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Abstract. Murdjoko A, Djitmau DA, Sirami EV, Siburian R, Ungirwalu A, Mardiyadi Z, Wanma JF, Mofu WY, Marwa J, Susanti CME, Tokede MJ, Imburi CS, Sagrim M, Mamboai H, Sonbait LY, Dwiranti F, Salosa YY, Paemboanan JB, Wiradyo ET, Unenor E, Benu NMH, Saragih ASB. 2021. Tree species diversity of Pegunungan Bintang, Papua, Indonesia as potency of wood supply. *Biodiversitas* 22: 5645-5655. The tropical rainforest is a primary global concern in many aspects. Therefore, this study aimed to describe the tree diversity in Pegunungan Bintang Forest, Papua, Indonesia. There are 10 dominant species from seedlings, saplings, poles, and trees, indicating the timber production potency. This study set systematic plots in Murkim and Teiraplu Sub-districts to collect taxonomic information, diameter, and clear bole height samples. The results showed that the forest was categorized as a tropical mixed due to diverse tree species. The leading plant families included *Moraceae*, *Myrtaceae*, *Euphorbiaceae*, *Lauraceae*, and *Anacardiaceae*, with various seedlings, saplings, poles, and trees. The potency of timber was reflected through sample distribution using the reverse J-shaped curve, identifying the merchantable trees with larger and smaller diameters as re-established. However, timber utilization management requires silvicultural treatments using selective logging by diameter limit and logging cycle for forest sustainability.

Keywords: New Guinea, Shannon-Wiener index, timber production, understory

INTRODUCTION

Tropical natural forests as one of the living natural resources still provide benefits and an essential role in life for fulfilling people's lives (Fredericksen and Putz 2003; Uddin et al. 2020; Sonbait et al. 2021). In addition, these forests also provide valuable functions for the sustainability of the ecosystem. For example, the function of forest ecosystems as a water catchment area is to assist in the process of the hydrological cycle so that the availability of water in its sources is correct and it will become a necessity for humans in particular (Lohbeck et al. 2014; Margono et al. 2014). In addition, the function globally is to balance the cycle of nutrients such as carbon, which is currently an international issue where tropical forests are used as carbon sinks and stores. Therefore, the existence of tropical forest ecosystems is essential in their role in social, economic, and ecological life in general (Rozendaal et al. 2019; Murdjoko et al. 2020; Tawer et al. 2021).

Papua (Indonesia) is one of the tropical rain forests, particularly the District of Pegunungan Bintang which consists of the morphology of lakes and rivers (alluvial and colluvial), denuded structural morphology, and glacier morphology. The variation of this area is spread from an altitude of 0 to 4.700 m above sea level (asl). Pegunungan Bintang District is a segment of Papua's central mountains, an active fold and fault area with a moderate to heavy, undulating topography at an altitude of 1.000-4.700 m asl, and a slope level of 30-45%. There are igneous and igneous rocks metamorphosed in the northern part due to folding and intensive fractures of the Pre-Tertiary and Quaternary age (0.5-2 million years ago). These rocks are characteristic of coal, petroleum, and other metal mineralization potential. The northern mountains of the Pegunungan Bintang District are a reasonably strong collision zone between the oceanic plate and the vast continent (Australia), a mountain (mount) with a slope of 30-45%. This plain consists of sedimentary layers that are part of the

coastal plains of Papua which indicate the dominance of the floodplain (Murdjoko et al. 2020).

In this tropical forest area in this area, the interaction between humans and forest resources has also occurred for a very long time. These humans have identified and used forest products to fulfill their needs. These forest products have become part of these human activities. This causes these forest products to have economic value in circulation in human activities (Ungirwalu et al. 2014; Ungirwalu et al. 2017). This condition causes the need for forest resources, in this case, timber forest products, to become an established economic mechanism. This condition is currently the reason that this tropical forest area can provide economic functions to humans (Kuswandi and Murdjoko 2015; Murdjoko et al. 2016b). For example, currently, timber forest products are products from tropical forest areas that have been utilized and become part of the economic cycle. The timber forest product is a commodity from trees in the tropical forest (Murdjoko 2013; Kübler et al. 2020). The utilization of these timber forest products has also been going on for a long time and was carried out in official or illegal conditions. Therefore, we hypothesized that the two Sub-districts contained higher diversity of tree species and the individual distribution of tree species over diameter class indicated the stock of tree as timber potency. Therefore, in this study, we aimed to reveal tree diversity in Pegunungan Bintang Forest, Papua, Indonesia as forest description, uncovered species following seedlings, saplings, poles, and trees, and described the potency of timber production. Besides, we provided advice for sustainable forest management during using the tree as a wood supply.

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MATERIALS AND METHODS

Study area

The study was conducted in Murkim and Teiraplu Sub-districts in Pegunungan Bintang District, Papua Province, Indonesia. The Murkim Sub-district is located in the

eastern part covering 359 km² as per the administrative boundaries. It is located at coordinates 140°39'35,289"–41°00'00,00" E and 04°00'59,196"–04°21'54,82" S (Figure 1). In contrast, the Teiraplu Sub-district is located in the north, spread at 1,469 km². It is located at coordinates 140°13'26,618"–140°30'47,699" E and 03°44'42,041"–04°26'23,674" S. The Pegunungan Bintang District is located in Papua Province, Indonesia, directly bordering Papua New Guinea (PNG). It covers 1,586,300 hectares and is dominated by mountainous areas (66.09%) and hilly areas (27.26%). Its area is approximately ± 4.01% of Papua Province, with a flat distance of 111km from West to East and 160 km from North to South (Kartikasari et al. 2012; Murdjoko et al. 2020).

