Population Dynamics of Pometia for The Period of Post-Selective Logging in Tropical Rainforest, Southern Papua, Indonesia

by Agustinus Murdjoko

Recuperation of Non-commercial Trees in Logged Forest in Southern Papua, Indonesia

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Abstract

Some parts of forest in southern Papua Indonesia is used as production forest. Therefore, cutting is one of factors which has impact to population of trees. Research was done to see recuperation of non-commercial species (Actinodaphne nitida, Blumeodendron sp.) in logged area. Integral projection models (IPMs) were applied to analyze population dynamics of the 2 species. Mortality, growth, fecundity, autocorrelation of growth were included in IPMs. Data were collected from 3 permanent sample plots (3 ha) between 2005–2009 in PT. Tunas Sawaerma, Assiki, and Boven Digul. Data showed a significance in autocorrelation of growth. In this research, IPMs can be used to describe recuperation of the tree species. Population dynamics occur in which trees have the same survival probability among diameter size, while growth of trees and autocorrelations contribute to the change of population structure of trees. Elastisity test of growth autocorrelation pointed out that A. nitida and Blumeodendron sp remain to grow faster over time and have a larger contribution to population growth than other species. In addition, the more faster-growing individuals will have the more significant contributions for population growth rate of A. nitida and Blumeodendron sp.

Keywords: Integral Projection Models, tropical forest, faster-growing individuals, population growth rate

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Introduction

In Indonesia, trees in production forest are divided as commercial and non commercial species where the commercial species now is the target of log production by cutting them in certain diameter. During 2005–2009, annual allowable cut (AAC) for permit for bussiness of wood forest products utilization-natural forest (IUPHHK-HA) in Papua was about 2 million m^3 (MoF 2010). In concession area, most species are regenerated by producing seeds. The seed in forest will germinate and grow in several phases as seedlings, saplings, poles, and trees. Thus, population of trees will change as a result of logging activity. For example, mortality of trees in logged area increased from 6 to 32% for all diameter classes due to felled trees and logging operation in Sabah, Malaysia (Woods 1989). Besides that, density of trees after logging decreases and diameter distribution can change (Appolinário et al. 2005). As a result, tree population of commercial or non-commercial species may change considerably due to logging activities. The population dynamics of commercial and non-commercial trees is an important field of research.

The research investigated the responses of non-commercial species, Actinodaphne nitida and Blume-odendron sp. left in the same area, especially evaluated the population dynamics of those after logging. However, logging also impacted non-commercial trees due to damage during felling and log removal. This may have led to a change in population dynamics of the non-commercial trees.

The important rates in tree populations are growth, survival and recruitment of new individuals in the population. Diameter growth rates among trees are different, due to a combination of genetic and environmental factors. As a result, some trees can reach high growth rates while other (suppressed) trees grow slowly or even die. In tree populations, the growth of individuals can be auto correlated in time, that is: the growth in 1 year is similar to that in another year. In this way, persistent growth differences can occur between individuals: some individuals grow slowly and keep growing slowly while others grow fast and keep growing fast. Growth differences between individuals can be related to light availability: this may allow individuals to grow faster or slower and do so persistently over time. The growth rate over time can be detected by means of analyzing of growth auto correlation (Pfister & Stevens 2002). In logged forests as well as in unlogged forests, such persistent growth differences can occur. Consequently, even though the individuals are in the same species, they can grow differently and could also have a differential impact for the population.

Integral projection models (IPMs) were constructed for each of the non-commercial species . IPMs are variations of matrix models but provide the same output as matrix model (population growth, sensitivity, elasticity, and age estimates). IPMs need continuous relations of growth, survival, and reproduction to be analyzed with size or age (Easterling et al. 2000; Zuidema et al. 2010). The IPMs has

2 advantages. First, the IPMs were related to vital rates (population growth, sensitivity, elasticity, and age estimates) to tree size. Secondly, variation between individuals is incorporated where in this matrix model might cause large variation (Zuidema *et al*. 2010). Therefore, IPMs are suitable to model for long-life and slow-growing species because the range of size category is made narrow to show the growth of those species. They are also highly suitable to study the effect of growth autocorrelation, as more than one variable that determines the vital rates can be included (Ellner & Rees 2006).

