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Debarking Productivity in Peatland Industrial Plantation Forest Harvesting Using Debark Ponton Darat (DPD) Gen 1 and Gen 2

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ABSTRACT

Timber harvesting activities in Industrial Plantation Forests on peatlands require specialized techniques and machinery due to the soft, wet, and low-bearing-capacity soil conditions. One of the important stages in this process is debarking, which involves removing the bark before the wood is further processed. To support debarking activities on peatlands, first-generation (Gen 1) and second-generation (Gen 2) Debar Ponton Darat (DPD) are used, both of which have been developed in terms of design and operational systems. This study aims to compare the productivity and efficiency of debarking using DPD Gen 1 and DPD Gen 2 under relatively similar working conditions on peatlands in Riau Province. The research method employed a quantitative approach through direct field observations using time-study methods over 15 work cycles involving two operators, each using DPD Gen 1 and DPD Gen 2. The collected data included work time and the volume of wood successfully debarked, which were then analysed descriptively to determine productivity values in units of m^3/hour. The results showed that the DPD Gen 1 had a higher average wood volume per cycle at 14.8 m^3 compared to the DPD Gen 2 at 12.1 m^3. However, the cycle completion time for the Gen 2 DPD was faster at 3.16 minutes compared to 5.08 minutes for the Gen 1 DPD. These conditions result in higher productivity for DPD Gen 2, reaching 15.3 m^3/h, while DPD Gen 1 achieves 14.8 m^3/h. The increase in productivity for DPD Gen 2 is thought to be influenced by the blade design, which is sharper and more densely spaced, making the bark peeling process faster and more efficient.

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1. Introduction

Timber harvesting in Industrial Plantation Forests is a series of production processes that aim to produce roundwood as raw material for industry. This process includes felling, skidding, gathering timber at the log collecting (TPn), debarking, and Log transportation to the mill [1]. In Riau Province, most areas Industrial Plantation Forests are developed on peatlands and utilized for the cultivation of forestry crops such as *Acacia* as raw material for the pulp and paper industry [2]. Based on Setiawan et al. [3], this study analyses the growth, biomass, and carbon accumulation of *Acacia crassicarpa* trees planted on tropical peatlands with varying peat depths, with the aim of supporting sustainable management and climate change mitigation through increased carbon sequestration in peatland ecosystems. However, peatlands have distinct characteristics compared to mineral soils, such as soft, wet soil conditions, low bearing capacity, and being highly influenced by water management conditions. Therefore, timber harvesting activities on peatlands require specialized techniques and machinery to ensure operations can be conducted effectively under conditions that are wetter and softer than mineral soils [4].

One of the initial processing activities that supports the utilization of timber in the field is the removal of bark, known as debarking [5]. Debarking is the process of removing or separating the bark from felled tree trunks before the wood is further processed or shipped to industry. This process aims to improve the efficiency and productivity of wood processing before moving on to the next stage. Debarking is generally performed immediately after felling because the moisture content in the bark is still high, allowing the removal to proceed more easily and effectively [6], [7]. In addition to improving the efficiency of the timber harvesting process in the field, debarking also helps reduce the moisture content of the wood, ensuring higher-quality logs reach the mill [8].

Debarking is usually carried out at logging collection (TPn), the felled logs are debarked using a debarking platform known as a Debark Ponton Darat (DPD), which is operated with the assistance of an excavator grapple [8]. This equipment is designed to support debarking operations on sites with low bearing capacity, enabling operations to proceed more effectively and efficiently. With technological advancements, the DPD has evolved from the first generation (*Gen 1*) to the second generation (*Gen 2*), featuring various improvements in technical and operational aspects. Differences in design and operational systems between the two generations of this equipment are believed to influence the productivity achieved during *debarking* operations.

Productivity is one of the performance metrics used to evaluate the results of an operational activity, particularly debarking. Debarking productivity is heavily influenced by various factors such as equipment capacity, machine type, time, work area, human resources (operators), methods, and other factors. Previous research has indicated that differences in debarking methods namely the direct method and the indirect method result in differences in productivity, with the direct method being assessed as having higher productivity than the immersion method [8]. An interesting aspect of examining the various factors affecting productivity is comparing the productivity differences between the use of DPD Gen 1 and DPD Gen 2 in *debarking* activities on peatlands. Consequently, the objective of this study is to measure the differences in productivity and efficiency of debarking using DPD Gen 1 and DPD Gen 2.