Samplings and survey

We applied the systematic plots during data collection where the 24 plots were placed in each Sub-district, Teiraplu, and Murkim, respectively. The distance among the plot was more or less 100 m. Then, the plot size was 20 m x 20 m for tree and 3 subplots (10 m x 10 m for pole, 5 m x 5 m for sapling, and 2 m x 2 m for seedling). Data were the number of individuals in the plot, species of tree, pole, sapling, and seedling for taxonomic information. Species were recognized to species level by means of morphological characters based on determinant keys and unidentified species were sent as voucher to the Herbarium Papuaense of Balai Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Manokwari and Herbarium Manokwariense (MAN) Pusat Penelitian Keanekaragaman Hayati Universitas Papua (PPKH-UNIPA), Manokwari. The scientific name of the species was based on World Flora Online (WFO) at the website: <http://www.worldfloraonline.org/>. Then, diameter and clear bole height was measured for tree pole and tree using phi band and Haga hypsometer, respectively. The diameter was measured at 1.3 m from the ground or at breast height and more or less 10 above the buttress. The clear bole height was measured at the vantage point below the first branch.



Figure 1. Location of research in Pegunungan Bintang Forest, Papua, Indonesia (symbolized by white box)

Data analysis

We calculated the diversity and evenness of species in both Sub-districts using the Shannon-Wiener index and Pielou's evenness, respectively, computed as:

$$H' = - \sum_{i=1}^S p_i \ln(p_i)$$

Where:

H' is Shannon-Wiener index

p_i is the number of samples where species i is present

Pielou's evenness was computed using:

$$J = H' / [\ln(S)]$$

Where: S is the total number of species for each type of forest (Spellerberg and Fedor 2003; Tawer et al. 2021).

Moreover, we also computed the Importance Value Index (IVI) of species by adding relative frequency, density, and dominance as:

$$IVI_i = RFR_i + RDe_i + RDo_i \text{ (for pole and tree)}$$

$$IVI_i = RFR_i + RDe_i \text{ (for sapling and seedling)}$$

Where: IVI_i is the important value index of species i , RFR_i is the relative frequency of species i , RDe_i is the relative density of species i , and RDo_i is the relative dominance of species i (Cottam and Curtis 1956; Murdjoko et al. 2016a; Fatem et al. 2020).

RESULTS AND DISCUSSION

Forest description

The two Sub-districts consist of natural tropical forests with high species diversity. The results showed 56 tree families with 185 species (Table 2). It indicated that the tree species diversity was high because this area was part of New Guinea harboring plenty of species vegetation

(Whitfeld et al. 2014; Cámara-Leret et al. 2020; Murdjoko et al. 2020). The identified trees were categorized into four phases: seedlings, saplings, poles, and trees. Additionally, other vegetation was identified as the primary category of tropical forests characteristics. However, this study's main objective was the tree species.

The forests are diverse with similar tree species, indicated by an almost similar Shannon-Wiener diversity index (H') at 2.758 for Murkim Sub-district and 2.765 for Teiraplu. The tree species evenness value distribution was 0.930 and 0.937 for Murkim and Teiraplu Sub-districts, respectively (Table 1). Therefore, the diversity and tree species are evenly distributed, and none dominates both forests (Spellerberg and Fedor 2003).

Besides, the distribution of taxon for family levels in the forest in the two sub-districts cannot be dominated by particular families. This condition indicates that the forest formed in these two sub-districts is a tropical mixed forest. However, it can be analyzed to show the position of the taxon at the family level in this forest based on the number of species and individuals so that many family levels in this forest can be sorted. From the analysis results, the families occupying the top five positions were *Moraceae*, *Myrtaceae*, *Euphorbiaceae*, *Lauraceae*, and *Anacardiaceae* (Figure 2). Furthermore, the five families have the most significant proportion with more than three percent, while the other 76 families have the same value with the highest distribution being three percent. Thus, the forests in these two sub-districts form a mixed tropical forest where this forest forms its ecosystem by interacting between species in several lifeforms that are present together with trees (Murdjoko et al. 2016a; Murdjoko et al. 2020).

Table 1. Diversity and evenness scores in the two sub-districts where H' is Shannon diversity index and J is Evenness

Location	Murkim		Teiraplu		Both sub-district	
	H'	J	H'	J	H'	J
Index	2.758	0.930	2.765	0.937	3.320	0.938
Standard deviation	0.495	0.051	0.245	0.036	0.518	0.027

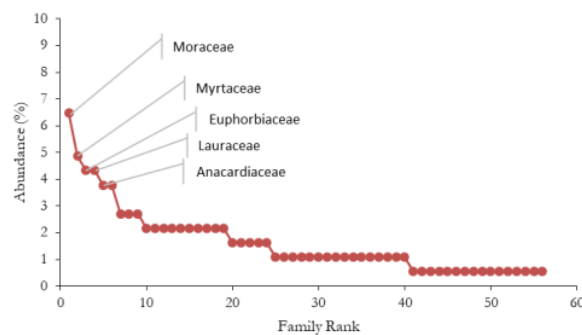


Figure 2. Taxon sequences for Family Rank (x-axis) based on the proportion of the number of species and individuals as a percentage (y-axis) in the two sub-districts

Table 2. List of tree species in two sub-districts and the “√” is the symbol of the presence of tree species

