Vegetation analysis and tree species diversity in KHDTK Gunung Bromo, Karanganyar, Central Java

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Abstract. Forest vegetation analysis and structure is necessary to understand in order to set up the basis of forest governance and management of the forest plan. This study aims to determine the potential, structure, species composition, and inventory of plant species of the forest stand in the educational forest, namely KHDTK Gunung Bromo. Analysis of vegetation methods on sampling plots 20 × 20 m was made in the forest area to collect trees data. The systematic sampling with the random start was used, with the plot distance 100 m. In total, there are 100 plots were measured. The results showed that total volume and tree densities were 261.66 m³/ha and 291 trees/ha. The stand was dominated by the trees with a diameter range of 20 – 30 cm. Species composition is dominated by Pinus merkusii with Species Importance Value (SIV), average volume, and density were 163.23%, 156.67 m³/ha, and 202 trees/ha, respectively. However, the sapling stage was dominated by Dalbergia latifolia that showed by SIV 119%, indicating that D. latifolia was able to regenerate itself until the sampling stage. In addition, in the seedling stage, Swietenia macrophylla was the dominant species with density 400 seedling/ha, indicating that seed was adaptive and easily spread.

1. Introduction

Forest Area with Specific Purposes of Gunung Bromo (KHDTK Gunung Bromo) is one of the educational forests located in Karanganyar, Central Java. The KHDTK Gunung Bromo is managed by Sebelas Maret University (UNS) Surakarta. This forest occupied 122.78 hectares area that mainly dominated by Pinus merkusii stand. Initially, the status of KHDTK Gunung Bromo was a limited production forest managed by Perhutani for pine company class. Thus, basically the P. merkusii stand were planted. Then, in April 2018 based on the Decree of the Minister of Environment and Forestry of the Republic of Indonesia No. SK177/MENLHK/SETJEN/PLA.O/4/2018 the management of the Gunung Bromo forest was managed by the Technical Implementation Unit of the Center for Forestry Education and Training (UPT Pusdiklathut UNS) [1].

The Gunung Bromo forest is a forest production that produces pine resin as the main product. The presence of pine as the dominant species planted in KHDTK Gunung Bromo is interesting to observe because it is one type of commercial wood species. In addition, in the past, Dalbergia latifolia was also an important commercial tree planted in those forest areas. However, nowadays the D. latifolia stand is rare to find.
In the past view decades, according to Perum Perhutani, the production of timber and non-timber products of the Gunung Bromo forest was low. However, the research conducted in KHDTK Gunung Bromo is still limited. Thus, in order to collect comprehensive information of KHDTK Gunung Bromo, intensive research should be conducted. Research on forest vegetation and structure is necessary to understand in order to set up the basis of forest governance and management of the forest plan KHDTK Gunung Bromo (UPT Pusdiklathut UNS). The study on the forests composition and structure is part of vegetation analysis that explains the interaction within and between tree species [2]. Forest structure divided into two, horizontal and vertical structures. Horizontal structure explains the diameter distribution of trees, while vertical structure explains the tree height distribution [3].

In the present study, stand volume and structure, tree and pole densities, and species composition were analyzed. The objectives of this study were to determine the potential, the structure (frequency, density, dominance, and Species Important Value), species composition, and inventory of plant species of the forest stand in KHDTK Gunung Bromo. To illustrate stand stratification, analysis of stand structure is carried out by horizontal and vertical diagrams using Sexi-Fs software.

2. Material and methods

2.1 Study area
The study was conducted at KHDTK Gunung Bromo, Karanganyar 7°34'21.93″-7°35'38,90″S and 110°59'40.39″-111°0'49.36″E with an altitude of 200 - 375.5 meters above sea level (figure 1). KHDTK Gunung Bromo is located at the KPH Surakarta, RPH Lawu Utara [4]. According to the Schmidt dan Fergusson classification, KHDTK Gunung Bromo was classified as type C, with the average rainfall, temperature, and relative humidity were 190 mm/month, 26-27°C, and 70-83%, respectively [5]. The soil type is alfisol and inceptisol [6].