In this study, the research questions were:
1 whether populations of non-commercial treespecies can maintain themselves after selective logging,
2 how populations of non-commercial trees are influenced by harvesting,
3 what the most important processes (growth, survival, reproduction) and categories/stages of trees for population growth of these species are,
4 how the growth autocorrelation in these species is and what is the effect on population growth.

Methods

The research data were collected during 2005–2009 in 3 permanent sample plots (PSPs) of PT Tunas Sawaerma in Assiki, Boven Digoel. The PSPs were located in logged forest. Then, trees were measured in each plot to collect diameter and height data. Each PSP has size 100 × 100 m (1 ha).

Type of forest as study area is low land plain with elevation 0–100 m. The forest has deep soil which is good in drainage but it is occasionally inundated. The alluvial soil is the most typical soil in this forest. Many important timber trees grow naturally. The forest is characterized by multi layers in the canopy forming strata. The low level of the forest consists of a shrub and herb layer associated with seedlings from trees. Other types of plants such as epiphytes, ferny plants, and climbing plants also associate with stands (Petocz 1989). This study analyzed 2 non-commercial species as presented in Table 1.

The data have been annually measured since 2005 in every July. The data consist of species, diameter and the number of trees of each species. The diameter is diameter at breast height (dbh) of each tree. The minimum diameter measured was 10 cm.

Statistical analysis Probabilities of survival of each species per year (P) were calculated using Equation *[1]*:

$$P = \frac{\text{number of individuals survive in time } t+1}{\text{number of individuals survive in time } t} \quad [1]$$

The probabilities of survival for each individual within species are the same. The mean growth function is established by a linear regression between diameter at time (t) and diameter ($t+1$) as shown in Equation *[2]*.

$$y_{(t+1)} = a + bx_{(t)} \quad [2]$$

note: $y_{(t+1)}$ is diameter in $t+1$ (cm), $x_{(t)}$ is diameter in t (cm), a is intercept and b is slope of regression.

To calculate growth autocorrelation, it was needed 4 year growth. Then, growth in time t and growth in time $t+1$ were to acquire residual growth in period 1 while growth in time $t+2$ and time $t+3$ were to obtain residual growth in period 2. Residuals of growth in period 1 were obtained by subtracting dbh of individual in i size (x_i) in time $t+1$ from y_i of linear equation of growth in time t and $t+1$. Similarly, residual of growth in period 2 was obtained by subtracting dbh of individual in i size (x_i) in time $t+3$ from y_i of linear equation of growth in time $t+2$ and $t+3$.

After that, growth autocorrelation was calculated by plotting residual of growth in period 1 and residual of growth in period 2 as shown in Equation *[3]*.

$$A_{(t+1)} = a + br_{(t)} \quad [3]$$

note: A($t+1$) is residual of growth in period 1 (cm), r(t) is residual of growth in period 2 (cm), a is intercept and b is slope of regression.

Due to missing data on the size of trees start to produce seeds and how many seeds produced by reproductive tree, assumption was set that individual of each species larger than 30 cm in dbh are reproductive. Recruitment of each species per year (I) was calculated by Equation *[4]*.

$$I = \frac{\text{number of new individual in time } t+1}{\text{number of trees larger than 30 cm in dbh in time } t} \quad [4]$$

Table 1 Name of study species and the number of individuals measured in the permanent sample plots (3 ha) for D05 (2005), D06 (2006), D07 (2007), D08 (2008), and D09 (2009)

Name of tree species	Family	Number of individuals				
		D05	D06	D07	D08	D09
Actinodaphne nitida	*Lauraceae*	60	63	67	77	93
Blumeodendron sp.	*Euphobiaceae*	65	64	65	70	66

Table 2 Probability of survival (per hectar) of 2 species from period time t to time $t+1$

Name of tree species	Number of individuals in time t	Number of individuals in time $t+1$	Survival probability per year
Actinodaphne nitida	20.0	19.7	0.98
Blumeodendron sp.	21.7	21.0	0.97

note: I is number of new individuals that enter the population at time $t+1$ in which those new individuals are produced by reproductive trees.