Tree species	Sub-district			
	Murkim	Tetraplu		
45				
<i>Acronychia brassii</i> T.G.Hartley	√			
<i>Acronychia reticulata</i> Lauterb.	√	√		
<i>Acronychia</i> sp.		√		
<i>Actinodaphne nitida</i> Teschner	√	√		
<i>Adinandra integririma</i> T.Anderson ex Dyer	√			
<i>Aglaiia argentea</i> Blume	√	√		
<i>Aglaiia spectabilis</i> (Miq.) S.S.Jain & S.Bennet	√	√		
<i>Alphitonia incana</i> (Roxb.) Teijsm. & Binn. ex Kurz	√	√		
<i>Alstonia scholaris</i> (L.) R. Br.	√	√		
<i>Alstonia spectabilis</i> R.Br.		√		
<i>Antiaris toxicaria</i> Lesch.	√	√		
<i>Antiaropsis decipiens</i> K.Schum.		√		
<i>Archidendron parviflorum</i> Pulle	√			
<i>Artocarpus altilis</i> (Parkinson ex F.A.Zorn) Fosberg	√	√		
<i>Beilschmiedia morobensis</i> Kosterm.	√			
<i>Bischofia javanica</i> Blume		√		
<i>Blumeodendron tokbrai</i> (Blume) Kurz		√		
<i>Buchanania arborescens</i> (Blume) Blume	√	√		
<i>Buchanania macrocarpa</i> Lauterb.	√	√		
<i>Callicarpa longifolia</i> Lam.	√	√		
<i>Calophyllum caudatum</i> Kaneh. & Hatus.	√	√		
<i>Calophyllum inophyllum</i> L.	√	√		
<i>Camposperma brevipetiolatum</i> Volken	√	√		
<i>Cananga odorata</i> (Lam.) Hook.f. & Thomson		√		
<i>Canarium asperum</i> Benth.		√		
<i>Canarium hirsutum</i> Willd.	√	√		
<i>Canarium indicum</i> L.	√	√		
<i>Canarium rigidum</i> (Blume) Zipp. ex Miq.	√	√		
<i>Carallia brachiata</i> (Lour.) Merr.	√			
<i>Casearia carrii</i> Sleumer	√	√		
<i>Casearia monticola</i> Sleumer	√			
<i>Casearia</i> sp.	√			
<i>Casearia urophylla</i> Gilg		√		
<i>Cerbera floribunda</i> K.Schum.	√	√		
<i>Chionanthus macrocarpus</i> Blume		√		
<i>Chisocheton ceramicus</i> Miq.	√	√		
<i>Chrysophyllum papuanicum</i> (Pierre ex Dubard) Royen	√	√		
<i>Cleistanthus papuanus</i> (Lauterb.) Jabl.	√	√		
<i>Cochlospermum gillivraei</i> Benth.	√			
<i>Commersonia bartramia</i> (L.) Merr.	√	√		
<i>Corynocarpus laevigatus</i> J.R.Forst. & G.Forst.	√	√		
<i>Cryptocarya palmerensis</i> C.K.Allen	√	√		
<i>Cryptocarya</i> sp.	√	√		
<i>Decaspermum parviflorum</i> (Lam.) A.J.Scott	√	√		
<i>Dillenia papuana</i> Martelli	√			
<i>Diospyros papuana</i> Valetton ex Bakh.	√			
<i>Diospyros pilosanthera</i> Blanco	√			
<i>Diospyros</i> sp.	√			
<i>Dracontomelon dao</i> (Blanco) Merr. & Rolfe	√	√		
<i>Drypetes globosa</i> (Merr.) Pax & K.Hoffm.		√		
<i>Dysoxylum mollissimum</i> Blume	√	√		
<i>Elaeocarpus angustifolius</i> Blume	√	√		
<i>Elaeocarpus arnhemicus</i> F.Muell.		√		
<i>Endiandra rubescens</i> (Blume) Miq.	√	√		
<i>Endiandra virens</i> F.Muell.		√		
<i>Endospermum medullosum</i> L.S.Sm.	√	√		
			<i>Eucalyptopsis papuana</i> C.T.White	√
			<i>Fagraea elliptica</i> Roxb.	√
			<i>Fagraea racemosa</i> Jack	√
			<i>Ficus annulata</i> Blume	√
			<i>Ficus chrysolepis</i> Miq.	√
			<i>Ficus hispida</i> L.f.	√
			<i>Ficus nodosa</i> Teijsm. & Binn.	√
			<i>Ficus racemosa</i> L.	√
			<i>Ficus robusta</i> Corner	√
			<i>Ficus septica</i> Burm.f.	√
			<i>Ficus</i> sp.	√
			<i>Ficus sycomorus</i> L.	√
			<i>Ficus variegata</i> Blume	√
			<i>Flindersia pimenteliana</i> F.Muell.	√
			<i>Galbulimima belgraveana</i> (F.Muell.) Sprague	√
			<i>Garcinia latissima</i> Miq.	√
			<i>Garcinia picrorhiza</i> Miq.	√
			<i>Garcinia</i> sp.	√
			<i>Girroniera nervosa</i> Planch.	√
			<i>Glochidion</i> sp.	√
			<i>Gmelina sessilis</i> C.T.White & W.D.Francis ex Lane-Poole	√
			<i>Gnetum gnemon</i> L.	√
			<i>Goniothalamus giganteus</i> Hook.f. & Thomson	√
			<i>Gonocaryum litorale</i> (Blume) Sleumer	√
			<i>Grewia eriocarpa</i> Juss.	√
			<i>Gymnacranthera farquhariana</i> (Hook.f. & Thomson) Warb.	√
			<i>Halfordia kendaek</i> Guillaumin	√
			<i>Haplolobus celebicus</i> H.J.Lam	√
			<i>Haplolobus floribundus</i> (K.Schum.) H.J.Lam	√
			<i>Haplolobus lanceolatus</i> H.J.Lam ex Leenh.	√
			<i>Harpullia carrii</i> Leenh.	√
			<i>Heritiera sylvatica</i> S.Vidal	√
			<i>Homalanthus novoguineensis</i> (Warb.) K.Schum.	√
			<i>Homalanthus populneus</i> (Geiseler) Pax	√
			<i>Homalium foetidum</i> Benth.	√
			<i>Hopea celtidifolia</i> Kosterm.	√
			<i>Hopea novoguineensis</i> Slooten	√
			<i>Hopea papuana</i> Diels	√
			<i>Horsfieldia irya</i> (Gaertn.) Warb.	√
			<i>Horsfieldia laevigata</i> Warb.	√
			<i>Horsfieldia parviflora</i> (Roxb.) J.Sinclair	√
			<i>Horsfieldia sylvestris</i> Warb.	√
			<i>Intsia palembanica</i> Miq.	√
			<i>Jagera pseudorhus</i> Radlk.	√
			<i>Kibara bullata</i> Philipson	√
			<i>Kibara coriacea</i> (Blume) Hook. f. & A. Thomps.	√
			<i>Kibara elongata</i> A.C.Sm.	√
			<i>Kleinhovia hospita</i> L.	√
			<i>Knema intermedia</i> Warb.	√
			<i>Lithocarpus rufovillosus</i> (Markgr.) Rehder	√
			<i>Litsea firma</i> (Blume) Hook.f.	√
			<i>Litsea ledermannii</i> Teschner	√
			<i>Litsea</i> sp.	√
			<i>Litsea timoriana</i> Span.	√
			<i>Maasia glauca</i> (Hassk.) Mols, Kessler & Rogstad	√
			<i>Maasia sumatrana</i> (Miq.) Mols, Kessler & Rogstad	√
			<i>Macaranga densiflora</i> Warb.	√
			<i>Macaranga gigantea</i> (Rchb.f. & Zoll.) Müll.Arg.	√
			<i>Macaranga mappa</i> (L.) Müll.Arg.	√
			<i>Macaranga tanarius</i> (L.) Müll.Arg.	√
			<i>Magnolia tsiampacca</i> (L.) Figlar & Noot.	√
			<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	√
			<i>Mallotus</i> sp.	√
			<i>Maniltoa browneoides</i> Harms	√
			<i>Maniltoa plurijuga</i> Merr. & L.M.Perry	√
			<i>Mastixiodendron pachyclados</i> (K.Schum.) Melch.	√
			<i>Medusanthera laxiflora</i> (Miers) R.A.Howard	√

