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The Species Diversity and Structure of The Limited Production Forest in Arui Watershed of Manokwari District of West Papua, Indonesia

Mahmud[1,4]✉, Ambar Kusumandari[2], Sudarmadji[3], Nunuk Supriyatno[2]

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[1]Faculty of Forestry, Universitas Papua, Indonesia
[2]Faculty of Forestry, Universitas Gadjah Mada, Indonesia
[3]Faculty of Geography, Universitas Gadjah Mada, Indonesia
[4]Doctoral Program of Forest Science, Universitas Gadjah Mada, Indonesia

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Abstract

The detailed causal factors of flood have not been established, whether because of the damage of upper watershed, sedimentation resulting in shallow river, forest conversion, the decrease in abundance and structure or high rainfall. The study aimed at finding out the species diversity and structure of the limited production forest (LPF) from the seedling to the tree stage of Arui watershed in Manokwari district. The species diversity was determined based on Shannon-Wiener index, while vegetation structure was determined based on Importance Value Index. There were totally 92 plots of samples drawn using systematic sampling. The results of vegetation analysis showed that there were 174 species of 43 families with the species diversity of 1.5-1.8 that was categorized as moderate. The four dominant species that were always found in seedling, sapling, pole and tree stages included: Pometia pinnata, Teijsmanniodendron bogoriense, Chisocheton ceramicus, and Horsfieldia irya. The conversion of the LPF into non-forestry sector for the purpose of accelerating development must be reviewed by considering hydrology, land, biodiversity, and social and regional aspects in order to prevent and to reduce flood in the coming days.

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✉ Correspondence Author:
Jalan Gunung Salju, Amban, Manokwari Barat, Papua Barat 98314
E-mail: mahmud_thia@yahoo.co.id

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INTRODUCTION

Flood is natural phenomenon taking place when very high intensity rain occurs, while ground is not able to well-absorb the rain water and then runoff happens (Paroissien et al., 2014; Vannier et al., 2016). The flood takes place because of the presence of excessive water flow that may result from the change in rainfall and surface runoff, limited capacity of river or drainage or dysfunctional waterworks (Hallegate et al., 2013; Ran & Budic, 2016). The excessive quantity of water will result in inundation. Climate change and land-use change have increased the ratio of rainfall to surface flows, the amount of water directly becoming runoff flooding increasing significantly, so that the peak discharge becomes greater and decreation water quality (Yan et al., 2013; Nasir et al., 2017).

Once the flood has taken place in Arui watershed on 29 February 2016, both local and central governments visited the affected area and promised to normalize the watershed. Allegedly conversion of LPF to oil palm plantations is a factor causing flooding. Before the forest is converted into the palm plantations, it used to be limited production forest. Today the limited production forest becomes the target of the conversion based on the verse 1 of the article 43 of the government regulation No. 104 of 2015 on the conversion of the main function of limited production forest into permanent production forest, the permanent production forest into limited production forest, and production conversion forest into limited production forest.

It is necessary to establish the species diversity and structure in the LPF considering that the flood in Arui watershed on 29 February 2016 was caused by the decrease in the species structure and abundance and high rainfall. The Arui watershed is situated west of Papua New Guinea Island well-known as tropical rain forest with high diversity of plants. The tropical rain forest includes many species, especially flora with high species diversity (Mesquita et al.,2015; Murdjoko et al.,2016a). There have been many studies conducted to uncover the diversity of the plant species (Kessler et al., 2014; Kuswandi et al., 2015). Some plant species have not been completely identified. Thereroe, some plant species have recently been classified taxonomically (Heatubun et al., 2014; Maturbongs et al.,2015). However, there is still lack of information of the abundance, the distribution and the association of the plant species with other plants in natural forest.

