Sub-population survey of *Dipterocarpus retusus* Bl. in Mount Gede Pangrango National Park

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Abstract. Dipterocarpaceae are globally important tree family due to its conservation status. Most of Dipterocarpaceae in Java are distributed in lowland area. However, several species exist in higher altitude such as Gede Pangrango National Park (GPNP) area. All Dipterocarpaceae species in GPNP are vulnerable or endangered based on IUCN Red List status. Dipterocarpaceae species are main priorities for plant conservation in GPNP. In this study we conducted early survey of *Dipterocarpus retusus* Bl. sub-population in Bodogol area (northwest slope of GPNP) at elevation 800-1000 m above sea level. We searched *D. retusus* individuals along trail in the Bodogol area from forest exterior towards forest interior. The sub-population of *D. retusus* detected in mixed forests that dominated by emergent Fagaceae species (*Castanopsis argentea*). Positive correlation between diameter and height may reflect low disturbance rate in Bodogol forest area. We also found negative effect of habitat elevation toward plant height, which mean that the centre of sub-population located in the lower elevation part of the sampling location. This study signifies the importance of Bodogol forest area that contain globally important Red List plant species.

Keywords: Bayesian, mountain forest, endangered species, plant conservation, trait-based ecology

1. Introduction

Palahlar gunung (*Dipterocarpus retusus* Bl.) is a globally important tree species due to its conservation status [1]. Indonesia contain the highest diversity of Dipterocarpaceae with totally four Dipterocarp species were found in Java and three out of four Dipterocarp species in Java are naturally distributed in western part of Java such as Gede Pangrango National Park (GPNP) area [1]. These three species are *Dipterocarpus hasseltii*, *Dipterocarpus retusus* and *Dipterocarpus gracilis* [1]. All Dipterocarpaceae species in GPNP are vulnerable or endangered based on IUCN Red List status [1, 2, 3, 4]. *D. hasseltii* and *D. retusus* Red List status are EN (Endangered). Red list status of *D. gracilis* is VU (Vulnerable) [2, 3, 4]. Thus, Dipterocarpaceae species are main priorities for plant conservation in GPNP [5, 6, 7].

Bodogol forest areas are transition zone between lowland and highland (mountainous) forests in GPNP [5]. At 800 m above sea level, Bodogol forests are relatively intact and the tree diversity is dominated by lowland tree species [5]. Bodogol forests area consists of 70 plant species of 30 families with tree density equal to 350 trees per hectares and dominated by Euphorbiaceae and *Schima wallichii* [6]. As many as 37 out of 70 recorded species in Bodogol forests area were not reported in previous studies of GPNP plant diversity [7].
There were several reports about Dipterocarpaceae records in Bodogol forests [6, 7]. The occurrence of Dipterocarpus hasseltii in Bodogol reported by Helmi et al. [6], but there was no further study about this species since D. hasseltii was detected outside the study plot. Furthermore, according to Ismail in Helmi et al. [6], there were two other Dipterocarp species detected in Bodogol (Anisoptera costata and Vatica sp.). The D. retusus sub population detection in Situ Gunung reported by Kalima and Wardani [7]. They surveyed 5 individual trees, 4 saplings, and 11 seedlings of D. retusus in Situ Gunung [7]. However, records and population studies of D. retusus in Bodogol has not been conducted yet. Population studies of D. retusus in GPNP, particularly Bodogol, are crucial due to its important conservation status.

The aims of this study are: a) to survey sub-population of D. retusus in Bodogol forest area, b) to examine the correlation between height and diameter, height and habitat elevation, and diameter with habitat elevation of surveyed D. retusus in Bodogol forest area.

2. Methods

2.1. Location
This study conducted in Gede Pangrango National Park area, in Bodogol forests area. Bodogol forests were located in the northwest slope of Mount Gede-Pangrango. Generally, Bodogol forest are mixed forests and dominated by Castanopsis argentea as its emergent tree. Bodogol forests consists of hilly topography and plane area with elevation between 450 and 3019 meters above sea level (asl). The survey in this study was conducted in Bodogol forest areas from 800 m asl to 1000 m asl. Bodogol forest zonation consists of sub-montane, montane, and sub-alpine. These forests area are border between upper lowland forests and lower sub-montane forests. Dominant tree species in this area are Altingia excelsa, Agathis dammara, Maesopsis eminii, Schima wallichii, Calliandra calothyrsus, and Pinus merkusii [8].

