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The growth of *Shorea leprosula* Miq. on sloping land topography with various slope directions in Gunung Dahu Research Forest, Bogor District

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Abstract. Shorea leprosula *Miq. is a tree species from the Dipterocarpaceae family that has high economic value with fast-growing characteristics. Given the commercial and ecological importance, this study was conducted to analyze the effect of slope class and its direction on the growth attributes of* S.leprosula*. Data on growth and abiotic factors were collected on* S.leprosula *stands with a spacing of 2m x 2m and 4m x 8m. The slope level was determined based on the slope classification, while the slope direction was determined based on the configuration of the slope according to the cardinal directions. The results showed that the slope class, slope direction, and the interaction between those two factors had a significant effect on the growth of* S.leprosula *at a spacing of 4m x 8m in terms of diameter and height of the stand. The interaction between the flat slope class and north-facing direction resulted in the highest average annual increment of a diameter of 1.79 cm/year; while the highest annual increment of the total height was reached those in the very steep slope class with a north-facing direction (0.82 m/year).*

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INTRODUCTION

The wood industry is one of the sub-sectors of the agro-industry that contributes quite a lot to the national economy. Still, the availability of natural wood resources is often limited. It was recorded that the national log production in 2019 decreased compared to 2018, amounting to 1.83 million m^3 in natural forests and 3.91 million m^3 in HTI (Industrial Plantation Forests) (KLHK, 2020). The decreasing trend of wood resources that comes along with the decreasing trend of forested land encourages various parties to establish plantation forests using fast-growing trees with high economic value. Meranti (*Shorea* spp.) is tree species from Dipterocarpaceae Family with high economic value and plays an important role in ecological function. Meranti is one of the important commodities that play a major role both in local and global timber trade.

Shorea leprosula Miq. is one type of red meranti that has prospects for development in plantation forests because it has high economic value and is a fast-growing species among other meranti species. *S. leprosula* grows naturally in Kalimantan, Sumatra and Maluku and naturally grows spread on land with flat to slighty sloping conditions (Abdurachman *et al.*, 2013). According to Pamoengkas and Prasetia (2014), the growth of *S. leprosula* aged 1-4 years at PT. Sarmiento Parakantja Timber, Central Kalimantan increased in diameter to 1.32 cm/year, while the growth of *S. leprosula* in PT. Balikpapan Forest Industries in the 4-year-old progeny test, the increment was 1.5-2.6 m/year for plant height, while the diameter increment was 1.66-2.78 cm/year (Naiem *et al.*, 2014). Its fast growth and straight and cylindrical tree trunk structure cause *S. leprosula* wood to be in great demand by wood entrepreneurs to produce plywood, joinery furniture, panels, floors, and ceilings (Mashudi *et al*., 2018).

Tree growth is influenced by several supporting factors, including slope class and slope direction. Setting the suitable land slope class will affect the appearance and productivity of plants. According to Andrian *et al*. (2014), the slope class of land greatly affects the dynamics of runoff and erosion, so it will affect plant growth, while the direction of the slope can determine the amount of sunlight that will be received plants (Wijayanto and Nurunnajah, 2012). According to Sukendro and Sugiarto (2012), the growth of meranti is influenced by various factors, one of which is the amount of sunlight received. The intensity of sunlight plays an important role in receiving energy for plants through photosynthesis. Research results Hut *et al*. (2018) show that slopes were facing north support forest growth the best, while slopes facing south show the lowest growth. The greater the intensity of sunlight received on the southern slopes can interfere with the photosynthesis process to inhibit plant growth. Diaconu *et al*. (2015), in their research also stated that the growth of European beech was disturbed on the slopes towards the southwest due to its warmer and drier climate, then Brunori *et al.* (1995) in their research showed that in general, trees on the northern slopes had high growth, stem biomass, and higher above-ground biomass compared to trees on the western and southern slopes, because the northern slopes get less direct sunlight, thereby reducing stress on trees caused by extreme temperatures.

Referring to these problems, research on the effect of slope and slope class on the growth response of *S. leprosula* is very important to determine the right silvicultural technique. However, research on the slope and slope class for *S. leprosula* species is still unavailable or needs little attention. Therefore, this study aims to analyze the effect of grade and slope on *S. leprosula* in the Gunung Dahu Research Forest area, Bogor Regency, West Java, to be used as a basis for designing silvicultural techniques in the field.

METHODS

Research Location

The study was conducted in Gunung Dahu Research at coordinates 06°36'30"-06°37'00" LS and 106°34'00"-106°35'30" East. Administratively it is located in Leuwiliang – Bogor, West Java. The Gunung Dahu Research Forest (HP) has a total area of 250 ha with the number of species planted both in the collection block and in the experimental block, namely ±33 types of meranti plants. The legal status of HP Gunung Dahu is still in the form of cooperation (MoU) with Perum Perhutani, which is intended as a location for research and development of dipterocarp species (KLHK, 2013).

Data Collection Methods

Data collection was carried out in *S. leprosula* stand at Plot 1 (spacing 2m x 2m), Plot 6, and Plot 7 (spacing 4m x 8m). Measured growth attributes were diameter, total height, crown cover, stand density, and environmental/abiotic factors (litter thickness and topsoil depth). The slope classes grouped into five classes based on Decree of the Minister of Agriculture Number 837/Kpts/Um/11/1980 concerning the Criteria and Procedures for Determining Protected Forest (Kementan, 1980), which consisted of flat (0%-8%), gentle (8%≤15%), slightly steep (15%≤25%), steep (25%≤45%) and very steep (>45%). Slope direction was determined based on the slope configuration according to the cardinal directions.