According to MoLEF (2017) the function of the forest area in the Arui watershed includes 9,499.27 hectares of LPF (40.58%), 2,577.12 hectares of conversion production forest (11.09%), 182.07 ha of protected forest (0.78%), 11,009.01 hectares of other uses (47.38%), 33.29 hectares of water (0.14%) and 4.46 hectares of fauna (0.02%). Thus, the function of the forest area is 52.45%, which is very big as compared to the government regulation stating that there should be minimally 20% of watershed that functions as forest. So, why did flood take place in Arui watershed? Was the flood caused by the damage of intermediary and upper course watershed, erosion/sedimentation, land converstion or the decrease in the abundance and the structure or rainfall? Therefore, it is necessary to immediately overcome the impact of the flood and to find out the causal factors of the flood.

The enforcement of the government regulation No. 104 of 2015 will threat the existence of the LPF. The abundance and the structure of the species in the LPF represent the data of the potential and the threat in the management by non-government organizations, stakeholders, forestry agency, and other parties concerned with the sustainability of forest resource. There are 40.58% LPF in the Arui watershed and the flood has taken place 3 times. However, there is still lack of information of the abundance and the distribution of the plant species growing in the LPF. There are now many threats to the LPF. One of the threats is the conversion of the forest into other uses that results in the loss of habitats. Therefore, it is necessary to identify the species in the LPF in the effort to manage the forest and to find out if the decrease in the species is one of the causal factors of the flood in the Arui watershed.

METHODS

The location of the study is limited production forest (LPF) representing natural tropical rain forest in West Papua. There are totally 92 plots of samples drawn using systematic plot sampling. The plot of the dimension of 20 x 20 m (0.04 hectare) is set for big trees and big individual tree of the diameter at breast height of more than 20 cm. The plot of the dimension of 10 x 10 m (0.01 hectare) is set for individual pole of the diameters at breast height in the range between 10 and 20 cm. The plot of the dimension of 5 x 5 m (0.0025 hectare) is set for individual sapling of the height of more than 1.5 m and of the diameter of less than 10 cm. The plot of the dimension of 2 x 2 m (0.0004 hectare) is set for individual seedling of the height of less than 1.5 m.

The plant species in the LPF are placed in pots and each individual is identified in accordance with their scientific names. They are identified by herbarium technician in two vegetation identifications. The number of each species in the pot is documented, while the diameter at breast height is 1.3 m or 20 cm above the support for the pole and the tree, except the seedling and the sapling. Important value index (IVI) is calculated for the tree in order to find out the distribution of each species of the tree in term of its dominance. The index is determined by adding relative frequency, relative density and relative dominance as follows: IVi = Rfri + Rdei + Rdoi where IV is the important value index of the species I, Rfri is the relative frequency of the species I, Rdei is the relative density of the spcies I, Rdoi is the relative dominance of the species i. Shannon-Weiner diversity index is used as parameter to describe the distribution of each species (Spellerberg & Fedor 2003).

Diversity index. Shannon-Wiener diversity index is calculated with the following formula:
H ‘= -Â [ni / N] log [ni / N]
Where: H ‘ = diversity index
ni = the number of individuals of each species
N = the number of individuals of all spcies
The species diversity is considered as high if H ‘>3, moderate if 1<H’<3 and low if ‘<1.

The decrease in the potential of the 10 species is dominant in the diameter of 30-40 cm, 40 cm and above and maximum diameter.

RESULTS AND DISCUSION

The results of the analysis of the vegetation in Arui watershed show that there are 174 species with 43 families containing the seedling level of 85 species and 38 families, the sapling level of 109 species and 36 families, the pole level of 65 species and 29 families, and the tree level of 87 species and 40 families.

Seedling Level

The 10 dominant species in the seedling level are *Pometia pinnata* followed respectively by *Pisonia longirostris, Chisocheton ceramicus, Teijsmanniodendron bogoriense, Syzygium sp* (Fig 6)*, Palaquium lobbianum, Piper aduncum, Horsfieldia irya, Sloanea pulcra* and *Siphonodon celatrian* (Table 1).

