BUKTI KORESPONDENSI ARTIKEL

Murdjoko A., Djitmau D. A., Sirami E. V., Siburian R. H. S., Ungirwalu A., Mardiyadi Z., Wanma J. F., Mofu W. Y., Marwa J., Susanti C. M. E., Tokede M. J., Imburi C. S., Sagrim M., Mamboai H., Sonbait L. Y., Dwiranti F., Salosa Y. Y., Paembonan J. B., Wiradyo E. T. et al. 2021 - Tree species diversity of Pegunungan Bintang, Papua, Indonesia as potency of wood supply. Biodiversitas 22 (12): 5665–75. doi:10.13057/biodiv/d221263

Berikut adalah proses pengiriman artikel, proses, komentar reviewer, perbaikan dan korespondensi dengan pihak editor jurnal yang dilakukan oleh penulis korespondensi seperti di bawah ini:

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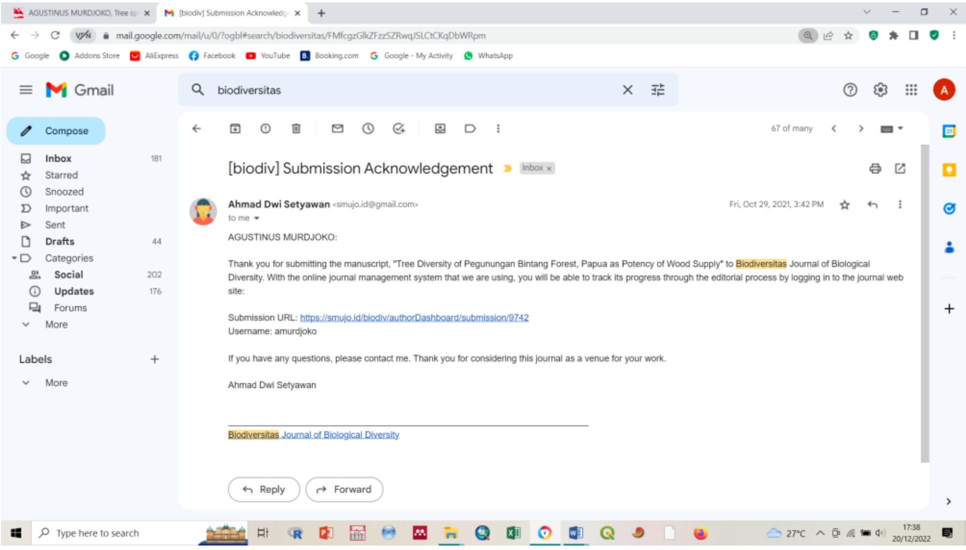
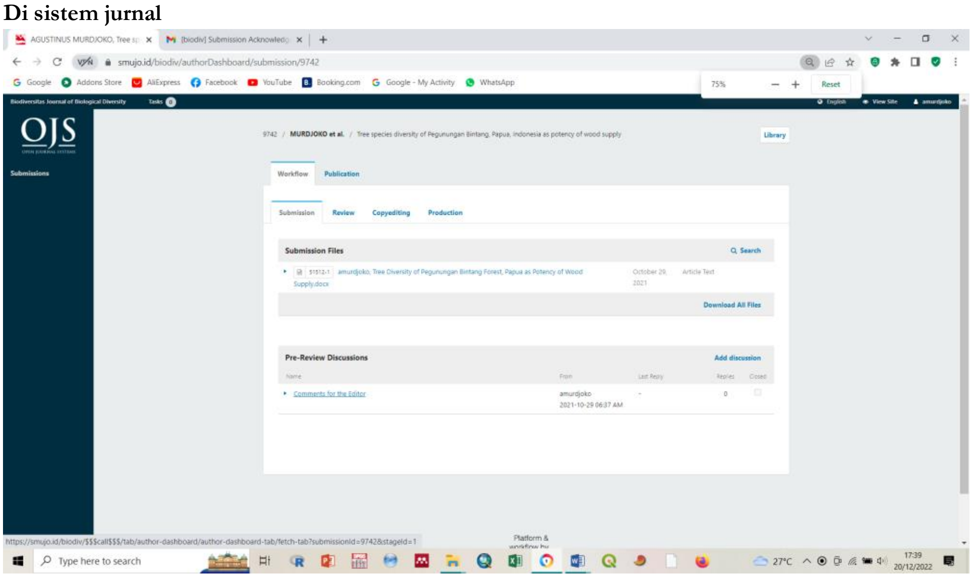
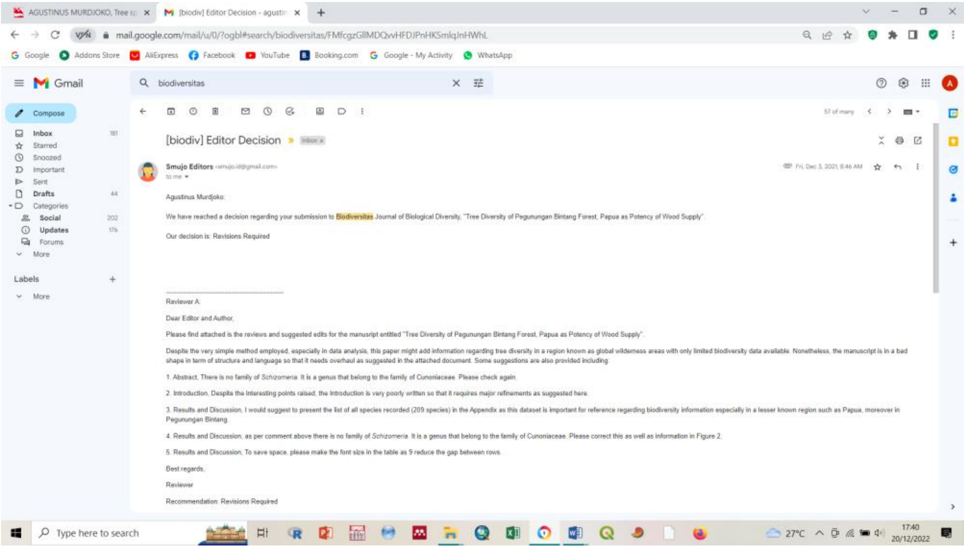
Pengiriman pertama



Di sistem jurnal



Keputusan editor


[biodiv] Editor Decision

Smujo Editors <smujo.id@gmail.com>

Fri, Dec 3, 2021, 8:46 AM

Agustinus Murdjoko:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Tree Diversity of Pegunungan Bintang Forest, Papua as Potency of Wood Supply".

Our decision is: Revisions Required

Reviewer A:

Dear Editor and Author,

Please find attached is the reviews and suggested edits for the manusript entitled "Tree Diversity of Pegunungan Bintang Forest, Papua as Potency of Wood Supply".

Despite the very simple method employed, especially in data analysis, this paper might add information regarding tree diversity in a region known as global wilderness areas with only limited biodiversity data available. Nonetheless, the manuscript is in a bad shape in term of structure and language so that it needs overhaul as suggested in the attached document. Some suggestions are also provided including:

1. Abstract. There is no family of *Schizomeria*. It is a genus that belong to the family of Cunoniaceae. Please check again.
2. Introduction. Despite the interesting points raised, the Introduction is very poorly written so that it requires major refinements as suggested here.
3. Results and Discussion. I would suggest to present the list of all species recorded (209 species) in the Appendix as this dataset is important for reference regarding biodiversity information especially in a lesser known region such as Papua, moreover in Pegunungan Bintang.
4. Results and Discussion, as per comment above there is no family of *Schizomeria*. It is a genus that belong to the family of Cunoniaceae. Please correct this as well as information in Figure 2.
5. Results and Discussion. To save space, please make the font size in the table as 9 reduce the gap between rows.

Best regards,

Reviewer

Recommendation: Revisions Required

Keputusan revisi mayor

Surat respon terhadap komentar reviewer dan revisi

Manokwari, 5 Januari 2022

Dear editor of Biodiversitas Journal of Biological Diversity

We would like to thank for giving the corrections of the manusript. Then, we have re-checked the improvements as we send the file entitled "9742-Article Text-54759-1-18-20211222_5 Januari 2022 Track Changes_VERSION" with red colour as the correctioin that we made. We are extremely garateful to reviewer to improve the English. Then, we also sent it to an English-proof reader as the certificate attached in this email.

