The growth performance of dipterocarps species and understorey diversity in the Gunung Dahu Research Forest, Leuwiliang, Bogor

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Abstract. Dipterocarps species is the main species composes Gunung Dahu research forest. Habitat suitability and growth performance of a species are some factors considered in the species selection for forest establishment. The understorey in a forest community serves to protect soil from erosion. This research aimed is to analyze the growth performance of various Dipterocarpaceae species and study understorey diversity in the research area. The measurement was conducted in four species trial plots contain ten Dipterocarps species consist of five individuals per species per plot or 200 individuals in total. The growth performance of Dipterocarp species was analyzed using the current annual increment (CAI) and mean annual increment (MAI) methods. The understorey diversity was analyzed using the Shannon-Wiener Index. The result showed that Shorea johorensis obtained the highest CAI, 0.95 cm year\textsuperscript{-1}, and Shorea platyclados got the highest MAI, 1.78 cm/year. S. platyclados and S. leprosula were projected to reach <40 cm in diameter after they got 25 years. The Gunung Dahu research forest's understorey was classified as moderate (1.68 - 2.33). The dominant understorey species, namely Oldenlandia auricularia, Neprolephis biserrate, Ottochloa nodosa, and Gleichenia linearis. This study concluded that the growth performance of Dipterocarps species in the study area varied, and the understorey condition was classified as moderate, where its diversity has a positive correlation with the crown openness.

1. Introduction
Dipterocarpaceae is a promising species and has high economic value [1, 2]. Dipterocarpaceae timber is classified in grade II-IV in terms of strength and grade III-IV for its durability. Those qualities make this species potentially high in world timber trading. High-quality timber affects the increase of its demand [3], including the timber of dipterocarps species. In the past few decades, this species has become the source of foreign exchange and proves that this species is economically important for timber and non-timber forest products.

Dipterocarpaceae family grows in various habitats, riparian - terrestrial, river - peat and mineral soil, undulating - lowland, ridge, slope, valley, and fertile - less fertile soil [4]. Land suitability will affect the growth of Dipterocarpaceae. The measurement of diameter increment is required to evaluate
the growth of a species to estimate the success of the planting program. The result can be considered for the species selection in the future human-made forest establishment [5]. The diameter increment of a species is site-specific so that it will not be able to predict the increment of the same species in the different sites [6]. That is affected by the ecological factors and the different growth characteristics.

The understory is vegetation that cannot grow as big as a tree, and it grows under a tree community. It has the main role in the ecological aspects. The understory has some effect on other vegetations, either stunt the growth or brings the nutrients available. The understory in the plantation plays roles: the biodiversity source, protecting the forest soil and its organism, helping to create a microclimate on the forest floor, protecting the soil from erosion, and maintaining soil fertility [7]. The role of the understory to the ecosystem makes it important to be studied.

Species selection is one of the efforts to rehabilitate the degraded land so that the species selected could give a good performance. Native species are recommended to be used as rehabilitation commodities to support the ecology, economy, and social aspects and keep the biodiversity high. Native species selection in the forest and land rehabilitation is expected to increase that activity's success and increase the ecological benefit through enrichment planting. Hence, this study aims to analyze the growth performance of Dipterocarpaceae as the rehabilitation commodity in Gunung Dahu Research Forest and its understory diversity.

2. Materials and Methods

2.1. Study site

This study was conducted in the Gunung Dahu Research Forest, Bogor District, West Java, Indonesia (06º36'30"-06º37'00" S and 106º34'00" -106 º35'30" E) (Figure 1). The total forest area is around 250 ha, with the elevation ranges from 550 to 900 m above sea level (asl), and the average precipitation is 2500-2700 mm per year. The study site is chosen purposively in the area where ten species of Dipterocarpaceae are planted.

![Figure 1. Map of study site in the Gunung Dahu Research Forest.](image)
2.2. Sampling design and measurement
The study was conducted in a planting area of 11 years Dipterocarpaceae, consisted of ten species. The measurement was done on all individuals in four plots of 0.1 ha in the study site to represent the condition of the study area. In those four plots, there are ten species with five individuals each at each plot. The total area was 0.4 ha which can be seen in Figure 2.

