Works experience of chainsaw operators in peat swamp forest plantation in increasing timber productivity and efficiency

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Abstract. Felling is one of the logging activities that determines wood production. The appropriate and correct felling technique in plantation forests can increase the Efficiency of Timber Utilization (ETU). This research was conducted in one of the peat swamp forest plantation in Riau. The research objective is to determine the effect of work experience on the productivity and ETU in peat swamp forest plantations. The research method is by measuring the volume of wood harvested through local felling technique carried out by two chainsaw operators with different work experience. The results showed that: 1) The work experience of the chainsaw operator can effect felling productivity, production cost and ETU; 2) The average felling productivity produced by operator B is 10.151 m$^3$/hour higher than operator A which is 8.888 m$^3$/hour; 3) The average felling production cost for operator B is IDR 9,319.83/m$^3$ lower than operator A which is IDR 10,812.79/m$^3$; and 4) The lowest possible felling technique can increase ETU by 5% which is equivalent to an additional profit for the company of IDR 3,769,075,000/year.

1. Introduction

Timber harvesting in peat swamp plantation forest is a key point in a series of activities of forest utilization, and it should be well planned to avoid damage on dynamic stability of forest environment. However, timber harvesting in such area is still low in productivity and has relatively high cost, and create environmental damage [1]. Felling is an initial step in a series of timber harvesting activities, where one of the objectives is obtaining raw materials for wood industry. This harvesting activity should consider felling techniques, field topography, and equipments being used. Up to now felling still use conventional felling technique (felling technique $V_{6cm}$= felling technique which is commonly practiced by local loggers in accordance with company policy which utilizes log until diameter limit of 6 cm, with low ETU). On the other hand, if felling is practiced with technique resulting in stump with height as low as possible felling technique of $V_{5cm}$ which create stump with height as low as possible and utilized stem until diameter limit of 5 cm), this will create high level utilization of wood [2,3]. Logging in peat swamp forest should consider land condition and characteristics of the majority of trees growing there, such as diameter for instance, that in the case where stem diameter is small or less than 40 cm, and with most of the stem ranging from soft to nearly hard, and therefore this require appropriate chainsaw [4,5]. Logging is an activity which affects very greatly the wood utilization efficiency, and therefore skill of chainsaw operator is one of the factors which determine the success of improving the ETU. Hiesl [6] reported that the skill of an operator requires at least three years of work experience to achieve 100% of the productivity potential. It is explained also that trained operators have 40% higher productivity as...
compared with those who have not received training. Although skill and work experience is one of the factors which affect work productivity, the ability of operator to adapt with change in working environment and with different situation should be given attention. Several things which should be considered in logging activities on peat swamp plantation forest are as follows: 1) Peat thickness which is more than 1 meter, with soil surface and foothold which always moving and is unstable. This condition makes it difficult for the chainsaw operator to arrange his foothold on the peat soil. Movement in peat soil can make the feet of the operator bog down in the peat soil. This is very dangerous for the safety of the operator during felling. Great thickness of peat affects the alertness of chainsaw operator, so that long duration of tree felling is needed; 2) Condition of fast growing trees in peat swamp plantation forest is dominated by species Acacia crassicarpa, where the characteristics of this species is desirable for pulp industry and is able to adapt to peat land. Acacia crassicarpa trees are harvested at average diameter of 19 cm and average tree height being utilized of 22 m. These tree characteristics which have small diameter and are not so tall, produce only smaller volume of wood as compared with those of pulpwood in dry land; and 3) Temperature at the surface of peat land is hotter than that in dry land [7,8]. Tono and Wawan [9] research results show that air temperature in peat forest area ranges between 30.04°C-34.45°C and soil temperature ranges between 25.9°C-30.21°C. Hot temperature can have impact on productivity of machine operator. High temperature on soil surface and air in the area of Peat Swamp Plantation Forest (PSPF) have consequences on rapid emergence of fatigue on the chainsaw operator.

Based on such background, this study is intended to determine the effect of work experience on the productivity and ETU in peat swamp forest plantations.

2. Materials and Methods

2.1. Time and location
Research was conducted in the beginning of year 2020 in the working area of IUPHHK-HT (Commercial Timber Forest Products Utilization Permit of Plantation Forest) of PT Satria Perkasa Agung (PT SPA), District of Simpang Kanan, Logging Block of RKT (Annual Working Plan) 2020, Logging Compartment No. SKNB 035301. This area belongs to the territory of Inderagiri Hilir regency, Riau province. Based on geographic position, this forest complex is situated between 102°39’10”-102°58’50”E and 000°04’10”LS - 000°12’55”N.

