BUKTI KORESPONDENSI ARTIKEL

Fatem SM, Djitmau DA, Ungirwalu A, Wanma OA, Simbiak VI, Benu NMH, Tambing J & **Murdjoko A** (2020) Species diversity, composition, and heterospecific associations of trees in three altitudinal gradients in Bird's Head Peninsula, Papua, Indonesia. Biodiversitas 21:3596–3605.

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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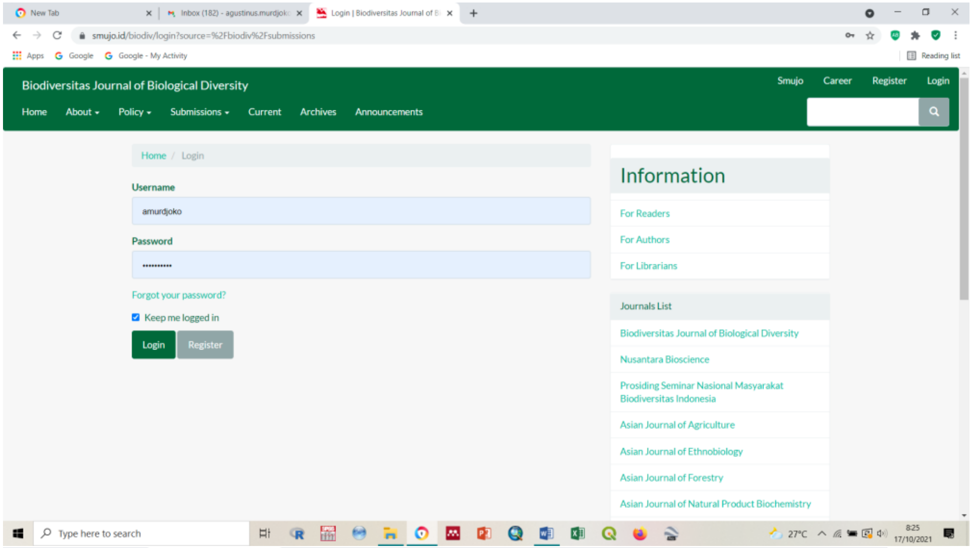

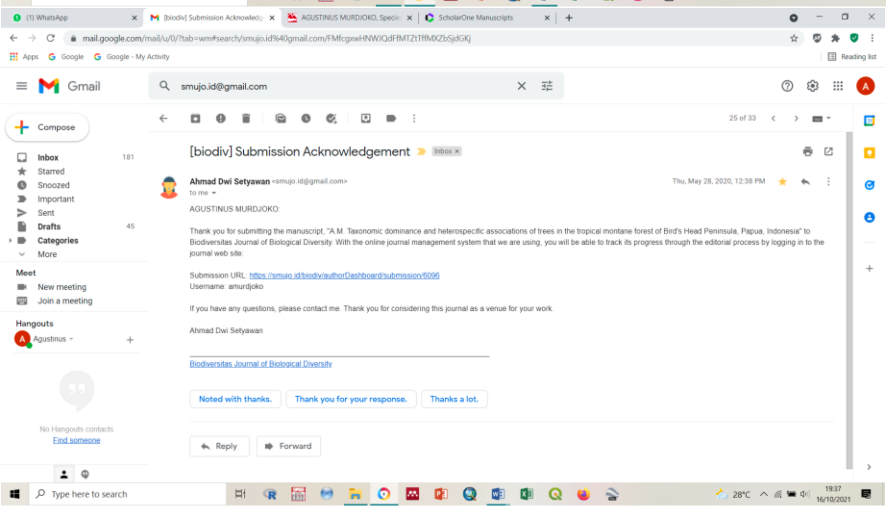

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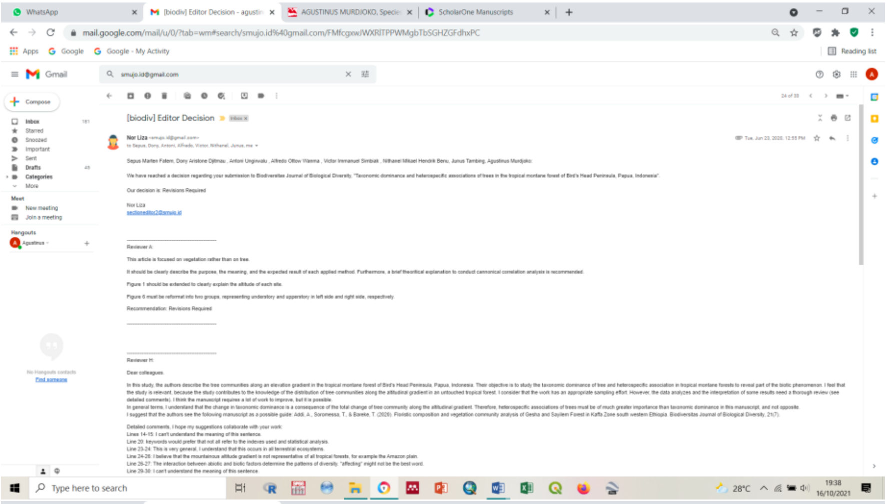

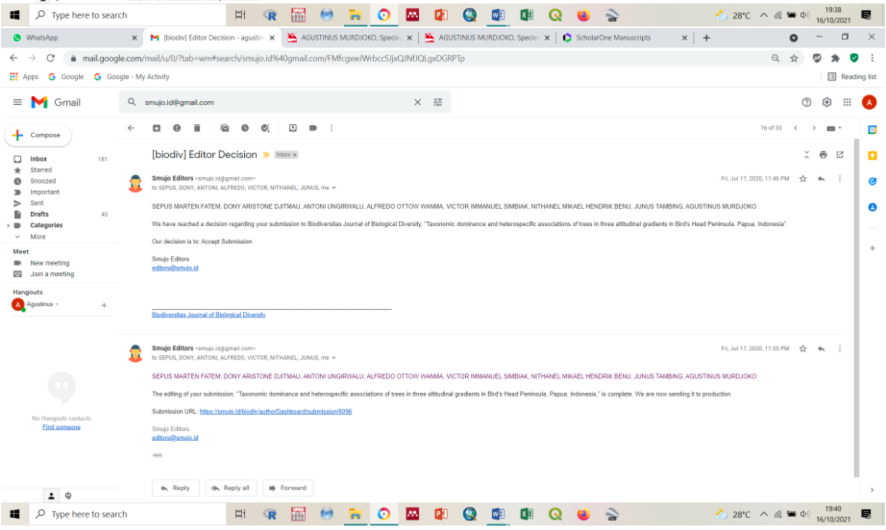

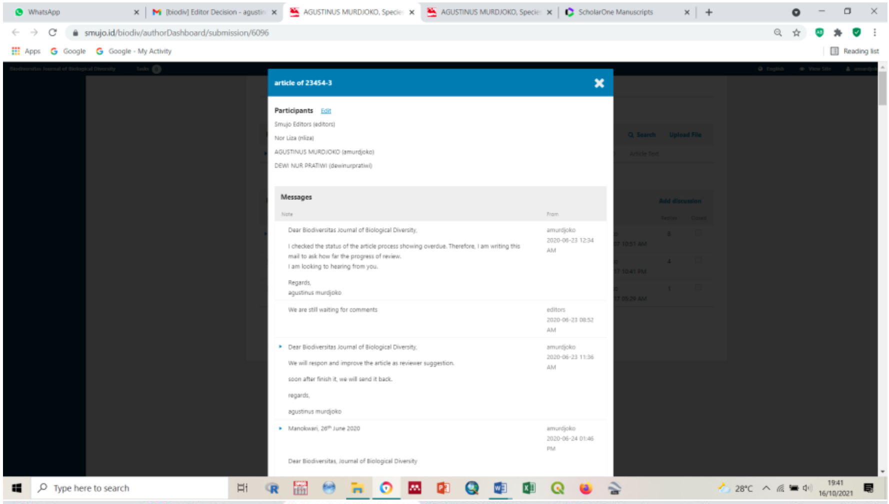
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I checked the status of the article process showing overdue. Therefore, I am writing this mail to ask how far the progress of review.
I am looking to hearing from you.
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editors
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soon after finish it, we will send it back.
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Manokwari, 26th June 2020
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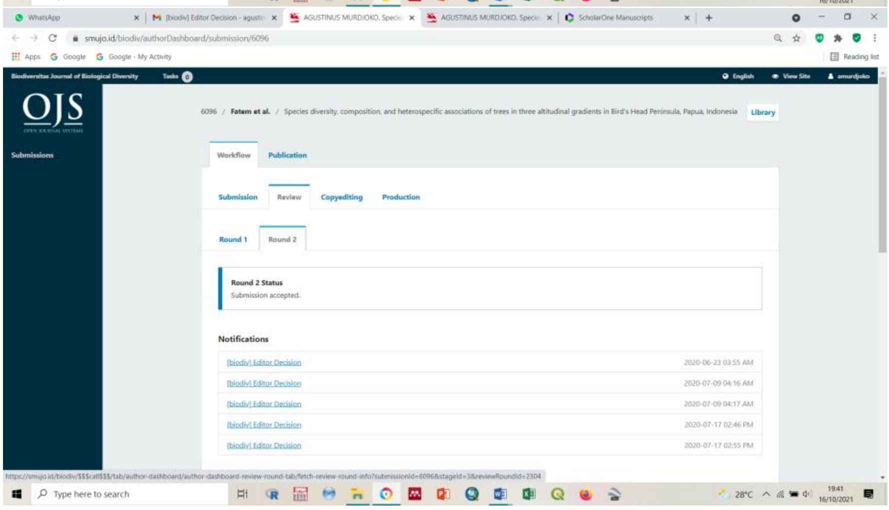
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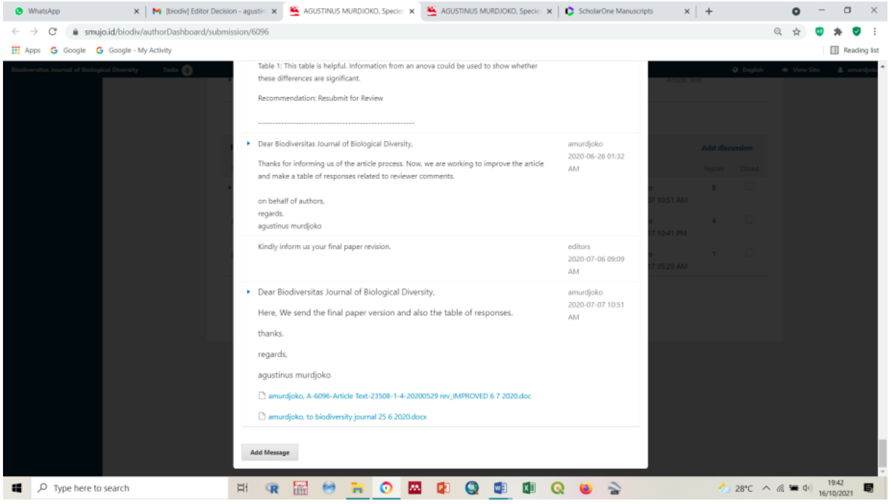


Surat respon terhadap komentar reviewer dan revisi

Manokwari, 6 July 2020

Dear Biodiversitas, Journal of Biological Diversity

We have already improved as suggestion of reviewers. The detail change can be seen in the file using "Track Changes". We also made the table of responses for the reviewer comments below.
We really thank to the reviewers for giving the useful comments.
Hopefully, we could contribute the science regarding tree biodiversity by getting published in Biodiversitas, Journal of Biological Diversity.

