Silvopasture based on Sengon (SBS) in the southern of Merapi Volcano and the development opportunities

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Abstract. Silvopasture is an important pillar for people in the southern part of Merapi Volcano. Silvopasture provides forage and also supports ecological recovery after the eruption. This research was aimed to determine the composition of stands, forage productivity and quality, and the opportunities of silvopasture development. Data were collected by a purposive method that divided the land into 4 categories based on the age of sengon stands: 2 years, 3 years, 4 years, and 5 years with 4 samples were taken from each category. Measurement of stands were collected using 20m x 20m plots. Inside the stands plot there were 5 plots of 1m x 1m ordered diagonally to collect forage samples. The variables observed include the species and the number of stands and forage, forage’s productivity (wet weight), also forage’s quality (organic matter, crude protein, and crude fiber). Data analysis used the Importance Value Index (IVI), Diversity Index (H’), and Analysis of Variance (ANOVA). The result showed that the land composed by timber stands (sengon, mahogany, mindi, mangium, and jabon), fruit stands (durian, guava, dersono guava, jengkol, melinjo, jackfruit, kokosan, and avocado), forage stands (gamal), and other stands (waru gunung). The observed forage were Panicum maximum, Cyperus rotundus, and Imperata cylindrica. Panicum maximum on SBS of 4 years old (shade intensity 92.93%) has the best productivity (0.077 ton/ha/year wet weight) and quality (10% crude protein, 20.6% crude fiber, and 83.4% organic matter). Silvopasture can be developed by intensifying the land space for stands and forage as well as increasing the land owner’s knowledge about silvopasture.

1. Introduction

People in the southern part of Merapi Volcano have close interaction with silvopasture. The intensive application of silvopasture after the eruption of Merapi in 2010 had a positive impact on the people around this area. Silvopasture supports stand growth and forage. After the eruption, forage has a role as a recovery crop in the damaged land.

In the southern part of Merapi Volcano, silvopasture can be found and developed in the land that is dominated by sengon (Falcataria moluccana). Sengon has a light type of canopy and the space under the stand can be utilized to cultivate forage [1]. The Kepuharjo Village’s people maximize forage that grows naturally in the land to reduce dependence on concentrate and minimize feed cost. So it can increase the profit that is obtained by the farmers [2], but we should also be aware of the quality and quantity of the forage.
The productivity and quality of forage may be influenced by the stand’s shade in silvopasture based on sengon (SBS) land. This shade of stand will have an impact on silvopasture development’s opportunities on forest land. It will lead to land management in order to support stand and forage sustainability. Therefore, this research aims to determine the composition of stands, productivity (based on wet weight) and quality (organic matter, crude protein, and crude fiber) of forage, and the opportunities of silvopasture development in the southern part of Merapi Volcano.

2. Material and method

This research was conducted from June until October 2018. Determination of the research site was based on altitude between 710–810 meters above sea level in Kepuharjo Village, and the criteria was land that applied agroforestry with silvopasture based on sengon (SBS) which has shade intensity above 50%. Data were collected by purposive method that divided the land into 4 categories based on the age of sengon stands: 2 years, 3 years, 4 years, and 5 years and 4 samples were taken from each category. Measurement of stands was collected using 20m x 20m plots. Inside the stands plot, there were 5 plots 1m x 1m ordered diagonally to collect forage’s sample. The variables that were observed include the species and the number of stands and forage, forage productivity (wet weight) and quality (organic matter, crude protein, and crude fiber) with proximate analysis. Forage productivity per hectare per year was calculated using the following formula [3]:

\[
PP = \frac{p}{L} \times 11
\]

Where is:
- \( P \) = Forage production (ton/ha/years)
- \( p \) = Forage sample production (ton/year)
- \( L \) = Total plot area (ha)
- \( l \) = Forage sample area (ha)