2. Research Significance

This study is hoped to provide information, particularly for industrial plantation companies, regarding differences in the productivity of debarking operations during timber harvesting, specifically regarding the use of DPD Gen 1 and DPD Gen 2. The application of innovative timber harvesting methods on peatlands significantly enhances the effectiveness and efficiency of operational activities, especially in peatland conditions characterized by low carrying capacity and high moisture levels. Additionally, the research findings are also expected to support the development of timber harvesting technologies better suited to the characteristics of peatlands and to enhance the effectiveness of on-site timber harvesting operations.

3. Methods

This study was conducted at one of the industrial plantation forest companies in Riau Province, specifically PT. RAPP Estate Pelalawan. The research methodology used a quantitative and qualitative approach through field observations, measurements, and data collection. The sample selected for this study consisted of two operators engaged in *debarking* activities in one of the compartments within the work area, using different types of *Debark Ponton Darat* (DPD): one operator used a Gen 1 DPD, and the other used a Gen 2 DPD. The sample was selected to compare *debarking* productivity based on the differences in the equipment used under relatively similar working conditions. Each operator's work process will be measured over 15 cycles. The selection of 15 cycles was based on an interview with the harvesting manager, who deemed this sufficient to measure productivity. Additionally, discussions and interviews were conducted with the harvesting manager, supervisors, and operators to obtain additional data and information.

Data on debarking machine productivity was collected using the time-study method, which involves identifying specific tasks performed in a repetitive work process to directly measure the time required for debarking activities in the field by recording the duration of each work process using a stopwatch [10]. Data analysis is used to measure the productivity level of the debarking machine by calculating the ratio of the volume of wood successfully debarked to the total working time required during the operational process.

Productivity was calculated using the following formula:

$$P = \frac{Vtotal}{H} \quad \text{..... (1)}$$

Description:

P = Productivity (ton/jam)

$Vtotal$ = Total wood volume (m^3)

H = Working time

Productivity calculations are based on actual working time obtained through a *time study*, including both effective and non-effective time (*delay*), so that the results reflect real world operational conditions in the field. Next, a descriptive comparison is conducted between the productivity of DPD Gen 1 and Gen 2 DPD to identify differences in equipment performance.

4. Results and Discussion

4.1. Debarking

The debarking process at PT. RAPP's Pelalawan Estate is carried out using a combination of grapple excavators and DPD equipment. This system was specifically developed to improve productivity and the quality of timber sent to the processing industry. The debarking process using the DPD is only performed on peatland for *Acacia crassicarpa* trees. Meanwhile, on mineral soil, debarking is performed directly during felling using a harvester machine called a tree shear. The timber harvesting processes on peatland and mineral soil differ in several ways; efforts to optimize and improve the efficiency of operations on peatland are continuously being made to ensure that the timber is easily transported and of high quality as it heads to the processing industry.

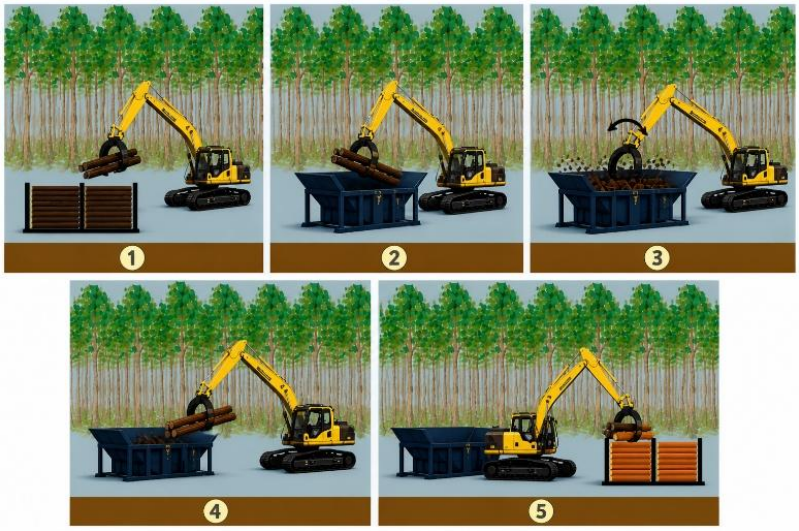

Figure 1. The *debarking* process: (1) loading the logs, (2) placing the logs on the DPD, (3) the debarking process, (4) log discharge from the DPD, and (5) stacking the logs in a new pile.

