Magna Scientia Advanced Research and Reviews

eISSN: 2582-9394

Cross Ref DOI: 10.30574/msarr

Journal homepage: https://magnascientiapub.com/journals/msarr/

(RESEARCH ARTICLE)

Check for updates

Felling and bucking of rosewood (*Darbergia latifolia*) related to harvesting productivity in Indonesia

Juang Rata Matangaran [1,*] and Mays Neneng Saputri [2]

[1] *Faculty of Forestry and Environment, IPB University, Bogor, Indonesia.*
[2] *Alumnus of Faculty of Forestry and Environment IPB University, Bogor, Indonesia.*

Magna Scientia Advanced Research and Reviews, 2023, 08(01), 141–151

Publication history: Received on 04 May 2023; revised on 14 June 2023; accepted on 16 June 2023

Article DOI: https://doi.org/10.30574/msarr.2023.8.1.0085

Abstract

Forest in Java generally is managed by a state-owned company named Perhutani. The most species planted by Perhutani is teak, but in one district in Central Java, Indonesia was planted by rosewood (*Dalbergia latifolia*) or sonokeling (the vernacular name). We researched harvesting rosewood's productivity in the Pati District of Central Java, Indonesia. The research objectives were to determine the felling and bucking of harvesting productivity and identify the working element of felling and bucking. Also, it analyzed the relationship between the diameter of tree felled related to working time, and the relationship between the amount of lumber in bucking in each log related to bucking time. The result showed that the harvesting productivity of rosewood on average was 2.90 m3/hour. This harvesting productivity was higher than in other locations in Java. In other locations in Java, harvesting productivity was 2.1 m3/hour. We found that an increase in tree diameter felled will increase the felling time, and the amount of lumber in bucking each tree will crease the bucking time. There were six working elements of effective work for felling and five effective working elements for bucking activities. Ineffective time of working element more than 20 % they occurred in bucking activity. The personal delay of the chainsaw operator caused it. This ineffective time can be reduced in order to increase productivity.

Keywords: Bucking; Felling; Perhutani; Rosewood; Sonokeling

1. Introduction

Plantation forests in Java have been managed by State Owned Company named Perhutani. There is an area of 2.4 million hectares of production forest of teak plantation forests and other tree species on the island of Java spread over the provinces of West Java, Banten Province, Central Java Province and East Java, and Madura Island [1]. This production forest plays a vital role because it is located in a densely populated area, and the population pressure is very high. Therefore, the Indonesian government manages these forests as sustainably as possible. Perhutani manages production forests on the island of Java. Perhutani is managing forest resources in Java and Madura Island. According to Perhutani 2022 data, every year, Perhutani harvests more than 650 thousand m^3 of wood. The lumber mainly comes from teak, pine, mahogany, rosewood, damar, acacia, jabon, sengon, gmelina, and rasamala [1].

Forest harvesting in Java is generally done manually and is important in employing local people. Besides teak, there is rosewood species (*Dalbergia latifolia*) or the vernacular sonokeling, planted and harvested by the Perhutani company. The Pati district in Central Java is one location that produces rosewood or sonokeling. Rosewood (*Dalbergia latifolia*) can reach a height of 20–40 meters with a trunk diameter of about 60 cm. Rosewood is originally from the sub-Himalayan region of India and was introduced to Indonesia around 1870, and it was first planted in the Keling area, so this type of wood is called rosewood [2]. It has a dark brown striped color and a beautiful pattern. The fiber is almost

* Corresponding author: Juang Rata Matangaran

smooth, the direction of the fiber is straight to wavy, and the surface is smooth and slightly shiny. This wood can be used for high-class household furniture, beautiful veneer, wooden floors, door and window frames, musical instruments, carved items, and wood sculptures [3]. However, rosewood is now a vulnerable species [4,5] (IUCN 2022; Lakhey *et al*. 2020). This condition makes the selling price of rosewood high even higher than the selling price of teak [1]. Therefore, it is necessary to increase the productivity of rosewood wood, considering its very high selling price.