Integral projection models Residuals of diameter growth rates can be used by each species as quality taken into account for integral projection models (Ellner & Ree 2006). Letter x symbolizes dbh of individual and q represents residual of growth. Then, both were integrated in IPMs as Equation *[5]*.

$$n(x',q',t+1) = \int_{L_2}^{U_2}\int_{L_1}^{U_1} K(x',q'\,|\,x,q)n(x,q,t)dxdq \qquad [5]$$

These IPMs have rectangle $(\Omega) = [L_1, U_1] \times [L_2, U_2]$, note: L_1=lower dbh in time t, L_2=lower dbh in time $t+1$, U_1=upper dbh in time t, and U_2=upper dbh in time $t+1$. Mesh points of both variables are shown in Equation *[6]* and Equation *[7]*

$$x_i = L_1 + (i - 0.5)h_1 \qquad [6]$$

$$q_i = L_2 + (i - 0.5)h_2 \qquad [7]$$

note: $h_j = (U_j - L_j)m_j$, for $j = 1, 2$. The midpoint rule as approximation of IPMs equation as shown in Equation *[8]*.

$$n(x_k,q_l,t+1) = h_1 h_2 \sum_{i=1}^{m1}\sum_{j=1}^{m2} K(x_k,q_l,x_i,xj)n(x_i,q_i,t) \qquad [8]$$

Elasticity test Elasticity test was performed in this model using formula from Ellner and Rees (2006). Previously, sensitivity was calculated. Sensitivity analysis was done to know how much λ (population growth rate) changes when $K_{(y0,x0)}$ change. $K_{(y,x)}$ will be replaced by $K_{(y,x)} + \varepsilon f_{r(y:x|y0,x0)}$, where f_r is an approximate δ function -a smooth non-negative function that is 0 if the distance from (y_0,x_0) to (y,x) is larger

than r, and $\int x \times x f_{r(y:x|y0,x0)}\,dydx=1$.

Then, $\lambda_{(\varepsilon y0,x0)}$ indicates the resulting dominant eigen value. The sensitivity function is described mathematically as shown in Equation *[9]*.

$$S_{(y0,x0)} = \lim_{s,r \to 0} \frac{\lambda(\varepsilon\,|\,y_0,x_0) - \lambda}{\varepsilon} \qquad [9]$$

And, the familiar sensitivity formula is shown in Equation *[10]*.

$$S_{(y,x)} = \frac{v(y)w(x)}{v,w} \qquad [10]$$

Elasticity is calculated as shown in Equation *[11]*.

$$e_{(y_0,x_0)} = \frac{K_{(y0,x0)}s_{(y0,x0)}}{\lambda} \qquad [11]$$

Results and Discussion

Survival The research result showed that the 2 species have probability to survive just over about 0.95 per year and the probabilities of survival are the same for individuals within species. For example, 98% individuals of *A. nitida* survived in time $t+1$.

Growth The result of the analysis showed a significant growth of each individual (Table 3). *A. nitida* grows faster than *Blumeodendron* sp. because intercept of regression is about 0.70 cm year^{-1}. The intercept can be an indicator how fast they grow in time $t+1$.

For each species, the research chose census intervals based on the strength of the correlation of residual growth from 4 periods namely D0506, D0607, D0708, and D0809. For example, D0506 was diameter growth of individual from 2005 to 2006. It means that dbh of each individual in 2006 was subtracted to dbh in 2005. Then, this was also done for D0607, D0708, and D0809. After the growth of D0506, D0607, D0708, D0809 were obtained, they were related to each other using correlation analysis.

Table 3 Size change in dbh for each species using linear regression x as size (dbh) in time t and y as size (dbh) in time $t+1$

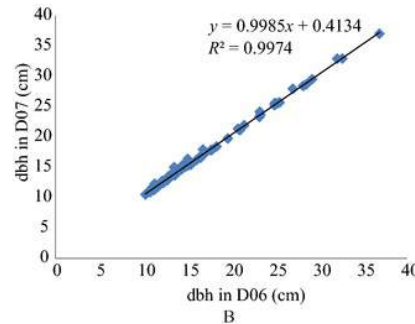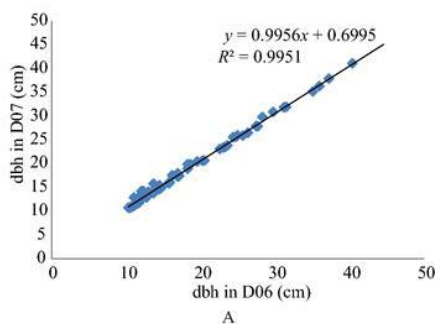| Name of tree species	Growth	R^2	P value
Actinodaphne nitida	$y = 0.69 + 0.99x$	0.9951	$P < 0.01$
Blumeodendron sp.	$y = 0.41 + 0.99x$	0.9974	$P < 0.01$

Figure 1 Growth equation of each species from time t in x axis (labeled as dbh in D06) to time $t+1$ in y axis (labeled as dbh in D07). Growth D0607 *Actinodapne nitida* (A) and Growth D0607 *Blumeodendron* sp. (B).

