
Research Article

Species composition and above ground biomass of a pine forest at Bodogol, Gunung Gede Pangrango National Park, West Java

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ABSTRACT. Species Composition and Above Ground Biomass (AGB) of a pine forest at Bodogol in Gunung Gede Pangrango National Park (GGPNP) was conducted over three years. A permanent plot of 200 x 50 m² was established and was then divided into 100 subplots sized 10 x 10 m². The highest Important Value was reached for Tusam (*Pinus merkusii*) with IV=140.9, followed by *Calliandra calothyrsus* (94.4) and *Piper aduncum* (28.9). In contrast, the Relative Growth Rate of *C. calothyrsus* was highest compared to other dominant trees. The number was highly contributed by a class distribution of less than 10 cm, generally filled by other species except pine trees, that were found on class distribution of more or equal to 30 cm. The changes of AGB ranged from 247.2 to 328.6 ton ha⁻¹, and the trend of increasing AGB may be attributed to the growth of pine trees. However, it showed that there are significant differences between 2009 and 2010 - 2011 (one way ANOVA, $P < 0.05$).

Keywords: AGB, Gunung Gede Pangrango NP, Relative Growth Rate, *Pinus merkusii*.

INTRODUCTION

Tusam or Sumatran pine (*Pinus merkusii*) is a pine native to the Malesia region in Southeast Asia. In Indonesia, it is mainly found in the mountains of northern Sumatra, with two outlying populations in central Sumatra on mounts Kerinci and Talang. In GGPNP, Sumatran pine was planted to rehabilitate the area mainly in the slope region and this was carried out by the

state forest corporation, Perum Perhutani and local people around the national park.

Above ground biomass (AGB) and carbon storage in the forest ecosystem play an important role in the global carbon cycle (Goodale *et al.*, 2002; Houghton, 2005). Forests as carbon reservoirs store more carbon per unit area than any other terrestrial ecosystem; they may act as an effective measure to mitigate elevated atmospheric carbon dioxide (CO₂) concentration through an increase in forested land. As a member, Indonesia is seeking to implement its commitments under the UNFCCC (United Nations Framework Convention on Climate Change) through nationwide amelioration of forest conditions to increase the level of carbon storage in the forest ecosystem and to reduce carbon emission up to 26%.

The 15,196 ha forest area in the GGPNP was expanded to 21,975 ha (Decree of the Ministry of Forestry No.174/Kpt.s-II/ June 10, 2003). The expanded area included the Perum Perhutani, located on the border of the park and close to residents. Common species found are the Agathis (*Agathis philippinensis*), Tusam (*P. merkusii*) and Kaliandra trees (*Calliandra calothyrsus*). Tusam is a plant that can be used in reforestation as pine has several functions including ecologically protecting land and timber production. In addition, pine is competitive to other plants, whereby it can prevent other plants from growing too close, thus stopping them from taking space and nutrients available (Marisa, 1990).

A few studies have investigated species composition and AGB in the pine forest in GGPNP, with most studies of forest composition and structural patterns concentrating on the mountainous and lowland vegetation of natural forests (Abdulhadi *et al.*, 1998; Sadili *et al.*, 2009; Yamada, 1975; Helmi *et al.*, 2009). Measurement of permanent sampling plots at certain intervals and over a one-year period is required to understand the process in which changes occur at individual and even species levels. However, there are no data on balance between growth, recruitment and mortality. Thus, the objective of the present study is to provide information on composition and AGB of pine forests over a three year period in Bodogol, GGPNP.

METHODOLOGY

Study site

This study was carried out at a lowland pine forest at Bodogol in the Gunung Gede Pangrango National Park (GGPNP), which is

situated at 06°46'5.47" S and 106°51'11.0" E at about 800 m above sea level (asl). The topography of the area is that of a hilly ridge with steep slopes. The characteristic of soil include acidic soil of pH 4.4, 13.8 of C/N ratio, 16 mg (100 g of soil)⁻¹ of phosphor, while other macro nutrients of calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) were respectively 3.7, 1.5, 0.1 and 0.2 cmol (g soil)⁻¹.

