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Natural regeneration capacity of *Shorea leprosula* Miq. at Gunung Dahu Research Forest in Bogor

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Abstract. Shorea leprosula *is one of the tree species within Dipterocarpaceae Family, which is a major source of timber production. The species has been planted massively in Gunung Dahu Research Forest (GDRF) in Leuwiliang, Bogor. Gunung Dahu Research Forest is a man-made dipterocarp forest that has varying slope classes, topography, and canopy cover. Furthermore, natural regeneration is an important ecological factor in assessing the ability of forest regeneration, including in a plantation forest. Therefore, it is necessary to know the effect of slope and canopy cover on the regeneration of* S. leprosula *in order to characterize what factors support and constrain the naturally regenerating forest of Gunung Dahu Research Forest. Regeneration capacity of the species was observed in purposive plots which have been recorded for their flowering events. Seedlings were grouped into seedlings and saplings. It was measured by census method on every slopes. Meanwhile, variable observed included number of available seedlings at each slope category slope with its canopy cover, height and diameter of seedlings, and litter thickness. The results show that a flat slope with shady canopy cover has the highest capacity of seedlings and the best growth. The uneven distribution of height and diameter indicates the need for silviculture action, such as, maintenance.*

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INTRODUCTION

Meranti is one of the Dipterocarpaceae Family, which is a commercial wood and widely known in Southeast Asian countries with various trade names. Among them, red meranti (*Shorea leprosula)* is the most common and diverse species which globally traded and valued for their economic importance. Furthermore, *S. leprosula* is a major timber with a significant role in ecology and economic aspect with relatively faster growth rates than other (Sukendro and Sugiarto 2012) shorea species. Their high rate of extraction should be followed by sustainable forest management practices in order to assure their future existence (Pooma and Newman 2017). Therefore, the preservation and existence of *S. leprosula* need to be maintained by implementing sustainable forest management. One of the indicators of sustainable plantation forest management is the creation of natural regeneration, which is characterized by the growth of natural regeneration.

Gunung Dahu Research Forest is a research forest where there is a test plot of meranti plants in which *S. leprosula* contains a total area of 250 ha and, based on previous research (Nurkhaeni 2019) has regenerated naturally. It is a good sign that the Gunung Dahu Research Forest has been able to conduct its natural regeneration function even though it is a plantation forest. Moreover, Gunung Dahu Research Forest has a silly topography and diverse slope. Slope is one of the factors which can affect the difference in light intensity received by plants, which is important for growth in height and diameter of regeneration and land productivity (Khalifa 2019).

Good natural regeneration is influenced by the creation of environmental conditions (microclimate) which support the growth, which among them is light intensity received that correlated with canopy closure. The more open canopy cover, the higher the light intensity. The need for light for meranti growth at seedling rates ranges from 50–85% (Bayau 2017). Furthermore, according to Suci and Heddy (2018) every plant or tree type has a different tolerance to sunlight. Canopy cover on each slope is different, so it can affect the regeneration capacity of *S. leprosula*. Previous research stated that *S. leprosula* requires shade at the beginning of its growth with a slope of less than 25% (Soekotjo 2009). *S. leprosula* flowering happens every 2-3 years (Wahyudi *et al.* 2014); besides emphasize that natural generation needs to be considered. The abundance and their distribution at different slope classes and canopy covers have not been revealed clearly. Therefore, this study aims to determine the regeneration capacity of *S. leprosula* on different slope class and canopy cover at a man-made dipterocarp forest of Gunung Dahu Research Forest.

METHODS

This study was conducted in March 2021 in the Gunung Dahu Research Forest, Pabangbon Village, Leuwiliang District, Bogor. The topography at the site was included in the category of slopes between 8-45%, with latosol soil type, and climate type B. Moreover, plot selection used the purposive sampling method. Heridiansyah (2012) stated that the purposive sampling method is the selection of criteria with a specific purpose in the data collection process. In this study, the criteria used were plots with the best natural regeneration, which were plots 2, 5, and 7 (Nurkhaeni 2019) with a total area of 3 hectares.

