigate the associations of tree species in lowland tropical forest in New Guinea. The associations depicted in this study were in the form of conspecific associations (among small and large individuals within same species) and heterospecific (among individuals of different species and divided into under and upper story). We established 48 rectangular plots created in Murkim and Teirawul as part of Pegunungan Bintang District, Papua Province. Canonical correspondence analysis (CCA) was used to analyze heterospecific and conspecific associations. The results showed that the understory and upper story vegetation had different patterns of heterospecific association. The understory configured three heterospecific associations, consisting of 5, 13, and 90 species, while the upper story formed four heterospecific associations with 4, 8, 11, and 63 species. The analysis of conspecific associations showed of 149 tree species recorded in the study sites, only 66 species that had both small and large individuals, displaying the pattern of conspecific association. Among them, 41 species had positive associations while 25 species had negative associations. Our findings enrich the knowledge in theoretical ecology of tropical forests, especially in New Guinea.

Keywords: Canonical correspondence analysis, CCA, Papuasia, tree community, tropical rainforest, vegan package

INTRODUCTION

Tropical rainforest is a complex ecosystem with many interactions between abiotic and biotic factors, particularly among vegetation (Vitousek 1984; Thomas and Baltzer 2002; Hunter et al. 2015). This complexity results in the vegetation that consists of many life forms from vertical and horizontal compositions that interact with each other to obtain sunlight, soil nutrients, and water, and to adapt with microclimatic conditions (Slik et al. 2015, 2018; Murdjoko et al. 2016a). The interactions among vegetation have occurred over a long period due to successional process (Fernández-Lugo et al. 2015). Where the vegetation shares the same ecological condition, the morphological and physiological characters become the driving factors of behavior in the natural tropical rainforest (Gustafsson et al. 2016; Johnson et al. 2017). The interactions among vegetation elements in the tropical rainforest in some cases represent symbiosis and inter and intra-species relationships (Legende and Fortin 1989; Magrach et al. 2014). These interactions can be in the form of competition and association. In old tropical rainforest, the interaction occurs intensively due to the absorption of light and water, where both are the primary growth factors (Yamamoto 2000; Montgomery and Chazdon 2001). In secondary forest, canopy gap is very open, leading to more light penetrating the forest floor (Itoh et al. 1997; Angelini et al. 2015; Murdjoko et al. 2017).

The association in vegetation communities can be in the form of conspecific or heterospecific and the form of association determines the pattern of the spatial distribution of forest ecosystems either. Conspecific association is the interaction of individuals of similar species while heterospecific occurs among different species of vegetation.
(Zhu et al. 2015; Wang et al. 2018). Conspecific and heterospecific associations occur during the successional process of the tropical rainforest (Farneda et al. 2018). Some studies explained that the association, either the conspecific or the heterospecific could be in a positive or negative pattern (Castilla et al. 2016).

Vegetation is distributed geographically with the diversity and pattern of plant communities that adapt to particular ecological niche (Brummitt 2001; Pan et al. 2013). Phytogeographic regions, including mainland New Guinea, have been studied for centuries. The vegetation in New Guinea spreads from coastal to high land areas, containing various types of ecosystems (Cámara-Leret and Dennehy 2019). As the result, New Guinea contains the highest diversity of flora, such as trees, climbers, shrubs, ferns, rattan, etc. (Murdjoko et al. 2016a) in which about 60% of the species are endemic (Cámara-Leret et al. 2020). For example, a forest area in New Guinea consists of a high diversity of tree species with more than 70 species per hectare that could be found (Robiansyah 2018; Fatem et al. 2020). While recently more and more studies have attempted to reveal the diversity of flora of New Guinea, little is known about plant communities that develop associations among them.

This study aimed to investigate the association of tree species in the lowland tropical forest in New Guinea. The associations depicted in this study were in the form of conspecific associations (among small and large individuals within same species) and heterospecific (among individuals of different species and divided into under and upper story). We hypothesized that the small and large tree species have heterospecific associations within the natural tropical rain forest. This kind of study is important to provide specific contribution of ecological research in the tropical rain forest of Southeast Asia, more specifically the New Guinea region (Brummitt 2001).

**MATERIALS AND METHODS**

**Study period and area**

This study was conducted in the northern part of Pegunungan Bintang District (Ind.: kabupaten), Papua Province, Indonesia (Figure 1). The study sites were located at Murkim (4°00'53"S and 140°49'17.24"E) and Teiraplu (3°59'13.46"S and 140°26'0.06"E) at an altitude of 155 m and 233 m above sea level (m asl), respectively. The ecosystem type of the two study sites are categorized as lowland areas where the southern part is bordered with the mountain range and the northern part is bordered with hills while the western and eastern parts are lowlands. Broadleaves and mixed forests are the dominant vegetation in this area, while the soil is grouped as Ultisols and Inceptisol. The climatic conditions are considered to be very humid with average temperature of 25°C for annual, 20.6°C for daily, and 16.3°C for minimum, and with monthly and annual average rainfall of 448.75 mm and 5385 mm, respectively (Kartikasari et al. 2012).

**Sampling and data collection**

Data were collected using sampling plot method with size of each plot 20 m x 20 m. In total, there were 48 rectangular plots established in which 24 plots were in Teiraplu and 24 plots were in Murkim. In both locations, the plots were placed to north directions at a distance of 100 m away from each other. In the 20 m x 20 m plot (A) we recorded and measured old trees with a diameter of more than 20 cm, and within this plot we established three nested sub-plots with size 10 m x 10 m (B) to record tree with diameter between 10 cm and 20 cm, size 5 m x 5 m (C) to record trees taller than 1.5 m, and size 2 m x 2 m (D) to record the species shorter than 1.5 m. The vegetation in plots A and B were classified as upper story and that in plots C and D were categorized as understory. For the understory vegetation, we recorded data of taxonomic names of every species and number of individuals, and while for the upper story vegetation we recorded data of taxonomic names of every species, number of individuals, and diameter (cm).