Litter thickness was carried out at each slope class and direction with five replications, and then the results were averaged. The depth of topsoil was measured by measuring the thickness of the humus layer. Topsoil is the most fertile soil layer and usually has a depth of about 5 cm to 30 cm. Leaf Area Index (LAI) measurements in the field were carried out based on a technique developed by Rich *et al*. (1999). LAI is defined as leaf area (which has been projected on a flat plane) per unit of the land surface area carried by tree canopy (Suwarsono *et al*., 2011).

Data Analysis Methods

Calculation of Average Tree Height and Diameter

The diameter at breast height was measured at the height of 1.3 meters above ground level using a *phiband* while tree height was measured using a *Haga hypsometer* (Hardjana, 2013).

MAI of Diameter and Height of Tree

MAI is the increase in stand volume per unit of time or the increase in stand value, both height increase and tree diameter each year (Fadhlullah *et al*., 2020). Calculation increment, average annual diameter, and height based on the formula of annual increment of the average (Mean Annual Increment or MAI), as follows:

$$I^{\bar{d}_i} = \frac{\bar{d}_i}{t_i} \text{ (cm /yr)} \qquad I^{\bar{h}_i} = \frac{\bar{h}_i}{t_i} \text{ (m /yr)}$$

Description:

$I^{\bar{d}_i}$ = increment average diameter in year i (cm /yr)

$I^{\bar{h}_i}$ = mean height increment in year i (m /yr)

$\bar{d}_i$ = average diameter in planting year i (cm)

$\bar{h}_i$ = average height in planting year i (m)

t_i = plant age in planting year i (yr)

Data Distribution

The data distribution pattern will be delivered in form boxplot using the application *IBM SPSS Statistics* 26. Boxplots are used to changes in variation and location between different data groups (Darsyah, 2014).

Canopy Opennes

Canopy openness or shade can be measured by the leaf area index (LAI), which used hemiview 2.1 as a tool for the conversion. The LAI equation in hemiview estimates half of the total leaf surface per unit base surface area. Calculation of LAI involves the use of Beer's Law (Rich *et al*., 1999). Criteria for shading class derived from the range of LAI value (Ratnasih, 2012) as follow: not open, open, and very open with LAI value at 0.1≤1.7; 1.7≤2.3; >2.3.

Stand Density

Stand density is the number of individuals of a species per unit area (Putra, 2015). Measurement on stand density was carried out using the density formula, as follows:

$$Stand\ density = \frac{Number\ of\ trees\ in\ the\ plot\ (trees\ /\ ha)}{Plot\ area\ expressed\ in\ hectares}$$

Data Analysis

Growth analysis was conducted to estimate the relationship between plant diameter and height at various slope classes and slope directions at the study site using ANOVA software *IBM SPSS Statistics* 26.

RESULTS AND DISCUSSION

General Conditions of Research Location

The Gunung Dahu Research Forest Forest built-in 1997-2000 by the Forest and Conservation Research and Development Center in collaboration with Komatsu, Japan. *S. leprosula* is a type of Dipterocarpaceae Family planted in the Gunung Dahu Research Forest. Plant growth is influenced by internal and external factors such as elevation, stand density, soil texture, and tree origin. The description on observed studied plot as shown in Table 1.

Table 1 The general description of the studied plots

Plot No	Plant Spacing (m)	Planting Technique	Planting Year	Elevation (m asl)	Area (Ha)	Stand Density[a] (Ind /ha)	Soil Texture[b]	Origin Tree
1	2 x 2	Total planting	1997	697	1	945	Clay	Cuttings
6	4 x 8	Mixed planting	1997	718	1	182	Clay	Cuttings
7	4 x 8	Mixed planting	1997	707	1	94	Clay	Cuttings

[a] Stand density refers to the density of the target species only (*S. leprosula*), [b]based on secondary data from Khalifa (2020)

Shorea leprosula Miq. is one species included in the Family Dipterocarpaceae in the red meranti group. This species has good prospects to be developed because it has a high trade value, both in regional and international markets. *S. leprosula* is a tropical tree species with a very wide natural distribution because this species is very tolerant in various sites and environmental conditions. *S. leprosula* generally grows in climate types A and B and is usually found in lowland Dipterocarp forests below 700 m above sea level (Hasnah, 2014). *S. leprosula* stands are located at almost the same altitude or altitude, which is in the range of 697-718 m above sea level. According to Fajri (2008), most types of Dipterocarpaceae grow in a wet climate and high humidity levels with an altitude of 0-800 m above sea level with rainfall above 2 000 mm/year with a short dry season. This is in accordance with the growing location of *S. leprosula* in the observation plot, which has a height and average annual rainfall that is in accordance with the general conditions of the *S. leprosula* species. Gunung Dahu Research Forest is located at an altitude of 550-900 m above sea level with a hilly and steep topography of the land and has a type of soil belonging to the reddish-brown latosol type. The average annual rainfall ranges from 2 500-2 700 mm per year (KLHK, 2013). Top soil thickness, litter thickness, and LAI (Leaf Area Index) are other variables that are measured to see the growth of *S. leprosul*a. Measured variables at each plot were presented in Table 2.

Table 2 shows that the average litter thickness and topsoil depth of the plots with a spacing of 4m x 8m were higher than those at a spacing of 2m x 2m. This is presumably because the land surface in the 4m x 8m distance plot is mainly covered by ferns. Hutasuhut and Febriani (2019) stated that generally, ferns live in the open and require a lot of sunlight, and can quickly distribute. The composition of the body structure of ferns that contain little lignin causes the resulting litter to be easily decomposed by soil microorganisms (Zulfikri *et al*., 2014). The highest average litter thickness in the steep slope class with the slope facing southwest is 9.80 cm. The highest average topsoil depth is in the flat slope class, with the slope facing north of 17.00 cm. It is presumably because each slope has a different gravity. Gravity is an absolute requirement for the process of transportation, erosion, and deposition. Sloping land has a greater working gravity than flat land (Suryanto and Wawan, 2017). According to Sari *et al*. (2017), the more sloping the slope is, the more soil particles that are splashed down by the impact of rainwater, resulting in thinner topsoil. Litter protects the soil from runoff and erosion caused by rainwater blows, even on large land slopes (Suryanto and Wawan, 2017). The average LAI value for each slope class on plots with a spacing of 2m x 2m has a higher average LAI value than at a spacing of 4m x 8m. The highest average LAI value is in the flat slope class, with the slope facing north (4m x 8m spacing). According to Reza *et al*. (2017), a high stand density means more trees in one plot, thus forming closed vegetation.