One of the ways to increase productivity is by optimizing the harvesting process. Some factors affect the harvesting productivity, such as tree diameter, the distance among the trees, operator skill, and the chainsaw used in felling. The skills of the chainsaw operator greatly determine the productivity of logging and reduce forest damage due to logging and forest clearing. The amount of forest openness is related to the movement of bulldozers in skidding, which is related to the destruction of forest soil, vegetation, and logging waste [6,7,8].

The objectives of this study were to find out the productivity of harvesting rosewood in felling and bucking and to analyze the relationship between the tree's diameter and felling time. Also, the relation between the amount of lumber in each bucking log is related to the bucking time. Also, we identify the working elements of felling and bucking activities in harvesting rosewood.

2. Material and methods

2.1. Study location and working element and time study

The research was conducted in the work area of Perhutani on the harvesting activities of rosewood. The research location is in Pati district (**Figure 1**). The number of sample trees is calculated for the adequacy of field data based on the average working time of each work element and its standard deviation. From the preliminary research, it was determined that the number of sample trees was 42 trees. We cut down 42 trees as replications ranging from 45–61 cm of the Breast Height Diameter (DBH). Measurements were carried out on as many as 6 to 7 trees for each measurement day. Each step is carried out in one measurement day. A chainsaw operator carried out the felling and bucking using a chainsaw Stihl 070. A Chainsaw operator works assisted by one helper. The operator was trained in logging safety.

We identify the working element of felling and bucking. Using a stopwatch time study, we measured the time of each working element. The type of working element is divided into effective work and ineffective work. Effective felling work starts with the operator walking toward the trees, falling the tree, and cutting the top of the branch. Ineffective work was the delay in working of the operator. Effective work of bucking started when the operator cut the branch and trimmed the log, and the ineffective work was delayed in working. We needed to identify and calculate the percentage of ineffective time to reduce the delay time and increase productivity.

The effective and ineffective times were measured in felling and bucking, and the calculation of percentage in each effective and ineffective time of felling and bucking formula:

Percentage of effective time in felling or bucking: = (Effective time in felling or bucking/ total time) x 100 %

Percentage of ineffective time in felling or bucking: = (Ineffective time in felling or bucking/total time) x 100 %

Effective and ineffective work were identified in Table 1, and the percentage of effective and ineffective time was in Table 3.

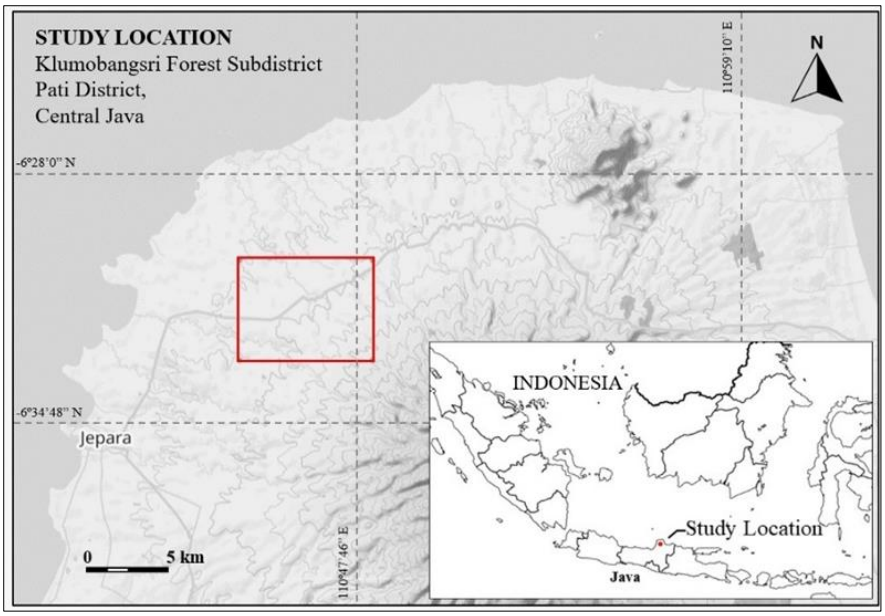

Figure 1 Study location in Pati district of Central Java, Indonesia

2.2. Felling and bucking productivity

The volume of the logs or lumbers was calculated by Indonesian Standard formula [9], and the productivity of felling and bucking was calculated by the volume divided by the working time in each cycle of the working element.