<i>Melicope bonwickii</i> (F. Muell.) T.G. Hartley	✓		<i>Ryparosa javanica</i> Koord. & Valetton	✓	✓
<i>Melicope elleryana</i> (F. Muell.) T.G. Hartley	✓	✓	<i>Schizomeria ovata</i> D.Don		✓
<i>Myristica ensifolia</i> J.Sinclair		✓	<i>Semecarpus papuana</i> Lauterb.	✓	✓
<i>Myristica fatua</i> Houtt.	✓	✓	<i>Siphonodon celastrineus</i> Griff.	✓	✓
<i>Myristica gigantea</i> King	✓	✓	<i>Siphonodon</i> sp.	✓	✓
<i>Myristica globosa</i> Warb.	✓		<i>Sloanea pullei</i> O.C.Schmidt ex A.C.Sm.	✓	✓
<i>Myristica hollrungii</i> Warb.		✓	<i>Spathiostemon javensis</i> Blume	✓	✓
<i>Nauclea orientalis</i> (L.) L.		✓	<i>Sterculia macrophylla</i> Vent.	✓	✓
<i>Neolamarckia cadamba</i> (Roxb.) Bosser	✓	✓	<i>Sterculia shillinglawii</i> F.Muell.	✓	✓
<i>Ochrosia glomerata</i> (Blume) F.Muell.	✓		<i>Streblus elongatus</i> (Miq.) Corner	✓	✓
<i>Octamyrtus insignis</i> Diels		✓	<i>Sundacarpus amarus</i> (Blume) C.N.Page	✓	✓
<i>Palaquium lobbianum</i> Burck	✓	✓	<i>Symplocos anomala</i> Brand	✓	
<i>Pararchidendron pruinosum</i> (Benth.) I.C.Nielsen		✓	<i>Symplocos gigantifolia</i> Noot.	✓	✓
<i>Parastemon versteeghii</i> Merr. & L.M.Perry	✓	✓	<i>Syzygium</i> sp. 1	✓	✓
<i>Phaleria macrocarpa</i> (Scheff.) Boerl.	✓		<i>Syzygium</i> sp. 2	✓	✓
<i>Picrasma javanica</i> Blume	✓		<i>Syzygium</i> sp. 3	✓	✓
<i>Pimelodendron amboinicum</i> Hassk.	✓	✓	<i>Syzygium versteegii</i> (Lauterb.) Merr. & L.M.Perry	✓	✓
<i>Pisonia longirostris</i> Teijsm. & Binn.	✓	✓	<i>Tabernaemontana aurantiaca</i> Gaudich.		✓
<i>Planchonella anteridifera</i> (C.T.White & W.D.Francis ex Lane-Poole) H.J.Lam		✓	<i>Teijsmanniodendron bogoriense</i> Koord.	✓	✓
<i>Planchonella keyensis</i> H.J.Lam	✓	✓	<i>Terminalia copelandi</i> Elmer	✓	✓
<i>Polyscias nodosa</i> (Blume) Seem.	✓	✓	<i>Terminalia kaernbachii</i> Warb.		✓
<i>Pometia acuminata</i> Radlk.	✓	✓	<i>Timonius carii</i> S.P.Darwin	✓	✓
<i>Pometia pinnata</i> J.R.Forst. & G.Forst.	✓	✓	<i>Timonius timon</i> (Spreng.) Merr.	✓	✓
<i>Premna corymbosa</i> Rottler & Willd.	✓	✓	<i>Tristaniopsis macrosperma</i> (F.Muell.) Peter	✓	✓
<i>Prunus arborea</i> (Blume) Kalkman	✓	✓	G.Wilson & J.T.Waterh.	✓	✓
<i>Prunus javanica</i> (Teijsm. & Binn.) Miq.	✓	✓	<i>Vatica rassak</i> Blume	✓	✓
<i>Pterocarpus indicus</i> Willd.	✓	✓	<i>Vitex pinnata</i> L.	✓	✓
<i>Pterocymbium beccarii</i> K.Schum.	✓		<i>Weinmannia alta</i> Engl.		✓
<i>Rapanea tempapan</i> P.Royen		✓	<i>Wendlandia</i> sp.	✓	✓
<i>Rhodamnia cinerea</i> Jack	✓	✓	<i>Xanthophyllum papuanum</i> Whitmore ex Meijden	✓	✓
<i>Rhus lamprocarpa</i> Merr. & L.M.Perry		✓	<i>Xanthostemon novaguineensis</i> Valetton	✓	✓
<i>Rhus taitensis</i> Guill.	✓	✓			

