















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## Pattern of tree diversity in lowland tropical forest in Nikiwar, West Papua, Indonesia

Received: 21 October 2020; Accepted: 4 February 2021












**Abstract:** Trees are significant components of ecosystems built by several widespread species. For instance, Papua forest is known to comprise abiotic and biotic elements. Also, certain plants have grown in popularity to a point where they are discovered almost everywhere. The purpose of this study, therefore, was to investigate tree diversity, distribution, and the importance of conservation. Data were collected in four locations using a total of 24 sample plots spread across *Idoor*, *Karst*, *Persemaian*, and *Torembi*, where seven, four, seven, and five plots were allocated, respectively. These forests formed a mixed natural plantation comprising 76 species from 35 families. Furthermore, *Idoor* and *Karst* generated the highest species diversity and varied significantly compared to *Persemaian*, while *Torembi* showed similarities with the other three locations. This condition formed three ecosystem communities across *Persemaian*, *Karst*, *Idoor*, and *Torembi*. Also, the composition of the dominant species showed variations at the seedling and sapling levels believed to structure the understory, while the pole and tree levels characterized the overstory. The total species status was described as critically endangered (CR) of two species, vulnerable (VU) of six species, least concern (LC) of 28 species, and data deficient (DD) species. Therefore, location management is advised to not only pay significant attention in terms of economic benefits but also ecological, including the provisions for *ex-situ* and *in-situ* conservation to support sustainable forest management.

**Keywords:** dendrogram, conservation, Importance Value Index, Shannon-Weiner, understory






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## Introduction

Tropical rain forests harbor high biodiversity along with abiotic factors. The high variation in vegetation creates a place of wildlife habitation (Bonnell et al., 2011; Rosin, 2014; Finnegan et al., 2019). Also, forests provide ecosystem functions, including nutrient cycles (Vitousek & Sanford, 1986; Gleason et al., 2010; Johnson & Turner, 2019), hydrological function (Edwards et al., 2014), and protection for soil and water. Consequently, tropical forests are imperative to preserve the integrity of naturally formed ecosystems (Luize et al., 2018). Moreover, current research showed that the role of tropical forests has a relationship with global warming (Taylor et al., 2017). Degradation and deforestation are driving factors of climate change as atmospheric composition indicate an increase in the number of greenhouse gases (Aguilos et al., 2018; Fleischer et al., 2019). The trees in tropical rain forests play an important role in ecological function such as watershed regulation, support biodiversity of vegetation and wildlife (Gaveau et al., 2013; Naniwadekar et al., 2015; Ueda et al., 2017; Riggs et al., 2020). Therefore, the understanding of forest conditions is vital to manage sustainability with declining vegetation over time. This instigates a change in ecosystems previously

stable or at equilibrium levels in the woods (Sist et al., 2015; Levis et al., 2017).

The forests of Papua presently contain natural tropical vegetation (Hughes et al., 2015; Kuswandi et al., 2015; Grussu et al., 2016; Cámara-Leret et al., 2020; Murdjoko et al., 2020). Although, some places have experienced changes in ecological function (Murdjoko, 2013; Kuswandi et al., 2015; Laurance, 2015; Murdjoko et al., 2017). Furthermore, the potential change in this region is possibly due to an impact from the pressure of development during regional expansion in Papua districts (Fatem et al., 2018; Indrawan et al., 2019; Tawer et al., 2020). This condition is a dilemma in sustainable forest management, on one hand, there is a high economic demand for timber or non-timber forest products and more threatening is the policy pressure to convert forest areas for other purposes. However, the woods need to be properly controlled. Therefore, proper knowledge of sustainable management particularly development planning is essential for various parties. This includes policymakers, the public or private sector, researchers, and others (Mansourian, 2017).

The benefit of these regions is understood from the view of forests as vegetation areas and also assessed in the comprehensive form with as much

detail as possible. Moreover, among these tropical forests, habitats in the form of ecosystems, animals, social culture, and environmental services are potentially provided by the existence of a stable condition within tropical forests (Liu & Slik, 2014). Therefore, it is imperative to study these regions particularly vegetation, including the distribution, population, species diversity, and others. This research was intended to study the diversity of trees and analyze the individual distribution, and conservation status of Nikiwar Forests, Teluk Wondama District as a natural tropical forest.

## Methods

### Study area

This research was conducted in Nikiwar District, Teluk Wondama Regency at four different locations, *Idoor*, *Karst*, *Persemaian*, and *Torembi*. The geographical coordinates are: *Idoor* at 2°27'54.32"S; 134°6'21.02"E, *Karst* at 2°29'6.26"S; 134°7'16.40"E, *Persemaian* in 2°25'49.28"S; 134°7'54.48"E, and *Torembi* at 2°23'27.09"S; 134°7'47.27"E. Furthermore, the forest is a primary type divided into four groups characterized by ecological conditions especially edaphic

and topographic factors. Furthermore, *Torembi* and *Persemaian* represent the eastern part while *Idoor* and *Karst* represent the western region.

### Data collection

The species are divided into four parts, seedlings, saplings, poles, and trees. Subsequently, seedlings are marked to have a height of less than 1.5 m. Also, saplings are marked with a height of more than 1.5 m and a diameter of less than 10 cm. The pole has a diameter between 10 cm and 20 cm and the tree has a diameter greater than 20 cm.

Also, data collected from each plot are individual species and each one is identified according to the scientific name. Two vegetation experts from the herbarium technician identified tree species. The unidentified species were set as a voucher and sent to Herbarium *Papuense*, Balai Penelitian dan Pengembangan Lingkungan Hidup, and Kehutanan (BP2LHK) Manokwari and Herbarium *Manokwariense* (MAN) Pusat Penelitian Keanekaragaman Hayati (PPKH) Universitas Papua. Subsequently, the number of each species in the plot was recorded. Also, diameter at breast height (1.3 m) or 20 cm above the buttress was calculated for poles and trees, excluding seedling and sapling phases.