The log volume calculation formula:

$$V = ((LBp + LBu)/2 \times p$$

$$LBp = (\pi Dp^2)/4$$

$$LBu = (\pi Dp^2)/4$$

Description:

V = Volume of log (m^3)
LBp = Large end area of the log (m^2)
LBu = Small end area of the log (m^2)
p = Length (m)
Dp = Average large end diameter (cm)
Du = Average small end diameter (cm)

The felling and bucking productivity were calculated with the formula:

$$Pt = Vt/Wt$$

Description:

Pt = felling or bucking productivity (m^3/hour)
Vt = Volume (m^3)
Wt = Felling or bucking time (hour)

We used linear regression analysis to determine the relationship between the diameter of the trees and the total working time of felling and the relation between the amount of lumber in each bucking log related to the bucking time.

3. Results

3.1. Working element, effective and ineffective working time, delay time

During felling and bucking, it measured the time of working, the diameter of the tree and the lumber, and the working elements were identified. The working cycle is a sequence of elements required to perform a job or produce a production unit. The actual time is obtained from the working cycle, the sum of the effective and ineffective working time. Effective working time is used to perform the working cycle without delay. Ineffective working time is a time delay (delay). Delay is divided into 3, namely personal delay (talking, smoking, and resting), mechanical delay (filing chains and repairing machines), and operational delay (refueling and changing operators). It is identifying the working elements in felling the trees (Table 1) and bucking activities (Table 2). The average percentage of effective and ineffective time for felling and bucking is in Table 3.

Table 1 Identification of working element of felling the tree

No	Working element (cycles) of felling	Start to work	End of work
Effective work			
1	The operator walks toward the tree	The operator walking leaving the previous tree	The operator reaches the tree to be felled
2	Clearing the area around the tree	End of the previous element	The undergrowth around the tree is clear
3	Start the chainsaw	End of the previous element	The chainsaw on/start
4	To find out the tree felling direction	End of the previous element	Felling direction determine
5	Felling, make undercut and back cut	End of the previous element	The tree felled
6	Trimming the top branches/crown	End of the previous element	The log clear from the branches
Ineffective work			
1	Personal delay (talking, smoking, resting)	End of the previous element	The end of the activity of talking, smoking, resting
2	Mechanical delay (sharpening the chain cutter and machine repair)	End of the previous element	At the end of the sharpening and repairing
3	Operational delay (opening the tank and filling in the gasoline and lubricant to the tank of the chainsaw	End of the previous element	The tank of gasoline and lubricant is full and close the tank correctly.

Table 2 Identification of working element of bucking the log

No	Working element(cycles) of Bucking	Start to work	End of work
Effective work			
1	The operator cut the branch and trimmed the top end and bottom end of the log.	The operator walking the log	The log is clear to be cut in sort size of length.
2	Trim the log from the end bottom	End of the previous element	Bucking is ending
3	Measure the lumber	End of the previous element	The diameter and length of the lumber were measured.
4	Marking the lumber with paint and a sledgehammer	End of the previous element	The lumber was marked

5	To record data in the administration book	End of the previous element	Data recorded in the book
Ineffective work			
1	Personal delay (talking, smoking, resting)	End of the previous element	The end of the activity of talking, smoking, resting
2	Mechanical delay (sharpening the chain cutter and machine repair)	End of the previous element	At the end of the sharpening and repairing
3	Operational delay (fill in the gasoline and lubricant to the tank of the chainsaw	End of the previous element	The tank of gasoline and lubricant is full.