With the high diversity of taxon species, the condition of this mixed natural forest can be analyzed to show several species that grow and dominate at the seedling, sapling, poles, and tree levels in each sub-district. The analysis used is to use the IVI in percentage, as shown in Table 3. At each level, it can be seen that the species present in the top ten positions differ. This indicates that the dynamic conditions of stand composition in this forest vary widely. The position of adult individuals, in this case, is the level of poles and trees, has a regeneration process that depends on the state of the forest, such as competition between species, so that many species at the seedling and sapling levels as a reflection of the regeneration of the adult individual are controlled by other species. For example, in Terapl Sub-district, at the adult level, it is *Melicope elleryana* (F. Muell.) T.G. Hartley, *Pararchidendron pruinosum* (Benth.) I.C.Nielsen, *Parastemon versteeghii* Merr. & L.M.Perry and *Vatica rassak* Blume.

However, there are many different species at the seedling and sapling levels, namely *Xanthostemon novaguineensis* Valetton, *Gymnacranthera farquhariana* (Hook.f & Thomson) Warb., *Macaranga densilora* Warb. and *Aglaiia argentea* Blume. This phenomenon is normal in tropical forests where adult species that dominate a certain area do not necessarily have good regeneration abilities. This is due to elusive factors in mixed tropical forest ecosystems. However, this situation can be presumed due to heterospecific and conspecific associations that occur as

a relationship between the same individuals in one species or different species (Murdjoko et al. 2016c; Murdjoko et al. 2017; Murdjoko et al. 2020). This kind of situation needs to be a concern in tropical forest management, especially for the problem of regeneration that occurs, so it is necessary not to intervene to support the regeneration process of species in this forest (Menezes et al. 2019; Mahayani et al. 2020).

Potential of timber products

From the conditions of this mixed tropical forest, tree species can be described to benefit potential timber forest products which can be seen from the indicators of the number of individuals and the volume per unit area of a hectare (de Avila et al. 2017). Therefore, the grouping of the potential distribution is based on the diameter class group with an interval of 10 cm (Figures 3 and 4). According to the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number: P.42 / Menlhk-Setjen / 2015 concerning Administration of Timber Forest Products Originating from Natural Forests, timber forest products consist of three, namely large logs (KBB), medium logs (KBS) and small logs (KBK). Therefore, the distribution of diameter classes for these two sub-districts is about 80 cm high and based on this regulation, forest areas in these two sub-districts can produce timber forest products in the form of KBK, KBS, and KBB.

Table 3. Ten leading species for seedlings, saplings, poles, and trees in each sub-district were dominant based on the Importance Value Index (IVI)

