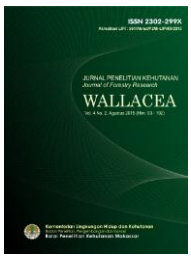

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ALTITUDINAL GRADIENT AFFECTS ON TREES AND STAND ATTRIBUTES IN MOUNT CIREMAI NATIONAL PARK, WEST JAVA, INDONESIA

(Gradien Ketinggian Memengaruhi Pohon dan Atribut Tegakan di Taman Nasional Gunung Ciremai, Jawa Barat, Indonesia)

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ABSTRACT

Understanding the effect of altitude on trees and stand attributes of tropical forests is crucial for the development of effective management and conservation strategies. However, study on this issue in Mount Ciremai National Park is still lacking. A total of 136 plots were set on the eastern slope of Mount Ciremai in Mount Ciremai National Park and investigated in six different altitudes: 500 m a.s.l., 840 m a.s.l., 1,300 m a.s.l., 1,400 m a.s.l., 1,780 m a.s.l., and 2,530 m a.s.l. The objective of this study was to analyze the effect of altitude to trees and stand attributes i.e. species and family richness, tree density, basal area, and tree biomass. The changes on trees and stand attributes to altitudinal gradient were analyzed using regression analysis. The result showed that tree species number, family number, tree basal area, and tree biomass significantly declined with increasing altitude, meanwhile tree density significantly increased with increasing altitude. These findings indicate a distinct effect of altitude on tree and stand attributes in Mount Ciremai National Park.

Keywords: Mount Ciremai National Park, tree density, tree basal area, tree biomass

ABSTRAK

Memahami pengaruh ketinggian terhadap pohon serta atribut tegakan untuk hutan tropis merupakan hal yang penting untuk pengembangan strategi konservasi dan pengelolaan hutan yang efektif. Namun demikian, informasi tentang analisis tersebut di Taman Nasional Gunung Ciremai masih kurang tersedia. Sebanyak 136 plot di Gunung Ciremai diteliti pada enam ketinggian yang berbeda: 500m dpl., 840m dpl., 1.300m dpl., 1.400m dpl., 1.780m dpl., dan 2.530m dpl. Tujuan dari penelitian ini adalah untuk menganalisis pengaruh ketinggian terhadap pohon dan atribut tegakannya yaitu jumlah jenis, jumlah suku, luas bidang dasar, kerapatan pohon dan biomassa pohon. Analisis yang digunakan menggunakan analisis regresi terhadap parameter pohon dan atribut tegakannya. Hasil yang diperoleh menunjukkan bahwa jumlah spesies, jumlah suku, luas bidang dasar dan biomassa pohon secara signifikan menurun seiring dengan kenaikan ketinggian, sementara itu kerapatan pohon secara signifikan naik seiring kenaikan ketinggian. Temuan ini mengindikasikan bahwa terdapat pengaruh yang berbeda dari ketinggian terhadap pohon dan atribut tegakan di Gunung Ciremai.

Kata kunci: *Kerapatan pohon, luas bidang dasar, biomassa pohon, Taman Nasional Gunung Ciremai*

I. INTRODUCTION

Altitude is a well known factor affecting structure and species composition in mountain vegetation (Rahbek, 1995; Siebert, 2005; Slik *et al.*, 2009; Kromer *et al.*, 2013). Beside altitude, several factors are also known to shape structure and species composition, for example energetic constraints on primary productivity and species-area relationships (Romdal and Grytnes, 2007). These factors are highly correlated because species richness patterns and composition are the result of both historical evolutionary and also ecological dynamics forces (Rangel and Diniz-Filho, 2005; Alexander *et al.,* 2011). Furthermore, for the mountain vegetation, edaphic changes are also important. These edaphic changes are often abrupt and affect structure and species composition (Siebert, 2005; Malhi *et al.*, 2010).