On behalf of authors,
Regards,

agustinus murdjoko

Reviewer G

Comments	Responses
L.14 : « clear » diversity ? Does this mean low diversity ?	The diversity of species decreased as the elevation increased, meaning that the lowest area had the highest number of tree species.
L.14-15 : I do not get the sense of this sentence	We have made clear. We analyse the associations in three different elevations.
L.16 : What do you mean by « dominancetree » ? Is it dominant species ?	Thanks for checking the error. The dominant tree. We have corrected.
L.18-19 : I miss details about local species sensitivity and conservation issues here.	We discussed the conservation status of species in the three locations.
<u>Introduction</u>	
L.26 : I do not really see the link with the previous statements	The elevations have impact on the ecological condition. Therefore, the tree species were influenced during growth, distribution, etc.
L.28 : Do you mean « seed dispersal » ?	Yes, the seed dispersal.
L.30 : Patterns in difference of what ? A particular characteristic of what ? Do you refer to flora composition or community diversity ?	Vegetation communities resulted from the abiotic factor.
L.32 : « Encompasses variation »	Yes, variation of abiotic factors have effect to variation of tree species.
L.33 : Do you mean biodiversity increases from coast to mountains ?	Vegetation diversity is more higher in lower area than in upper area.
L.39 : What do you mean by « vegetation condition » ?	In general, vegetation condition is useful. However, in this research we focused on the tree diversity.
L.40 : What certain circumstances do you refer to ?	Vegetation aspects such as diversity, association etc, but this research took tree species. For future research, we will continue to collect more data related to vegetation.
L.42 : What biotic phenomenon are you talking about ? Flora composition ? Here, I would find appropriate to have a sum up of what is already know about those forests and about their conservation status.	We would collect complete data as we could. However, due to limiting factor, we only collect tree as main focus.
L.44 : What do you mean by taxonomic tree ?	Taxonomic tree is described as diversity of tree on species, genus and family criteria.
<u>Material & Methods</u>	
L.55 : « characterized by mountainous reliefs »	The mountainous topography.
L.68 : I got the idea, but reformulate the description. Plus, I do not understand : in which plot do you take the height ? Do you use it in analysis ?	In line 67, we use height as category to classify tree during data collection.
L.78 : What doyou mean by « diversity », richness in family ?	Yes, we mentioned the species diversity per family as displayed in Figure 2.
L.79 : In the Shannon index, *pi* is not the number of samples, it is the frequency of the species.	Thanks, we have already corrected “not three location, but each location”.

L.83 : Please, define how you measure relative frequency, density, and dominance.	We used the calculation from "(Cottam and Curtis 1956; Curtis and McIntosh 1950)".
<u>Results and Discussion</u>	
L.96 : *Burseraceae* in italic	Thanks, we have already corrected.
L.97 : Which number of species ?	The number of species per family as shown in Figure 2.
L.99 : But in figure 2, more families sho higher species number in upper plots.	Yes, the number of species per family, but the number of tree species and diversity was lower in higher area.
L.103 : « Decreased »	We used "decline" as synonym of decrease.
L.109 : « Contrasted » more than « dynamic » as you don't look at changes in time.	We compared the variation between upperstory and understory.
L.110 : What is « even »	We changed as "period".
L.111-112 : I do not agree, if the mortality is random the eveness should not change.	As the seedling establishment is vulnerable resulting in higher mortality of new trees after germination.
L.113 : Higher richness but not necessarily higher diversity. Evenness is actually lower in the understorey.	We described and discussed the Table 1.
L.114 : No limited dispersal, environmental filtering may rather be involved.	The seed dispersal could be
L.114 : You don't have lower diversity in higher elevation in table 1 !	The understory showed lower diversity.
From L.127 : There are no discussion, only results. What kind of species are involved ? Are there specific strategies ? What does this imply for conservation ?	We added the discussion in "tree communities as species interactions"
L.159 : You mean you grouped tree communities following spatial location ?	Yes, the tree communities were a result of the different elevation.
L.160 : Based on their occurrence	Tree communities were formed as tree associations.
L.161 : their presence	The abundance of tree species.
L.161-163 : I do not get this sentences	The four communities were displayed by different colour in Figure 5.
L.163 : Not density, richness	We used the density of species to group the community.
L.167 : Do you mean you performed the same analysis, restricted to seedlings and saplings ? Where are the rseults ? How do you define seedplings, poes, etc ?	We grouped the seedling and sapling as understory.
L.169 : Specie association do not explain dominance. What are the results that allows you to say so ?	Yes, tree association does not explain the dominant species, but it explained the shape of species group.
L.171 : When did we start talking about lifespan	The lifespan could be used to explain the forming of the community.
L.174 : What do you have to say so ?	Those were possible driving factors of communities.
L.192 : But you do not look at this aspect	Yes, this is general factor that solar radiation has impact on the forming of community.

L.194 : It does not concern you subject	Those were the discussion regarding the driving factors.
L.195 : Idem, this does not come from your analysis	Yes, the factor could be used to explained the forming of communities.
L.196 : These are general statements, not linked to your study	We agree with you, but we put the factors to invite future research concerning tree communities.

Reviewer H

Comments	Responses
Lines 14-15: I can't understand the meaning of this sentence.	We have made it clear. It explained that the diversity of tree species decreased as the elevation increased.
Line 20: keywords would prefer that not all refer to the indexes used and statistical analysis.	Thanks. We add "Canonical correspondence analysis (CCA)" to mention the method that we applied.
Line 23-24: This is very general, I understand that this occurs in all terrestrial ecosystems.	We here gave the general factors in the beginning then the specific factors.
Line 24-26: I believe that the mountainous altitude gradient is not representative of all tropical forests, for example the Amazon plain.	Yes, indeed, the research revealed the variation of elevation in this area. In the discussion, we only discussed the study area.
Line 26-27: The interaction between abiotic and biotic factors determine the patterns of diversity. "affecting" might not be the best word.	We used "resulting in".
Line 29-30: I can't understand the meaning of this sentence.	The sentences explained the variation of elevations influencing the ecological conditions.
Line 40: Which certain circumstances?	The ecological conditions.
Line 43-44: This hypothesis only contemplates the existence of a spatial pattern, therefore it would be interesting to investigate the possible causes of that spatial pattern. You see an analogous explanation in Hawkins, B.A. and Felizola Diniz-Filho, J.A. (2004), 'Latitude' and geographic patterns in species richness. Ecography, 27: 268-272. doi:10.1111/j.0906-7590.2004.03883.x	We have improved the sentences particularly hypothesis.
Line 45: What do you mean "the phenomenon of vegetation"	"Phenomenon" is the ecological process.
Line 55: …the tree diversity? …across	Thanks, we have corrected.
Line 64: It would be necessary to clarify the year and season in which the sampling was carried out.	Thanks, we have corrected.
Line 66: area in.??	Thanks, we have corrected.
Line 68: cm as,??	Thanks, we have corrected.
Line 78: The idea of carrying out these analyzes does not follow from the introduction, objective or hypotheses.	Thanks, we have corrected.
Line 80: I understand that pi refers to the relative frequency of species i, in this case the proportion of samples in which the species was present, not the number of samples where species i was present.	Thanks, we have corrected.
Line 80: ln (S) refers to Hmax. For a given richness (S), the H will be maximum when the individuals are distributed equally among the species. Therefore, you must use the S of the sample that you calculated the H index, not the total S that is obtained by adding the three locations.	We have changed and made clear the sentences related to the aims of research.

Shannon, C.E. & Weaver, W. (1949). The mathematical theory of communication (Urbana, IL. University of Illinois Press IL.	We used article of them.
Pielou, E.C. (1975). Ecology diversity.	We used article of them.
Line 83: Change IVi for IVIi	Thanks, we have corrected.
Line 86: Reading your manuscript, I understand that you did a correspondence analysis (CA), since you used species data per site. I understand that the canonical correspondence analysis is used when you have data on environmental variables by site and species data by site. The cca function, in Vegan package, perform ca analyzes when only input species per site data.	We applied Canonical correspondence analysis (CCA) as one of multivariate that could explain the community.
Line 101: I believe that adding statistical analyzes that provide a value would strengthen your interpretation of the observed diversity pattern.	Thanks. We have made it clear.
Line 113: I do not understand your interpretation of the results. Observing the Shanon index, only in area A the understory is more diverse than in the upperstory, in area B and area C the opposite occurs. On the other hand, evenness is always greater in the upperstory, therefore more diverse than the understory for all areas.	We explained the variation of diversity along the elevation.
Line 113-114: Other possibilities are physiological restrictions due to environmental change related to altitude change or interspecific competition (i.e. competitive exclusion).	Yes, physiological restrictions could be used to explain the driving factors.
Line 124: (m) Unit is not required in this table. Check all tables and figures.	Thanks, we have corrected.
Line 128: Repeats line 101.	Thanks, we have corrected the information.
Lines 163-164: I would only say that these four species are shared by communities A and B, not that they form a community of 4 species.	Thanks, we have improved the information.
Lines 164-165: Why do you talk about density if you only used presence data for the analysis?	We applied the abundance of tree species.
Lines 165-166: At least, the sum of all axes can explain 100% of the observed variation. However, you report that the first two axes explain 146% of the variation. You should check this information.	Yes, thanks. We have already corrected the result of cca.
Line 167: This sentence should go in the figure epigraph.	Yes, the abbreviations are shown in the Appendix 1.
Line 228: I expected some final considerations about the work as the closing of the manuscript	We elaborated the driving factors such as socio culture factors.
Line 332: sp does not italicize	Thanks, we have corrected.