![Figure 2](image)

**Figure 2.** The four plots are established in the study site. Each plot consists of ten Dipterocarps species with five individuals per species.

The data collected was primary, namely the diameter, height, and slope. The understorey inventory was in three plots of 2x2 m inside the bigger plot used for observing the growth of Dipterocarps species (Figure 3). The data collected were the number of species and the herbarium sample to be identified in the herbarium. Identification is made by comparing the herbarium sample and the literature from [8], comparing with the former identified species, and discussing with a botanist.

![Figure 3](image)

**Figure 3.** The plots of 2x2 m for inventorrying the understorey diversity in the Gunung Dahu research forest.

2.3. Data analysis
The increment is the increase of the tree dimension per unit time. Based on [9], there are three types of increments, the Current Annual Increment (CAI), Periodic Annual Increment (PAI), and Mean Annual Increment (MAI). In this study, we only calculate CAI and MAI with the below formula:
\[ MAI = \frac{D_t}{t} \]
\[ CAI = \frac{D_t - D_{t-1}}{T} \]

MAI (Mean Annual Increment)
\( D_t \) = tree diameter in age-\( t \) (cm)
\( t \) = age (year)

CAI (Current Annual Increment)
\( D_t \) = tree diameter when it is observed (cm)
\( D_{t-1} \) = tree diameter year/s before (cm)
\( T \) = time intervals (months)

\[ V = LBDS \times T \times F \]
\[ V \] = volume
\[ LBDS = \frac{1}{4} \pi d^2 \]
\( T \) = height
\( F \) = form factor 0.6

The role of the understorey in the ecosystem could be analyzed using the Important Value Index (IVI). The formulas are listed below:

\[ IVI = \text{Relative density} + \text{relative frequency} \]

Density = \( \frac{\text{The number of individuals}}{\text{Total area sampled}} \)

Relative density = \( \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100\% \)

Frequency = \( \frac{\text{Area of plots in which a species occurs}}{\text{Total area sampled}} \)

Relative frequency = \( \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100\% \)

The understorey diversity at each plot were analysed using Shannon-Wiener Index. The formula are listed below:

\[ H' = -\sum_{i=1}^{N} (p_i)(\ln p_i) \]
\[ p_i = \sum_{i=1}^{N} \frac{n_i}{N} \]

\( p_i \) = the comparison between the number of an individual species and the number of all species
\( n_i \) = the number of individual species-i,
\( N \) = the total number of individuals of all species
The different species diversity at each plot was analyzed using Sorensen Similarity Index. The formula used is below:

\[
IS = \frac{2W}{(A+B)} \times 100\%
\]

- \(IS\) = Similarity index,
- \(W\) = the number of similar species in both plots,
- \(A\) = the number of species in plot A,
- \(B\) = the number of species in community B.

This study used one-way ANOVA to analyze the effect of species on the diameter and height. When the effect does exist, then the test is continued with the Duncan test. Finally, we did the correlation analysis to investigate the effect of crown density on the diameter and height. The growth data from 10 species of Dipterocarpaceae were analyzed using IBM SPSS Statistics 25.

3. Result and Discussion

3.1. The growth performance and predicted diameter

The Current Annual Increment (CAI) is expected to examine the diameter increment within a year. *S. johorensis* reached the highest of CAI, 0.95 cm year\(^{-1}\) (Table 1). That result is supported by [10], which stated that the diameter increment of *S. johorensis* was 1 cm year\(^{-1}\) and categorized this species as the fast-growing species. However, the diameter increment of each species is different, caused by the physiological factor and the species' capacity to grow in the open competition [11].

