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Characterizing nutrient status and growth of *Macaranga gigantea* in tropical rainforest gaps after selective logging in East Kalimantan, Indonesia

DWI SUSANTO[1,♥], HAYATUDIN[1], ARIS SETIAWAN[1], HERI PURNOMO[1], DADDY RUHIYAT[2], RUDIANTO AMIRTA[2]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Mulawarman University. Jl. Barong Tongkok No. 4 Gunung Kelua, Samarinda-75123, East Kalimantan, Indonesia. Tel./Fax.: +62-541-749140, 749152, 749153, ♥email: susantodwiki@yahoo.com
[2]Faculty of Forestry, Mulawarman University, Jl. Ki Hajar Dewantara Kampus Gunung Kelua, Samarinda, East Kalimantan, Indonesia

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Abstract. *Susanto D, Hayatudin, Setiawan A, Purnomo H, Ruhiyat D, Amirta R. 2017. Characterizing nutrient status and growth of Macaranga gigantea in tropical rainforest gaps after selective logging in East Kalimantan, Indonesia. Biodiversitas 18: 996-1003.* Selective logging caused the formation of forest gaps, which stimulate the growth of the pioneer tree species. This study aims to determine the characteristic of soil nutrients status and plant growth of *Macaranga gigantea* in the tropical rainforest gaps after selective logging in East Kalimantan, Indonesia. We established research plots 50mx50m in natural forest production, 1 until 10 years after selective logging. The measured data of each plot is the number of trees of *M. gigantea*, its stem diameter, and its height, and also the soil and leaf nutrient concentration. The results showed that the soil has a pH (H_2O) of 5.3 ± 0.27, cation exchange capacity of 10.6 ± 2.98 meq. 100 g-1, base saturation of 27.7 ± 10.44%, while the concentration of nutrients carbon of 1. 04 ± 0.27%, nitrogen of 0.10± 0.02%, phosphorus of 6.35 ± 3.4%, potassium of 67.15± 30.1%, calcium of 1.7 ± 1.09% and magnesium of 0. 99 ± 0.8%. The highest stem diameter and height of *M. gigantea* (19.5 cm; 18.07 m) was obtained in plots of 8 years after selective logging and then declined, while the highest diameter increment and height increment obtained in plants located in a plot of 4 years after selective logging and decline until 10 years after selective logging. The concentration of nutrients accumulated in the leaves of *M. gigantea* was N with 1.51 ± 0.19%, P with 0.16 ± 0.01%, K with 1.37 ±0.28%, Ca with 1.78 ± 0, 43% and Mg with 1.53 ± 0.37%. The soil nutrients concentration of N, K, Ca and Mg correlated with plant growth of *M. gigantea* ($p \leq 0.05$), potassium concentration of soil positively correlated with a potassium concentration of leaves ($p \leq 0.05$), whereas magnesium concentration in the leaf correlated with plant growth ($p \leq 0.05$). We suspect that bases nutrient elements, potassium, calcium, and magnesium are nutrients absorbed in large quantities by *M. gigantea* and extremely important to its growth.

Keywords: Forest gaps, growth, *Macaranga gigantea*, selective logging

INTRODUCTION

One of the natural production forest management in Indonesia is by selective logging which has been utilized in recent year. The system was developed for the management of tropical rain forests in Indonesia and to preserve the supply of timber from natural forests. In the selective logging system, dipterocarp forest exploitation is done by limiting the type of harvested trees only on red meranti and white meranti, limiting the diameter and the number of felled trees for regeneration as well as considering other factors relating to sustainability (Rimbawanto 2006).

Timber harvesting in tropical rainforests causes the formation of gaps (felling gaps) which is unavoidable. Timber harvesting system by selective logging and selective planting significantly increase the canopy openness and light conditions of the opened forest compared to the primary forest. Canopy openness was found for each element, including skid trail, logging gaps, and strip cutting lines (Romell and Karlsson 2009; Inada et al. 2014). Gap area was positively correlated with the diameter of the fallen tree and the basal area of felled trees (Sapkota and Ode'n 2009; Arihafa and Mack 2013). Berthiaume and Kneeshaw 2009 showed that the gap sizes affected the light distribution in gaps. Gap size increased the diversity of plants (Kern et al. 2013), and canopy openness positively affected survival probability of pioneer tree species (Goodale et al. 2014; Hamrang et al. 2015). Seedling densities of pioneer species initially showed an increase in all sites after logging (Duah-Gyamfi et al. 2014).

Generally, after logging in tropical rain forest, most species of the genus Macaranga invade the logging gaps (Silk et al. 2002; Okuda et al. 2003; Zakaria et al. 2008; Inada et al. 2014; Sancayaningsih and Bait 2015). Canopy openness is a deciding factor in the Macaranga species abundance and species richness of the gap (Yiing et al. 2008) and Macaranga gigantea becomes the major contribution of forest aboveground biomass due to its great number of diameter which influences the number of aboveground biomass, namely, 1,063 $ton.ha^{-1}$ (Hadhirah et al. 2015). Until now *M. gigantea* is still considered as forest weed and has never been cultivated, while recent studies claim that wood of *M. gigantea* is potential as an alternative wood pulp and ethanol feedstocks due to its chemical composition, high growth ability and adaptability (Mindawati et al. 2010; Amirta et al. 2016a; 2016b; Susanto et al. 2016a).