![Figure 1. Map of KHDTK Gunung Bromo Scale 1:10.000](image)

2.2 Data collection
Analysis of vegetation methods on sampling plots 20 × 20 m², 10 × 10 m², 5 × 5 m², and 2 × 2 m² were made in the forest area to collect trees, pole, sapling, and seedling data. The tree living stages
were classified by its diameter and height as reported by [11]. The classification of tree stages were as follows: tree (DBH > 20 cm), pole (DBH 10-20 cm), sapling (height 1.5-3 m), and seedling (height < 1.5 m) [11]. The systematic sampling with the random start was used, with the plot distance 100 m. In total, there are 100 plots were measured, The sample plots were located on the field through systematic distance (100 × 100 m) with a random start point (Figure 1). For the horizontal forest structure, the tree height (total and free-branch) was measured by Haga Altimeter. Furthermore, to understand the vertical forest structure the DBH and canopy width were measured by the diameter tape and band tape, respectively.

2.3 Methods
Species Importance Value (SIV) was determined to analyze the species composition and species domination. Thus, SIV for each species was calculated by adding up the values of relative density (RD), relative frequency (RF), relative dominance [7]. The basal area was considered for dominancy and relative dominance (RD), calculated by: RD = (basal area of species × 100)/total basal area of all species. The species diversity index was computed using the Shannon-Wiener information function [8] [9] [10] as: \( H' = \Sigma n_i / n \ln n_i \), where: \( n_i \) = denote to the SIV of a species and \( n \) = denote to the sum of total SIV of all species. The species evenness index was computed using the evenness index (E) as: \( E = H'/\ln S \), where \( \ln \) is natural logarithm, \( S \) is the total species number in each plot. The species richness index Margalef (R) was determined by: \( R = (S-1)/\ln N \), where \( S \) is the total species number in each plot, \( N \) is the total of all individual species. Furthermore, the data were processed by using spreadsheet software (Microsoft Excel 2007).

Regression analysis was applied to analyze the relations between DBH and tree height for the main planted tree species. Potential stands include the potential number of trees (trees/ha) and potential volume of stands (m³/ha). In this present study, stand potency was differentiated based on tree species and diameter groups. The horizontal diagram were classified based on the tree strata classification as reported by [11]. The height for strata A (emergent canopy), B (medium canopy), C (lower canopy), D (shrubs, sapling, fern, tall herbs), and E (ground layer) were >30, 20-30, 5-20, 1-5, and <1 m, respectively [11]. Furthermore, the diameter groups of tree stage for vertical diagram were classified for each 10 cm. To illustrate stand stratification, analysis of stand structure is carried out by horizontal and vertical diagrams using Sexi-Fs software.

3 Result and discussion
3.1 Stand structure of KHDTK Gunung Bromo
Stand structure of KHDTK Gunung Bromo was divided into horizontal and vertical structures. The main tree stand of KHDTK Gunung Bromo that measured in this present study was Pinus merkusii. In addition, in some plots, there was also the other main planted tree species that also measured, Swietenia macropylla and Dalbergia latifolia. However, the other tree species that found the sampling plot were also measured. The horizontal structure explains stand growth. Furthermore, it was important to predict stand growth in the future [12]. Figure 2 shows the diameter class distribution in relation to tree densities. This figure explains the horizontal structure in KHDTK Gunung Bromo. The diameter classes were consist of 6 groups. The tree’s diameter was mainly in the range of 20-30 cm and the tree number is decreasing by increasing diameter class (figure 2). The distribution of growth (diameter) classes in the plantations or even age forests will follow a normal distribution pattern or bell-shaped distribution curve [13], [14]. As the even-aged stand canopy closes, inter-tree competition for resources (light, water, nutrients) will lead to the weakening and mortality of some tree, therefore, the older stands with large diameters are reduced [13]. Thus, the distribution of vegetation in KHDTK Gunung Bromo is in normal condition.
Smith [15] suggested that stratification may (1) optimize light utilization, (2) increase CO₂ concentrations within the forest canopy, (3) increase pollination and dispersal rates, (4) reduce predation on flowers, fruit, and leaves, and (5) increase the structural integrity of the forest. In addition, it has been recognized that the forest canopy has a complex structure that is important for environmental interactions, regeneration, growth, and biotic habitat [16]. Figure 3 shows the vertical structure or vertical stratification of trees in KHDTK Gunung Bromo. The vertical structure of KHDTK Gunung Bromo was dominated by strata C (<20 m). Only a few trees can reach strata B (20-30 m) and strata A (> 30m). *P. merkusii* was the main tree species that occupied strata A, B, and C. This was true because *P. merkusii* was the main tree that planted in KHDTK Gunung Bromo. According to the data obtained by Perum Perhutani [4], the *P. merkusii* planted in KHDTK Gunung Bromo has different ages. Thus, the tree height and tree diameter were might differ for each sampling plot. Based on the present study, it was found that the tree stands in a sampling plot have an almost similar height in KHDTK Gunung Bromo forest area, especially for main planted species, *P. merkusii*. Figure 4 shows the illustration of vertical and horizontal diagrams of the *P. merkusii* forest stand.