Reviewer R

Comments	Responses
Abstract	
14-15: It is hard for me to understand what pattern this sentence is describing: "The understory showed clear diversity compared to understory in a gradient of elevations compared to upperstory"	Thanks, we have corrected the sentences and made it clear. We describe the variation of vegetation along the elevation.
15-16: Similarly, it is hard to know what this means: "where the dominance tree has a different pattern in the three locations between understory and upperstory"	The dominance tree described the difference of tree along the elevation. We grouped the tree into two according to vertical structure.
17-18: This clause is also hard to understand: "in which the four communities were in the lower, middle, upper area, and other groups"	We described the four communities in the Figure 5.
18: "as" is not necessary before "data deficient"	Thanks, we have corrected.
Introduction	
29-31: I do not understand the point being made here and it seems important. Are the authors distinguishing between stands of more than one species (heterospecific associations) vs. stands of just one species (conspecific associations)?	The conspecific association here, we analysed the association among the species.
44-45: I do not understand this sentence "This study only focused on the tree as part of the vegetation in which the presence of the tree could explain the phenomenon of vegetation." Are the authors trying to say that only tree-dominated or forested sites were considered?	We focused on tree in this research. For future research, we will collect more data concerning the vegetation as biotic factor and abiotic factor such as soil.
Methods	
66: This clause is very important: "representing lower area, middle area, and upper area in" But it is hard to tell what it means. Did the authors pick topographically low-lying, intermediate, and uphill spots in each site for plot placement?	We grouped the elevation as lower, midle and upper. We were trying to collect data as representation of elevation. However, as the limiting factors we had such as accessibility and permit from local people.
66-70: It is really hard to understand how many subplots of each kind (roman numerals I-IV) were surveyed. This is very important information, but it is unclear.	We distinguished the plot and subplot during data collection as shown in the method.
78-81: Why are simple hypothesis tests not used to compare H' and J', for instance, among the three sites? This could be a simple anova and post-hoc test. Since independent plots were measured at each site, hypothesis testing seems possible.	We used the diversity and evenness indices to analyse trees in the three locations. We only compared the value indices without taking statistical analysis such as anova and t test.
Results	
93: again, the use of "lower", "middle", and "upper" here is confusing and could be more sophisticated. I am not sure if the authors are referring to altitude among sites or topography within sites.	We grouped the three locations to represent the different elevations.
163-164: I do not understand this description of the fourth community delineated using CCA: "while	The four species present as group. Therefore, we distinguished them as different community.

the rest species presented dominantly more than location formed a single community (4 species)”	
184-200: Again, it seems that formal comparisons using statistics (hypothesis tests) could	Here, we described the distribution of individuals based on diameter class.
212 (and elsewhere in the manuscript): The authors treat data deficient species (in terms of IUCN conservation concern) as though they are a separate group. I think these do not need to be mentioned except briefly (perhaps early in the paragraph), at which the authors can simply say something like “Sufficient data were not available to assess the conservation status of two species).	Thanks, we indeed made them clear as we could.
Figures	
Figure 1: It would be helpful to print the elevation of each site on this map so that readers can tell immediately which is the lowest vs. highest site.	Thanks, we have described the location in the study area.
Fig. 2: This should be made into a table.	Thanks, we have already made them into Figure 2.
Figs. 3-4: I like these figures.	Thanks, we described the results in the graphs as concise as we could.
Table 1: This table is helpful. Information from an anova could be used to show whether these differences are significant.	We on compared the value of indices.

Bentuk revisi

Taxonomic dominance and heterospecific associations of trees in the tropical montane forest of Bird's Head Peninsula, Papua, Indonesia

Abstract. We studied the taxonomic dominance of tree and heterospecific association in tropical montane forests to reveal part of the biotic phenomenon. Those locations are part of the Bird's Head Peninsula in the province of West Papua, Indonesia. The locations were the representation of lower, middle, and upper areas of natural tropical forest. Systematic random sampling was applied during data collection. We applied importance value index (IVI) for taxonomic diversity and canonical correspondence analysis (CCA) for heterospecific associations. The research revealed that the taxonomic diversity of trees generally decreased as the elevation increase in terms of family, genera, and species level. The understory showed clear diversity compared to understory in a gradient of elevations compared to upperstory. The dominant species was also different along the elevation where the dominant tree has a different pattern in the three locations between understory and upperstory. The individuals distributed in those locations followed the reversed-J shape model. Moreover, the gradient of elevation has shaped the types of tree communities in which the four communities were in the lower, middle, upper area, and other groups. Of all species, twenty-six species were grouped data deficient (2 spp), least concern (20 spp), near threatened (3 spp), and vulnerable (1 sp).

Commented [U1]: Insert the applied data analysis

Commented [WiQS2R1]: We have included the analysis in this part.

Commented [U3]: 26

Commented [U4]: Reformat this sentece

Commented [WiQS5R4]: Thanks. We have rewritten the sentence.

Keywords: Canonical correspondence analysis, conservation status, Pielou's evenness, Shannon-Wiener index, Vegan package

Running title: Dominant and heterospecific associations of trees

INTRODUCTION

The natural tropical forest comprises the variations of ecological conditions particularly biotic and abiotic factors (Ashton 2018; Brown et al. 2014; Pan et al. 2013). The abiotic factors could be regarding climatic and edaphic variations. The topographical arrangement in the natural tropical forest varies from lower area to mountain area resulting in the variations of ecological conditions (Duivenvoorden 1995; Hunter et al. 2015; Vázquez G and Givnish 1998). Consequently, the biotic factors are impacted by the variations resulting in the gradient of diversity. Therefore, the vegetation shows the difference from lower to upper circumstances concerning taxonomic diversity, density, abundance, vertical structure, and seed dispersal (Addi, Soromessa, and Bareke 2020; Huang et al. 2003; Phillips and Lewis 2014; Putz and Romero 2014) The pattern of the difference also forms vegetation communities as conspecific and heterospecific associations in which the communities create a particular characteristic (Clark et al. 2018; Trogisch et al. 2017).

Bird's Head Peninsula is located in the western part of Papua, Indonesia where the location encompasses the variation of abiotic factors such as topographical gradient. Thus, vegetation diversity is higher distributed from coastal areas to mountain areas. Most area of Bird's Head Peninsula is untouched forest as a consequence of low accessibility. Some parts of this area have been situated officially as conservation areas. Therefore, the management of the forest in this area is focusing on the conservation program (Bappeda Tambrauw 2015). For example, the Tambrauw district has been declared as a conservation district to promote the sustainability of the forest. Thus, the development program of this district must be considering the conservation concept (Fatem et al. 2018; Fatem and Asem 2015). Hence, to support valid information regarding natural resources specifically vegetation conditions, the research must be conducted systematically in Bird's Head Peninsula as the vegetation showed the different responses in certain circumstances (Fatem and Asem 2015; Robiansyah 2018). For this reason, we studied the taxonomic dominance of tree and heterospecific association in tropical montane forests to reveal part of the biotic condition (Ding et al. 2019).

We hypothesized that the taxonomic dominance differed as a consequence of the different elevation of tropical montane forests in Bird's Head Peninsula and the variation of the taxonomic tree formed the tree communities. This study only focused on the tree as part of the vegetation in which the presence of the tree could explain the phenomenon of vegetation. We expected that this research would encourage future research in Bird's Head Peninsula to support scientific information as a contribution to the conservation program.

Commented [U6]: Remember to define the tree. This relates to sampling design, data collection and the Figue 6

Commented [WiQS7R6]: Thanks. We indeed focused on tree that grouped as understory and upperstory.

MATERIALS AND METHODS

Study area

This research was conducted in Tambrauw Mountains as part of Tambrauw Regency, West Papua, Indonesia. The sites were located in A (0°49'54.14"S and 132°29'17.78"E), B (0°43'3.49"S and 132°23'47.15"E), and C (0°40'28.82"S and 132°13'1.32"E) as the representation of lower area (A), middle area (B), and upper area (C), respectively. Those locations are part of the Bird's Head Peninsula in the province of West Papua, Indonesia. The area was characterized by the mountainous topography with the variations of the elevations and slopes. Therefore, we selected the three locations to describe the tree along the elevation differences as A was about 488 m a.s.l., B was around 950 m a.s.l., and C was more or less 1200 m a.s.l. (Figure 1). The three locations are part of the conservation area of Tambrauw Mountain.

Commented [U8]: Use common words to explain location

Commented [WiQS9R8]: Thanks. We have substituted the word in this sentence.

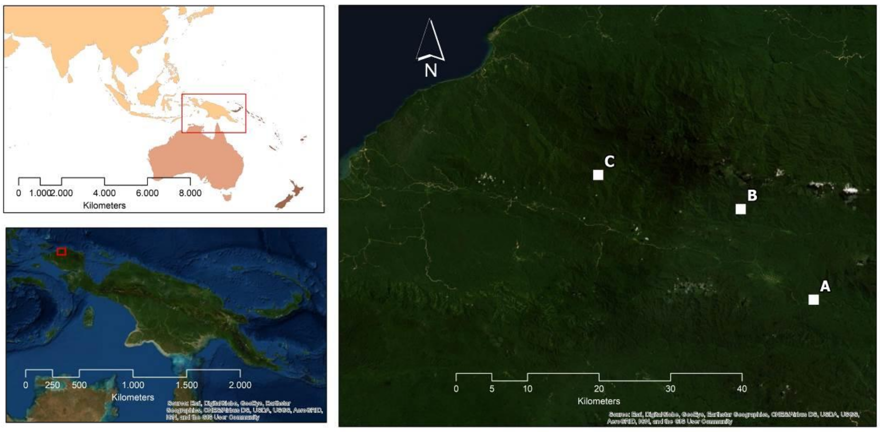


Figure 1. Location of research in three sites. The letter of A symbolizes lower area, B is middle area, and C is area with upper condition based on elevation above sea level.

Commented [U10]: This figure does not clearly give an explantion about the altitude of each site

Sampling and data collection

We placed the twenty plots of 20 m x 20 m in each location with at least 100 m as the distance between plot representing lower area, middle area, and upper area in. In every plot of 20 m x 20 m (I) to collect

Commented [U11]: Please be consistence with A, B, and C tree with diameter larger than 20 cm, there were subplots consisting of 10 m x 10 m (II) to collect tree with diameter between 10 cm and 20 cm, 5 m x 5 m (III) to collect tree with diameter less than 10 cm, as well as the height, was taller than 150 cm, and 2 m x 2 m (IV) to collect tree as the height less than 150 cm. The plot I and II were set to sample the upperstory and the plot III and IV were to sample understory. The data were species identification, number of individuals, and diameter (cm). Species were identified by setting the vouchers and sent 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 names of species, genera, and families were based on The Plant List (TPL) (at the website: http://www.theplantlist.org/). We also checked the conservation status on The International Union for Conservation of Nature's Red List of Threatened Species (at the website: https://www.iucnredlist.org/).

Commented [U12]: Please give layout design

Commented [U13]: collected

Commented [U14]: comprises?

Data analysis

Commented [U15]: Give numbering for equations, Describe briefly the meaning and the expected result of each method

Commented [WiQS16R15]: Thanks for the comments. We have added the scientific information regarding the statistical analysis.

The diversities of species of families among the three locations were analyzed. We also examined the species diversity and evenness by applying Shannon-Wiener index and the calculation is $H' = -\sum_{i=1}^{S} p_i \ln\ (p_i)$ where H' is Shannon-Wiener diversity index, p_i is number of samples where species *i* is present; and Pielou's evenness as $J' = H'/(ln\ (S))$ in which S is total number of species of each location (Pielou 1966; Shannon 1948; Spellerberg and Fedor 2003).

Taxonomic species composition was analyzed through The Importance Value Index (IVI) as $IVI_i = RFr_i + RDe_i + RDo_i$ where IVI_i is important value index of species *i,* RFr_i is relative frequency of species *i,* RDe_i is relative density of species *i,* RDo_i is relative dominance of species *I* for the upperstory and the understory, the index of species followed $IVI_i = RFr_i + RDe_i$ (Cottam and Curtis 1956; Curtis and McIntosh 1950).

We applied Canonical correspondence analysis (CCA) to analyze the heterospecific associations among species in three locations (Ter Braak 1986; Murdjoko et al. 2017). We set 66 columns as species of tree and 60 rows as plots the representation of lower area (20 plots), middle area (plots), and upper area (20 plots) during computation. This analysis was to describe the tree communities formed in three locations where there was the tendency of species to be present as a group or community. Chi-square test (χ^2) was performed to validate the CCA. The computations followed the Vegan package in R version 3.5.3 (Oksanen et al. 2019).