Referring to the decision of the Minister of Forestry No. 163/Kpts-II/2003 on May 26, 2003 on the classification of the species of trees as the basis of charging forestry cost. At the seedling level there are only 3 commercial species: *Pometia pinnata, Syzygium* sp dan *Palaquium lobbianum,*(Figure 5) while other species are not identified. The absence of the commercial species in Papua such as *Instia bijuga* dan *I. palembanica* represents a challenge in the LPF. The presence of the species *Piper aduncum* has been the indicator of massif logging and timber harvesting. It is because the species *Piper aduncum* usually will grow in an area that has been long opened since the logging has been over. Though the management of the LPF should be limited and selective in extracting forest products, the exploitation of timbers in the LPF can not be organized in high intensity or at large scale. However, it is found in general that the extraction of the forest products is organized in mountainous areas with moderately steep to steep topography. Following the existing directive in land use, the use of land should consider slope class, soil type and erosion rain intensity (the total score of 125-175) in the LPF/ buffering zone. According to Kuswandi & Murd-

Table 1. The 10 dominant species at seedling stage.

Species	Family	PLOT	D	Rdei	Rfri	IVI
Pometia pinnata	Sapindaceae	25	0.24	21.44	10.42	31.86
Pisonia longirostris	Nyctagibnaceae	10	0.07	6.23	4.17	10.40
Chisocheton ceramicus	Meliacea	14	0.05	4.24	5.83	10.07
Teijsmanniodendron bogoriense	Lamiaceae	11	0.06	5.48	4.58	10.07
Syzygium sp.	Myrtaceae	8	0.06	4.99	3.33	8.32
Palaquium lobbianum	sapotaceae	9	0.05	4.24	3.75	7.99
Piper aduncum	Piperaceae	5	0.04	3.24	2.08	5.32
Horsfieldia irya	Myristicaceae	7	0.02	1.99	2.92	4.91
Sloanea pulcra	Elaeocarpaceae	4	0.03	2.99	1.67	4.66
Siphonodon celatrianus	Celastraceae	6	0.02	1.74	2.5	4.24

Note: D (density), Rdei (Relative density), Rfri (Relative frequency), IVI: Important Value Index joko (2015) the problems in the management of logged natural forest (logging area) are the diversity of the logging area, especially in term of the composition of species, tree density, the condition of stand structure, harvesting intensity.

Sapling Level

The 10 dominant species at the sapling level are *Pisonia longirostris* followed respectively by *Pometia pinnata, Piper aduncum, Chisocheton ceramicus, Aglaila argentea* (Figure 8), *Horsfieldia irya, Pleomele angustifolia, Teijsmanniodendron bogoriense, Macaranga* spp. and *Geniostoma rupestre* (Table 2). According to Mawazin & Subiakto (2013), dominant species are those that are beneficial for the environment in which they live efficiently as compared to other species in the same environment. The dominance of certain species is described at the dominance level over other species in a community as indicated by the magnitude of the important value index.

Table 2 shows that at the pole level there are 2 species of commercial tree, including *Pometia pinnata* (commercial 1) and *Macaranga* spp (commercial 2), while other species are non-commercial. *Pometia pinnata* is endemic species of Papua and easy to grow with wide spread in Papua. It grows easily rapidly in open area with sufficient sung light. It is consistent with Murjoko et al. (2016a) that the *Pometia pinnata* significantly contributes to the growth rate of its population because residual trees grow rapidly in open area with sufficient sun light. Meanwhile, *Macaranga* spp. is pioneer species that usually grow in logging area and in the area that has been seriously affected by fire.

The lack of the commercial species represents a challenge and it deserves serious attention in the development of the commercial species in Papua. It indicates that there has been forest encroachment in the LPF. In the coming 50 years it will be a challenge for the LPF because the commercial species will not be found so that people will probably used non-commercial species of

Table 2. The 10 dominant species at sapling stage

Species	Family	PLOT	D	Rdei	Rfri	IVI
Pisonia longirostris	Nyctagibnaceae	22	1.00	6.20	6.86	13.07
Pometia pinnata	Sapindaceae	19	0.92	5.71	5.93	11.63
Piper aduncum	Piperaceae	7	1.08	6.70	2.18	8.88
Chisocheton ceramicus	Meliacea	11	0.84	5.21	3.43	8.64
Aglaila argentea	Meliacea	10	0.56	3.47	3.12	6.59
Horsfieldia irya	Myristicaceae	10	0.52	3.23	3.12	6..34
Pleomele angustifolia	Asparagaceae	9	0.56	3.47	2.81	6.28
Teijsmanniodendron bogoriense	Lamiaceae	10	0.44	2.73	3.12	5.85
Macaranga spp.	Euphorbiaceae	9	0.44	2.73	2.81	5.54
Geniostoma rupestre	Loganiaceae	10	0.32	1.99	3.12	5.10