**Figure 2.** Diameter classes distribution in relation to the tree densities.

**Figure 3.** Vertical structure of trees; strata A (>30m), strata B (20-30 m), and strata C (<20 m)
Figure 4. Illustration of vertical and horizontal diagrams of the *P. merkusii* forest stand

Figure 5. Relationships between diameter breast height and tree height in (a) *Pinus merkusii*, (b) *Swietenia macrophylla*, and (c) *Dalbergia latifolia*
Individual diameter at breast height outside bark and tree height are key variables in forestry applications and used to study forest structure [17]. In the present study, the relationships between stem diameter and tree height of three commercial tree species that planted in KHDTK Gunung Bromo, namely: *P. merkusii*, *S. macrophylla*, and *D. latifolia* were shown in figure 5. A significant correlation was found between stem diameter and tree height for those three tree species ($r = 0.37$, $0.54$, and $0.49$, respectively for *P. merkusii*, *S. macrophylla*, and *D. latifolia*), indicating that the larger the stem diameter the higher the trees will be. Quantifying the relationships between tree height and diameter is, therefore, necessary to predict heights of the remaining trees [18].

### 3.2 Tree species and compositions of KHDTK Gunung Bromo

Gunung Bromo forest was the pine class production forest. Thus, *P. merkusii* was the main stand. However, there was also another tree species found in KHDTK Gunung Bromo. Table 1 shows the tree species found in KHDTK Gunung Bromo. There were 29 tree species and 17 families. The tree species were found in four types of tree stages: tree (18 species), pole (15 species) sapling (8 species), and seedling (5 species) (table 1, figure 6). Fabaceae was the most found family in the site with 6 species, followed by Meliaceae with 3 species (Table 1). Thus, it was considered that even though KHDTK Gunung Bromo was a production forest, it was also relatively rich in vegetation biodiversity. The species that found were not only timber species but also plants with other benefits, such as *Flacourtia rukam*. *F. Rukam* fruit has potential value as a source of antioxidant components [19]. Thus, KHDTK Gunung Bromo has another potential to be developed.

Based on Table 1, the tree species that found in tree stage was *Acacia* sp, *Tamarindus incica*, *Antidesma bunius*, *Dillenia* sp., *Endospermum diadendum*, *Delonix regia*, *Cinnamomum* sp., *Sterculia foetida*, *Schleichera oleosa*, *Swietenia mahagony*, *Swietenia macrophylla*, *Memecylon* sp., *Phyllantaceae*, *Pinus merkusii*, *Adenanthera pavonina*, *Falcataria moluccana*, *Dalbergia latifolia*, and *Vitex* sp. The tree species found in the pole stage was *Acacia* sp., *Myrtaceae*, *Tectona grandis*, *Sterculia foetida*, *Schleichera oleosa*, *Oroxylum indicum*, *Swietenia mahagony*, *Swietenia macrophylla*, *Pinus merkusii*, *Polyscias nodosa*, *Flacourtia rukam*, *Falcataria moluccana*, *Vitex* sp., *Antidesma bunius* and *Dalbergia latifolia*. Furthermore, in the sapling stage, there was *Acacia* sp., *Tectona grandis*, *Elaeocarpus ganitrus*, *Mangifera indica*, *Pinus merkusii*, *Trema tementosa*, *Swietenia macrophylla*, and *Dalbergia latifolia*. In addition, the species found in the seedling stage was *Syzygium cumini*, *Flacourtia inermis*, *Swietenia macrophylla*, *Dalbergia latifolia*, and *Sesbania grandiflora*.