Collecting Data

Data collection methods included the data collection of *S. leprosula* seedlings growth and environmental conditions data. The collection of growth data used the census method. Saplings and seedlings are the levels of regeneration from which growth data are taken. Meanwhile, the diameter was measured by using a digital caliper, and the height was measured by sewing tape. Seedlings were taken from each class of the research plot.

Environmental condition data include slope, canopy cover, and litter thickness. Slopes were measured by using a clinometer with slope welding of Kemenhut (2013). Canopy cover was obtained from the value of the leaf area index. The leaf area index obtained from the photo of the canopy cover in the research plot was used on a shady tree located in the center of the plot, which was then processed by using Hemiview. Canopy cover was classified according to Ratnasih (2013).

Data Analysis

Data analysis was processed by using Microsoft Excel and IBM SPSS. Furthermore, the data taken from the research plot was processed by dividing the high class of tillers, looking for the important value index to find out which type of seedling dominates, and the ANOVA test. The division of the sapling height class is used to find the highest seedling frequency at a certain height, the important value index to know the greatest abundance of seedlings, and the ANOVA test to know which grade of slope supports seedling abundance and growth (Nurkhaeni 2019).

RESULTS AND DISCUSSION

Environmental Conditions of the Mount Dahu Research Forest

The condition of *S. leprosula* stands can be seen in Table 1. The planting year of *S. leprosula* in plots 2 and 5 is 1997, and t the planting year in plots 7 is 1998. Rachmat *et al.* (2021) stated that planting activities of meranti stands in the Gunung Dahu Research Forest use seeds from nature and cuttings. Since research plots have different spacing, it makes the condition of *S. leprosula* different in each research plot.

Table 1 Condition of *S. leprosula* stands in various research plots

Plot	Spacing (m)	Planting Year	Plot Area (ha)	The Origin of the Tree	Flowering History
2	3 x 3	May-97	1	Cuttings	3 times
5	4 x 4	Jun-97	1	Seed	3 times
7	4 x 4	Jan-98	1	Cuttings	3 times

Source: Nurkhaeni (2019)

S. leprosula is a type of opportunistic gap which has an inhibiting factor for early growth especially external factors, such as light intensity and the space where it grows (Sukendro and Sugiarto 2012). Therefore, environmental conditions have a major effect on the regeneration of *S. leprosula*. The physical condition of the research plot can be seen in Table 2.

Table 2 Physical condition of the research plot

Plot	Elevation (masl)	Slope Class	Litter Thickness (cm)	LAI
2 (3 x 3) m	718	Flat	4,4	2,39
		Sloping	4,6	1,88
		Slightly Steep	4,2	1,64
		Steep	8,8	1,38
		Very Steep	14,2	0,55
5 (4 x 4) m	679	Flat	2,7	2,73
		Sloping	3,2	1,26
		Slightly Steep	3,6	1,33
7 (4 x 8) m	707	Flat	10	1,92
		Sloping	13,8	0,65
		Slightly Steep	8,6	0,55
		Steep	10	0,54

Wahyudi *et al.* (2014) stated that the optimal altitude for *S. leprosula* growth is in lowland forests which is around 0–700 masl. It is certainly different from the conditions in the Gunung Dahu Research Forest which has an altitude ranging from 679–718 masl with a sloping topograph. Thus, it makes the altitude as an inhibiting factor for the growth and development of *S. leprosula*, especially at the seedling level. Furthermore, the slopes which found on the research plots are very widely, from flat to slightly steep. The difference in slope class in each plot is because of the hilly topography so that not every plot has found five slope classes. Surface run-off on steep slopes will further increase the rate of rainwater falling to the ground so that erosion rates will be higher (Lathifah and Yunianto 2013). That is why canopy cover on slopes has an important role. Canopy cover can be determined by Leaf Area Index (LAI). The flat slope class in each research plot has the highest LAI value. The shade of canopy cover can be affected by the diameter of mother trees. Moreover, Nurhajah (2014) stated that the diameter of the canopy cover will be less shady.

Based on research which had conducted by Nurkhaeni (2019) show that mother trees in plots 2, 5, and 7 have an average of 41,6 cm; 44,86 cm; and 46,67 cm, so that 7 plot has a low LAI value.