For identification, we collected the specimens of the plant and sent it to the Herbarium Papuense of Balai Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Manokwari and Herbarium Manokwariense (MAN) Pusat Penelitian Keanequaragaman Hayati Universitas Papua (PPKH-UNIPA), Manokwari. The species name was updated according to The Plant List (TPL) at the website of http://www.thepartlist.org/.

**Statistical analysis**

The heterospecific and conspecific associations were analyzed using the canonical correspondence analysis (CCA) (Ter Braak 1986; Caceres and Legendre 2009), and the chi-square test ($\chi^2$) was implemented to validate the model of CCA (Fatem et al. 2020). Furthermore, this association used the number of each individual (density) as a value in which the columns were the species and the rows were the 48 plots. The conspecific association correlated the under and upper story as small and large individuals. The columns represented the species, while the 48 plots under and upper story represented the rows. The species that did not have under and upper stories were otherwise excluded. The result of CCA displayed species in the graph with the position in the two axes. To investigate the conspecific association whether it was positive or negative, the Euclidean distance between each species as well as the under and upper stories were conducted (Murdjoko et al. 2016b, 2017). If the result of Euclidean distance of species is below the average, then the conspecific association is said to be positive, and vice versa. The vegan package in R version 3.5.3 was used to calculate the statistical analysis (Oksanen et al. 2019).
RESULTS AND DISCUSSION

Heterospecific associations

The heterospecific association was grouped into two: understory and upper story, based on the structure of trees in tropical forests. As such, the analyses of multivariate statistics for the understory and upper story were separated since the natural tropical rainforest is complex with the vegetation structures forming the ecosystem. The structure was also simplified by distinguishing them into two main parts.

From the CCA result, the understory and upper story showed different patterns of heterospecific association. The understory configured three groups of communities based on species as the structure of the associations. The three groups are shown in Figure 2.

The results showed that 108 species of trees formed the association in natural tropical forests, and was valid statistically as $\chi^2 = 10.686$, df = 2461, p-value = 1. The species of understory showed heterospecific associations as tree groups where the first consisted of 90 species (blue boxes), the second contained 13 (green boxes), and the third comprised of 5 species (red boxes) (Figure 2). The name of the species in the boxes in Figure 2 was abbreviated and the complete name can be seen in Table S1.

The CCA result showed that the upper story vegetation community had a pattern of association with a valid result of $\chi^2 = 11.344$, df = 1955, p-value = 1. The upper story consisted of 86 species which formed four heterospecific associations, consisting of the first group (63 species) in the grey boxes, second group (11 species) in the red boxes, third group (8 species) in the purple boxes, and fourth group (4 species) in the blues boxes (Figure 3). The complete name of species presented in Figure 3 can be seen in Table S2.

The association pattern of the understory and upper story differed from one another even though they grew in the same natural forest. The difference in association has likely resulted from the variation of the vertical structure of the tropical forest. The upper story vegetation has reached the emergent layers of forest canopy, allowing species to benefit by getting more sunlight (Murdjoko et al. 2016a, 2017; Fatem et al. 2020). The formation of understory was caused by competition due to it is below the canopy layers with low solar radiation (Rüger et al. 2011; Laurans et al. 2014; Angelini et al. 2015).

For centuries, the formation of tropical forests has been a sequential process in which large numbers of species compete dynamically each other (Brown et al. 1990; Wright and Muller-Landau 2006; Liu and Slik 2014; Almeida et al. 2019). The heterospecific association can be related to the fact that trees interact with each other to form symbiosis with other life forms, such as liana, fern, herb, epiphyte, etc. (Johnson et al. 2017; Cirimwami et al. 2019; Steege et al. 2019). The primary factor influencing the pattern of tree communities of understory and upper story during tropical forest succession was probably caused by the abiotic factors, especially to gain nutrients, water, and sunlight as materials to support metabolisms, especially photosynthesis. Nonetheless, many studies showed that the morphological and physiological characters have also affected different responses of species to grow and develop (Goodale et al. 2012; Gustafsson et al. 2016). For example, the nature of shade tolerance species may be a factor that allows small tree species to survive the competition and obtain limited sunlight below the canopy layers (Givnish 1999; Montesinos-Navarro et al. 2018). Therefore, it is
crucial to study the shade-tolerant characters of a species in the rainforest in order to explain forest dynamics in more detail. This study is unable to reveal such characters concerning the light competition because that is beyond the scope of this study.

Conspecific associations

The analysis of conspecific associations was conducted using 149 species that grew in the study sites, but only 66 species that had small and large individuals as understory and upper story. The result of CCA showed statistically valid result as χ² = 5.8784, df = 2904, p-value = 1 (Figure 4). In addition, it displayed the pattern of conspecific association as 41 species had positive association while 25 species had negative association. In the positive association, the small and large individuals of the 41 species were distributed closely in the same area, representing the tendency of mature trees to reproduce and germinate. Conversely, in the negative association, the small individuals of the 25 species grew mainly far from the large ones that represent the matured trees. The full list of the taxonomic name of the species in Figure 4 is presented in Table S3, and the conspecific association can be used to analyze their density dependence since the tropical forest is the place for the high diversity of trees.