2.2. Plot setting
The survey conducted in an observation strip (single plot) area that covered 6 hectares in total. We searched D. retusus along trail in the Bodogol area, as long as 3 km and 20 m wide. We searched the individuals of D. retusus from the forest edge into the forest area of Bodogol.

2.3. Data collection
When we found adult trees, seedling or juvenile of D. retusus, we measured its height and diameter breast height (dbh) of the tree trunk (for adult trees), and trunk diameter for seedling and juvenile. We also recorded GPS coordinate data, and habitat abiotic factors of surveyed D. retusus. These abiotic factors are soil acidity, soil humidity, air temperature, and air humidity.

2.4. Data analysis
Bayesian linear regression model conducted to examine the correlation between: a) trunk diameter and tree height of D. retusus. (1); b) tree height and habitat elevation of D. retusus (2); and c) trunk diameter and habitat elevation of D. retusus (3). Bayesian linear regression analysis conducted in R [9] using package rjags to call JAGS from R and Rstudio [10]. These three models (1), (2), and (3) are formulated as following:

\[ y_{i0} = a_0 + b x_{i0} + \epsilon_i \] (1)
\[ p_{i0} = c_0 + d q_{i0} + \epsilon_i \] (2)
\[ m_{i0} = e_0 + f n_{i0} + \epsilon_i \] (3)

where \( y_{i0} \) and \( p_{i0} \) refers to height, and \( m_{i0} \) refers to trunk diameter of species \( i \) respectively. While \( x_{i0} \) refers to diameter and \( q_{i0} \) and \( n_{i0} \) refers to habitat elevation.
Bayesian analysis used in this study to cope with limited data samples from survey records. By using Bayesian method, we simulate (using Markov Chain Monte Carlo, MCMC simulation) the plausible data distribution and its uncertainties based on the available data. In the Bayesian analysis in this study, we used naive priors with normal distribution and set the standard deviation to 0.01. We centered the explanatory variable values by subtracting it with its mean value. The MCMC simulation conducted for 1 million iterations with burn in phase of the first 500 thousand iterations and conducted using 3 chains. The R code for all three Bayesian analyses provided in Appendix A, B, and C.

![Figure 1](image.png)

**Figure 1.** The composition of total surveyed *D. retusus* within the survey plot. Class A: dbh < 5 cm, class B: 5 cm < dbh < 10 cm; class C: 10 cm < dbh < 20 cm, class D: 20 cm < dbh < 30 cm, and class E: dbh > 30 cm.

3. Result and discussion
We found 4 trees, 3 small trees, 2 saplings, and 38 seedlings (figure 1). The *D. retusus* sub-population occurs in mixed forests that dominated by emergent Fagaceae species (*Castanopsis argentea*). We did not find other *D. retusus* population beyond 950 m above sea level in this forest area.

Based on figure 1, the diameter class of surveyed *D. retusus* have reverse “J” shape. According to Daniel *et al.* [11], reverse “J” shape of tree population class diameter indicates the normal and stable composition of those tree species population composition.

Based on the analysis conducted, we detected the positive correlation between height and trunk diameter of *D. retusus* and the negative correlation between height and habitat elevation (table 1). We did not detect significant correlation between trunk diameter and habitat elevation. Predicted *D. retusus* diameter based on its height presented in figure 2.

| Model                                      | Coefficient | 95% CI            |
|--------------------------------------------|-------------|-------------------|
| *Height vs Trunk diameter (e1)             | 1.141       | [1.021, 1.262]    |
| *Height vs Habitat elevation (e2)          | -0.140      | [-0.219, -0.060]  |
| Trunk diameter vs Habitat elevation (e3)    | -0.054      | [-0.127, 0.019]   |

**Table 1.** Bayesian regression results for all analyzed models (e1, e2, and e3) of studied *D. retusus* sub-population. The first and the second values in 95% CI brackets are the lower and upper limit of those 95% credible interval. Effect of independent variables were detected when 95% credible interval did not contain zero value. Detected effect model marked by asterisk (*).
Figure 2. (A) Predicted *D. retusus* height (blue line) based on its trunk diameter (1), (B) predicted *D. retusus* height (blue line) based on habitat elevation (2), and (C) Predicted *D. retusus* diameter (blue line) based on habitat elevation (3). Blue lines represent the model predictions. Dots are real data measurement values. Grey areas around the model regression line represent model uncertainties (95% credible intervals based on Bayesian analysis results).