Based on the results of the study, each plot has a different litter thickness. Litter is an organic material that has the ability to provide additional nutrients after it decomposes into compost (Abdurachman *et al.* 2013). The litter which dominates the research plots is *S. leprosula* litter, bamboo litter, and understorey litter. The higher litter thickness is 14,2 cm on plot 2 with a very steep slope and 13,8 cm on plot 7 with a sloping slope. The thick litter is due to the presence of dense ferns, which makes the pile of litter difficult to be decomposed. Moreover, Andayaningsih *et al.* (2013) stated that ferns could grow well in the open area, the more open the canopy cover so the most abundant the ferns. The ferns have a long decomposition time. Litter decomposition is the process of overhauling litter as a source of organic matter by microbes into nutrient energy (Aprianis 2011).

Regeneration of *S. leprosula* Seedlings Under Various Environmental Conditions

Based on the results of the study, the growth data of *S. leprosula* seedlings can be seen in Table 3. *S. leprosula* seedlings are most commonly found in the flat to slightly steep slope class with a shady canopy cover. *S. leprosula* is a plant that at the beginning of its growth has a sensitivity to light since it is a semitolerant species. It is accordance with the statement of Setiawan *et al.* (2015) which stated that *S. leprosula* has genetic characteristics which require low light intensity for early growth or need a shady canopy. The condition of plots 2 and 7, with steep and slightly steep slope classes with a canopy cover that is not shady has the least number of seedlings. Meanwhile, a slope which exceeds 25% is suspected be the cause of it. Khalifa (2019) stated that *S. leprosula* is more able to grow on flat slopes (0–8%) since its habitats is in low land forests. In open shade, the seedlings can still be alive but if this happened for a long time, the *S. leprosula* seedlings will wither, dry up, and die.

Table 3 Growth data and IVI of *S. leprosula* seedlings

Plot	Slope Class	N (individual)	Diameter (mm)	Height (cm)	INP (%)
2 (3 x 3) m	Flat	851	2,19	21,24	35,08
	Sloping	270	1,91	20,69	16,82
	Slightly Steep	49	1,71	19,10	9,87
	Steep	10	1,65	16,80	8,64
	Very Steep	2	1,25	10,50	8,39
5 (4 x 4) m	Flat	929	2,92	35,58	37,53
	Sloping	334	2,09	23,95	18,83
	Slightly Steep	331	1,97	22,31	18,11
7 (4 x 8) m	Flat	419	2,20	22,14	21,50
	Sloping	4	1,70	15,75	8,45
	Slightly Steep	1	1,30	10,00	8,36
	Steep	1	1,20	11,00	8,36
Amount		3.181			200

The number of *S. leprosula* seedlings found in the low on very steep slope classes is thought to be caused by the thickness of the litter. *S. leprosula* has the ability to prune itself naturally so that it can increase the stock of organic matter on the soil surface. Moreover, fern litter which decomposes slowly, has a high litter thickness of up to 14,2 cm, and very high fern height causes a slow rate of litter decomposition. It is in accordance with the research which had conducted by Pamoengkas and Erizilina (2019) in the Haurbentes

Research Forest, Jasinga, which stated that with a litter thickness of 4,03 cm, more *S. leprosula* seedlings are found than those with a higher litter thickness.

Based on the results of the study, each slope in the research plot 7 is overgrown by ferns and undergrowth which dominate, such as *Clidemia hirta* and *Echinocloa colonum*. The presence of this understorey is thought to inhibit the growth of *S. leprosula* seedlings. It is in accordance with the statement of Wibowo (2006) that weeds, such as ferns, can inhibit the growth of the main crop due to competition in nutrients, light water, and the space where they grow. Furthermore, Ngatiman and Nurcahyono (2016) stated that more open canopy cover causes sunlight can reach the forest floor, so weed development is faster than young staple plants (less than 3 years). At the beginning of its growth, *S. leprosula* has properties that are sensitive to light, so it needs to be shaded for the beginning of its growth. The ferns found in plot 7 dominate as land cover, and their height exceeds the observer. According to Malla and Acharya (2018), land cover dominated by understorey or grass causes the regeneration of a plant to be hampered when compared to plots where there are few understorey plants.