2.2. Materials
Equipments being used were chainsaw Stihl MS 382, Personal Protective Equipment (PPE), tally sheet, stationery/writing, apparatus and machette. Materials being used were trees, lubricants, and oil fuel.

2.3. Methods
Determining (purposively), one logging compartment which will be immediately logged. Determining 2 personnel operators, one with working experience of less than 5 years, and the other with working experience of more than 5 years, as chainsaw operator. Each operator conducted logging with local technique (stem utilization until diameter of 6 cm in accordance with company policy = logging technique Ø6 cm) as many as 30 trees. Logging technique until diameter of 5 cm (logging technique Ø5 cm) which was conducted through measurement of difference of stem lengths between those of Ø6 cm and those of Ø5 cm as many as 30 trees each.

Measurement of parameters, comprising productivity, ETU and felling production cost i.e. productivity: recording of working time (duration) and wood volume; production cost: recording all expenditures such as those for fuel, oil/lubricants, wage, productivity, depreciation, maintenance/repair, interest rate, tax and salary cost; and ETU: diameter of butt (lower end), diameter of top (upper end), stem length, and stump height.
2.4. Data analysis
Productivity is calculated with the following formula:

\[ P = \frac{V}{T} \]  

(1)

where, \( P \): productivity (m³/hour), \( V \): volume = \( \frac{1}{4} \pi D^2 L \) (m³), \( W \): felling time/duration (hour), \( \pi \): 22/7, 
\( D \): average diameter (m), \( L \): stem length (m)

Efficiency of Timber Utilization (ETU):

\[ ETU = \frac{V_p}{V_m} \times 100\% \]  

(2)

where, \( ETU \): Efficiency of Timber Utilization (%), \( V_p \): Volume being utilized (m³), \( V_m \): volume ought to be able to be utilized (m³)

Logging production cost was calculated using formula from FAO [10]. For determining the appropriate felling technique which comprise the aspect of productivity, ETU, and aspect of cost, t-test was performed [11]. For learning the effect of chainsaw operator working experience on felling productivity increase and ETU, independent sample t test was performed using SPSS 25.0. Procedure for decision making was as follows:

- If the value of sig (2-tailed) > 0.05, then \( H_0 \) was accepted and \( H_1 \) was rejected, which implied that there was no difference in average productivity of felling and ETU between operator A and operator B.

- If the value of sig (2-tailed) < 0.05, then \( H_0 \) was rejected and \( H_1 \) was accepted, which implied that there is difference in average productivity of felling and ETU between operator A and operator B.

3. Results and Discussion

3.1 General condition of the company
Most of the study area possess field slope between 0-15% , with elevation between 3-16 m asl. Soil types are podsolic, alluvial, organosol hemic and organosol sapric. Climate type based on Schmidt & Ferguson classification belongs to type A with monthly rainfall of 109 mm/month. Highest monthly rainfall is 195 mm/month and the lowest 29 mm/month and there is no dry month. Forest stand in the study area is akasia (Acacia crassicarpa) trees from family of Leguminosae. The akasia stand has density of around 1667 trees/ha (for trees with diameter of 10 cm or more). Most of the trees did not have buttress. On the average, most undergrowth vegetation had moderate density. In the Annual Working Plan (RKPT) of year 2020, PT SPA of Simpang Kanan District harvests wood from area as large as 2354.9 ha with production target of 397,691 m³ and average annual wood production of (average production realization in the past 5 years) 753,815 m³, with maximum Annual Allowable Cutting (AAC) of 1,331,090 m³ comprising wood species Acacia crassicarpa (data source: production realization of PT SPA District of Simpang Kanan, RKT 2015-2019). In the timber harvesting, the main equipments are as follows: chainsaw and its accessories for felling; excavator for skidding; excavator for loading and unloading, and hauling; logging truck for hauling in land route; and iron boat (pompong) or iron canoe for hauling in water route.