Of 149 species, 83 species did not have either small or large individuals, suggesting that the species experienced poor regeneration. Some large individuals act as putative parent trees, even though they have failed to establish seedlings due to many factors (Seidler and Plotkin 2006; Rahman and Tsukamoto 2015). One possible factor is caused by the competition of seedlings with other plants on the forest floor, on which many life forms are found. Another rationale is that the seeds and seedlings are eaten by herbivores (Swaine et al. 1987; Houter and Pons 2014).

Many studies have reported that herbivores are found in tropical rainforest since the forest provides a lot of food, for example, during germination, the dicotyledonous tree plants develop shoot from the plumule of the germinating seed (Houter and Pons 2014; Sawada et al. 2015).

The distribution of individual trees in tropical forests is influenced by the ability to interact with other species. This pattern of conspecific association should be studied frequently to figure out the method of regeneration and distribution of species. Forest floor encompasses many species with different life forms as a strategy to survive and grow during the competition (Dezzotti et al. 2019). Many lianas and climbers grow fast to occupy the forest canopy and space available for sunlight. These plants suppress a certain seedling establishment (Carreño-Rocabado et al. 2012). The competition to gain sunlight, nutrition, and water is presumed as the limiting factor suffered by some species since they cannot survive below putative parent trees.

Seed dispersal can be the driving force behind the spatial distribution of plants in tropical forests. Moreover, the morphological and anatomical characters of seeds and fruits also influence species regeneration and distribution. For example, small and winged seeds of tree species can spread out by falling around and away from the parent trees (Sebbenn et al. 2008; Lü and Tang 2010). However, factors such as competition, herbivory, and allelopathy have led to a clear and negative association in natural tropical forests (Padmanaba and Corlett 2014; Menezes et al. 2019). In contrast, large seeds mostly fall around the parent trees and since they survived germination, they can grow as positive conspecific associations. Therefore, the conspecific association pattern should be studied to know the natural regeneration of certain species in tropical rainforest.

**Figure 2.** The result of Canonical Correspondence Analysis (CCA) to analyze the heterospecific associations for understory.
Figure 3. The result of Canonical Correspondence Analysis (CCA) to analyze the heterospecific associations for the upper story

Figure 4. The result of Canonical Correspondence Analysis (CCA) to analyze conspecific associations between the small and the large individuals of the same species
The implication of associations to ecological knowledge for sustainable management of primary forest

The study of conspecific and heterospecific associations in tropical rainforest is extremely important to determine the spatial distribution pattern, especially the conspecific association. In addition, a model of natural regeneration of tree species can be described, and the result can indicate the pattern of recruitment in the population dynamics of tree species (Goodale et al. 2012; Piotto et al. 2019). Tropical rainforest is primarily dominated by flowering plants with their reproduction season is in annual period (Baker et al. 1998; Pan et al. 2013; Câmara-Leret et al. 2020). Furthermore, a suitable area for certain species to grow has resembled in the conspecific association since the study correlates small individuals with the large ones within the same species. The pattern of conspecific association can also be used to observe natural regeneration. For example, the most appropriate area to plant tree species in-situ conservation programs can be decided when artificial regeneration is necessary (Armstrong et al. 2011; Vergara-Rodriquez et al. 2017). The heterospecific association describes the pattern of growth in tropical rainforest since the forest includes the great diversity of tree species. The forest took several decades to develop, and this present study has been able to analyze the pattern of tree species association. Ecological studies on the theme of species association in tropical rainforest need to be replicated in other contexts of region, ecosystem type and forest conditions as tropical forest is very complex as made up of different life forms that interact and create vertical and horizontal structures in the climax phase of the successional process (Chazdon 2003; Brokaw and Scheiner 2012).

