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Tree Association with *Pometia* and its Structure in Logging Concession of South Papua Forest

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Abstract

Part of forests in Papua is still as logging concession. Pometia spp. are target species, but there is still a lack of information regarding the ecological condition of those species. Thus, the objectives of this research were to describe what tree species (small and large individuals) associated with Pometia, how logging and soil properties influence the association and to analyze the structure of Pometia in term of diameter distribution. Canonical correspondence analysis (CCA) was applied to describe the association and its relationship with environmental factors (soil and litterfall). The results showed that association of small and large individuals of trees with both Pometia showed a different pattern in which the small individuals had a positive association and had certain tree species as a community. This association resulted from logging activity leading to the change in ecological conditions. Conversely, the association between large tree species with Pometia acuminata Radlk. and Pometia pinnata J. R. Forst. & G.Forst. showed negative pattern and tree species correlated with both Pometia were different. C content of litterfall had a positive correlation with large Pometia acuminata and its community from environmental factors. Furthermore, the small individuals of Pometia were dynamic as a response to logging in which a number of the small individuals of Pometia tended to increase after logging.

Keywords: tropical rainforest, logged forest, canonical correspondence analysis, tree species

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Introduction

Forest of south Papua is characterized as lowland area and some parts of them are still intended as logging concession (Murdjoko 2013; Kuswandi 2014; Kuswandi & Murdjoko 2015). During logging activities, ecological conditions change in term of understory species composition, tree structures, soil conditions, and microclimatic circumstances (Arbainsyah et al. 2014). In this area, tree regeneration is natural since there is no plantation program in this logged forest because the plantation is only done in ex-skid trail and ex-log yard. Therefore, understory species especially seedlings resulted from natural processes as seedling establishment(Murdjoko 2013).

Trees as target species are selectively logged in this concession area and the rest are left as remaining trees (Sandor & Chazdon 2014; Osazuwa-Peters et al. 2015). One of the target species is from genus *Pometia.* Two species that have been taxonomically identified are *Pometia acuminata* Radlk. and *Pometia pinnata* J.R.Forst. & G.Forst. (Kuswandi *et al*. 2015; Murdjoko *et al*. 2016). Both species are less studied concerning population and distribution. Hence, we singled out both species as the focus of this study. Furthermore, the population dynamics of *Pometia* in forests is generally as an impact of abiotic and biotic factors where the logging leads to alteration of conditions. Thus, the pattern of understory establishment would possibly differ from condition in the primary forest where the condition remains stable (Win *et al*. 2012). Besides that, edaphic factors like soil properties are responsible for providing place for growing. Parent materials have contributed to soil characteristic during the forming of soil through decay process since long time ago. Decomposition of organic matter also takes place in the soil. Furthermore, nutrients and water are stored in soil (Khairil *et al*. 2014; Chiti *et al*. 2015) Those processes can be facilitated when climatic factors supported by creating suitable circumstances. Climatic factors in the tropical rainforest can be described as microclimate and macro climate. The microclimate is mainly as a result of the condition of tropical rainforest such as moisture understory (Cicuzza *et al*. 2013; Sawada *et al*. 2015).

Biotic factors can also influence dynamics of the stand where flora and fauna have functioned as either facilitation or competition (Velho *et al*. 2012). In the tropical rainforest, many trees grow in the same area resulting in competition to get a place. Hence, density and basal area of trees can affect

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growth and even mortality of trees. The presence of other trees can also be seen as a factor that affects trees (Ruslandi et al. 2012). Even though fauna also plays important role in trees, the contribution of fauna will not be taken into account during this study.

As described above, the presence of other trees in selectively logged over forest play a crucial role in the dynamic of *Pometia* trees. Hence, this study described trees that had an association with *Pometia* in unlogged and logged forest. Besides that, the structure of *Pometia* based on its density between unlogged and logged forest was compared. In this study, primary forest is seen as the approach of trees before logging in which tree descriptions in both conditions were analyzed whether the tree description based on the density was similar or not. Moreover, hypothetically, after several years logged over forest condition in term of stem density, species composition, and abiotic conditions will be close to primary forest (Ding et al. 2012; Rutten et al. 2015).

To analyze that condition, canonical correspondence analysis (CCA) will be applied to figure out tree communities in both conditions. The CCA is useful to take into account tree species, plot distribution and environmental factors as integrated calculation (Ter Braak 1986; Ter Braak 1987). Over the time, alteration of tropical rainforest can take place resulting from natural and anthropogenic causes (Huth et al. 2004). In this study, the focus of alteration is as a result of selective logging as the anthropogenic cause which can change the condition of tropical rainforest. The biotic and abiotic situation of this forest before selective logging will differ from the condition after selective logging. In brief, *Pometia* trees in both situations will be certainly affected.