The data were analyzed using Importance Value Index (IVI), Diversity Index (H’), and Analysis of Variance (ANOVA) to find out the effect of sengon age toward forage productivity and quality. Importance Value Index (IVI) were calculated as follows [4]:

\[
\text{IVI for sapling, poles, and trees} = RF + RA + RD
\]

\[
\text{IVI for seedling and forage} = RF + RA
\]

Abundance (A)  
\[
= \frac{\sum \text{Number of respective species} \times \text{Extent of sampling area}}{\sum \text{Number of respective species} \times \text{Extent of sampling area}}
\]

Relative Abundance (RA)  
\[
= \frac{\sum \text{Abundance of respective species} \times 100 \%}{\sum \text{Total abundance of all species} \times 100 \%}
\]

Frequency (F)  
\[
= \frac{\sum \text{Number of plot were species existed}}{\sum \text{Number of sampling area}}
\]

Relative Frequency (RF)  
\[
= \frac{\sum \text{Frequency of respective species} \times 100 \%}{\sum \text{Total frequency of all species} \times 100 \%}
\]

Dominance (D)  
\[
= \frac{\sum \text{Basal area of respective species} \times \text{Basal area of respective species} \times \text{Extent of sampling area}}{\sum \text{Basal area of respective species} \times \text{Basal area of respective species} \times \text{Extent of sampling area}}
\]
Relative Dominance (RD) = \frac{\text{Basal area of respective species}}{\text{Total basal area of all species}} \times 100 \%

Diversity Index of species were calculated using the following formula [5]:

\[ H' = - \sum p_i \ln p_i \]

with \( p_i = \frac{n_i}{N} \)

Where is:
- \( H' \) = Shannon-Wiener Diversity Index
- \( p_i \) = Proportion of individuals of one particular species found divided by the total number of individuals found
- \( n_i \) = Number of one particular species
- \( N \) = Total number of individuals found

3. Result and discussion

3.1. Stand composition of the land

Data of stand composition were collected in SBS land on the southern part of Merapi Volcano. The result showed that there were various species of trees in the silvopasture land on various ages of sengon (Table 1). It showed that beside timber log, SBS land could also produce fruits and forage.

| No | Species                      | Number of trees |
|----|------------------------------|-----------------|
| 1  | Durian (Durio zibethinus)    | 1               |
| 2  | Gamal (Gliricidia sepium)    | 3               |
| 3  | Jabon (Anthocephalus cadamba)| 3               |
| 4  | Guava (Psidium guajava)      | 2 1 1           |
| 5  | Dersono Guava (Syzygium malaccense) | 1   |
| 6  | Jengkol (Archidendron pauciflorum) | 1   |
| 7  | Kokosan (Lansium domesticum) | 1               |
| 8  | Mahogany (Swietenia macrophylla) | 1 3   |
| 9  | Mangium (Acacia mangium)     | 1 2            |
| 10 | Waru Gunung (Hibiscus macrophyllus) | 1 1 1 |
| 11 | Melinjo (Gnetum gnemon)      | 1               |
| 12 | Mindi (Melia azedarach)      | 8 1 3          |
| 13 | Jackfruit (Artocarpus heterophyllus) | 4   |
| 14 | Sengon (Falcatoria moluccana) | 295 177 269 115 |
| 15 | Avocado (Persea americana)   | 1               |
|    | Total                        | 303 194 275 127 |

Based on the observation, light intensity might be reduced even though sengon has a light type of crown. It is caused by the narrow spacing between the planted trees in SBS land. Besides, there were some trees that have a wide crown, like mindi. It also helps to reduce sunlight to reach the forest floor. These tree species could be divided into 4 categories based on their utilization: timber stands (sengon, mahogany, mindi, mangium, and jabon); fruit stands (durian, guava, dersono guava, jengkol, melinjo, jackfruit, kokosan, and avocado); forage stands (gamal); and others (waru gunung).

| No  | Species                      | Important Value Index (%) |
|-----|------------------------------|---------------------------|
| 1   | Durian (Durio zibethinus)    | 10,432                    |
The composition of tree species in the silvopasture land on various ages of sengon were dominated by sengon. The result showed that sengon has a higher IVI score than other species (Table 2). Sengon has a higher number of trees than other species in the land (Table 1), so it makes the sengon’s IVI score higher too. For the farmers, sengon is more interesting compared to other species because it is a pioneer species that can grow in marginal land within a short period of time (between 6-8 years). The leaves can also be used as forage too [6].