According to Schmidt & Ferguson (1957), the climate in the study area belongs to type A with mean annual rainfall of approximately 3121.3 mm ± 131.3 (SE). Based on calculated data of climate for nine years, rainfall tended to be low during the dry season recording 133.3 to 199.2 mm (July to September), while the wettest time is from December to March with rainfall reaching to 414.2 mm in December. The monthly temperature varied from 25.1 to 26.2 °C, with mean monthly temperature of 25.7 °C ± 0.2 (SE). High fluctuation of temperature was recorded in March at 25.1 °C ± 0.6 (SE), as shown in Figure 1.

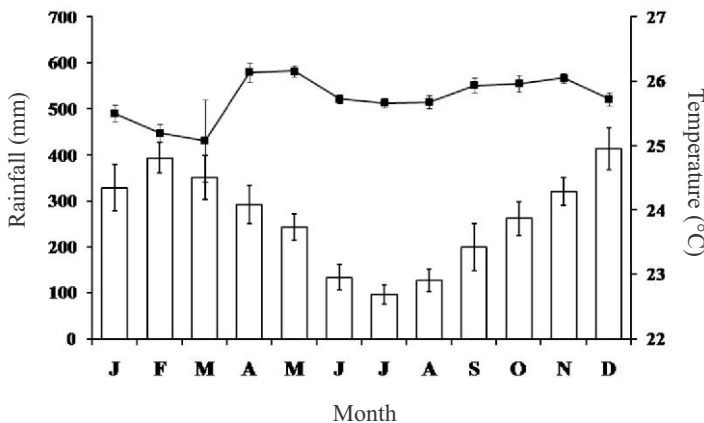


Figure 1. Monthly changes of rainfall (histogram) and temperature (black square) within nine years (2002-2010). Data was collected from a Meteorological Station close to Gunung Gede Pangrango National Park (GGPNP). Data represents as mean ± SE.

Sampling plots

A permanent plot of 200 x 50 m² was established in the pine forest and was divided into 100 subplots of 10 x 10 m² each to allow better control of measurement. The first enumeration of the plot was made in 2009. All trees with girth breast height (gbh) of more or equal to 15 cm were labeled with aluminum tags, identified, measured and recorded on a 1.3 m above ground or above buttress level. Re-measurement two times in 2010 and 2011 were done, and recruitment tree (new individuals growing up to 15 cm in gbh) and dead trees were recorded. A similar measurement was also conducted for all surviving and recruited trees. All species recorded were collected as voucher specimens for further scientific identification.

Data analysis

The density, frequency and dominance of expressed basal area, the relative value and importance value of each species were measured by the equation of Mueller-Dombois & Ellenberg (1972). The growth was calculated based on girth increment of surviving trees, as relative growth rate (RGR) by Kohyama & Hotta (1986), as follows:

$$RGR = (\ln G10 - \ln G09)/t$$

where G09 and G10 are the girth at breast height in the first and the second measurement respectively, and t is period of study in year.

A similar calculation was performed between the second and third year and between the first and third year. Above ground biomass was estimated/calculated using the allometric equation developed by Midgley (2003).

RESULTS AND DISCUSSION

Species Composition

The total number of species recorded in the sampling plot was 29. The total number of individual trees in the sampling plot decreased from 841 trees ha⁻¹ (2009) to 779 trees ha⁻¹ (2011). The total basal area ranged from 33.9 in 2009 to 36.9 m² ha⁻¹ in 2011. The most dominant species in terms of important value (IV) within the three year period was *Pinus merkusii*, which reached about 50% of IV (140.9), followed by *Calliandra calothyrsus* (94.4) and *Piper aduncum* (28.9 of IV) (Table 1). The high IV of pine trees could be attributed to the large stem circumference and its occurrence in all sub-plots. The 23 other species that grow naturally with pine vegetation had an IV lower than 10.

Table 1. Fifteen leading tree species based on Important Value (IV) of pine forest at Bodogol, GGPNP (2009-2011).