| Species          | Average         |   |
|------------------|-----------------|---|
|                  | CAI (cm year\(^{-1}\)) | MAI (cm year\(^{-1}\)) |
| *S. platyclados* | 0.79 ± 0.54     | 1.78 ± 0.40     |
| *H. gregaria*    | 0.71 ± 0.37     | 0.70 ± 0.21     |
| *S. leprosula*   | 0.88 ± 0.52     | 1.62 ± 0.56     |
| *H. dryobalanoides* | 0.72 ± 0.32 | 0.90 ± 0.28     |
| *S. pinanga*     | 0.74 ± 0.45     | 1.11 ± 0.11     |
| *S. johorensis*  | 0.95 ± 0.35     | 1.34 ± 0.25     |
| *S. ovalis*      | 0.88 ± 0.48     | 1.40 ± 0.55     |
| *S. seminis*     | 0.41 ± 0.39     | 0.46 ± 0.13     |
| *V. sumatrana*   | 0.65 ± 0.48     | 0.79 ± 0.32     |
| *S. smithiana*   | 0.66 ± 0.65     | 0.62 ± 0.31     |

Remarks: CAI = Current Annual Increment, MAI = Mean Annual Increment

In terms of ecological aspects, *S. johorensis* could grow in a 40% slope and red-yellow podsolic soil with clay texture area [12]. The ecological requirement of *S. johorensis* is similar to *S. leprosula*. Hence, that condition is presumed as the factor that brings the similar CAI value of *S. leprosula* (0.88 cm year\(^{-1}\)) and *S. johorensis* (0.95 cm year\(^{-1}\)). [13] explained that *S. leprosula*, *S. parvifolia*, *S. platyclados*, *S. macrophylla*, and *S. johorensis* are red meranti that includes a fast-growing species.

*S. seminis* got the lowest CAI value, 0.41 cm year\(^{-1}\) (Table 1). The habitat where *S. seminis* grows is in the lowland forest, and it is different from the condition in the Gunung Dahu research forest. That condition affects the CAI result of *S. seminis* besides the initial characteristic of the species itself. The growth of *S. seminis* is relatively slow as it needs seven months to grow in the polybag in the seedling phase before it can be planted in the field [14].
The MAI measurement is expected to see the average growth of diameter per year in a specific period. Based on the result of this study, *S. platyclados* got the highest value of MAI 1.78 cm year\(^{-1}\). That result is slightly lower than the MAI value of *S. platyclados* in Kalimantan, 1.81 cm/year [15]. The different needs of microclimate are presumed as the factor that affects that difference. Furthermore, [16] stated *S. platyclados* would reach the highest growth significantly in 26 months old as the support of its photosynthesis process in the open area. *S. platyclados* is a semi-tolerant species in which, when it gets older, it needs a more open environment to optimize its capacity in photosynthesis and maximize its growth. [17] compared the growth of *S. leprosula* and *S. johorensis* through their annual increment of 1.94 cm year\(^{-1}\) and 1.59 cm year\(^{-1}\), respectively.

*S. seminis* got the lowest MAI among the other Dipterocarpaceae species in the Gunung Dahu research forest is caused by some factors such as the unsuitable habitat, the low water availability, and the relatively steep slope. [18] reported that *S. seminis* prefer to grow near the river. Hence, the Gunung Dahu research forest seemed to be unsuitable habitat for *S. seminis*. [19] stated that the growth rate is affected by many factors; nutrition and water competition. Furthermore, it stated that the low diameter growth occurs as the competition's effect, resulting in the poor stand.

The Dipterocarpaceae species increment is different, proven by the different performance of each species in the early stage and at different years depending on the canopy openness or the environmental condition. [11] in their publication explained that each species has different characteristics of CAI diameter caused by tolerant and intolerant characteristics, the need for space to grow, and the competition factor.

Indonesia's intensive silviculture technique (SILIN-TPTJ) determined the minimum diameter increment is (expected) 1.6 cm year\(^{-1}\) in 25 years, which needs to reach 40 cm in diameter and be ready to be cut. Based on Figure 4, *S. platyclados* and *S. leprosula* in Gunung Dahu are predicted to meet the minimum diameter requirement of SILIN-TPTJ. This result is supported by the study result from [20] that explained *S. leprosula* could be a species model in the intensive silviculture technique (SILIN-TPTJ). The diameter and height of five years *S. leprosula* and *S. platyclados* are 9.71 - 9.06 cm in diameter and 8.6 - 7.8 m in height is the best among the other species using intensive silviculture technique (SILIN-TPTJ) [17]. Some treatments cause the increasing diameter and height in the intensive silviculture technique (SILIN-TPTJ), such as crown opening, fertilizing, improved seed utilization, and environmental manipulation. Hence, the intensive silviculture technique (SILIN) is expected to affect the diameter and height growth positively [21].