The number of species at the tree stage is higher than other growth stages (poles, sapling, and seedlings). This finding was uncommon for the production forest. As a production forest, KHDTK Gunung Bromo should consist of relatively uniform age stand and tree species. However, the number of species found in sapling and seedling was lower rather than tree and pole, indicating that the natural rejuvenation is a lack in the plantation forest due to the closed canopy (figure 6).

![Figure 6. Number of species in each tree stages](image-url)
Table 1. Tree species found in KDHTK Gunung Bromo

| No | Local name  | Species                | Family          | Tree stage          |
|----|-------------|------------------------|-----------------|---------------------|
| 1  | Akasia      | Acacia sp.             | Fabaceae        | Tree, pole, sapling |
| 2  | Asam        | Tamarindus indica      | Fabaceae        | Tree                |
| 3  | Buni        | Antidesma bunius       | Euphorbiaceae   | Tree, pole          |
| 4  | Dillenia    | Dillenia sp.           | Dilleniaceae    | Tree                |
| 5  | Duwet       | Syzygium cumini        | Myrtaceae       | Seedling            |
| 6  | Endospermum | Endospermum diadendum  | Euphorbiaceae   | Tree                |
| 7  | Flamboyan   | Delonix regia          | Fabaceae        | Tree                |
| 8  | Jambu-jambuan | Syzygium cumini       | Myrtaceae       | Pole                |
| 9  | Jati        | Tectona grandis        | Verbenaceae     | Pole, sapling       |
| 10 | Jenitri     | Elaeocarpus ganitrus   | Elaeocarpus     | Sapling             |
| 11 | Kayu manis  | Cinnamomum sp.         | Lauraceae       | Tree                |
| 12 | Kepuh       | Sterculia foetida      | Malvaceae       | Tree, pole          |
| 13 | Kesambi     | Schleichera oleosa     | Sapindaceae     | Tree, pole          |
| 14 | Lidah sapi/Bungli | Oroxylum indicum    | Bignoniaceae    | Pole                |
| 15 | Lobi-lobi   | Flacourtia inermis     | Salicaceae      | Seedling            |
| 16 | Mahagoni    | Swietenia mahagony     | Meliaceae       | Tree, pole          |
| 17 | Mahoni      | Swietenia macrophylla  | Meliaceae       | Tree, pole, seedling| |
| 18 | Mangga hutan| Mangifera indica       | Anacardiaceae   | Sapling             |
| 19 | Memecylon   | Memecylon sp.          | Memecylaceae    | Tree                |
| 20 | Phyllantaceae | Phyllantaceae        | Phyllantaceae   | Tree                |
| 21 | Pinus       | Pinus merkusii         | Pinaceae        | Tree, pole, sapling |
| 22 | Polyscias   | Polyscias nodosa       | Araliaceae      | Pole                |
| 23 | Rukam       | Flacourtia rukam       | Salicaceae      | Pole                |
| 24 | Saga        | Adenanthera pavonina   | Fabaceae        | Tree                |
| 25 | Sengon      | Falcatoria moluccana   | Fabaceae        | Tree, pole          |
| 26 | Sonokeling  | Dalbergia latifolia    | Fabaceae        | Tree, pole, sapling, seedling |
| 27 | Trema       | Trema tementosa        | Cannabaceae     | Sapling             |
| 28 | Turi        | Sesbania grandiflora   | Fabaceae        | Seedling            |
| 29 | Vitex       | Vitex sp.              | Verbenaceae     | Tree, pole          |

Table 2 shows the Species Importance Value (SIV) and density in the tree and pole stage for each tree species. The total tree density was 291 trees/ha. *P. merkusii* shows the highest SIV at the tree (163.23%) and pole (172.36%) stage compared to other species (Table 2). The tree density for *P. merkusii* was 202 tree/ha (Table 2). It is true, as mentioned above that KHDTK Gunung Bromo was pine class production. Thus, pine is the dominant species planted there.