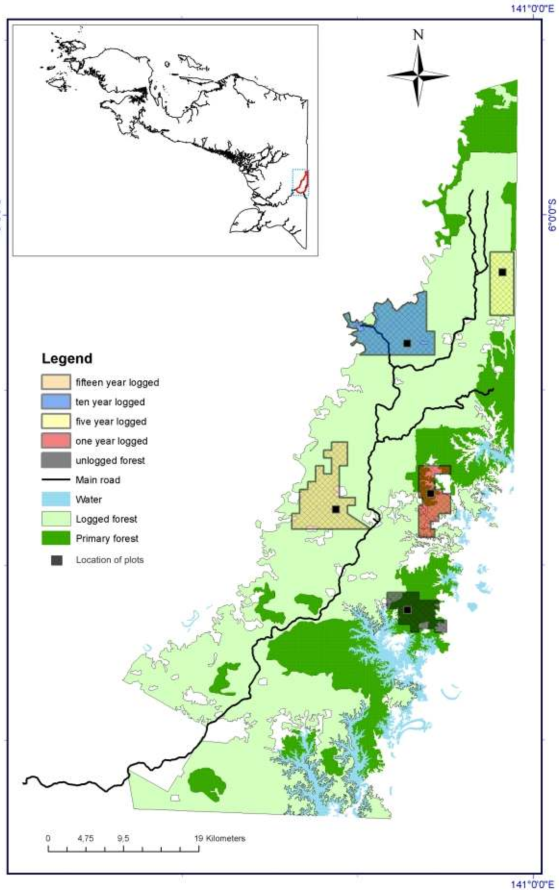

Figure 1 Location of research in South Papua.

For that reason, to what extent the *Pometia* trees influenced by selective logging is, therefore, interesting to be investigated. The objectives of this research were: to describe what tree species (small and large individuals) associated with *Pometia*, how logging and soil properties influence the association, and to analyze the structure of *Pometia* trees in the stands in term of its diameter distribution.

Methods

Study area This research took place in south Papua where the area is lowland forest with an elevation of below 200 m asl on average. The geographical position is between E140º21`–140º59` and S05º50`–06º42` (Figure 1). This area has an annual rainfall ranging from about 3000–4000 mm and daily moisture was on the average between 75% and 85% (Petocz 1989). Families of *Dipterocarpaceae*, *Lauraceae* and *Myrtaceae* dominate this area . This study area is a logging concession of PT Tunas Timber Lestari where the forest is isolated by Muyu and Uwim Merah River in the west and Fly River in the east, while in the northern part is mountainous area and in the southern part is an ex-timber concession. Data were collected in the unlogged forest as primary forest and logged forest consisting of one-year, five-year, ten-year, and fifteen-year logged forest.

Data collection and sampling Tree species in this forest were collected that were divided into four phases as seedlings, saplings, poles, and trees. Seedlings are typified to have a height less than 1.5 m. Saplings were characterized with a height greater than 1.5 m and diameter of less than 10 cm. Poles were characterized to have a diameter between 10 and 20 cm. Trees were typified to have a diameter greater than 20 cm (Forestry Department 1989). Seedlings and saplings were then grouped as small individuals while poles and trees were classified as large individuals. Plots were placed systematically using nested sampling where seedling was 2 m × 2 m, sampling was 5 m × 5 m, the pole was 10 m × 10 m and tree was 20 m × 20 m. In the primary forest, 46 plots were placed while in logged forest 120 plots were established. Data in each plot consisted of *species of individuals* - each was identified according to scientific name; *Number of individuals*-Number of individuals in each species per plot were documented; *Diameter*-Diameter at breast height (DBH) or 20 cm above the buttress was measured for trees or individuals > 5 cm in diameter. *Edaphic factors*-Soil property was soil organic matter (SOM) while litterfall was also collected in a plot with 1 m × 1 m in size for each plot to analyze C content and dried weight. Analysis of soil and litterfall to obtain the estimates of C content and dried weight was done in Laboratorium Balai Pengkajian Teknologi Pertanian Yogyakarta.

Data analysis To analyze tree association with *Pometia*, canonical correspondence analysis (CCA) was applied as multivariate analysis (MVA) to see the distribution of tree species corresponding to locations of both logged forest and

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primary forest. In this analysis, the variable of importance value index of tree species is the value of species as a row (m) while the column is as plot (n). Then, those were expressed as matrix m × n. Environmental factors used in this analysis were abiotic factors namely organic matter, litterfall and time after logging. The environmental factor is defined as matrix m × q. The computation was performed using R statistical program version 3.3.1. with VEGAN package (R Development Core Team 2005; Oksanen *et al.* 2013). After getting CCA graph, tree species positively associated with either *P. acuminata* or *P. pinnata* were obtained from Euclidean distance between tree species in the same quadrant and either *P. acuminata* or *P. pinnata.* The Euclidean distance between them was calculated as average and confidence interval of 95% was applied to decide the positive association.

The structure of *Pometia* was analyzed by means of plotting density against the class diameter of DBH where the density was the number of individuals of *Pometia* species per hectare (trees ha^{-1}). The relationship can be described mathematically as where $y = f(DBH)$ where y is a number of individuals of *Pometia* per hectare (tree ha^{-1}), DBH is diameter at breast height (m) and f is a function of the relationship. The function was determined using either linear or nonlinear equations. Furthermore, bias (E) and the adjusted coefficient of determination (R^2_{adj}) were used to be criteria to choose the best equation.

Results and Discussion

Association between *pometia* and tree species in unlogged and logged forest The tree species in both unlogged and logged forests showed a pattern of species association. This research grouped tree species association as seedlings and saplings as small individuals while poles and trees as large individuals. In this research, 176 tree species were recorded in both unlogged and logged forest. Then, 159 tree species were categorized as small individuals and 127 tree species were classified as large individuals (Appendix 1). The species of *Pometia* were *P. acuminata* and *P. pinnata*. By means of CCA, tree species and edaphic factors were plotted in Figure 2. At that time, the associations were based on the distance between other individuals of other species and both *Pometia acuminata* and *Pometia pinnata*.