Tabel 2 Characteristics of each observed plot

No	Slope Classes	Directions of Slope	Average Thickness of Litter (cm)	Average Depth of Top Soil (cm)	Average LAI Per Grade Slope	Slope Classes
1	2 x 2	Flat	West	4.34	10.40	1.61
2	2 x 2	Slightly sloping	South	1.90	8.80	1.64
3	2 x 2	Rather steep	North	4.40	9.00	1.54
4	2 x 2	Rather steep	South	3.54	9.20	1.54
5	2 x 2	Rather steep	Northeast	3.72	10.80	1.54
6	2 x 2	Rather steep	West	2.90	8.00	1.54
7	2 x 2	Rather steep	Southwest	3.40	8.80	1.54
8	2 x 2	Steep	South	5.06	7.60	1.68
9	2 x 2	Steep	Northeast	3.20	10.50	1.68
10	2 x 2	Very steep	West	3.60	9.00	1.65
11	4 x 8	Flat	North	7.70	17.00	1.93
12	4 x 8	Slightly sloping	Northwest	6.50	15.40	0.65
13	4 x 8	Slightly sloping	West	5.90	14.60	0.65
14	4 x 8	Rather steep	South	4.26	14.10	0.55
15	4 x 8	Rather steep	North	5.20	15.00	0.55
16	4 x 8	Steep	West	5.40	14.20	0.55
17	4 x 8	Steep	Southwest	9.80	14.86	0.55
18	4 x 8	Steep	North	6.00	15.00	0.55
19	4 x 8	Very steep	North	6.20	15.28	1.51

Growth of Height and Diameter of *S. leprosula* in Various slope

Growth is the process of changing shape or increasing the size, weight, and volume of a living thing. Growth in each plant consists of two different forms, namely vertical growth or plant height and horizontal growth or plant diameter growth (Amiruddin *et al*., 2017). Plant height and diameter are the easiest to measure tree growth characteristics and are most often used as standards for plant quality (Omon, 2010). The measurement of average growth and mean annual increment (MAI) can be seen in Table 3.

The highest average annual increment growth and the average height growth of *S. leprosula* at a spacing of 4m x 8m were in the very steep slope class with the slope facing north, while for diameter the slope class was facing north. Highest growth annual increment average growth height *S. leprosula* with a planting distance of 2m x 2m in the rather steep slope class with the slope facing north, while for the diameter, namely in the rather steep slope class, the slope facing south. Growth is influenced by two factors, namely internal factors, and external factors. Internal factors are the genetic abilities possessed by plants, while external factors are factors that come from outside the plant, such as nutrients in the soil, water availability, and sunlight (Buntoro *et al*., 2014). Plant growth occurs due to internal physiological processes due to the interaction between internal and external factors that influence it (Pamoengkas and Prayogi, 2011).

Differences in penetration of solar radiation can be one of the external factors that can affect differences in plant height and diameter growth. It is because light intensity is an important factor in the photosynthesis process for plant growth and development. According to Firdaus and Ariffin (2019), plants will optimally receive sunlight in stands planted on flat slopes rather than on steep slopes. It is suspected that on a steep slope, the position of the trees will cover each other so that on a flat slope, the sunlight will be more evenly distributed than on a steeper slope. This is in accordance with the results of the study when viewed from the horizontal growth of plants (diameter growth). The diameter growth of *S. leprosula* in the observation plots showed that the flat slopes (4m x 8m) and rather steep (2m x 2m spacing) had a larger growth diameter than the steep slopes, but showed a different or reversed phenomenon when compared to steep slopes seen in terms of growth in an anticlinal or vertical manner as seen by the increase in plant height. The best growth in total height of *S. leprosula* (4m x 8m spacing) was on a very steep slope class. According to Wijayanto and Nurunnajah (2012), solar radiation reception will vary significantly from place to place. It is caused by differences in latitude and atmospheric conditions, especially clouds, and on a micro-scale, the direction of the slope determines the amount of radiation received by plants.

Tabel 3 Average height and diameter and average annual increment of *S. leprosula* in various slope classes and direction

No	Spacing (m)	Slope Class	Direction of Slope	Number of Individuals (Ind)	Average		Increment (MAI)	
					Total Height (m)	Diameter (cm)	Total Height (m/year)	Diameter (cm/year)
1	2 x 2	Flat	West	172	13.86	20.45	0.58	0.85
2	2 x 2	Slightly sloping	South	61	14.24	19.91	0.59	0.83
3	2 x 2	Rather steep	North	60	14.34	21.24	0.60	0.89
4	2 x 2	Rather steep	South	93	13.84	22.70	0.58	0.95
5	2 x 2	Rather steep	Northeast	58	14.09	19.88	0.59	0.83
6	2 x 2	Rather steep	West	64	13.39	20.67	0.56	0.86
7	2 x 2	Rather steep	Southwest	73	13.03^{min}	19.91	0.54^{min}	0.83
8	2 x 2	Steep	South	171	14.19	19.98	0.59	0.83
9	2 x 2	Steep	Northeast	50	14.23	18.50^{min}	0.59	0.77^{min}
10	2 x 2	Very steep	West	143	13.96	19.51	0.58	0.81
11	4 x 8	Flat	North	14	19.15	42.89^{max}	0.80	1.79^{max}
12	4 x 8	Slightly sloping	Northwest	24	17.02	34.10	0.71	1.42
13	4 x 8	Slightly sloping	West	20	16.06	32.50	0.67	1.35
14	4 x 8	Rather steep	South	25	16.27	33.62	0.68	1.40
15	4 x 8	Rather steep	North	51	18.38	32.33	0.77	1.35
16	4 x 8	Steep	West	28	16.00	34.08	0.67	1.42
17	4 x 8	Steep	Southwest	17	17.14	38.36	0.71	1.60
18	4 x 8	Steep	North	19	17.35	34.97	0.72	1.46
19	4 x 8	Very steep	North	78	19.74^{max}	35.03	0.82^{max}	1.46