![The Diameter Prediction of 25 Years Dipterocarpaceae](image)

**Figure 4.** The predicted diameter of 25 years Dipterocarpaceae in Gunung Dahu research forest.
3.2. Understorey diversity
The highest value of the Important Value Index in the Gunung Dahu is reached by *Oldenlandia Auricularia*, 37.86 (Table 2). *O. auricularia* is an invasive species that is fast growing so that it can survive from the effects of allelopathy [22], [23] explained that the limiting factors of vegetation growth are soil fertility related to microorganism activity, light intensities, and invasive species. Mainly, the invasive species spread massively in a group or evenly. The vegetative reproduction of an invasive species that grows with its parent is a force that drives grouping [24], [25] explained that an invasive species that threatens the ecological condition is a species with no natural enemies, reproduces, spreads, and shapes a shade easily, and is commonly found as shrubs, lianas, herbs, trees, and palms. The possible management option of the Dipterocarpaceae stands in Gunung Dahu from invasive species is through weeding periodically to optimize the growth of Dipterocarpaceae species.

**Table 2.** The understorey's important value index in the study site.

| Species                  | D       | RD (%) | F     | RF (%) | IVI |
|--------------------------|---------|--------|-------|--------|-----|
| *Oldenlandia auricularia*| 62500.00| 29.53  | 0.67  | 8.33   | 37.86|
| *Isachne pulchella*      | 36666.67| 17.32  | 0.33  | 4.17   | 21.49|
| *Ottochloa nodosa*       | 22500.00| 10.63  | 0.67  | 8.33   | 18.96|
| *Setaria palma*ta*      | 22500.00| 10.63  | 0.67  | 8.33   | 18.96|
| *Clidemia hirta*        | 11666.67| 5.51   | 0.67  | 8.33   | 13.85|
| *Neoprolepis biserrate* | 9166.67 | 4.33   | 0.67  | 8.33   | 12.66|
| *Symplocos cochincheniensis* | 8333.33 | 3.94   | 0.67  | 8.33   | 12.27|
| *Rolandra fruticose*    | 15833.33| 7.48   | 0.33  | 4.17   | 11.65|
| *Melastoma malabathricum* | 4166.67 | 1.97   | 0.67  | 8.33   | 10.30|
| *Macaranga gigantea*    | 1666.67 | 0.79   | 0.67  | 8.33   | 9.12 |
| *Taenitis blechnoides*  | 8333.33 | 3.94   | 0.33  | 4.17   | 8.10 |
| *Chromolaena odorata*   | 4166.67 | 1.97   | 0.33  | 4.17   | 6.14 |
| *Melastoma polyanthum*  | 1666.67 | 0.79   | 0.33  | 4.17   | 4.95 |
| *Macaranga triflora*    | 833.33  | 0.39   | 0.33  | 4.17   | 4.56 |
| *Ipomoea Cf. indica*    | 833.33  | 0.39   | 0.33  | 4.17   | 4.56 |
| *Curculigo latifolia*   | 833.33  | 0.39   | 0.33  | 4.17   | 4.56 |

The understorey diversity in the Gunung Dahu is categorized as a medium (Table 3). The highest understorey diversity is 2.33 in Plot 2. The study from [23] stated that canopy openness is significantly affecting the understorey diversity. Table 3 shows that less canopy openness is followed by less understorey diversity. The different canopy cover in a stand will form a different microclimate in the forest ground. On the other hand, the different rate of litter decomposition at each stand results in a different supply of organic matter in the forest ground, which affects the understorey diversity [26].