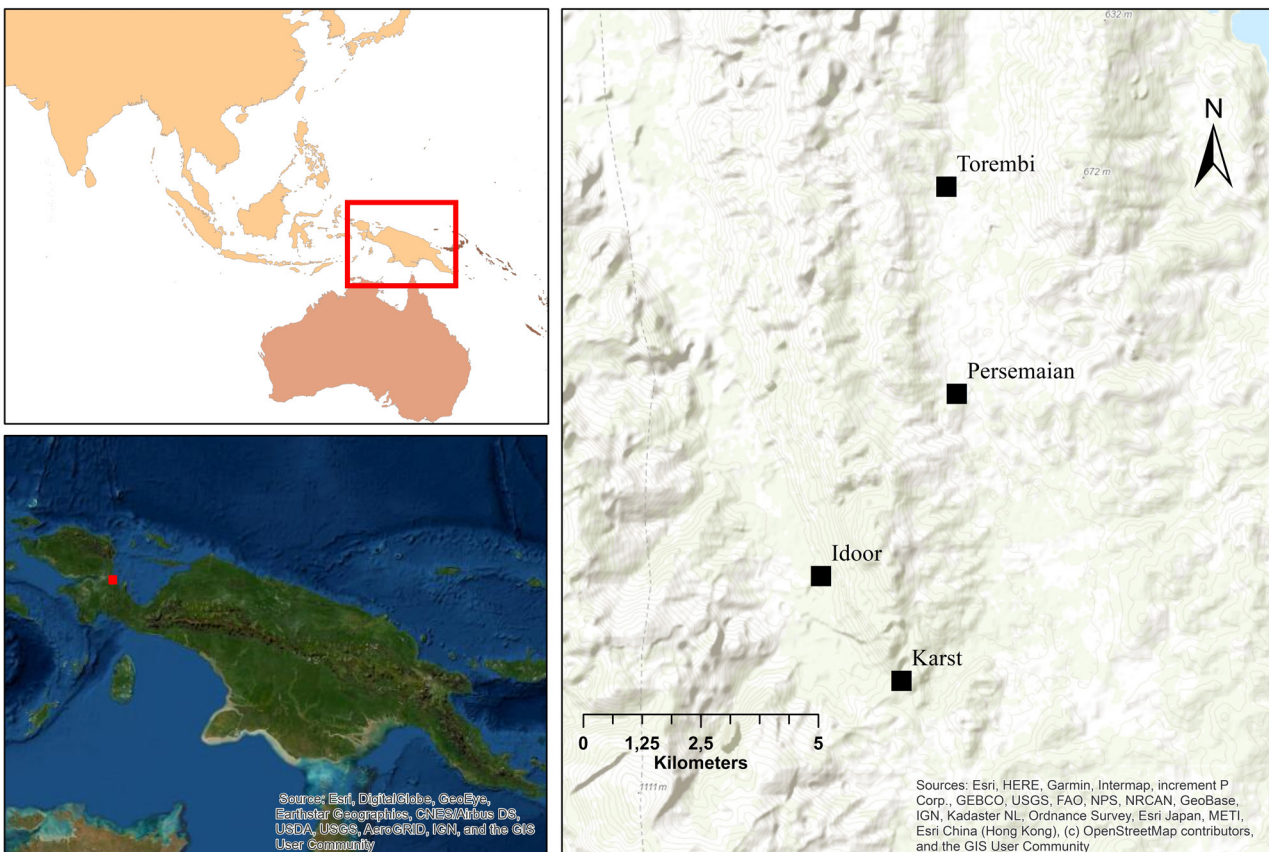


Fig. 1. Location of research (black boxes). The location is administratively part of Nikiwar District, Teluk Wondama Regency, West Papua, Indonesia

The plot used for this study consisted of four sizes, 2 m × 2 m for seedlings; 5 m × 5 m for saplings; 10 m × 10 m for the pole, and 20 m × 20 m for trees. A total of 23 plots were put in place with 7 plots in *Idoor*, 4 plots in *Karst*, 7 plots in the *Persemaian*, and 5 plots in *Torembi*. Also, plots at each location were randomly arranged on transects where the distances between plots at least 50 m were.

## Data analysis

The basal area (BA) is calculated by considering the diameter of the tree species as follows,  $BA_i = \sum D_i^2 \times 0.7854$ , where  $BA_i$  = basal area (m<sup>2</sup>) of tree species  $i$ ,  $D_i$  = diameter (m) of tree species  $i$ , and  $0.7854 = \pi / 4$ . Then, to evaluate BA per hectare, the tree species are divided based on using the plot area (m<sup>2</sup> ha<sup>-1</sup>) as density. However, BA for each tree species describes the extent of dominance at the site. Density is used to ascertain the number of tree species per hectare (trees ha<sup>-1</sup>). Frequency shows the distribution of each tree species. Next, the number of plots with the tree species  $i$ , is divided by the total number of sample plots. Therefore, frequency is calculated using the equation  $Fr_i = \frac{n_i}{N}$  where  $Fr_i$  = Fre-

quency of tree species  $i$ ,  $n_i$  = number of plots where tree species  $i$  was located and  $N$  = total number of sample plots.

Importance Value Index (IVI) determines the distribution of each tree species in terms of dominance (Curtis & McIntosh, 1950; Nirmal Kumar et al., 2011). This index is calculated by adding the relatives of frequency, density, and dominance as  $IVI_i = RFr_i + RDe_i + RDo_i$  where  $IVI_i$  = importance value index of tree species  $i$ ,  $RFr_i$  = relative frequency of tree species  $i$ ,  $RDe_i$  = relative density of tree species  $i$ , and  $RDo_i$  = relative dominance of tree species  $i$ . Diversity Index – the diversity between locations was tested using a diversity index (Shannon, 1948; Spellerberg & Fedor, 2003). Also, the Shannon-Weiner diversity index was chosen as a parameter to describe the distribution of each species in terms of the number of individuals by calculating the evenness (E) (Pielou, 1966). A diversity index is calculated using the equation,  $H' = -\sum p_i \ln(p_i)$  where  $H'$  = Shannon-Weiner diversity index and  $p_i$  = number of samples with tree species  $i$ . The evenness is measured by the equation  $E = \frac{H'}{\ln(S)}$  where  $S$  is the number of species for each location.

Statistical analysis

## Statistical analysis

Cluster dendrogram and the analysis of variance (ANOVA) were applied to investigate the statistical

variation between the four locations. The computation was performed with R-3.6.3 for Windows (R Development Core Team 2014) and vegan package (Oksanen et al., 2019).