^{min} states the minimum value; ^{max} states the maximum value

Different slope directions cause the difference in light reception received by trees, on very steep slopes the direction of the slope facing north is more optimal sunlight received by plants. According to Asrianny *et al*. (2008) areas located south of the equator, slopes facing north and east tend to provide a better quality of growing place than slopes facing south and west. Added by Soetrisno (1998), slopes affect tree growth. Slopes facing east are exposed to the morning sun and will be more protected from the influence of southwest winds. The north-facing slopes are protected from the effects of the sun during the day and protected from the wind.

Setiawan (2009) stated that the wind would affect the temperature and humidity of the soil, besides that the wind can help plant growth by helping to supply carbon dioxide for the photosynthesis process. High wind speed will cause large evaporation. A large lack of air through can interfere with plant growth. According to Violita *et al*. (2017) lack of water can affect plant growth indirectly. The reduced amount of water reserves in plants will cause a decrease in the turgidity of plant cells, so that it will trigger the procurement and procurement of plant cells. The observations on the best growth diameter at a spacing of 2m x 2m showed different results, land with a slope facing south produced the best growth. This was presumably because other factors affected the growth of the stand, such as the grade of slope, leaf area index, litter thickness, and topsoil depth.

The difference in the amount of solar radiation received can also be seen from the LAI value of stands, the higher the LAI value, the higher the photosynthate-producing potential. LAI plays an important role in increasing the efficiency of the distribution of solar energy in the canopy profile, increasing the shade value on the leaves, increasing the energy distribution process to the interior of the low canopy profile. A high LAI value in a dense population of stands can have consequences for severe competition. The higher the LAI value of the plant, the higher the ability of the canopy to reduce the energy that reaches the deeper part of the canopy, as a result the lower leaves of the plant become inefficient in the photosynthesis process, so that plant growth becomes less than optimal (Prasetyo, 2004). The results showed a different phenomenon. Flat slopes with slopes facing north have more optimal plant growth than those on slopes facing the other direction, although the LAI value on flat slopes is higher than the LAI value on other slopes, which is 1.93.

This is because a high LAI value can have greater consequences on competition in dense stands populations, while the flat slope class facing north has a wide spacing (4m x 8m). Plant growth can also be affected by the growth of other plant parts. Furthermore, Handayani *et al*. (2014) stated that the growth of one part of the plant is followed by the growth of other parts of the plant. Putri and Putra (2013) stated that the size of the trunk diameter of a tree is positively correlated with the size of the canopy, the larger the diameter of the trunk of a tree, the greater the size of the canopy. Trees that have a wider canopy size and more roots are thought to be able to compete for environmental factors such as light, nutrients, and air more optimally so that tree growth will be more optimal as well (Wijayanto and Nurunnajah, 2012). Furthermore, Pratiwi and Safe'i (2018) state that the canopy is wide and describes the growing site conditions that support growth, such as conditions with other trees, the humidity of the growing site, or other influences. It is a competition for space and light, which greatly affects the speed of plant growth.

Differences in annual increments of mean total height and average plant height growth can also be influenced by several other factors such as soil depth and litter thickness. Topsoil is soil in the top layer of soil with a depth of about 5-30 cm and usually contains natural materials or organic substances formed from weathering or decay of plant and animal remains that are fertilizing soil. The thickness of the litter can also affect plant growth. The thick feel will protect the surface from the collision of raindrops that fall so as to reduce soil splitting and carry away the topsoil due to surface runoff. Soil runoff energy will be large in areas with sloping land topography, so that on steep land with little litter and humus cover, it can deplete the top layer of soil (Septianugraha and Suriadikusumah, 2014). According to Abdurachman *et al*. (2013), litter is organic material that can provide additional food after it decomposes and becomes compost so that plants get enough food and increase growth. The nutrient content in the litter and the nutrient content in the soil will affect the development of the tree level.

Stand density can also affect differences in annual increments of total height and average diameter and average total height and diameter of plants. Siahaan *et al*. (2011) stated that individual tree growth would increase at a denser stand density, but the total growth per unit area would increase. Stand density on very steep slopes, the slopes facing north and on flat slopes with the slopes facing north, because the slopes are subject to a distance setting of 4m x 8m. Spacious spacing allows plants to grow well without experiencing a lot of competition between plants in obtaining nutrients and sunlight for the photosynthesis process. At a tight spacing the plant leaves will tend to be close together so that they do not receive maximum sunlight so that the photosynthate produced is not optimal (Magfiroh *et al*., 2017).

Furthermore, Wijayanto and Nurunnajah (2012) stated that the growth of a plant would increase if the temperature increases and humidity decrease, a stand that has a canopy that rarely has high temperature and low humidity, while a stand that has a relatively dense crown has a surface temperature. Decreasing and high humidity. Density is related to the occurrence of competition for growing space, interception of light, water, and nutrients needed by plants, an increase in density means a higher level of competition, as well as if the density level is lower, the level of competition will be lower as well (Pithaloka *et al*., 2015).