Table 3 The average percentage of working time for felling and bucking

Working time	**Activities for Felling**		**Activities for Bucking**	
	second (s)	**percentage (%)**	**second (s)**	**percentage (%)**
Effective time	193.29	96.12	1463.75	77,41
Ineffective time	7.82	3.88	427.21	22,59
Actual time (total)	201.11	100	1890.96	100

3.2. Felling and bucking productivity and linear regression

In this research, the productivity of harvesting rosewood was determined only by felling and bucking activities. The felling and bucking were measured in six days, and we every day measured six to seven trees felling and bucking. The result showed that the average productivity of total felling and bucking was 2.90 ± 0.82 m^3/ hour (Table 4). Table 5 shows that productivity in other districts is lower than the study results in the Pati district Klumobangsri subdistrict. This study in the Pati district reached the lowest productivity of 1.23 m^3/hour to the highest of 3.78 m^3/hour or an average of 2.90 ± 0.82 m^3/hour. Another study showed that productivity was 2,10 ± 0,59 m^3/hour (Table 5).

Table 4 The Average productivity of felling and bucking (m^3/hour)

No	**Volume (m^3)**	**Working time (second)**		**Productivity (m^3/hour)**
		Felling	**Bucking**	
Day 1	a	b	c	(a/((b+c)/3600))
1	1.22	169	1,337	2.92
2	1.23	128	1,774	2.33
3	1.30	195	1,960	2.17
4	1.57	324	1,352	3.37
5	1.85	223	1,472	3.73
6	2.16	194	1,864	3.78
7	2.42	179	2,290	3.53
Average & Stdv 3.15±0.69				
Day 2				
8	0.84	120	1,009	2.68
9	1.59	169	1,481	3.47
10	1.68	124	1,608	3.49
11	1.07	227	1,079	2.95
12	0.73	244	504	3.51

13	1.67	204	2,146	2.56
14	2.15	158	1,980	3.62
Average & Stdv 3.18±0.44				
Day 3				
15	0.46	114	1,136	1.32
16	3.47	319	2,898	3.88
17	1.38	184	1,580	2.82
18	1.97	235	2,342	2.75
19	2.60	276	2,429	3.46
20	1.56	284	2,907	1.76
21	2.99	279	2,901	3.38
Average & Stdv 2.77±0.93				
Day 4				
22	0.50	57	1,152	1.49
23	2.93	229	2,748	3.54
24	1.77	187	2,187	2.68
25	0.97	170	1,084	2.78
26	1.07	231	1,569	2.14
27	1.78	214	1,479	3.78
28	1.58	168	1,603	3.21
29	2.06	187	2,557	2.70
Average &Stdv 2.79±0.74				
Day 5				
30	3.19	264	2,023	5.02
31	1.82	172	1,705	3.49
32	1.80	244	1,291	3.22
33	2.13	207	2,600	2.73
34	0.57	97	1,565	1.23
35	1.65	348	1,423	3.35
36	1.65	180	1,678	3.20
Average &Stdv 3.32±1.19				
Day 6				
37	2.32	187	2,654	2.94
38	2.12	157	2,899	2.50
39	2.13	333	3,266	2.13
40	2.64	181	2,406	3.67
41	0.44	67	1,034	1.44
42	2.03	218	2,081	3.18
Average & Stdv 2.64±0.80				
Total: Average & Stdv 2.90±0.82				

Table 5 Some research about felling and bucking productivity in Java

Activities	Researchers	Location	Productivity (m3/hour)
Felling & bucking	Retno (2001)	Purwakarta (West Java)	1.55
(Teak harvesting)	Sulistianto (2016)	Ciamis (West Java)	1.99
	Setiani (2016)	Randublatung (Central Java)	1.55
	Barokah (2016)	Saradan (East Java)	2.62
	Alsyakirin (2018)	Banjar (West Java)	2.82
Average			2,10 ± 0,59
Felling &bucking* (Rosewood harvesting)	this research	Pati (Central Java)	2.90 ± 0.82

*Location: Pati district, central Java, wood species rosewood.