At the sapling stage, the highest SIV shown by *D. latifolia*. This condition might be related to the high root coppicing ability of this species. In addition, the conditions in the favorable habitat triggered the regeneration and establishment of the species [20]. This also indicates that *D. latifolia* is adaptable to the low light. The seedling of *D. latifolia* is shade tolerant and classified as a moderate light demander [21]. It coppices well and produces root-suckers in large numbers [22]. Therefore, for the further development of saplings, the overhead light is necessary.
In the seedling stage, *S. macrophylla* shows the highest SIV, indicating that *S. macrophylla* seedlings were the most common seedling found in the forest floor compared to other species (table 2; figure 6). Nilson and Wardle [23] reported that understories, including seedling, were the sustainable indicator for the forest ecology. The presence of wings in *S. macrophylla* seed makes it easy to spread through the wind blow. Camara-Cabrales and Kelty [24] have been reported that the distribution of *S. macrophylla* seeds covers an area of 0.37-0.47 ha with a range of 30-50 m from the parent tree. Furthermore, the parent tree produces an average of 133 fruits or capsules. A single fruit contains 45 winged seeds. They also reported that 75 percent of these winged seeds are viable. *S. macrophylla* also produces allelopathy compounds, so that it can suppress the growth of other tree species especially on the forest floor. Cumming *et al.* [25] have been reported that the growth of understorey can be suppressed by the composition of light, water, and nutrition and also the presence of allelopathy. Thus, it is clear that *S. macrophylla* is an adaptive tree species that well-adapt to the close canopy and dominates the seedling stage on the forest floor.

Table 3 shows the species diversity index (H'), Species Richness Index (R), Species Evenness Level (E) and Dominance Index (DI) of each tree stage. In the tree, pole, and sapling level H' were intermediate while H' seedling was low. Thus indicating natural regeneration of the other species was low and due to dominating of *S. macrophylla* seedling as shown in figure 7. Species diversity reflects the status of the ecosystem or community. Moreover, a high species diversity contributes to the stability of the ecosystem. Species Richness Index Margalef (R) and Dominance index of all tree stages were low. Thus indicating the ecosystem in this area was intervened by humans because this area is a production forest with limited species.