The understorey conditions in the Gunung Dahu Research Forest are similar to those found at PT Balikpapan Forest Industries, namely *Clidemia hirta* and *Echinocloa colonum* (Ngatiman and Nurcahyono 2016). *Clidemia hirta* which is found in the Gunung Dahu Research Forest is mostly found in clumped ferns, while *Echinocloa colonum* is found in almost all soil surfaces overgrown with *S. leprosula* seedlings. It can inhibit the growth of *S. leprosula* seedlings so that the number of *S. leprosula* seedlings is not abundant in plots 2 and 7 with gentle slopes, rather steep and very steep. Massive weed disturbances have a very negative impact on seedlings. *C. hirta* or kala roots are annual shrubs or tough weeds. The roots are strong and deep and if the stem is cut down, new shoots will grow (Faisal *et al.* 2013). Ngatiman and Nurcahyono (2016) stated that *C. hirta,* which is found in almost all research plots can inhibit the growth of *S. leprosula* seedlings which were taller than *C. hirta*. However, in some slope classes; such as, plots 2 and 5, *C. hirta* which is found do not exceed the seedling height so that *S. leprosula* seedlings could still compete for growth. The fungus found in plot 7 is suspected to be *Chlorophyllum cf. molybdtes*. It is based on Putra's research (2020) where the mushroom research results are the same as the mushrooms found in the Gunung Dahu Research Forest. In addition, *C. molybdtes* has a part consist of a hood (pileus), lamellae, and has a true stalk (stipe). This mushroom is a wild mushroom which is classified as poisonous. *C. molybdtes* is found on the surface of the soil covered with ferns. Silvicultural measures such as maintenance need to be conducted in order to reduce undergrowth that can trigger the growth of this poisonous fungus.

Plot 7, with flat slopes, has a fairly abundant number of seedlings. The location of slope, which is located between two hills, causes the seeds that fall from above to fall towards the valley, which is a class of flat slopes, and there is also bamboo which is a shade for the seedlings. Moreover, traces of wild boars are found in plot 7. According to Albert *et al.* (2014), wild boars dig the ground when wallowing and use their snouts when looking for food in the form of worms so that it is thought to stimulate the germination of *S. leprosula* seeds which are not shaded since the seeds are covered by the soil surface and grew in loose soil.

Good natural regeneration is related to the role of the mother tree. There are different numbers of *S. leprosula* mother trees in the research plot. It is stated by Nurkhaeni (2019) that the number of mother trees found in plot 2 was 34 mother trees, plot 5 was 27 mother trees, and plot 7 found 6 mother trees. The average diameter of the mother trees in plots 2, 5, and 7 are 41,6; 44,86; and 46,67 cm; respectively, with a height of 21,1 cm; 21,03 cm; and 21,08 cm. According to Sumarna (2008), the trunk diameter of the mother tree has a close relationship with the area of the canopy, which is closely related to the ability of the tree to produce natural regeneration. The average diameter in plot 5 does not differ much from the largest diameter in plot 7, so the mother tree in plot 5, with a very shady canopy cover on the flat slope class, supports the best regeneration of *S. leprosula* seedlings. Moreover, environmental conditions, such as the number of ferns in several classes of slopes in plot 2 causes less *S. leprosula* seedlings to be found in plot 5 even though the plot has more mother trees. Meanwhile, the small number of seedlings in plot 7 is due to the smaller number of mother trees and relatively less dense canopy cover compared to plots 2 and 5. According to Nurkhaeni (2019), the more mother trees are found in a field, the more natural regeneration will be found a lot.

The abundance of *S. leprosula* seedlings in plot 2 is not as much as in plot 5 since plot 2 is a path for ecotourism, so many visitors pass. Moreover, Nurkhaeni (2019) stated that the Gunung Dahu Research Forest is not only beneficial for the environment and microclimate but also plays a role in ecotourism. The abundance of *S. leprosula* seedlings in plot 2 is not as much as in plot 5 since plot 2 is a path for ecotourism, so many visitors pass. The soil in research plot 2 has a more sandy texture than that which is not traversed by visitors. The path in plot 2 is also traversed by buffalo which are grazed by residents. It can also cause *S. leprosula* seedlings which grow to be trampled and eventually die. In research plot 2, even though it has many mother trees, the regeneration is not as good as in research plot 5.