3.2 Productivity of felling by two chainsaw operators
Chainsaw operators have roles in increasing felling productivity and lowering the production cost. Average felling productivity of the two chainsaw operators are presented in Table 1.
Table 1 Average productivity of logging $V_{6cm}$, N = 30

| Aspect | $V_{6cm}$(m³) | Logging time (hour) | Productivity (m³/hour) |
|--------|---------------|---------------------|------------------------|
| Operator A |               |                     |                        |
| Min-Max | 0.231-0.664   | 0.032-0.057         | 6.841-12.823           |
| Average | 0.400         | 0.045               | 8.888                  |
| SD     | 0.110         | 0.006               | 1.667                  |
| Operator B |               |                     |                        |
| Min-Max | 0.263-0.664   | 0.025-0.057         | 7.517-11.823           |
| Average | 0.423         | 0.042               | 10.151                 |
| SD     | 0.101         | 0.008               | 1.263                  |

Remarks: $V_{6cm}$ = Wood volume until diameter limit of 6 cm; SD = standard deviation; N = Number of replications; * = Diameter range 15-23 cm, with average 18.5 cm; ** = Diameter range 15-23 cm, with average 18.8 cm

Table 1 showed that average productivity of the two chainsaw operators was different from each other. Operator B showed average logging productivity which was higher than that of operator A, which was due to the fact that operator B possessed working experience as chainsaw operator as long as 9 years, as compared with that of operator A which was just 4.5 years. This difference in average productivity can be shown from average logging time of operator B which was faster than that of operator A, with average tree diameter at breast height of 18.8 cm greater than that in the location of operator A. Longer duration of working experience creates better working skill. These research results support the theory Robbins [12] which explains that “We can say a positive relationship between tenure and job productivity” which means that length of working experience (period) and skill is positively correlated. The longer the working period, the higher will be the experience and skill which will support their work, so that their productivity will increase. The results of this study are in agreement with empirical study from Adiati [13], Yudi and Wardana [14] which explained that working experience has positive and significant effect toward personnel productivity. Working experience as chainsaw operator is one of the factors which affect the average productivity of logging. This was in agreement with what was written by Muhdi [15 and Dulsalam et al. [16] which explains that skill of chainsaw operator affects average productivity of logging. Average productivity of logging by the two chainsaw operators is shown by results of t test, where $t_{calculated} = 3.308^{**} > t_{table} (99\%, 58) = 2.682$, so that it is suggested that chainsaw operator B was better than chainsaw operator A. Silayo [17] explained that the increasing of productivity average of felling could be achieved if the operators were provided with job training skill of logging. Fagbenle et al. [18] explained that one of the factors which affect employee’s productivity is originated from the employee him/herself, namely the human factors which comprise among others the working experience. Working experience as explained by Manulang [19], is the process of establishment of knowledge and skill on method of a job for employee through involvement in the execution of the job. Working experience is a factor which has the greatest effect on the growth of a venture. The large amount of experience possessed by the employees will result in large growth of the venture. The longer the period of career that a worker is performing his job, the higher will be his/her skill. High skill will have positive impact upon his performance, such as less duration of time needed to complete the job and better quality of the job result [20].

Effect of working experience of chainsaw operator on increase of felling productivity is presented in Table 2. From Table 2 it is known that the value of sig 2 tailed 0.002 < 0.05 so that $H_0$ is rejected, which implies that there was significant difference of average logging productivity between chainsaw operator A and chainsaw operator B. Therefore, it can be suggested that average productivity of logging exhibited by the two operators with different working experience, is different. The column of mean difference shows that difference of average productivity of felling between operator A and that of operator B was -1.263.033, and because the value is negative, it means that operator A possessed average felling productivity which was lower than operator B. The longer experience of chainsaw operator, will be...
achieve the higher felling productivity average. These results were not different from research results of Suhartana and Yuniaawati [21] in the area of industrial plantation forest (HTI) of PT SPA in 2013, which showed that logging activity in the study area used logging apparatus Chainsaw STIHL MS-381 which produced average volume of *Acacia crassicarpa* being felled as much as 0.595 m$^3$, with average duration of felling completion of 0.078 hour, so it was found that average felling productivity was 8 m$^3$/hour.