Species	F	D	Do	RF	RD	RDo	IVI (%)
Sub-district Teiraplu							
Seedlings							
<i>Xanthostemon novaguineensis</i>	0.17	0.92	n.a	2.90	8.56	n.a	11.46
<i>Gymnacranthera farquhariana</i>	0.29	0.58	n.a	5.07	5.45	n.a	10.52
<i>Fagraea racemosa</i>	0.25	0.38	n.a	4.35	3.50	n.a	7.85
<i>Aglaia argentea</i>	0.17	0.46	n.a	2.90	4.28	n.a	7.18
<i>Geniostoma rupestre</i>	0.17	0.46	n.a	2.90	4.28	n.a	7.18
<i>Canarium hirsutum</i>	0.13	0.50	n.a	2.17	4.67	n.a	6.84
<i>Garcinia latissima</i>	0.17	0.33	n.a	2.90	3.11	n.a	6.01
<i>Gnetum gnemon</i>	0.21	0.25	n.a	3.62	2.33	n.a	5.96
<i>Vatica rassak</i>	0.21	0.21	n.a	3.62	1.95	n.a	5.57
<i>Canarium indicum</i>	0.17	0.25	n.a	2.90	2.33	n.a	5.23
Saplings							
<i>Macaranga densiflora</i>	0.42	0.88	n.a	4.39	5.87	n.a	10.25
<i>Aglaia argentea</i>	0.42	0.83	n.a	4.39	5.59	n.a	9.97
<i>Fagraea racemosa</i>	0.33	0.67	n.a	3.51	4.47	n.a	7.98
<i>Teijsmanniodendron bogoriense</i>	0.33	0.67	n.a	3.51	4.47	n.a	7.98
<i>Vatica rassak</i>	0.25	0.54	n.a	2.63	3.63	n.a	6.26
<i>Pararchidendron pruinosum</i>	0.25	0.33	n.a	2.63	2.23	n.a	4.87
<i>Canarium indicum</i>	0.21	0.38	n.a	2.19	2.51	n.a	4.71
<i>Gmelina sessilis</i>	0.21	0.29	n.a	2.19	1.96	n.a	4.15
<i>Prunus arborea</i>	0.21	0.29	n.a	2.19	1.96	n.a	4.15
<i>Canarium hirsutum</i>	0.21	0.25	n.a	2.19	1.68	n.a	3.87
Poles							
<i>Melicope elleryana</i>	0.13	0.25	0.00	3.70	6.38	7.30	17.38
<i>Pararchidendron pruinosum</i>	0.17	0.25	0.00	4.94	6.38	4.78	16.10
<i>Acronychia reticulata</i>	0.17	0.21	0.00	4.94	5.32	3.57	13.82
<i>Lithocarpus rufovillosus</i>	0.13	0.17	0.00	3.70	4.26	5.36	13.32
<i>Parastemon versteeghii</i>	0.17	0.17	0.00	4.94	4.26	4.07	13.26
<i>Vatica rassak</i>	0.17	0.17	0.00	4.94	4.26	3.74	12.93
<i>Xanthostemon novaguineensis</i>	0.08	0.17	0.00	2.47	4.26	4.85	11.57
<i>Pometia pinnata</i>	0.08	0.13	0.00	2.47	3.19	4.54	10.20
<i>Homalanthus novoguineensis</i>	0.08	0.17	0.00	2.47	4.26	3.02	9.75
<i>Prunus arborea</i>	0.13	0.13	0.00	3.70	3.19	2.39	9.28
Trees							
<i>Parastemon versteeghii</i>	0.46	0.58	0.07	11.00	12.96	17.78	41.74
<i>Vatica rassak</i>	0.25	0.33	0.02	6.00	7.41	5.27	18.67
<i>Lithocarpus rufovillosus</i>	0.29	0.29	0.02	7.00	6.48	4.31	17.80
<i>Xanthostemon novaguineensis</i>	0.21	0.21	0.03	5.00	4.63	6.93	16.56
<i>Giromiera nervosa</i>	0.25	0.25	0.01	6.00	5.56	3.65	15.20
<i>Intsia palembanica</i>	0.08	0.08	0.02	2.00	1.85	4.82	8.67
<i>Decaspermum parviflorum</i>	0.13	0.13	0.01	3.00	2.78	2.33	8.11
<i>Teijsmanniodendron bogoriense</i>	0.13	0.13	0.01	3.00	2.78	2.27	8.05
<i>Eucalyptopsis papuana</i>	0.04	0.04	0.02	1.00	0.93	5.66	7.59
<i>Litsea timoriana</i>	0.13	0.13	0.01	3.00	2.78	1.81	7.58
Sub-district Murkim							
Seedlings							
<i>Hopea novoguineensis</i>	0.44	2.64	n.a	7.38	22.37	n.a	29.76
<i>Canarium indicum</i>	0.40	0.84	n.a	6.71	7.12	n.a	13.83
<i>Premna corymbosa</i>	0.24	0.60	n.a	4.03	5.08	n.a	9.11
<i>Lithocarpus rufovillosus</i>	0.20	0.48	n.a	3.36	4.07	n.a	7.42
<i>Ficus robusta</i>	0.20	0.44	n.a	3.36	3.73	n.a	7.08
<i>Glochidion sp.</i>	0.16	0.36	n.a	2.68	3.05	n.a	5.74
<i>Sloanea pullei</i>	0.20	0.28	n.a	3.36	2.37	n.a	5.73
<i>Fagraea racemosa</i>	0.16	0.20	n.a	2.68	1.69	n.a	4.38
<i>Maniltoa brownneoides</i>	0.16	0.20	n.a	2.68	1.69	n.a	4.38
<i>Chrysophyllum papuanicum</i>	0.04	0.36	n.a	0.67	3.05	n.a	3.72

			3			3	
Saplings							
<i>Ficus</i> sp.	0.52	1.28	n.a	4.63	7.60	n.a	12.23
<i>Macaranga densiflora</i>	0.40	0.84	n.a	3.56	4.99	n.a	8.55
<i>Premna corymbosa</i>	0.40	0.84	n.a	3.56	4.99	n.a	8.55
<i>Ficus robusta</i>	0.36	0.60	n.a	3.20	3.56	n.a	6.77
<i>Syzygium</i> sp. 1	0.36	0.48	n.a	3.20	2.85	n.a	6.05
<i>Hopea novoguineensis</i>	0.24	0.60	n.a	2.14	3.56	n.a	5.70
<i>Ficus sycamoros</i>	0.24	0.44	n.a	2.14	2.61	n.a	4.75
<i>Callicarpa longifolia</i>	0.24	0.40	n.a	2.14	2.38	n.a	4.51
<i>Canarium indicum</i>	0.24	0.36	n.a	2.14	2.14	n.a	4.27
<i>Intsia palembanica</i>	0.24	0.36	n.a	2.14	2.14	n.a	4.27
Poles							
<i>Syzygium</i> sp. 1	0.24	0.36	0.01	7.14	9.09	9.03	25.27
<i>Hopea novoguineensis</i>	0.20	0.24	0.00	5.95	6.06	6.61	18.62
<i>Alphitonia incana</i>	0.08	0.28	0.01	2.38	7.07	8.58	18.03
<i>Ficus</i> sp.	0.16	0.20	0.00	4.76	5.05	5.61	15.42
<i>Intsia palembanica</i>	0.16	0.16	0.00	4.76	4.04	3.71	12.51
<i>Gymnacranthera farquhariana</i>	0.12	0.12	0.00	3.57	3.03	3.16	9.76
<i>Hopea papuana</i>	0.08	0.12	0.00	2.38	3.03	3.43	8.85
<i>Pometia acuminata</i>	0.08	0.12	0.00	2.38	3.03	3.20	8.61
<i>Canarium hirsutum</i>	0.08	0.08	0.00	2.38	2.02	3.15	7.55
<i>Parastemon versteeghii</i>	0.08	0.12	0.00	2.38	3.03	2.11	7.52
Trees							
<i>Intsia palembanica</i>	0.24	0.28	0.09	6.82	7.45	25.98	40.24
<i>Hopea novoguineensis</i>	0.44	0.48	0.05	12.50	12.77	13.06	38.33
<i>Lithocarpus rufovillosus</i>	0.16	0.20	0.02	4.55	5.32	4.56	14.43
<i>Buchanania arborescens</i>	0.16	0.16	0.01	4.55	4.26	3.88	12.68
<i>Knema intermedia</i>	0.16	0.16	0.01	4.55	4.26	2.71	11.51
<i>Vatica rassak</i>	0.12	0.16	0.01	3.41	4.26	2.09	9.76
<i>Palaquium lobbianum</i>	0.12	0.12	0.01	3.41	3.19	2.40	9.00
<i>Hopea papuana</i>	0.08	0.08	0.01	2.27	2.13	2.60	7.00
<i>Tristanopsis macrosperma</i>	0.08	0.08	0.01	2.27	2.13	2.37	6.77
<i>Camptosperma brevipetiolatum</i>	0.08	0.08	0.01	2.27	2.13	2.11	6.51

