Natural regeneration potential of red meranti (Shorea leprosula Miq.) in 20-years-old man-made hilly dipterocarp forest

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Abstract. Shorea leprosula Miq is one of major tropical timber within the dipterocarp family and known as red meranti in global trade. The species has been subjected to intensive timber extraction due to their high economic value and natural abundance in primary tropical forest. Timber supply of this species has been known to only from natural forests and none have been reported from commercial plantation. Thus, population decline, habitat contraction and local extinction become the major issues related to the species. This research was conducted to determine the natural regeneration potential of S. leprosula in 20-years-old man-made hilly dipterocarp forest. The research was located at Gunung Dahu Research Forest (GDRF), a 250 Ha-mixed dipterocarp forest established since 1997 in Bogor- West Java as landscape restoration together with native biodiversity conservation program. Five S. leprosula plots were chosen consisting from different spacing distance of 2 m x 2 m, 3 m x 3 m, and 4 m x 4 m. Result showed that each plot has been experiencing different total number of fruiting times, ranging from 1- 3 times, with total numbers of natural juvenile reached 652 stocks. Among them, seedling were the most stocks available at GDRF, with the most dominant occupied at height class of 11 cm – 33 cm and 34 cm – 55 cm. Natural stocks were absent from 2 observed plots due to high human alteration at those area. Canopy openness, altitude and human intervention/disturbance are among the factors that affecting the regeneration potential at GDRF.

1. Introduction
Meranti (Shorea spp.) is a highly valued commercial timber that has high durable wood and play significant role in national and global market [1]. Their high economical value promotes over exploitation and caused significant decrease in their existence in the wild, thus conservation action is needed to preserve their genetic sources. One of many things to assess in conservation efforts of a species are regeneration capabilities, whether it occurs naturally or artificially assisted regeneration. Naturally, forest plants can regenerate itself from the seeds that reach the forest floor however many constraints and factors may limit the germination success. Low regenerative potential of some species can lead to population decline and increase in their scarcity.
Gunung Dahu Research Forest (GDRF) is a research area that accommodates plot experiment on vulnerable Shorea species. It established to reconstruct the ecological function of the degraded forested land while conserving the major tropical tree family of Dipterocarp. Later on, community awareness has also increased due to its success in building the economic benefit from environmental value of the forested land through ecotourism. One of the indicators for successful forest restoration is the establishment of natural regeneration characterized with wilding stock growth and the security of the species biodiversity. The availability of good seeds and seedlings in respectable amount is crucial to sustain forest restoration efforts, because good seeds determine the success of replantation. One of the main factors for a proper natural regeneration to occur is by maintaining suitable condition for seedling growth. High wilding survival rate is influenced by environmental factors, one of them is light intensity [2]. Most of the species in Dipterocarpaceae family have no specific fruiting season, so once it bears fruits and produce planting stocks is one of the crucial step in their regeneration aspect. Hence, research on Meranti (Shorea spp.) regeneration potential is essential.

Natural regeneration is an important factor behind forest conservation. However, there were lack of research on Dipterocarpaceae regeneration ability yet. Considering that condition, research on natural regeneration potential based on environmental condition for Shorea leprosula is important to act as the basis for sustainable forest management. This research aimed to analyze the natural regeneration stage of Shorea leprosula and environmental condition that supported Shorea leprosula’s growth in GDRF-Bogor, West Java-Indonesia.

2. Methods

2.1. Research location

Research was conducted in GDRF, specifically in previously identified Shorea leprosula plot which already have been recorded for their flowering/fruting season, the plots were plot 1, 2, 5, 7, and 21 A. Plot layout is shown in Figure 1.

![Figure 1](image-url)
2.2. Supporting and environment data collection
Measurements were also conducted on supplementary environment data comprised of light intensity, inclination, canopy closure, and soil texture. Supplementary data is a compilation of secondary data which collected from interviews and record of previous fruiting. Densiometer was used for measuring canopy cover. Canopy cover measurement was done using [3] method. Light intensity value was measured using lux meter on five observation spots while inclination was measured using clinometer as detailed by [4]. Soil texture was tested by taking disturbed soil samples following [5] method.

2.3. Wildings measurement
On each observation plots, trees that already bear flowers and fruits were recorded based on the results of interview and available secondary data. Measurements was conducted on each mother tree to account for the presence of natural regeneration by recording number wildings surrounding each tree, average seedling height, average seedling distance from mother tree, and determining height class using statistical formula. All available wildings at observed plots were measured using census.