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| No. | Code  | Species                                           | Group 1 | Group 2 | Group 3 |
|-----|-------|---------------------------------------------------|---------|---------|---------|
| 1   | Kiba_ch | *Kibara coryacea* (Blume) Hook. f. & A. Thomps.  | +       |         |         |
| 2   | Rhus_la | *Rhus lamprocarpa* Merr. & L.M.Perry              | +       |         |         |
| 3   | Dios_pi | *Diospyros pilosanthera* Blanco                  | +       |         |         |
| 4   | Lits_le | *Lithsea ledermannii* Tscherner                  | +       |         |         |
| 5   | Maca_gi | *Macaranga gigantea* (Rchb.f. & Zoll.) Müll.Arg. | +       |         |         |
| 6   | Maca_ta | *Macaranga tanarius* (L.) Müll.Arg.              | +       |         |         |
| 7   | Seme_pa | *Semecarpus papuana* Lauterb.                   | +       |         |         |
| 8   | Ster_sh | *Sterculia shillinglawii* F.Muell.              | +       |         |         |
| 9   | Case_cq | *Casearia carrii* Sleumer                      | +       |         |         |
| 10  | Xant_no | *Wendlandia* sp                             | +       |         |         |
| 11  | Teij_bo | *Teijsmanniodendron bogoriense* Koord.        | +       |         |         |
| 12  | Flin_pi | *Flindersia pimenteliana* F.Muell.               | +       |         |         |
| 13  | Case_sp | *Casearia* sp                                 | +       |         |         |
| 14  | Hapl_ce | *Haplolobus celebicus* H.J.Lam                | +       |         |         |
| 15  | Myri_en | *Myristica ensifolia* J.Sinclair              | +       |         |         |
| 16  | Octa_in | *Octamyrus insignis* Diels                    | +       |         |         |
| 17  | Piso_lo | *Pisonia longirostris* Teijsm. & Binn.        | +       |         |         |
| 18  | Wend_sp | *Wendlandia* sp                             | +       |         |         |
| 19  | Timo_ca | *Timonius carrii* S.P.Darwin                    | +       |         |         |
| 20  | Prun_ja | *Prunus javanica* (Teijsm. & Binn.) Miq.     | +       |         |         |
| 21  | Hapl_fl | *Haplolobus floribundus* (K.Schum.) H.J.Lam | +       |         |         |
| 22  | Anti_de | *Alstonia spectabilis* R.Br.                   | +       |         |         |
| 23  | Buch_ar | *Buchanania arborescens* (Blume) Blume       | +       |         |         |
| 24  | Cryp_pa | *Crypocarya palmerensis* C.K.Allen            | +       |         |         |
| 25  | Gmel_se | *Gmelina sessilis* C.T.White & W.D.Francis ex Lane-Poole | + |         |         |
| 26  | Garci_pi | *Garcinia pictorhiza* Miq.                  | +       |         |         |
| 27  | Para_ve | *Parastemon versteegii* Merr. & L.M.Perry | +       |         |         |
| 28  | Knem_in | *Knema intermedia* Warb.                   | +       |         |         |
| 29  | Case_mo | *Casearia monticola* Sleumer                    | +       |         |         |
| 30  | Half_ke | *Halfordia kendack* Guillaumin                | +       |         |         |
| 31  | Syzy_ve | *Syzygium versteegii* (Lauterb.) Merr. & L.M.Perry | + |         |         |
| 32  | Ficu_ro | *Ficus robusta* Corner                         | +       |         |         |
| 33  | Heri_sy | *Heritiera sylvatica* S.Vidal                | +       |         |         |
| 34  | Cerb_fl | *Cerbera floribunda* K.Schum.              | +       |         |         |
| 35  | Myri_gl | *Myristica globosa* Warb.                    | +       |         |         |
| 36  | Dryp_gl | *Drypetes globosa* (Merr.) Pax & K.Hoffm.   | +       |         |         |
| 37  | Phal_ma | *Phaleria macrocarpa* (Scheff.) Boerl.        | +       |         |         |
| 38  | Cana_ri | *Canarium rigidum* (Blume) Zipp. ex Miq.     | +       |         |         |
| 39  | Lits_ti | *Lithsea timoriana* Span.                  | +       |         |         |
| 40  | Timo_di | *Timonius timon* (Spreng.) Merr.            | +       |         |         |
| 41  | Homa_lo | *Heritiera sylvatica* S.Vidal                | +       |         |         |
| 42  | Endo_me | *Endospermum medulosum* L.S.Sm.                 | +       |         |         |
| 43  | Pome_pi | *Pometia pinnata* J.R.Forst. & G.Forst.      | +       |         |         |
| 44  | Kiba_bu | *Kibara bullata* Philipson                    | +       |         |         |
| 45  | Drac_da | *Dracantomelon dao* Blanco (Blanco) Merr. & Rolfe | + |         |         |
| 46  | Goni_gi | *Goniothalamus giganteus* Hook.f. & Thomson | +       |         |         |
| 47  | Nauc_or | *Nauclea orientalis* (L.) L.                  | +       |         |         |
| 48  | Beil_mo | *Beilschmiedia morobensis* Kosterm.           | +       |         |         |
| 49  | Cara_br | *Carallia brachiata* (Lour.) Merr.            | +       |         |         |
| 50  | Lits_sp | *Lithsea* sp                             | +       |         |         |
| 51  | Pime_am | *Pimelodendron amboinicum* Hassk.            | +       |         |         |
| 52  | Medu_la | *Medusandra laxiflora* (Miers) R.A.Howard | +       |         |         |
| 53  | Myri_fa | *Myristica fatica* Hoult.                | +       |         |         |
| 54  | Gono_li | *Gonocaryum litorale* (Blume) Sleumer        | +       |         |         |