Table 3. H’ score and shade intensity in the silvopasture land on a various age of sengon

| No | Age of Sengon | Shade Intensity (%) | Diversity Index (H’) |
|----|---------------|---------------------|---------------------|
| 1  | 2 years       | 80,49%              | 0.13                |
| 2  | 3 years       | 74.83%              | 0.3                 |
| 3  | 4 years       | 92.93%              | 0.09                |
| 4  | 5 years       | 83.28%              | 0.41                |

Diversity index in the silvopasture land impacted by IVI score of trees species. The diversity of the land could be divided into 3 categories relies on the score: \(0 \leq H’ \leq 2\) (low); \(2.1 \leq H’ \leq 3\) (medium); and \(H’ \geq 3\) (high) [7]. Based on the result, it showed that H’ score in the silvopasture lands on various ages of sengon is low (Table 3). The diversity was low because sengon dominated the land, and also the other species have fewer individuals than sengon (1).
3.2. Forage Productivity
In the silvopasture land on a various age of sengon, 3 species of forage were found, they were *Panicum maximum, Cyperus rotundus, and Imperata cylindrica*. Those forage grow in a limited area. Despite limited space to grow, *Panicum maximum* has thick clumps and rather dominant than *Cyperus rotundus* and *Imperata cylindrica*.

![Forage production based on wet weight in the silvopasture land on a various age of sengon](image)

*Figure 1. Forage production based on wet weight in the silvopasture land on a various age of sengon

*not significant for a 95% confidence interval*

Based on ANOVA results it showed that the various ages of sengon were not significantly influencing the production of forage based on the wet weight (P>0.05). But *Panicum maximum* has the higher wet weight's production than the other species, especially on 4 years old SBS land (Figure 1). This condition was possible because *Panicum maximum* is a species that can tolerate shade and drought, also well adapted with Leguminosae [8]. Beside that, among those 3 species of forage, only *Panicum maximum* that edible for cattle.

3.3. Forage quality

3.3.1. Organic Matter
To get to know more about forage quality, the component of forage including its organic matter should be analyzed. Based on ANOVA results, it showed that organic matter of forage was not significantly affected by various ages of sengon. In the 4 years old’s SBS land, most of the forage had a higher percentage of organic matter, it is *Panicum maximum* 83,4% and *Cyperus rotundus* 92,5%. *Imperata cylindrica* had 92% of organic matter in the 3 years old’s SBS land (Figure 2).
Organic matter can be found as a component content of forage, especially in the dry matter. It is because dry matter consists of organic matter and inorganic matter. Organic matter composed of protein, fat, crude fiber, and nitrogen-free extract. So, organic matter could give an overview of chemical content of forage [9].

3.3.2. Crude Protein
Crude protein also component content in forage, especially grass. Cattle needed amounts of protein for in order to grow well, to work, and produce milk. Forage provides particular amounts of protein, but still not enough for cattle [10].

Based on the results, it showed that crude protein’s percentage among the various ages of sengon is no different (Figure 3). But, *Imperata cylindrica* has a higher percentage of crude protein with 14.1% in the 3 years old’s SBS land. *Panicum maximum* also has a higher percentage of crude protein in the 3 years old’s SBS land with 11.9%. But *Cyperus rotundus* has a higher percentage of crude protein in the 4 years old’s SBS land with 8.91%.

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**Figure 2.** Organic matter’s percentage of forage in the silvopasture land on a various age of sengon *not significant for a 95% confidence interval*

Organic matter can be found as a component content of forage, especially in the dry matter. It is because dry matter consists of organic matter and inorganic matter. Organic matter composed of protein, fat, crude fiber, and nitrogen-free extract. So, organic matter could give an overview of chemical content of forage [9].