In small individuals (Figure 2 A), a total of 24.5% was explained as the variance of both axes in which the first axis (CCA1) was 13.4% and a second axis (CCA2) was 11.1%. The tree species were distributed in four directions of the quadrant. The both small individuals of *Pometia* species were on the lower left quadrant. The tree species that had a positive association with *P. acuminata* (the blue boxes with dashed line) were 29 tree species and the tree species that had a positive association with *P. pinnata* (the blue boxes with solid line) were 7 species (Table1). The Euclidean distances of those species were below 2.18 with *P. pinnata*.

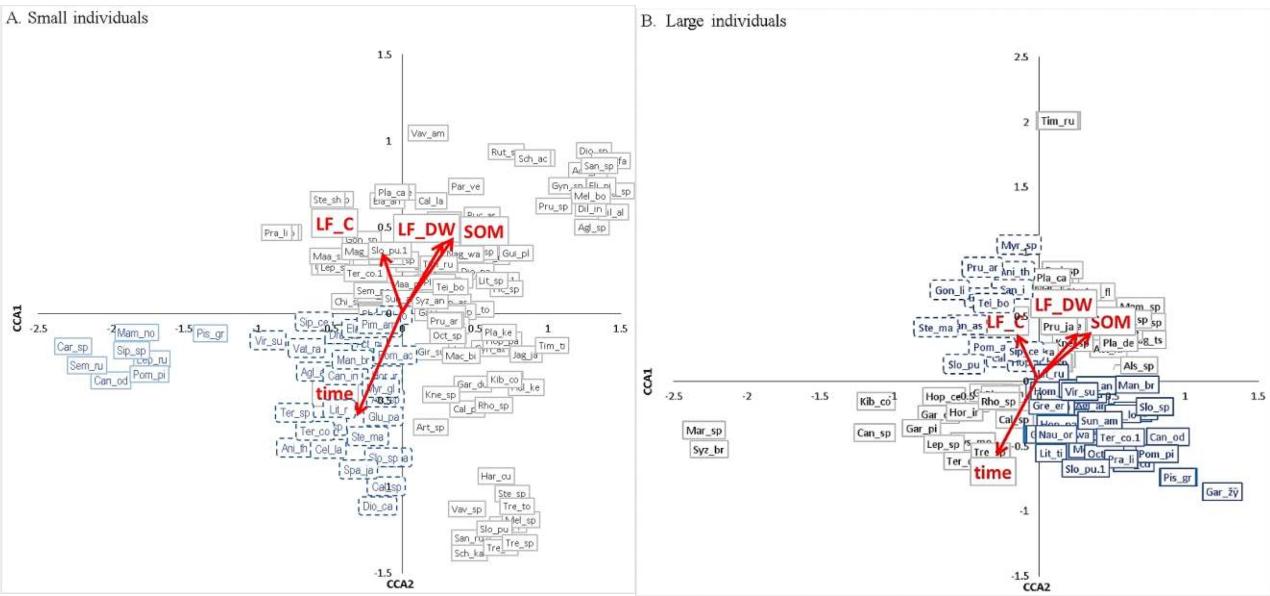

Figure 2 Distribution of tree species in unlogged and logged forest using Canonical correspondence analysis (CCA) where small individuals are shown in Graph A and large individuals are shown in Graph B. SOM symbolizes soil organic matter (%), LF_C is C content in litter fall (%), LF_DW denotes dried weight (g) and time is period of logged forest. The red arrows show direction of relationship pattern. The abbreviated name inside boxes are tree species name. The blue boxes with dashed line are tree species associated with *Pometia acuminata* Radlk., while the blue boxes with solid line are tree species associated with *Pometia pinnata* J. R. Forst. & G. Forst. The black boxes with solid line are tree species not associated with both *Pometia acuminata* Radlk. and *Pometia pinnata* J. R. Forst. & G. Forst. The complete names of tree species are presented in Appendix 1

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The large individuals of tree species positively associated with *P. acuminata* and *P. pinnata* (Figure 2. B.) were distributed in opposite directions, which were on upper left quadrant and lower right quadrant, respectively. The both axes of CCA explained 34.8 % of the variation in which the first axis showed 17.6% variation and second axis showed 17.2% variation. The tree species close to *P. acuminata* (the blue boxes with dashed line) were 13 species (Table 2). Those tree species had Euclidean distance under 0.99 with *P. acuminata* . Moreover, 47 tree species (the black boxes with solid line) had a positive association with *P. pinnata* (Table 2). The Euclidean distances of those species were less than 1.33 compared with *P. pinnata* .

Perturbation of edaphic condition after logging Soil and litterfall conditions after logging tended to have opposite directions with a period of logged forest (Figure 2A and Figure 2B.). SOM which symbolizes soil organic matter (%) and LF_DW which denotes dried weight (g) went to upper right quadrant while time that is a period of logged forest move to lower left quadrant. On the other hand, LF_C which is C content in litter fall (%) went to upper left quadrant. The longer period of logged forest led to the gradual decrease of SOM and dried weight of litterfall. In contrast, the C content of litterfall tended to increase steadily in that period.