We make a table of responses of reviewer comments below:

Comments	Response
Abstract There is no family of *Schizomeria*. It is a genus that belong to the family of *Cunoniaceae*. Please check again.	Thank you very much. We have corrected the family name and graph 2 as well.
Introduction Despite the interesting points raised the Introduction is very poorly written so that it requires major refinements as suggested here.	We have added some sentences to support the statement in the introduction. We also wrote the hypothesis of this research ‘’ We hypothesized that the two districts contained higher diversity…" in the last paragraph to focus on the aim of the research as a background.

Results and Discussion I would suggest to present the list of all species recorded (185 species) in the Appendix as this dataset is important for reference regarding biodiversity information especially in a lesser known region such as Papua moreover in *Pegunungan Bintang*.	We have provided the species list in Appendix 1 as suggested where we present the species found in both districts.
Results and Discussion as per comment above there is no family of *Schizomeria*. It is a genus that belong to the family of *Cunoniaceae*. Please correct this as well as information in Figure 2.	Thank you for correcting. We have changed the graph and also in the text.
Results and Discussion To save space, please make the font size in the table as 9 reduce the gap between rows.	Thank you very much for giving the input. We have changed the font size as suggested to make it efficient.

Hopefully, this process could improve the manuscript and get published in Biodiversitas Journal as International Journal.

Best regards,

Agustinus Murdjoko

Bentuk revisi

Tree Diversity of *Pegunungan Bintang* Forest, Papua as Potency of Wood Supply

Abstract. The tropical rainforest is a primary global concern in ecological, socio-cultural, and economic aspects. Therefore, sustainable forest management that provides benefits in the long term is of great importance especially in the region known as global wilderness areas such as in Papua, Indonesia. This study aimed to do an inventory of tree species diversity and composition in terms of seedlings, saplings, poles, and trees in the forest of *Pegunungan Bintang*, Papua, and to investigate their potential as timber and wood products. Data were collected using the systematic plot method in two districts (i.e. *Teiraplu*, and *Murkim*) in which 24 plots were established in each district. The results showed that 185 tree species were belonging to 56 families in the two studied sites combined, suggesting that tree species diversity at the studied sites was high which is the characteristic of the New Guinea region. 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 potential of timber was reflected through sample distribution using the reverse J-shaped curve, implying 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: Shannon-Wiener index, New Guinea, timber production, understory.

Abbreviations (if any): All important abbreviations must be defined at their first mention there. Ensure consistency of abbreviations throughout the article.

Running title: Tree diversity as timber supply

INTRODUCTION

Commented [AR1]: Despite the interesting points raised, the Introduction is very poorly written so that it requires major refinements as suggested here.

Natural tropical forests play an immense role and provide various benefits for people's lives (Fredericksen & Putz 2003, Sonbait et al. 2021). These forests also deliver a wide range of ecosystem services for environmental sustainability. For example, natural forests in the tropics serve as water catchment areas to assist the hydrological cycle, i.e. providing water resources especially during the dry season, and preventing floods and landslides particularly during the rainy season (Lohbeck et al. 2014, Margono et al. 2014). In the global context, tropical forests sequester and store a great amount of carbon, acting as a forefront agent of climate change mitigation. Therefore, the existence of tropical forest ecosystems is very important in terms of social, economic, and ecological aspects (Rozendaal et al. 2019, Murdjoko et al. 2020, Tawer et al. 2021).

Papua, Indonesia has a vast extent of tropical rain forests particularly in the regency of *Pegunungan Bintang*. This region consists of a wide range of geomorphological features including various lakes and rivers (alluvial and colluvial), denuded structural morphology, and glacier morphology. *Pegunungan Bintang* landscape stretches from an altitude of 0 to 4.700 m above sea level (asl). *Pegunungan Bintang* is a segment of the Central Mountains of Papua which is 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%. In the northern part, there are igneous rocks formed due to folding and intensive fractures of the Pre-Tertiary and Quaternary ages (0.5-2 million years ago). The presence of these rocks is an indicator of the potential for coal, petroleum, and other metal mineralization. The northern mountains of *Pegunungan Bintang* Regency are a fairly strong collision zone between the oceanic plate and the vast continent (Australia). *Pegunungan Bintang* Regency also consists of sedimentary layers of the floodplain that are part of the coastal plains of Papua (Murdjoko et al. 2020).

In the existence of tropical forests, the interaction between humans and forest resources has been occurring for a very long time. The local inhabitants have identified and used forest products to fulfill their needs and the forest products have become an integral part of their cultures and socio-economic activities (Ungirwalu et al. 2014, Ungirwalu et al. 2017). In particular, the needs for timber products lead to the utilization of timber in the forest, implying the economic function of forest to humans (Murdjoko 2013; Kuswandi & Murdjoko 2015, Murdjoko et al. 2016b; Kübler et al. 2020). The utilization of timber forest products has also been going on for a long time in *Pegunungan Bintang*, whether it is carried out legally or illegally.

We hypothesized that the two 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 particularly the presence of large trees. Therefore, in this study, we aimed to do an inventory of tree species diversity and composition in terms of seedlings, saplings, poles, and trees in the forest of *Pegunungan Bintang*, Papua, Indonesia, and to investigate their potential as timber and wood products. Besides, we provided advice for sustainable forest management during the use of the tree as a wood supply.

MATERIALS AND METHODS

Study area

The study was conducted in *Murkim* and *Teiraplu* districts, *Pegunungan Bintang* Regency (Figure 1). The *Pegunungan Bintang* Regency is located in Papua Province, directly bordering Papua New Guinea (PNG). *Pegunungan Bintang* Regency 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 which stretches 111km from west to east and 160 km from north to south (Kartikasari et al. 2012, Murdjoko et al. 2020). *Murkim* district is located in the northernmost eastern part with an extent of 359 km^2. It is located at coordinates 140°39'35.289 "- 41°00'00.00" East Longitude and 04°00'59.196"- 04°21'54.82" South Latitude. *Teiraplu* District is located in the north with an extent of 1,469 km^2. It is located at coordinates 140°13'26.618 "- 140°30'47.699" East Longitude and 03°44'42.041"-04°26'23.674" South Latitude.

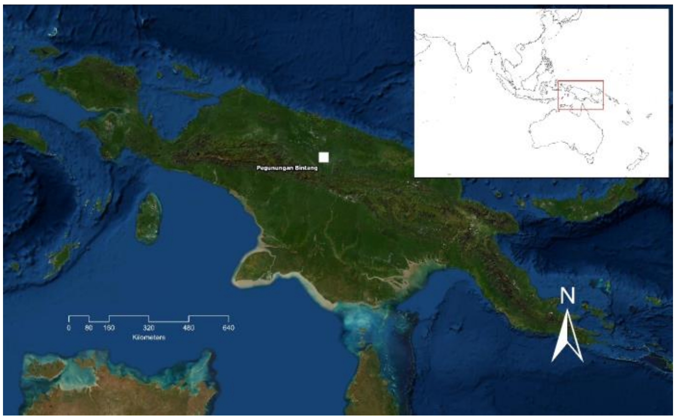


Figure 1. Map of study location in *Pegunungan Bintang* Regency, Papua Indonesia (white box).

Data collection procedure

Data were collected using a systematic plot method in which 24 plots were established in each studied district (*Teiraplu*, and *Murkim*). The distance between plots was more or less 100 m. Plot with size 20 m x 20 m was established to sample trees, and within it, subplots with size 10 m x 10 m, 5 m x 5 m, and 2 m x 2 m were created to sample poles, saplings, and seedlings. All plants within the plot and subplots were recorded regarding the taxonomic information and number of individuals for trees, poles, saplings, and seedlings. The plants recorded were identified to species level by means of morphological characters based on determinant keys, while 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) of *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/. Diameter and clear bole height were measured using phi band and

Haga hypsometer, respectively, at 1.3 m from the ground or at breast height (DBH), or 10 cm above the buttress. The clear bole height was measured at the vantage point below the first branch.

Data analysis

We calculated the diversity and evenness of species in both districts by means of the Shannon-Wiener index and Pielou's evenness (Spellerberg & Fedor 2003, Tawer et al. 2021). The Shannon-Wiener index was 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 index was computed as

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

Where S is the total number of species for each type of forest.

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

$IVI_i = RFr_i + RDe_i + RDo_i$ for pole and tree; and

$IVI_i = RFr_i + RDe_i$ 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 & Curtis 1956, Murdjoko et al. 2016a, Fatem et al. 2020).