RESULTS AND DISCUSSION

Diversity of tree

Commented [U17]: Keep in mind the definition of tree

Commented [WiQS18R17]: Thanks. As stated in the introduction that we focused on the tree.

We enumerated 30 Families, 44 genus, and 66 species in these three locations distributing 20 families in lower, 15 families in middle, and 15 in upper. The genera per location were 29 in lower, 20 in the middle, and 18 in the upper. The number of species found in lower, middle, and upper were 35 species, 24 species, and 27 species respectively. The number of species per family for three locations was presented in Figure 2. The families of *Myrtaceae*, *Anacardiaceae*, *Burseraceae*, *Lauraceae*, and *Myristicaceae* consisted of species at least three species in lower while the rest families showed the number of species more or less two species. In the middle, the families of *Myristicaceae*, *Sapindaceae*, and *Sapotaceae* contained at least two species. In the upper, *Myrtaceae*, *Lauraceae* and *Fagaceae* were the families had the species number at least three. The family diversity was higher in the lower area compared with the two areas and the species diversity showed the same pattern as family diversity.

The species diversity varied among the three locations (Table 1). In the comparison of tree species, we grouped the species as the three locations and the structure of the tree (understory and upperstory). The species diversity revealed the decline of the diversity from the lower, middle, and upper where the

Shannon-wiener Index changed decreasingly. The pattern of the species diversity of all tree category was similar to the tree diversity of understory, while the tree diversity of upperstory showed the increase from lower to middle and then slightly dropped from the middle to upper. The decreasing index of Pielou's evenness occurred in all categories and understory. However, the Pielou's evenness index for upperstory showed the fluctuated pattern where the J' dropped from lower to middle and marginally rose from the middle to upper.

The diversity of understory is more dynamic than the diversity of upperstory since the understory comprises the juvenile phase of the tree as seedlings (Murdjoko et al. 2016b). During the seedling establishment, this period is crucial as a result of the high mortality rate of seedlings (Dong et al. 2014; Lu et al. 2014; Y. Zhu et al. 2015). The process can be explained that the seedlings just germinated would compete and interact with other vegetation and also can be as food for some mammals (Sinery 2013). Therefore, higher diversity occurs in the understory. Moreover, the decrease of diversity across elevation assumingly results from the limited dispersal of some species to the higher elevation. Thus, the higher elevation, the less diversity of species in this location. The dispersal of species counts on the seed or fruit characteristics such as height, shape, and whether edible or not for animals (Clark et al. 2018; Yguel et al. 2019).

Commented [U19]: The heading is focused on tree. Please rearrange from the beginning to cover not only tree

Commented [WiQS20R19]: Thanks. The seedlings here explained that the regeneration after germination is dynamic in which new individuals appear as a result of reproduction process whether vegetative or regenerative way.

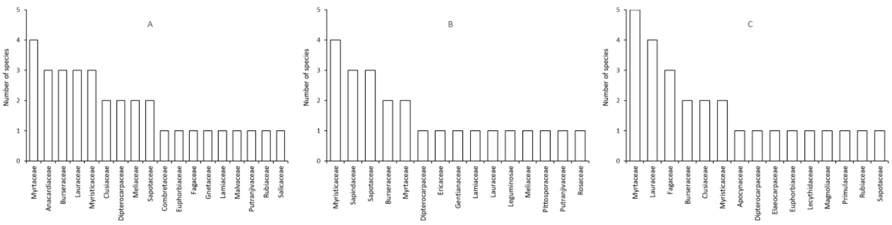


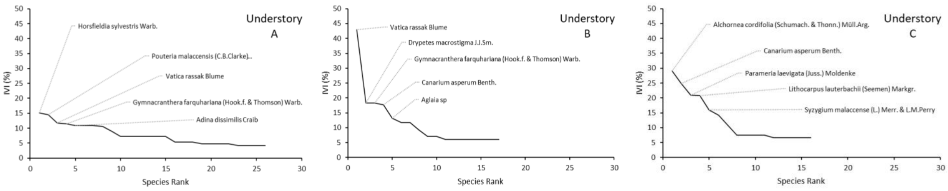
Figure 2. Number of species per family in three sites. The letters of A, B, and C are symbols of lower area, middle area, and upper area respectively.

Table 1. Shannon-wiener Index (H') and Pielou's evenness index (J') for three sites (mean [standard deviation]). The letter of A symbolizes lower area, B is middle area, and C is area with upper condition based on elevation above sea level

		A		B		C	
All	H'	2.365	[0.115]	1.914	[0.101]	1.602	[0.067]
	J'	0.785	[0.007]	0.691	[0.014]	0.578	[0.006]
Upperstory	H'	1.896	[0.044]	2.088	[0.184]	2.087	[0.054]
	J'	0.912	[0.021]	0.888	[0.053]	0.906	[0.023]
Understory	H'	2.286	[0.160]	1.799	[0.045]	1.474	[0.001]
	J'	0.870	[0.006]	0.781	[0.020]	0.690	[0.027]

The dominant species of tree

In the comparison of tree species, we grouped the species as the three locations. The dominant species showed the difference not only among three locations and also among understory and upperstory (Figures 3 and 4). The dominant species in understory were *Horsfieldia sylvestris* Warb.,*Pouteria malaccensis* (C.B.Clarke) Baehni, *Vatica rassak* Blume, *Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb., and *Adina dissimilis* Craib for the lower; Vatica rassak Blume, *Drypetes macrostigma* J.J.Sm., *Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb., *Canarium asperum* Benth., and *Aglaia sp* for the middle; and *Alchornea cordifolia* (Schumach. & Thonn.) Müll.Arg., *Canarium asperum* Benth., *Parameria laevigata* (Juss.) Moldenke, *Lithocarpus lauterbachii* (Seemen) Markgr., and Syzygium malaccense (L.) Merr. & L.M.Perry for the upper. For the upperstory, the dominant species were *Pimelodendron amboinicum* Hassk., *Vatica rassak* Blume, *Dracontomelon dao* (Blanco) Merr. & Rolfe, *Teijsmanniodendron bogoriense* Koord., and *Pterygota horsfieldii* (R.Br.) Kosterm. for the lower; *Intsia palembanica* Miq., *Vatica rassak* Blume, *Gymnacranthera farquhariana*



(Hook.f. & Thomson) Warb., *Canarium asperum* Benth., and *Teijsmanniodendron bogoriense* Koord. for the middle; and *Lithocarpus lauterbachii* (Seemen) Markgr., *Quercus argentata* Korth., *Elaeocarpus leucanthus* A.C.Sm., *Syzygium anomalum* Lauterb., and *Garcinia beccarii* Pierre for the upper.

Figure 3. Rank abundance curves of species (x-axis) against Importance Value Indices (IVI) (y-axis) in three sites for understory. The letter of A symbolizes lower area, B is middle area, and C is area with upper condition based on elevation above sea level

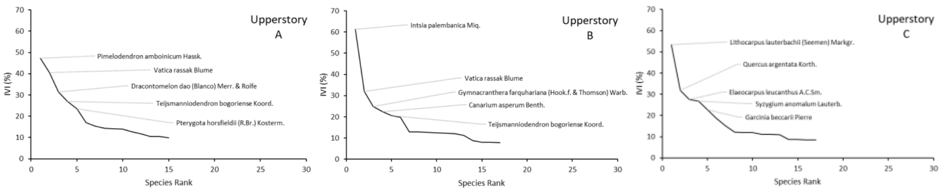


Figure 4. Rank abundance curves of species (x-axis) against Importance Value Indices (IVI) (y-axis) in three sites for upperstory. The letter of A symbolizes lower area, B is the middle area, and C is the area with upper condition based on elevation above sea level

Tree communities as species interactions

We grouped the species tree as communities where they presented in the same area of the study area. We applied Canonical correspondence analysis (CCA) to cluster the species based on the diversity Then, CCA displayed that the species formed the four communities (Figure 5). There was the number of species distributed in three locations as lower (27 species), middle (16 species), and upper (19 species) while the rest species presented dominantly more than location formed a single community (4 species). The density of species shaped the four tree communities in this research based on the distribution across the difference of elevation. The CCA explained the variation of 57.65 % in the first axis (CCA1) and 42.35 % in the second axis (CCA2). The validation of CCA showed that the Chi-squared test (χ^2) test= 1.4611, df = 130, p-value > 0.05. Therefore, the CCA was valid to describe the heterospecific associations as the distribution phenomenon of species. The species name of abbreviations in Figure 5 can be seen in Appendix 1. Regardless of the species growth forms as seedlings, saplings, poles, and mature trees, the distribution of species has the tendency as shown in Figure 5 in which some species were dominant in the lower area, middle area, upper area, and some species grew in the lower and middle area. The communities in this research were as the explanation of species dominancy forming the pattern. Each species has character during the interaction or association such as physiological, anatomical, phenological, and so on (Crausbay and Martin 2016; Pavón, Hernández-Trejo, and Rico-Gray 2000; H. Zhu et al. 2015). The lifespan of each species also has an impact on the community forming (Ganivet et al. 2020; Jiang et al. 2015; Zuidema et al. 2013). The seed characteristics determine the distribution of species during the dispersal. Therefore, the process of community forming involves wildlife in the spreading (Finnegan, Pigeon, and MacNearney 2019; Naniwadekar et al. 2015). However, in this research, the ecological condition in the different elevations was the driving factor as a place to grow for the species. Thus, this information would be useful to manage natural forests such as during plantation. Moreover, the study of conspecific associations is also interesting to find out how the individuals within species interact particularly the regeneration (Murdjoko et al. 2016a; Seidler and Plotkin 2006; Y. Zhu et al. 2015).

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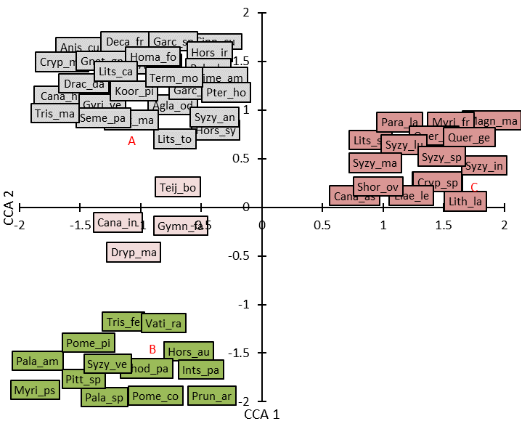

Figure 5. Canonical correspondence analysis (CCA) plot showing the heterospecific association of trees in three sites. The red letter of A symbolizes lower area, B is the middle area, and C is the area with upper condition based on elevation above sea level

Distribution of individuals based on diameter class

The individuals of species were distributed based on the diameter class up to more than 100 cm regardless of the species. However, the number of individuals in the higher diameter was only a few unlike the number of individuals in the lower diameter class was plenty (Figure 6). The model of the distribution was similar among the three locations. The graph of the distribution of individuals was analyzed through the proportion (%). The proportions of individuals were higher in the small individuals rather than the larger individuals as the characteristic of individuals in natural tropical forests regardless of species. Of all small individuals, only a few numbers of the individuals would grow up to larger individuals in which this pattern of proportion showed the reversed-J shape. The small individuals compete and interact with each other to reach the canopy level as they require solar radiation (Bagchi, Press, and Scholes 2010; Metz, Sousa, and Valencia 2010; Zangaro et al. 2016). The competition only occurs among individuals of the tree, but also between other vegetation in different lifeforms such as lianas, herbs, and ferns. The competition and interaction are to obtain nutrients in soil and sunlight, so the relationship among vegetation as symbiosis (Barron, Purves, and Hedin 2011; Taylor, Chazdon, and Menge 2019) On a broad scale, symbiosis in the natural tropical forest takes place not only among vegetation but also with other organisms such as wildlife and microorganism (De Cáceres, Legendre, and He 2013; Silver, Brown, and Lugo 1996; Y. Zhu et al. 2015).