Table 3. The 10 dominant species at pole stage

Species	Family	PLOT	Rdei	Rfri	Rdoi	IVI
Gironniera nervosa	Ulmaceae	9	8.04	7.81	8.38	24.23
Pometia pinnata	Sapindaceae	6	5.36	5.21	4.53	15.1
Teijsmanniodendron bogoriense	Lamiaceae	4	3.57	3.47	5.47	12.51
Litsea timorina	Lauraceae	4	3.57	3.47	4.67	11.71
Pimelodendron amboinicum	Euphorbia-ceae	4	3.57	3.47	4.33	11.37
Chisocheton ceramicus	Meliacea	4	4.46	3.47	3.25	11.18
Gymnacantera farquaria	Myristicaceae	8	3.70	4.28	3.08	11.06
Pometia accuminata	Sapindaceae	4	3.57	3.47	3.91	10.95
Octomeles sumatrana	Datiscaceae	4	3.57	3.47	3.79	10.83
Horsfieldia irya	Myristicaceae	4	1.78	1.74	5.47	8.99

Note: Rdei (Relatif density), RDoi (Relative dominance), Rfri (Relative frequency), IVI: Important Value Index tree. If it continues, the people will probably expand to the conservation area close to the LPF.

Pole Level

The 10 dominant species at the pole level are *Gironniera nervosa* followed respectively by *Pometia pinnata, Teijsmanniodendron bogoriense, Litsea timorina, Pimelodendron amboinicum, Chisocheton ceramicus, Gymnacantera farquaria,* and *Pometia akuminata*.

Table 3 shows that there are two species of tree widely know as commercial trees. They are *Pometia pinnata (*Figure 4) and *Octomeles sumatrana*. Meanwhile, there are 8 non-commercial species of tree, including *Gironniera nervosa Teijsmanniodendron Bogoriense* (Figure 2)*, Litsea timorina, Pimelodendron amboinicum, Chisocheton ceramicus, Gymnacantera farquaria, Pometia acuminata (*Figure 1), and *Horsfieldia irya* (Figure 3). The *Gironniera nervosa* has the highest IVI among other species. According to Kuswandi et al. (2015) the species with the highest IVI in a habitat may be the indicator of the habitat. The decrease in the commercial species resulting from logging will have significant impact on the change in structure. The change in floristic composition will have significant impact on the structure and vegetation growth in a logging area (Sandor & Chazdon, 2014).

Figure 1. *Pometia acuminata*

Figure 2. *Teijsmanniodendron bogoriense*

Figure 3. *Horsfieldia irya*

Figure 4. *Pometia pinnata*

Table 4. The 10 dominant species at tree stage

Species	Family	PLOT	Rdei	Rfri	RDoi	IVI
Pometia pinnata	Sapindaceae	34	23.37	11.97	13.74	49.08
Gironniera nervosa	Ulmaceae	21	8.12	7.39	5.34	20.85
Teijsmanniodendron bogoriense	Lamiaceae	15	5.93	5.28	8.88	20.09
Octomeles sumatrana	Datiscaceae	14	4.69	4.93	8.61	18.23
Eudia elleryana	Rutaceae	9	5	3.17	4.88	13.05
Pimelodendron amboinicum	Euphorbia-ceae	14	5.62	4.93	2.04	12.59
Chisocheton ceramicus	Meliacea	13	4.37	4.58	3.61	12.56
Horsfieldia irya	Myristicaceae	9	2.81	3.17	3.42	9.4
Homalium foetidum	Salicaceae	6	2.19	2.11	3.58	7.88

Figure 5. *Palaquium lobbianum*

Figure 6. *Syzygium* sp.