RESULTS AND DISCUSSION

Tree species diversity

The two studied districts consisted of natural tropical forests with high species diversity. The results showed that 185 tree species were belonging to 56 families. This finding suggests that tree species diversity at the studied sites was high which is the characteristic of the New Guinea region(Whitfeld et al. 2014, Cámara-Leret et al. 2020, Murdjoko et al. 2020, Sheil et al. 2021). The two studied sites had relatively similar Shannon-Wiener diversity index (H') with 2.758 for *Murkim* District and 2.765 for *Teiraplu*. The tree species evenness value distribution was 0.930 and 0.937 for *Murkim* and *Teiraplu* Districts, respectively (Table 1), suggesting that tree species were evenly distributed, and none dominated both forests (Spellerberg & Fedor, 2003).

Commented [AR2]: I would suggest to present all these species in the Appendix as this dataset is important for reference regarding biodiversity information especially in a lesser known region such as Papua, moreover in Pegunungan Bintang.

Table 1. Shannon-Wiener diversity index (H') and Pielou's evenness index(J) at two studied sites in two districts in *Pegunungan Bintang* Regency.

Location	*Murkim*		*Teiraplu*		Both District	
Index	H'	J	H'	J	H'	J
Mean	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

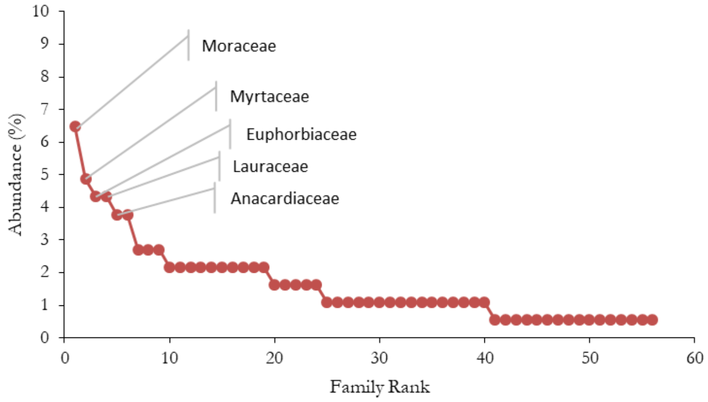


Figure 2. Taxon sequences for Family Rank (x-axis) based on the proportion of the number of species and individuals as a percentage (y-axis) in the two districts.

The distribution of taxon at family level in the two studied sites can be said to be not dominated by a certain family. Based on the number of species and individuals, families that occupied the top five positions were *Moraceae, Myrtaceae, Euphorbiaceae, Lauraceae,* and *Anacardiaceae* (Figure 2). The five families had the greatest proportion with a value of more than three percent, while the other 76 families had the same value with the highest proportion being three percent. This result implies that the forests at the two studied sites were mixed tropical forests (Murdjoko et al. 2016a, Murdjoko et al. 2020).

Table 2. Ten species with the highest Importance Value Index (IVI) at seedlings, saplings, poles, and trees at the studied site in *Teiraplu* District.

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Seedlings

No	Species	F	D	RF	RD	IVI (%)
1	*Xanthostemon novaguineensis* Valeton	0.17	0.92	2.90	8.56	11.46
2	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb.	0.29	0.58	5.07	5.45	10.52
3	*Fagraea racemosa* Jack	0.25	0.38	4.35	3.50	7.85
4	*Aglaia argentea* Blume	0.17	0.46	2.90	4.28	7.18
5	*Geniostoma rupestre* J.R.Forst. & G.Forst.	0.17	0.46	2.90	4.28	7.18
6	*Canarium hirsutum* Willd.	0.13	0.50	2.17	4.67	6.84
7	*Garcinia latissima* Miq.	0.17	0.33	2.90	3.11	6.01
8	*Gnetum gnemon* L.	0.21	0.25	3.62	2.33	5.96
9	*Vatica rassak* Blume	0.21	0.21	3.62	1.95	5.57
10	*Canarium indicum* L.	0.17	0.25	2.90	2.33	5.23

Saplings

No	Species	F	D	RF	RD	IVI (%)
1	*Macaranga densiflora* Warb.	0.42	0.88	4.39	5.87	10.25
2	*Aglaia argentea* Blume	0.42	0.83	4.39	5.59	9.97
3	*Fagraea racemosa* Jack	0.33	0.67	3.51	4.47	7.98
4	*Teijsmanniodendron bogoriense* Koord.	0.33	0.67	3.51	4.47	7.98
5	*Vatica rassak* Blume	0.25	0.54	2.63	3.63	6.26
6	*Pararchidendron pruinosum* (Benth.) I.C.Nielsen	0.25	0.33	2.63	2.23	4.87

7	*Canarium indicum* L.	0.21	0.38	2.19	2.51	4.71
8	*Gmelina sessilis* C.T.White & W.D.Francis ex Lane-Poole	0.21	0.29	2.19	1.96	4.15
9	*Prunus arborea* (Blume) Kalkman	0.21	0.29	2.19	1.96	4.15
10	*Canarium hirsutum* Willd.	0.21	0.25	2.19	1.68	3.87

Poles

No	Species	F	D	Do	RF	RD	RDo	IVI (%)
1	*Melicope elleryana* (F. Muell.) T.G. Hartley	0.13	0.25	0.00	3.70	6.38	7.30	17.38
2	*Pararchidendron pruinosum* (Benth.) I.C.Nielsen	0.17	0.25	0.00	4.94	6.38	4.78	16.10
3	*Acronychia reticulata* Lauterb.	0.17	0.21	0.00	4.94	5.32	3.57	13.82
4	*Lithocarpus rufovillosus* (Markgr.) Rehder	0.13	0.17	0.00	3.70	4.26	5.36	13.32
5	*Parastemon versteeghii* Merr. & L.M.Perry	0.17	0.17	0.00	4.94	4.26	4.07	13.26
6	*Vatica rassak* Blume	0.17	0.17	0.00	4.94	4.26	3.74	12.93
7	*Xanthostemon novaguineensis* Valeton	0.08	0.17	0.00	2.47	4.26	4.85	11.57
8	*Pometia pinnata* J.R.Forst. & G.Forst.	0.08	0.13	0.00	2.47	3.19	4.54	10.20
9	*Homalanthus novoguineensis* (Warb.) K.Schum.	0.08	0.17	0.00	2.47	4.26	3.02	9.75
10	*Prunus arborea* (Blume) Kalkman	0.13	0.13	0.00	3.70	3.19	2.39	9.28

Trees

No	Species	F	D	Do	RF	RD	RDo	IVI (%)
1	*Parastemon versteeghii* Merr. & L.M.Perry	0.46	0.58	0.07	11.00	12.96	17.78	41.74
2	*Vatica rassak* Blume	0.25	0.33	0.02	6.00	7.41	5.27	18.67
3	*Lithocarpus rufovillosus* (Markgr.) Rehder	0.29	0.29	0.02	7.00	6.48	4.31	17.80
4	*Xanthostemon novaguineensis* Valeton	0.21	0.21	0.03	5.00	4.63	6.93	16.56
5	*Gironniera nervosa* Planch.	0.25	0.25	0.01	6.00	5.56	3.65	15.20
6	*Intsia palembanica* Miq.	0.08	0.08	0.02	2.00	1.85	4.82	8.67
7	*Decaspermum parviflorum* (Lam.) A.J.Scott	0.13	0.13	0.01	3.00	2.78	2.33	8.11
8	*Teijsmanniodendron bogoriense* Koord.	0.13	0.13	0.01	3.00	2.78	2.27	8.05
9	*Eucalyptopsis papuana* C.T.White	0.04	0.04	0.02	1.00	0.93	5.66	7.59
10	*Litsea timoriana* Span.	0.13	0.13	0.01	3.00	2.78	1.81	7.58

Table 2. Ten species with the highest Importance Value Index (IVI) at seedlings, saplings, poles, and trees at the studied site in *Murkim* District