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Mount Ciremai is one of the active volcanoes located in West Java, Indonesia. This mountain is the highest mountain in West Java which the top reach 3,078 m a.s.l. whilst the lowest forested area is 500 m a.s.l. Several studies of various field aspects have been conducted in this mountain area such as hydrogeology of the mountain (Irawan *et al*., 2009), management and zonation in the buffer area (Bismark *et al*., 2007), the history of mountain activity and its impact to the surrounding area (Pratomo, 2008), geological structure of the mountain (Samodra, 2008), and herpetofaunal community (Riyanto, 2011). Nevertheless, as a new national park in Indonesia (declared in 2004), the analysis of how altitudinal gradient affect tree and stand attributes from the lowest forested area (500 m a.s.l.) to the subalpine zone (>2.400 m a.s.l.) on this mountain is still lacking. Only few number of vegetation studies have been conducted in this mountain, for example a vegetation study at the border area at elevation 500 m a.s.l. (Gunawan, 2007) and a tree diversity study in submontane zone at elevation 1,100 m a.s.l. (Junaedi, 2008).

A better understanding of altitudinal effect is one of the crucial knowledge for the development of an effective conservation and management system. Furthermore, the knowledge about that effect may also be required to solve ecological problem for biological conservation and management purposes, to monitor management practices or to provide prediction for possible future changes (Kent and Coker, 1992). Hence, the objective of this study is to describe the effect of altitudinal gradient to tree and stand attributes which are species and family number, tree density, tree basal area, and tree biomass in Mount Ciremai National Park.

II. MATERIALS AND METHODS

A. Study sites

The study was carried out in 2005, 2007, and 2009 in Mount Ciremai National Park, West Java, Indonesia. Mount Ciremai National Park is located within geographical position of 108°20' – 108°40' East Longitude and 6°40' – 6°58' South Latitude. The top of the mountain formed a conical shape with elevation reach 3,078 m a.s.l. and be the highest mountain in West Java Province, Indonesia. Topographically, around 26.52% of the area has 0°– 8° in slope, and 73.48% has slope more than 8°. Administratively, the area was located in two regency in West Java Province, which are Kuningan Regency in East side and Majalengka Regency in West side of the mountain. This research was carried out only in Kuningan Regency (Darma and Linggarjati tracks). The National Park was covering 15,500 hectares with 8,700 hectares located in Kuningan Regency and the rest 6,800 hectares in Majalengka Regency. Based on Schmidt and Ferguson climate classification type, Mount Ciremai National Park has B and C climate type with 2,000 – 4,000 mm annual rainfall and 18° – 22°C in air temperature.

B. Study design and data collection

Tree composition was inventoried in six different altitude areas which are 500 m a.s.l., 840 m a.s.l., 1,300 m a.s.l., 1,400 m a.s.l., 1,780 m a.s.l., and 2,530 m a.s.l. The transect lines were established parallel with mountain topography at each altitudes. In each transect line, we established 10 m x 10 m plots, except in the 500 m a.s.l. we established 20 m x 20 m. The total number of plot established was 136 plots (Table 1). Inventories included tree species identification and measurement of tree diameter at breast height (D) of all trees larger than 10 cm in each plot. All identified species names were standardized using The Plant List (www.theplantlist.org).

C. Data Analysis

To analyze the effect of altitude on tree and stand attributes (species and family number, tree density, tree basal area, and tree biomass), we applied regression analysis (polynomial regression or calibration model) using STATGRAPHIC® CENTURION XV software. The polynomial regression procedure is designed to construct a statistical model describing the impact of single quantitative factor X (altitude of plots) on a dependent variable Y (species and family number, tree density, basal area, and tree biomass). A polynomial model involving X and power of X is fit to the data. Tests were run to determine the proper order of the polynomial.

To estimate tree biomass, we used allometric equation developed by Chave *et al*. (2005). The formula that we used is for the wet forest equation as this better approximates the above ground biomass of montane forests (Slik *et al*., 2010) which is:

Tree Biomass = ρ x exp(-1.239 + 1.980ln(D) + 0.207(ln(D))^2 – 0.0281)ln(D))^3)

Where ρ is wood specific gravity and D is tree diameter of breast height.