Therefore, the observation of individual distribution between small and larger individuals was imperative to describe the regeneration process. For future research, it is crucial to analyze the individual distribution for certain species to figure out the natural regeneration process, so the result would be beneficial for the management of the natural tropical forest.

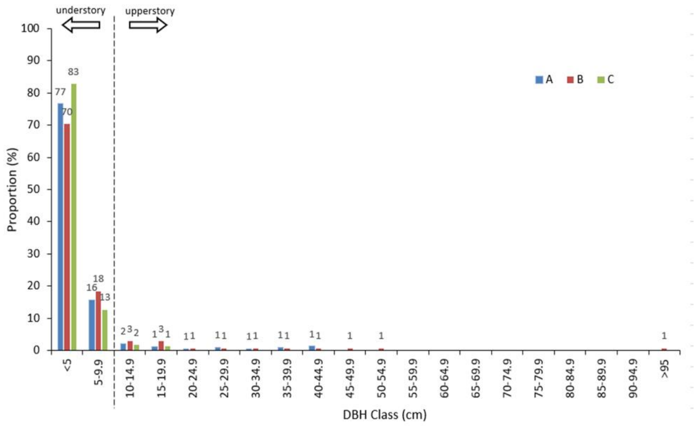

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Figure 6. Distribution of individuals based on the DBH class (cm) in three plots displaying the understory at left side and upperstory at the right side. The letter of A symbolizes lower area, B is the middle area, and C is the area with upper condition based on elevation above sea level

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Conservation status of species in the three locations

We found that of all species, there were species categorized as data deficient, least concern, near threatened, and vulnerable based on the International Union for Conservation of Nature's Red List of Threatened Species (https://www.iucnredlist.org/). Then, the species were distributed in the three locations (Table 2). Of all species, there were 26 species identified with the conservation status. Then, we checked on the distribution of species along with the conservation status. The status of data deficient (DD) was only present in the lower location (C). At least nine species with conservation status was the least concern (LC) in the three locations. The three locations were the place for the species with near threatened (NT) and the species with vulnerable (VU) was only present in the lower location. We paid attention to the species with conservation status near threatened (NT) namely *Aglaia odorata* Lour., *Cryptocarya massoy* (Oken) Kosterm., and *Pouteria malaccensis* (C.B.Clarke) Baehni; and vulnerable (VU) viz. *Anisoptera curtisii* Dyer ex King.

Table 2. Conservation status of tree species based on The IUCN Red List in three sites. The letter of A symbolizes lower area, B is middle area, and C is area with upper condition based on elevation above sea level (m). N.A. is data not available

Locations	Conservation status				
	N.A.	data deficient (DD)	least concern (LC)	near threatened (NT)	vulnerable (VU)
A	20	0	11	3	1
B	14	0	9	1	0
C	14	2	9	2	0

The four species with conservation status at least near threatened and vulnerable were less dominant species except for *P. malaccensis*. Hence, those should be in consideration in the management of the natural tropical forest. For example, future research should focus on the dispersal, regeneration, and the utilization of those species (Li et al. 2020; Padmakumar et al. 2018; Vlam et al. 2017). This could be one of the conservation programs to support the conservation district of Tambrauw. Besides, the species with conservation status not available were also studied to gain more scientific information. Furthermore, the concept of forest conservation could be implemented widely not only focusing on biotic such as vegetation but the socio-culture aspect could be also considered (Ungirwalu et al. 2017; Ungirwalu, Awang, and Murdjoko 2014).

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Appendix 1.

Plant Community A			Plant Community B			Plant Community C			Plant Community OTHER		
Adin_di	=	*Adina dissimilis* Craib	Agla_sp	=	*Aglaia sp*	Alch_co	=	*Alchornea cordifolia* (Schumach. & Thonn.) Müll.Arg.	Cana_in	=	*Canarium indicum* L.
Agla_od	=	*Aglaia odorata* Lour.	Fagr_el	=	*Fagraea elliptica* Roxb.	Ardi_se	=	*Ardisia serrata* (Cav.) Pers.	Dryp_ma	=	*Drypetes macrostigma* J.J.Sm.
Agla_sp.1	=	*Aglaia spectabilis* (Miq.) S.S.Jain & S.Bennet	Harp_ar	=	*Harpullia arborea* (Blanco) Radlk.	Barr_as	=	*Barringtonia asiatica* (L.) Kurz	Gymn_fa	=	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb.
Anis_cu	=	*Anisoptera curtisii* Dyer ex King	Hors_au	=	*Horsfieldia australiana* S.T.Blake	Cana_as	=	*Canarium asperum* Benth.	Teij_bo	=	*Teijsmanniodendron bogoriense* Koord.
Cana_hi	=	*Canarium hirsutum* Willd.	Ints_pa	=	*Intsia palembanica* Miq.	Cryp_od	=	*Cryptocarya odorata* Guillaumin			
Cinn_cu	=	*Cinnamomum culitlawan* (L.) J.Presl	Myri_ps	=	*Myristica pseudoargentea* Warb.	Cryp_sp	=	*Cryptocarya sp*			

Cryp_ma	=	*Cryptocarya massoy* (Oken) Kosterm.	Pala_am	=	*Palaquium amboinense* Burck	Elae_le	=	*Elaeocarpus leucanthus* A.C.Sm.
Deca_fr	=	*Decaspermum fruticosum* J.R.Forst. & G.Forst.	Pala_sp	=	*Palaquium sp*	Lith_la	=	*Lithocarpus lauterbachii* (Seemen) Markgr.
Drac_da	=	*Dracontomelon dao* (Blanco) Merr. & Rolfe	Pitt_sp	=	*Pittosporum spinescens* (F.Muell.) L.W.Cayzer, Crisp & I.Telford	Lits_sp	=	*Litsea* sp
Garc_be	=	*Garcinia beccarii* Pierre	Pome_co	=	*Pometia coriacea* Radlk.	Magn_ma	=	*Magnolia macklottii* (Korth.) Dandy
Garc_sp	=	*Garcinia* sp	Pome_pi	=	*Pometia pinnata* J.R.Forst. & G.Forst.	Myri_fr	=	*Myristica fragrans* Houtt.
Gnet_gn	=	*Gnetum gnemon* L.	Prun_ar	=	*Prunus arborea* (Blume) Kalkman	Para_la	=	*Parameria laevigata* (Juss.) Moldenke
Gyri_ve	=	*Gyrinops versteegii* (Gilg) Domke	Rhod_pa	=	*Rhododendron papillatum* Balf. f. & R.E. Cooper	Quer_ar	=	*Quercus argentata* Korth.
Homa_fo	=	*Homalium foetidum* Benth.	Syzy_ve	=	*Syzygium versteegii* (Lauterb.) Merr. & L.M.Perry	Quer_ge	=	*Quercus gemelliflora* Blume
Hors_ir	=	*Horsfieldia irya* (Gaertn.) Warb.	Tris_fe	=	*Tristaniopsis ferruginea* (C.T.White) Peter G.Wilson & J.T.Waterh.	Shor_ov	=	*Shorea ovalis* Blume
Hors_sy	=	*Horsfieldia sylvestris* Warb.	Vati_ra	=	*Vatica rassak* Blume	Syzy_in	=	*Syzygium inophyllum* DC.
Koor_pi	=	*Koordersiodendron pinnatum* Merr.				Syzy_lu	=	*Syzygium luehmannii* (F.Muell.) L.A.S.Johnson
Lits_ca	=	*Litsea calophylla* (Miq.) Mansf.				Syzy_ma	=	*Syzygium malaccense* (L.) Merr. & L.M.Perry
Lits_to	=	*Litsea tomentosa* Blume				Syzy_sp	=	*Syzygium sp*
Pala_lo	=	*Palaquium lobbianum* Burck						
Pime_am	=	*Pimelodendron amboinicum* Hassk.						
Pout_ma	=	*Pouteria malaccensis* (C.B.Clarke) Baehni						
Pter_ho	=	*Pterygota horsfieldii* (R.Br.) Kosterm.						
Seme_pa	=	*Semecarpus papuana* Lauterb.						
Syzy_an	=	*Syzygium anomalum* Lauterb.						
Term_mo	=	*Terminalia morobensis* Coode						
Tris_ma	=	*Tristaniopsis macrosperma* (F.Muell.) Peter G.Wilson & J.T.Waterh.						

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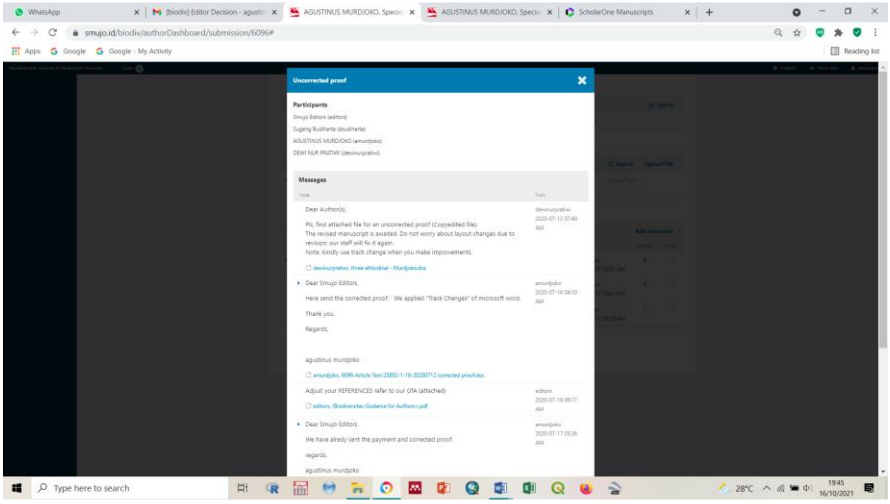

Pengecekan terakhir sebelum cetak

Species diversity, composition, and heterospecific associations of trees in three altitudinal gradients in Bird's Head Peninsula, Papua, Indonesia

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Abstract. *Fatem SM, Djitmau DA, Ungirwalu A, Wanma AO, Simbiak VI, Benu NMH, Tambing J, Murdjoko A. 2020. Species diversity, composition, and heterospecific associations of trees in three altitudinal gradients in Bird's Head Peninsula, Papua, Indonesia. Biodiversitas 21: 3596-3605.* The region of Bird's Head Peninsula, West Papua, Indonesia has a high level of vegetation diversity distributed from coastal to mountain areas. Yet, the information regarding this diversity is limited. We studied species diversity, composition, and heterospecific association of trees in three altitudinal gradients in Bird's Head Peninsula to reveal the biotic phenomenon in the region. Systematic random sampling was applied during data collection in three locations representing lower, middle, and upper altitudes of natural tropical forest. We applied diversity indices to investigate taxonomic diversity, importance value index (IVI) to reveal floristic composition and canonical correspondence analysis (CCA) for heterospecific associations. In total, we recorded 30 families, 44 genera, and 66 species in the three locations. There were 20 families in lower area and each 15 families in middle and upper areas while the genera per site were 29 in lower, 20 in the middle, and 18 in the upper. The number of species found in lower, middle, and upper areas was 35 species, 24 species, and 27 species respectively. The research revealed that the taxonomic diversity of trees generally decreases as the elevation increases in terms of family, genera, and species level. The dominant species was also different across elevation gradients in which the dominant tree had a different pattern in the three locations between understory and upperstory. Moreover, the gradient of elevation has shaped the type of tree communities, suggesting interactions and associations among tree species. Of all species recorded, 26 species were listed in IUCN Red List with two species were under data deficient, 20 species were least concern, three species were near threatened, and one species was vulnerable.