Seedlings

No	Species	F	D	RF	RD	IVI (%)
1	*Hopea novoguineensis* Slooten	0.44	2.64	7.38	22.37	29.76
2	*Canarium indicum* L.	0.40	0.84	6.71	7.12	13.83
3	*Premna corymbosa* Rottler & Willd.	0.24	0.60	4.03	5.08	9.11
4	*Lithocarpus rufovillosus* (Markgr.) Rehder	0.20	0.48	3.36	4.07	7.42
5	*Ficus robusta* Corner	0.20	0.44	3.36	3.73	7.08
6	*Glochidion* sp	0.16	0.36	2.68	3.05	5.74
7	*Sloanea pullei* O.C.Schmidt ex A.C.Sm.	0.20	0.28	3.36	2.37	5.73
8	*Fagraea racemosa* Jack	0.16	0.20	2.68	1.69	4.38
9	*Maniltoa browneoides* Harms	0.16	0.20	2.68	1.69	4.38
10	*Chrysophyllum papuanicum* (Pierre ex Dubard) Royen	0.04	0.36	0.67	3.05	3.72

Saplings

No	Species	F	D	RF	RD	IVI (%)
1	*Ficus* sp	0.52	1.28	4.63	7.60	12.23
2	*Macaranga densiflora* Warb.	0.40	0.84	3.56	4.99	8.55

3	*Premna corymbosa* Rottler & Willd.	0.40	0.84	3.56	4.99	8.55
4	*Ficus robusta* Corner	0.36	0.60	3.20	3.56	6.77
5	*Syzygium* sp1	0.36	0.48	3.20	2.85	6.05
6	*Hopea novoguineensis* Slooten	0.24	0.60	2.14	3.56	5.70
7	*Ficus sycomorus* L.	0.24	0.44	2.14	2.61	4.75
8	*Callicarpa longifolia* Lam.	0.24	0.40	2.14	2.38	4.51
9	*Canarium indicum* L.	0.24	0.36	2.14	2.14	4.27
10	*Intsia palembanica* Miq.	0.24	0.36	2.14	2.14	4.27

Poles

No	Species	F	D	Do	RF	RD	RDo	IVI (%)
1	*Syzygium* sp1	0.24	0.36	0.01	7.14	9.09	9.03	25.27
2	*Hopea novoguineensis* Slooten	0.20	0.24	0.00	5.95	6.06	6.61	18.62
3	*Alphitonia incana* (Roxb.) Teijsm. & Binn. ex Kurz	0.08	0.28	0.01	2.38	7.07	8.58	18.03
4	*Ficus* sp	0.16	0.20	0.00	4.76	5.05	5.61	15.42
5	*Intsia palembanica* Miq.	0.16	0.16	0.00	4.76	4.04	3.71	12.51
6	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb.	0.12	0.12	0.00	3.57	3.03	3.16	9.76
7	*Hopea papuana* Diels	0.08	0.12	0.00	2.38	3.03	3.43	8.85
8	*Pometia acuminata* Radlk.	0.08	0.12	0.00	2.38	3.03	3.20	8.61
9	*Canarium hirsutum* Willd.	0.08	0.08	0.00	2.38	2.02	3.15	7.55
10	*Parastemon versteeghii* Merr. & L.M.Perry	0.08	0.12	0.00	2.38	3.03	2.11	7.52

Trees

No	Species	F	D	Do	RF	RD	RDo	IVI (%)
1	*Intsia palembanica* Miq.	0.24	0.28	0.09	6.82	7.45	25.98	40.24
2	*Hopea novoguineensis* Slooten	0.44	0.48	0.05	12.50	12.77	13.06	38.33
3	*Lithocarpus rufovillosus* (Markgr.) Rehder	0.16	0.20	0.02	4.55	5.32	4.56	14.43
4	*Buchanania arborescens* (Blume) Blume	0.16	0.16	0.01	4.55	4.26	3.88	12.68
5	*Knema intermedia* Warb.	0.16	0.16	0.01	4.55	4.26	2.71	11.51
6	*Vatica rassak* Blume	0.12	0.16	0.01	3.41	4.26	2.09	9.76
7	*Palaquium lobbianum* Burck	0.12	0.12	0.01	3.41	3.19	2.40	9.00
8	*Hopea papuana* Diels	0.08	0.08	0.01	2.27	2.13	2.60	7.00
9	*Tristaniopsis macrosperma* (F.Muell.) Peter G.Wilson & J.T.Waterh.	0.08	0.08	0.01	2.27	2.13	2.37	6.77
10	*Campnosperma brevipetiolatum* Volkens	0.08	0.08	0.01	2.27	2.13	2.11	6.51

Note: F: frequency, D: density, Do: dominance, RF: relative frequency, RD: relative density, RDo: relative dominance, and IVI (%): Importance Value Index

The composition of vegetation at the two studied sites was analyzed based on the Importance Value Index (IVI) as shown in Tables 2 and 3. It can be seen that the top ten most important species differed across life stages and between the two studied sites. This indicates that the dynamic conditions of stand composition in these forests varied widely. The position of adult plants (i.e. poles and trees) depends on the current state of composition and the dynamics of succession which are strongly affected by competition among species in the juvenile stages (i.e. seedlings and saplings). For example, in Teraiplu District, at the adult level, there were *Melicope elleryana*, *Pararchidendron pruinosum*, *Parastemon versteeghii* and *Vatica rassak*. However, at the seedling and sapling levels, there were different species, namely *Xanthostemon novaguineensis*, *Gymnacranthera farquhariana*, *Macaranga densilora* and *Aglaia argentea*. This phenomenon is a normal state in tropical forests where adult species that dominate a site do not necessarily have good regeneration abilities. This is due to elusive factors in mixed tropical forest ecosystems. This situation can be presumed due to heterospecific and conspecific associations that occur as a form of 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).

Species potentials for timber and wood products

The potentials for timber and wood products were inferred from the number of individuals and the volume per unit area (de Avila et al. 2017). In this research, the diameter class of tree species was grouped with an interval of 10 cm (Figure 3 and Figure 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 are classified into three groups, namely large logs (KBB), medium logs (KBS) and small logs (KBK).

Based on the results of this study, the DBH of trees recorded in the studied sites ranged from 0-80s cm (Figure 3), suggesting that the forest can produce timber in the form of KBK, KBS, and KBB. The number of individuals with the diameter class below 10 cm was the highest and decreased as the diameter class increased (Figure 3). However, the potential for timber to be utilized is assumed for diameter classes above 10 cm. Using the diameter measurement, the economic value of the timber can be estimated using its volume (Groenendijk et al. 2017).

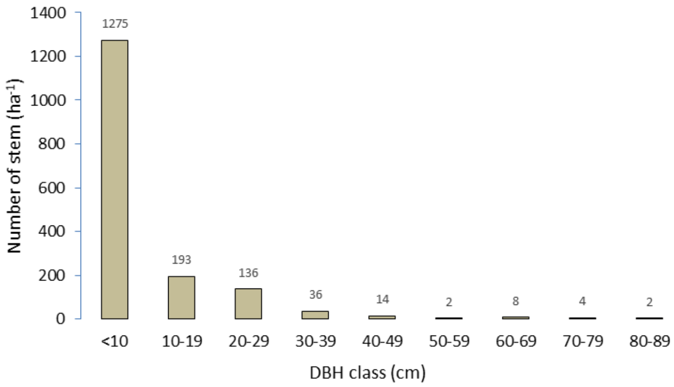

Figure 3. Diameter class distribution (individuals per hectare) in the two studied sites combined in *Pegunungan Bintang* Regency.

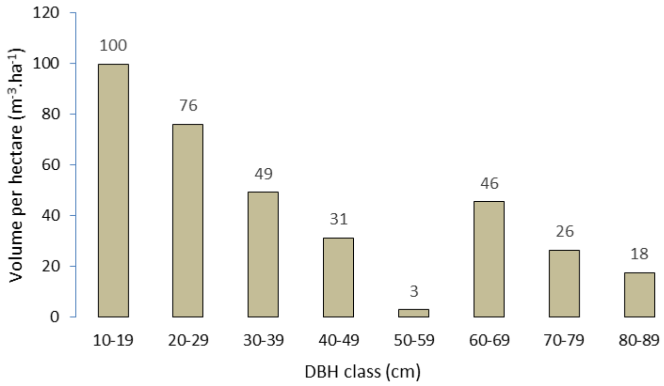

Figure 4. Potential standing timber volume (m^3 per hectare) based on diameter class distribution in the two studied sites combined in *Pegunungan Bintang* Regency.