Information about the nutrient elements uptake patterns and growth of *M. gigantea* from natural succession in forest gaps after selective logging has not been found. Our focus in this study was to determine the growth of *M. gigantea* pioneer trees on forests gap after selective logging and their nutrient element status. The results of this study are expected to supplement the data on the characteristics of soil nutrients, on the growth *M gigantea* from natural succession and nutrient uptake patterns and we hope form that it can be the basis for the cultivation of this plant in the future.

MATERIALS AND METHODS

Study area

This study was conducted in a logging concession located in Penajam Paser Utara, East Kalimantan Province, Indonesia. The concession has been managed by logging company PT Balikpapan Forest Industries (located 116° 01 '- 116° 45' East and 00° 42 '- 01° 18' South). This logging company has conducted the selective logging of desired Shorea species for many years in some areas.

The study consists of six plots in forest gaps having the age of: (1) 1 year (01^{o} 05 '48.4 "S and 116^{o} 23' 17.9" E); (2) 2 years (01^{o} 05 '56.2 " S and 116^{o} 23 '03.0 "E); (3) 4 year (01^{o} 04' 05.7" S and 116^{o} 22 '21.4 "E); (4) 6 years (01^{o} 04' 51.3 "S and 116^{o} 18 '30.7" E); (5) 8 years (01^{o} 04' 31.9 "S and 116^{o} 20 '02.8" E) and (6) 10 years (01^{o} 08 '14.9 "S and 116^{o} 24' 54.9" E) after selective logging (Figure 1). The forest type is lowland dipterocarp forest. Highest annual rainfall is 3207.6 mm, highest monthly rainfall is in June (316.3 mm) and the lowest is in August (162.3 mm). The wet period is between 9-12 months, while the dry period is between 0-2 months (Anonymous 2012). Data analysis of growth was performed in the Laboratory of Plant Physiology Faculty of Mathematic and Natural Science, Mulawarman University and data analysis of the characteristics of the soil nutrients status and leaves of *M. gigantea* were performed in the Soil Science Laboratory, Faculty of Forestry, Mulawarman University. The study had been done on February until June 2013.