No	Species name	Families	IV
1	<i>Pinus merkusii</i> Jungh. & De Vr.	Pinaceae	140.9
2	<i>Calliandra calothyrsus</i> Meiss.	Leguminosae	94.4
3	<i>Piper aduncum</i> L.	Piperaceae	28.9
4	<i>Maesopsis eminii</i> Engl.	Rhamnaceae	9.0
5	<i>Dendrocnide stimulans</i>	Urticaceae	4.6
6	<i>Omalanthus populneus</i> (Geisl.) Pax	Euphorbiaceae	3.6
7	<i>Cecropia peltata</i> L.	Moraceae	2.1
8	<i>Arthocarpus elasticus</i> Bl.	Moraceae	1.7
9	<i>Payena lucida</i> (Don.) DC.	Sapotaceae	1.4
10	<i>Mallotus paniculatus</i> (Lam.) Mull.	Euphorbiaceae	1.1
11	<i>Schima wallichii</i> (DC.) Korth.	Theaceae	1.1
12	<i>Pithecolobium clypearia</i> Bth.	Fabaceae	1.0
13	<i>Bridelia monoica</i> Merrill	Euphorbiaceae	1.0
14	<i>Trevesia sundaica</i> Miq.	Araliaceae	0.9
15	<i>Peronema canescens</i> Jack.	Verbenaceae	0.8

Tree density and relative growth rate

The tree density decrease because the increment of tree density from recruitment was lower than the trees loss to mortality, such as *C. calothyrsus*. The death of this species was 12.5% due to the steep area. The relative growth rate (RGR) of *C. calothyrsus* was highest and could influence the number of individuals despite a small increase in stem diameter RGR. The increase of tree density also was followed by increase of basal area, although the recruited trees were lower than that lost through mortality. Pine trees covered the highest basal area, reaching 89.3 (2011) to 91.0% (2009) of the total basal area in the sampling plot, although the RGR was lower than *C. calothyrsus* and *Piper aduncum* (Table 2). However, the differences both in density and basal area were not significant (ANOVA, $P > 0.05$).

The species that disappeared from the plot occurred at low density (one or two trees per ha), and any cause of mortality might eliminate them from the plots. However, in their absence, they might be replaced by newly recruited trees due to ingrowth. Some of the species found in the plot had low density, only less than one tree per ha, as typically found in a tropical rain forest (Whitmore, 1984).

The mean diameter increment of all species ranged from 0.2 to 1.0 cm yr⁻¹. This range value is comparable to those reported in some tropical rain forests in Southeast Asia (Nicholson, 1965; Manokaran & Kochummen, 1993; Sist *et al.*, 2002), but a bit lower compared to the Amazonian rain forest (Nebel *et al.*, 2001; Silva *et al.*, 2002; Laurence *et al.*, 2004). Some of the previous studies reported that the growth pattern was highly dependent on tree size. Based on absolute growth rate, it was found that big trees tended to have quicker growth as larger trees occupy the canopy and have more energy supply and higher photosynthetic rates. Some studies on pine tree areas showed that only several trees could grow under the pine canopy as pine leaf litter on the ground produce allelopathy substrates that inhibit tree growth (Marisa, 1990).

Forest structure

In three years, the number of individuals decreased and showed similar trends in a higher diameter class of 40-50 cm (Figure 2). The number was highly contributed by the class distribution of less than 10 cm, which was generally filled by other species of pine, while pine trees were found on class distribution of more or equal to 30 cm.

Table 2. Relative Growth Rate (RGR) of 15 leading species in year 2009, 2010 and 2011.