According to a study by Suhada et al. [8], the implementation of DPD at PT. RAPP has been shown to increase productivity and efficiency in the debarking process compared to conventional methods. The debarking process consists of five stages, as shown in Figure 1. These stages are: (1) the wood is grabbed from the wood pile by clamping, then (2) the wood is fed into the DPD, (3) the wood is then debarked by flipping and rubbing it against the debarking blades, (4) in the next stage, the wood, now free of bark, is removed from the DPD and (5) placed on a new wood pile.

4.2. Debark Ponton Darat Gen 1 VS Gen 2

Along with the development of industrial plantations, timber harvesting activities have also continued to evolve through the application of innovations and technologies to improve productivity and operational efficiency in the field. Harvesting machines used to felling, logging, and process timber in an integrated manner, including the mechanical debarking process using

debarking machines designed to remove bark quickly and cleanly without damaging the heartwood. The use of this mechanical technology not only accelerates the harvesting process but also reduces environmental impact and improves workplace safety, making it a key trend in modern plantation forest management [11]. One of the innovations in the *debarking* process is the development of the DPD from Gen 1 to Gen 2 (Figures 2 and 3). The differences between the two generations of these machines lie in their distinct technical characteristics regarding design, wood-holding capacity, and debarking mechanisms. The mechanical debarking process within the DPD utilizes friction between the log and the walls and metal structures of the pontoon, causing the bark to peel off gradually.

Figure 2. DPD generation 1

Figure 3. DPD generation 2

Figure 4. Knife blade Gen 1

Figure 5. Knife blade Gen 2

For the DPD Gen 1, the blades appear rounder, shorter, and have relatively wider spacing between them. This shape results in less friction against the surface of the log during the peeling process (Figure 4). Meanwhile, in the DPD Gen 2, the blades are more pointed, protrude more, and are arranged more closely together, resulting in greater contact and friction against the log (Figure 5). This accelerates the bark removal process and increases debarking productivity. According to a study by Kunickaya et al. [12] on the effect of the knife sharpening angle on the debarking process, the sharper the blade (smaller angle), the greater the contact pressure and the larger the area of contact with the wood, resulting in shorter debarking times and increased productivity. Another study by Zyryanov [13] also showed that innovations in portable debarking machines, such as the use of toothed washers that function similarly to a knife blade or cutting tool, generate more effective mechanical force during the debarking process. Thus, the modified blade design on the DPD Gen 2 is believed to be one of the factors contributing to the increased effectiveness and productivity of field debarking operations.

4.3. Time and Productivity of the Debarking Process

The time and productivity of the *debarking* process observed on DPD Gen 1 and DPD Gen 2 were measured using four main components that make up a full cycle, namely: (1) wood *grab*, which is the time required for the operator to pick up and clamp the wood from the pile using a *grapple*, (2) placing the wood inside the DPD, (3) the debarking process, which is the time spent agitating and rubbing the logs within the pontoon structure until the bark is removed (4) removing the debarked logs from the DPD and returning them to the clean log pile. This process was repeated 15 times using the *time study* method, as referenced in Reynaldi & Puspitasari [10], which states that this method is the appropriate approach for assessing the efficiency of repetitive work processes. The data from the time measurements of the debarking process using the DPD Gen 1 and DPD Gen 2 over 15 work cycles are presented in Tables 1 and 2.