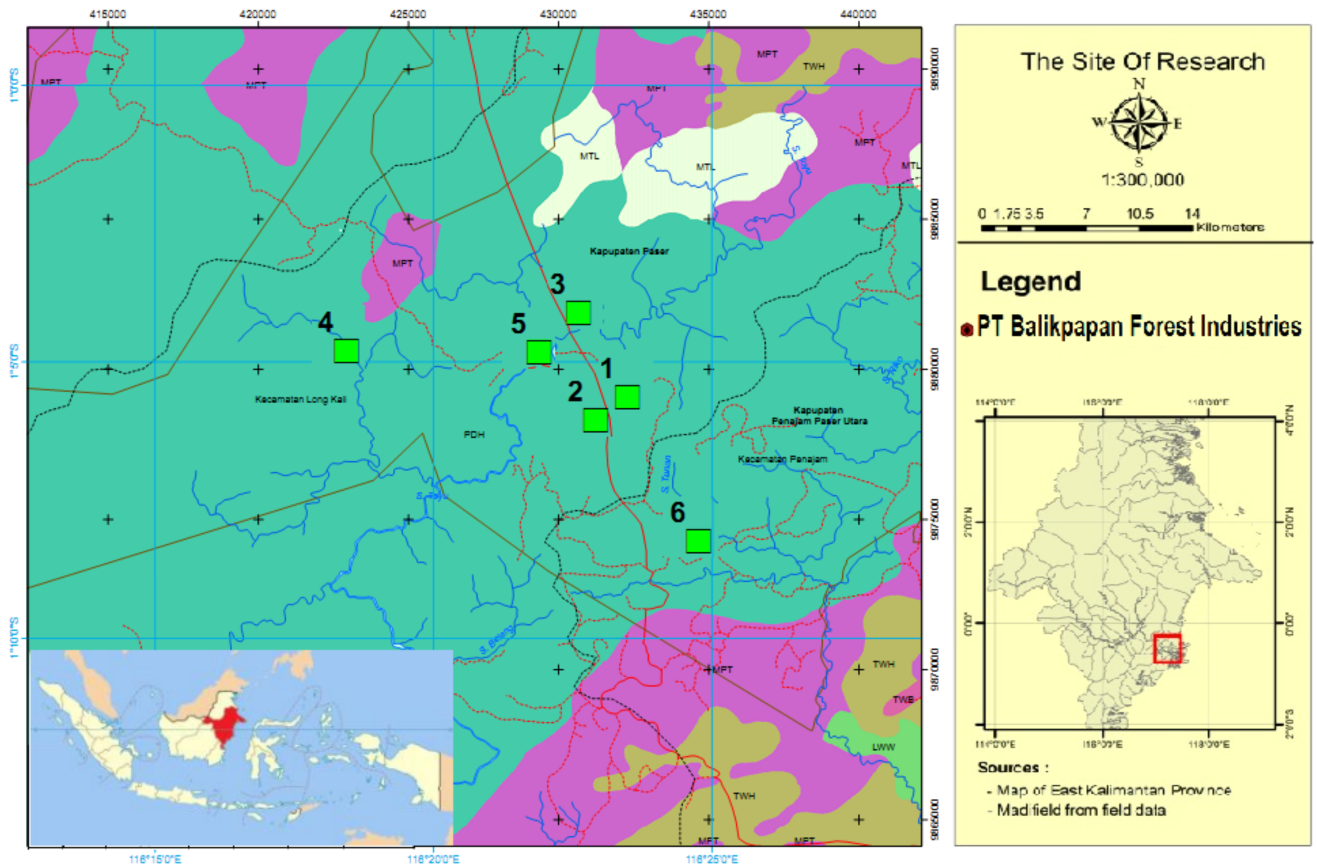

Figure 1. Map of the study area in the concession area of PT Balikpapan Forest Industries, East Kalimantan (■: research plots). Note: 1. 1 year; 2. 2 years; 3. 4 years; 4. 6 years; 5. 8 years and 6. 10 years after selective logging

Procedure

Prior to this research, the site surveys were conducted and interviews with the management of PT Balikpapan Forest Industries were undergone for finding the exact forest gaps location of 1, 2, 4, 6, 8 and 10 years after selective logging. Then a plot with the size of 50m x 50m was created in each forest gaps., Every plot point was determined by a global position system (GPS). All *M. Gigantea* trees found along the research plot was recorded and the diameter and height of stem were measured (Susanto et al. 2016b).

Measurement of diameter and height trees

On each plot, the plants of *M. Gigantea* were counted, then the diameter of the stem (DBH) and stem height of each was measured using clinometers.

Soil sampling

On each plot, 4 drill points with 0-30 cm and 30-60 cm deep were done to take the soil samples for as much as 500 g of each depth. The samples were air-dried in a laboratory for analyzing the total of nitrogen, phosphorus, potassium, calcium and magnesium.

Leaves sampling

Leaf samples are taken from the vertical position of each component in the canopy (bottom, middle and top). Next, 500 g of each leaf samples were taken from each study plot and were inserted in a plastic bag and brought to the laboratory for leaf nutrients analysis.

Analysis of soil nutrients concentration

The chemical analysis covered the soil pH, cation exchange capacity, base saturation and concentration of soil nutrients, N total and was done with Kjeldahl method (extraction, distillation, titration), while P total was done with Bray P-1 methods. Their extracts were measured with a spectrophotometer. For the total of K, Ca and Mg was done with method of saturation with ammonium acetate at pH 7.0 and measurements were performed with AAS (Atomic Absorption Spectrometer)

Analysis of the leaves nutrient elements concentration

For the analysis of leaf nutrient concentration, total N was obtained with Kjeldahl method (extraction, distillation, titration). For the measurement of nutrient of P, K, Ca and Mg, plant components were extracted by methods of High-Pressure Digestion at a temperature of 180^{o}C for 10 hours with a reducing HNO_3 concentrate. Phosphorus was measured by a calorimetric technique using nitric acid-molybdate-vanadate as coloring agents and then was measured with a spectrophotometer at a wavelength of 470 nm. Potassium, calcium, and magnesium were measured with Atomic Absorption Spectrophotometer (Syahrinudin 1997).

Data analysis

Descriptive analysis was conducted on the data obtained from the field, namely: number of trees, stem diameter, height, soil and leaves nutrient concentration. To determine the correlation between the concentration of soil nutrients with *M. gigantea* growth and leaf nutrient concentrations was conducted with regression analysis, and to determine the significance was conducted with t-test on the value of r (p 0.05-0,1).

RESULTS AND DISCUSSION

Chemical soil properties

Mean soil acidity was 5.3 ± 0.27, the minimum was 4.9 and maximum was 5.8, and they were classified as acid soil. Cation exchange capacity on research plots ranged from low (6.23 meq.100 g^{-1}) to moderate (16.7 meq.100 g^{-1}) with a mean of 10.6 ± 2.98 meq.100 g^{-1}) in low status. Base saturation average was 27.7 ± 10.44%, the minimum was 13.82%, and the maximum was 51.78%. Nutrient concentration status of soil was as follows: concentration of nitrogen was on the status of very low to low (0.06 to 0.16%) with the average value of 0.10 ± 0.02%. The concentration of phosphor was in the range of 1.56% to 11.71% with the status of very low to low and with the average value of 6.3 ± 3.4%. The concentration of potassium on the research plots was very low to low (29.05% -111.20%). In general, the concentration of Ca on plots of research was also very low until low in the range of 0.91% to 4.63%, with the average value of 67.2 ± 30.1%. The concentration of Mg was on the status of very low to high, ranging from 0.22% to 3.32%, with the average value of 0.98 ± 0.8% (Table 1).