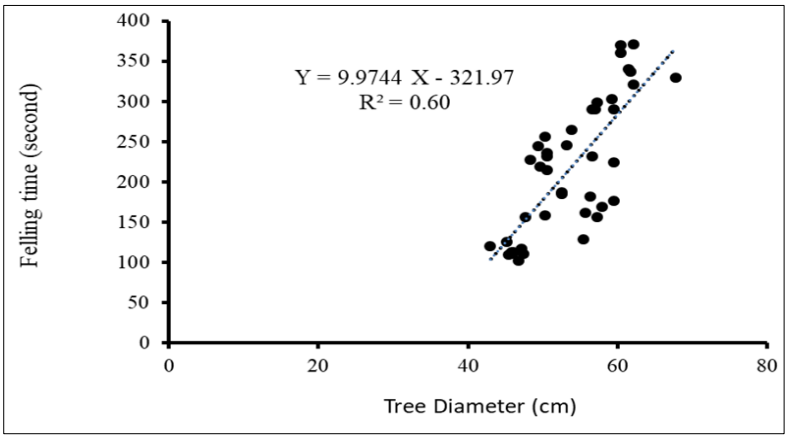

Figure 2 Relationship between tree diameter and felling time

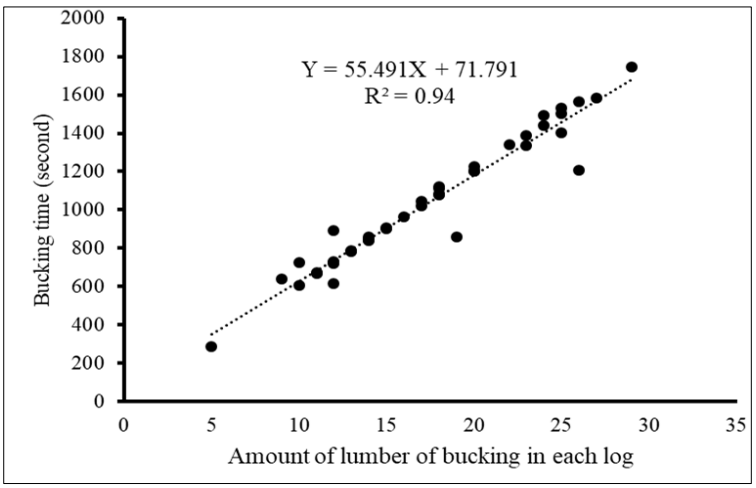

Figure 3 The relationship between the amount of lumber bucking in each log and bucking time

This research showed a relationship between tree diameter and felling time. It is presented by equation Y = 9.9744X – 321.97 (R2= 0.60) Figure 2. The relationship between the amount of lumber of bucking in each log showed in Figure 3. It is presented by equation Y = 55.491X + 71,791 (R2= 0.94) (Figure 3).

4. Discussion

Logging is carried out by felling the rosewood. After falling, the fallen tree will be bucked to become a sort of lumber. After bucking, the lumber will be skidded to the collecting site. The measurement of effective working time and ineffective working time was directly calculated in the field. The chainsaw operator uses effective working time to carry out the main activities in the felling and bucking of each work element. Meanwhile, ineffective working time is the time used by chainsaw operators outside of main activities such as resting, talking, and smoking. The measurement of working time aims to determine the use of time on each work element so that it can be seen that excessive working time can be reduced or the use of a small amount of time can be added [10]. We found six working elements of effective work for felling and three ineffective working elements for felling delay time. Five working elements were effective for bucking, and three ineffective for bucking delay time (Table 1, Table 2). The average percentage of effective time for felling each tree is 96,12%, and the ineffective time is only 3.88% (Table 3). The average percentage of bucking logs to become lumber is 77,41%, and 22,59% of the ineffective time (Table 3). Ineffective time it occurred in bucking caused by personal delay of chainsaw operator.

The average productivity of total felling and bucking was 2.90 ± 0.82 m^3/ hour. The highest average productivity was 3.78 m^3/hour, and the lowest was 1,23 m^3/hour (Table 4).