**Table 3.** The understorey diversity index at each plot.

| Plot | H'  | K Annotation | Canopy cover (%) |
|------|-----|--------------|------------------|
| 1    | 2.18| Moderate     | 75.3             |
| 2    | 2.33| Moderate     | 80.6             |
| 3    | 1.68| Moderate     | 81.2             |
| 4    | 1.95| Moderate     | 88.4             |

Remarks: H' = Diversity index
3.3. Rehabilitation effort in Gunung Dahu Research Forest

Species selection in the rehabilitation activity should consider the use of native species that is most adaptable to the condition after degradation and is expected to have an optimum growth of diameter and height. Based on this study, *S. platyclados* and *S. leprosula* can be chosen as rehabilitation commodities. The other species with the highest diameter CAI, *S. johorensis*, also be considered an alternative species in the rehabilitation activity in the Gunung Dahu research forest. That selection of *S. johorensis* as the alternative rehabilitation species is supported by the statement from [10], who stated that *S. johorensis* in Indonesia is one of the most priority *meranti* species to be planted. The rehabilitation activity is started by extracting information about the method or technique of rehabilitation, species adaptation trial, and planting area preparation [27].

*S. platyclados* and *S. leprosula* are considered the most suitable rehabilitation commodities in the Gunung Dahu research forest. This area is the most suitable habitat for those species in terms of its slope, soil, altitude, and air temperature. The other factors that affect the growth of *S. platyclados* and *S. leprosula* are canopy cover and nutrient competition. The success of rehabilitation activity and forest establishment can be increased through genetic improvement of native species in the next phase [28]. Furthermore, the species above could be chosen as the rehabilitation commodities on the other areas similar to the Gunung Dahu research forest.

4. Conclusion

*S. platyclados*, *S. leprosula*, and *S. johorensis* are the most suitable rehabilitation commodities in the Gunung Dahu research forest. They presented the optimum growth of Dipterocarps species in the Gunung Dahu research forest. The choice to use native species in rehabilitation seems promising in terms of ecological, social, and economic aspects. The understory diversity in the study area is categorized as a medium with the most dominant species, *Oldenlandia Auricularia*.

References

[1] Saridan A and Fajri M 2014 Potensi jenis dipterokarpa di Hutan Penelitian Labanan, Kabupaten Berau, Kalimantan Timur JPED 8(1) 7-14
[2] Paulus M, Swasono R A and Diana R 2021 The potential of dipterocarpaceae in the karst of Sangkulirang Mangkalihat In JSTS-19 pp. 277-282
[3] Fitriani N, Kasmara H and Maulana J 2016 Ketahanan kayu meranti merah dan kayu kamper terhadap serangan rayap tanah Seminar Nasional Pendidikan Biologi dan Sains Tek
[4] Symington C F 1943 Foresters Manual of Dipterocarps Kuala Lumpur Malaysia Forest Department
[5] Istomo, Wibowo C and Hidayati N 1999 Evaluasi pertumbuhan tanaman meranti (Shorea spp.) di Ha rubentes BKPH Jasinga KPH Bogor Perum Perhutani Unit III Jawa Barat JMHT 5(2) 13-22
[6] Wahyudi 2011 Pertumbuhan tanaman dan tegakan tinggal pada tebang pilih tanam indonesia intensif, situs kasus di Areal Kerja IUPHHK-HA PT Gunung Meranti Provinsi Kalimantan Tengah [Thesis] Bogor Indonesia Institut Pertanian Bogor
[7] Nikmah N, Jumari and Wiryani E 2016 Struktur komposisi tumbuhan bawah tegakan jati di Kebun Benih Klon (KBK) Padang Bojonegoro JAB 5(1) 30-38
[8] Soerjani M, Jahja A, Kostermans and Tjitrosopomo G 1987 Weeds of Rice in Indonesia Jakarta Indonesia Balai Pustaka
[9] Prodan M 1968 Forest Biometrics London UK Perganon press
[10] Soerianegara I and Lemmens 1994 Plant Resources of South-East Asia 5 Timber trees: Major commercial timbers Bogor Indonesia Prosea Foundation
[11] Abdulah L and Darwo 2015 Model riap tegakan hutan alam produksi di Pulau Buru Maluku JPHT 12(1) 1-10
[12] Sutedjo, Hartati W, Marjenah, Kustiawan W, Sumaryono, Mardji D and Rujehan 2014 *Shorea leprosula* Miq *dan Shorea johorensis* Foxw Samarinda Indonesia Balai Besar Penelitian Dipterokarpa