Growth of *Macaranga gigantea* tree

Macaranga gigantea growth and its number of trees in research plots are quite varied (Table 2, Figure 2). It might be caused by the availability of seed sources which are different in each research plot.

The relationship between plots logged (years after selective logging) with the growth of *M. gigantea* (mean diameter and height) presented in Figure 2.

Leaf nutrient concentration

Mean nitrogen concentration in leaf was 1.51 ± 0.19%. At 4-6 years after selective logging, *M. gigantea* plant accumulates more nitrogen for growing (1.68 to 1.80%), higher than the nitrogen concentration at 1-2 years and 8-10 years after selective logging. The phosphor of leaves has the smallest concentration, range from 0.15% to 0.18%, while the greatest nutrient concentration is calcium (1.13-2.25%), with an average value of 1.78 ± 0.43% (Table 3).

Correlation between soil and leaf nutrient concentration with growth of *Macaranga gigantea*

The relationship between the mean of diameter and height of *M. gigantea* with soil nitrogen and potassium concentration at 0-30 cm and 30-60 cm deep was statistically significant (p = 0.1), but it was not significant for phosphor, calcium, and magnesium. The relationship between the mean of diameter increment and soil nutrient concentration at a depth of 0-30 cm and 30-60 cm were statistically significant to the elements Ca and Mg (Table

4). The correlation between the leaf potassium concentration with soil potassium concentration at a depth of 0-30 cm and 30-60 cm were statistically significant (Table 5). The concentration of leaf magnesium with the mean of diameter and height of trees was statistically significant (p = 0.05), but it was not significant for the nutrients of N, P, K and Ca (Table 6).

The concentration of nitrogen and potassium in the soil at a depth of 0-30 cm negatively correlated with stem diameter, height, diameter increment and height increment (Table 4, Figure 3). Based on the r-value, soil nitrogen and potassium concentration moderately correlated with *M. gigantea* growth. The r-value of 0.75 and 0.80 showed that 75% and 88% of M. *gigantea's* growth change was affected by nitrogen and potassium concentration variable, while the remaining 25% and 20% could be affected by other factors. Soil calcium and magnesium concentration positively correlated with a mean of diameter increment of *M. gigantea*, with r-value of 0.77 and 0.73. Leaf magnesium concentration negatively correlated with a mean of stem diameter and height.

Discussion

The chemical property of soil in the study is acidic soil, while cation exchange capacity and base saturation are very low to low. Soil nutrient status (nitrogen, phosphorus, potassium, calcium and magnesium) at research plot are very low to low. Imai et al. 2012 reported that the total amount of P which was exported out as timber from the ecosystem by heavy selective logging was estimated at 24.0 kg ha^{-1}, while the amount of the labile P in the topsoil was 12.8 kg.ha^{-1}, indicating that labile P might become deficient by more than 12 kg ha^{-1} for biomass recovery. Excessive logging can induce limitation of P on post-logging biomass recovery. On the other hand, rehabilitating degraded forest land with dipterocarp and non-dipterocarp species had improved both soil nutrient status and valuable timber stock. The soils were acidic with low levels of organic matter and exchangeable bases associated with high level of Al saturation. The negative change derivate from the organic matter and clay minerals play an important role in retaining soil nutrient and probably influence the soil nutrient status (Hamzah et al.2009).

Table 5. Correlation coefficient from results of regression analysis and p-value for significance through t-test between soil nutrient concentration and leaf nutrient concentration of *M. gigantea*

Nutrient elements	Soil depth	r	t
Nitrogen (%)	0-30	-0.16	0.76
	30-60	0.06	0.91
Phosphorus (ppm)	0-30	-0.44	0.37
	30-60	-0.57	0.27
Potassium (ppm)	0-30	**0.78**	**0.06**
	30-60	0.40	0.42
Calcium (cmol.kg^{-1})	0-30	-0.64	0.17
	30-60	0.26	0.61
Magnesium (cmol.kg^{-1})	0-30	0.37	0.46
	30-60	-0.14	0.79