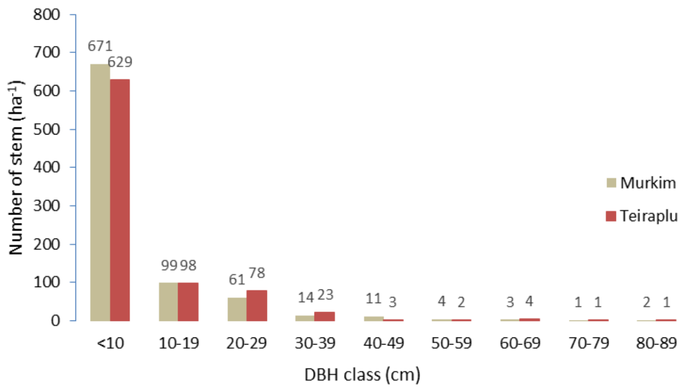

Figure 5. Diameter class distribution (individuals per hectare) in each studied site in *Murkim* and *Teiraplu* Districts.

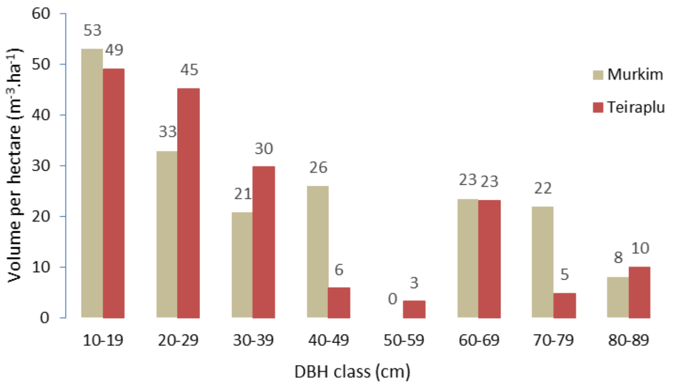

Figure 6. Potential standing timber volume (m^3 per hectare) based on diameter class distribution in each studied site in *Murkim* and *Teiraplu* Districts.

From the calculation of timber potential in each diameter class, it can be seen that the highest volume was in the diameter class of 10-19 cm with around 100 m^3 ha^{-1}, and tends to decrease along with the increase in diameter (Figure 4). This result suggests that the potential of timber yield in these two districts was still in great volume since there were trees from small to large diameters that formed mixed natural forest structures. The reversed J shape curve in the graphs was an indicator that the forest had a good condition (Myanmar 2016, Padmakumar et al. 2018). The large trees here would not cut totally as selective cutting is probably implemented. The remnant large trees could have a function as putative parent trees where they play an imperative role during the fecundity phase (Qiu et al. 2021). Based on the distribution of the number of individuals per hectare across diameter class for the two districts, it can be seen that the number of individuals in the two districts did not differ (Figure 5) which was indicated by the distribution of the number of individuals was still complete for each diameter class. As per volume, the abundance per hectare decreased along with the increase in the diameter class. The distribution of potential timber forest products between the two districts also is not largely different. This can be seen from the shape of the distribution that is almost the same in the two districts. Only in the 50-59 cm diameter class, there was no individual in *Teiraplu* District. Conclusively, the potential for timber forest products in the two districts was yielded from the small-diameter class to the largest diameter class (i.e. 80-89 cm) (Figure 6).

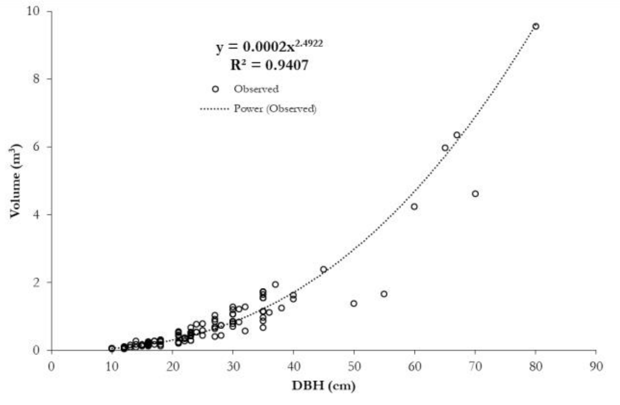

Figure 7. The relationship between the diameter (DBH: cm) and the volume of standing wood (m^3). Note: $y = 0.0002x^{2.4922}$ is an equation formed with the coefficient of determination (R^2) is 0.9407. In this equation, x is the diameter (DBH) and y is the volume of wood.

Based on the distribution of potential timber forest products measured in units of volume (m^3) per tree and diameter (cm), a regression was made. The result of regression analysis produces a mathematical equation of $y = 0.0002x^{2.4922}$ (Figure 7). The coefficient of determination is 0.9407, which is close to 1 (Ishihara et al. 2016), suggesting this equation can be used to calculate the volume of standing trees in the forest. This result is in line with previous studies that state DBH can be used to predict the volume of timber in the tropical forest (Harja et al. 2012, Tang et al. 2017, Andrade et al. 2019).

Tree diversity to support sustainable timber production

The tropical rainforest has a high diversity of vegetation in which trees are the dominant life form (Murdjoko et al. 2021a, Murdjoko et al. 2021b). The studied sites are part of intact natural forests in lowland areas so that the ecological process can occur naturally without human intervention. The regeneration of trees is depending on the existence of putative parent trees. Besides, seed dispersal also plays a crucial role in the regeneration and distribution of species. This research revealed that the forest is in a stable ecological state in which vertical layers such as the forest floor and canopy layer were in good condition (Murdjoko et al. 2017, Moreno-Mateos et al. 2020). There were plenty of small trees as future trees in the forest regardless of species and the forest would grow naturally as the character of old-growth forest (Murdjoko 2013, Murdjoko et al. 2016b). This forest also benefits from other biotic factors which can support the sustainability of tropical rain forest.

The vertical structure of this forest indicated that larger trees were present. Trees might contribute up to 30 % of species richness, especially in the New Guinea ecosystem (Cámara–Leret & Dennehy 2019, Cámara-Leret et al. 2020). Nonetheless, as regional development is occurring in *Pegunungan Bintang* Regency, the demand for timber would probably increase to meet the need for infrastructure development. The studied forest is possible to 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 possibly carried out with a certain diameter limit and logging intensity. The mechanism of timber exploitation must be in line with the national regulation, for example by following the reduced impact logging (RIL) method.

The local government should pay attention to the regulation, socio-culture, private sectors, non-governmental organizations (NGOs), and other stakeholders. To achieve the goals of sustainable forest management, actors must get involved either directly or indirectly. Many production forests in tropical countries are mainly located close or overlapped with areas of local people. Thus, timber extraction from customary forests should be conducted carefully. 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 the goals of regional development (Ungirwalu et al. 2021).

To sum up, the forest in *Pegunungan Bintang* Regency was formed by the high diversity of tree species which form a tropical mixed forest. The families of *Moraceae, Myrtaceae, Euphorbiaceae, Lauraceae,* and *Anacardiaceae* were the dominant family in *Pegunungan Bintang* with a variety of species in seedlings, saplings, poles, and trees. The potential of timber can be seen from the distribution of individuals following the reverse J-shaped curve indicating that the trees were merchantable and provide 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.

Appendix 1. List of tree species in two districts and the "√" is the symbol of the presence of tree species.