| 55  | Lith_ru | *Lithocarpus rufovillosus* (Markgr.) Rehder  | +       |         |         |
| 56  | Hope_pa | *Hopea papuana* Diels                | +       |         |         |
| 57  | Dill_pa | *Dillenia papuana* Martelli            | +       |         |         |
| 58  | Mast_pa | *Mastixiodendron pachyclados* (K.Schum.) Melch. | + |         |         |
| 59  | Pome_ac | *Pometia acuminata* Radlk.                   | +       |         |         |
| 60  | Kiba_el | *Kibara elongata* A.C.Sm.                    | +       |         |         |
| 61  | Clei_pa | *Cleistanthus papuanus* (Lauterb.) Jabl.     | +       |         |         |
| 62  | Ints_pa | *Intsia palembanica* Miq.                  | +       |         |         |
| 63  | Galb_be | *Galbulimima belgraveana* (F.Muell.) Sprague | +       |         |         |
| No. | Term_co | Terminalia copelandi | Elmer                  |
|-----|---------|---------------------|-----------------------|
| 64  | Giro_ne | Gironniera nervosa  | Planch.               |
| 65  | Mani_pl | Maniltoa plurijuga  | Merr. & L.M.Perry     |
| 66  | Hope_ce | Hopea celtidifolia  | Kosterm.              |
| 67  | Meli_el | Melicope elleryana  | (F. Muell.) T.G. Hartley |
| 68  | Garc_sp | Garcinia sp         |                       |
| 69  | Pala_lo | Palaquium lobbianum | Burck                |
| 70  | Camp_br | Campnosperma brevipetiolatum | Volkens |
| 71  | Ster_ma | Sterculia macrophylla | Vent.             |
| 72  | Harp_ca | Harpallia carrii   | Leenh.               |
| 73  | Hors_la | Horsfieldia laevigata | Warb.            |
| 74  | Arch_pa | Archidendron parviflorum | Pulle     |
| 75  | Chry_pa | Chrysophyllum papuanicum (Pierre ex Dubard) Royen |
| 76  | Fagr_ra | Fagraea racemosa    | Jack                  |
| 77  | Klei_ho | Kleinhovia hospita  | L.                    |
| 78  | Endi_ru | Endiandra rubescens (Blume) Miq. |
| 79  | Tris_ma | Tristaniopsis macrosperma (F.Muell.) Peter G.Wilson & J.T.Waterh. |
| 80  | Cory_la | Corynocarpus laevigatus J.R.Forst. & G.Forst. |
| 81  | Cryp_sp | Cryptocarya sp     |                       |
| 82  | Tab_ga | Tabernaemontana aurantiaca | Gaudich. |
| 83  | Mali_sp | Mallotus sp       |                       |
| 84  | Deca_pa | Decaspermum parviflorum (Lam.) A.J.Scott |
| 85  | Agla_sp | Aglaia spectabilis (Miq.) S.S.Jain & S.Bennet |
| 86  | Rapa_te | Raphanea tempuspan P.Royen |
| 87  | Calo_ca | Calophyllum caudatum | Kaneh. & Hatus. |
| 88  | Xant_pa | Xanthophyllum papuanum Whitmore ex Meijden |
| 89  | Hapl_la | Haplolobus lanceolatus H.J.Lam ex Leenh. |
| 90  | Alst_sp | Alstonia spectabilis R.Br. |
| 91  | Dios_sp | Diospyros sp       |                       |
| 92  | Elae_an | Elaeocarpus angustifolius Blume |
| 93  | Rypa_ja | Ryparocarpus javanica Koord. & Valeton |
| 94  | Rhod_ci | Rhodamnia cinerea | Jack                  |
| 95  | Myri_gi | Myristica gigantea | King                  |
| 96  | Anti_to | Antiaris toxicaria | Lesch.                |
| 97  | Calo_in | Calophyllum inophyllum | L.       |
| 98  | Para_pr | Pararachidendron pruinosum (Benth.) I.C.Nielsen |
| 99  | Siph_ce | Siphonodon celastrineus Griff. |
| 100 | Siph_sp | Siphonodon sp     |                       |
| 101 | Maas_gl | Maasia glauca (Hassk.) Mols, Kessler & Rogstad |
| 102 | Term_ka | Terminalia kaernbacchii Warb. |
| 103 | Spath_ja | Spathiolepis javensis Blume |
| 104 | Dyso_mo | Dysoxylum mollissimum Blume |
| 105 | Plan_ke | Planchonella keyensis H.J.Lam |
| 106 | Ficus_sp | Ficus sp       |                       |
| 107 | Hors_pa | Horsfieldia parviflora (Roxb.) J.Sinclair |
| No. | Code  | Species                                              | Group 1 | Group 2 | Group 3 | Group 4 |
|-----|-------|------------------------------------------------------|---------|---------|---------|---------|
| 1   | Hors_ir | *Horsfieldia irya* (Gaertn.) Warb.                   |         | +       |         |         |
| 2   | Garc_la | *Garcinia latissima* Miq.                            |         | +       |         |         |
| 3   | Alst_sc | *Alstonia scholaris* (L.) R. Br.                     |         | +       |         |         |
| 4   | Endi_vi | *Endiandra virens* F.Muell.                          |         | +       |         |         |
| 5   | Siox_pu | *Sloanea pullei* O.C.Schmidt ex A.C.Sm.              |         |         | +       |         |
| 6   | Galh_be | *Galbulima belgraevana* (F.Muell.) Sprague           |         |         | +       |         |
| 7   | Pome_sc | *Pometia acuminata* Radlk.                           |         | +       |         |         |
| 8   | Chis_ce | *Chisocheton ceramicus* Miq.                         |         | +       |         |         |
| 9   | Dyso_mo | *Dysoxylum mollissimum* Blume                        |         | +       |         |         |
| 10  | Endo_me | *Endospernum medullosum* L.S.Sm.                     |         | +       |         |         |
| 11  | Pime_am | *Pimelodendron amboinicum* Hassk.                    |         | +       |         |         |
| 12  | Gono_li | *Gonocaryum littorale* (Blume) Sleumer               |         | +       |         |         |
| 13  | Stre_el | *Streblus elongatus* (Miq.) Corner                   |         | +       |         |         |
| 14  | Homa_fo | *Heritiera sylvatica* S.Vidal                       |         | +       |         |         |
| 15  | Gnet_gn | *Gnetum gnemon* L.                                   |         | +       |         |         |