Linear regression analyses of dbh at time t and time $t+1$ showed high determination coefficients (R^2) for each species indicating very strong correlations (Figure 1). The size of dbh in time $t+1$ can be explained by means of equation of linear regression of each species.

Recruitment Numbers of new individuals varied among species as presented in Table 4. New individuals of *Blumeodendron* sp. was produced more than new individuals of *A. nitida* (Table 4). Those new individuals were produced by reproductive trees of each species in the area of 3 ha. *A. nitida* showed lower recruitment of new individual than that of *Blumeodendron* sp. The highest number of recruitment is *Blumeodendron* sp. which produces 5 new individuals per reproductive tree per year that enter population in time $t+1$. New individuals that enter population in time $t+1$ have dbh about 10.50 cm on average. Moreover, each new individual of each species deviated less than 0.5 cm in general (Table 5). Those variations of new individuals were required to be integrated in IPMs.

Growth autocorrelation The residual growth was calculated by subtracting growth in D0506 (2005–2006) with regression line of growth. It was also done for the rest. After getting residual growth of D0506 (2005–2006), D0607 (2006–2007), D0708 (2007–2008), and D0809 (2008–2009), correlation was used for residual growth. Then, the strong correlations of residual growths were chosen to be used for making equation of growth autocorrelation. For *A. nitida,* residual growth of D07 (2006–2007) and D08 (2007–2008) were selected.

From the Figure 2, each graph shows the distribution of residual growths from period 1 to period 2. By using this, characteristics of individuals from each species can be seen as individual that can grow whether faster or slower from time t (x) and time $t+1$ (y). For instance, characteristic of faster-growing individuals are that some individuals grow above average of growth in time t and they can remain to grow above average of growth in time $t+1$. Therefore, those individuals are in the right upper quadrant. Equations of growth autocorrelation of both species are presented in Table 6. The equations show significantly in linear regression.

Table 4 Number of new individuals and reproductive trees of each species

Name of tree species	Reproductive tree ha⁻¹	new individual ha⁻¹ year⁻¹
Actinodaphne nitida	2.33	1.67
Blumeodendron sp.	1	5

Table 5 Recruitment of each species in time $t+1$ from reproductive trees

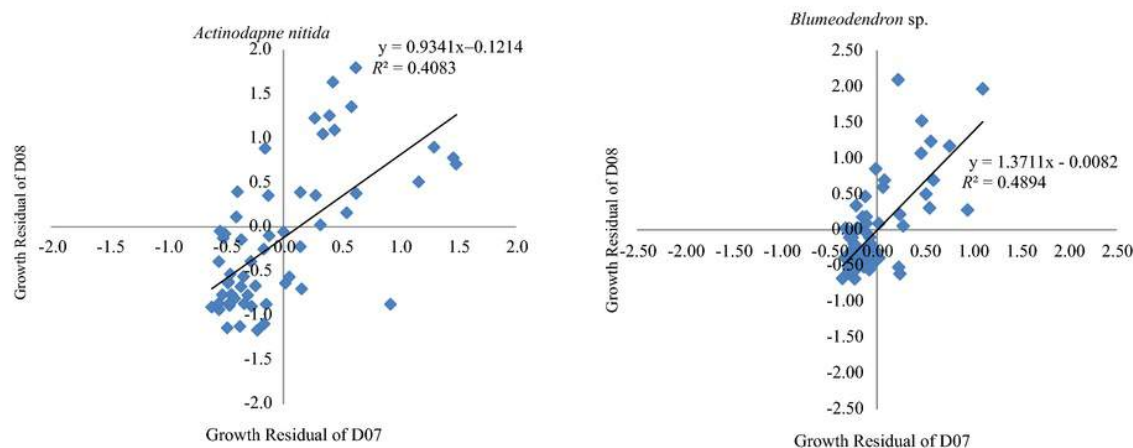| Name of tree species	Recruitment (new individual reproductive⁻¹ tree⁻¹ ha⁻¹ year⁻¹)	Average of dbh of new individual (cm ha⁻¹)	Standard deviation of dbh of new individual (cm ha⁻¹)
Actinodaphne nitida	0.71	10.62	0.36
Blumeodendron sp.	5	10.5	0.33

Figure 2 Equation of growth residual of each species time t in x axis (labeled as growth residual of D07) to time $t+1$ in y axis (labeled as growth residual of D08).