Table 2 Effect of working experience of chainsaw operator on the increase of felling productivity

| Levene's Test for equality of variances | T-test for equality of means | 95% Confidence Interval of the Difference |
|----------------------------------------|-----------------------------|----------------------------------------|
| F                                      | Sig.                        | t  | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Productivity                           | Equal variances assumed     | 2.932 | .092 | - | 58 | .002 | -381.884 | -498.610 |
|                                        | Equal variances not assumed | 3.30 | .002 | 7 | 33 | 1,263.0 | 2,027.45 | 6 |
|                                        |                             | 3.30 | .002 | 7 | 33 | 1,263.0 | 2,028.65 | 0 |

Several research results in relation with average felling productivity in plantation forest are as follows: 1) Research results by Câmpu and Ciubotaru [22] showed that average felling productivity in casuarina tree in Rumania using chainsaw husqvarna 365 was 10.138 m$^3$/hour (4.55 trees/hour) in the first stand and 11.344 m$^3$/hour (4.33 trees/hour) in the second stand; 2) Sitohang et al. [23] reported that the highest average productivity of felling was obtained by using chainsaw with trade mark Stihl, namely as large as 77.91 m$^3$/hour, whereas that which use chainsaw with trade mark New West was 70.39 m$^3$/hour. In the use of chainsaw with trademark Stihl and chainsaw with trade mark New West, capacity of the oil tank was 0.6 liters. It means that the chainsaw being used were of small sizes. From several samples being observed, it was known that the average time being used for felling of one tree was 12.15 seconds, it comprised the work of cutting one tree and walking to the next tree and felling down the tree. Therefore, one minute work was able to fell down 5 trees. One hour work would be able to fell 300 trees. If productive work per day was 8 hours, then the average productivity per day was 2,400 trees; 3) Study by Sukadaryati et al. [24] showed that tree felling in people/privately owned forest in Ciamis used chainsaw with average felling productivity for gmelina trees in Kertabumi village as large as 4.880 m$^3$/hour, whereas logging productivity of mixed trees in Bojonggedang village was on the average 3.392 m$^3$/hour.

3.3 Felling production cost

For learning the production cost of timber harvesting activities, there is a need for calculation of machine cost for each felling activity (Table 3). Machine cost divided by productivity in each activity will reveal production cost in each activity. Average production cost of felling is presented in Table 4. From the data of machine cost, the amount of felling production cost is known. From calculation of felling cost, the average cost of felling for each operator was IDR 10,812.79/m$^3$ (operator A) and IDR 9,319.83/m$^3$ (operator B). Such cost calculation showed that operator B exhibited felling production cost which was lower than that of operator A with difference of IDR 10,812.79/m$^3$-9,319.83/m$^3$ = IDR 1,492.96/m$^3$. If the production of the harvested timber is more than 100 m$^3$ in one year, then the difference is very large. Average cost of felling production for operator B was lower than that of operator A, and this was due to average productivity of felling by operator B which was higher than that of operator A.
Table 3. Components of felling cost

| Cost components          | Amount (IDR/hour) |
|--------------------------|-------------------|
| Depreciation cost        | 7,200             |
| Insurance cost           | 144               |
| Interest cost            | 720               |
| Tax cost                 | 96                |
| Fuel cost                | 5,724             |
| Oil / lubricant cost     | 572.4             |
| Maintenance / repair cost| 7,200             |
| Wage cost                | 71,428.6          |
| Total cost of machine    | 93,085            |

Productivity of timber harvesting can affect production cost; the higher the productivity, the lower will be the production cost. Study by Stover [25], Suhartana and Yuniawati [26], explained that cost per unit volume of a course follow the level of productivity. Meanwhile, study by Germain et al. [27] explained that operator experience affects production cost. To prove the difference of logging production cost of the two operators, t test was performed. Result of t-test showed that $t_{\text{calculated}} = 3.593 > t_{\text{table}} (99\%, 58) = 2.682$. This implies that from the aspect of production cost, operator B exhibited better performance than that of operator A, so that the average logging production cost of operator B was lower than that of operator A.

Table 4. Average felling production cost $V_{6\text{cm}}$, N = 30

| Aspect          | Productivity (m$^3$/hour) | Felling production cost (IDR/m$^3$) |
|-----------------|----------------------------|------------------------------------|
| Operator A      |                            |                                    |
| Min-Max         | 6.841-12.823               | 7,259.236-13,606.548               |
| Average         | 8.888                      | 10,812.79                          |
| SD              | 1.667                      | 1,898.154                          |
| Operator B      |                            |                                    |
| Min-Max         | 7.517-11.823               | 7,872.965-12,383.001               |
| Average         | 10.151                     | 9,319.83                           |
| SD              | 1.263                      | 1,255.923                          |

Average felling production cost in this research was higher than that of study results from [22], for logging of A. mangium wood with chainsaw Stihl type, namely IDR 5,235/m$^3$ (RIL) and IDR 6,171/m$^3$ (local technique). The low felling cost was due to the phenomenon that all components of felling cost, particularly the costs for purchasing the consumable materials (oil fuel, oil lubricant and service) were cheaper than the purchase during this research in the year 2020.