Structure of *Pometia* in unlogged and logged forest The individuals of *Pometia* in the unlogged forest were distributed from small class diameter to large class diameter (green bar). In logged forest, some individuals were absent in certain class diameter. In general, the number of individuals of *Pometia* in unlogged forest differed from in logged forest. In one year logged the forest, the number of individuals of *Pometia* declined especially the small individuals. Afterward, the number of small individuals in 5 and 10 years logged forest rose about fourfold compared to the unlogged forest. Then, in 15 years logged the forest, the number of individuals with a diameter below 10 cm were absent while the number of individuals with a diameter between 10 cm and 20 cm appeared by about 60 ind ha^{-1} and 20 ind ha^{-1}, respectively.

From Table 3, only equations of 1 year logged forest was not significant ($P > 0.05$), but the other four equations were significant ($P < 0.05$) for power equations. Therefore, the equations were used to obtain patterns of the structure of *Pometia*. The lowest coefficient of determination (R^2) was in the unlogged forest where the equation explained about 70% variation distribution of individuals over diameter class (Figure 4). The 3 significant equations explained the variation of individual distribution against diameter class at least about 90 %.

Table 1 Small individuals of tree species had a positive association with both *Pometia acuminata* Radlk. and *Pometia pinnata* J. R. Forst. & G. Forst. in which there were 29 tree species associated with *P.acuminata* and 7 tree species with *P. pinnata.*

Name of tree species that had a positive association with	
Pometia acuminata Radlk.	*Pometia pinnata* J.R.Forst. & G.Forst.
Actinodaphne nitida Teschner	*Cananga odorata* (Lam.) Hook.f. & Thomson
Aglaia argentea Blume	*Carrierea* sp.
Alstonia scholaris (L.) R. Br.	*Lepisanthes rubiginosa* (Roxb.) Leenh.
Alstonia spectabilis R.Br.	*Mammea novoguineensis* (Kan. & Hat.) Kosterm.
Anisoptera thurifera subsp. polyandra (Blume) P. S. Ashton	*Pisonia grandis* R. Br.
Archidendron parviflorum Pulle	*Semecarpus rufovelutinus* Ridl.
Calophyllum sp.	*Siphonodon* sp.
Canarium hirsutum Willd.	
Canarium indicum L.	
Celtis latifolia (Blume) Planch.	
Diospyros calycantha O. Schwarz	
Dracontomelon dao (Blanco) Merr. & Rolfe	
Elaeocarpus culminicola Warb.	
Gluta papuana Ding Hou	
Horsfieldia irya (Gaertn.) Warb.	
Lithocarpus rufovillosus (Markgr.) Rehder	
Maniltoa browneoides Harms	
Myristica globosa Warb.	
Palaquium lobbianum Burck	
Pimelodendron amboinicum Hassk.	
Planchonella sp.	
Siphonodon celastrineus Griff.	
Sloanea sp.	
Spathiostemon javensis Blume	
Sterculia macrophylla Vent.	
Terminalia complanata K.Schum.	
Terminalia sp.	
Vatica rassak Blume	
Virola surinamensis (Rol. ex Rottb.) Warb.	

Table 2 Large individuals of tree species were positively associated with both *Pometia acuminata* Radlk. and *Pometia pinnata* J. R. Forst. & G. Forst. where 13 tree species were associated with *P. acuminata* and 47 tree species with *P. pinnata.*

Name of tree species that had a positive association with	
Pometia acuminata Radlk.	*Pometia pinnata* J. R.Forst. & G.Forst.
Anisoptera thurifera subsp. *polyandra* (Blume) P.S.Ashton	*Adenanthera novo-guineensis* Baker f.
Canarium asperum Benth.	*Aglaia argentea* Blume
Canarium hirsutum Willd.	*Alphitonia incana* (Roxb.) Teijsm. & Binn. ex Kurz
Canarium indicum L.	*Calophyllum* laticostatum P. F. Stevens
Elaeocarpus angustifolius Blume	*Calophyllum peekelii* Lauterb.
Gonocaryum litorale (Blume) Sleumer	*Campnosperma brevipetiolatum* Volkens
Hopea iriana Slooten	*Cananga odorata* (Lam.) Hook. f. & Thomson
Myristica sp.	*Chisocheton ceramicus* Miq.
Prunus arborea (Blume) Kalkman,	*Chisocheton* sp.
Siphonodon celastrineus Griff.	*Cleistanthus oblongifolius* (Roxb.) Müll.Arg.
Sloanea pulchra (Schltr.) A.C.Sm.	*Dracontomelon dao* (Blanco) Merr. & Rolfe
Sterculia macrophylla Vent.	*Dysoxylum* sp.
Teijsmanniodendron bogoriense Koord.	*Elaeocarpus arnhemicus* F. Muell.
	Endiandra rubescens (Blume) Miq.
	Fagraea racemosa Jack
	Ficus drupacea Thunb.
	Ficus sp.
	Flacourtia inermis Roxb.
	Flindersia pimenteliana F.Muell.
	Garcinia × mangostana L.
	Garcinia latissima Miq.
	Gironniera subaequalis Planch.
	Glochidion sp.
	Gnetum gnemon L.
	Grewia eriocarpa Juss.
	Guioa pleuropteris (Blume) Radlk.
	Harpullia cupanioides Roxb.
	Homalium foetidum Benth
	Hopea papuana Diels
	Lithocarpus rufovillosus (Markgr.) Rehder
	Litsea timoriana Span.
	Maniltoa browneoides Harms
	Melicope elleryana (F. Muell.) T.G. Hartley
	Myristica globosa Warb.
	Nageia wallichiana (C.Presl) Kuntze
	Nauclea orientalis (L.) L.
	Octomeles sumatrana Miq.
	Palaquium lobbianum Burck
	Pisonia grandis R. Br.
	Prainea limpato (Miq.) Beumee ex K.Heyne
	Rhodamnia cinerea Jack
	Sloanea pullei O. C. Schmidt ex A.C.Sm.
	Sloanea sp.
	Sundacarpus amarus (Blume) C. N . Page
	Syzygium anomalum Lauterb.
	Terminalia copelandi Elmer
	Virola surinamensis (Rol. ex Rottb.) Warb.