The height and diameter of *S. leprosula* seedlings also have the best values in the flat slope class, and there is a more shady canopy in plot 5. In addition, Setiawan *et al.* (2015) stated that the increase in seedling height is directly proportional to the increase in diameter; besides, the growth will always be higher than the diameter due to the nature of the plant, which always prioritizes looking for upward sunlight. The best growth in height and diameter of seedlings is in plot 5 on the three slope classes.

The flat slope class has the best diameter and height values. It is in accordance with the research which had conducted by Abdurachman *et al.* (2013) and Soekotjo (2009), which stated that *S. leprosula* grows well in the <25% slope class, especially in the flat slope class. In addition, the sloping and slightly steep slope classes have good height and diameter, although the canopy cover is not shady. It is because many of the seedlings which grow are found on the bamboos as their shade on the slopes.

Distribution of Height and Diameter of *S. leprosula*

The distribution of tiller height based on the frequency distribution can be seen in Figure 1. Based on Figure 1, it can be seen that the natural regeneration of *S. leprosula* is found at a frequency of 20–25cm with a total of 1.004 individuals. The frequencies of 2–7 cm and 8–13 cm are only found by an individual with conditions when in the field *S. leprosula* seedlings were covered by litter on the ground surface.

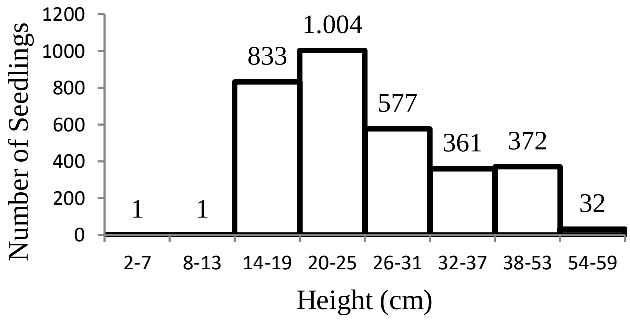

Figure 1 High frequency distribution *of S. leprosula* seedlings in whole research plot

Each plot and slope class has relatively symmetrical distribution of seedling height data. It indicates that the seedling height is not evenly distributed. The distribution of *S. leprosula* seedling's height which is close to symmetrical, is in the sloping slope class of plot 5 and plot 2. The data which are spread symmetrically indicates that the data are normally distributed. Based on Figure 2, it can be seen that in the flat slope class, plot 5 has the highest variation in seedling data. According to Khalifa (2019), data on seedling height spread above the median value show that many seedlings are found to be higher than the average. Moreover, outlier data are found in the flat slope class of plot 2 with a high seedling value which is quite high from the middle value. The outlier data is thought to have come from *Shorea leprosula* seedlings which have existed since Nurkhaeni's research (2019). Outlier data which is below the mean, indicates the presence of newly germinated seedlings. The diameter of natural regeneration of *S. leprosula,* which spreads throughout the research plot, is influenced by various environmental factors so that different diameters are found on each slope or in each research plot. This difference in diameter can lead to outliers found during data collection in the field.