Tree Stage

The10 dominant species at the tree level are *Pometia pinnata* followed respectively by *Gironniera nervosa, Teijsmanniodendron bogoriense, Octomels sumatrana, Eudia elleryana, Pimelodendron amboinicum, Chisocheton ceramicus, Horsfieldia irya,* and *Homalium foetidum.* According to Kuswandi *et al.* (2015) the species with the highest IVI are more likely to continuously grow and to survive.

There are only 3 commercial species at the tree level(Table 4). They are *Pometia pinnata, Octomeles sumatrana* and *Homalium foetidum*. Meanwhile, there are 7 less familiar species, including *Gironniera nervosa, Teijsmanniodendron bogoriense, Eudia elleryana, Pimelodendron amboinicum* (Figure 9), *Chisocheton ceramicus (*Figure 7), *Horsfieldia irya,* dan *Pterocarpus indicus.* The presence of only three commercial species represents a challenge for the managers of the LPF. The LPF in Arui watershed has long been encroached, especially for the commercial species so that the species from the sapling level to the tree level do not grow very well. The causal factor of the decrease in the commercial species is the lack of awareness of the people of the importance of the LPF. If the decrease continues for long time, it will have serious impact on the dynamic equilibrium of the forest. The condition is at the forest dynamic equilibrium level (Lima et al., 2016; Ma et al., 2016).

Figure 7. *Chisocheton ceramicus*

Figure 8. *Aglaia argentea*

Figure 9. *Pimelodendron amboinicum*

Species Diversity

The species diversity from the seedlings to the trees is 1.55-1.81, which is categorized as moderate (Table 5).

Table 5. Diversity of various tree stages

Stage	∑ species	∑ Individual	H'
Seedling	85	401	1.55
Sapling	109	403	1.78
Poles	65	127	1.81
Trees	87	321	1.65

The diversity of tree species describes the characteristics of a special high-logged forest where harvested only certain types and diameters so that diversity is maintained (Whitfeld et al., 2014). Growth stands to gain vertical growing space also led to more types of competing to meet the vertical space, causing the individual to be high density (Laurans et al.,2014). The 174 species of *Intsia palembanica* are found only at the pole and tree levels, while there is not any species found at the seedling level. The species *Instia bijuga* is also not found at all levels. The absence of the *I. palembanica* of the 10 dominant trees indicates that there has been serious illegal logging so that natural regeneration does not take place. The two species become the reliable ones with high commercial value for any timber company in Papua. Besides that the two species has relative wide ecological niche, further growth requires full light. The lack of the species will endanger the living environment. So, it is necessary to recommend the species as endangered ones.

According to Tokede et al. (2013) it is easy to obtain the seeds of the *Intsia bijuga* and the *I. palembanica* in their natural habitat because they are abundantly available, but sometimes the regeneration under the core trees, especially on the sandy ground is hard to find. The supply of Merbau stands in intact forest and in logging area is still enough for the regeneration of the core trees and logged trees though they are not evenly distributed. The supply of the core trees and the natural regeneration in the logging area show that the species Merbau is not an endangered species. Therefore, there is not any sufficient reason to register the species in CITIES list.

The Decrease in Potential

The potential of stands decreases gradually for years. One of the parameters is the diameter of the stands. Table 6 shows that there is not any *Pterocarpus indicus* of the diameter of the stands of 30-40 cm found in the LPF (0%), while *Eudia elleryana* has the highest diameter (38%).

It indicates that there is only less than 50% of the trees with the diameter of 30-40 cm in the Arui watershed of the tropical forest, while the remaining trees are of the diameter of 1-30 cm. The big trees will be able to reduce surface flow, to increase interception, to reduce wind velocity, and to improve infiltration capacity. The tropical forest at equilibrium level is categorized as primary forest (Murdjoko et al., 2016b). However, the composition and the structure of the forest can change because of the presence of disturbance, especially the presence of anthropogenic factor. The forest will recover and its dynamics refers to secondary tropical forest (Castro-Luna et al., 2011).