## Results

### Diversity and taxonomic composition

This research generated 76 tree species from 35 identified families. Subsequently, the dendrogram was grouped into three, including *Idoor* and *Torembi* (combined), *Persemaian*, and *Karst* (Fig. 4). Also, the dominant families varied among the four forests where *Sapindaceae*, *Myristicaceae*, *Meliaceae*, *Euphorbiaceae*, and *Ebenaceae* in *Idoor*; *Euphorbiaceae*, *Ebenaceae*, *Leguminosae*, *Sapindaceae*, and *Apocynaceae* in *Karst*; *Dipterocarpaceae*, *Phyllanthaceae*, *Leguminosae*, *Myristicaceae*, and *Myrtaceae* in *Persemaian*; *Myristicaceae*, *Sapindaceae*, *Lauraceae*, *Dipterocarpaceae*, and *Lamiaceae* in *Torembi* (Fig. 2). Under the species level of species within the four locations, the species distribution was uniformly distributed based on Evenness (E) (Fig. 3 B). However, the number of individuals showed more variation with *Torembi*, followed by *Persemaian*, *Idoor*, and *Karst*. Diversity Index ( $H'$ ) differed significantly in species distribution ( $P = 0.002$ ), while the evenness index did not show any significant difference ( $P = 0.302$ ). *Persemaian* was observed with the lowest diversity compared to the other three locations. Furthermore, *Idoor* and *Karst* indicated the highest species diversity, while *Torembi* maintained a similar situation as all locations (Fig. 3 A and Fig. 5).

Species at the seedling level in *Idoor* were dominated by *Myristica* sp, *Pometia* sp, *Aglaia* sp, and *Diospyros* sp, while *Karst* was mainly presented by *Diospyros* sp, *Myristica* sp, *Palaquium amboinense* Burck, and *Spathostemon* sp. Furthermore, *Vatica rassak* Blume, *Myristica* sp, *Baccaurea* sp, and *Neonauclea* sp, were present in *Persemaian*, followed by *Myristica* sp, *Palaquium amboinense* Burck, *Pometia* sp, and *Canarium* sp in *Torembi*. At

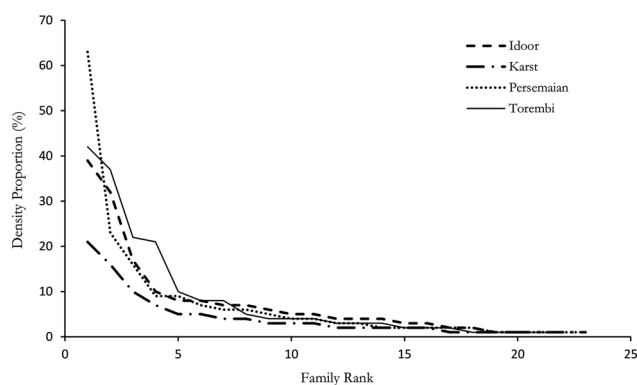


Fig. 2. Composition of family rank of tree in four locations

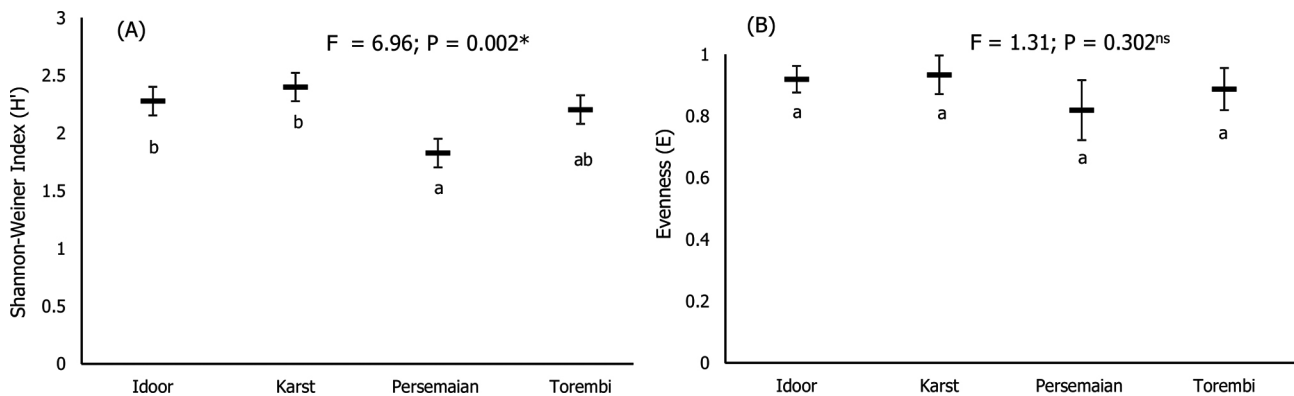


Fig. 3. The diversity index ( $H'$ ) in A and Evenness (E) in B where F is analysis of variance (ANOVA), the asterisk (\*) is the significance of F values from the ANOVA indicated that  $P < 0.05$ , ns is no significance of F values from the ANOVA indicated that  $P > 0.05$ , and the different lowercase letters show the significant differences

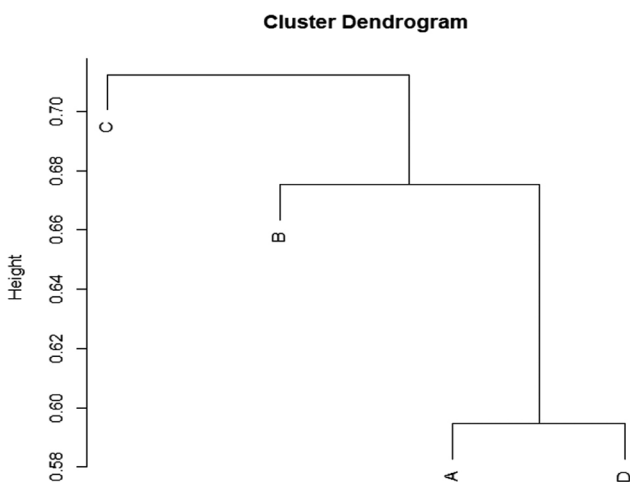


Fig. 4. Cluster dendrogram of the four locations which are represented by uppercase, viz., A – Idoor, B – Karst, C – Persemaian, D – Torembi

this seedling level, three species termed *Myristica* sp, *Pometia* sp, and *Palaquium amboinense* Burck existed in more than two places (Fig. 6). Specifically, *Myristica* sp showed dominance in these four locations with a high importance value index. This indicates the species with a high capacity to regenerate, particularly during the fertilization and germination processes.