3. Results and discussion

3.1. Shorea leprosula stand at Gunung Dahu Research Forest
Stand conditions of S. leprosula on each observation plot in petak 1, 2, 5, 7 dan 21A as summarized in Table 1.

| Species      | Plot No. | Planting distance | Planting year | Plot area (ha) | Origin | Fruiting season (times) |
|--------------|----------|-------------------|---------------|---------------|--------|-------------------------|
| S. leprosula | 1        | 2 x 2 m           | Nov-97        | 1             | cutting| 3                       |
| S. leprosula | 2        | 3 x 3 m           | Mei-97        | 1             | cutting| 3                       |
| S. leprosula | 5        | 4 x 4 m           | Jun-97        | 1             | seed   | 3                       |
| S. leprosula | 7        | 4 x 4 m           | Jan-98        | 1             | cutting| 3                       |
| S. leprosula | 21 A     | 4 x 4 m           | Jun-99        | 7.2           | seed   | 1 times                 |

Table 1 determined that Shorea leprosula stands planted in GDRF has clear records. Each plot has specific spacing distance and planting year that differs from the others. The total area of planting plot is 1 ha for plot 1, 2, 5, and 7, while plot 21 A has the largest area of 7.2 ha. There were two kinds of plant source utilized in this experiment, plot 1, 2, and 7 were originated from cuttings, whereas plot 5 and 21 A were originated from seeds. Flowering records on plot 1, 2, 5, 7 shows that the stands in these plots were already flower and bear fruits for 3 times, more frequent that that of plot 21A which been flowering for 1 time. Besides stand history, others observed environmental condition as described in Table 2.

| Plot No. | Canopy openness (%) | Light intensity percentage (%) | Light intensity (lux) | Inclination (%) | Elevation (m,asl) | Soil texture    |
|----------|---------------------|-------------------------------|----------------------|-----------------|------------------|-----------------|
| 1        | 14.04               | 11.19                         | 325                  | 35              | 697–718          | Loamy sand      |
| 2        | 32.5                | 40.15                         | 1166.25              | 20              | 693–707          | Loamy sand      |
| 5        | 31.2                | 36.19                         | 1051.25              | 35              | 682–702          | Loamy sand      |
| 7        | 42.64               | 60.88                         | 1768.75              | 20              | 711–716          | Loamy sand      |
| 21 A     | 21.06               | 24.52                         | 712.5                | 40              | 687–745          | Sandy loam      |
Table 3. Average height, diameter and number of trees of S. leprosula stands in each observation plot

| Plot No. | Planting distance | Average total height (m) | Average diameter (cm) | Total number of mother tree in plot |
|----------|-------------------|--------------------------|-----------------------|-----------------------------------|
| 1        | 2 x 2 m           | 21.5                     | 40.79                 | 9                                 |
| 2        | 3 x 3 m           | 21.1                     | 42.6                  | 34                                |
| 5        | 4 x 4 m           | 21.03                    | 44.86                 | 27                                |
| 7        | 4 x 4 m           | 21.08                    | 46.67                 | 6                                 |
| 21 A     | 4 x 4 m           | 19.63                    | 43.04                 | 24                                |

Stand records and environmental condition mentioned above can be utilized to support the growth of *Shorea leprosula* stands. According to [6] the structure of forest stands can represent the forest status which linked to the distribution of tree individuals of various diameters and canopy sizes. GDRF is considered an even-aged forest, because all stands in a plot were planted on nearly the same time, average height and diameter of *Shorea leprosula* presented in table 3.

Table 3 described that the average of height and diameter of *Shorea leprosula* were relatively similar on each observation. The relatively similar value may be considered as that the species were planted in nearly the similar time (Table 1). Average height and diameter of stands at the almost the similar value could also emphasize the age similarities between plots. Diameter increment of plot 1 was 1.85 cm/year, on plot 2 was 1.89 cm/year, plot 5 was 2.04 cm/year, plot 7 was 2.22 cm/year, and for plot 21 A was 2.15 cm/year, the difference of diameter increment on each plot is related to the difference in plant spacing of each plot. As the spacing gets wider, diameter increment values also tend to get higher as shown in plot 5, 7 and 21 A with spacing of 4 m × 4 m, while plot 1 and 2 have less diameter increments than previous plots with their respective spacing of 2 m × 2 m and 3 m × 3 m. This is consistent with statement from [7], following their research on 5 years old *Shorea leprosula* stands, highest diameter and diameter increment values were found on the subjects with the widest space between stands, which is 3 m × 3 m. Another insight from different age class, [8] determined that 7 years old *Shorea leprosula* planted in PT Sari Bumi Kusuma had the diameter increment of 2.31 cm/year. Plot 7 have the highest diameter increment compared to other plots with similar planting distance. Different planting stock origin, whether from cutting or seed, seemed to have no significant values compare to seed origin in term of the average height and diameter. This proves that stands sourced from cuttings can also shows excellent growth in the field.