Keywords: Canonical correspondence analysis, conservation status, Pielou's evenness, Shannon-Wiener index, Vegan package

INTRODUCTION

Natural forest in tropical regions comprises a variety of ecological conditions, which can be divided into biotic and abiotic factors (Pan et al. 2013; Brown et al. 2014; Ashton 2018). The abiotic factors consist of climatic and edaphic variables, while the biotic factors consist of living organisms. The topographical arrangement of natural tropical forests varies from lower area to mountain area, resulting in variations of ecological conditions (Duivenvoorden 1995; Hunter et al. 2015; Vázquez and Givnish 1998). Consequently, the biotic factors are impacted by such variations, resulting in the gradient of biological diversity.

In tropical region, vegetation as a component of biotic factors shows differences in term of taxonomic diversity, population density, abundance, floristic composition, vertical structure and dispersal pattern (Huang et al. 2003; Phillips and Lewis 2014; Putz and Romero 2014; Addi et al. 2020). The pattern of the difference also forms vegetation communities as conspecific and heterospecific associations in which the communities create a particular characteristic (Trogisch et al. 2017; Clark et al. 2018). The conspecific association occurs between individuals in the same species of trees such as juveniles and mature individuals (Luo et al. 2009; Murdjoko et al. 2016a). The heterospecific association is the interaction of individuals among different species of trees (Zhu et al. 2015b; Johnson et al. 2017; Atanasso et al. 2019).

Bird's Head Peninsula is located in the western part of Papua, Indonesia in which administratively the area belongs to Province of West Papua, Indonesia. The region encompasses a high variety of abiotic factors, such as topographical gradient, resulting in a high level of vegetation diversity, which is distributed from coastal areas to mountain areas. The area harbors biotic factors with high diversity of flora and fauna. However, only little has been published scientifically i.e., wildlife (Shaverdo et al. 2016; Szczepański et al. 2018; Kaiser et al. 2019; Pattiselanno et al. 2019) and vegetation (Heatubun 2002; Heatubun et al. 2009, 2013; Maturbongs et al. 2014, 2015; Sillanpää et al. 2017; Robiansyah 2018).

Most area of Bird's Head Peninsula is pristine forest as the consequence of the low accessibility. Some parts of this region have been officially assigned as conservation areas, as such the management of the forest in this region is focused on conservation purposes (Bappeda Tambrauw 2015). For example, the Tambrauw District, which is located in the Bird's Head Peninsula, has been declared as conservation district to promote the sustainability of the forest. Thus, development program of this district must consider the principle of nature conservation (Fatem and Asem 2015; Fatem et al. 2018).

Hence, to provide baseline information regarding the natural resources in Bird's Head Peninsula, particularly the vegetation conditions, research must be conducted systematically in the region as the vegetation shows different responses to different biotic and abiotic factors (Fatem and Asem 2015; Robiansyah 2018). For this rationale, we studied the taxonomic dominance of tree and heterospecific association in tropical montane forests to reveal the biotic condition. We hypothesized that taxonomic dominance differs as the consequences of the difference in elevation of tropical montane forests in Bird's Head Peninsula and the taxonomic variation of the tree communities (Ding et al. 2019). This study only focused on the tree as part of the vegetation in which the presence of the tree could explain the phenomenon of vegetation overall. We expected that this research would encourage future research in Bird's Head Peninsula to enrich scientific information to support conservation program.

MATERIALS AND METHODS

Study period and area

This research was conducted in Tambrauw Mountains, which is part of the Bird's Head Peninsula, Tambrauw District, West Papua Province, Indonesia (Figure 1). The study took place in three different sites representing three altitudes: Site A at lower area with an altitude of 488 meters above sea level (m asl) (S 0°49'54.14" and E 132°29'17.78), B at middle altitude of 950 m asl (S 0°43'3.49"S and E 132°23'47.15"), and C at high altitude of 1200 m asl (S 0°40'28.82"S and E 132°13'1.32"). The area was characterized by the mountainous topography with variations in elevation and slope. The data were collected in October 2019.

Sampling and data collection

We established twenty plots of 20 m x 20 m in each research site with at least 100 m distance between plots. We then made subplots nested in each plot to measure four stages of tree growth: (i) 20 m x 20 m subplot to collect mature tree (diameter > 20 cm); (ii) 10 m x 10 m subplot to collect young tree (diameter between 10-20 cm); (iii) 5 m x 5 m subplot to collect tree sapling (diameter < 10 cm with height > 150 cm; (iv) 2 m x 2 m subplot to collect tree seedling (height < 150 cm). The first two subplots were set to sample the upperstory and while the latter two subplots were to sample understory. Data collected were the name of tree species, number of individuals, and diameter (cm). For identification of tree species, herbarium specimens were collected and sent to the Herbarium *Papuaense*, Forestry and Environment Research and Development Agency Manokwari and Herbarium *Manokwariense* (MAN), Research Center of Biodiversity, Papua University, Manokwari. The scientific names of species, genera, and families were checked based on The Plant List (TPL) (at the website: http://www.theplantlist.org/). We also checked the conservation status of the species on The

International Union for Conservation of Nature's Red List of Threatened Species (at the website: https://www.iucnredlist.org/).

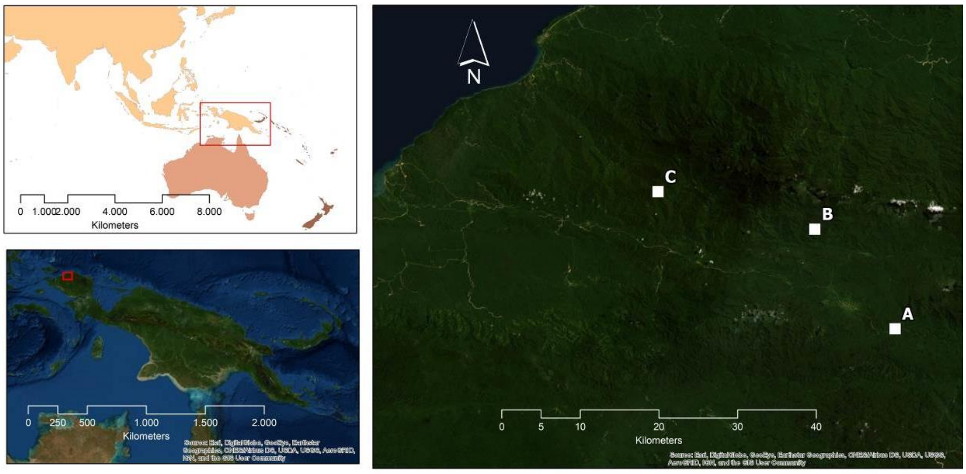


Figure 1. Location of research in three sites. The letter of A symbolizes lower area, B is middle area, and C is area with upper area based on elevation above sea level

Data analysis

The diversity in the three study sites was analyzed (Shannon 1948; Pielou 1966; Spellerberg and Fedor 2003) by calculating Shannon-Wiener diversity index as follows:

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

Where: H' is Shannon-Wiener diversity index, p_i is number of samples where species *i* is present.

We also calculated the evenness using Pielou's evenness as:

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

Where: S is total number of species of each location.

Taxonomic species composition was analyzed through the Importance Value Index (IVI) and calculated as follows (Curtis and McIntosh 1950; Cottam and Curtis 1956):

$IVI_i = RFr_i + RDe_i + RDo_i$ (i.e. for the upperstory)

$IVI_i = RFr_i + RDe_i$ (i.e. for the understory)

Where; IVI_i is important value index of species *i,* RFr_i is relative frequency of species *i,* RDe_i is relative density of species *i,* RDo_i is relative dominance of species *i.*

We applied Canonical Correspondence Analysis (CCA) to analyze the heterospecific associations among species in three locations (Ter Braak 1986; Murdjoko et al. 2017). This analysis was to investigate the tree communities formed in the three locations whether there was a tendency of species to present as a group or community. In the computation, we set 66 columns to fit with the total number of tree species recorded and 60 rows as the sum of plots across the tree study sites (i.e. every 20 plots in lower area, middle area, and upper area). Chi-square test (χ^2) was performed to validate the CCA. The computations used *vegan* package in R version 3.5.3 (Oksanen et al. 2019).

RESULTS AND DISCUSSION

Tree diversity

In total, we recorded 30 families, 44 genera, and 66 species in the three locations. There were 20 families in lower area and every 15 families in middle and upper areas while the genera per site were 29 in lower, 20 in the middle, and 18 in the upper. The number of species found in lower, middle, and upper areas was 35 species, 24 species, and 27 species respectively. In the lower site, the families of *Myrtaceae*, *Anacardiaceae*, *Burseraceae*, *Lauraceae*, and *Myristicaceae* consisted of at least three species while the other families had two species or less (Figure 2). In the middle site, the families of *Myristicaceae*, *Sapindaceae,* and *Sapotaceae* contained at least two species. In the upper, *Myrtaceae*, *Lauraceae* and *Fagaceae* were the families that had the species number at least three. The diversity at family level was higher in the lower area compared with the two areas and the species diversity showed the same pattern as family diversity.

Species diversity varied among the three locations (Table 1). To compare tree species diversity, we grouped species at the three locations and the structure of the tree (understory and upperstory). The results revealed the decline in species diversity from the lower, middle, and upper, indicated by the decrease in Shannon-Wiener index. The pattern of species diversity of understory was similar to tree category in general, while the diversity of upperstory showed an increase from lower to middle and then slightly decline from the middle to upper. The decreasing index of Pielou's evenness occurred in all categories and understory. However, Pielou's evenness index for upperstory showed fluctuating pattern where the J' dropped from lower to middle and marginally increase from the middle to upper.

The diversity of understory is more dynamic than the diversity of upperstory since the understory comprises the juvenile phase of the tree as seedlings (Murdjoko et al. 2016b). During the seedling establishment, this period is crucial as a result of the high mortality rate of seedlings (Dong et al. 2014; Lu et al. 2014; Zhu et al. 2015c). The process can be explained that the seedlings that just germinated would compete and interact with other vegetation and also can be as food for some animals (Sinery 2013). Therefore, higher diversity tends to occur in the understory. Moreover, the decrease of diversity as elevation increase is likely due to the limited dispersal of some species to the higher elevation. Thus, the higher elevation, the less diversity of species. The dispersal of species is also affected by the seed or fruit characteristics such as height, shape, and whether edible or not for animals (Clark et al. 2018; Yguel et al. 2019).