Differences in the growth of *S. leprosula* are also influenced by the conditions in which it grows. The results showed that *S. leprosula* planted on undulating, flat, to very steep land in the Gunung Dahu Research Forest area, the highest mean diameter increment (MAI) of *S. leprosula* at the age of 24 years reached 1.79 cm/year. Hardjana and Susanti (2014) stated that the increment of the average annual diameter of *S. leprosula* plants derived from uprooted seedlings and cuttings on young bushes after fires aged 15 years in the plantation forest area of PT. Inhutani I Long Nah reaches 1.55 cm/year. Hardjana (2013) stated that *S. leprosula* from cuttings, which were planted in the peat area of PT. Arara Abadi Riau achieved an increase in diameter at the age of 13 years by 1.51 cm/year, while *S. leprosula* planted in the Gunung Dahu Research Forest's highland area at the age of 15 years, the diameter increment reached 1.46 cm/year. Meijer in Mindawati and Tiryana (2002) classifies the growth speed of a tree species into five classes based on the increment in stem diameter, namely very fast (increment>1.4 cm/year), fast (increment= 1.19-1.4 cm/year), normal (increment= 0.79-1.19 cm/year), slightly slower (increment= 0.36-0.79 cm/year), and slow (increment<0.36 cm/year).

The increase in the average year diameter (MAI) of *S. leprosula* in the Gunung Dahu Researchl Forest area based on the classification of growth speed of a species according to Meijer in Mindawati and Tiryana (2002) for *S. leprosula* planted with a spacing of 2m x 2m on various grades of slope and The direction of the slopes was mostly normal because the increments ranged from (0.79-1.19 cm/year), while the average annual diameter of *S. leprosula* stands planted at 4m x 8m on various grades of slopes and slopes in Gunung Dahu Research Forest belongs to the fast to very fast class because the average diameter increment ranges from (1.19-1.4 cm/year) and (>1.4 cm/year). Differences in *S. leprosula* plants were due to differences in the environment, growing site, age difference, it was also suspected that there were differences in silvicultural treatment applied to each growing site. Soekotjo (1976) explained that the growth of both the growth in height and diameter or the base area of a stand would be different compared to the growth of each tree. The increment or volume is influenced by several variable factors. Furthermore, it is said that the increment or total volume in a certain area is influenced by factors such as the type of plant, the composition of the stand, the quality of the growing site, the form of the stand, the density of the stand, disturbances of external factors and the silvicultural treatment applied to each growing site.

Distribution of Height and Diameter of *Shorea leprosula.*

Data distribution for diameter and height of *S. leprosula* in various slope classes and directions can be seen in Figures 1 and 2.

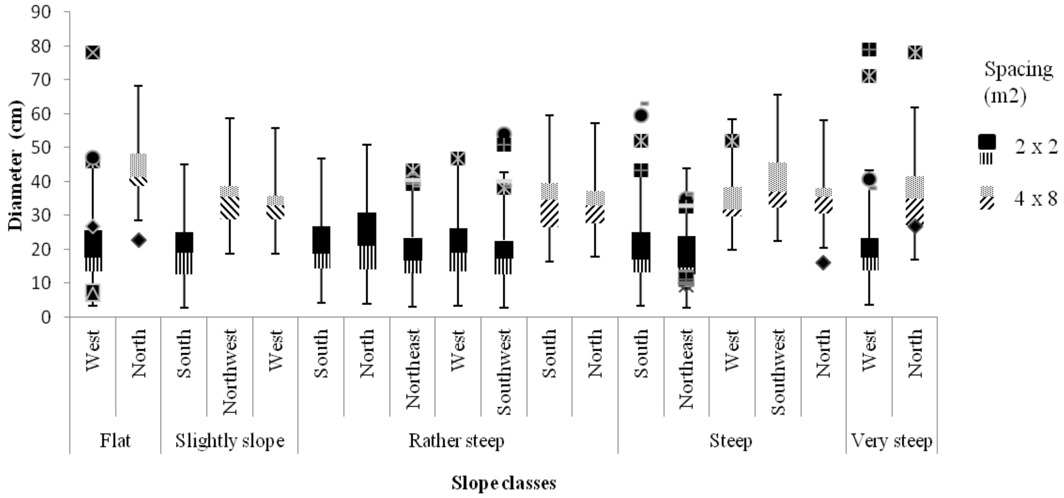

Figure 1 Distribution of data on *S. leprosula* diameter in various slope classes and directions

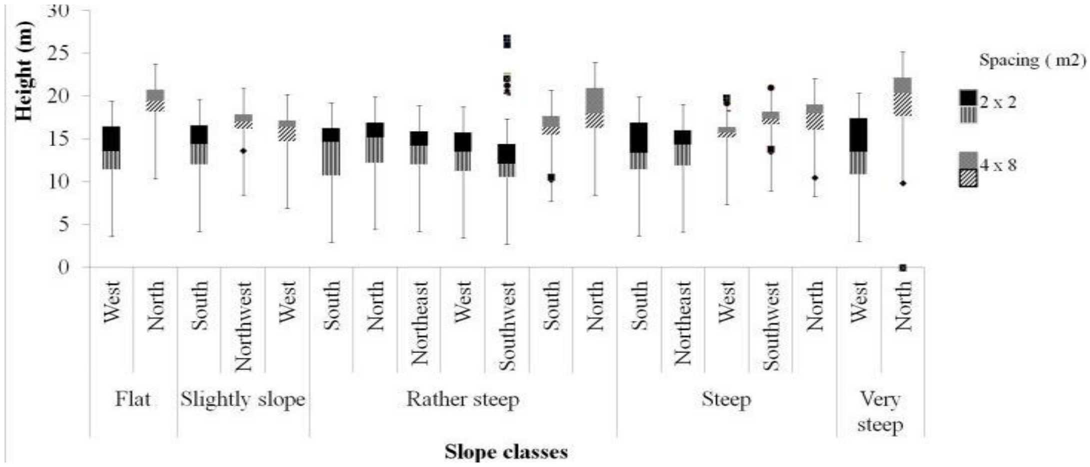

Figure 2 Distribution of data on *S. leprosula* height in various slope classes and directions