Note: F is the frequency, D is the density, Do is the dominance, RF is the Relative Frequency, RD is the Relative Density, RDo is the Relative Dominance and the IVI (%) is the Importance Value Index, n.a. is not applicable

Therefore, in presenting this data, it is divided into groups of diameter classes so that the potential for this forest product is included and can be managed according to the type of wood to be produced. In these two sub-districts, the number of individuals in the diameter class below 10 cm is the highest and decreases with the increasing diameter class (Figure 3). However, the potential for timber forest products is found in diameter classes above 10 cm where these forest products can be used or utilized. In addition, the economic value of the potential of these forest products can be measured in quantity and later by volume (Groenendijk et al. 2017).

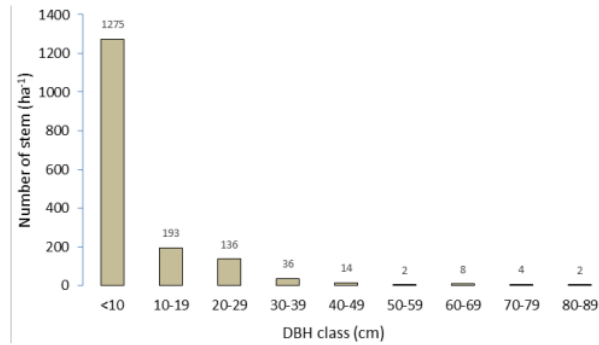
From the calculation of the potential for timber forest products according to volume per unit area in hectares and diameter class (cm), it can be seen that the highest volume is in the 10-19 cm diameter class around 100 m³.ha⁻¹ then tends to decrease. The increase in diameter except in diameter class 50-59 cm (Figure 4). This situation shows that the potential of timber forest products in these two sub-districts is still complete, where small to large diameters are still formed in this mixed natural forest structure. The reverse J-shaped curve in the graphs indicated that the forest had a more or less good condition (Myanmar 2016; Padmakumar et al. 2018). Based on the distribution of the

number of individuals per unit area of a hectare and diameter class for the two sub-districts, it can be seen that the number of individuals scattered in the two sub-districts did not experience a big difference (Figure 5). The distribution of the number of individuals is still complete for each diameter class. This distribution pattern shows a decrease and an increase in the diameter class. The distribution of potential timber forest products in the two sub-districts does not indicate a big difference. This can be seen from the shape of the distribution that is almost the same in the two sub-districts. Only in the 50-59 cm diameter class, there are no individuals in Teiraplu Sub-district. Conclusively, the potential for timber forest products in the two sub-districts spreads from the small-diameter class to the largest diameter class, namely 80-89 cm (Figure 6).

A correlation relationship can be made between the two conditions based on the distribution pattern of potential timber forest products measured in units of volume (m³) per tree and diameter (cm). The result of regression analysis produces a mathematical equation is $y = 0.0002x^{2.4922}$, where the form of the equation formed is a power pattern (Figure 7). With the following explanation, y is the volume of the tree in cubic meters (m³) and x is the

individual diameter. The coefficient of determination formed is 0.9407, which correlates closely to 1 (Ishihara et al. 2016), so this equation can be used to calculate the volume of standing trees in the forest. The diameter at

breast height (DBH) can predict the volume of timber in the tropical forest (Harja et al. 2012; Tang et al. 2017; Andrade et al. 2019).



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Figure 3. Distribution of the number of individuals in units of area (hectares) by diameter class in the Murkim and Teiraplu Sub-district

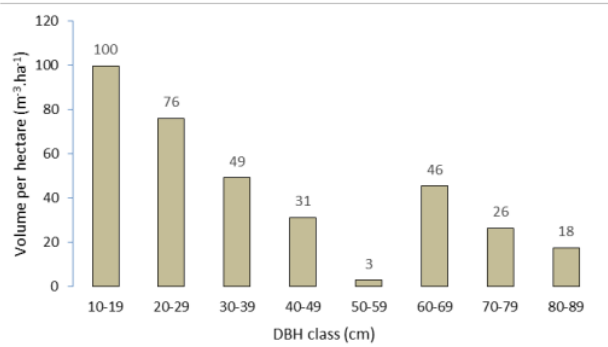


Figure 4. Potential standing wood volume in units of area (hectare) based on the distribution of diameter classes in the Murkim and Teiraplu Sub-district