Note: Bold values denote significance at $p < 0.10$

Table 1. Chemical properties of soil in forest gaps after selective logging

Year after logging	Soil depth (cm)	Soil chemical properties							
		pH (H_2O)	CEC (meq.100 g^{-1})	BS (%)	N (%)	P (ppm)	K (ppm)	Ca (cmol.g^{-1})	Mg (cmol.g^{-1})
1	0-30	5.5	12.14	27.34	0.16	9.88	107.96	1.52	1.2
	30-60	5.3	16.07	36.90	0.11	11.71	48.30	4.63	0.99
2	0-30	4.9	12.11	18.52	0.12	4.68	96.71	0.78	0.93
	30-60	5.1	11.51	13.82	0.09	6.50	55.59	0.97	0.27
4	0-30	5.8	13.13	51.78	0.11	7.80	102.14	2.83	3.32
	30-60	5.7	12.92	32.02	0.09	9.88	111.20	2.01	1.73
6	0-30	5.0	9.82	25.76	0.13	4.94	75.03	1.47	0.64
	30-60	5.3	11.05	18.34	0.08	8.58	53.14	1.26	0.41
8	0-30	5.4	6.23	29.67	0.09	1.56	49.26	1.40	0.22
	30-60	5.2	6.54	34.37	0.06	1.56	31.25	1.20	0.91
10	0-30	5.1	7.81	26.01	0.11	2.34	46.16	0.98	0.79
	30-60	5.4	8.05	17.81	0.07	6.76	29.05	0.91	0.34
Mean		5.3±0.27	10.6±2.98	27.7±10.4	0.10±0.02	6.3±3.4	67.2±30.1	1.7±1.0	0.98±0.8

Table 2. Data inventory of stands of *Macaranga gigantea* in forest gaps after selective logging.

Macaranga gigantea	Year after selective logging						Mean
	1	2	4	6	8	10	
N.2500 m$^{2-1}$	28	18	5	75	39	8	
N.ha^{-1}	112	72	20	300	156	32	
Mean diameter (cm)	2.5	2.9	11.9	14.2	**19.5**	14.2	
Mean Height (m)	2.17	3.51	9.64	12.21	**18.07**	10.07	
Basal area (m^2.ha^{-1})	0.064	0.060	0.045	5.855	**5.633**	1.226	
Volume (m^3.ha^{-1})	0.08	0.13	1.47	42.42	48.77	13.09	
Diameter increment (cm.th^{-1})	2.5	1.5	**3.0**	2.4	2.4	1.4	2.2±0.6
Height increment (m.th$^{-1)}$)	2.17	1.76	**2.41**	2.04	2.26	1.01	1.9±0.5
Volume increment (m^3.ha^{-1}th^{-1})	0.08	0.065	0.368	**7.07**	6.096	1.309	2.5±3.2

Table 3. Mean Leaves nutrient concentration of *Macaranga gigantea* in forest gaps after selective logging.

Leaf nutrient concentrate (%)	Year after selective logging						Mean
	1	2	4	6	8	10	
Nitrogen	1.36	1.46	1.80	1.68	1.45	1.32	1.51±0.19
Phosphorus	0.16	0.18	0.15	0.16	0.17	0.16	0.16±0.01
Potassium	1.77	1.46	1.55	1.03	1.29	1.11	1.37±0.28
Calcium	2.20	1.67	1.13	1.95	1.49	2.25	1.78±0.43
Magnesium	1.80	1.84	1.61	1.55	0.83	1.57	1.53±0.37

Table 4. Correlation coefficient from regression analysis results and the p-value for significance through t-test between soil nutrient concentration and growth of *Macaranga gigantea*

Soil nutrient concentration (%)	Depth (cm)	D	t	H	t	DI	t	HI	t
Nitrogen	0-30	0.75	**0.08**	0.77	**0.07**	0.19	0.83	0.08	0.87
	30-60	0.88	0.19	0.88	**0.02**	0.25	0.62	0.28	0.58
Phosphorus	0-30	0.68	0.13	0.69	0.12	0.54	0.27	0.48	0.33
	30-60	0.63	0.18	0.71	0.11	0.32	0.53	0.13	0.80
Potassium	0-30	0.80	**0.05**	0.76	**0.08**	0.40	0.42	0.51	0.30
	30-60	0.18	0.72	0.19	0.71	0.62	0.18	0.54	0.26
Calcium	0-30	0.17	0.74	0.14	0.77	0.88	**0.02**	0.66	0.14
	30-60	0.55	0.25	0.54	0.26	0.46	0.34	0.41	0.42
Magnesium	0-30	0.19	0.70	0.25	0.62	0.55	0.25	0.38	0.45
	30-60	0.09	0.86	0.09	0.86	0.85	**0.03**	0.70	0.11

Note: Bold values denote significance at $p < 0.10$. D= stem diameter, H= stem height, V= volume of stem, DI= diameter increment, HI=height increment, and t= t-test values

Table 6. Correlation coefficient from results regression analysis and p-value for significance through t-test between leaf nutrient concentration and growth of *Macaranga gigantea*

Leaf nutrien elements (%)	D	t	H	t	DI	t	HI	t
Nitrogen	0.21	0.68	0.23	0.65	0.67	0.14	0.59	0.21
Phosphorus	0.27	0.65	0.10	0.84	0.62	0.18	0.19	0.70
Potassium	0.69	0.12	0.63	0.17	0.37	0.46	0.48	0.33
Calcium	0.24	0.63	0.33	0.51	0.53	0.28	0.63	0.17
Magnesium	0.84	**0.03**	0.91	**0.01**	0.21	0.68	0.23	0.65