No	Tree Species	District

		Murkim	Teiraplu
1	*Acronychia brassii* T.G.Hartley	√	
2	*Acronychia reticulata* Lauterb.	√	√
3	*Acronychia* sp		√
4	*Actinodaphne nitida* Teschner	√	√
5	*Adinandra integerrima* T.Anderson ex Dyer	√	
6	*Aglaia argentea* Blume	√	√
7	*Aglaia spectabilis* (Miq.) S.S.Jain & S.Bennet	√	√
8	*Alphitonia incana* (Roxb.) Teijsm. & Binn. ex Kurz	√	√
9	*Alstonia scholaris* (L.) R. Br.	√	√
10	*Alstonia spectabilis* R.Br.		√
11	*Antiaris toxicaria* Lesch.	√	√
12	*Antiaropsis decipiens* K.Schum.		√
13	*Archidendron parviflorum* Pulle	√	
14	*Artocarpus altilis* (Parkinson ex F.A.Zorn) Fosberg	√	√
15	*Beilschmiedia morobensis* Kosterm.	√	
16	*Bischofia javanica* Blume		√
17	*Blumeodendron tokbrai* (Blume) Kurz		√
18	*Buchanania arborescens* (Blume) Blume	√	√
19	*Buchanania macrocarpa* Lauterb.	√	
20	*Callicarpa longifolia* Lam.	√	√
21	*Calophyllum caudatum* Kaneh. & Hatus.	√	√
22	*Calophyllum inophyllum* L.	√	√
23	*Campnosperma brevipetiolatum* Volkens	√	√
24	*Cananga odorata* (Lam.) Hook.f. & Thomson		√
25	*Canarium asperum* Benth.		√
26	*Canarium hirsutum* Willd.	√	√
27	*Canarium indicum* L.	√	√
28	*Canarium rigidum* (Blume) Zipp. ex Miq.	√	√
29	*Carallia brachiata* (Lour.) Merr.	√	
30	*Casearia carrii* Sleumer	√	√
31	*Casearia monticola* Sleumer	√	
32	*Casearia* sp	√	
33	*Casearia urophylla* Gilg		√
34	*Cerbera floribunda* K.Schum.	√	√
35	*Chionanthus macrocarpus* Blume		√
36	*Chisocheton ceramicus* Miq.	√	√
37	*Chrysophyllum papuanicum* (Pierre ex Dubard) Royen	√	√
38	*Cleistanthus papuanus* (Lauterb.) Jabl.	√	√
39	*Cochlospermum gillivraei* Benth.	√	
40	*Commersonia bartramia* (L.) Merr.	√	√
41	*Corynocarpus laevigatus* J.R.Forst. & G.Forst.	√	√
42	*Cryptocarya palmerensis* C.K.Allen	√	√
43	*Cryptocarya* sp	√	√
44	*Decaspermum parviflorum* (Lam.) A.J.Scott	√	√
45	*Dillenia papuana* Martelli	√	
46	*Diospyros papuana* Valeton ex Bakh.	√	
47	*Diospyros pilosanthera* Blanco	√	
48	*Diospyros* sp	√	
49	*Dracontomelon dao* (Blanco) Merr. & Rolfe	√	√
50	*Drypetes globosa* (Merr.) Pax & K.Hoffm.		√
51	*Dysoxylum mollissimum* Blume	√	√
52	*Elaeocarpus angustifolius* Blume	√	√
53	*Elaeocarpus arnhemicus* F.Muell.		√
54	*Endiandra rubescens* (Blume) Miq.	√	√
55	*Endiandra virens* F.Muell.		√
56	*Endospermum medullosum* L.S.Sm.	√	√
57	*Eucalyptopsis papuana* C.T.White		√
58	*Fagraea elliptica* Roxb.		√
59	*Fagraea racemosa* Jack	√	√
60	*Ficus annulata* Blume		√
61	*Ficus chrysolepis* Miq.	√	
62	*Ficus hispida* L.f.		√

63	*Ficus nodosa* Teijsm. & Binn.	√	√
64	*Ficus racemosa* L.	√	√
65	*Ficus robusta* Corner	√	√
66	*Ficus septica* Burm.f.	√	
67	*Ficus* sp	√	√
68	*Ficus sycomorus* L.	√	
69	*Ficus variegata* Blume	√	
70	*Flindersia pimenteliana* F.Muell.	√	
71	*Galbulimima belgraveana* (F.Muell.) Sprague	√	√
72	*Garcinia latissima* Miq.	√	√
73	*Garcinia picrorhiza* Miq.	√	√
74	*Garcinia* sp	√	√
75	*Gironniera nervosa* Planch.	√	√
76	*Glochidion* sp	√	
77	*Gmelina sessilis* C.T.White & W.D.Francis ex Lane-Poole	√	√
78	*Gnetum gnemon* L.	√	√
79	*Goniothalamus giganteus* Hook.f. & Thomson		√
80	*Gonocaryum litorale* (Blume) Sleumer	√	√
81	*Grewia eriocarpa* Juss.	√	
82	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb.	√	√
83	*Halfordia kendack* Guillaumin		√
84	*Haplolobus celebicus* H.J.Lam	√	
85	*Haplolobus floribundus* (K.Schum.) H.J.Lam	√	√
86	*Haplolobus lanceolatus* H.J.Lam ex Leenh.	√	√
87	*Harpullia carrii* Leenh.	√	
88	*Heritiera sylvatica* S.Vidal	√	√
89	*Homalanthus novoguineensis* (Warb.) K.Schum.		√
90	*Homalanthus populneus* (Geiseler) Pax	√	
91	*Homalium foetidum* Benth.	√	√
92	*Hopea celtidifolia* Kosterm.	√	
93	*Hopea novoguineensis* Slooten	√	√
94	*Hopea papuana* Diels	√	√
95	*Horsfieldia irya* (Gaertn.) Warb.	√	√
96	*Horsfieldia laevigata* Warb.	√	√
97	*Horsfieldia parviflora* (Roxb.) J.Sinclair	√	
98	*Horsfieldia sylvestris* Warb.	√	
99	*Intsia palembanica* Miq.	√	√
100	*Jagera pseudorhus* Radlk.	√	√
101	*Kibara bullata* Philipson		√
102	*Kibara coriacea* (Blume) Hook. f. & A. Thomps.	√	
103	*Kibara elongata* A.C.Sm.	√	
104	*Kleinhovia hospita* L.		√
105	*Knema intermedia* Warb.	√	
106	*Lithocarpus rufovillosus* (Markgr.) Rehder	√	√
107	*Litsea firma* (Blume) Hook.f.	√	√
108	*Litsea ledermannii* Teschner	√	
109	*Litsea* sp	√	
110	*Litsea timoriana* Span.	√	√
111	*Maasia glauca* (Hassk.) Mols, Kessler & Rogstad		√
112	*Maasia sumatrana* (Miq.) Mols, Kessler & Rogstad		√
113	*Macaranga densiflora* Warb.	√	√
114	*Macaranga gigantea* (Rchb.f. & Zoll.) Müll.Arg.	√	
115	*Macaranga mappa* (L.) Müll.Arg.	√	
116	*Macaranga tanarius* (L.) Müll.Arg.	√	√
117	*Magnolia tsiampacca* (L.) Figlar & Noot.		√
118	*Mallotus philippensis* (Lam.) Müll.Arg.	√	√
119	*Mallotus* sp	√	√
120	*Maniltoa browneoides* Harms	√	√
121	*Maniltoa plurijuga* Merr. & L.M.Perry	√	
122	*Mastixiodendron pachyclados* (K.Schum.) Melch.		√
123	*Medusanthera laxiflora* (Miers) R.A.Howard	√	√
124	*Melicope bonwickii* (F. Muell.) T.G. Hartley	√	
125	*Melicope elleryana* (F. Muell.) T.G. Hartley	√	√
126	*Myristica ensifolia* J.Sinclair		√