Growth rate, diversity and distribution diameter and total height of *S. leprosula* on various grades of slopes and slopes. Stands of *S. leprosula* with a spacing of 4m x 8m had an average diameter and total height greater than that of *S. leprosula* at a spacing of 2m x 2m. It is due to the struggle for nutrients between plants, so the wider the spacing between plants, the better the plant growth will be. Spacing has implications for the yield per unit area and affects plant growth (Erwin *et al*., 2015). Mawazin and Suhaendi (2008) added that planting trees with more spaced spacing causes fewer trees on the site. There is less competition between plants, presumably because the availability of light space and nutrients for plants will be fulfilled.

The long box (Figures 1 and 2) shows the level of spread or diversity of data (Junaidi, 2014). Based on Figure 1, it is known that the two stands of *S. leprosula,* both at a spacing of 2m x 2m and 4m x 8m have relatively the same box size. It means that most of the stands of *S. Leprosula* at a spacing of 2m x 2m and 4m x 8m have a relatively similar level of data diameter diversity. The larger the box size, the greater the diameter diversity level, and vice versa. Figure 2 shows that the known stands of *S. Leprosula* stands at a spacing of 2m x 2m have a relatively larger box size than the stands of *S. Leprosula* at a spacing of 4m x 8m. This means that most of the stands of *S. Leprosula* at a spacing of 2m x 2m have a higher level of data diversity than stands of *S. Leprosula* at a spacing of 4m x 8m. The data that occurs is thought to be due to competition between the competition for nutrients in the soil, which is high between trees so that the average diameter and height become more varied and spread out.

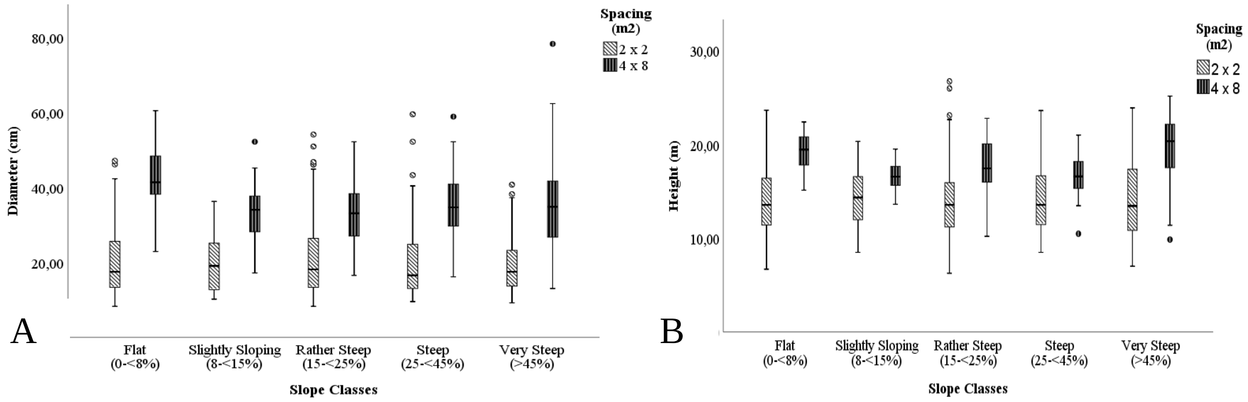

Figure 3 Distribution of *Shorea leprosula* heights (A) and diameter (B) in various slope classes

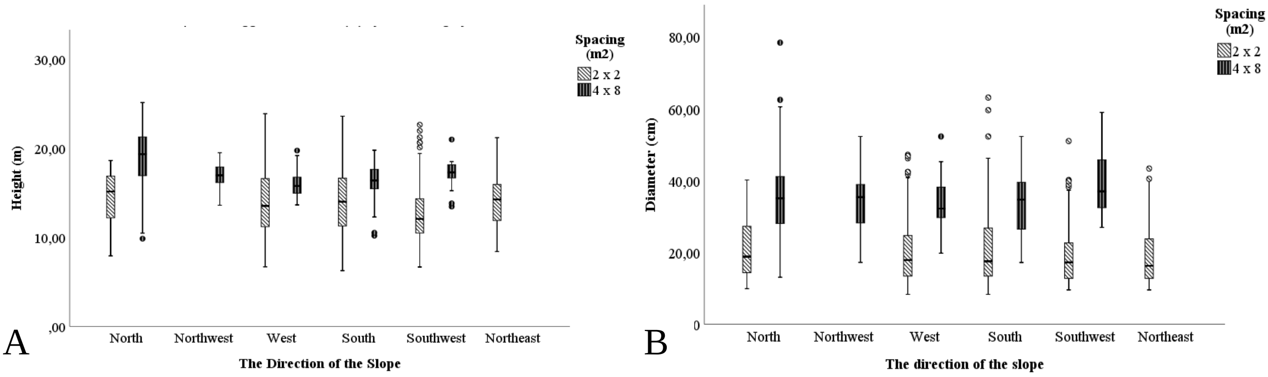

Figure 4 Data distribution of *Shorea leprosula* heighs (A) and diameter (B) in various slope directions.