In general, the structure of *Pometia* followed reverse J-shaped distribution from small individuals with a diameter below 5 cm (unlogged forest, five years logged forest and ten years logged forest) and a diameter between 10 cm up to 20 cm. The highest number of small individuals of *Pometia* was in ten years after logging, then followed by the number of individuals of *Pometia* in five years logged forest and unlogged forest. Afterward, the number of individuals of *Pometia* was seemingly similar for all forest types starting from class diameter 20−24 cm to 45−49 cm, only in fifteen years after logging that the individuals were present in class diameter up to 55−59 cm.

Environmental alteration, tree communities and *pometia* structure during post-selective logging The pattern of association was different between small and large individuals. The small individuals of *P. acuminata* and *P. pinnata* tended to be close each other along with other tree species, which have positive association (Figure 2 A). In contrast, large individuals of *Pometia* itself were not distributed in the same quadrant (Figure 2 B). It suggests that those large individuals of both *P. acuminata* and *P. pinnata* showed negative association. In this forest, the both *P. acuminata* and *P. pinnata* were not close together to grow (Murdjoko *et al*. 2016) as they had negatively conspecific association. Therefore, the tree species associated with both *Pometia* were different. In the tropical rainforest, individuals of same species showed nonspecific associations whether positive or negative (Nichols *et al*. 1999; Bagchi *et al*. 2010; Howe 2014; Sawada *et al*. 2015). The *Pometia* had a negative association between small and large individuals in this forest (Murdjoko *et al*. 2016). In logged forest, there is no plantation and enrichment program. Thus, regeneration of the logged forest is natural processes (Murdjoko 2013; Kuswandi & Murdjoko 2015). Furthermore, seeds produced by mature trees were spread out to a particular area. That process was the beginning of association development in this forest. Therefore, seedling establishment after germination grew in the different tree composition. Some seedlings survived and then benefit from certain ecological circumstances, resulting in the positive association. In contrast, some seedlings were suppressed to the environment, leading to the negative association (Zambrano *et al*. 2014). Thus, small individuals of both *Pometia* showed a positive association, suggesting that both seedlings were

Table 3 The power equations of distribution of *Pometia* individuals in unlogged forest (UF), 1 year logged forest (1_year logged), 5 year logged forest (5_year logged), 10 year logged forest (10_year logged), and 15 year logged forest (15_logged). R^2 is coefficient of determination, F is F value of regression anova and P is probability of error. Asterisk (*) denotes significance of equations while *ns* is not significant based on power equation.

Forest types	Equation	R^2	F	P
UF	$y = 18.088x^{-1.441}$	0.690	19.29	0.04^{*}
1_year logged	$y = 5.2881x^{-0.746}$	0.326	1.47	0.29^{ns}
5_year logged	$y = 72.358x^{-2.123}$	0.949	61.77	0.01^{*}
10_year logged	$y = 95.999x^{-2.073}$	0.896	42.61	0.01^{*}
15_year logged	$y = 50.271x^{-1.978}$	0.921	21.79	0.01^{*}

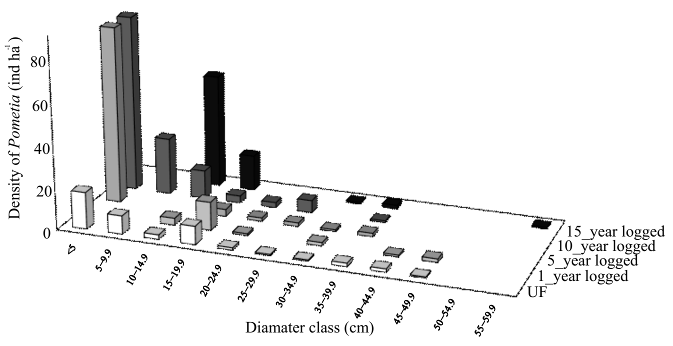

Figure 3 Structure of *Pometia* based on diameter class (cm) in unlogged forest (UF), one year logged forest (1_year logged), five year logged forest (5_year logged), ten year logged forest (10_year logged) and fifteen year logged forest (15_logged). UF (□), 1_year logged (■), 5_year logged (■), 10_year logged (■), 15_year logged (■).

able to share area to grow. On the other hand, the other tree species located in upper right quadrant were a negative association with both *Pometia* as they have opposite direction (Figure 2 A). The positive association of seedlings was presumably established dynamically in which after logging seedling composition changed as environmental factors altered such as light availability and nutrients in the soil (Corrià-Ainslie et al. 2015; Toriyama et al. 2015; Shen et al. 2016). That can be seen in the structure of *Pometia* altered as respond to the circumstance change. Thus, the number of small individuals of *Pometia* increased in five and ten years after logging (Figure 3). Later on, the small individuals grew in fifteen years after logging. Therefore, the number of small individuals of *Pometia* increased during post-logging.