It is also the case of the 10 dominant species. The *Pimelodendron amboinicum* of the diameter of 41 cm and above is the lowest (6%), while the *Pometia pinnata* was the highest (38%) and the *Teijsmanniodendron Bogoriense* has the maximum

Table 6. The decrease in the tree stage in Arui watershed.

Species	Family	∑ (individual)	A (individual)	B (individual)	C (cm)
Pometia pinnata	Sapindaceae	44	14 (32%)	17 (39%)	70
Gironniera nervosa	Ulmaceae	26	6 (23%)	5 (19%)	75
Teijsmanniodendron bogoriense	Lamiaceae	19	5 (26%)	7 (37%)	91
Octomels sumatrana	Datiscaceae	15	2 (13%)	5 (33%)	81
Eudia elleryana	Rutaceae	16	6 (38%)	4 (25%)	60
Pimelodendron amboinicum	Eupohorbiaceae	18	1 (6 %)	1 (6%)	45
Chisocheton ceramicus	Meliaceae	14	4 (29%)	2 (14%)	70
Horsfieldia irya	Myristicaceae	9	2 (22%	5 (55%)	60
Homalium foetidum	Salicaceae	7	1 (14%)	2 (28%)	85
Pterocarpus indicus	Fabaceae	3	0	2 (32%))	80

Note: A (Total of 30-40 cm in diameter), B (Total of 41 cm and up in diameter), C (Maximum diameter)

diameter (91 cm). The loss of the big trees indicates that illegal logging has taken place and it is the surrounding people of the LPF who commit the illegal logging. The LPF may be exploited only using selective method. The LPF in Arui watershed represents a logging area that there are various plants growing in the forest (Table 6). The diversity may result in the increasingly various plants growing in the forest. There are plants that grow relatively fast, while there are also those that grow relatively faster (Muhdin et al., 2015). The habit of the local people who harvest Matoa fruits by felling down Matoa trees deserves serious attention because it can decrease biodiversity and species abundance. It is not only the Matoa trees that are endangered by the local wisdom of the local people, but also other species may die if the trees are felled down. The fluctuation of the growth of the population may result from the gap of the crown because of the felling of the trees (Fayolle et al., 2014; Kuswandi &Murdjoko, 2015). So, it is necessary to introduce a new method in harvesting Matoa fruits, such as by directly picking the fruits without felling the Matoa tree down.

The issuance of the government regulation No. 104 of 2015 on the procedure and the method of changing the function of forest area has the potential to pose threat to the LPF in the Arui watershed. Flood has taken place in the Arui watershed in 2014-2016 and 2017. The objective of the government regulation is to accelerate the development outside of agricultural area. The government regulation states that the change in the forest area is allowed in permanent production forest by palm plantation (21.46%). Of course, it is necessary for us to anticipate the future of the LPF that is converted into palm plantation and hence the conversion must be prevented because the conversion of the forest into the palm plantation is very dangerous. According to Oksana et al. (2012) the conversion of the forest into palm plantation may cause the change in the chemical properties of soil such as pH, organic-C, cation exchange capacity, total N and organic matter. Meanwhile, according to Asdak (2010) the conversion of the forest function into palm plantation will increase the peak debit in wet season and increase air debit in dry season.

According to Suprayogi et al.(2013) illegal logging may interfere with the distribution of river flow in lower course. The water debit of a river will be very high in wet season and may cause flood, but it is very low in dry season. The change in land use or the implementation of improper agrotechnology can influence the quality and the quantity of the flowing water in the lower course. Therefore, it is necessary to organize long-term flood mitigation by preventing the illegal logging because it causes serious forest damage, the loss of surface soil and soil solidification.

CONCLUSION

The results of the vegetation analysis show that there are 174 species of 43 families with the species diversity from the seedling level to the tree level of 1.5-1.8, which is categorized as moderate. The four dominating species that are always found in all levels are *Pometia pinnata, Teijsmanniodendron bogoriense, Chisocheton ceramicus* and *Horsfieldia irya.* The small percentage of the reliable commercial species at the LPF in Papua (*Intsia bijuga* and *I. palembanica*) poses a threat to the stands of the two species. Therefore, it is necessary for the management of the LPF to involve the existing stakeholders. The decrease in the potential of the commercial timbers is indicative of the presence of illegal logging in the LPF for long time. If it continues, flood disaster will recur in the future. Therefore, the change in the forest function should be made not only for economic reason, but also should be made by considering the threats such as flood and landslides.