| 16  | Homa_no | *Homalanthus novoguineensis* (Warb.) K.Schum.        |         | +       |         |         |
| 17  | Cory_la | *Corynocarpus laevigatus* J.R.Forst. & G.Forst.      |         | +       |         |         |
| 18  | Drac_da | *Dracomontomen dao* (Blanco) Merr. & Rolfe           |         | +       |         |         |
| 19  | Cana_od | *Canarium indicum* L.                                |         | +       |         |         |
| 20  | Pter_be | *Pterocymbium beccarii* K.Schum.                     |         | +       |         |         |
| 21  | Pala_lo | *Palaquium lobbianum* Burck                          |         | +       |         |         |
| 22  | Cana_in | *Canarium indicum* L.                                |         | +       |         |         |
| 23  | Cara_br | *Carallia brachiata* (Lour.) Merr.                   |         | +       |         |         |
| 24  | Timo_ca | *Timonius carri* S.P.Darwin                          |         | +       |         |         |
| 25  | Hors_sy | *Horsfieldia sylvestris* Warb.                       |         | +       |         |         |
| 26  | Maas_su | *Maassia sumatrana* (Miq.) Mols, Kessler & Rogstad  |         | +       |         |         |
| 27  | Hope_pa | *Hopea papuana* Diels                                |         | +       |         |         |
| 28  | Hope_ce | *Hopea celtidifolia* Kosterm.                        |         | +       |         |         |
| 29  | Rhus_ta | *Rhus taitensis* Guill.                              |         | +       |         |         |
| 30  | Acti_ni | *Actinodaphne nitida* Teschner                       |         | +       |         |         |
| 31  | Dill_pa | *Dillenia papuanae* Martelli                         |         | +       |         |         |
| 32  | Medu_la | *Medusanthera laxiflora* (Miers) R.A.Howard         |         | +       |         |         |
| 33  | Teij_bo | *Teijsmanniodendron bogoriense* Koord.               |         | +       |         |         |
| 34  | Tris_ma | *Tristaniopsis macroperma* (F.Muell.) Peter G.Wilson & J.T.Waterh. |         | +       |         |         |
| 35  | Call_lo | *Callicarpa longifolia* Lam.                         |         | +       |         |         |
| 36  | CommBa | *Commersonia bartramiaria* (L.) Merr.                |         | +       |         |         |
| 37  | Dios_pi | *Diospyros pilosanthera* Blanco                      |         | +       |         |         |
| 38  | Knem_in | *Knema intermedia* Warb.                             |         | +       |         |         |
| 39  | Dryp_gl | *Drypetes globosa* (Merr.) Pax & K.Hoffm.           |         | +       |         |         |
| 40  | Cryp_pa | *Cryptocarya palmerensis* C.K.Allen                 |         | +       |         |         |
| 41  | Meli_el | *Melicope elleryana* (F. Muell.) T.G. Hartley       |         | +       |         |         |
| 42  | Lits_t | *Litsia timoriana* Span.                             |         | +       |         |         |
| 43  | Siph_ce | *Siphonodon celastrineus* Griff.                     |         | +       |         |         |
| 44  | Siph_sp | *Siphonodon sp*                                      |         | +       |         |         |
| 45  | Vite_pi | *Vitex pinnata* L.                                   |         | +       |         |         |
| 46  | Poly_no | *Polyscias nodosa* (Blume) Seem.                     |         | +       |         |         |
| 47  | Pome_pi | *Pometia pinnata* J.R.Forst. & G.Forst.              |         | +       |         |         |
| 48  | Agla_ar | *Aglaias argentea* Blume                             |         | +       |         |         |
| 49  | Acr_so | *Acronychia sp*                                      |         | +       |         |         |
| 50  | Gmel_se | *Gmelina sessilis* C.T.White & W.D.Francis ex Lane-Poole |         | +       |         |         |
| 51  | Mani_br | *Maniloba brownoides* Harms                          |         | +       |         |         |
| 52  | Prun_ar | *Prunus arborea* (Blume) Kalkman                    |         | +       |         |         |
| 53  | Camp_br | *Campnosperma brevipediolatum* Volkens               |         | +       |         |         |
| 54  | Hors_la | *Horsfieldia laevigata* Warb.                        |         | +       |         |         |
| 55  | Cana_hi | *Campnosperma brevipediolatum* Volkens               |         | +       |         |         |
| 56  | Deca_pa | *Decaspernum parviflorum* (Lam.) A.J.Scott           |         | +       |         |         |
| 57  | Calo_in | *Calophyllum inophyllum* L.                          |         | +       |         |         |
| 58  | Heri_sy | *Heritiera sylvatica* S.Vidal                       |         | +       |         |         |
| 59  | Clei_pa | *Cleistanthus papaunus* (Lauterb.) Jabl.            |         | +       |         |         |
| 60  | Elae_an | *Elaeocarpus angustifolius* Blume                   |         | +       |         |         |
| 61  | Gyman_fa | *Gymnacanthera farquhariana* (Hook.f. & Thomson) Warb. |         | +       |         |         |
| 62  | Grew_er | *Grewia eriocarpa* Luss.                             |         | +       |         |         |
| 63  | Xant_no | *Wendlandia sp*                                      |         | +       |         |         |