Population dynamics   Both species have λ less than 1, indicating that this population is decreasing over time. The λ of *Blumeodendron* sp. is 0.764, which suggest that this population decrease 23.55% from time *t* to time *t+1*. The λ of *A. nitida* is 0.909, which means that population decline 9.1 % of total population.

The stable stage distributions of 2 species are generated by the IPMs, based on the vital rates and independent starting situation. In general, most individuals that have small dbh are more abundant than individuals that have larger dbh.

Population structures of relative frequency of *Blumeodendron* sp. follow negative exponential distribution from about dbh 10 cm to dbh 40 cm. Individuals of *Blumeodendron* sp. which are larger than dbh 30 cm remain constant and low in relative frequency. Stable size distribution of each species shows a peak in every graph (Figure 4). New individuals entering to population are not precisely at 10 cm but they have standard deviation less than 0.5 cm (Table 5).

These structures of relative frequency of both species will continue to be as projected by IPMs in Figure 4, whether population is increasing in number of individual for each class diameter or population is going down as shown from population growth rate (λ).

The stable stage distributions produced by IPMs were plotted along with observed distributions for time *t* to time *t+1* to see the degree of correspondence (Figure 3). From graphs in Figure 3, distribution of diameter classes between IPMs result (blue bar), observed data in time *t* and observed data in time *t+1* are similar where more individuals are distributed in small dbh than in big dbh for each species. IPM results of *A. nitida*, *Blumeodendron* sp., and observed data show strong similarity as shown in Figure 3.

To see how similar between IPMs result and observed distribution are proportional similarity index was applied (Horvitz & Schemske 1995). Based on Proportional Similarity Index, it can be said that distribution of IPMs result and observed data are similar (Table 8).

Residual distribution   In Figure 5, each panel shows how residual of individual is distributed for each species. The residual is the deviance of the growth line of individuals (Figure 3). If residual of individual deviates larger than 0, it means that the individual grows faster as a consequence of

Table 6   Growth autocorrelation of each tree species where *r* is residual growth in period 1 and *A* is residual growth in period 2

Name of tree species	Growth autocorrelation	R^2	P Value
Actinodaphne nitida	$A = 0.9341r - 0.1214$	0.4083	$P < 0.01$
Blumeodendron sp.	$A = 1.3711r - 0.0082$	0.4894	$P < 0.01$

Table 7   Population growth rate (λ) of tree population

Name of tree species	Population growth rate (λ)
Actinodaphne nitida	0.909
Blumeodendron sp.	0.764

Table 8   Proportional similarity index between IPMs result and observed data. Compared the similarities in two comparison, first is between IPM result and time t, second is between IPM result and time t+1. If Proportional Similarity Index (%) is close 100% meaning that comparison is similar, if Proportional Similarity Index (%) is close to 0% meaning that comparison is not similar

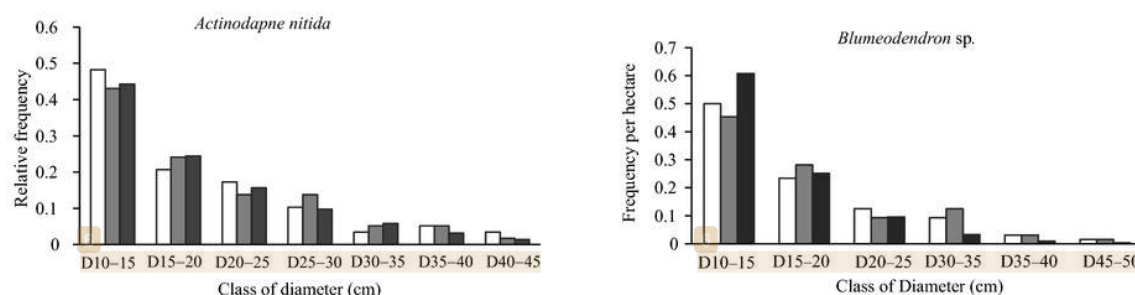| Name of tree species	Proportional Similarity Index (%)	
	(IPM results vs time *t*)	(IPM results vs time *t+1*)
Actinodaphne nitida	93.9	95.9
Blumeodendron sp.	87.6	84.7