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REFERENCES

Asdak, C. (2010). Hydrology and Management Watershed . Yogyakarta. Gajah Mada University Press.

Castro-Luna, A., Castillo-Campos, G., & Sosa, V. (2011). Effects Of Selective Logging And Shifting Cultivation On The Structure And Diversity Of A Tropical Evergreen Forest In South-Eastern Mexico. *Journal of Tropical Forest Science*, 23(1), 17–34.

Fayolle, A., Picard, N., Doucet, J., Swaine, M., &Bayol, N. (2014). Forest Ecology And Management A New Insight In The Structure, Composition And Functioning Of Central African Moist Forests. *Forest Ecology and Management*, 329, 195–205.

[GoIR]Government of Republic Indonesian (2015). PP No. 104/2015 Tata cara Perubahan Peruntukan dan Fungsi Kawasan Hutan. Pemerintah Republik Indonesia. Jakarta

Hallegatte S., Green C., Nicholas R.J., Corfee M.J. (2013). Future flood losses in major coastal cities. Nature Climate Change, 3, 802–806. doi:10.1038/ nclimate1979

Heatubun, C. D., Zona, S., & Baker, W. J. (2014). Three new genera of arecoid palm (Arecaceae) 59(1), 61–68. Kew Bulletin, Hughes, M., Barber, S., Heatubun, C. D., & Gagul, J. Bertault, J., & Sist, P. (2015). An experimental comparison of different harvesting intensities with Begonia yapenensis (sect. Symbegonia, Begoniaceae), a new species from Papua, Indonesia European Journal of Taxonomy, 119, 1–6.

Kuswandi, R., & Murdjoko, A. (2015). Population Structures of Four Tree Species in Logged-Over Tropical Forest in South Papua, Indonesia : An Integral Projection Model Approach. *Indonesian Journal of Forestry Research*, 2(2), 93–101.

Kuswandi, R., Sadono, R., Supriyatno, N., & Marsono, D. (2015). Keanekaragaman Struktur Tegakan Hutan Alam Bekas Tebangan. Jurnal Manusia dan Lingkungan, 22(2), 151–159

Kessler, M., Salazar, L., Homeier, J., & Kluge, J. (2014). Species richness-productivity relationships of tropical terrestrial ferns at regional and local A transcontinental comparison of scales. Journal of Ecology, 102(6), 1623–1633.

Laurans, M., Hérault, B., Vieilledent, G.,and Vincent, G., (2014). Vertical Stratification Reduces Competition for Light in Dense Tropical Forests. Forest Ecology and Management, 329:79-88.

Ma, L., Lian, J., Lin, G., Cao, H., Huang, Z., & Guan, D. (2016). Forest Dynamics and Its Driving Forces of Sub-Tropical Forest in South China. *Scientific reports*, 6, 1–10.

Maturbongs, R. A., Dransfield, J., & Mogea, J. P. (2015). Daemonorops komsaryi (Arecaceae)—a new rattan from the Bird's Head Peninsula, Indonesian New Guinea, 195(4), 297–300.

Mawazin, dan Subiakto, A. (2013). Keanekaragaman dan Komposisi Jenis Permudaan Alam Hutan Rawa Gambut Bekas Tebangan di Riau. Indonesian Forest Rehabilitation Journal, 1(1):59-73.

Mesquita, R. de C. G., Santos, M. P. E. dos, Massoca, C. C. J., Bentos, T. V., & Williamson, G. B. (2015). Amazon Rain Forest Succession: Stochasticity or Land-Use Legacy? BioScience, 65(9), 849–861.

[MoF] Ministry of Forestry. (2003). Ministry of Forestry Decree Number 163/ Kpts-II/2003 for Pengelompokan Jenis Kayu Sebagai Dasar Pengenaan Iuran Kehutanan. Jakarta. Ministry of Forestry.