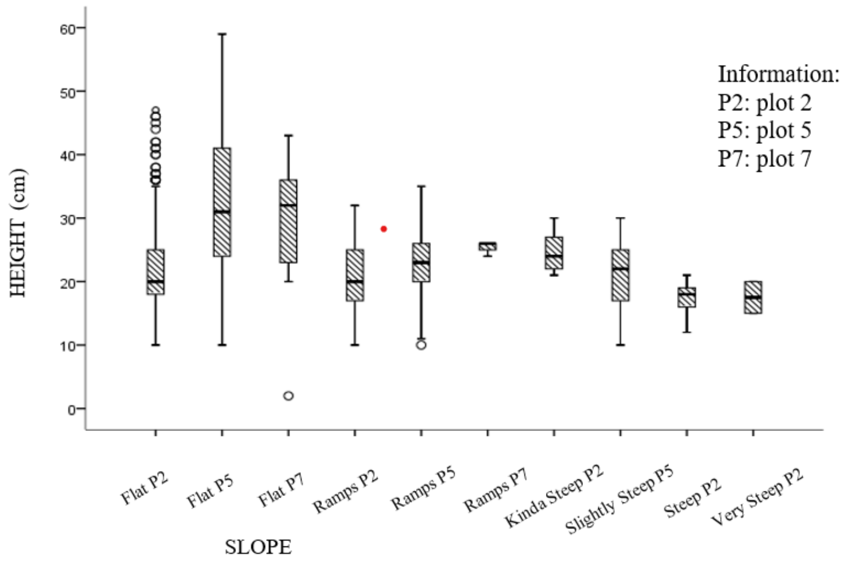

Figure 2 Distribution of boxplot height for *S. leprosula* seedlings

Figure 3 shows that the diameter distribution in the flat slope class plot 7 has a symmetrical and normal diameter distribution. This is different from other slope classes. It can be seen that the median line is not located in the middle of the box or whisker. The flat slope class in plot 5 has a very shady canopy cover so the diameter distribution is the most diverse and has the largest diameter value. In addition, the boxplot with the smallest size is seen in the very steep slope class plot 2, and the gentle slope class plot 7 since only one seedling is found, so the data obtained do not vary.

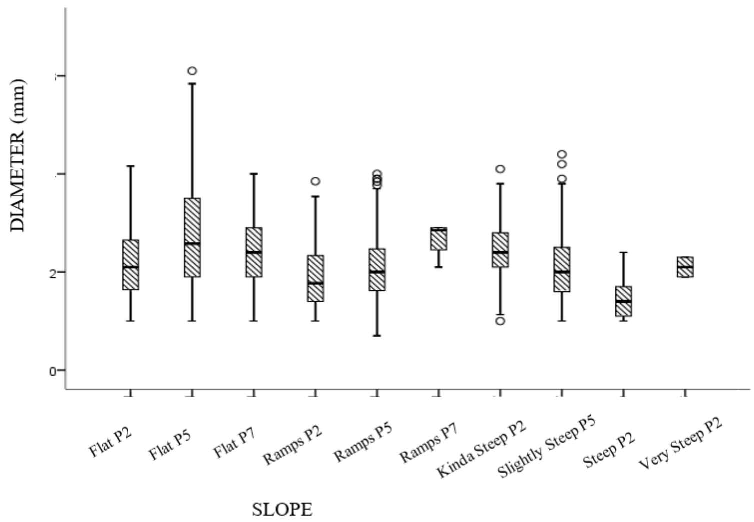

Figure 3 Distribution of boxplot diameter of *S. leprosula* seedlings

Based on the results of the study, the highest grade of the seedling is found at a frequency of 20–25 cm. Seedlings with a height of 20–25 cm are evenly distributed in all classes of slopes in the research plot, but seedlings that exceed the average are found in the flat and gentle slope classes. It is because, on the flat and sloping slopes, the canopy cover is relatively shadier or closed so that the intensity of sunlight entering the forest floor is less than the more open canopy cover. Lower sunlight intensity causes plants to be able to optimize stem growth and stimulate shoot growth (Lakitan 2001). The seedlings' height reaching 59 cm is also suspected because the seedlings have grown since Nurkhaeni's research (2019). Newly germinated seedlings have a low height that is not even visible because they are covered by litter.

The normal diameter distribution was only found in the flat slope class plot 7. This was because, in the flat slope class plot, *S. leprosula* seedlings that grew were found on shady bamboo so that the growth was more uniform than *S. leprosula* which grew under the canopy cover of the stand *S. leprosula*. The largest diameter distribution can be seen in plot 5 flat slope classes. The diameters found are almost 6 mm. Moreover, the flat slope class in plot 5 has a very shady or closed canopy cover, so it causes an increase in the diameter of *S. leprosula* seedlings. It is in accordance with the research which had conducted by Setiawan *et al.* (2015) that shading up to 90% conducted on *S. leprosula* seedlings can increase their diameter growth.