Figure 3   Comparison between stable size distribution from IPMs distribution (■) which is labeled as RELSSD and observed data from time *t* (□) labeled as REL 2006 in time *t* to next year (■) labeled as REL 2007 in time *t+1*.

growing above average of growth from time *t* to time *t*+1. So this is persistent fast grower. Then, the individual tends to keep the same growth rate to next time. On the other hand, if residual of individual moves away less than 0, it means that the individual grows slowly as a result of growing below average of growth from time *t* to time *t*+1, so this is the persistent slow grower from Figure 5. More individuals of *Blumeodendron* sp. are faster-growing individuals because they are on side wheretheir residuals are larger than 0, compared to slow-growing individuals as shown by *A. nitida*. It seems that more residual distributed on the left side.

Elasticity Then, elasticity of each category based on residual growth was calculated and plotted in Figure 5 to see whether distribution between faster-growing individuals and slow-growing individuals have an effect on population growth of each species. Each graph in Figure 6 also show that individuals which have small dbh contribute more to population growth rate than individuals that have large dbh. For *Blumeodendron* sp., individuals that have dbh less than about 20 cm contribute more to population growth rate than individuals that have dbh larger than about 20 cm. *A. nitida* has the highest elasticity in dbh between 25 cm and 30 cm
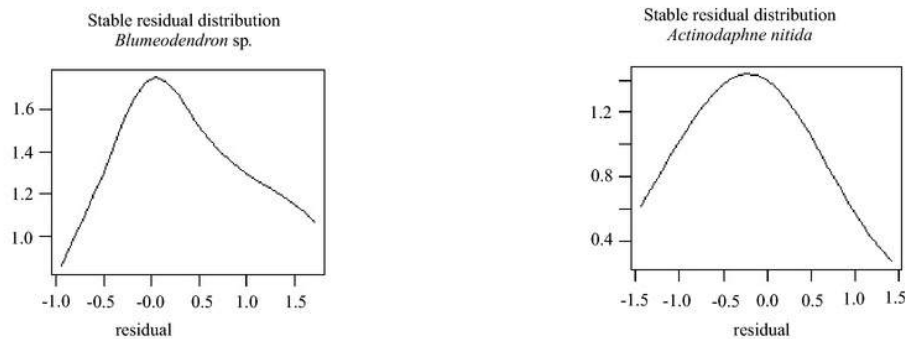
Figure 4 Stable residual distribution of each species. If residual of individual deviate larger than 0, it means that the individual grow faster or if residual of individual deviate less than 0, it means that the individual grow slower.
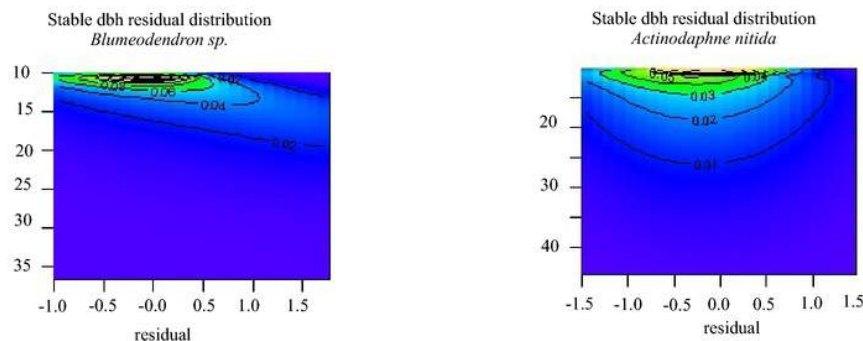
Figure 5 Elasticity for residual distribution and dbh of each species. Residuals were derived from residual growth between period 1–2. The graphs show elasticity larger in small dbh while lower in large dbh.
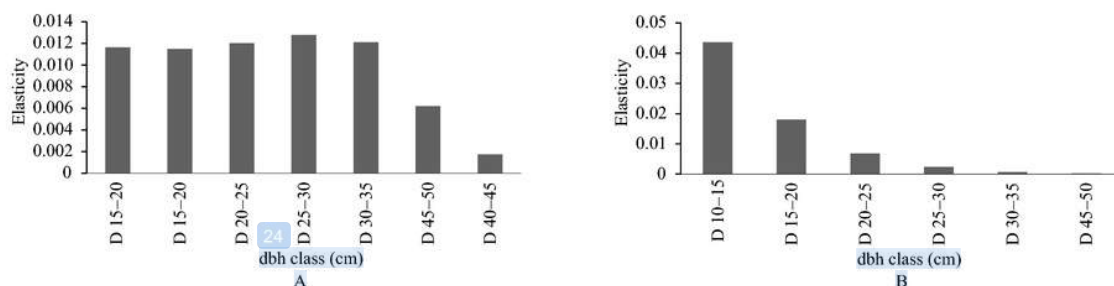
Figure 6 Elasticity of dbh classes of each species: *Actinodapne nitida* (A), *Blumeodendron* sp. (B).