At the sapling level in Idoor region, *Myristica* sp, *Aglaia cucullata* (Roxb.) Pellegr., *Baccaurea* sp, and *Ganophyllum falcatum* Blume were observed, followed by *Chisocheton macrophyllus* King, *Diospyros* sp, *Spathiostemon javensis* Blume, and *Buchanania* spume in Karst. Furthermore, several species of *Baccaurea* sp, *Vatica rassak* Blume, *Fagraea racemosa* Jack, and *Syzygium* sp were discovered in Persemaian, while in Torembi, the dominant species involved *Chisocheton macrophyllus* King, *Myristica* sp, *Syzygium* sp, and *Alstonia scholaris* (L.) R. Br. (Fig. 7). Also, 2 species, termed *Myristica* sp and *Syzygium* sp, occurred in more than one location. These conditions indicate the ability to develop

from seedling to sapling level as both varieties were more effective, particularly *Myristica* sp.

Various groups at the pole level differ from species dominance at seedling and sapling levels. This is observed in Idoor, and is dominated by *Pimelodendron amboinicum* Hassk., *Pometia coriacea* Radlk., *Macaranga tanarius* (L.) Müll.Arg. and *Horsfieldia sylvestris* Warb. Also, in Karst, abundant species, including *Pimelodendron amboinicum* Hassk., *Intsia palembanica* Miq., *Pometia acuminata* Radlk. and *Ficus septica* Burm.f. were present. In Persemaian, the majority of individuals at the pole level were *Vatica rassak* Blume, *Pimelodendron amboinicum* Hassk., *Myristica fatua* Houtt. and *Syzygium* sp, while for Torembi, the number of groups of *Vatica rassak* Blume, *Pimelodendron amboinicum* Hassk., *Teijsmanniodendron* sp, and *Myristica fatua* Houtt occurred in large quantity at the pole (Fig. 8). Of all the species present at the pole level, three varieties, termed *Pimelodendron amboinicum* Hassk., *Vatica rassak* Blume, and *Myristica fatua* Houtt were extensive, especially *P. amboinicum*. At the tree level, *Tetrameles nudiflora* R. Br., *Camptosperma brevipetiolatum* Volken, *Pometia coriacea* Radlk., and *Pometia acuminata* Radlk. developed in large numbers within the Idoor region, while *Pometia acuminata* Radlk., *Intsia palembanica* Miq., *Ficus pungens* Reinw. ex Blume and *Pimelodendron amboinicum* Hassk occurred in Karst, where more existed as dominant species. Furthermore, Persemaian was dominated by *Intsia palembanica* Miq., *Vatica rassak* Blume, *Myristica fatua* Houtt., and *Hopea papuana* Diels, while *Vatica rassak* Blume, *Teijsmanniodendron hollrungii* (Warb.) Kosterm., *Artocarpus altilis* (Parkinson ex F.A. Zorn) Fosberg, and *Pometia coriacea* Radlk occurred abundantly in Torembi (Fig. 9). Among all species, *Pometia coriacea* Radlk., *Pometia acuminata* Radlk., *Intsia palembanica* Miq., and *Vatica rassak* Blume were individuals cultivated and controlled in more than one location, specifically, *I. palembanica* is known to dominate the tree level.

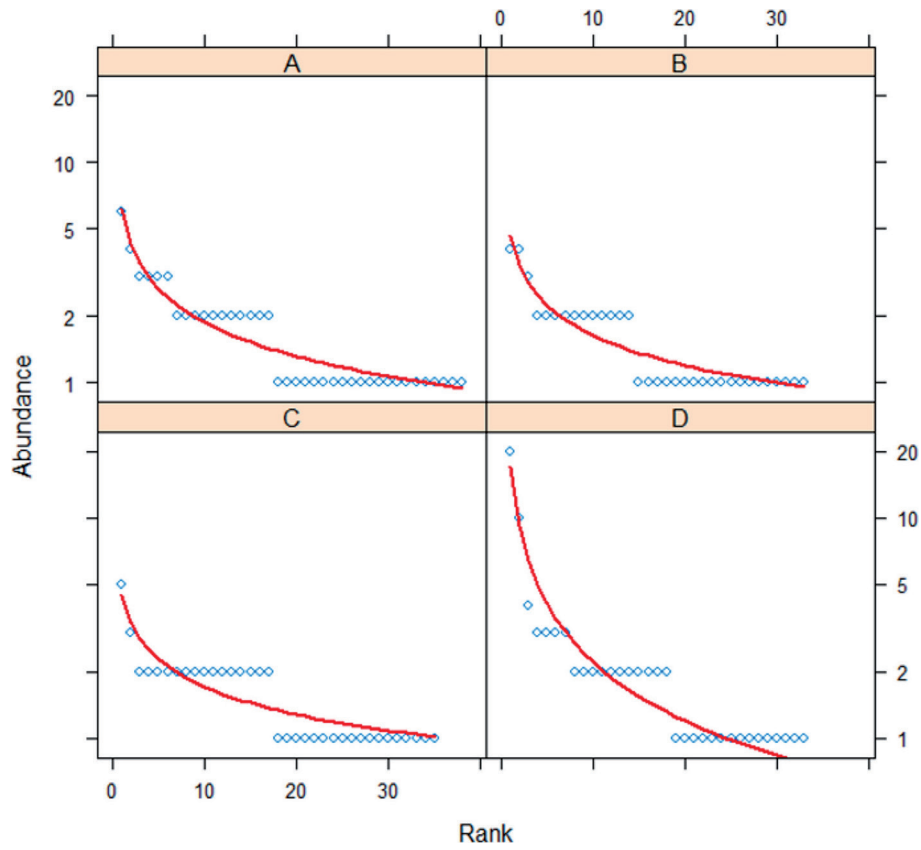


Fig. 5. Proportion of individual abundance based on the tree species in four locations. A – Idoor, B – Karst, C – Persemaian, D – Torembi