![Figure 7](image_url)
| Tree stage | Species               | SIV (%) | Density (trees/ha) |
|------------|-----------------------|---------|--------------------|
| Tree       | Pinus merkusii        | 163.23  | 202                |
|            | Swietenia macrophylla | 78.92   | 76                 |
|            | Dalbergia latifolia   | 9.15    | 2                  |
|            | Swietenia mahagoni    | 5.70    | 2                  |
|            | Memecylon sp.         | 4.01    | 1                  |
|            | Vitex sp.             | 3.94    | 2                  |
|            | Acacia sp.            | 3.73    | 2                  |
|            | Schleichera oleosa    | 3.58    | 1                  |
|            | Adenanthera pavonina  | 3.46    | 1                  |
|            | Antidesma bunius      | 3.33    | 1                  |
|            | Sterculia foetida     | 3.13    | 1                  |
|            | Cinnamomum sp.        | 2.78    | 1                  |
|            | Falcataria moluccana  | 2.78    | 1                  |
|            | Dillenia sp.          | 2.73    | 1                  |
|            | Phyllantaceae         | 2.55    | 1                  |
|            | Endospermum diadenum  | 2.52    | 1                  |
|            | Tamarindus indica     | 2.43    | 1                  |
|            | Delonix regia         | 2.03    | 1                  |
| Poles      | Pinus merkusii        | 172.36  | 72                 |
|            | Swietenia macrophylla | 92.54   | 36                 |
|            | Dalbergia latifolia   | 13.16   | 5                  |
|            | Falcataria moluccana  | 3.81    | 4                  |
|            | Schleichera oleosa    | 3.43    | 4                  |
|            | Swietenia mahagoni    | 3.00    | 3                  |
|            | Acacia sp.            | 2.80    | 3                  |
|            | Flacourtia rukam      | 1.26    | 1                  |
|            | Oroxylum indicum      | 1.13    | 1                  |
|            | Tectona grandis       | 1.12    | 1                  |
|            | Sterculia foetida     | 1.11    | 1                  |
|            | Myrtaceae             | 1.10    | 1                  |
|            | Vitex sp.             | 1.08    | 1                  |
|            | Polyscias nodosa      | 1.05    | 1                  |
|            | Antidesma bunius      | 1.04    | 1                  |
| Sapling    | Dalbergia latifolia   | 118.49  | 5                  |
|            | Pinus merkusii        | 63.25   | 2                  |
|            | Swietenia macrophylla | 52.98   | 1                  |
|            | Acacia sp.            | 23.54   | 1                  |
|            | Tectona grandis       | 11.29   | 1                  |
|            | Elaeocarpus ganitrus  | 10.38   | 1                  |
|            | Trema tementosa       | 10.32   | 1                  |
|            | Mangifera indica      | 9.74    | 1                  |
| Seedling   | Swietenia macrophylla | 132.25  | 4500               |
|            | Dalbergia latifolia   | 52.18   | 3214               |
|            | Syzygium cumini       | 5.78    | 143                |
|            | Flacourtia inermis    | 4.89    | 71                 |
|            | Sesbania grandiflora  | 4.89    | 71                 |
| Total      |                       | 300.00  | 291                |
Table 3. Species Diversity Level ($H'$), Species Richness Index ($R$), Species Evenness Level ($E$) and Dominance Index (DI) of each tree stages

| Tree stages | $H'$ | $R$ | $E$ | DI |
|-------------|------|-----|-----|----|
| Tree        | 1.52 | 2.41| 0.53| 0.37|
| Pole        | 1.18 | 2.27| 0.44| 0.43|
| Sapling     | 1.67 | 1.95| 0.80| 0.24|
| Seedling    | 0.91 | 0.85| 0.56| 0.51|

3.3 Stand potency

Table 4 shows stand potency of commercial tree in KHDTK Gunung Bromo. The total stand potency and three tree main planted species, namely *P. merkusii*, *S. macrophylla*, and *D. latifolia*, for tree stage were 261.66, 156.67, 69.92, and 14.41 $m^3$/ha, respectively. The tree species that showed the highest volume was *P. merkusii*, indicating that *P. merkusii* was the main species in KHDTK Gunung Bromo (table 4).

Table 4. Stand potency of tree and pole each species

| No | Species                      | Volume ($m^3$/ha) | Tree | Pole |
|----|------------------------------|-------------------|------|------|
| 1  | *Acacia* sp.                | 1.46              | 0.15 | -    |
| 2  | *Tamarindus indica*         | 0.12              | -    | -    |
| 3  | *Antidesma bunius*          | 5.40              | 0.04 | -    |
| 4  | *Dillenia* sp.              | 0.97              | -    | -    |
| 5  | *Endospermum diadenum*      | 0.38              | -    | -    |
| 6  | *Delonix regia*             | 0.10              | -    | -    |
| 7  | *Myrtaceae*                 | -                 | 0.04 | -    |
| 8  | *Tectona grandis*           | -                 | 0.04 | -    |
| 9  | *Cinnamomum* sp.            | 0.48              | -    | -    |
| 10 | *Sterculia foetida*         | 0.52              | 0.03 | -    |
| 11 | *Schleicheria oleosa*       | 0.78              | 0.11 | -    |
| 12 | *Oroxyllum indicum*         | -                 | 0.02 | -    |
| 13 | *Swietenia mahagonoy*       | 1.85              | 0.15 | -    |
| 14 | *Swietenia macrophylla*     | 69.92             | 6.44 | -    |
| 15 | *Memecylon* sp.             | 4.42              | -    | -    |
| 16 | *Phyllantaceae*             | 0.31              | -    | -    |
| 17 | *Pinus merkusii*            | 156.67            | 13.10| -    |
| 18 | *Polyzosia nodosa*          | -                 | 0.01 | -    |
| 19 | *Flacourtia rukam*          | -                 | 0.04 | -    |
| 20 | *Adenanthera pavonina*      | 1.72              | -    | -    |
| 21 | *Falcatoria moluccana*      | 0.52              | 0.16 | -    |
| 22 | *Dalbergia latifolia*       | 14.41             | 0.30 | -    |
| 23 | *Trema tementos*            | -                 | -    | -    |
| 24 | *Sesbania grandiflora*      | -                 | -    | -    |
| 25 | *Vitex* sp.                 | 1.62              | 0.02 | -    |
| **Total** | **261.66** | **20.65** |      |      |

