The potential of woody waste biomass from the logging activity at the natural forest of Berau District, East Kalimantan

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Abstract. The fifth principle of Sustainable Forest Management of the Forest Stewardship Council (FSC) is to encourage the efficient use of forest products and services to ensure economic viability and a wide range of environmental and social benefits, and one of the criteria is to minimize logging waste. Therefore, identification, calculations, and monitoring of logging waste should be done. The purpose of this study were to know the potential of logging waste in logging area and to know the estimated volume of waste based on the Annual Allowable Cut (AAC). This research was carried out at PT Karya Lestari, Berau District, East Kalimantan. It was found that the highest percentage of waste was in the form of the main trunk canopy, followed by the branches, stump, twigs and the rest of the bucking. It was also found that there was quite strong positive relationship between the volume of felled trees with its logging waste volume, and the estimated volume of logging waste based on AAC was 40,623 m$^3$ per year. This result shows that the potential logging waste is high and it is recommended for the company to do logging on trees with small volumes or lower diameter class (40-89 cm).

1. Introduction

The logging waste is one of the problems that must be addressed in the process of forest harvesting in natural forests because among the objectives of the forest harvesting activities are to maximize the value of wood and optimize the supply of industrial raw materials. There are four main activities in forest harvesting: logging, skidding, loading and hauling [1], that have to go well and sequentially so that the logging operation can be successful. If the process is not done with good and proper planning, logging as the first stage in forest harvesting can be the most potent activity to produce wood waste. The success of tree felling can be measured, among others, from the level of damage to the environment and the waste produced.

In line with that, the fifth principle of Sustainable Forest Management (SFM) by the Forest Stewardship Council (FSC) is to encourage the effective utilization of various products and services from forests to ensure economic capability and environmental and social benefits, which is one of the criteria is to minimize waste of wood harvesting (logging waste). SFM itself is a global aim for guarantee timber supply, protection of forest environmental services (such as carbon sequestration), protection of forest habitats, and protection of secure place for over than 1.6 billion human being who depend on forest [2,3,4,5]. Therefore, all harvesting activities in the forest company should get more
attention, one of which is to identify, calculate, and monitor the waste of timber harvesting. However, waste in good condition can still be utilized, for example for raw materials of advanced products, raw materials for sawn, core veneer, and chips, even some of the stem waste deserve to be used as logs[6], the material of sawmill industry [7], bioenergy [8,9,10,11], and bio-based polymeric materials [12].

The purpose of this research were to know the potential of logging waste that occurs in the plot of harvest due to timber harvesting and to know the estimated volume of logging waste based on the Annual Allowable Cut (AAC). Research on wood waste in timber companies was absolutely necessary. On the basis of that information, corrective action in the forest harvesting process can be done so that the wood waste that occurs can be minimized, thus increasing the efficiency and effectiveness of timber harvesting. In addition, the existing waste potential data also becomes important information in the efforts of further waste utilization.

2. Materials and Methods

2.1. Study area
The study was conducted at Karya Lestari Company, Berau District, East Kalimantan Province, Indonesia, for ±3 months, at the 2014 Annual Work plan block. Geographically, the work area of Karya Lestari Company is located between 116°40'12.2"-116°59'46.7" East Longitude and 01°35'15.6"-01°48'4.4" North Latitude. Based on the distribution of forest groups, Karya Lestari Company is included in the Gie River Forest Group and according to government administration, it is included in Kelay Sub-district, Berau District, East Kalimantan Province, Indonesia (Figure 1). Meanwhile, based on forestry administration, Karya Lestari Company is included in Sambaliung Forestry Unit, Berau Forestry Department, East Kalimantan Provincial Forestry Office.

2.2. Scope of logging waste
In this research, the logging waste that we measured is the whole part of the remaining logging trees or all parts of commercial rods that left in the harvest plots consisting of stumps, the rest of the bucking, main rod of the crown, the branches and twigs. The definition of it is as follows: commercial rods are stems from the top of the stump until the first branch or stem which has been issued by forest concessions as a commercial rods; the top rod is the stem part of the first branch to the canopy which is an extension of the main (commercial) stem; branches and twigs is a canopy component of a felled tree that is above the first branch; the stump is the bottom of the tree under the notch and the notch reply; and the short cut is the stem part of the main stem containing the defect and needs to be cut [6].

![Figure 1. Study Area at Berau District, East Kalimantan Province, Indonesia](image-url)
In this research, we used term of the main rod of the canopy for top rod, and term of the rest of the bucking for shortcut.

2.3. Data collection and analysis
The number of sample trees measured was 60 trees, randomly selected and scattered on the logging plot. Each part of the logging waste, identified and classified as a stump, the rest of the bucking, the main rod of the crown, branch or twig, then each piece of waste is measured in diameter and length. We calculated waste volume by using the following formula:

\[ V = \frac{1}{4} \pi d^2 L \times 10^{-3} \]  

(1)

With \( V \) = volume of logging waste (m\(^3\)); \( d \) = diameter (cm); and \( L \) = length of logging waste (m).
To estimate the volume of logging waste based on Annual Allowable Cut (AAC) we used linear regression with following equation:

\[ V_l = a + bV \]  

(2)

With \( V_l \) = Estimated volume of logging waste based on AAC (m\(^3\)); \( a, b \) = constant and \( V \) = Volume of AAC (m\(^3\)).