| Ref  | Common Name       | Scientific Name                                                                 |
|------|-------------------|---------------------------------------------------------------------------------|
| 64   | Rhod_ci           | *Rhodamnia cinerea* Jack                                                        |
| 65   | Arto_al           | *Artocarpus altillis* (Parkinson ex F.A.Zorn) Fosberg                          |
| 66   | Para_pr           | *Pararchidendron pruinum* (Benth.) I.C.Nielsen                                  |
| 67   | Plan_ke           | *Planchonella kevensis* H.J.Lam                                                 |
| 68   | Dios_pa           | *Diospyros papuana* Valeton ex Bakh.                                             |
| 69   | Ochr_gl           | *Ochrosia glomerata* (Blume) F.Muell.                                           |
| 70   | Myri_fa           | *Myristica fata* Houtt.                                                          |
| 71   | Ster_sh           | *Sterculia shillinglawii* F.Muell.                                              |
| 72   | Syzy_sp2          | *Syzygium sp2*                                                                  |
| 73   | Syzy_sp3          | *Syzygium sp3*                                                                  |
| 74   | Xant_pa           | *Xanthophyllum papuanum* Whitmore ex Meijden                                     |
| 75   | Euca_pa           | *Eucalyptopsis papuana* C.T.White                                                |
| 76   | Flin_pi           | *Flindersia pimenteliana* F.Muell                                               |
| 77   | Hapl_fl           | *Haplolobus floribundus* (K.Schum.) H.J.Lam                                     |
| 78   | Lits_fi           | *Litsea firma* (Blume) Hook.f.                                                   |
| 79   | Term_co           | *Terminalia copelandi* Elmer                                                    |
| 80   | Calo_ca           | *Calophyllum caudatum* Kaneh. & Hatus.                                           |
| 81   | Coch_gi           | *Cochlospermum gillivraei* Benth.                                               |
| 82   | Buch_ar           | *Buchanania arborescens* (Blume) Blume                                          |
| 83   | Fagr_el           | *Fagraea elliptica* Roxb.                                                        |
| 84   | Prun_ja           | *Prunus javanica* (Teijsm. & Binn.) Miq.                                         |
| 85   | Endi_ru           | *Endiandra rubescens* (Blume) Miq.                                               |
| 86   | Cryp_sp           | *Cryptocarya sp*                                                                |
| No. | Code  | Species                                               |
|-----|-------|-------------------------------------------------------|
| 1   | Agla_ar | Aglaia argentea Blume                                |
| 2   | Agla_ar | Aglaia argentea Blume                                |
| 3   | Buch_ar | Buchanania arborescens (Blume) Blume                 |
| 4   | Buch_ar | Buchanania arborescens (Blume) Blume                 |
| 5   | Calo_ca | Calophyllum caudatum Kaneh. & Hatus.                 |
| 6   | Calo_ca | Calophyllum caudatum Kaneh. & Hatus.                 |
| 7   | Calo_in | Calophyllum inophyllum L.                             |
| 8   | Calo_in | Calophyllum inophyllum L.                             |
| 9   | Camp_br | Campnosperma brevipetiolatum Volkens                 |
| 10  | Camp_br | Campnosperma brevipetiolatum Volkens                 |
| 11  | Cana_hi | Canarium hirsutum Wild.                              |
| 12  | Cana_hi | Canarium hirsutum Wild.                              |
| 13  | Cana_in | Canarium indicum L.                                  |
| 14  | Cana_in | Canarium indicum L.                                  |
| 15  | Cara_br | Carallia brachiata (Lour.) Merr.                     |
| 16  | Cara_br | Carallia brachiata (Lour.) Merr.                     |
| 17  | Clei_pa | Cleistanthus papuanaus (Lauterb.) Jabl.              |
| 18  | Clei_pa | Cleistanthus papuanaus (Lauterb.) Jabl.              |
| 19  | Cory_la | Corynocarpus laevigatus J.R.Forst. & G.Forst.        |
| 20  | Cory_la | Corynocarpus laevigatus J.R.Forst. & G.Forst.        |
| 21  | Crypt_pa | Cryptocarya palmerensis C.K.Allen                    |
| 22  | Crypt_pa | Cryptocarya palmerensis C.K.Allen                    |
| 23  | Crypt_sp | Cryptocarya sp                                       |
| 24  | Crypt_sp | Cryptocarya sp                                       |
| 25  | Deca_pa | Decaspernum parviflorum (Lam.) A.J.Scott             |
| 26  | Deca_pa | Decaspernum parviflorum (Lam.) A.J.Scott             |
| 27  | Dill_pa | Dillenia papuana Martelli                            |
| 28  | Dill_pa | Dillenia papuana Martelli                            |
| 29  | Dios_pi | Diospyros pilosanthera Blanco                         |
| 30  | Dios_pi | Diospyros pilosanthera Blanco                         |
| 31  | Drac_da | Dracontomelon dao (Blanco) Merr. & Rolfe             |
| 32  | Drac_da | Dracontomelon dao (Blanco) Merr. & Rolfe             |
| 33  | Dryp_gl | Drypetes globosa (Merr.) Pax & K.Hoffm.              |
| 34  | Dryp_gl | Drypetes globosa (Merr.) Pax & K.Hoffm.              |