Based on Tables 1 and 2, the average debarking time and productivity using the DPD Gen 1 was 5.08 minutes, and 3.16 minutes for the DPD Gen 2. This is consistent with previous research, which reported an average debarking process duration of 4–5 minutes, with a total time of 60–75 minutes [8]. The number of logs successfully debarked in a single cycle averaged 16 logs for DPD Gen 1 and 13 logs for DPD Gen 2. Meanwhile, the time difference between DPD Gen 1 and DPD Gen 2 over 15 cycles was 28.78 minutes; DPD Gen 2 had a relatively shorter processing time.

Table 1. Time and Productivity of the DPD Gen 1

Cycle	Time (minutes)					
	Number of logs	Grab	Loading logs onto the DPD	Debarking process	Log discharge from the DPD	Total
1	15	0.15	0.39	3.14	0.18	3.86

Cycle	Time (minutes)					
	Number of logs	Grab	Loading logs onto the DPD	Debarking process	Log discharge from the DPD	Total
2	15	0.24	0.52	3.23	0.17	4.16
3	17	0.35	0.32	4.9	0.19	5.76
4	19	0.18	0.49	7.15	0.16	7.98
5	18	0.9	0.5	4.32	0.17	5.89
6	11	0.12	0.46	3.48	0.15	4.21
7	23	0.16	0.16	4.47	0.19	4.98
8	12	0.9	0.18	3.25	0.15	4.48
9	19	0,19	0.17	5.54	0.18	6.08
10	13	0.21	0.6	3.41	0.13	4.35
11	15	0.8	0.29	6.21	0.14	7.44
12	17	0.13	0.13	3.37	0.15	3.78
13	18	0.14	0.14	3.55	0.13	3.96
14	11	0.6	0.7	2.41	0.11	3.82
15	18	0.13	0.7	4.52	0.13	5.48
Total	**241**	**5.2**	**5.75**	**62.95**	**2.33**	**76.23**
Average	**16**	**0.35**	**0.38**	**4.20**	**0.16**	**5.08**

Table 2. Time and Productivity of the DPD Gen 2

Cycle	Time (minutes)					
	Number of logs	Grab	Loading logs onto the DPD	Debarking process	Log discharge from the DPD	Total
1	13	0.17	0.12	2.36	0.14	2.79
2	15	0.12	0.16	2.57	0.13	2,98
3	11	0.7	0.11	2.53	0.15	3,49
4	17	0.18	0.9	2.50	0.2	3,78
5	19	0.18	0.10	3.15	0.16	3,59
6	10	0.9	0.7	2.04	0.11	3,75
7	11	0.16	0.11	2.26	0.14	2,67
8	13	0.10	0.11	2.15	0.17	2,53
9	10	0.19	0.6	1.55	0.16	2.5
10	14	0.15	0.6	3.24	0.17	4.16
11	10	0.25	0.6	2.07	0.19	3.11
12	16	0.26	0.7	2.10	0.13	3.19
13	10	0.21	0.5	1.20	0.14	2.05

Cycle	Number of logs	Time (minutes)				
		Grab	Loading logs onto the DPD	Debarking process	Log discharge from the DPD	Total
14	13	0.19	0.7	2.55	0.18	3.62
15	15	0.10	0.7	2.29	0.15	3.24
Total	**197**	**3.86**	**6.71**	**34.56**	**2.32**	**47.45**
Average	**13**	**0.26**	**0.45**	**2.30**	**0.15**	**3.16**

However, when comparing the amount of wood processed over 15 cycles, DPD Gen 1 processed more wood than Gen 2, with a difference of 44 logs. The difference in the amount of wood between Gen 1 and Gen 2 is generally influenced by process efficiency and working capacity per cycle. In DPD Gen 1, the cycle time is relatively longer, averaging 5.08 minutes, particularly during the peeling stage, which takes significantly more time. This allows operators to load more wood per cycle to maximize *output* per cycle. Because the process takes longer, operators tend to fill the debarking hopper more fully to maintain high output per cycle. In contrast, the DPD Gen 2 has a significantly shorter cycle time, averaging 3.16 minutes, making the process faster and more dynamic. Under these conditions, operators tend to load a smaller but more optimal amount of wood because the DPD's capacity is adjusted to ensure the process remains fast, with efficiency achieved through higher cycle frequency rather than the volume of wood per cycle. Increasing the number of logs in the debarking system can indeed boost wood output per work cycle. However, an excessively large load capacity risks causing movement constraints between logs, thereby prolonging the debarking process. In contrast, a *debarking* system with a shorter cycle time tends to yield higher productivity because the frequency of work cycles increases. According to research by Spinelli et al. [14], the number of logs and interactions between logs in the mechanical debarking process significantly affect the smooth movement of the wood as well as the efficiency of bark removal.