3. Results and Discussion

3.1. Summary of sample trees
In this study, we observed and measured 60 sample trees with species Shorea sp. in the 2014 Annual Working Plan block. The smallest diameter of the sample tree measured was 45 cm and the largest diameter of 166 cm with an average diameter was 77 cm. The following table presents the sample tree distribution measured:

| Class of Diameter (cm) | Amount of sample trees |
|------------------------|------------------------|
| 40-49                  | 1                      |
| 50-59                  | 12                     |
| 60-69                  | 14                     |
| 70-79                  | 12                     |
| 80-89                  | 5                      |
| 90-99                  | 8                      |
| 100-109                | 4                      |
| 110-119                | 1                      |
| ≥120                   | 3                      |
| **Total**              | **60**                 |

From table 1, we can see that the measured tree samples were dominated by trees with diameter of 50-79 cm that was as many as 38 trees, and the remaining 32 samples were spread over the diameter of 40-49 cm (1 tree), 80-89 cm (5 trees), 90-99 cm (8 trees), 100-119 cm (1 tree) and ≥120 cm (4 trees).

3.2. Forms of logging waste
Logging waste is log part of commercial stem, short pieces, stumps, branches and twigs [6]. The forms of logging waste found in the logging area were stump (the bottom of the tree under the notch and the notch reply), the rest of the bucking (in the form of short pieces or logs, including the main stem part
that is defective or damaged and needs to be cut), the main rod of the crown (the stem part from the first branch to the canopy which is an extension of the main stem), branches and twigs (the canopy component of the felled tree that is above the first branch), as we can see at Figure 2.

![Figure 2](image-url)

**Figure 2.** Forms of the logging waste at the logging area: (a) stump; (b) rest of the bucking; (c) main rod of the crown and branches; and (d) twigs.

From the calculation of the volume of each waste, by using equation (1), the results obtained that the largest waste was in the form of main rod of canopy (43.43%), followed by waste in the form of branches (26.12%), stumps (13.63%), twigs (11.13%) and rest of the bucking (5.69%). Figure 3 shows the percentage of waste volume in each form.

![Figure 3](image-url)

**Figure 3.** Percentage of waste volume in each form.

Most of the stump as the remaining logging that found on the logging block exceeded the recommended limit for natural forest, which was 50 cm above the soil surface. The stump contained in the sample tree was mostly above 1 m high and some of them were reached more than 3 m height. In addition to the physical condition of the trunk containing defects or damaged by harvesting, short pieces produced due to trimming at the base or tip also cause the residual waste bucking. This condition could actually be avoided by increasing control and monitoring of logging activities, and
also by improving the logging and bucking techniques [6] such as by applying of more environmental friendly logging techniques.

3.3. Volume of logging waste

The log volume data of the felled trees is obtained from the company's data, while the volume of logging waste is calculated using formula (1). The volume calculation of felled trees and logging waste generated from 60 sampling trees obtained the following data: the total volume of felled trees was 618.7 m$^3$ and the total logging waste volume that occurs in logging area was 509.7 m$^3$, whereas the average volume of logged trees was 10.3 m$^3$ and the average volume of waste produced by each felled tree was 8.5 m$^3$. Total volume of felled trees and total volume of logging waste was shown in figure 4.

![Figure 4. Total volume of felled trees and logging waste in each diameter class.](image)

Figure 4 showed that in general, the total volume of logging waste produced is lower than the volume of the felled tree, except in the 110-119 cm diameter class, where the volume of waste generated is greater than the volume of the felled tree. It could also be seen in figure 4 that in the smaller diameter class, which were in the 60-69 cm, 70-79 cm, and 80-89 cm diameter classes, the waste produced was much smaller than the volume of the felled trees compared to the greater diameter class. The calculation of waste in the sample tree in the 70-79 cm diameter class showed the best result, where the waste produced was much smaller than the volume of the felled tree.

We also did regression analysis of the 60 data from felled trees and its logging waste volumes, which was shown in Figure 5.
Figure 5. Graph of relationship between felled tree volume and waste volume by linear model

From Figure 5, with s value 5.283 and r value 0.696 it could be seen there was quite strong positive relationship between the volumes of felled trees with its logging waste volume. It was also could be seen the tendency that logging on smaller volumes of trees will result in a smaller volume of logging waste while logging on larger volumes will relatively result in a much larger volume of logging waste as well. From the results in figures 4 and 5, we found do more logging on smaller volume of trees or in smaller diameter class (40-89 cm) than logging on larger volume of trees or larger diameter classes can be one possible alternative to minimize the resulting of logging waste.

The result of the analysis also produces constant value a=1,939 and b=0,636, so equation (2) become \( V_l = 1.939+0.636V \). Until year 2021, Karya Lestari Company planned to harvest the average area of the cutting block ± 1,250 ha per year and the annual harvest volume is estimated at 58,365 m³. Thus, the volume of logging waste that will be generated was estimated at 40,623 m³ per year which is high. The existence of waste in the forest leads to lower efficiency of timber harvesting. Several studies have shown that the efficiency of harvesting timber in natural forests ranges from 75 to 87%[13]. On the other hand, potential of logging waste can also be utilized for various utilization efforts. The potential of logging waste from logged trees up to 15 cm in diameter is 57% [13]. Actually, high potentialities of plant waste for many industrial processes were overviewed [14], as the global issue of energy scarcity in the world today, whereas biomass and waste biomass must contribute to development a bioeconomy to the energy transition in combination with the other renewable energies [15]. Furthermore, utilization of woody biomass, which is produced from two specific sources: waste wood from sawmills, and logging waste left in forest land, has positive impact for regional economic development [16]. In the future, it is important to do more study on the utilization of logging waste, especially in East Kalimantan.

4. Conclusion
The potential of logging waste is high. In addition to efforts to minimize the logging waste, the potential of waste can also be utilized for various utilization efforts. There is a quite strong relationship between the volume of felled trees and the volume of its waste produced, therefore it is recommended for the company to do logging on trees with small volumes or lower diameter class (40-89 cm).
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