No	Species name	RGR		
		2009-2010	2010-2011	2009-2011
1	<i>Calliandra calothyrsus</i> Meiss.	34.87	11.74	44.37
2	<i>Piper aduncum</i> L.	5.48	2.37	7.85
3	<i>Pinus merkusii</i> Jungh. & De Vr.	5.53	2.12	7.65
4	<i>Maesopsis eminii</i> Engl.	3.96	0.96	4.91
5	<i>Dendrocnide stimulans</i>	1.25	0.36	1.47
6	<i>Cecropia peltata</i> L.	0.90	0.15	1.05
7	<i>Pithecolobium clypearia</i>	0.56	0.07	0.58
8	<i>Trevesia sundaica</i> Miq.	0.36	0.08	0.44
9	<i>Arthocarpus elasticus</i> Bl.	0.09	0.29	0.38
10	<i>Bridelia monoica</i> Merrill	0.08	0.27	0.35
11	<i>Payena lucida</i> (Don.) DC.	0.27	0.04	0.31
12	<i>Ficus fluva</i> Reinw. ex Blume	0.20	0.04	0.24
13	<i>Ficus</i> sp.	0.03	0.20	0.24
14	<i>Schima wallichii</i> (DC.) Korth.	0.19	0.03	0.22
15	<i>Symplocos fasciculata</i> Zoll.	0.14	0.02	0.16

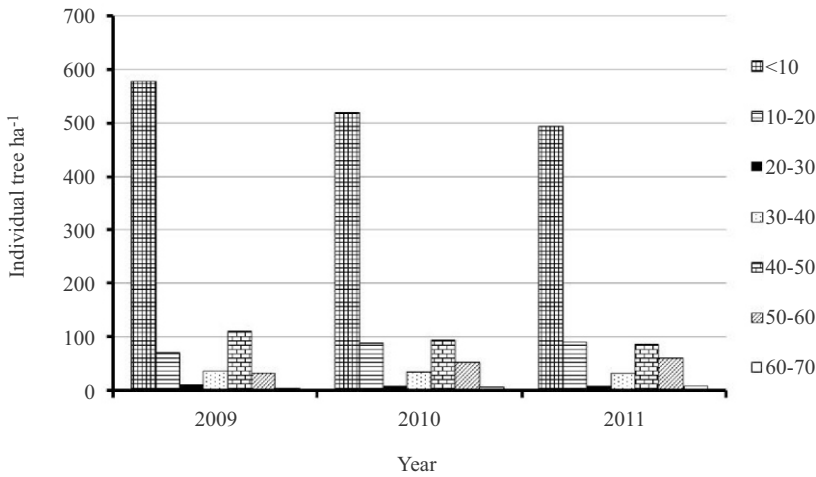


Figure 2. Diameter distribution in the respective years of 2009 to 2011 in pine forest of GGPNP.

In horizontal (diameter) and vertical (height) structures, almost no tree species except pine, had parameters larger than pine trees due to the characteristics of non-shaded tolerant species. No significant differences were found in structures over three years (ANOVA, $P > 0.05$), although the number of individuals decreased over time.

Above ground biomass

From the measured variables, the diameter and height and the above ground biomass (AGB) of each tree was calculated. Then, AGB of all trees was summed up to estimate the AGB of each tree for each measurement (Figure 3). The

changes of AGB ranged from 247.2 to 328.6 tonne ha^{-1} , and the trend of increasing AGB may be attributed to the growth of pine trees. However, it showed that there are significant differences between 2009 and 2010-2011 (ANOVA, $P < 0.05$). Most species showed smaller change, lower than one tonne ha^{-1} in AGB during the three year period, indicating that carbon uptake by these species was limited over that period.

Compared to other tropical regions, it showed that the AGB, in the present study, was lower than the AGB formula used by Brown (1997) and Chave *et al.* (2005). The similar pattern of estimating AGB for all individual trees is shown in Figure 3.