Growth rate, different Diversity and distribution diameter and total height of *S. leprosula* on various grades of slopes and slopes. The distribution diameter and total height of *S. leprosula* stands located at a distance of 2m x 2m and 4m x 8m had an abnormal distribution. This is characterized by the median value that is not in the middle of the box, and the length of the whiskers is not the same, and there are outliers. The boxplot diagrams (Figures 1, 2, 3 and 4) have larger box sizes at the bottom and top of the middle-value data, and there are several boxplots with a shape that tends to be symmetrical. Still, there are some outlier data at the top of the boxplot accompanied by a whisker at the top. The longer top, it shows that the data distribution tends to the top. The boxplot size, which tends to be larger at the bottom if it is depicted on a normal curve will be skewed to the left, while the larger bloxplot size at the top if it is depicted on a normal curve will be skewed to the right. According to Hardjana and Suastati (2014) both the total and diameter of the plants are said to be normal with a frequency of diameter size and total height which are mostly found around the mean (average) value of the stands and decrease in diameters smaller or larger than the stands, so it looks like a bell. This is a competition between individuals in obtaining nutrients, air, and light, therefore more intensive maintenance is needed such as vertical and horizontal to reduce competition in space and to provide competition for the entry of light between plants and pathways weeds (Pamoengkas and Prasetia, 2014).

Effect of Slope Class and Direction on Height and Diameter of *S. leprosula*

The results of the ANOVA test showed that the slope factor and the interaction of slope and slope (4m x 8m spacing) gave a significantly different effect on the diameter and growth height of *S. leprosula*. The factor of slope direction, spacing of 4m x 8m only had a significant effect on the growth of *S. leprosula* height. Significantly different values experienced H0, because each test had a significance value smaller than the significant level (Pr<0.05). This is presumably because *S. leprosula* is a semi-tolerant species, which is a woody plant species that initially requires shade (Setiawan *et al*., 2015). *S. leprosula* requires full sunlight intensity in the tree phase, so it is suspected that the slope and slope factors do not significantly affect the growth of *S. leprosula* with a spacing of 2m x 2m because the spacing that limits the competition for nutrients and light requirements for plants is relatively larger (Mawazin and Suhaedi, 2012). Gebretsadik (2012) stated that in his research, the average height growth of *G. robusta* did not have a significant difference in various slope variations, the average growth was more sensitive to slope variations compared to plant diameter.

Table 4 Duncan's further test results in the effect of various grades of slope on the diameter and height of *S. Leprosula*

Spacing (m)	Slope class	Diameter (cm)	Height (m)
2 x 2	Flat	20.45 ± 8.81[a]	13.85 ± 3.61[a]
	Slightly sloping	19.90 ± 7.69[a]	14.24 ± 2.92[a]
	Rather steep	21.02 ± 9.45[a]	13.71 ± 3.39[a]
	Steep	19.64 ± 9.24[a]	14.20 ± 3.29[a]
	Very steep	19.51 ± 9.48[a]	13.95 ± 4.03[a]
4 x 8	Flat	42.89± 10.06[a]	19.14 ± 2.26[a]
	Slightly sloping	33.37± 7.53[b]	16.58 ± 1.52[b]
	Rather steep	32.75± 8.21[b]	17.68 ± 2.75[b]
	Steep	35.48± 7.88[b]	16.70 ± 1.91[b]
	Very steep	35.03± 11.37[b]	19.73 ± 3.12[a]

[a]The numbers in the same column followed by the same letter show that the treatment is not significantly different at the 5% test level (Duncan's multiple interval test)

Duncan's further test results in Table 4 show that the slope class has a significantly different effect on the growth of diameter and stand height of *S. leprosula* with a spacing of 4m x 8m. The best effect of slope class on the height growth of *S. leprosula* with the best mean height was on the very steep and flat slope class, while the highest average diameter value was for the flat slope class. The difference in slope class will affect the size of the runoff, which directly affects the nutrient content in the soil. Wati *et al*. (2014) in his research, showed that the amount of runoff on the slopes of 8-12% was lower than the amount of runoff on the slopes of 12-16%. This shows that the higher the grade of the land slope, the amount of runoff will increase. Furthermore, Faudy *et al*. (2014) stated that the greater the slope would result in greater soil erosion as well. A high rate of erosion will result in a decrease in soil fertility, resulting in reduced nutrients available for plants. The decrease in nutrient levels in the soil will cause a decrease in plant growth. The results also showed that the steep slope class produced the best height growth of *S. leprosula*. These things are forgotten on the slopes which have high litter thickness. Litter in the form of leaves, fanfare and so on that has not undergone weathering will hinder the flow of air over the ground even though it is located at.

Duncan's further test results in Table 5 show that the slopes have a significantly different effect on height growth in *S. leprosula* stands with a spacing of 4m x 8m. The best growth with the highest average value is on the slopes facing north. Slopes facing north will be better for plant growth than south slopes because slopes in the north are more protected from the effects of the sun during the day and wind, while slopes facing south can receive six times the amount of solar radiation compared to slopes facing south. slope to the north. (Auslander *et al*., 2003). Hut *et al*. (2018) stated that solar radiation will be greater in the southern sub-region, relatively high temperatures caused by solar radiation cause an increase in soil evaporation and plant transpiration and cause a warmer and drier microclimate, so that plant growth is less than optimal. Harjadi (2017) added that slopes facing south might be the greatest for erosion and landslides, which can cause plant growth to be less than optimal.