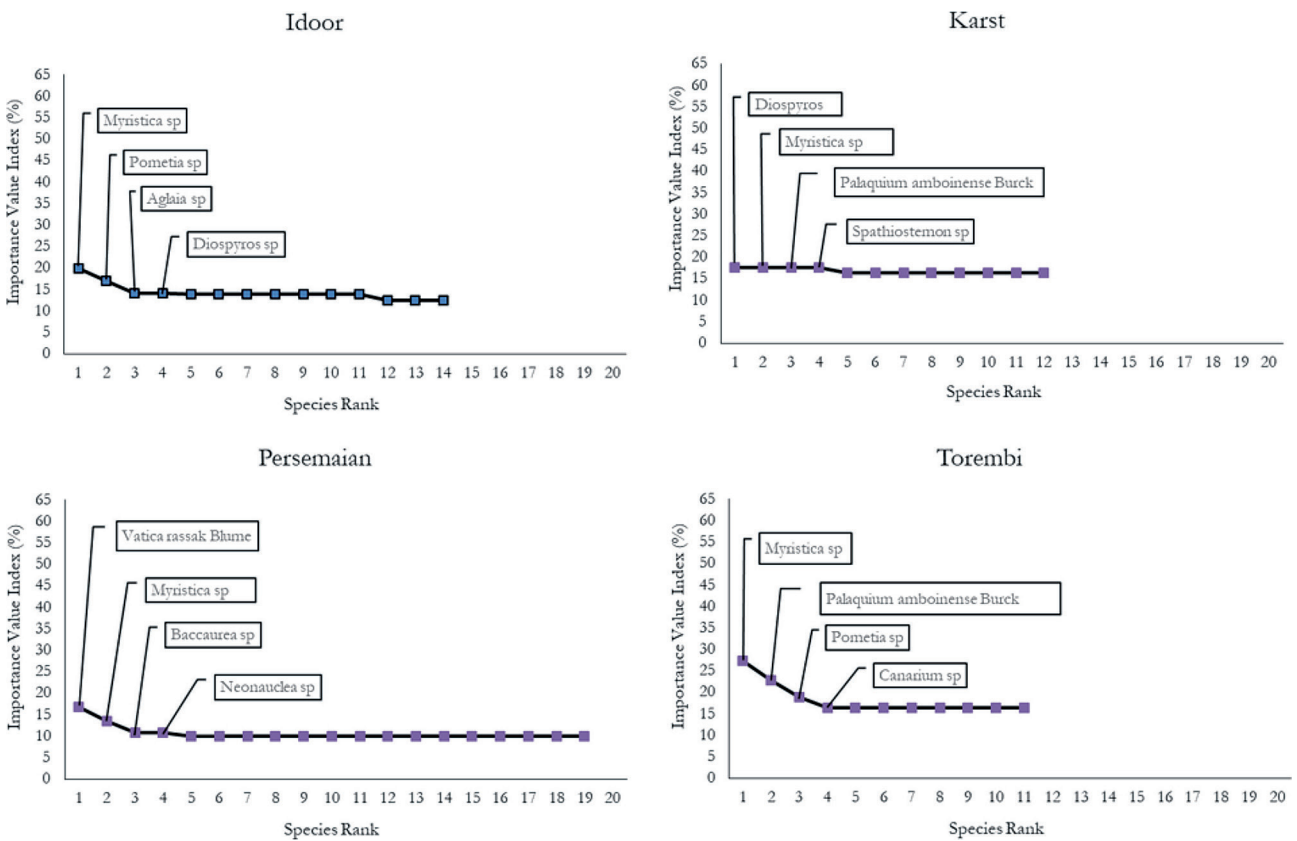


Fig. 6. Importance Value Index (IVI) for seedlings and the label show the four most dominant species in each location

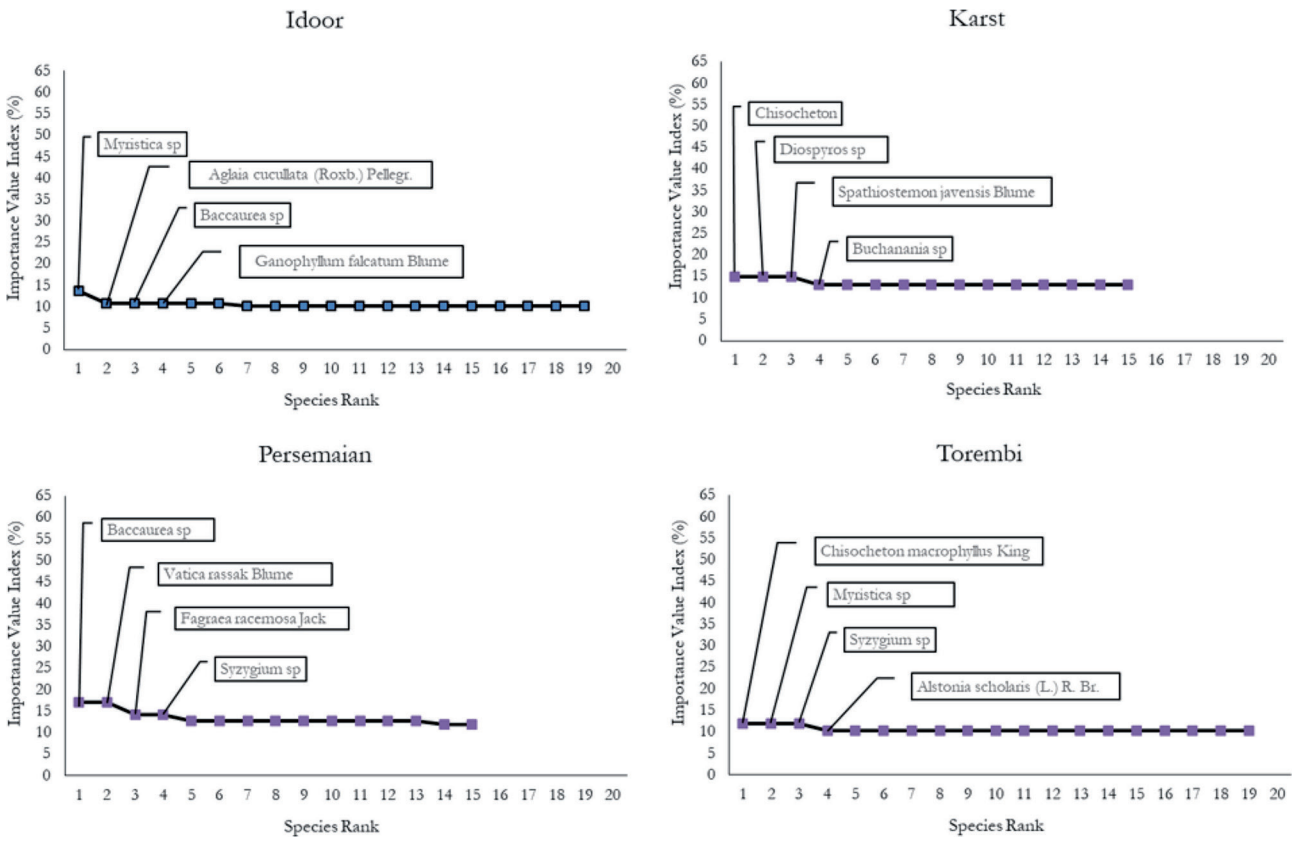


Fig. 7. Importance Value Index (IVI) for saplings and the label show the four most dominant species in each location