**Figure 3.** Crude protein’s percentage of forage in the silvopasture land on a various age of sengon *not significant for a 95% confidence interval*
Crude protein in every grass influenced by sunlight intensity that they received. Shade intensity of more than 50% showed that the percentage of crude protein is higher than the intensity which less than 50%. Forage that grows under the stand shade has nitrogen higher, it is because nitrogen is available and can easily be absorbed by the plant [11].

3.3.3. Crude Fiber
Crude fibers are composed by lignin, hemicellulose, and cellulose. Fiber usually shows index of forage quality and was used to give an overview of the undigested components. At this point, crude fiber close enough with digestible components of forage by the cattle [12].

![Figure 4. Crude fiber’s percentage of forage in the silvopasture land on a various age of sengon *not significant for a 95% confidence interval](image)

Based on the result, it showed that the forage’s crude fiber was not significantly affected by various ages of sengon. The higher percentage of crude fiber was on Panicum maximum in the 4 years old’s SBS land with 30.6%. Cyperus rotundus has a higher percentage of crude fiber in 5 years old’s SBS land with 24.9%, while Imperata cylindrica has a higher crude fiber in 3 years old’s SBS land with 27.1%. Crude fiber material in forage depends on the species, and were not affected by stress [13]. The mature plant has more crude fiber material than the juvenile one. It is because the plant cell walls has grown harder and thick as a plant support [11].

3.4. Opportunities for silvopasture development
Because of the high advantages, farmers in the southern part of Merapi Volcano established silvopasture based on sengon. The advantages were integrating between long-term and short-term yield; and support land recovery after the eruption in 2010. Forage, including grass, was the short-term yield to support livestock, especially dairy cows (more dominant than beef-cattle). The stands will produce timber log as the long-term yield and will only be harvested when the farmers need a bigger amount of income to pay their bills. Sengon was one of the most potential species to be established in the southern part of Merapi Volcano. It is a fast-growing species with a large volume of yield. The annual average increment of sengon’s volume is around 10–25 and 30–40 m³/ha in 8–12 years rotation [14]. Its volume can reach an annual average increment of about 39 m³/ha in 10 years rotation with maximum volume increment about 50 m³/ha in a fertile land [15].

Land utilization in the southern part of Merapi Volcano had a characteristic, it was caused by a risk from the eruption of Merapi Volcano. Merapi Volcano is categorised as an active Mountain in the world
and might explode in some period. So, land utilization focused on yield diversification with the agroforestry system, including silvopasture. The farmers applied silvopasture based on sengon in hetero culture way because there were some other species too in SBS land besides sengon. From this condition, silvopasture based on sengon is the best way for land recovery after the eruption of Merapi Volcano in 2010.

To provide sunlight supply, we should determine tree spacing and consider choosing tree species with light canopy type. The priority was to choose the potential species with a high market price, and it refers to sengon. Sengon can be established in hetero culture land which is contiguous with other species like fruit stands or timber stands. Reference to established silvopasture refers to 4 years old’s SBS land which has 92% shade intensity that supports the best productivity and quality of forage in dry season. Silvopasture in the southern part of Merapi Volcano should be selective to decide the forage’s species, and Panicum maximum is recommended to cultivate. Cut and carry system in silvopasture is more recommended than grazing in the land. So, the landowners should optimize space usage of their land intensively. Then it will provide timber and non-timber forest products like fruits, forage, and other farm products.

4. Conclusion

Based on this research, Panicum maximum is recommended to be established in the silvopasture system because of its high productivity and quality compared to the other grass. Among those 3 species of forage, just Panicum maximum that qualified as an edible forage and can grow well under heavy shade intensity (sunlight supply <50%) especially in 4 years old’s SBS land.

The lands in the southern part of Merapi Volcano are quite well for establishing sustainable silvopasture. Silvopasture development in this region should consider the type of stand and forage, optimizing space under the stand intensively, land preparation and management plans, tree spacing, while also educating the communities especially the landowners, about silvopasture practice.

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