Table 1. Shannon-Wiener Index (H') and Pielou's evenness index (J') for the three study sites (mean [standard deviation]). The letter of A symbolizes lower area, B is middle area, and C is area with upper altitude based on elevation above sea level

		A (Lower area)		**B** (Middle area)		**C** (Upper area)	
All	H'	2.365	[0.115]	1.914	[0.101]	1.602	[0.067]
	J'	0.785	[0.007]	0.691	[0.014]	0.578	[0.006]
Upperstory	H'	1.896	[0.044]	2.088	[0.184]	2.087	[0.054]
	J'	0.912	[0.021]	0.888	[0.053]	0.906	[0.023]
Understory	H'	2.286	[0.160]	1.799	[0.045]	1.474	[0.001]
	J'	0.870	[0.006]	0.781	[0.020]	0.690	[0.027]

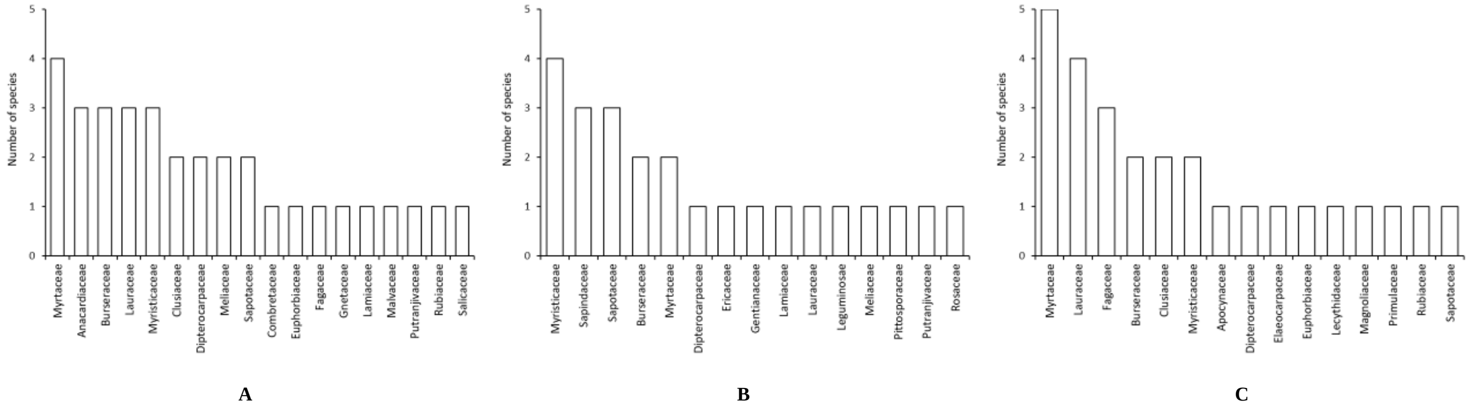
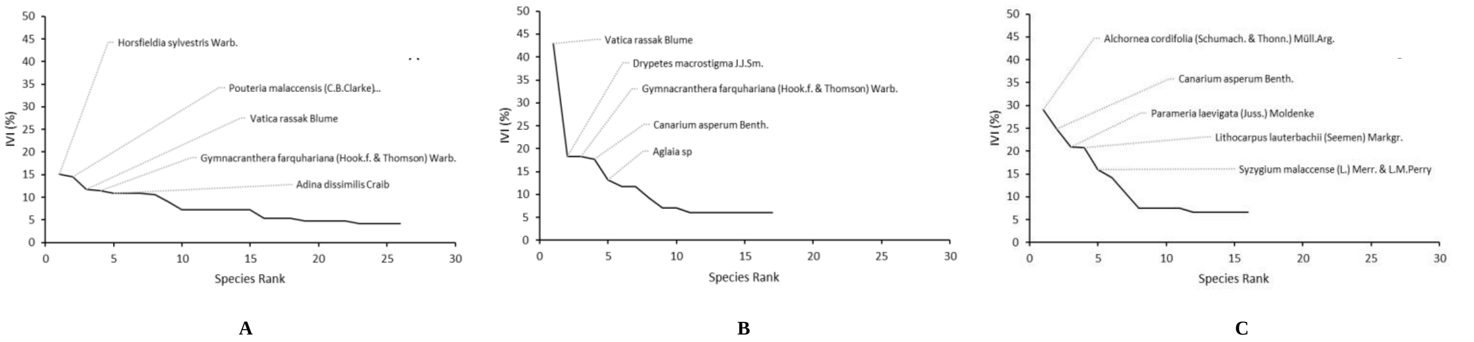
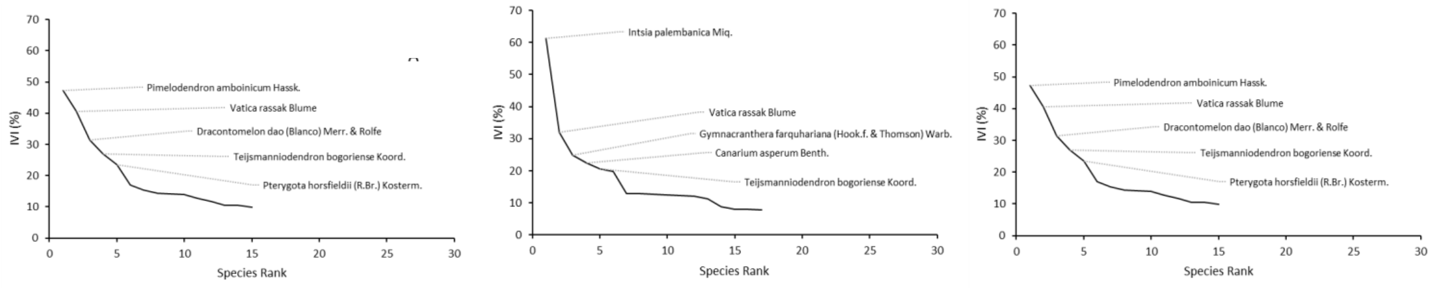


Figure 2. Number of species per family in the three study sites. The letters of A, B, and C are symbols of the lower area, middle area, and upper area, respectively.





A **B** **C**

Figure 4. Top five dominant tree species for understory in the three sites based on Importance Value Index (IVI). The letter of A symbo lizes lower area, B is the middle area, and C is the area upper

Dominant tree species

We compared dominant tree species across the three study sites and growth stages. The results showed that there were differences in dominant tree species not only across the three locations but also the growth stages (i.e. understory and upperstory (Figures 3 and 4). The dominant species for understory were *Horsfieldia sylvestris* Warb., *Pouteria malaccensis* (C.B.Clarke) Baehni, *Vatica rassak* Blume, *Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb., and *Adina dissimilis* Craib in the lower study site; *Vatica rassak* Blume, *Drypetes macrostigma* J.J.Sm., *Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb., *Canarium asperum* Benth., and *Aglaia sp* in the middle site; and *Alchornea cordifolia* (Schumach. & Thonn.) Müll.Arg., *Canarium asperum* Benth., *Parameria laevigata* (Juss.) Moldenke, *Lithocarpus lauterbachii* (Seemen) Markgr., and *Syzygium malaccense* (L.) Merr. & L.M.Perry in the upper site. The dominant species for upperstory were *Pimelodendron amboinicum* Hassk., *Vatica rassak* Blume, *Dracontomelon dao* (Blanco) Merr. & Rolfe, *Teijsmanniodendron bogoriense* Koord., and *Pterygota horsfieldii* (R.Br.) Kosterm. in the lower site; *Intsia palembanica* Miq., *Vatica rassak* Blume, *Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb., *Canarium asperum* Benth., and *Teijsmanniodendron bogoriense* Koord. In the middle site; and *Lithocarpus lauterbachii* (Seemen) Markgr., *Quercus argentata* Korth., *Elaeocarpus leucanthus* A.C.Sm., *Syzygium anomalum* Lauterb., and *Garcinia beccarii* Pierre in the upper site.

Tree communities as species interactions

We grouped tree species as communities to investigate whether there are interactions among them. We applied Canonical Correspondence Analysis (CCA) to cluster the species. We found group of species in the three study sites with the number of species in the lower area is 27 species, the middle area with 16 species, and upper area with 19 species (Figure 5). On the other hand, there are four species presented dominantly in more than one location. The density of species shaped the four tree communities in this research based on the distribution across the difference of elevation. The CCA explained the variation of 57.65 % in the first axis (CCA1) and 42.35 % in the second axis (CCA2). The validation of CCA showed that the Chi-squared test (χ^2) test= 1.4611, df = 130, p-value > 0.05. Therefore, the CCA was valid to describe the heterospecific associations as the distribution phenomenon of species. The species name of abbreviations in Figure 5 can be seen in Table S1.

Regardless of the growth stage as seedlings, saplings, poles/young trees, and mature trees, some species tend to be dominant in the lower area, middle area, and upper area which explain the pattern of communities formed (Figure 5). Each species has physiological, anatomical, and phenological characteristics that affect the interactions and associations with other species (Pavón et al. 2000; Zhu et al. 2015a; Crausbay and Martin 2016). For example, the lifespan of species affects the community formed (Zuidema et al. 2013; Jiang et al. 2015; Ganivet et al. 2020), and the seed characteristics determine the distribution of species during the dispersal which often involves animals (Naniwadekar et al. 2015; Finnegan et al. 2019). However, in this research, the ecological conditions of each location, which differs in elevation, is likely the driving factors that form tree community. The conspecific association also relate to regeneration processes which might beneficial when developing conservation program such as planting for restoration (Seidler and Plotkin 2006; Zhu et al. 2015c; Murdjoko et al. 2016a).

Distribution of individuals based on diameter class

Our study found that diameter class is not equally distributed and the distribution forms the reversed-J shape in which lower diameter trees dominated the stands than the higher diameter ones (Figure 6). This pattern is uniform across the three locations which is common in natural tropical forests. Of all young individuals with lower diameter class, only a few numbers of them that would grow to mature individuals as young individuals would compete and interact with each other to reach the canopy level as they require solar radiation (Bagchi et al. 2010; Metz et al. 2010; Zangaro et al. 2016). The competition not only occurs among individuals of trees but also other vegetation in different lifeforms such as lianas, herbs, and ferns. The competition and interaction are to obtain nutrients in soil and sunlight, so the relationship among vegetation as symbiosis (Barron et al. 2011; Taylor et al. 2019). On a broad scale, symbiosis in natural tropical forests takes place not only among vegetation but also with other

organisms such as wildlife and microorganism (Silver et al. 1996; De Cáceres et al. 2013; Zhu et al. 2015c).
Therefore, the observation of size distribution between small and larger individuals is imperative to describe the regeneration process. For future research, it is crucial to analyze size distribution for certain species to figure out the natural regeneration process, so the result would be beneficial for the management of the natural tropical forest.

Conservation status

In total across the three locations, there were 26 species identified with the conservation status based on the International Union for Conservation of Nature Red List of Threatened Species (https://www.iucnredlist.org/) (Table 2). The status of data deficient (DD) was only present in the lower location (C), while at least nine species least concern (LC) status across the three locations. There were species with near threatened (NT) in the three locations, while vulnerable (VU) was only present in the lower location. Tree species with status near threatened (NT) are *Aglaia odorata* Lour., *Cryptocarya massoy* (Oken) Kosterm., and *Pouteria malaccensis* (C.B.Clarke) Baehni; and vulnerable (VU) is *Anisoptera curtisii* Dyer ex King.