Note: Bold values denote significance at $p < 0.10$. D= stem diameter, H= stem height, V= volume of stem, DI= diameter increment, HI=height increment, and t= t-test value

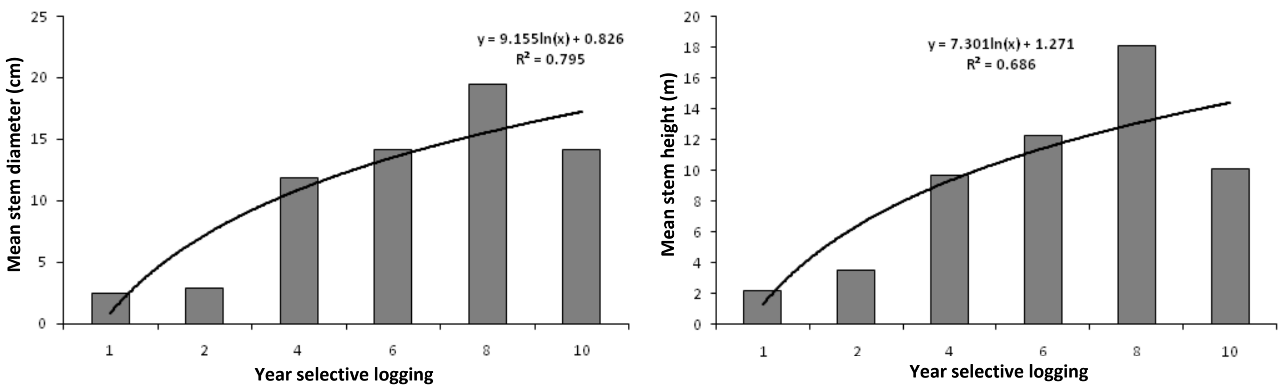

Figure 2. Growth of *Macaranga gigantea* in forest gaps after selective logging

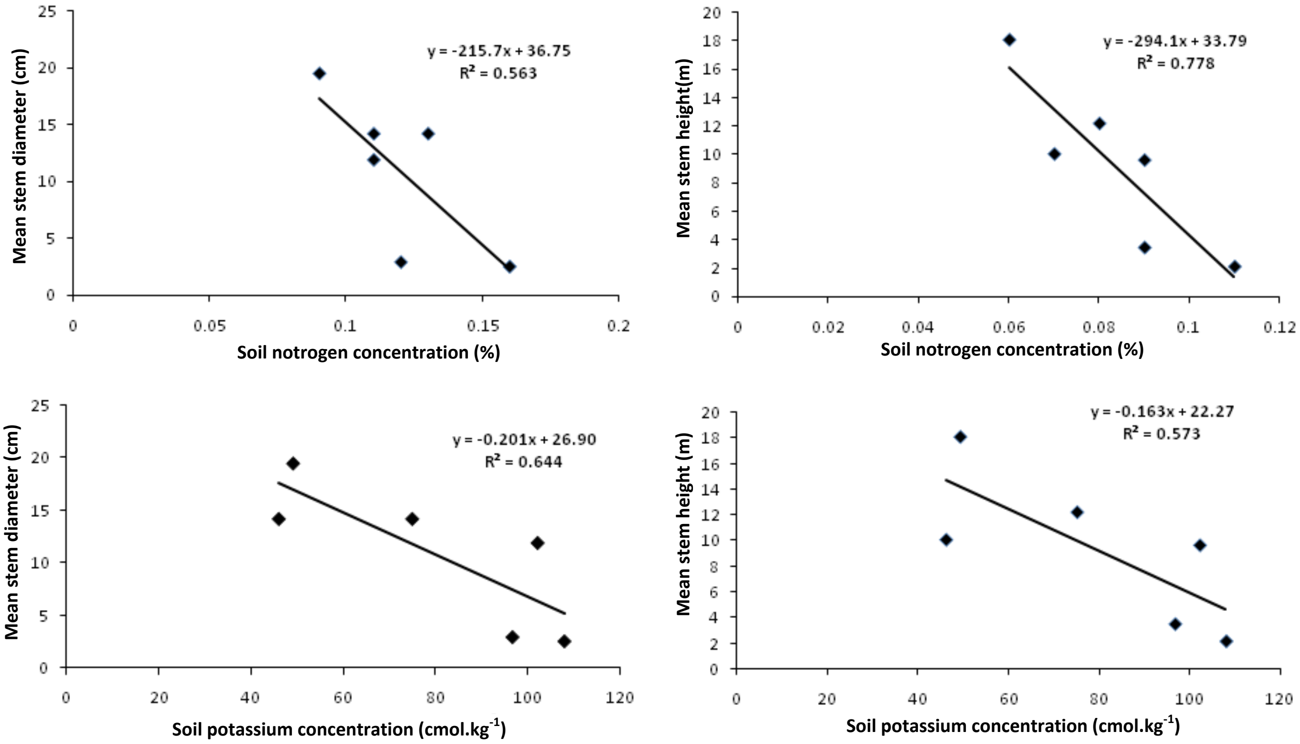

Figure 3. Relationships between soil nutrient concentration and growth of trees *M. gigantea* at forest gaps after selective logging. (a) soil N concentration Vs stem diameter (b) soil N concentration Vs stem height, (c) soil K concentration Vs stem diameter (d) soil K concentration Vs stem height