Plot 1, 2, 5, 7 and 21A had the number of mother trees of 9, 34, 27,6 and 24 respectively. Difference in the numbers of mother trees between plots may be generated due to individual competition, resulting in only several trees that experienced to bear flowers and fruits. According to [9], generative phase of *Shorea leprosula* happens every 2 – 3 years. On flowering season, mature trees will produce large amounts of flower, that is different from *Shorea leprosula* stands in GDRF which flowering and fruiting lessen compare to those in their natural habitat. That difference may cause to the altitude of the area which is higher than 700 mdpl, which exceeds the optimal altitude for *Shorea leprosula* growth [10].

3.2. Abundance of wildings stock

GDRF is a research-oriented forest with minimum maintenance and roguing done after transplanting. Suitable environment and tree physiological condition could be the factor linked to the presence of natural regeneration. Height frequency distribution on the stages of wilding stock in *Shorea leprosula* plots is shown in the figure 2.
Figure 2. Height frequency distribution on the stages of wilding stock in *Shorea leprosula* plots

Figure 2 confirms that *Shorea leprosula* natural regeneration in GDRF were only found in plot 2, 5, and 7, while the absence of natural regeneration was found in plot 1 and 21 A. Number of wilding stage at each observed plot as shown in table 4.

| Wilding stage | Plot 1 | Plot 2 | Plot 5 | Plot 7 | Plot 21 A |
|---------------|--------|--------|--------|--------|-----------|
| Seedlings     | 0      | 156    | 230    | 13     | 0         |
| Saplings      | 0      | 0      | 1      | 1      | 0         |
| Total         | 0      | 156    | 231    | 14     | 0         |

Table 4 showed that seedling stage were the dominant growing stage from all three plots. The total number of seedlings found were 299 individuals, while there was only 2 individuals found in the stage of saplings. The dominance of seedling stage may be related with the stand’s age that was 21-22 years. Flowering record showed that the maximum observed fruiting season was only 3 t the year. As the frequent flowering happened at GDRF sofar at more and less happened once within 5 years, the stand that experienced 3 times fruiting season took place place at year 12, 17 and 22 after planting. According to [9] *Shorea leprosula* is starting to consistently flowering in about year 13-15, indicating that natural regeneration on *Shorea leprosula* stands in observation plots were able to flowers steadily.

Plot 1 has no natural regeneration, few mother plants that only consist of 9 individuals and low flowering intensity was suspected to be the cause for the absence of wildings. Aside from those, the presence of ferns could prevent the fruits to reach the ground surface, rendering them to be unable for speouting/germination. Inability to germinate and competition with thick lower vegetation leads to poor natural regeneration. Plot 21 A with more numbers of mother plant ( 24 individuals) also shown no signs of wildings. From available record, at the year of observation the plot was experiencing its first year fruiting seasson and this could lead to the absence of wildings in this plots. As for plot 5, it was plot with highest number of natural regeneration, comprising of 231 individuals, followed by plot 2 which has 156 individuals. Even though plot 7 has a really small amount natural regeneration of only 14 individuals, this plot has the highest value of diameter increment among other plots. In their
research, [10] stated that size difference in *Shorea leprosula* mother plants significantly affect the heights and diameters of its seedlings. Large mother plant tends to produce higher height and diameter growth. It can be inferred from plot 2 and 5 high natural regenerations, higher number of mother plants would increase the regenerative potentials of the plot. While the mother plant with the highest number of natural regeneration growing around it were having large diameters as seen in plot 2 (54.2 cm) and plot 5 (59 cm). That mother plant that carries good phenotype tend to produce good wildlings because the good traits will be inherited to its offsprings [11]. Difference in natural regeneration numbers also suspected due to the dense flowering in plot 2 and 5, while plot has less 7 flowering. High flowering intensity contributes to higher fruit productivity which leads to higher sprouting and natural regeneration potential. According to [9] the germination rate could exceed 90% when seed were fully mature.