| 35  | Dysyo_mo | Dysoxylum mollissimum Blume                          |
| 36  | Dysyo_mo | Dysoxylum mollissimum Blume                          |
| 37  | Elae_an | Elaeocarpus angustifolius Blume                      |
| 38  | Elae_an | Elaeocarpus angustifolius Blume                      |
| 39  | Endi_ru | Endiandra rubescens (Blume) Miq.                     |
| 40  | Endi_ru | Endiandra rubescens (Blume) Miq.                     |
| 41  | Endo_me | Endospernum meduloosum L.S.Sm.                       |
| 42  | Endo_me | Endospernum meduloosum L.S.Sm.                       |
| 43  | Flin_pi | Flindersia pimenteliana F.Muell.                     |
| 44  | Flin_pi | Flindersia pimenteliana F.Muell.                     |
| 45  | Galb_be | Galbulimima belgraveana (F.Muell.) Sprague          |
| 46  | Galb_be | Galbulimima belgraveana (F.Muell.) Sprague          |
| 47  | Garc_la | Garcinia latissima Miq.                              |
| 48  | Garc_la | Garcinia latissima Miq.                              |
| 49  | Giro_ne | Gironniera nervosa Planch.                           |
| 50  | Giro_ne | Gironniera nervosa Planch.                           |
| 51  | Gmel_se | Gymnelia sessilis C.T.White & W.D.Francis ex Lane-Poole |
| 52  | Gmel_se | Gymnelia sessilis C.T.White & W.D.Francis ex Lane-Poole |
| 53  | Gnet_gn | Gnetum gnemon L.                                     |
| 54  | Gnet_gn | Gnetum gnemon L.                                     |
| 55  | Gono_li | Gonocarpus littorale (Blume) Sleumer                 |
| 56  | Gono_li | Gonocarpus littorale (Blume) Sleumer                 |
| 57  | Gymn_fa | Gymmacranthera farquhariana (Hook.f. & Thomson) Warb. |
| 58  | Gymn_fa | Gymmacranthera farquhariana (Hook.f. & Thomson) Warb. |
| 59  | Hapl_fl | Haplolobus floribundus (K.Schum.) H.J.S.Volkens    |
| 60  | Hapl_fl | Haplolobus floribundus (K.Schum.) H.J.S.Volkens    |
| 61  | Heri_sy | Heritiera sylvatica S.Vidal                         |
| 62  | Heri_sy | Heritiera sylvatica S.Vidal                         |
| 63  | Homa_fo | Homalium foetidum Benth.                             |
| 64  | Homa_fo | Homalium foetidum Benth.                             |
| 65  | Hope_ce | Hopea celtidifolia Kosterm.                          |
| 66  | Hope_ce | Hopea celtidifolia Kosterm.                          |
| 67  | Hope_no | Hopea novoguineensis Slooten                         |
68 Hope_no  S  Hopea novoguineensis Slooten
69 Hope_pa  L  Hopea papuanica Diels
70 Hope_pa  S  Hopea papuanica Diels
71 Hors_la  L  Horsfieldia laevigata Warb.
72 Hors_la  S  Horsfieldia laevigata Warb.
73 Ints_pa  L  Intsia palembanica Miq.
74 Ints_pa  S  Intsia palembanica Miq.
75 Knein_in  L  Kneona intermedia Warb.
76 Knein_in  S  Kneona intermedia Warb.
77 Lith_ru  L  Lithocarpus rufolillosus (Markgr.) Rehder
78 Lith_ru  S  Lithocarpus rufolillosus (Markgr.) Rehder
79 Lits_ti  L  Litsea timoriensis Span.
80 Lits_ti  S  Litsea timoriensis Span.
81 Man_br  L  Manioba browneoides Harms
82 Man_br  S  Manioba browneoides Harms
83 Medu_la  L  Medusandra laxiflora (Miers) R.A. Howard
84 Medu_la  S  Medusandra laxiflora (Miers) R.A. Howard
85 Mel_el  L  Melicope elleryana (F. Muell.) T.G. Hartley
86 Mel_el  S  Melicope elleryana (F. Muell.) T.G. Hartley
87 Myri_fa  L  Myristica fatua Houtt.
88 Myri_fa  S  Myristica fatua Houtt.
89 Pala_lo  L  Palaquium lobianum Burck
90 Pala_lo  S  Palaquium lobianum Burck
91 Par_ar  L  Parachondron pruinosa (Benth.) L.C. Nielsen
92 Par_ar  S  Parachondron pruinosa (Benth.) L.C. Nielsen
93 Para_ve  L  Parastemon versteeghii Merr. & L.M.Perry
94 Para_ve  S  Parastemon versteeghii Merr. & L.M.Perry
95 Pime_am  L  Pimelodendron amboinicum Hassk.
96 Pime_am  S  Pimelodendron amboinicum Hassk.
97 Plan_ke  L  Planchonella keyensis H.J.Lam
98 Plan_ke  S  Planchonella keyensis H.J.Lam
99 Pome_ac  L  Pometia acuminata Radlkl.
100 Pome_ac  S  Pometia acuminata Radlkl.
101 Pome_pi  L  Pometia pinnata J.R.Forst. & G.Forst.
102 Pome_pi  S  Pometia pinnata J.R.Forst. & G.Forst.
103 Prun_ar  L  Prunus arboarea (Blume) Kalkman
104 Prun_ar  S  Prunus arboarea (Blume) Kalkman
105 Prun_ja  L  Prunus javanica (Teijsm. & Binn.) Miq.
106 Prun_ja  S  Prunus javanica (Teijsm. & Binn.) Miq.
107 Rhod_ci  L  Rhodamnia cinerea Jack
108 Rhod_ci  S  Rhodamnia cinerea Jack
109 Siph_ce  L  Siphonodon celsastrineus Griff.
110 Siph_ce  S  Siphonodon celsastrineus Griff.
111 Siph_sp  L  Siphonodon sp
112 Siph_sp  S  Siphonodon sp
113 Sloa_pu  L  Sloanea pullei O.C.Schmidt ex A.C.Sm.
114 Sloa_pu  S  Sloanea pullei O.C.Schmidt ex A.C.Sm.
115 Ster_sh  L  Sterculia shillinglazii F.Muell.
116 Ster_sh  S  Sterculia shillinglazii F.Muell.
117 Syzy_sp1  L  Syzygium sp1
118 Syzy_sp1  S  Syzygium sp1
119 Teij_bo  L  Tejsgmaniodendron bogoriense Koord.
120 Teij_bo  S  Tejsgmaniodendron bogoriense Koord.
121 Term_co  L  Terminalia copelandi Elmer
122 Term_co  S  Terminalia copelandi Elmer
123 Timo_ca  L  Timonius carrii S.P.Darwin
124 Timo_ca  S  Timonius carrii S.P.Darwin
125 Tris_ma  L  Tristaniopsis macrosperma (F.Muell.) Peter G.Wilson & J.T.Waterh.
126 Tris_ma  S  Tristaniopsis macrosperma (F.Muell.) Peter G.Wilson & J.T.Waterh.
127 Vati_ra  L  Vatica rassak Blume
128 Vati_ra  S  Vatica rassak Blume
129 Xant_pa  L  Xanthophyllum papuanum Whitmore ex Meijsden
130 Xant_pa  S  Xanthophyllum papuanum Whitmore ex Meijsden
131 Xant_no  L  Xanthostemon novoguineensis Valeton
132 Xant_no  S  Xanthostemon novoguineensis Valeton