The uneven distribution of diameter and height on the research plot indicates the need for silvicultural treatment. The height and diameter of the seedlings of *S. leprosula* are still far below the value to reach the sapling level. Furthermore, based on the results of the study on the natural regeneration of *S. leprosula* at the sapling level, only 2 individuals are found with a height of 3,8 m and 3,75 m. It indicates that *S. leprosula* is inhibited in continuing its growth rate. According to Hardjana and Suastati (2014), optimizing the growth of *S. leprosula* requires intensive silvicultural treatment and its environment, such as the openness of the growing space, so that for the next level of regeneration, the light factor can be the dominant factor to stimulate the growth of *S. leprosula*. The abundance of seedlings indicates the environmental conditions which need to be different for saplings to grow. In addition, Irwanto (2006) stated that at each growth phase of *S. leprosula*, it is necessary to reduce the intensity of the shade. It is because the need for *S. leprosula* to light increases along with the increase in growth. In addition, Pamoengkas and Prasetia (2014) stated that intensive maintenance, such as vertical and horizontal release, will reduce competition for light requirements between plants and undergrowth so that the diameter distribution is normal or relatively the same.

The saplings found are thought to be the result of seedling growth in 2018-2019, when the mother tree of *S. leprosula* was 21–22 years old. Wahyudi *et al.* (2014) stated that *S. leprosula* flowers and bears fruit every 2–3 years, while according to Nurkhaeni (2019) *S. leprosula* in the Gunung Dahu Research Forest last flowered and bore fruit at the age of 22 that is in 2019. It can be seen from the data on seedlings which have the highest height at a frequency of 20–25 cm, 14–19 cm, and 26–31 cm. In addition, based on Nurkhaeni's research (2019), the seedlings found are only 387 individuals with an average seedling height of 11–55 cm with only two saplings. It indicates that many *S. leprosula* seedlings are inhibited in continuing their growth rate; however, the number of seedlings compared to saplings also indicates a positive effect. According to Sapkota *et al.* (2009), the abundance of seedlings which are more than saplings indicates that the forest where the seedlings grew has never been logged and is a good forest type for regeneration potential.

Regression Analysis and ANOVA Test

Based on the results of the study, on different slopes and canopy cover, the growth of *S. leprosula* seedlings measured is found to be different. Therefore, an ANOVA test was conducted Table 4. The results of the variance in Table 4 show that the slope significantly affects the diameter and height of *S. leprosula* seedlings with significant values of 0,0018 and 0,001 which are below 0,05. Furthermore, the canopy cover parameter show a significant value which means that canopy cover has a significant effect on the growth of the diameter and height of *S. leprosula* seedlings. The interaction between slope and canopy cover has a significant value of more than 0,05 so that the interaction of slope with canopy cover has no significant effect on growth in diameter and height of *S. leprosula* seedlings (Table 5).

Table 4 Recapitulation of the results of variance (ANOVA) of the effect of slope and canopy distance on diameter and height parameters of *Shorea leprosula* seedlings

Parameter	Diameter	High
Slope	0,018 *	0,001 *
Canopy Cover	0,000 *	0,000 *
Slope * canopy cover	0,644ns	0,763ns

The numbers in the table are significant values. * = the treatment has a significant effect on the 95% confidence interval with a significant value (Pr < F) 0,05 (α); ns = treatment has no significant effect on the 95% confidence interval with a significant value (Pr > F) 0,05 (α)

Table 5 Duncan's continued test results of the effect of various slope classes on diameter and height parameters of *Shorea leprosula* seedlings

Slope Class	Diameter	High
Flat	2,382 ± 0,22b	25,435 ± 0,243c
Sloping	1,969 ± 0,266ab	24,846 ± 2,997bc
Slightly steep	1,941 ± 0,420ab	21,842 ± 0,472bc
Steep	1,609 ± 0,240a	16,273 ± 2,702ab
Very steep	1,259 ± 0,563a	10,500 ± 6,336ab