According to [9] *Shorea leprosula* grows optimally at an altitude under 700 masl, that condition was different from GDRF which has an altitude ranging from 690-745 masl, causing unoptimal *Shorea leprosula* growth which leads to low numbers of yielding individuals and inadequate numbers of natural regeneration. Different from natural regeneration in KHDTK Haurbentes, [12] stated in her research, number of seedlings found on same species reached 95000 individuals for 8 observation plots. That was may be caused by the altitude of KHDTK Haurbentes which was ranging between 233-350 masl which is an optimal growing habitat for *Shorea leprosula*. Another factors are the difference in stand age in KHDTK Haurbentes that reached 76 years, 64 years, 31 years, and 30 years while the stands in GDRF still ranging about 20-22 years, indicating that older stand age would increase natural regeneration potential.

Based on [7] *Shorea leprosula* can grow in various soil types, it is further supported by the stands adaptability to grow in yellow-red podzolic soil of KHDTK Haurbentes and reddish brown latosolic soil of GDRF. Inclination does not affect the growth of *Shorea leprosula* as stated by [10] *Shorea leprosula* can grow at hillsides and valleys. Soil texture of *Shorea leprosula* stands in Gunung Dahu Research Forest were loamy sand and sandy loam. It is consistent with [9] which stated that *Shorea leprosula* Miq and *Shorea johorensis* Fox of PT ITCI Hutani Manunggal grows on sandy loam soils.

Shorea, which is a semitolerant species, requires little light or a shade covering at beginning of its growth. Plot 2, 5 and 7 were having light intensity ranging from 1051.25-1768.75 lux. The value of light intensity is correlated with canopy openness, that means the light intensity value measured on the forest floor will get higher if the value of canopy openness is also high. According to [13] Dipterocarpaceae are plants that need shade cover at the beginning of their growth with optimal light intensity received at 50%. The intensity of penetrating light in *Shorea leprosula* stands were about 11.19-60.88 %, plot 1 was a plot with the lowest value of light intensity measuring only 11.19 %, this low value of light intensity could be the reason why natural regeneration absence in the plot, while the plot which have the highest amount of natural regeneration were having light intensity of 36.19%. Plot with the highest value of light intensity is plot 7 measuring at 60.88% which could explain why there’s a higher distribution of natural regeneration in later stages, since the development from seedling stage to sapling stage needs greater light intensity.

Environmental condition especially light intensity (LI) on *Shorea leprosula* block with the most natural regeneration at KHDTK Haurbentes shows nearly identical with the plots in GDRF, of about 1006.35-1158.55 lux, those LI value were suitable for natural regeneration growth of *Shorea leprosula* especially at seedling stage. The small number of available sapling stage of natural regeneration indicated the light intensity of research location were not yet suitable for supporting the sapling stage, because of greater light intensity was requires for sapling stage to grow. According to [14], the required light intensity on seedling stage was smaller on that of sapling and pole for *S. johorensis*. Seedlings were mostly found on areas that covered by bamboo or other plants. The wide range dispersion of its seeds were made possible by 5 winged structure on *Shorea leprosula* fruits. Sufficient amount of plant litters is one of the organic matter source that sustain the growth of wilding stock. These litters sourced from Shorea stands leaf droppings, fallen trunks, or even from underneath plant matters.
Aside from benefitting habitats and microclimate of the surrounding environment, GDRF also generated economic benefit for surrounding community in the form of ecotourism. However, development of ecotourism area can also bring negative impact on the forest. Plot 2 with great natural regeneration potential with 34 mother plants is located in the ecotourism area, disturbances like the slashing of wildings and utilization of Shorea stands as ecotourism property hinder its natural regeneration from reaching its maximum potential, by creating unsuitable condition for Shorea seeds to grow. Aside from tourism disturbances, the presence of roads and paths used by buffalo that heads to nearby village causing several seedlings to be damaged from getting trampled and unable to recover as observed in plot 5. Cassava cultivation by nearby people on plot 5 and 21 A brings unsuitable growing condition for natural regeneration growth.

4. Conclusion
Natural regeneration pattern of red meranti in different plot of GDRF showed that generally each plot has different total number of fruiting times, ranging from 1-3 times, with total numbers of natural juvenile reached 652 stocks. Natural stocks were absent from 2 observed plots due to high human alteration. The natural stock showed that the most dominant occupied at height class of 11 cm – 33 cm and 34 cm – 55 cm. Canopy openness, altitude and human intervention/disturbance are among the factors that affecting the regeneration potential at GDRF.

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