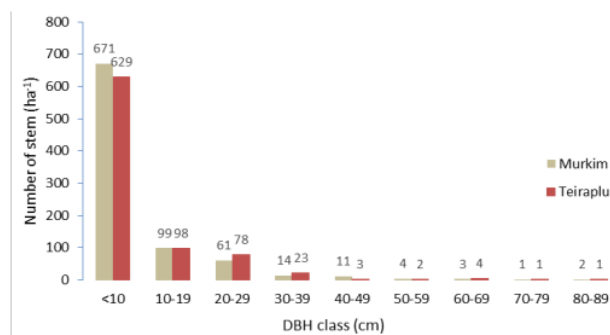


Figure 5. Distribution of the number of individuals in units of area (hectares) by diameter class in Murkim and Teiraplu Sub-district

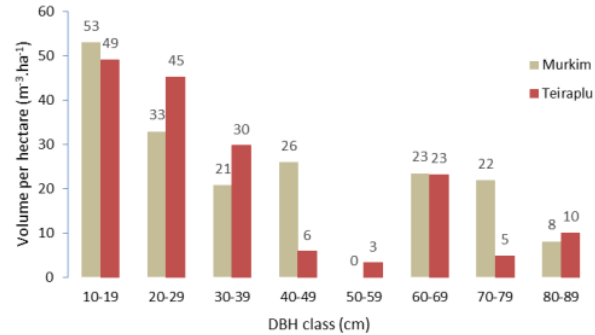


Figure 6. Distribution of potential standing timber volume in units of area (hectares) based on diameter classes in Murkim and Teiraplu Sub-district

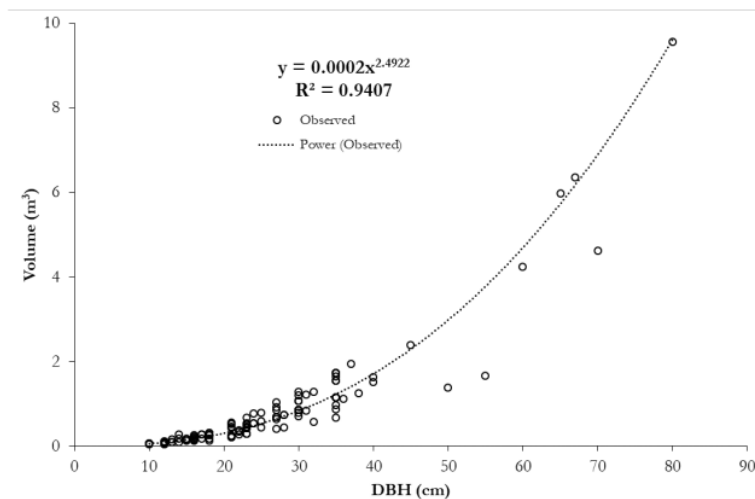


Figure 7. The relationship between the diameter (DBH) in cm and the volume of standing wood in cubic meters (m³). Information: $y = 0.0002x^{2.4922}$ is an equation formed with the coefficient of determination (R^2) is 0.9407. In this equation, x is the diameter (DBH) in cm and y is the volume of wood standing in cubic meters (m³)

Tree diversity to support sustainable product

The tropical rainforest provides high diversity of vegetation in which the trees are the dominant structure and other lifeforms (Murdjoko et al. 2021a; Murdjoko et al. 2021b). This area is part of a lowland area comprising the ecological process without human intervention. The regeneration of trees depends on the existence of putative parent trees. Besides, seed dispersal also plays a crucial role in the resurrection and distribution of species. This research revealed that the forest is a stably ecological circumstance where vertical layers such as forest floor and canopy are naturally delicate (Murdjoko et al. 2017; Moreno-Mateos et al. 2020). Therefore, the stock of small trees as future trees are available in this forest regardless of the particular species. Then, the forest would grow naturally as the character of old-growth forest (Murdjoko 2013; Murdjoko et al. 2016b). This forest also benefits

other biotic factors to promote the sustainability of tropical rain forest.

As described in this research, the vertical structure of this forest uncovered that trees, particularly more giant trees, are firmly present as part of vegetation diversity. As one of the lifeforms in tropical forests, the trees contain more or less 30 % of species richness, especially in the New Guinea ecosystem (Cámara-Leret and Dennehy 2019; Cámara-Leret et al. 2020). Based on the observation, local people still conduct the swidden practices as their livelihood enormously counts on the forest (Ungirwalu et al. 2014; Ungirwalu et al. 2017). As regional development, the demand for timber would probably increase to meet the infrastructure development including this area part of Pegunungan Bintang District. Thus, this finding described the timber stock and the sustainability for managing the timber product. The forest can be the source of timber

supply, but the management must pay attention to the silvicultural method in tropical mixed forests. The selective cutting could be carried out with a certain diameter limit and logging intensity. The mechanism of timber exploitation must be in line with the national regulation.

This recommendation could be performed correctly as the local government pays attention to the regulation, socio-culture, private sector, non-governmental organizations (NGOs), and other stakeholders. To achieve the goals of sustainable forest management, actors must get involved either direct way or an indirect way. The production forests in tropical countries are mainly located close or overlaid position with areas of local people. Thus, the involvement of customary forests could be considered carefully as one of the main objectives of forest management. In this case, the timber could be the main product of the forest, but the local people must be included in this program to support regional development goals (Ungirwalu et al. 2021).

To sum up, the forest in Pegunungan Bintang Forest was formed by the high diversity of tree species known as a tropical mixed forest. The families of *Moraceae*, *Myrtaceae*, *Euphorbiaceae*, *Lauraceae*, and *Anacardiaceae* were the dominant families in Pegunungan Bintang Forest with a variety of species in seedlings, saplings, poles, and trees. The potency of timber can be seen from the distribution of individuals following the reverse J-shaped curve, indicating that the trees were merchantable and provided enough regeneration of trees. However, the management of timber utilization requires silvicultural treatments by applying selective logging with diameter limit cut and logging cycle to promote sustainable forest management.

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