Note: -, there was no tree/pole stage found in the sampling plot
The other species in the tree stage that has high potency was *S. macrophylla* (table 4). In KHDTK Gunung Bromo, *S. macrophylla* stands were found in the pure stand or mixed stand with *P. merkusii*. Beside for diversity timber product, *S. macrophylla* trees were planted mainly in the local protected area for the ecological function. It has deep roots that can protect the soil from landslide and improving the quality of land [26].

In the past when the Gunung Bromo forest was managed by Perum Perhutani, the main commercial trees were not only *P. merkusii*, but also *D. latifolia*. However, based on the results as shown in table 4, the volume of the remaining *D. latifolia* in KHDTK Gunung Bromo was limited, only 14.41 and 0.30 m³/ha for tree and pole stages, respectively. However, the seedling of *D. latifolia* is remarkably easy to find out there due to their ability to grow thought the roots and seed (figure 7). Under natural conditions, *D. latifolia* reproduces by seed, root sucker or coppice. The root system is well developed, consisting of deep taproots and lateral roots. When near the soil surface, roots produce suckers [22]. Thus, in the future, if the canopy opens the seedling of *D. latifolia*, together with *S. macrophylla*, it might grow until they reach the tree stage and change the forest composition and structure.

In the pole stage, the stand potency was 20.65, 13.1, 6.44, and 0.30 m³/ha for total, *P. merkusii*, *S. macrophylla*, and *D. latifolia*, respectively (table 4). The potency of the pole stage was very low, indicating that Perum Perhutani as the former manager of this area applied rotation in the short duration. Thus, caused the trees have a similar age and diameter.

### Conclusion
The horizontal structure showed that the Gunung Bromo forest was consist of three main canopies: emerged, medium, and low canopy. The vertical structure shows a normal distribution of diameter. The trees with a stem diameter of 20-30 cm were dominant. Total tree species that found in KHDTK Gunung Bromo were 29 tree species, in four tree living stages. The total volume of trees KHDTK Gunung Bromo was 261.66 m³/ha and the density of 291 trees/ha. In the tree and pole stage, *P. merkusii* was dominant. *P. merkusii* shows SIV, volume, and density of 163.23%, 156.67 m³/ha, and 202 trees/ha, respectively. In the sapling stage, *D. latifolia* shows species important value of 118.4%, indicating that *D. latifolia* was able to naturally regenerate. In the seedling stage, *S. macrophylla* shows the highest density compared to other species. The density of *S. macrophylla* was 400 seedling/ha, indicating that *S. macrophylla* seeds were adapt to the forest floor. Based on the present study, *P. merkusii* was the dominant species. The tree diameter and height of *P. merkusii* relatively uniform. Thus, the KHDTK Gunung Bromo manager should consider enriching the tree species. Especially promote the other tree species that already established to increase species diversity. *Dalbergia latifolia* was one of the recommended tree species that can be developed in KHDTK Gunung Bromo. This species has the ability to easily regenerate through root suckers. In addition, *D. latifolia* is also valued for its luxurious wood.

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