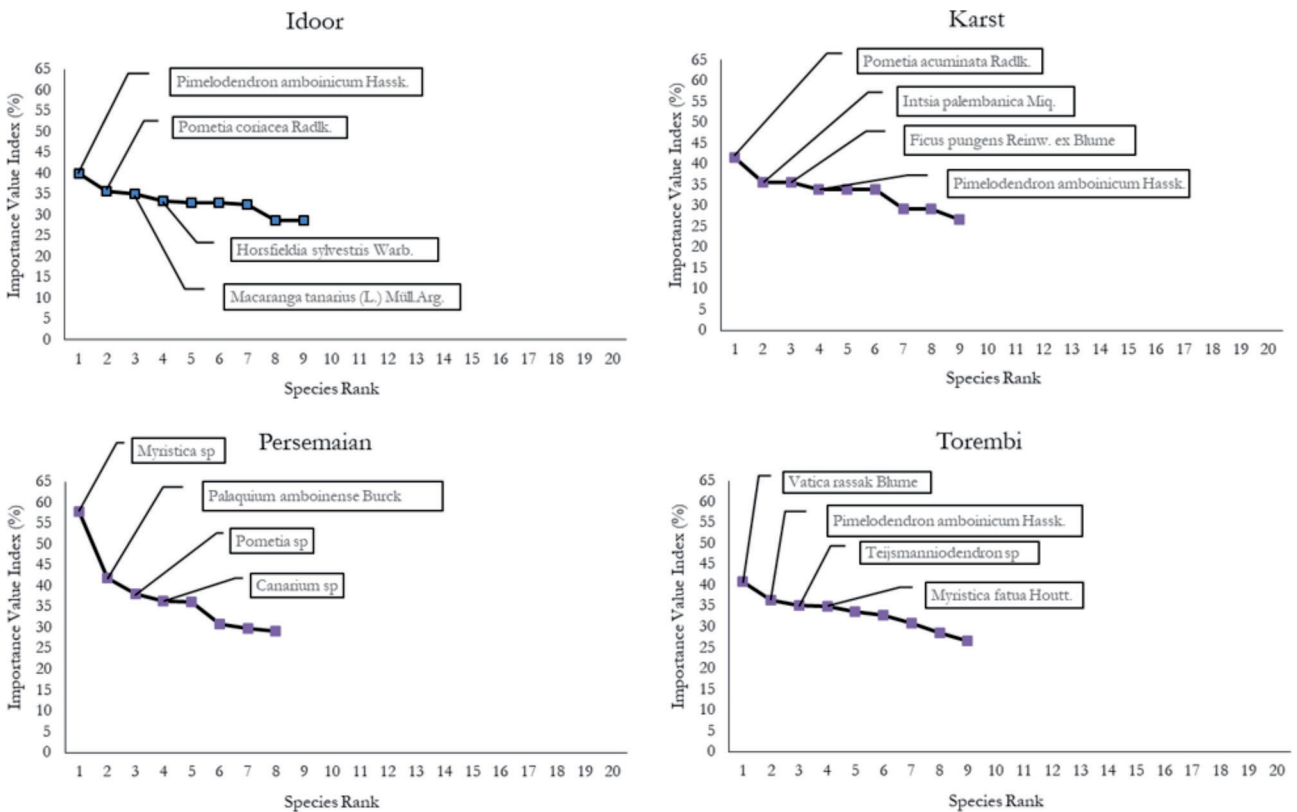


Fig. 8. Importance Value Index (IVI) for poles and the label show the four most dominant species in each location

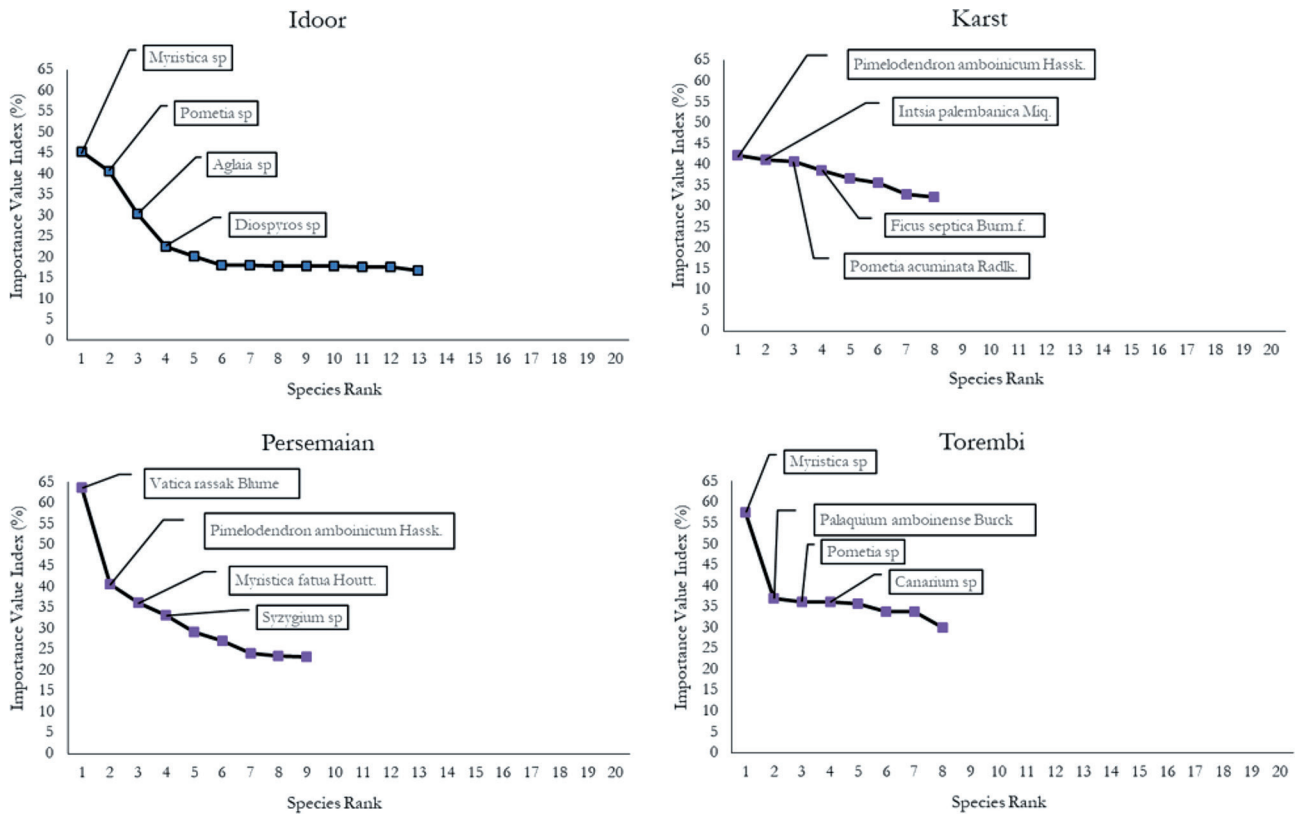


Fig. 9. Importance Value Index (IVI) for trees and the labels show the four most dominant species in each location