127	*Myristica fatua* Houtt.	√	√
128	*Myristica gigantea* King	√	√
129	*Myristica globosa* Warb.	√	
130	*Myristica hollrungii* Warb.		√
131	*Nauclea orientalis* (L.) L.		√
132	*Neolamarckia cadamba* (Roxb.) Bosser	√	√
133	*Ochrosia glomerata* (Blume) F.Muell.	√	
134	*Octamyrtus insignis* Diels		√
135	*Palaquium lobbianum* Burck	√	√
136	*Pararchidendron pruinosum* (Benth.) I.C.Nielsen		√
137	*Parastemon versteeghii* Merr. & L.M.Perry	√	√
138	*Phaleria macrocarpa* (Scheff.) Boerl.	√	
139	*Picrasma javanica* Blume	√	
140	*Pimelodendron amboinicum* Hassk.	√	√
141	*Pisonia longirostris* Teijsm. & Binn.	√	√
142	*Planchonella anteridifera* (C.T.White & W.D.Francis ex Lane-Poole) H.J.Lam		√
143	*Planchonella keyensis* H.J.Lam	√	√
144	*Polyscias nodosa* (Blume) Seem.	√	√
145	*Pometia acuminata* Radlk.	√	√
146	*Pometia pinnata* J.R.Forst. & G.Forst.	√	√
147	*Premna corymbosa* Rottler & Willd.	√	
148	*Prunus arborea* (Blume) Kalkman	√	√
149	*Prunus javanica* (Teijsm. & Binn.) Miq.	√	√
150	*Pterocarpus indicus* Willd.	√	√
151	*Pterocymbium beccarii* K.Schum.	√	
152	*Rapanea tempanpan* P.Royen		√
153	*Rhodamnia cinerea* Jack	√	√
154	*Rhus lamprocarpa* Merr. & L.M.Perry		√
155	*Rhus taitensis* Guill.	√	√
156	*Ryparosa javanica* Koord. & Valeton	√	√
157	*Schizomeria ovata* D.Don		√
158	*Semecarpus papuana* Lauterb.	√	
159	*Siphonodon celastrineus* Griff.	√	√
160	*Siphonodon* sp	√	√
161	*Sloanea pullei* O.C.Schmidt ex A.C.Sm.	√	
162	*Spathiostemon javensis* Blume	√	√
163	*Sterculia macrophylla* Vent.	√	√
164	*Sterculia shillinglawii* F.Muell.	√	√
165	*Streblus elongatus* (Miq.) Corner	√	√
166	*Sundacarpus amarus* (Blume) C.N.Page		√
167	*Symplocos anomala* Brand	√	
168	*Symplocos gigantifolia* Noot.		√
169	*Syzygium* sp1	√	√
170	*Syzygium* sp2	√	
171	*Syzygium* sp3	√	
172	*Syzygium versteegii* (Lauterb.) Merr. & L.M.Perry	√	
173	*Tabernaemontana aurantiaca* Gaudich.		√
174	*Teijsmanniodendron bogoriense* Koord.	√	√
175	*Terminalia copelandi* Elmer	√	
176	*Terminalia kaernbacchii* Warb.		√
177	*Timonius carii* S.P.Darwin	√	√
178	*Timonius timon* (Spreng.) Merr.	√	√
179	*Tristaniopsis macrosperma* (F.Muell.) Peter G.Wilson & J.T.Waterh.	√	√
180	*Vatica rassak* Blume	√	√
181	*Vitex pinnata* L.	√	
182	*Weinmannia alta* Engl.		√
183	*Wendlandia* sp	√	
184	*Xanthophyllum papuanum* Whitmore ex Meijden	√	√
185	*Xanthostemon novaguineensis* Valeton		√

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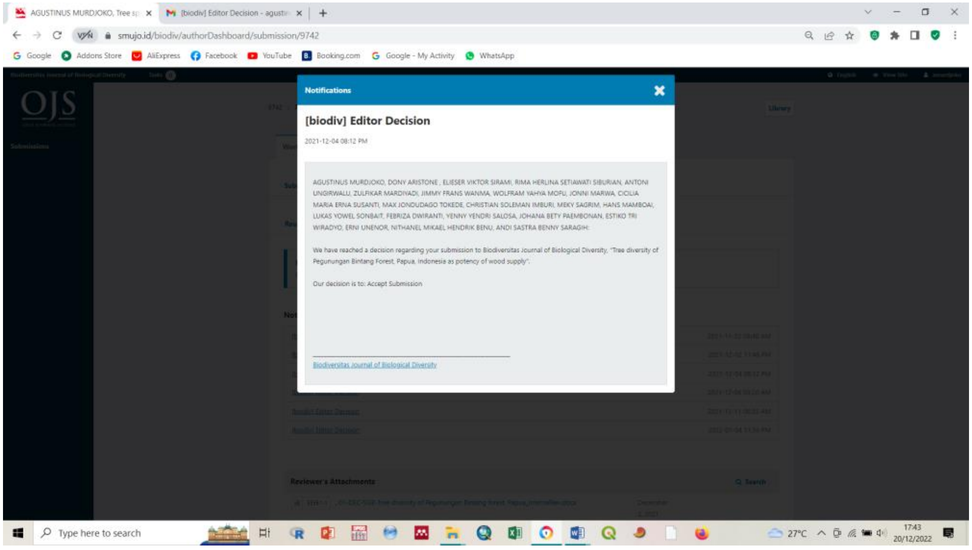

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Tree Diversity of *Pegunungan Bintang* Forest, Papua as Potency of Wood Supply

Abstract. 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. In this study, systematic plots were set in Murkim and Teiraplu 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 *Vitaceae, Melastomataceae, Cunoniaceae, Schizomeria,* and *Loganiaceae*, 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: Shannon-Wiener index, New Guinea, timber production, understory.

Abbreviations (if any): All important abbreviations are defined at their first mention consistently throughout the article.

Running title: Tree diversity in timber supply

INTRODUCTION

Tropical forests are part of the living natural resources that enhance the population's sustenance (Fredericksen & Putz 2003). These forests improve the ecosystem sustainability, including the hydrological cycle for constant water supply (Lohbeck et al. 2014, Margono et al. 2014). Their global function is to balance the nutrient cycle such as carbon, which is currently an international issue used as carbon sinks and stores. Therefore, tropical forest ecosystems are significant for social, economic, and ecological life (Rozendaal et al. 2019, Murdjoko et al. 2020, Tawer et al. 2021).
The tropical rain forests in Papua, especially the Regency of *Pegunungan Bintang*, consist of lakes and rivers (alluvial and colluvial), denuded structural morphology, and glacier morphology at an altitude of 0 to 4.700 m above sea level (asl). The *Pegunungan Bintang* Regency is a segment of Papua's Central Mountains consisting of an active fold and fault area with a moderate to heavy, undulating topography at an altitude of 1.000 – 4.700 m above the sea level and at 30-45% slope level. The northern part has igneous rocks metamorphosed through folding and intensive fractures during the Pre-Tertiary and Quaternary ages (0.5-2 million years ago). These rocks show potential characteristics for coal, petroleum, and other metal mineralization. The Regency's northern mountains stand at a strong collision zone between the oceanic plate and the vast continent (Australia), at a 30-45% slope. They are part of the Papua coastal plains, consisting of sedimentary layers indicating floodplain dominance (Murdjoko et al., 2020).
The population in the tropical forest has coexisted and utilized its resources for a long time. The forest resources are part of the population's activities and enhance their economic value (Ungirwalu et al., 2014; Ungirwalu et al., 2017). The continuous utilization of these resources, such as timber, creates an economic mechanism (Kuswandi & Murdjoko 2015, Murdjoko et al. 2016b). Timber is a tree product which has been officially or illegally utilized over a long time (Murdjoko 2013, Kübler et al. 2020), however its prolong exploitation is detrimental to the forest ecosystem. Therefore, this study examined the tree diversity in *Pegunungan Bintang* forest, Papua, Indonesia. Furthermore, it uncovered the 10 dominant species using seedlings, saplings, poles, and trees, and described the timber production potency.

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MATERIALS AND METHODS

Study area

The study was conducted in Murkim and Teiraplu districts in *Pegunungan Bintang* Regency. The Murkim district is located in the northernmost eastern part covering 359 km2 as per the administrative boundaries. It is located at coordinates 140°39'35,289 "- 41°00'00,00" East Longitude and 04°00'59,196"- 04°21'54.82" South Latitude (Figure 1). In contrast, the Teiraplu District is located in the north, spread at 1,469 km^2. It is located at coordinates 140°13'26,618 "- 140°30'47,699" East Longitude and 03°44'42,041"-04°26'23,674" South Latitude. The *Pegunungan Bintang* Regency is located in Papua Province, 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).

Figure 1. Location of research (symbolized by white box).

Samplings and survey

The study used data from 24 systematic plots in Teiraplu and Murkim districts. The distance among the plots was about 100 m, measuring 20 m x 20 m for the tree with three subplots (10 m x 10 m for pole, 5 m x 5 m for a sapling, and 2 m x 2 m for seedling). The data included the plot of individuals, tree species, pole, sapling, and seedling for taxonomic information. The species level was categorized by morphological characteristics based on key determinants, while the unidentified species was 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 species' scientific name was based on The Plant List (TPL) on the website: http://www.theplantlist.org/. The tree pole diameter and clear bole height measurements used phi band, and the Haga hypsometer measured the trees. The diameter was measured at 1.3 m above the ground or breast height and 10 above the buttress. The clear bole height was measured at a vantage point below the first branch.

Data analysis

The species diversity and evenness were calculated 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 total samples where species *i* is present. Pielou's evenness was computed using $J=H'/[\ln(S)]$, where S is the total species for each forest type (Spellerberg & Fedor 2003, Tawer et al. 2021). The Importance Value Index (IVI) of species was computed by adding relative frequency, density, and dominance as $IVI_i=RFr_i+RDe_i+RDo_i$ for pole and tree, and $IVI_i = RFr_i + RDe_i$ for sapling and seedling where IVI_i is the critical 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 & Curtis 1956, Murdjoko et al. 2016a, Fatem et al. 2020).