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while *Blumeodendron* sp. has the highest elasticity in small dbh (Figure 6).

Then, elasticity of residual growth was grouped into two sides. They were elasticity which is larger than 0 as fast growing individuals and elasticity which is less than 0 as slow growing individuals. Then, elasticity of faster-growing individuals and slow-growing individuals were compared to see how much faster-growing individuals contribute to population growth rate (λ). Comparison of elasticity of faster-growing individuals and slow-growing individuals larger than 1 means that faster-growing individuals contribute more than slow-growing individuals to the population growth rate. Results of the comparison are presented in Table 9.

Relationship between vital rates and population growth rate (λ) Mortality rate of each species is low and does not vary across dbh class. It means that individual of each species has the same probability of survival. This probably happened because individuals of all species that included in this analysis were measured from dbh 10 cm. Yosi *et al*. (2011) also found that the number of individuals that have diameter 10–29 cm increased in harvested forest in Papua New Guinea and the number of those in diameter above 70 cm decreased. Therefore, most of individuals of 2 species could survive to grow and reach large dbh in this area.

For both species, their population projected to go down as shown by population growth rate (λ) <1. This is probably as a result of having a low recruitment of new individuals. Primack *et al*. (1985) found that growth rates of trees in harvested forest declined in 3rd and 4th after harvest. However, the growth rates of trees in logged forest are still larger than growth rates of trees in primary forest. Then, after a couple of decades, the growth rates of trees in the logged forest would be similar to growth rates of trees in the primary forest because trees in logged forest would reach climax phase (Primack & Lee 1991; de Graaf *et al*. 1999; Krisnawati & Wahjono 2010).

Moreover, growth of each individual within species has significance over the time and then the growth of individuals effect to the population. It can be seen that even though *Blumeodendron* sp. has high number in recruitment, it's population is still decreasing over time because of growth of *Blumeodendron* sp. The distribution of individuals among dbh classes could be a factor that influences population growth. As shown in Figure 3, individuals of *Blumeodendron* sp. are only distributed from 10 cm to 40 cm, resulting in declining population.

A. nitida and *Blumeodendron* sp. are not commercial species and these species are not distributed widely. Even though *A. nitida* and *Blumeodendron* sp. are not cut, these species are projected to decline in abundance. Logging impact could affect negatively to those species in which during cutting trees, mortality of seedling or high saplings. Sist and Nguyen-Thé (2002) reported that tree mortality in logged forest could double compared to tree mortality in primary forest. The tree mortality in logged forest occurred more in the area in which logging took a place. Therefore, logging activities led to damages to remaining trees. In this study, the causes of the decline cannot be derived from this study, but they need to be studied in detail in the field.

Growth autocorrelation within species to asses persistence growth of trees Studying growth autocorrelation is necessary because it can help to understand growth of individuals over time. This study can provide information whether individuals within species can grow faster because those individuals can grow persistently over the time. In general, those species has a characteristic from slow-growing to fast-growing individual. The variation of characteristic of individuals within species may happen as a result of competition among them (Bolnick *et al*. 2003).

From Figure 2, individuals which on the above line of growth autocorrelation and have positive residual growth can tell that those individual persist over time. Therefore, those individuals are considered to be maintained in this area because they have function to increase population by growing faster and producing new individuals. As stated by Brienen *et al*. (2006), growth of individuals in the next year rely on growth of individuals in the previous year. Size and growth rate have an effect on autocorrelated growth of each individuals. The growth autocorrelation of individuals are different within species as a consequence of differences in site condition, and then the individuals will maintain growth over time (Rozendaal & Zuidema 2011). Even though the measurement of persistent growth differences within species seems difficult to be analyzed in short time, the persistent growth differences significantly affect timber yield (Brienen & Zuidema 2007).