3.4. Efficiency of timber utilization (ETU)

Average ETU is presented in Table 5 which shows that operator B exhibited average ETU $V_{5\text{cm}}$, volume of wood being utilized ($V_{5\text{cm}}$), volume difference ($V_{5-6\text{cm}}$) and stem length difference ($V_{5-6\text{cm}}$) which were higher than those of operator A. The larger wood volume being produced or collected, the greater will be the efficiency value of wood utilization. Also, the average height of stump exhibited by operator B was shorter than that of operator A. Average stump height being exhibited will also affect the average volume of wood being utilized. The lower the stump height, the higher will be the average volume of wood being utilized. Therefore, operator B in the application of logging technique $V_{5\text{cm}}$ produced average ETU, which was better than that of operator A.
From calculation results it was known that with felling technique of V_5cm, this could increase ETU by 0.99-0.94 = 5%. Based on field data and quotation from company office, it was known that average log production per year is 753,815 m³, so that on the basis of increase of wood utilization by 5%, the company would get additional advantage in the form of production increase per year by 5% x 753,815 m³ = 37,690.75 m³ per year. Wood price was IDR 500,000/m³, and the apropriate profit for the company was 20% or IDR 100,000/m³, so that the company will get additional profit of 37,690.75 m³ x IDR 100,000/m³ = IDR 3,769,075,000/year. Considering the profit which will be obtained, then there is opportunity for the company to adopt the felling technique of V_5cm. Effect of working experience of chainsaw operator on the increase of ETU is presented in Table 6.

Table 6 Effect of working experience of chainsaw operator on the increase of ETU

| Levene's Test for equality of variances | T-test for equality of means | 95% Confidence Interval of the Difference |
|----------------------------------------|-----------------------------|-----------------------------------------|
|                                        | Mean Difference             | Std. Error Difference                   | Lower          | Upper       |
| Efficiency, equal variances assumed    | -4.646                      | .000                                    | -.00633        | .00136      | -.00906     | -.00360     |
|                                        | 36.444                      | .000                                    | -.00633        | .00136      | -.00910     | -.00357     |
| Efficiency, not assumed                | -4.646                      | .000                                    | -.00633        | .00136      | -.00906     | -.00360     |

Table 6 shows that the value of sig 2 tailed 0.000 < 0.05, so that H₀ is rejected, which implies that there was significant difference in ETU between chainsaw operator A and chainsaw operator B. Therefore, it can be suggested that average ETU exhibited by the two operators with different working experience, was different. Column of mean difference shows that average ETU between operator A and operator B was -0.000633, and because the value is negative, it is said that operator A produced average ETU which was lower than operator B. The longer the experience of chainsaw operator, the higher will be the average ETU being exhibited. These research results showed average ETU which was higher than those of 1). Study by Suhartana et al. [28] in the felling of *Acacia mangium* in East Kalimantan with ETU by felling technique of V_5cm as large as 98.7% and V_6cm as large as 96.0%, so that the company will get additional profit as large as IDR 345,866,400/ year. Such difference was due to the phenomenon that in the East Kalimantan company, average volume of wood stem being utilized was lower, namely that for felling technique V_5cm was as large as 0.298 m³ and that for V_6cm was as large as 0.348 m³. Average volume of wood stem being produced affected the average ETU; and 2) Study by Suhartana and Yuniawati [2] which showed that felling of mixed forest wood in West Kalimantan exhibited average ETU with felling technique V_5cm as large as 99.3% and that of V_6cm as large as 93.3% with
average volume of each felling technique were 0.817 m³ and 1.004 m³, with difference of 0.055 m³. The company will get additional profit of IDR 74,400,000/year.

4. Conclusion
This study concluded that chainsaw operator with working experience of more than 5 years (B) exhibited productivity (10.151 m³/hour as compared with 8.888 m³/hour) and ETU (99% as compared with 94%) which were higher; and production cost (IDR 9,319.83/m³ as compared with IDR 10,812.79/m³) which was lower than those of operator with working experience of less than 5 years (A).

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Authors’ Contribution
S. Suhartana (main contributor) designed the study, developed the methodology, performed the experiment, analyzed the data and wrote the manuscript. Yuniawati (co-author) analyzed the data and wrote the manuscript.