To determine wood specific gravity (*ρ)*, we used the value of oven-dry wood density at 15% of moisture content for each species from Wood Density Database provided by World Agroforestry Center. If species were not found in the database, we used the genus-level average to estimate the species value since it has been shown that genus-level average captured up to 70% of wood density variability in Indonesia tree species (Slik, 2006).

Total tree biomass per hectare for each altitude was calculated by summing tree biomass estimation of all trees in each altitude and dividing this estimation by the total survey area sampled in each altitude (Table 1).

Table 1. The number of plots and total area of plots in six transect lines of the study
Tabel 1. *Jumlah total plot dan total luasan plot pada enam garis transek penelitian*

Transect [Transek]	Size of transect (panjang transek) (m)	Altitude [Ketinggian] (m a.s.l.)	Plot size [Ukuran plot] (m x m)	Number of plot [Jumlah plot]	Total area of plots [Luasan plot] (hectare)
1	420	500	20 x 20	21	0.84
2	250	840	10 x 10	25	0.25
3	250	1,300	10 x 10	25	0.25
4	300	1,400	10 x 10	30	0.30
5	250	1,780	10 x 10	25	0.25
6	100	2,530	10 x 10	10	0.10
		Total		136	1.99

III. RESULTS AND DISCUSSION

Tree and stand attributes varied on each altitudinal gradient in Mount Ciremai National Park (Table 2). Species and family number were higher in lower than in higher altitudes. The highest species and family number were observed in the altitude of 500 m a.s.l. reaching 53 species belongs to 24 families. Meanwhile, the highest tree density was observed in the altitude of 1,780 m a.s.l. reaching 900 trees ha^{-1}. The highest tree basal area and tree biomass were found in the altitude of 500 m a.s.l. reaching 55.24 m^2 ha^{-1} for basal area and 496.9 ton ha^{-1}, respectively.

Species number in Mount Ciremai National Park gradually decreased with increasing altitude (Fig. 1.a.; R^2=0.89, d.f.=1, $p<0.05$). A similar finding was found for family number (Fig. 1.b.; R^2=0.82, d.f.=1, $p<0.05$). This finding was in accordance with the theory that the number of woody species in tropical forests tends to decrease with increasing altitude and latitude (Rahbek, 1995; Aiba and Kitayama, 1999; Givnish, 1999; Acharya *et al.,* 2011; Kraft *et al*., 2011). Forests at higher elevations tends to have less species number because they have smaller species pools reflecting more severe past disturbance (Aiba *et al*., 2005; Oommen and Shanker, 2005). The decline in species richness due to higher altitudes in Mount Ciremai National Park (Fig. 1.a.) was similar with a pattern observed in Mount Kerinci in Sumatra and Mount Pangrango in Java (Ohsawa, 1991), Mount Kinabalu in Borneo (Kitayama, 1992; Aiba and Kitayama, 1999), Dongling Mountains in China (Ren *et al.,* 2006), Subansiri in Eastern Himalaya (Behera and Kushwaha, 2007), and Lore Lindu National Park in Central Sulawesi (Culmsee and Pitopang, 2009).

Tree density in Mount Ciremai National Park gradually increased with increasing altitude (Fig. 1.c.; R^2=0.76, d.f.=1, $p<0.05$). This finding was similar with the result in Selangor Peninsular Malaysia (Nakashizuka *et al*., 1992), Mount Gadut West Sumatera (Nishimura *et al*., 2006), and Borneo forests (Slik *et al*., 2010). A deviation from this pattern can be observed at altitude 2,530 m a.s.l. Tree density was decreased from 900 tree ha^{-1} at altitude 1,780 m asl to 550 trees ha^{-1} at altitude 2,530 m a.s.l. Compared to Mount Kinabalu (Kitayama, 1992) at the similar range of altitude (500 m a.s.l. to 2,500 m a.s.l.), tree density in Mount Ciremai National Park was higher than tree density in Mount Kinabalu. Tree density in Mount Ciremai National Park was found 598 trees ha^{-1}, whereas in Mount Kinabalu, tree density was found 524 trees ha^{-1}.