Contribution of faster-growing individuals to population growth Population growth rate (λ) can be an indicator whether population is declining or increasing. Temporal growth autocorrelation will have an effect on population growth. The faster-growing individuals will contribute to increase population growth rate (λ) because those individuals will reach certain size faster than slow-growing

Table 9 Comparison of elasticity of faster-growing individuals if category of dbh have residual > 0 and slow-growing individuals if category of dbh have residual < 0. The comparison have 2 groups which are group with comparison < 1 meaning less contribution of faster-growing individuals and group with comparison > 1 meaning more contribution of faster growing individuals to population growth rate (λ).

Name of tree species	Comparison of elasticity (residual > 0 / residual < 0)
Actinodaphne nitida	1.143452
Blumeodendron sp.	1.879642

individuals. As a result, those individuals will have shorter time to reach reproductive age than slow-growing individuals and this will produce new individuals. Moreover, the survival rate of faster-growing individuals is high because they only have shorter time but the mortality probability is low. Therefore, the faster-growing individuals will contribute more to population growth rate (λ) than the slow ones. In this research, elasticity was used to detect whether this is the case. To know whether fast-growing individuals have more influence to population growth rate than slow-growing individuals, the research used elasticity analysis. It was divided into elasticity of fast-growing individuals and that of slow-growing individuals.

For *A. nitida* and *Blumeodendron* sp., faster-growing individuals are important for population growth rate compared to slow-growing individuals (Comparison of elasticity > 1). As studied by Jansenet *et al.* (2012), faster-growing individuals contributed more about twice to population growth than slow-growing individuals. Furthermore, the presence of fast-growing juveniles in the past played an important role because they could reach reproductive size faster than slow-growing juveniles. In addition, the fast-growing juveniles had low risk of mortality (Zuidema *et al.* 2009).

By knowing the faster-growing individuals, those individuals can be maintained in this area in order to increase population growth (λ). The faster-growing individuals will contribute mainly to population growth and viability, even in small number of individuals. They would have an important role to increase population. A study of *Cedrela odorata* by Zuidema *et al.* (2009) showed that differences between faster-growing individuals and slow-growing individuals were larger in diameter below 10 cm than the differences between those in diameter above 40 cm. Similarly, in this study, faster-growing individuals are present more in small dbh than in large dbh. Based on elasticity of individual sizes, small individuals of *Blumeodendron* sp. has higher elasticity than large individuals (Figure 6). This is as result of large number of individuals in small dbh in stable size distribution. Therefore, the small individuals will give a large contribution to the population growth. Zuidema *et al.*(2011) reported that juvenile of trees which diameter category were < 20 cm had positive correlations in growth.

In contrast, *A. nitida* has the highest elasticity in dbh between 25 cm and 30 cm. Individuals of those species in this size contribute more than other individuals because in this size individuals are producing new individuals. As reported by Ghazoul and McLeish (2001), the numbers of reproductive trees have impact to an increase of population of trees because seeds are produced and then seeds germinate as new individuals. In this study, the new individuals will enter population as one of factors which can lead to increase population growth rate (λ).

Implication for sustainable forest management
Implications of persistent fast growers to the sustainable forest management of tropical forest is that site condition for supporting growth will be known and individuals which are persistent growers can be maintained in order to increase population growth rate (λ). The site condition is known by

measuring abiotic and bioatic factors where persistent fast growers grow. Then, condition of forest can be manipulated by using silvicultural treatments as improved forest management practices (Dauberet *et al.* 2005; Macphersona *et al.* 2010). Furthermore, the tendency of trees on logged area should be focused on persistent fast growers.

Conclusion

Based on this research, population of *A. nitida* and *Blumeodendron* sp. are declining over time even though these species are non-commercial species, which means that after selective logging those 2 non-commercial species were influenced by logging activitites. However, growth of individuals is playing an important role in term of contributing population growth rate. In addition, it can be predicted that population of these species could recuperate after selective logging because more faster-growing individuals will have a significant contribution for population growth rate (comparison of elasticity > 1).

Acknowledgement

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