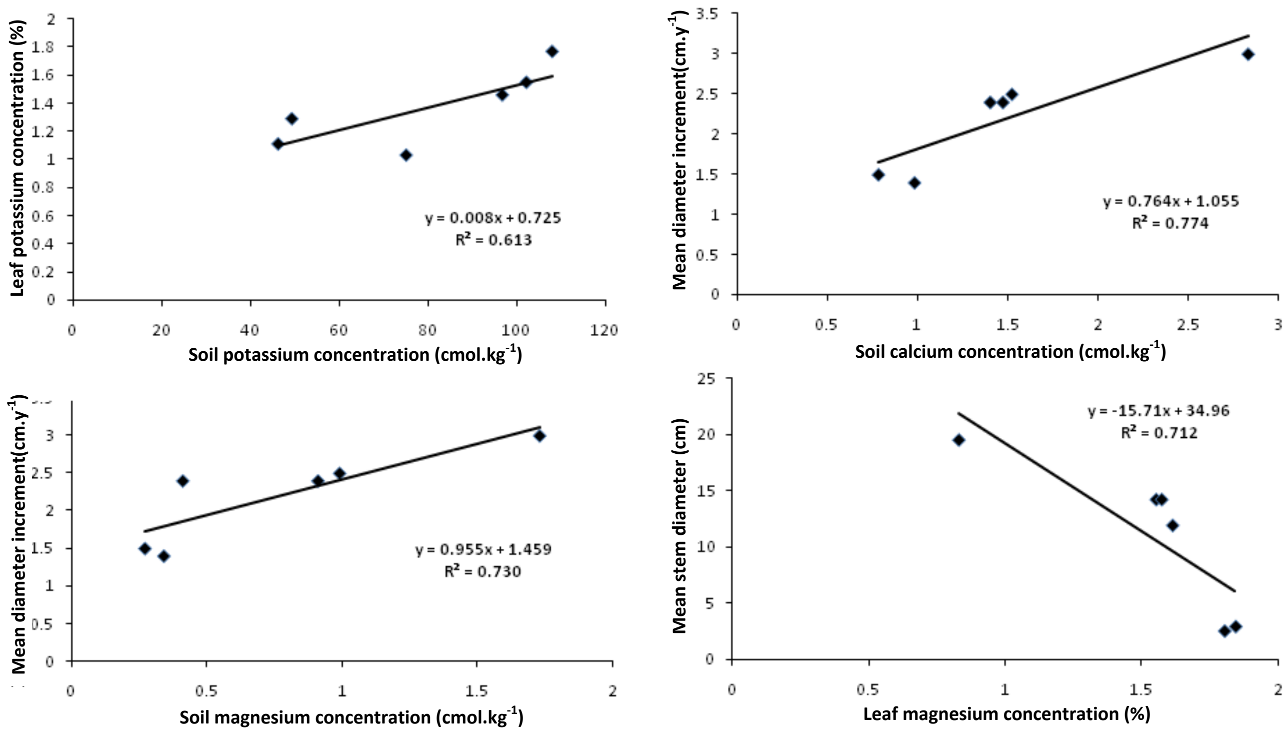

Figure 4. Relationships between leaf nutrient concentration with soil nutrient concentration and growth of *M. gigantea* trees at forest gaps after selective logging. (a) K concentration of soil Vs K concentration of leaf (b) Ca concentration of soil Vs mean of diameter increment, (c) Mg concentration of soil Vs mean of diameter increment, (d) Mg concentration of leaf Vs mean of diameter

In this study, the number of *M. gigantea* trees in forest gaps is varied, depending on the source of seeds and the light intensity. Macaranga seeds defenses are associated with species, light requirement for regeneration (Tiansawat et al. 2014), and canopy openness which positively affects survival probability, while herbivory decreases survival and is highest in understory conditions (Goodale et al. 2014). The highest of mean of diameter and stem height (19.5 cm; 18.07 m) were obtained by *M. gigantea* trees on plot 8 years after selective logging, and then they were declined. The highest of diameter and height increment on *M. gigantea* were obtained on plot 4 years after selective logging and continued to decline until 10 years. In more intensive logged plots, growth rates of trees increased (Ruslandi et al. 2012). Mean diameter of *M. gigantea* in the secondary forest were 3.6 ±2.1cm, 4.6± 2.6 cm, 5.4±3.2 cm, 5.9 ± 3.8 cm after 2, 3, 4, 5 years after fire in Bukit Soeharto Education Forest, East Kalimantan, Indonesia (Hiratsuka et al. 2006).