Table 2. Tree and stand attributes in Mount Ciremai National Park
Tabel 2. *Pohon dan atribut tegakan di Taman Nasional Gunung Ciremai*

Altitude [Keting-gian] (m asl.)	Plot Number [Jumlah plot]	Species Number [Jumlah jenis]	Family Number [Jumlah suku]	Tree Density [Kerapatan pohon] (tree ha^{-1})	Tree Basal Area [Luas bidang dasar pohon] (m^2 ha^{-1})	Tree Biomass [Biomassa pohon] (kg ha^{-1})	Max. DBH (cm)
500	21	53	24	344	55.24	496,857	130.0
840	25	35	22	464	42.44	289,575	102.5
1,300	25	35	19	724	25.88	195,626	70.6
1,400	30	31	17	610	36.18	248,950	88.2
1,780	25	30	20	900	35.00	254,191	60.3
2,530	10	8	7	550	21.20	62,782	23.5

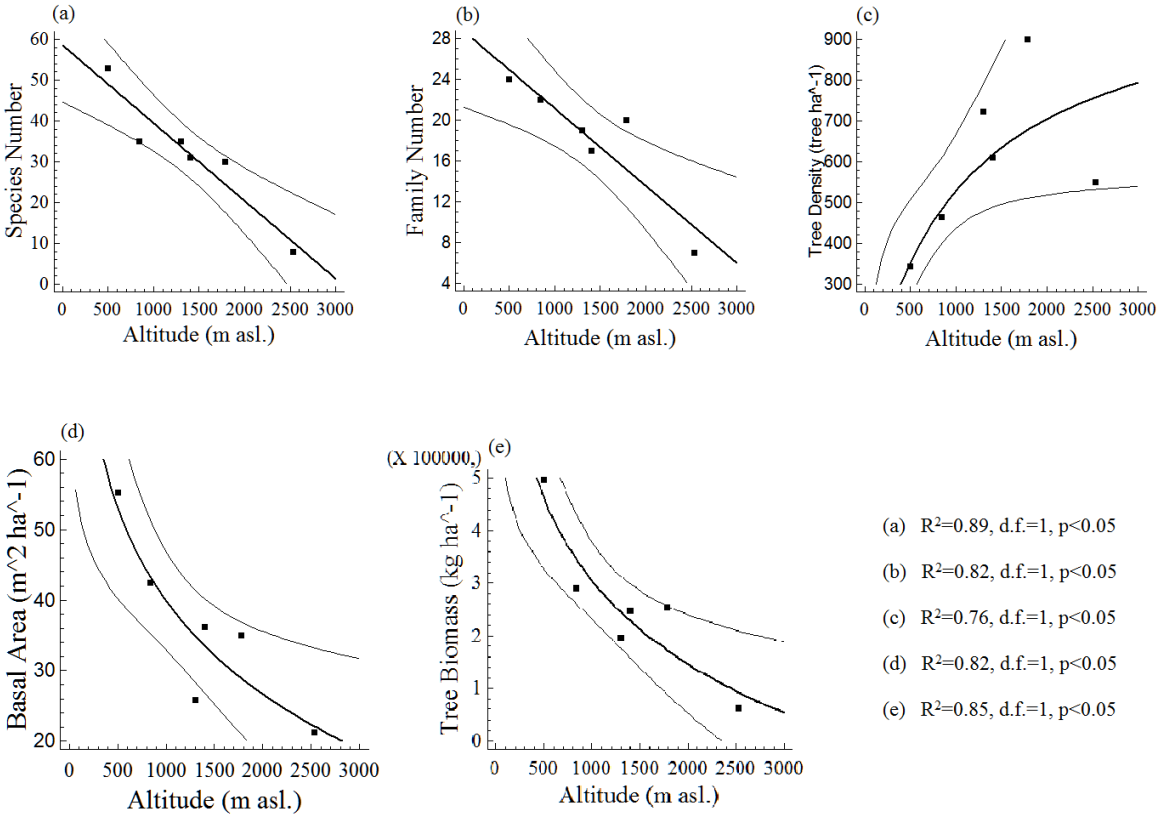

Figure 1. Tree and stand attributes in Mount Ciremai National Park, Indonesia; regressions analysis between altitude and (a) species number, (b) family number, (c) tree density, (d) basal area, and (e) tree biomass.
Gambar 1. *Pohon dan atribut tegakan di Taman Nasional Gunung Ciremai, Indonesia; analisis regresi antara ketinggian dan (a) jumlah spesies, (b) jumlah suku, (c) kerapatan pohon, (d) bidang dasar, dan (e) biomassa pohon.*

Tree basal area in Mount Ciremai National Park was negatively related to altitude (Fig. 1.d., R^2=0.82, d.f.=1, p<0.05). This finding was contradicted with Borneo's forests where basal area increased with increasing altitude (Slik *et al*., 2010). Basal area values in Mount Ciremai National Park were observed from 21.2 m^2 ha^{-1} (at 1,530 m a.s.l.) to 55.24 m^2 ha^{-1} (at 500 m a.s.l.). This value was relatively lower than in Mount Kinabalu at altitudes between 500 m a.s.l. and 2,600 m a.s.l. (Kitayama, 1992). Kitayama's result (1992) showed the lowest value of basal area was 27.5 m^2 ha^{-1} (at 1,000 m a.s.l.) and the highest value of basal area was 59.5 m^2 ha^{-1} (at 2,600 m asl). This result indicates that trees in Mount Ciremai National Park have smaller diameter sizes compared to those in Mount Kinabalu. The possible explanation regarding this different result because species patterns and structures were the result of both contemporary-historical ecological and evolutionary forces (Cannon *et al*., 2008; Alexander *et al.,* 2011), for example the type and the disturbance history of the mountain are different. Mount Kinabalu is not a volcanic mountain; meanwhile Mount Ciremai is a volcanic mountain that erupted in 1937. Therefore, those factors should be acted as the drivers for these differences between Mount Ciremai and Mount Kinabalu.