In large individuals, both *Pometia* has negative association, bringing about certain tree species associated with either *P. acuminata* or *P. pinnata.* The association of large individuals has been established before logging period. This can be said that the association of tree species with large individuals of either *P. acuminata* or *P. pinnata* was original association in this tropical forest. The tree species on the upper right and lower left quadrant (Figure 2 B) were not associated with large individuals of either *P. acuminata* or *P. pinnata*. The change of edaphic factors as a result of logging did not affect the association since the soil organic matter and amount of litterfall have upper right quadrant as direction (Figure 2 B). It is a presumption that the edaphic change in this logged forest probably affected the growth of both *Pometia* and other tree species that had a positive association with one of them. Therefore, research on dynamics of individuals after logging would be necessary to find out the effect of logging on remnant trees, especially *Pometia*.

In general, distribution of both *Pometia* had a similar pattern of distribution of individuals in tropical rain forest in which a number of small individuals were more abundant than a number of large individuals (Murdjoko 2013; Kuswandi & Murdjoko 2015). As a result, the natural

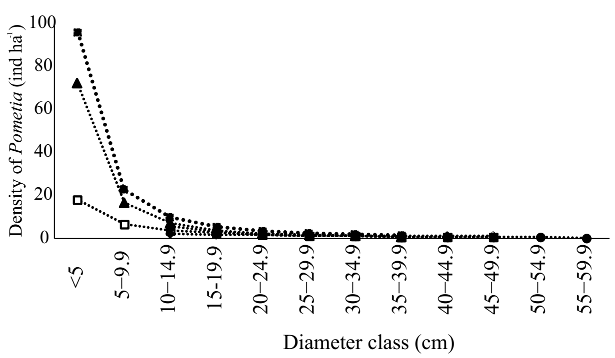

Figure 4 Plotting of *Pometia* individuals based on equations (Table 3) in unlogged forest (UF), one year logged forest (1_year logged), 5 year logged forest (5_year logged), ten year logged forest (10_year logged) and fifteen year logged forest (15_logged). UF (••••□•••), 1_year logged (••••◆•••), 5_year logged (••••▲•••), 10_year logged (● ● ●■● ●), 15_year logged (••••●•••).

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regeneration in this forest occurred continuously. However, there is no positive conspecific association between small and large individuals of *Pometia* (Murdjoko *et al*. 2016). As a consequence, this can be a consideration in term of enrichment planting program that artificial plantation of *Pometia* should be close the tree species that have a positive association with *Pometia*.

The structure of *Pometia* individuals showed a different number between a condition in unlogged and logged forest (Figure 3). The number of small individuals (diameter less than 20 cm) were higher after logging especially in five and ten years after logging. At that time, seedling establishment of *Pometia* benefited from the opening of canopy gap resulting from logging activities where irradiance could reach understory. Most of the early seedling establishment in tropical rainforests require the irradiance to grow (Duah-Gyamfi et al. 2014; Goodale et al. 2014; Whitfeld et al. 2014). On the other hand, the absence of larger individuals of *Pometia* in logged forest indicated that the logged forests are still recovering from logging impact. Some studies in tropical rainforest addressed that to recover from logging affect; it would take more than 40 years (Gourlet-Fleury *et al*. 2013; Osazuwa-Peters *et al*. 2015). Hence, based on the structure of *Pometia,* fifteen years after logging the condition of logged forests have not recuperated.

Conclusion

Association of small and large individuals of trees with both *P. acuminata* and *P. pinnata* showed a different pattern in which the small individuals had a positive association. The small individuals of *P. acuminata* and *P. pinnata* tended to grow closely. Hence, small tree species positively associated with both *Pometia* were similar. In contrast, the association between large tree species with *P. acuminata* and *P. pinnata* was different where the association showed a negative pattern. Thus, tree species correlated with both *Pometia* were different. The different pattern of small individuals was a result of logging impact in which ecological circumstance changed resulting in alteration of microclimate. Of environmental factors, only C content of litterfall had a positive correlation with large *P. acuminata* and its community. Based on the distribution of individuals of *Pometia*, the small individuals of *Pometia* were dynamic as a response to logging in which a number of the small individuals of *Pometia* tended to increase after logging.