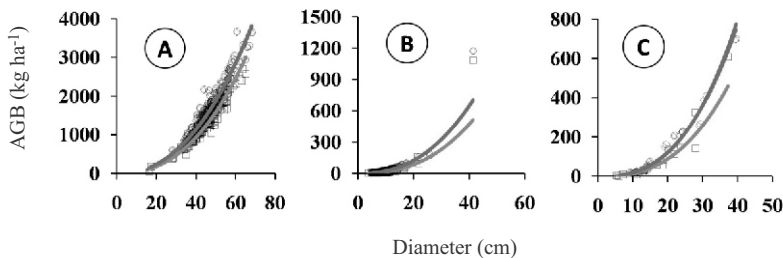


Figure 3. The biomass estimation of trees in the respective years of 2009, 2010 and 2011 at pine forest of GGPNP. Green line represents the estimation of AGB in the present study, while the brown and blue lines indicate the estimation of AGB by Chave *et al.* (2005) and Brown (1997), respectively.

The pine tree contributed high AGB over three years compared to other species, ranging from 238.4 to 315.3 tonne ha⁻¹, followed by *Calliandra calothyrsus* (4.96 to 7.50) and *Maesopsis eminii* (1.69 to 2.78 tonne ha⁻¹) (Figure 4). High contribution of AGB was highly affected by diameter and height variables, and even some studies related to specific gravity value of species (Ketterings *et al.*, 2001; Chave *et al.*, 2005).

Significant differences between years, 2009 and 2010-2011, in each species was found

only in pine trees (one way ANOVA, $P < 0.05$). The similar pattern of estimating AGB for each dominant species is shown in Figure 4. The trend line of each equation is listed in Table 3 with high correlation coefficient (R^2). High value R^2 could be influenced by the class distribution of each species, as all species had the highest value. For the dominant contribution species, it is clear that the African tree (*M. eminii*) had higher value compared to the other two species, suggesting the fitting formula would be more fixed if the class diameter was randomly distributed.

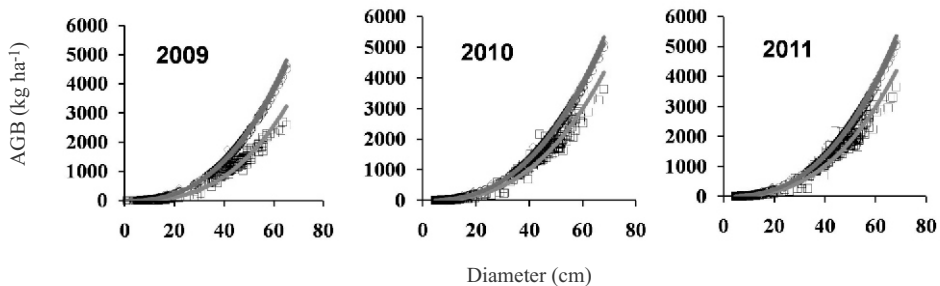


Figure 4. The high contribution of AGB in the respective years of 2009, 2010 and 2011 at pine forest of GGPNP. A. *Pinus merkusii*, B. *Calliandra calothyrsus* and C. *Maesopsis eminii*. Line types as in Figure 3.

Table 3. The equation for estimating above ground biomass (AGB) in pine forest at Bodogol, GGPNP (2009-2011).

No	Species Name	Equation	R^2
1	<i>Pinus merkusii</i>		
	2009	$AGB = 0.132 D^{2.399}$	0.934
	2010	$AGB = 0.258 D^{2.274}$	0.931
2	<i>Calliandra calothyrsus</i>		
	2009	$AGB = 0.047 D^{2.493}$	0.850
	2010	$AGB = 0.097 D^{2.388}$	0.857
3	<i>Maesopsis eminii</i>		
	2009	$AGB = 0.032 D^{2.643}$	0.954
	2010	$AGB = 0.042 D^{2.659}$	0.972
4	All species		
	2009	$AGB = 0.027 D^{2.79}$	0.983
	2010	$AGB = 0.056 D^{2.654}$	0.985
	2011	$AGB = 0.055 D^{2.660}$	0.985

CONCLUSION

The changes in density and basal area in the pine forest were a bit lower than those found in several other tropical forests. The differences were probably due to more species have entered the plot and more recruited trees passing the minimum diameter limit. The vegetation in the pine forest maintains its diversity, structural features and above ground biomass, and even carbon storage over the period of study. A longer period of monitoring with regular measurements is necessary to clarify these trends.

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