Pioneer species like *M. pearsonii* and *M. gigantea* can grow with mean of diameter (DBH) of 21 cm and 28 cm, respectively, in 25 years (Verburg et al. 2008), and Nadhirah et al. 2015 reported that maximum diameter (DBH) has been recorded was 77.7 cm and it was recorded at University Technology Malaysia secondary forest. Susanto et al. (2016b) reported that mean of stem diameter was 27.88 cm and mean of stem height was 17.74 m in the secondary forest 6 years after shifting cultivation, mean diameter increment was 2.4±1.4 $cm.y^{-1}$, mean of height increment was 1.8±0.8 $m.y^{-1}$ and mean of volume increment was 0.9±1.1 $m3.ha^{-1}.y^{-1}$. In this study, the highest mean diameter and height were found in forest gaps 8 years after selective logging. In secondary forest after shifting cultivation, mean diameter and mean diameter increment of *M. gigantea* were higher than mean diameter and mean diameter increment in forest gaps after shifting cultivation. The preparation of shifting cultivation with clear-cutting and slash-burn methods affected in the forest gaps and light condition, and it was higher than forest gaps and light condition was better in forest gaps after selective logging in naturally production forest.

Lawrence (2001) reported that N concentration ranged 15 - 20 $mg.g^{-1}$, while phosphor concentration ranged 1.7 to 2.7 $mg.g^{-1}$ in the seedling canopy of *M. gigantea*. On the other hand, Ishida et al.2005 reported that the highest nitrogen concentration of *M. gigantea* leaves which grow naturally was 2.5 $mol.kg^{-1}$ at sapling stratum, 2.0 $mol.kg^{-1}$ at sucker stratum and the lowest nitrogen concentration was found at seedling and mature stratum, namely 1.5 mol.kg-1. Breulmann et al. 2006 also reported that phosphor concentration on Macaranga in the natural forests in Malaysia ranged 0.06% to 0.09%, while potassium content was 0.71% to 0.82%. In secondary forest after shifting cultivation, leaf nutrient concentration of *M. gigantea* was 1.94±0.13% of nitrogen, 0.22±0.08% of phosphor and 0.66±0.27% of potassium (Susanto et al. 2016b). In this study, leaf nitrogen and phosphorus in forest gaps after selective logging were lower than leaf nitrogen and phosphorus in the secondary forest after shifting cultivation. On the other hand, leaf's potassium concentration in forest gaps was higher than leaf's potassium in the secondary forest after shifting cultivation.

The foliar mineral nutrient concentration of the trees generally correlated with the environmental factors such as elevation, topographic position, slope, vegetation type, and soil nutrient status (Chi Wua et al. 2007). In a fire-disturbed urban forest, the foliar N and P concentration could be used as a parameter to assess the nutrient environments of tree species restored (Kim et al. 2015).

Soil's potassium concentration positively correlated with leaf's potassium concentration, with r-value of 0.70, it could be concluded that 70% of the variance of leaf's potassium of *M. gigantea* was affected by soil's potassium concentration variable, while the remaining 30% could be explained by other factors. Nutrient base elements (potassium, calcium, and magnesium) which were 70% to 90% accumulated in aboveground biomass in naturally rain forest in East Kalimantan, Indonesia (Ruhiyat 1993; Meckensen 1999; Meckensen et al. 2001). Sheriff and Miller (1991) reported that total K was the main growth-limiting nutrient in both reserves based on soil and foliar data. Efficient nutrient use was essential for biomass production by tropical trees growing in infertile soils. The P which was used efficiently was more affected by other factors like soil conditions than the use of N efficiently, and the differences in the tree groups significantly affected the use of both nutrients efficiently. Some aspects of the general suitability of Acacia and Eucalyptus species were for tropical plantations in fertile soils (Inagaki and Tange 2014).

In conclusion, the highest of stem diameter and height of *M. gigantea* (19.5 cm; 18.07 m) was obtained in plots 8 years after selective logging, while the highest of diameter increment and high increment obtained in plot 4 years after selective logging. The concentration of nutrients accumulated in the leaf of *M. gigantea* are as follows: N was 1.51 ± 0.19%, P was 0.16 ± 0.01%, K was 1.37 ±0.28%, Ca was 1.78 ±0.43% and Mg was 1.53 ± 0.37%. The soil nutrients concentration of N, K, Ca and Mg correlated with plant growth of *M. gigantea* ($p \leq 0.05$), potassium concentration of soil positively correlated with a potassium concentration of leaves ($p \leq 0.05$), whereas Mg leaf's nutrient concentrations were correlated with plant growth ($p \leq 0.05$).

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