### Distribution of individual tree based on the diameter

Wood forest products are described in the form of diameter distribution in each location, where the greater diameter is known to increase the potentials for these products. At these locations, individual trees spread out at various diameters ranging from insignificant values to approximately 200 cm. This generates a distribution pattern in tropical forests where individuals with lesser diameter are more extensive compared to the number of individuals with a larger diameter.

Based on the results of the non-linear regression analysis, the equation formed was specified as  $y = 2.4422x^{-0.23}$  with  $R^2 = 0.27$  (Fig. 10). This showed the larger diameter instigates lesser individuals in the forest area. Furthermore, the diameter size drastically decreases, commencing from 40 cm, while the number of individual diameters below 25 cm demonstrated higher values. Meanwhile, individuals with diameters above 100 cm existed in *Idoor* and *Persemaian*.

### Conservation status of tree species

In the four forest types, certain species develop from a variety. Table 1 shows the results of conservation status analysis based on the website [www.iucnredlist.org](http://www.iucnredlist.org), as 76 tree species (Table 1). Table 2 highlights four significant statuses, termed critically endangered (CR) of 2 species, vulnerable (VU) of 6 species, least concern (LC) of 28 species, and data deficient (DD) species. Of all these varieties, CR and VU specifically indicated a status population decline in forest areas caused by the conversion of the

[www.iucnredlist.org](http://www.iucnredlist.org), as 76 tree species (Table 1). Table 2 highlights four significant statuses, termed critically endangered (CR) of 2 species, vulnerable (VU) of 6 species, least concern (LC) of 28 species, and data deficient (DD) species. Of all these varieties, CR and VU specifically indicated a status population decline in forest areas caused by the conversion of the

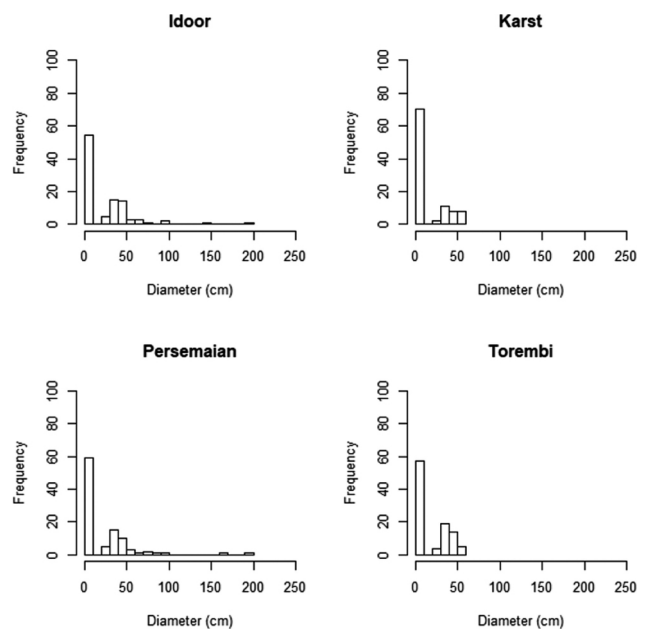


Fig. 10. The proportion of individuals based on diameter class in each location



Table 1. Conservation status of tree species in the four locations

Species	Family	Conservation status	Population status
<i>Memecylon</i> sp	Melastomataceae	Critically Endangered (CR)	Decreasing
<i>Syzygium</i> sp	Myrtaceae	Critically Endangered (CR)	
<i>Crudia</i> sp	Leguminosae	Vulnerable (VU)	
<i>Garcinia</i> sp	Clusiaceae	Vulnerable (VU)	Decreasing
<i>Intsia bijuga</i> (Colebr.) Kuntze	Leguminosae	Vulnerable (VU)	
<i>Litsea</i> sp	Lauraceae	Vulnerable (VU)	
<i>Pisonia</i> sp	Nyctaginaceae	Vulnerable (VU)	Stable
<i>Pterygota</i> sp	Malvaceae	Vulnerable (VU)	
<i>Aglaia sapindina</i> (F.Muell.) Harms	Meliaceae	Least Concern (LC)	
<i>Alstonia scholaris</i> (L.) R. Br.	Apocynaceae	Least Concern (LC)	
<i>Breonia chinensis</i> (Lam.) Capuron	Rubiaceae	Least Concern (LC)	
<i>Baccaurea</i> sp	Phyllanthaceae	Least Concern (LC)	
<i>Bischofia javanica</i> Blume	Phyllanthaceae	Least Concern (LC)	Stable
<i>Calophyllum inophyllum</i> L.	Clusiaceae	Least Concern (LC)	Stable
<i>Cerbera floribunda</i> K.Schum.	Apocynaceae	Least Concern (LC)	Stable
<i>Cynometra ramiflora</i> L.	Leguminosae	Least Concern (LC)	
<i>Cynometra</i> sp	Leguminosae	Least Concern (LC)	
<i>Nageia wallichiana</i> (C.Presl) Kuntze	Podocarpaceae	Least Concern (LC)	Decreasing
<i>Diospyros</i> sp	Ebenaceae	Least Concern (LC)	
<i>Ficus septica</i> Burm.f.	Moraceae	Least Concern (LC)	Stable
<i>Ganophyllum falcatum</i> Blume	Sapindaceae	Least Concern (LC)	Stable
<i>Gnetum gnemon</i> L.	Gnetaceae	Least Concern (LC)	
<i>Horsfieldia irya</i> (Gaertn.) Warb.	Myristicaceae	Least Concern (LC)	
<i>Horsfieldia sylvestris</i> Warb.	Myristicaceae	Least Concern (LC)	
<i>Macaranga tanarius</i> (L.) Müll.Arg.	Euphorbiaceae	Least Concern (LC)	Stable
<i>Medusanthera laxiflora</i> (Miers) R.A.Howard	Stemonuraceae	Least Concern (LC)	Decreasing
<i>Melicope elleryana</i> (F. Muell.) T.G. Hartley	Rutaceae	Least Concern (LC)	Stable
<i>Spathiostemon javensis</i> Blume	Euphorbiaceae	Least Concern (LC)	Stable
<i>Spathiostemon</i> sp	Euphorbiaceae	Least Concern (LC)	
<i>Prunus</i> sp	Rosaceae	Least Concern (LC)	Stable
<i>Tabernaemontana aurantiaca</i> Gaudich.	Apocynaceae	Least Concern (LC)	Stable
<i>Tetrameles nudiflora</i> R. Br.	Tetramelaceae	Least Concern (LC)	Stable
<i>Teijsmanniodendron hollrungii</i> (Warb.) Kosterm.	Lamiaceae	Least Concern (LC)	Stable
<i>Teijsmanniodendron</i> sp	Lamiaceae	Least Concern (LC)	Stable
<i>Vatica rassak</i> Blume	Dipterocarpaceae	Least Concern (LC)	Decreasing
<i>Vitex quinata</i> (Lour.) F.N.Williams	Lamiaceae	Least Concern (LC)	
<i>Aglaia cucullata</i> (Roxb.) Pellegr.	Meliaceae	Data Deficient (DD)	Decreasing
<i>Aglaia</i> sp	Meliaceae	Data Deficient (DD)	Decreasing