[MoLEF] Ministry of Life Enviromental and Forestry. (2017). Laporan Monitoring dan Evaluasi Pengelolaan DAS Arui Tahun 2017. Jakarta. Ministry of Life Environmental and Forestry.

Muhdin, E., Suhendang, D., Wahjono, H., Purnomo, Istomo, dan Simangunsong, B.C.H.(2008). Keragaman Struktur Tegakan Hutan Alam Sekunder. J. Man. Hut. Trop., 14(2):81-87.

Murdjoko, A., Marsono, D., Sadono, R. & Hadisusanto, S. (2016). Plant Species Composition and Their Conspecific Association in Natural Tropical Rainforest, South Southern Papua, Indonesia. Biosaintifika: Journal of Biology & Biology Education, 8(1), 33-46

Murdjoko, A., Marsono, D., Sadono, R. & Hadisusanto, S. (2016). Population Dynamics of *Pometia* for The Period of Post-Selective Logging in Tropical Rainforest, Southern Papua, Indonesia. Biosaintifika: Journal of Biology & Biology Education, 8(3), 321-330

Nasir, A., Muhamad, B.S., Bahruni. (2017). Optimization of Land Use Collaborative Management Model Perum Perhutani: Study Case KPH Pekalongan Barat. Jurnal Manajemen Hutan Tropika 23 (1)25-36. https://doi.org/10.7226/jffm.23.1.25

Oksana, Irfan M, Huda MU.2012. P engaruh alih fungsi lahan hutan menjadi perkebunan kelapa Sawit terhadap sifat kimia tanah. *Jurnal Agroteknologi* 3 (1): 2934.

Paroissien J.B. , Darboux .FE., Couturier A., Devillers B. (2014). A method for modeling the effects of climate and land use changes erosion and sustainability of soil in a mediterranean watershed languedoc, france. *Journal of Environmental Management*. www.elsevier.com/locate/jenvma.

Ran, J., Budic, Z.N. (2016). Integrating spatial planning and flood risk management: A new conceptual framework for the spatially integrated policy infrastructure. Computers, Environment, and Urban Systems Journal. Science Direct www.elsevier.com/locate/ceus

Sandor, M. E., & Chazdon, R. L. (2014). Remnant Trees Affect Species Composition But Not Structure Of Tropical Second-Growth Forest. *Plos One*, 9(1), e83284.

Spellerberg, I.F., dan Fedor, P.J., (2003). Attribute to Claude Shannon (1916–2001) And A Plea For More Rigorous Use Of Species Richness, Species Diversity and The 'Shannon–Wiener'Index, Global Ecology, and Biogeography, 12(3):177-179

Suprayogi,S., Purnama, L.S., Darmanto,D.(2013). Hydrology dan Management Watershed. Pengelolaan Daerah Aliran Sungai. Yogyakarta. Gajah Mada University Press.

Tokede, M.J., Mambai, B., Pangkali, L., Mardiyadi, Z. (2013). Natural Standing Stock And Trade Analysis Of Merbau In Papua. Seminar nasional Sistem Pengelolaan Hutan Lestari 2-3 Desember 2013. Dinas Kehutanan Propinsi Papua Barat.

Vannier O, Anguetin S, Braud 1.2016. Investigating the role of geology in the hidrological response of Mediterranean cathment prone to flash floods: regional modeling study and proses understanding. *Journal of Hydrology*. 541 (2016) 158-172 www.elsevier. Com / locate / jhydro

Whitfeld, T.J., Lasky, J.R., Damas, K., Sosanika, G., Molem, K., and Montgomery, R.A. (2014).

Species Richness, Forest Structure, and Functional Diversity during Succession in the New Guinea Lowlands. Biotropica, 46(5):538-548.
Yan, B., Fang, N.F., Zhang, PC., Shi, Z,H. (2013). Impacts of land use change on watershed streamflow and sediment yield: An assessment using hydrologic modelling and partial least squares regression. Journal of Hydrology. homepage www.elsevier.com/locate/jhydro