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Appendix 1 Species Name

Scientific name	Code	Individual size	
		small	large
Actinodaphne nitida Teschner	Act_ni	√	√
Adenanthera novo-guineensis Baker f.	Ade_no	√	√
Adenanthera pavonina L.	Ade_pa	√	√
Aglaia argentea Blume	Agl_ar	√	√
Aglaia spectabilis (Miq.) S.S.Jain & S.Bennet	Agl_sp	√	√
Alphitonia incana (Roxb.) Teijsm. & Binn. ex Kurz	Alp_in		√
Alstonia scho laris (L.) R.Br.	Als_sc	√	√
Alstonia spectabilis R.Br.	Als_sp	√	√
Anisoptera thurifera subsp. polyandra (Blume) P.S.Ashton	Ani_th	√	√
Antiaris toxicaria Lesch.	Ant_to	√	
Archidendron parviflorum Pulle	Arc_pa	√	
Artabotrys sp.	Art_sp	√	
Barringtonia sp.	Bar_sp		√
Blumeodendron tokbrai (Blume) Kurz	Blu_to	√	√
Brachychiton sp.	Bra_sp	√	
Brackenridgea sp.	Bra_sp	√	√
Breonia chinensis (Lam.) Capuron	Bre_ch		√
Buchanania arborescens (Blume) Blume	Buc_ar	√	√
Calophyllum caudatum Kaneh. & Hatus.	Cal_ca	√	√
Calophyllum laticostatum P.F.Stevens	Cal_la	√	√
Calophyllum peekelii Lauterb.	Cal_pe	√	√
Calophyllum sp.	Cal_sp	√	√
Campnosperma brevipetiolatum Volkens	Cam_br	√	√
Cananga odorata (Lam.) Hook.f. & Thomson	Can_od	√	√
Canarium asperum Benth.	Can_as	√	√

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Scientific name	Code	Individual size	
		small	large
Canarium hirsutum Willd.	Can_hi	√	√
Canarium indicum L.	Can_in	√	√
Canarium sp.	Can_sp	√	√
Carallia brachiata (Lour.) Merr.	Car_br	√	
Carrierea sp.	Car_sp	√	
Celtis latifolia (Blume) Planch.	Cel_la	√	
Cerbera floribunda K.Schum.	Cer_fl	√	
Chisocheton ceramicus Miq.	Chi_ce	√	√
Chisocheton sp.	Chi_sp	√	√
Cinnamomum sp.	Cin_sp		√
Cleistanthus oblongifolius (Roxb.) Müll.Arg.	Cle_ob	√	√
Cochlospermum gillivraei Benth.	Coc_gi		√
Corynocarpus laevigatus J.R.Forst. & G.Forst.	Cor_la	√	√
Cynometra ramiflora L.	Cyn_ra	√	√
Dillenia alata (R.Br. ex DC.) Banks ex Martelli	Dil_al	√	
Dillenia indica L.	Dil_in	√	√
Diospyros calycantha O.Schwarz	Dio_ca	√	
Diospyros papuana Valeton ex Bakh.	Dio_pa	√	
Diospyros pilosanthera Blanco	Dio_pi	√	√
Diospyros sp.	Dio_sp	√	
Dracontomelon dao (Blanco) Merr. & Rolfe	Dra_da	√	√
Dysoxylum mollissimum Blume	Dys_mo	√	√
Dysoxylum sp.	Dys_sp	√	√
Elaeocarpus angustifolius Blume	Ela_an	√	√
Elaeocarpus arnhemicus F.Muell.	Ela_ar	√	√
Elaeocarpus culminicola Warb.	Ela_cu	√	√
Elaeocarpus sp.	Ela_sp	√	√
Endiandra sp.	End_sp	√	√
Endiandra rubescens (Blume) Miq.	End_ru	√	√
Endospermum medullosum L.S.Sm.	End_me	√	
Fagraea racemosa Jack	Fag_ra	√	√
Fagraea sp.	Fag_sp	√	√
Ficus drupacea Thunb.	Fic_dr		√
Ficus sp.	Fic_sp	√	√
Ficus variegata Blume	Fic_va	√	
Flacourtia inermis Roxb.	Fla_in		√
Flindersia amboinensis Poir.	Fli_am		√
Flindersia pimenteliana F.Muell.	Fli_pi	√	√
Garcinia × mangostana L.	Gar_×		√
Garcinia dulcis (Roxb.) Kurz	Gar_du	√	√
Garcinia latissima Miq.	Gar_la	√	√
Garcinia picrorhiza Miq.	Gar_pi	√	√