Table 2. The number of species with conservation status in the four location

Locations	Conservation status			
	Critically Endangered (CR)	Vulnerable (VU)	Least Concern (LC)	Data Deficient (DD)
Idoor	1	4	13	1
Karst	2	0	12	0
Persemaian	1	3	11	1
Torembi	1	1	11	0

landscape to other purposes without any provision of *ex-situ* conservation programs. Therefore, 8 species, particularly the types with decreasing population status, including *Memecylon* sp and *Garcinia* sp, were assumed to demand more attention in the regeneration

process, which is achieved by human intervention, e.g. planting. Specifically, in Papua, the species *Intsia bijuga* (Colebr.) Kuntze with a commercial value and construction material input requires a program to support the regeneration process.

Based on total species distribution, the groups with CR status existed in all the locations, while VU occurred only in *Karst*. Also, LC species were scattered across the entire region. This situation showed critical interventions involving species regeneration, especially CR and VU are necessary. Also, the research revealed the four locations are places or habitats of these species. Therefore, preserving natural areas from forests appears as a suitable initiative towards providing opportunities and growth for these species. Further studies on regeneration, spatial

distribution, and the distinct characteristics of these species are paramount to support conservation programs, particularly species with critically endangered (CR) and vulnerable (VU) status.

## Discussion

The species indigenous to each location constitute the communities. Based on the vegetation analyses of the four locations, a diverse natural forest with evenly distributed breeds was formed. This condition is typical of primary tropical forests in Papua. A wide variety of vegetation including lianas, rattan, herbs, forest floor coverings, epiphytes, and others are native to these zones (Murdjoko et al., 2016a). However, this study is limited to the seedlings, saplings, poles, and trees located in *Idoor*, *Persemaian*, *Karst*, and *Torembi* regions.

Generally, vegetation in the under-story layer of dense forests is exposed to less sunlight, high humidity, and lower temperatures than other flora (Nopiansyah et al., 2017; de Winter et al., 2018). *Myristica* sp was discovered to dominate this stratum. Therefore, the species are speculated to be tolerant of these conditions, particularly shade. Meanwhile, poles and trees constitute the upper-story. At this level, *V. rassak* is prevalent because the plant grows well under exposure to direct sunlight, low humidity as well as high temperature (Corrià-Ainslie et al., 2015).

This species is present at the highest stratum and also in the undergrowth. Meanwhile, some plants, including, *I. palembanica* do not have this ability. Therefore, such plants, especially those common to the upper canopy, bear flowers and fruit, but are unable to support regeneration in lower altitudes (Murdjoko et al., 2016b). This may be a limiting factor concerning species-specific predation. Also, the probability of a seed to germinate at the forest floor influences individual initiation. Furthermore, seedlings capable of thriving in the presence of little or no sunlight have higher chances of survival (Gudiel et al., 2016; Fatem et al., 2020).

This increases the competition between plants at the understory as there are numerous shade-tolerant plants in a typical tropical woodland (Do et al., 2019). Besides, some individuals of flora are allelopathic and are capable of releasing biochemical agents to impede growth or even kill these contenders (Facelli & Pickett, 1991; Ladwig et al., 2012). Also, the presence of species-specific herbivorous predators may influence continuity in a bio-diverse habitat (Balandier et al., 2006).

## Recommendations for management based on sustainable principles

Tree diversity and ecosystem formation are common characteristics of a mixed natural forest. Hence, there is a potential for bio-diversified vegetation. Also, these species possess economic benefits (Gaveau et al., 2014; Pryde et al., 2015; Colín-Urieta et al., 2018). Furthermore, the ecological use of these locations ought to be considered. For instance, *Karst* is a highland zone and may serve as a rainwater catchment area when conserved. Meanwhile, *Idoor*, *Persemaian*, and *Torembi* constitute the lowlands and are readily accessible sources of timber as well as other forest products.

However, Critically Endangered (CR) and Vulnerable (VU) species must be properly managed to avoid a population decline. Therefore, inventory is necessary to ascertain the degree of diversity. Also, *in-situ* and *ex-situ* programs may be integrated to increase effectiveness (Todou et al., 2014; Ren et al., 2019). For instance, in the *Persemaian* region, this may be achieved by the creation of a buffer location where fauna of economic and ecological importance are made available and those of CR and VU status remain preserved. Subsequently, the success of this technique is evaluated through continual research. Furthermore, the germination and growth supporting capacity of habitats are studied to provide practical solutions for nursery development and acceleration of regrowth in slowly regenerating plants, including *I. palembanica*.

## Acknowledgments

The authors are grateful to *Kopermas Kami Nassey* for financial support towards the Biodiversity and Conservation Assessment in Nikiwar Forest, Teluk Wondama Regency, West Papua. The authors are also thankful to Jonathan Mozes Nassey, indigenes of Nikiwar district, Bertha Mangallo, Ihwan Tjolli, Hubertus Matanubun, Maria J. Sadsoeitoeboen, Jacob Manusawai, Daniel Leonard Haumahu for field assistance, permit, and administration during the research. We also thank the anonymous reviewers for improving this article.

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