Tree biomass in Mount Ciremai National Park tend to decreased with increasing altitude (Fig. 1.e., R^2=0.85, d.f.=1, p<0.05). This result was similar with the results found in tropical mountain forest of Ecuador (Leuschner *et al.*, 2007). However, this result contradicted with Borneo's and Atlantic moist forests, where a positive correlation between altitude and above-ground biomass was reported (Slik *et al*., 2010, Alves *et al.*, 2010). The value of biomass in Mount Ciremai was lower than the value of the Borneo's forests (Slik *et al*., 2010) and Amazonian forests (Malhi *et al*., 2006). In Mount Ciremai National Park, the average of tree biomass accounted for 258 ton ha^{-1}, whereas mean values of Borneo's and Amazonian forests were 457.1 ton ha^{-1} and *c.* 288.6 ton ha^{-1}, respectively.

The results of this study showed that altitude has significant effects on tree and stand attributes. This study also underlines the high importance for nature conservation of the entire Mount Ciremai National Park's forests. At the higher altitude, even though they have lower diversity compared to lower altitudes, but it might have and play important role as they might have endemic and rare species that requires more specific habitat to grow. Furthermore, there is a special need for conservation management efforts in the lower altitudinal zones especially at the border of the National Park (500 m a.s.l.). These areas should be of highest priorities for nature conservation because species and family richness is much higher in the lower zones compared to higher altitudes. Moreover, the lower altitude zones are most threatened, while the forest threats gradually decline with increasing altitude.

IV. CONCLUSION

Tree and stand attributes in Mount Ciremai National Park follows general pattern of flora as the effect of altitudinal gradient. Tree species and family richness, tree basal area, and tree biomass significantly declined with increasing altitude, meanwhile tree density significantly increased with increasing altitude.

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