Detected correlation between height and diameter of *D. retusus* reflects three insights. Firstly, height-diameter model result in this study is an informative model to predict *D. retusus* height based on its diameter. Height-diameter model is common analysis in planted tree contexts or natural tree stands. Height-diameter correlation were vary along species, landscape, stand density, and ecosystem types [13]. Secondly, detected positive correlation between height and diameter in this study may reflect that *D. retusus* in this study site may exposed to a minimum external threat. This finding may be an indicator of effective conservation activity in GPNP, including Bodogol, to conserve important plant species such as *D. retusus*. However, the population structure of *D. retusus* in Bodogol shows that there is a big gap between seedling numbers and juvenile/sapling/tree population. These may indicate that seedling survival rates of *D. retusus* are relatively low. Thirdly, significant positive correlation on height-diameter model may be a sign for good resilience capacity of *D. retusus* trees from natural disturbance in this ecosystem. There were several massive wind storms occurred in GPNP during the past [14] and may also occurred in Bodogol area.

In general, abiotic factors may contribute to *D. retusus* seedling survival. Firstly, Dipterocarp seedlings are shade tolerant and can survive under competition with lower forest layer species [15]. However, at further development stage of the seedlings, *D. retusus* is a light tolerant species. Therefore, a *D. retusus* seedling will grow to its maximum height when it located in a forest with lower tree density figures. Their survival and growth rates were depended on canopy gap existence and light availability. The absence of canopy gap and dense shade may cause the low survival of *D. retusus* seedlings that need sufficient amount of light to grow and survive. Thus, light resources limitation may cause a big gap of individual numbers between seedlings and bigger diameter class individuals (small trees and trees). Secondly, water is a crucial factor for big seed size of *D. retusus* to germinate. Water needs for germination in big seed size is relatively bigger than small seed size [16].
Dipterocarp seeds can easily germinate under high rain intensity. In contrast, Dipterocarp seed germination rate will be inhibited at low rain intensity. The soil moisture of *D. retusus* habitat in Bodogol are relatively high (from 65% to 85%) and supports the germination of *D. retusus* seeds.

So far, previous *D. retusus* population in GPNP was recorded from Situ Gunung region. Similar to Bodogol area, at Situ Gunung with single plot sampling size as big as 20 meters by 4 kilometers, there were 5 trees, 4 saplings, and 11 seedlings with tree density figure 2.5 trees/ha, 2 saplings/ha, and 2.2 seedlings/ha [7]. Seedling density of *D. retusus* in Bodogol is higher than Situ Gunung sub-population. The abundant seedlings in Bodogol may be affected by relatively intact forest cover in this area. Bodogol forest area located at 800 m asl (upper lowland forest), a transition zone between lowland forest and lower montane forest [5].

We detected negative correlation in height-elevation model. The result of the model may assert that the center of *D. retusus* sub-population were located in the lower elevation part of the sampling location. However, we did not detect correlation between diameter and elevation. Even though this undetected diameter-elevation correlation may indicate that population structure of *D. retusus* in this ecosystem did not structured along different elevation (because diameter size indicate tree maturity), but the correlation was negative, similar to height-elevation model figures. Even though *D. retusus* fruits are equipped with wings, but the distribution of the seedlings within a population are relatively clumped, and distributed not too far from its mature tree [17]. Dipterocarp seed dispersal are relatively short (50 m more less from its adult tree) [15], causing Dipterocarp seeds to have high germination rate because located at well-shaded and humid area.

All detected individuals of *D. retusus* in this study were occur at location with high slope elevation, similar to habitat contour preferences of Dipterocarpus spp. in Siberut Island, West Sumatra [18]. At Mount Cakrabuana, Sumedang, *D. retusus* found at habitat with 26% - 100% slope and largest population found at 44% slope [1]. Most of *D. retusus* in Situ Gunung also found at 45% slope habitat [7].

4. Conclusion

We surveyed 4 trees, 3 small trees, 2 saplings, and 38 seedlings of *D. retusus* sub-population in Bodogol forest area. We detected positive and negative correlation between height and trunk diameter and between height and habitat elevation of *D. retusus* respectively. We did not detect any significant correlation between trunk diameter and habitat elevation.

The result of this study is useful for plant conservation practices and management in general, and *D. retusus* conservation in particular. First, the results of this study can be utilized as monitoring data and or baseline data of *D. retusus* population in GPNP to conduct updated conservation status analysis of this species in general. Second, this study results signify the importance of GPNP as conservation area that contain important IUCN Red List species. Finally, ecological and population monitoring studies of endangered plant species are crucial for plant conservation, either for conservation technical aspects in particular or conservation management in general.

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