Table 5 Duncan's further test results the effect of various slope directions on the diameter and height of *S. Leprosula*

Spacing (m)	Slope Direction	Diameter (cm)	Height (m)
2 x 2	North	21.24 ± 8.38[a]	14.33 ± 2.83[a]
	West	20.14 ± 8.97[a]	13.81 ± 3.65[a]
	South	20.74 ± 9.57[a]	14.10 ± 3.36[a]
	Southwest	19.91 ± 10.01[a]	13.02 ± 4.21[a]
	Northeast	19.24 ± 8.63[a]	14.15 ± 2.95[a]
4 x 8	North	34.85 ± 10.23[a]	18.97 ± 2.81[a]
	Northwest	34.10 ± 7.74[a]	17.01 ± 1.39[b]
	West	33.42 ± 7.01[a]	16.02 ± 1.43[b]
	South	33.61 ± 8.93[a]	16.27 ± 2.37[b]
	Southwest	38.35 ± 8.78[a]	17.14 ± 1.78[b]

[a]The numbers in the same column followed by the same letter show that the treatment is not significantly different at the 5% test level (Duncan's multiple interval test)

Table 6 Duncan's further test results influence the interaction of various slope directions and slope classes on the diameter and height of *S. Leprosula*

Spacing (m)	Slope Class	Slope Direction	Diameter (cm)	Height (m)
2 x 2	Flat	West	20.45 ± 8.80[a]	13.85 ± 3.61[a]
	Slightly sloping	South	19.91 ± 7.69a	14.24 ± 2.92[a]
	Rather steep	Utara	21.24 ± 8.38a	14.33 ± 2.83[a]
	Rather steep	North	22.69 ± 10.46a	13.83 ± 3.61[a]
	Rather steep	South	19.88 ± 9.20a	14.09 ± 2.90[a]
	Rather steep	Northeast	20.72 ± 8.28a	13.38 ± 2.78[a]
	Rather steep	Southwest	19.91 ± 10.01a	13.02 ± 4.21[a]
	Steep	South	19.98 ± 9.57a	14.19 ± 3.38[a]
	Steep	Northeast	18.49 ± 7.89a	14.23 ± 3.03[a]
	Very steep	West	19.50 ± 9.48a	13.95 ± 4.03[a]
4 x 8	Flat	North	42.89 ± 10.06a	19.14 ± 2.26[a]
	Slightly sloping	Northwest	34.10 ± 7.74b	17.01 ± 1.39[ab]
	Slightly sloping	West	32.50 ± 7.38b	16.05 ± 1.54[c]
	Rather steep	South	33.61 ± 8.93b	16.27 ± 2.37[c]
	Rather steep	North	32.32 ± 7.89b	18.37 ± 2.68[ab]
	Steep	West	34.08 ± 6.79b	16.00 ± 1.39[c]
	Steep	Southwest	38.35 ± 8.78ab	17.14 ± 1.78[bc]
	Steep	North	34.97 ± 8.28b	17.35 ± 2.39[bc]
	Very steep	North	35.02 ± 11.37b	19.73 ± 3.12[a]

[a]The numbers in the same column followed by the same letter show that the treatment is not significantly different at the 5% test level (Duncan's multiple interval test)

Duncan's further test results in Table 6 show that the interaction between the slope class and the slope gave a significantly different effect on the diameter and growth height of *S. leprosula* stands at a spacing of 4m x 8m. The best diameter is on a flat slope with the slope facing north, with an average of 42.89±10.06 cm. The best growth was in the very steep and flat slope class, with the slope facing north with an average of

19.73±3.12 m and 19.14±2.26 m. The data from the research showed that the growth values were almost the same as the stands of *S. leprosula* in the Carita Research Forest (HP) at the age of 24 years, which had an average height of 25.39 m and a diameter of 40.20 cm (Bustomi *et al*., 2009). Differences in the average growth of plant height and diameter are forgotten because of differences in light penetration, flat slopes of sunlight received more evenly from plants. Land slope is also significantly related to soil water content. Gunung Dahu Research Forest is an area that has high rainfall of 2 500-2 700 mm per year, so it will affect soil moisture. Thus the amount of air content for each slope will be different. Steep slopes will have lower water content due to surface runoff or faster flow movements than flat, gentle or wavy slopes.

Availability of water in the soil which greatly affects plant growth directly. According to Hermawan (2004), soil water content describes the characteristics of groundwater which relates to the ability of the soil to hold water when conditions are very critical, the higher the water content in dry wind conditions, the greater the ability of the soil to store water for plants when it occurs drought as during the dry season. The water content will tend to decrease by 0.38% for every 1% increase in slope class. It is because the steeper the land, the lower the water content of the soil. Soil erosion by air in sloping areas also causes the soil to begin to erode and be transported so that it will only leave less fertile soil which can cause a decrease in plant productivity. The higher the slope of the land will have an impact on the decrease in soil organic matter, air content and soil pH (Banjarnahor *et al*., 2018). Banjarnahor *et al*. (2018) in his research results show that increasing the grade of the slope, the diameter of the stem is getting smaller, as well as the height of the plant is increasing. This phenomenon is different from the results of the study, there are several classes of slopes in the observation plot which show the average value of the highest tree height in the steep slope class. This is presumably due to the incompatibility of the growing site with its natural distribution resulting in abnormal growth, characterized by a greater increase in height with a relatively smaller stem size. According to Soekotjo (2009*) S. leprosula* can grow well on slopes to gentle slopes and at altitudes below 700 m above sea level. It was also suspected that there were other external factors such as stand density, slope direction, biology and other environmental factors that affected the growth in height and diameter of *S. leprosula* on the observation map.

CONCLUSION

Differences in slope class and slope direction caused differences in growth diameter and the total height of *S. leprosula.* The distribution of the growing site of *S. leprosula* naturally occurs on flat to gentle slopes, so if planted on a rather steep to very steep slope, it will produce abnormal growth where the plant will grow taller and thinner. Therefore, the best height growth of S. leprosula at a planting distance of 4m x 8m, which is a very steep slope class and the slope faces north, while at a planting distance of 2m x 2m, the slope class is rather steep with a slope facing north. The best growth in diameter of *S. leprosula* is in the flat slope class, the slope facing north is in the flat slope class, and the slope is facing north for a planting distance of 4m x 8m, while at a planting distance of 2m x 2m, the slope class is rather steep, the slope is facing south. The growth of S. leprosula was also influenced by environmental factors such as stand density, canopy treatment, soil nutrients, and silvicultural treatment is given.

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