4.4. Comparison of Debarking Productivity Between DPD Gen 1 and DPD Gen 2

Productivity of machines in timber harvesting is defined as the productivity of a timber harvester, calculated as the ratio of the volume of timber successfully harvested by the machine in cubic meters to the machine's effective operating time in seconds [15]. That is, productivity is calculated as the amount of timber produced per unit of the machine's effective operating time. Productivity measurements conducted during the debarking process involve the volume of wood (in cubic meters) between the DPD Gen 1 and DPD Gen 2 machines. This can be observed based on results per cycle and per hour. This measurement serves as an indicator of the debarking process's efficiency, expressed as the ratio of output produced to the time required. The results of the comparison of debarking productivity between DPD Gen 1 and Gen 2 are presented in Table 3.

Table 3. Comparison of Debarking Productivity

Cycle	DPD Gen 1		DPD Gen 2	
	Log volume/cycle (m3)	Log volume/hour (m3)	Log volume/cycle (m3)	Log volume/hour (m3)
1	0.9	14.3	0.8	17.2
2	0.9	13.3	0.9	18.6
3	1.0	10.9	0.7	11.6
4	1.2	8.8	1.0	16.6
5	1.1	11.3	1.2	19.5
6	0.7	9.6	0.6	9.8
7	1.4	17.1	0.7	15.2
8	0.7	9.9	0.8	19.0
9	1.2	11.5	0.6	14.8
10	0.8	11.0	0.9	12.4
11	0.9	7.4	0.6	11.9
12	1.0	16.6	1.0	18.5
13	1.1	16.8	0.6	18.0
14	0.7	10.6	0.8	13.3
15	1.1	12.1	0.9	17.1
Average	**14.8**	**11.7**	**12.1**	**15.3**

Table 3 shows that the DPD Gen has a higher wood volume productivity per cycle at 14.8 m^3 compared to the DPD Gen 2 at 12.1 m^3. However, when viewed in terms of hourly productivity, the DPD Gen 2 has a higher volume of 15.3 m^3. This indicates that DPD Gen 1 can handle a larger volume of wood per work cycle compared to DPD Gen 2. Nevertheless, the time required to complete a single cycle on DPD Gen 1 is relatively longer. Conversely, although the volume of wood processed by DPD Gen 2 in a single cycle is smaller, the cycle completion time is faster. Consequently, the productivity results of the DPD Gen 2 are more effective and efficient compared to the DPD Gen 1. Although the volume of wood processed in each cycle is smaller, the DPD Gen 2 has a faster cycle completion time, allowing for a higher number of work cycles to be completed in one hour. This results in higher hourly productivity for the DPD Gen 2 compared to the DPD Gen 1. This indicates that the design and operational system improvements in the DPD Gen 2 are capable of enhancing productivity and operational efficiency in field *debarking* activities.

5. Conclusions

Based on the results of research on the productivity of the DPD Gen 1 and DPD Gen 2 in debarking operations at peatland plantation forests, it can be concluded that improvements to the design and operating system of the DPD Gen 2 have successfully increased productivity and operational

efficiency. The DPD Gen 2, with its sharper and more densely spaced blades, can accelerate the bark stripping process, resulting in a shorter work cycle compared to the DPD Gen 1. Although the DPD Gen 1 can strip a larger volume of wood per cycle, the time required is longer compared to the DPD Gen 2. Conversely, the DPD Gen 2 peels a smaller amount of wood per cycle but with a faster processing time, resulting in a higher number of cycles and thus higher hourly productivity. Consequently, the DPD Gen 2 has proven to be more effective and efficient in supporting debarking activities on peatlands in terms of both time and productivity. This innovation has proven beneficial for timber harvesting on peatlands, ensuring that the quality and quantity of timber reaching the processing industry are guaranteed.

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