[13] Wahyudi I and Sitanggang J J 2016 Kualitas kayu meranti merah (*Shorea leprosula* Miq.) hasil budi daya *JIPI* 21(2) 140-145

[14] Turjaman M, Tamai Y, Segah H, Limin S H, Osaki M and Tawaraya K 2006 Increase in early growth and nutrient uptake of *Shorea seminis* seedlings inoculated with two ectomycorrhizal fungi *JTFS* 18(4) 243-49

[15] Purnomo S, Na’iem M and Hardiwinoto S 2013 The growth of selected *Shorea* spp in secondary tropical rain forest: the effect of silviculture treatment to improve growth quality of *Shorea* spp. *J. Proenv* 17 160-66

[16] Ang L H and Maruyama Y 1995 Survival and early growth of *Shorea platyclados, Shorea macroptera, Shorea assamica, and Hopea nervosa* in open planting *JTFS* 7 541-57

[17] Widyatno, Soekotjo, Na’iem M, Hardiwinoto S and Purnomo S 2011 Pertumbuhan meranti (*Shorea* spp.) pada sistem tebang pilih tanam jalur dengan teknik silvikultur intensif (TPTJ-SILIN) *JPHKA* 8(4) 373-83

[18] Tampubolon S, Manurung T F and Latifah S 2018 Sebaran tengkawang (*Shorea* spp.) berdasarkan fitogeografi pada hutan adat pengajit Desa Sahlan Kecamatan Seluas Kabupaten Bengkayang *JHL* 6(4) 883-93

[19] Marsoem S N 2013 Studi mutu kayu jati di Hutan Rakyat Gunungkidul *JIK* 7(2) 108-22

[20] Wahyudi and Panjaitan S 2011 Model pertumbuhan dan hasil tanaman *Shorea leprosula* pada sistem tebang pilih tanam jalur teknik silin *JPED* 5(2) 37-46

[21] Unenor E, Tanjung R H R and Keiluhu H J 2015 Implementasi sistem silvikultur TPTI dan TPTJ teknik silvikultur intensif (SILIN) dalam pengelolaan hutan di Papua *JBP* 7(2) 53-60

[22] Priyatmoko A 2019 Asosiasi *Lophatherum gracile* dan tumbuhan invasif lainnya di Desa Ngesrepbalong Kecamatan Limbangan Kabupaten Kendal *Seminar Nasional Sains dan Entrepreneurship VI* pp.1-11

[23] Purnomo D W, Usmadi D and Hadiah J T 2018 Dampak keterbukaan tajuk terhadap kelimpahan tumbuhan bawah pada tegakan pinus Oocarpa schiede dan Agathis alba (lam) Foxw *JIK* 12 61-73

[24] Indriyanto 2006 *Ekologi Hutan* Jakarta Indonesia Bumi Aksara

[25] Nursanti and Adriadi A 2018 Keanekaragaman tumbuhan invasif di kawasan Taman Hutan Raya Sultan Thaha Saifuddin, Jambi *Medkon* 23(1) 85-91

[26] Kunarso A and Azwar F 2012 Keragaman jenis tumbuhan bawah pada berbagai tegakan hutan tanaman di Benakat, Sumatera Selatan *JPHT* 10(2) 85-98

[27] Appanah S and Turnbull M J 1998 A Review of Dipterocarps: Taxonomy, Ecology, and Silviculture Bogor Indonesia CIFOR

[28] Leakey R R and Simons A J 1998 The domestication and commercialization of indigenous trees in agroforestry for the alleviation of poverty In *Directions in Tropical Agroforestry Research* pp. 165-176 Dordrecht the Netherlands Springer

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**Authors’ contribution**

All authors contributed equally to this work as the main contributor.