RESULTS AND DISCUSSION

Forest description

The two districts consist of natural tropical forests with high species diversity. The results showed that there were 80 tree families with 209 species. 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-

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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 diversity index (H') at 2.758 for Murkim District and 2.765 for Teiraplu. The tree species evenness value distribution was 0.930 and 0.937 for Murkim and Teiraplu Districts, respectively (Table 1). Therefore, the diversity and tree species are evenly distributed, and none dominates both forests (Spellerberg & Fedor, 2003).

Table 1. Diversity and evenness scores in both districts where H 'is Shannon diversity index and J is Evenness.

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

The taxon's family level is evenly distributed in both forests, hence categorized as tropical mixed forests. However, the analysis can sort the taxon's family level position based on total species and individuals. The analysis showed that the top five families include *Vitaceae*, *Melastomataceae*, *Cunoniaceae*, *Schizomeria,* and *Loganiaceae* (Figure 2). These families had the most significant proportion with a value above three percent, while the other 76 families had a similar value with the highest distribution being three percent. Therefore, both districts had a mixed tropical forest ecosystem formed by various species interactions with trees (Murdjoko et al. 2016a, Murdjoko et al. 2020).

Table 2. Top ten dominant species for seedlings, saplings, poles, and trees in each district based on the Importance Value Index (IVI).

District Teiraplu
Seedlings
Saplings
Poles
Trees

District Murkim
Seedlings
Saplings
Poles
Trees

Note: F shows the frequency, D the density, Do the dominance, RF the Relative Frequency, RD the Relative Density, RDo the Relative Dominance, and the IVI (%) is the Importance Value Index.

The analysis of highly diverse taxon species can determine the various dominating species at each district's seedling, sapling, poles, and tree levels. The Importance Value Index (IVI) in percentage was used for the analysis in Table 2, indicating the different top ten species in each level. The results indicated that the dynamic conditions of stand composition varied widely. The adult individual's positions showed that poles and tree regeneration depend on forest conditions such as species competition. Therefore, various species at the seedling and sapling levels reflect the regeneration of the adult individual controlled by others. This can be seen in Teraplu District, and the adult level includes *Melicope elleryana* (F. Muell.) T.G. Hartley, *Pararchidendron pruinosum* (Benth.) I.C.Nielsen, *Parastemon versteeghii* Merr. & L.M.Perry and Vat*i*ca *rassak* Blume.

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There are various species at the seedling and sapling level, such as *Xanthostemon novaguineensis* Valeton, *Gymnacranthera farquhariana* (Hook. f. & Thomson) Warb., *Macaranga densilora* Warb. and *Aglaia argentea* Blume. In most tropical forests with dominating adult species, certain areas lack regeneration abilities due to elusive factors in their ecosystems. However, this can also result from heterospecific and conspecific associations caused by individual or different species relationships (Murdjoko et al. 2016c, Murdjoko et al. 2017, Murdjoko et al. 2020). This is a significant concern for tropical forest management, especially avoiding intervention on the species regeneration (Menezes et al. 2019, Mahayani et al. 2020).

Potential of Timber Products

The forest trees offer potential timber benefits based on the total individuals and the volume per hectare (de Avila et al., 2017). Therefore, the potential distribution is grouped based on the diameter class at a 10 cm interval (Figure 3 and Figure 4). According to the Indonesian Regulation of the Minister of Environment and Forestry Number: P.42 / Menlhk-Setjen / 2015 on the natural forest products administration, there are three categories of timber, large (KBB), medium (KBS), and small logs (KBK). The diameter classes distribution for both forests is about 80 cm high and, based on the regulation, can produce all timber categories. Therefore, the data is grouped into diameter classes to include and manage the timber potential based on the wood produced. Both districts recorded the highest total individuals in the diameter class below 10 cm that decreases with each increasing diameter class (Figure 3). However, the utilized timber potential is found in diameter classes above 10 cm. The potential timber economic value can be measured in quantity followed by volume (Groenendijk et al., 2017).

Figure 3. Distribution of total individuals in the unit area (hectares) by diameter class in both districts.

Figure 4. Potential standing wood volume in the unit area (hectare) based on the distribution of diameter classes in both districts.

Figure 5. Distribution of total individuals in the unit area (hectares) by diameter class in both districts.

Figure 6. Distribution of potential standing timber volume in area units (hectares) based on diameter classes in both districts

The potential timber calculations based on volume per unit area in hectares and diameter class (cm) indicate the highest volume in the 10-19 cm diameter class, around 100 $m^3.ha^{-1}$, before decreasing with each level increase except in diameter class 50-59 cm (Figure 3). Therefore, both districts show timber potential with small to large diameters in their mixed natural forest structure. The reverse j shaped curve in the graphs indicated that the forest had a nearly good condition (Myanmar 2016, Padmakumar et al. 2018). The total individual distribution per hectare and diameter class were similar in both districts (Figure 5). Therefore, the individual distribution is complete for each diameter class and decreases with each diameter class increase. The potential timber distribution is almost similar in both districts, as shown by similar distribution shapes. There are no individuals in the 50-59 cm diameter class in Teiraplu District. Also, the timber potential for both districts includes the small to the largest diameter class, namely 80-89 cm (Figure 6).

Figure 7. The relationship between the diameter (DBH) in cm and the standing wood volume in cubic meters (m^3). Information: $y = 0.0002x^{2.4922}$ is an equation formed with the determination coefficient (R^2) is

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0.9407. In this equation, x is the diameter (DBH) in cm, and y is the wood standing volume in cubic meters (m^3).

A correlation relationship can be established based on the potential timber distribution pattern measured in volume unit (m^3) per tree and diameter (cm). The regression analysis results showed a mathematical equation: $y = 0.0002x^{2.4922}$ as a power pattern equation (Figure 7). Therefore, y is the tree volume in cubic meters (m^3), while x is the individual diameter. The determination coefficient formed is 0.9407, which closely correlates to 1 (Ishihara et al. 2016), making the equation suitable for calculating the standing tree's volume. The DBH can predict the timber volume in the tropical forest (Harja et al. 2012, Tang et al. 2017, Andrade et al., 2019).

Tree diversity to support sustainable product

The tropical rainforest consists of diverse vegetation dominated by trees, including other lifeforms (Murdjoko et al. 2021a, Murdjoko et al. 2021b). It stands on a lowland area that comprises the ecological process with minimal human intervention. The trees regeneration and species distribution depend on the putative parent trees and seed dispersal. This study revealed that the forest is a stable ecological circumstance with natural vertical layers like a forest floor and canopy (Murdjoko et al. 2017, Moreno-Mateos et al., 2020). Various small tree species are available for the future, which naturally grows following the old-growth forest (Murdjoko 2013, Murdjoko et al. 2016b). This forest benefits other biotic factors for its continuous sustainability.

The study discovered that the forest's vertical structure, including large trees, consisted of diverse vegetation. The trees are part of the tropical forests lifeforms with about 30 % species, especially in the New Guinea ecosystem (Cámara–Leret & Dennehy 2019, Cámara-Leret et al. 2020). The locals depend on the swidden practices for their livelihood (Ungirwalu et al. 2014, Ungirwalu et al. 2017). The area's regional development would require a high volume of timber to improve the infrastructure. Therefore, timber availability depends on sustainable management achieved by the silvicultural method in tropical mixed forests. The selective cutting is based on specific diameter limits and logging intensity following the national regulation.

The study recommended that the local government focus on the regulation, socio-culture, private sector, non-governmental organizations (NGOs), and other stakeholders to maintain timber sustainability. Therefore, they should be directly or indirectly involved in sustainable forest management. The forests production in tropical countries is located close or overlaid position with populated areas. Therefore, the customary forest's involvement could be considered the main objective of forest management by involving the locals in regional development (Ungirwalu et al., 2021).

In conclusion, the *Pegunungan Bintang* forest included diverse tree species categorized as a tropical mixed forest. The dominant families included *Vitaceae*, *Melastomataceae*, *Cunoniaceae*, *Schizomeria,* and *Loganiaceae* with various seedlings, saplings, poles, and trees. The individual distribution showed the timber potency using the reverse J-shaped curve, indicating that the trees were merchantable and had available trees regeneration. However, timber utilization management requires silvicultural treatments to promote sustainability using selective logging with a diameter limit and a logging cycle.

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