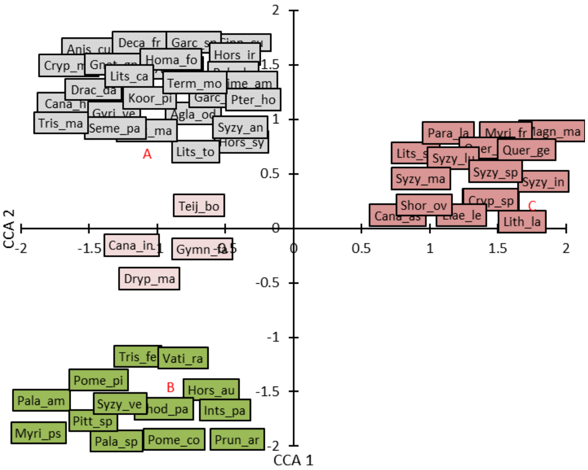


Figure 5. Canonical correspondence analysis (CCA) plot showing the heterospecific association of tree species in the three sites. The red letter of A symbolizes lower area, B is the middle area, and C is the upper area.

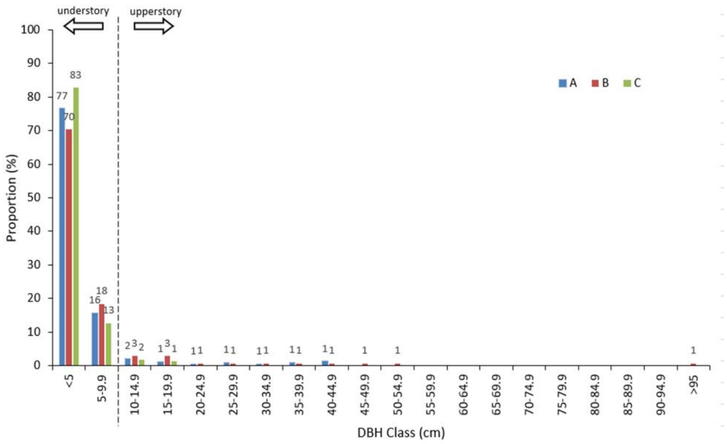


Figure 6. Distribution of individuals based on the DBH class (cm) in the three study sites displaying the understory at left side and upperstory at the right side. The letter of A symbolizes lower area, B is the middle area, and C is the upper area.

Table 2. Conservation status of tree species in the three sites based on the IUCN Red List. The letter of A symbolizes lower area, B is middle area, and C is upper area. N.A. is data not available

Locations	Conservation status				
	N.A.	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)
A	20	0	11	3	1
B	14	0	9	1	0
C	14	2	9	2	0

Table S1. Species name in Canonical correspondence analysis (CCA) plot

		Plant Community A
Adin_di	:	*Adina dissimilis* Craib
Agla_od	:	*Aglaia odorata* Lour.
Agla_sp.1	:	*Aglaia spectabilis* (Miq.) S.S.Jain & S.Bennet
Anis_cu	:	*Anisoptera curtisii* Dyer ex King
Cana_hi	:	*Canarium hirsutum* Willd.
Cinn_cu	:	*Cinnamomum culitlawan* (L.) J.Presl
Cryp_ma	:	*Cryptocarya massoy* (Oken) Kosterm.
Deca_fr	:	*Decaspermum fruticosum* J.R.Forst. & G.Forst.
Drac_da	:	*Dracontomelon dao* (Blanco) Merr. & Rolfe
Garc_be	:	*Garcinia beccarii* Pierre
Garc_sp	:	*Garcinia* sp
Gnet_gn	:	*Gnetum gnemon* L.
Gyri_ve	:	*Gyrinops versteegii* (Gilg) Domke
Homa_fo	:	*Homalium foetidum* Benth.
Hors_ir	:	*Horsfieldia irya* (Gaertn.) Warb.
Hors_sy	:	*Horsfieldia sylvestris* Warb.
Koor_pi	:	*Koordersiodendron pinnatum* Merr.
Lits_ca	:	*Litsea calophylla* (Miq.) Mansf.
Lits_to	:	*Litsea tomentosa* Blume
Pala_lo	:	*Palaquium lobbianum* Burck
Pime_am	:	*Pimelodendron amboinicum* Hassk.
Pout_ma	:	*Pouteria malaccensis* (C.B.Clarke) Baehni
Pter_ho	:	*Pterygota horsfieldii* (R.Br.) Kosterm.
Seme_pa	:	*Semecarpus papuana* Lauterb.
Syzy_an	:	*Syzygium anomalum* Lauterb.
Term_mo	:	*Terminalia morobensis* Coode
Tris_ma	:	*Tristaniopsis macrosperma* (F.Muell.) Peter G.Wilson & J.T.Waterh.
		Plant Community B
Agla_sp	:	*Aglaia* sp
Fagr_el	:	*Fagraea elliptica* Roxb.
Harp_ar	:	*Harpullia arborea* (Blanco) Radlk.
Hors_au	:	*Horsfieldia australiana* S.T.Blake
Ints_pa	:	*Intsia palembanica* Miq.
Myri_ps	:	*Myristica pseudoargentea* Warb.
Pala_am	:	*Palaquium amboinense* Burck
Pala_sp	:	*Palaquium* sp
Pitt_sp	:	*Pittosporum spinescens* (F.Muell.) L.W.Cayzer, Crisp & I.Telford
Pome_co	:	*Pometia coriacea* Radlk.
Pome_pi	:	*Pometia pinnata* J.R.Forst. & G.Forst.
Prun_ar	:	*Prunus arborea* (Blume) Kalkman
Rhod_pa	:	*Rhododendron papillatum* Balf. f. & R.E. Cooper
Syzy_ve	:	*Syzygium versteegii* (Lauterb.) Merr. & L.M.Perry
Tris_fe	:	*Tristaniopsis ferruginea* (C.T.White) Peter G.Wilson & J.T.Waterh.
Vati_ra	:	*Vatica rassak* Blume
		Plant Community C

Alch_co	:	*Alchornea cordifolia* (Schumach. & Thonn.) Müll.Arg.
Ardi_se	:	*Ardisia serrata* (Cav.) Pers.
Barr_as	:	*Barringtonia asiatica* (L.) Kurz
Cana_as	:	*Canarium asperum* Benth.
Cryp_od	:	*Cryptocarya odorata* Guillaumin
Cryp_sp	:	*Cryptocarya sp*
Elae_le	:	*Elaeocarpus leucanthus* A.C.Sm.
Lith_la	:	*Lithocarpus lauterbachii* (Seemen) Markgr.
Lits_sp	:	*Litsea* sp
Magn_ma	:	*Magnolia macklottii* (Korth.) Dandy
Myri_fr	:	*Myristica fragrans* Houtt.
Para_la	:	*Parameria laevigata* (Juss.) Moldenke
Quer_ar	:	*Quercus argentata* Korth.
Quer_ge	:	*Quercus gemelliflora* Blume
Shor_ov	:	*Shorea ovalis* Blume
Syzy_in	:	*Syzygium inophyllum* DC.
Syzy_lu	:	*Syzygium luehmannii* (F.Muell.) L.A.S.Johnson
Syzy_ma	:	*Syzygium malaccense* (L.) Merr. & L.M.Perry
Syzy_sp	:	*Syzygium* sp
		Plant Community OTHER
Cana_in	:	*Canarium indicum* L.
Dryp_ma	:	*Drypetes macrostigma* J.J.Sm.
Gymn_fa	:	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb.
Teij_bo	:	*Teijsmanniodendron bogoriense* Koord.

The four species with conservation status of near threatened and vulnerable were less dominant species except for *P. malaccensis*. Hence, those should be in consideration in the management of the natural tropical forest. For example, future research should focus on the dispersal, regeneration, and the utilization of those species (Vlam et al. 2017; Padmakumar et al. 2018; Li et al. 2020). This could be one of the conservation programs to support the conservation district of Tambrauw. Besides, the species with conservation status not available need to be studied to gain more scientific information. Furthermore, the concept of forest conservation could be implemented widely not only focusing on biotic such as vegetation but the socio-culture aspect could be also considered (Ungirwalu et al. 2014, 2017).

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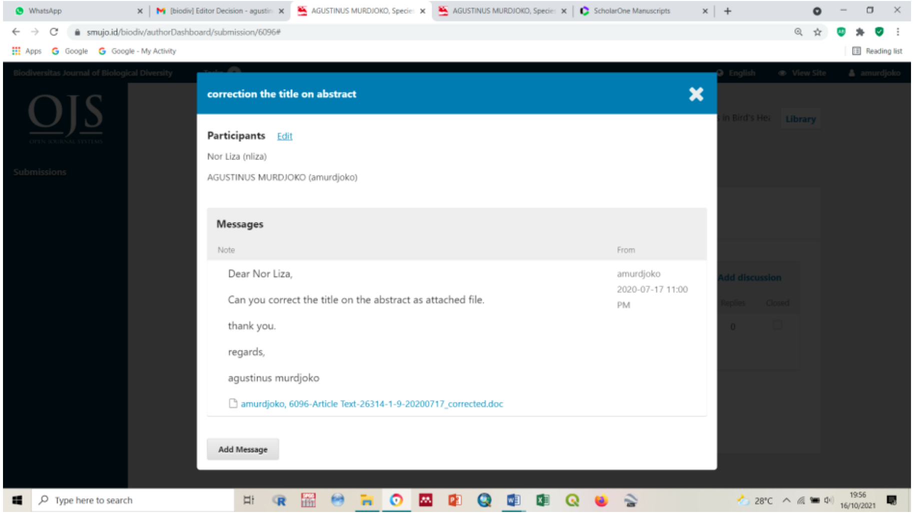
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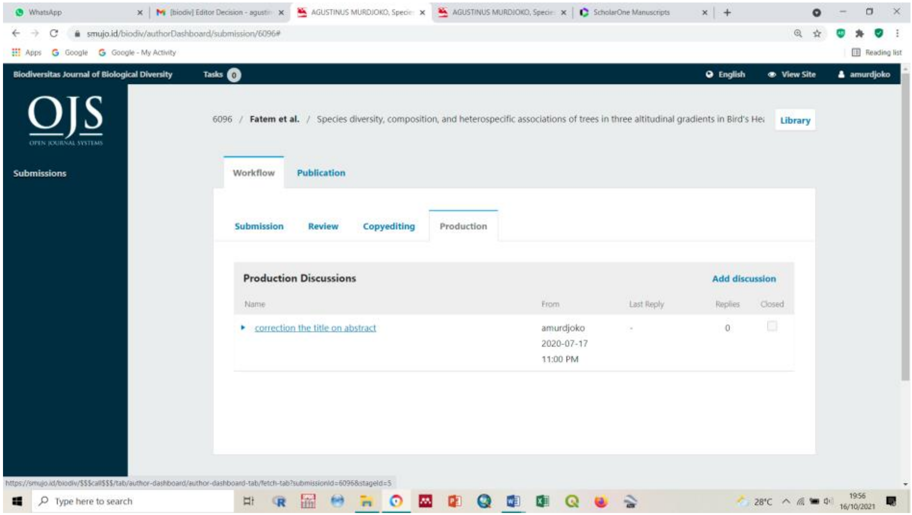
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