The results of variance show that there is an influence of slope and canopy cover on the height and diameter of *S. leprosula* seedlings. Therefore, Duncan's further test is conducted to determine in detail the class of slope and canopy cover which has the most significant effect on differences in growth of *S. leprosula*. The results of Duncan's further test, as shown in Table 5 show that the influence of flat with steep and very steep slope classes is significantly different so that the difference in the growth of *S. leprosula* between the two slope classes is much different. However, there is no significant difference in the flat, gentle, and slightly steep slope classes. Meanwhile, the gentle, slightly steep, steep and very steep slope classes are also not significantly different. It shows that on the same slope (flat, sloping, slightly steep or sloping, slightly steep, steep, very steep), growth in diameter of *S. leprosula* has the same relative increase and value or not much difference in growth. The difference in canopy cover in each research plot is thought to have an effect on the natural regeneration of *S. leprosula*. Duncan's further test results in Table 6 show that each canopy covers significantly different growth in both diameter and height.

Table 6 The results of Duncan's continued test of the effect of various canopy covers on diameter and height parameters of *Shorea leprosula* seedlings

Canopy Cover	Diameter	High
Very leafy	2,228 ± 0,398a	29,365 ± 4,482a
Shady	2,063 ± 0,031b	21,419 ± 0,350b
Not shady	1,722 ± 0,154c	18,114 ± 1,730c

The best increase in height is seen in the very shady canopy cover as well as the increase in diameter. Furthermore, the analysis of variance shows that the slope and canopy cover affect the growth of the diameter and height of *S. leprosula* seedlings. The interaction between slope and canopy cover does not directly affect the growth of diameter and height of seedlings. Therefore, Duncan's further test is only conduted on slope and canopy cover. The difference in growth in diameter and height is evident in the flat with steep and slightly steep slope classes. It indicates that the difference in slope class affects the growth in diameter and height of *S. leprosula* seedlings. Treatment should be applied to steep or very steep slopes to get optimal growth of *S. leprosula* seedlings. It is because terracing is a water and soil conservation method which can shorten the length of a slope or reduce a slope without knowing the fertility of the soil (Adilah and Chofyan 2019). Based on the results of data collection in plot 2, the number of *S. leprosula* seedlings is found in the flat slope class from the terracing treatment. Terraces can be made according to the steepness of the slopes. In addition, according to Bokings *et al.* (2013), the steeper a slope class is, the narrower the terrace width will be. Slope is very influential on landslides so that the steeper the frequency of landslides, the greater.

Different canopy cover, which is very shady, shady, and not shady, also causes the growth of diameter and height of *S. leprosula* seedlings to be different in each cover. It indicates that the natural regeneration of *S. leprosula* is sensitive to shade at the beginning of its growth. The more shady canopy cover is better able to protect the soil from erosion which can wash away nutrients. Therefore, the more shady canopy cover the seedlings grow since the nutrient needs of the soil are fulfilled. It is in accordance with the research results of Tewonto *et al.* (2020), which stated that the more land that is covered with a canopy, the greater the erosion can be reduced. Not only is it able to control erosion due to rainwater, but canopy cover is also useful for controlling erosion caused by wind by intercepting the wind as a windbreak and also slowing down the movement of the wind. In addition, Dewi *et al.* (2012) stated in their research that erosion could be minimized since dense canopy cover plays an important role in reducing the kinetic power of rainwater. The denser canopy cover also makes the interception capacity high compared to the less frequent canopy cover (Rico and Smith 2011).

CONCLUSION

The different slopes and canopy cover in each research plot indicate differences in the abundance and growth of *S. leprosula* seedlings. The highest abundance of *S. leprosula* seedlings is in the flat slope class in each study plot with a total of 929 individuals in plot 5, 851 individuals in plot 2, and 419 individuals in plot 7. Moreover, the characteristics of *S. leprosula* seedlings are that they require shade at the beginning of their growth. The shadier the canopy cover on the flat slope class to the slightly steep slope class, the growth of *S. leprosula* seedlings both in height and in diameter increased. Treatments such as maintenance need to be conducted in order to reduce the growth inhibiting factors of *S. leprosula* seedlings.

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