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Appendix 1 Species name

Scientific name	Code	Individual size	
		small	large
Garcinia sp.	Gar_sp	√	√
Geniostoma sp.	Gen_sp	√	√
Gironniera subaequalis Planch.	Gir_su	√	√
Glochiadion sp.	Glo_sp	√	√
Gluta papuana Ding Hou	Glu_pa	√	√
Gnetum gnemon L.	Gne_gn	√	√
Goniothalamus sp.	Gon_sp	√	
Gonocaryum litorale (Blume) Sleumer	Gon_li	√	√
Grewia eriocarpa Juss.	Gre_er	√	√
Grewia sp.	Gre_sp	√	
Guioa pleuropteris (Blume) Radlk.	Gui_pl	√	√
Gymnacranthera farquhariana (Hook.f. & Thomson) Warb.	Gym_fa	√	√
Gynotroches axillaris Blume	Gyn_ax	√	
Gynotroches sp.	Gyn_sp	√	
Gyrinops versteegii (Gilg) Domke	Gyr_ve	√	
Halfordia kendack Guillaumin	Hal_ke	√	√
Haplolobus floribundus (K.Schum.) H.J.Lam	Hap_fl	√	√
Harpullia cupanioides Roxb.	Har_cu	√	√
Homalium foetidum Benth	Hom_fo	√	√
Hopea celtidifolia Kosterm.	Hop_ce	√	√
Hopea iriana Slooten	Hop_ir	√	√
Hopea papuana Diels	Hop_pa	√	√
Horsfieldia irya (Gaertn.) Warb.	Hor_ir	√	√
Horsfieldia sp.	Hor_sp	√	
Jagera javanica (Blume) Kalkman	Jag_ja	√	
Kibara coriacea (Blume) Hook. f. & A. Thomps.	Kib_co	√	√
Knema sp.	Kne_sp	√	√
Lasianthus sp.	Las_sp	√	
Lepisanthes rubiginosa (Roxb.) Leenh.	Lep_ru	√	
Lepisanthes sp.	Lep_sp	√	√
Lithocarpus rufovillosus (Markgr.) Rehder	Lit_ru	√	√
Litsea guppyi (F. Muell.) F. Muell. ex Forman	Lit_gu	√	
Litsea sp.	Lit_sp	√	
Litsea timoriana Span.	Lit_ti		√
Maasia glauca (Hassk.) Mols, Kessler & Rogstad	Maa_gl	√	√
Maasia sumatrana (Miq.) Mols, Kessler & Rogstad	Maa_su	√	√
Macaranga bifoveata J.J.Sm.	Mac_bi	√	√
Magnolia tsiampacca (L.) Figlar & Noot.	Mag_ts	√	√
Mammea novoguineensis (Kan. & Hat.) Kosterm.	Mam_no	√	
Mammea sp.	Mam_sp	√	√
Manilkara fasciculata (Warb.) H.J.Lam & Maas Geest.	Man_fa	√	√
Maniltoa browneoides Harms	Man_br	√	√
Maniltoa plurijuga Merr. & L.M.Perry	Man_pl	√	

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Appendix 1 Species name

Scientific name	Code	Individual size	
		small	large
Maranthes corymbosa Blume	Mar_co	√	√
Maranthes sp.	Mar_sp	√	√
Mastixiodendron sp.	Mas_sp	√	
Melicope sp.	Mel_sp	√	
Melicope bonwickii (F.Muell.) T.G.Hartley	Mel_bo	√	
Melicope elleryana (F.Muell.) T.G.Hartley	Mel_el	√	√
Myristica globosa Warb.	Myr_gl	√	√
Myristica sp.	Myr_sp	√	√
Nauclea orientalis (L.) L.	Nau_or		√
Neolitsea sp.	Neo_sp	√	
Ochrosia sp.	Och_sp		√
Octamyrtus sp.	Oct_sp	√	
Octomelessumatrana Miq.	Oct_su		√
Palaquium lobbianum Burck	Pal_lo	√	√
Parastemon versteeghii Merr. & L.M.Perry	Par_ve	√	√
Pimelodendron amboinicum Hassk.	Pim_am	√	√
Pisonia grandis R.Br.	Pis_gr	√	√
Planchonella anteridifera (C.T.White & W.D.Francis ex *Lane*-Poole) H.J.Lam	Pla_an	√	√
Planchonella densinervia (K.Krause) H.J.Lam	Pla_de		√
Planchonella keyensis H.J.Lam	Pla_ke	√	√
Planchonella sp.	Pla_sp	√	√
Planchonia careya (F.Muell.) R.Knuth	Pla_ca	√	√
Polyalthia sp.	Pol_sp	√	√
Pometia acuminata Radlk.	Pom_ac	√	√
Pometia pinnata J.R.Forst. & G.Forst.	Pom_pi	√	√
Popowia sp.	Pop_sp	√	
Prainea limpato (Miq.) Beumee ex K.Heyne	Pra_li	√	√
Prunus arborea (Blume) Kalkman	Pru_ar	√	√
Prunus javanica (Teijsm. & Binn.) Miq.	Pru_ja	√	√
Prunus sp.	Pru_sp	√	
Rhodamnia cinerea Jack	Rho_ci	√	√
Rhodomyrtus sp.	Rho_sp	√	√
Ruta sp.	Rut_sp	√	
Santiria rubiginosa Blume	San_ru	√	
Santiria sp.	San_sp	√	
Schefflera actinophylla	Sch_ac	√	
Schizomeria katastega Mattf.	Sch_ka	√	
Semecarpus papuana Lauterb.	Sem_pa	√	
Semecarpus rufovelutinus Ridl.	Sem_ru	√	
Siphonodon celastrineus Griff.	Sip_ce	√	√
Siphonodon sp.	Sip_sp	√	√
Sloanea pulchra (Schltr.) A.C.Sm.	Slo_pu	√	√
Sloanea pullei O.C.Schmidt ex A.C.Sm.	Slo_pu1	√	√
Sloanea sp.	Slo_sp	√	√
Spathiostemon javensis Blume	Spa_ja	√	

Appendix 1 Species name

Scientific name	Code	Individual size	
		small	large
Sterculia macrophylla Vent.	Ste_ma	√	√
Sterculia shillinglawii F.Muell.	Ste_sh	√	
Sterculia sp.	Ste_sp	√	
Sundacarpus amarus (Blume) C.N.Page	Sun_am	√	√
Syzygium acutangulum Nied.	Syz_ac		√
Syzygium anomalum Lauterb.	Syz_an	√	√
Syzygium branderhorstii Lauterb.	Syz_br		√
Teijsmanniodendron bogoriense Koord.	Tei_bo	√	√
Terminalia complanata K.Schum.	Ter_co	√	√
Terminalia copelandi Elmer	Ter_co1	√	√
Terminalia sp.	Ter_sp	√	√

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