A comparison with others research in Java can be seen in Table 5. Table 5 shows that productivity in other districts is lower than the study results in the Pati district Klumobangsri subdistrict. Research in Purwakarta West Java [11] and in Randublatung Central Java [12] showed productivity of 1.55 m^3/hour. Other research in Ciamis West Java [13] showed productivity of 1.99 m^3/hour and in Saradan East java was 2.62 m^3/hour [14]. The productivity of several studies is discribe in Table 5. The highest productivity in Banjar West Java was 2.82 m^3/hour [15]. All felling and bucking productivity is still lower than in this study. This study in the Pati district reached the lowest productivity of 1.23 m^3/hour to the highest of 3.78 m^3/hour or an average of 2.90 ± 0.82 m^3/hour. Another study showed that productivity was 2,10 ± 0,59 m^3/hour (Table 5).

The research site's highly skilled chainsaw operators have attended the training. The chainsaw operator followed during this research is one of the chainsaw operators with a Sustainable Forest Management certificate with the fastest processing and 29 years of experience in chainsaw operators. Low productivity is due to damage to chainsaws that originates from a lack of understanding of chainsaw operators regarding tool care and maintenance, as well as using local product spare parts, and the damage rate is high [16]. Harvesting productivity is influenced by several factors, such as log diameter, working time, skid distance, work skills, and field conditions [17]. Harvesting costs are closely related to harvesting productivity; the greater the costs incurred, the greater the productivity.

The relationship between tree diameter and felling time is presented in **Figure 2**. It shows that an increase in tree diameter felled will increase the felling time. The diameter of the tree effect about ± 60% of the increase in felling time. The relationship between the amount of lumber of bucking in each log showed in **Figure 3**. The more lumber in each log, the more bucking time is needed. An increase in lumber bucking in each log will increase the bucking time. The amount of bucking lumber in each log affects about ± 94% of the increase in bucking time. Efforts to increase productivity are in line with increasing wages. However, it should be noted that the rest time for workers and physical and mental health related to working time improves work productivity [18]. Several studies on logging productivity show that felling productivity is influenced by tree diameter and distance between trees [19,20,21,22,23]. A Research shows the performance of several types of chainsaws on felling efficiency [24], while other research showed that the larger the diameter of the trees that are cut, the lower the cost of Felling [25].

Occupational accidents due to logging affect the productivity of felling. In an accident, the operator stops working and does not get the harvested production. Several studies have shown occupational accidents in logging operations. In Japan, accidents due to logging operations generally account for 57% of fatal accidents when felling using chainsaws [26]. The importance of getting information about safety through training needs to be carried out [27] as well as the need for regulations on safety for chainsaw operators [28,29]. Research showed that it need to consider the risk of work accidents in felling hung-up trees [30].

Operators play a crucial role in determining the direction of tree fall; felling techniques and the right direction of fall determine the volume of logs that can be utilized. Cracking and breaking logs due to felling reduces felling productivity. In addition, the correct direction of felling can reduce damage caused by felling trees [31]. The importance of paying attention to felling direction and felling intensity affects the amount of damage to remaining stands [32], in addition to the disturbance of soil and water quality degradation and vegetation damage due to logging operations in tropical forests [33,34]

5. Conclusion

The harvesting productivity of rosewood in the Pati District of Central Java, on average, was 2.90 m^3/hour. In other locations in Java, harvesting productivity was 2.1 m^3/hour. This productivity is higher than in other harvesting locations on Java Island, Indonesia. The chainsaw operator was skillful and was the main factor in this felling and bucking activities.

The is a relationship between tree diameter felled and felling time. An increase in tree diameter felled will increase the felling time. Also, the amount of lumber bucking in each log affects the bucking time, the bucking time increase in conjunction with the increase of lumber in each log.

There were six working elements of effective work for felling and five effective working elements for bucking activities. Also, we found three working elements of ineffective work. More than 20 % of ineffective time occurred in bucking caused by the personal delay of the chainsaw operator. The delay time, especially personal delay, as ineffective time should be reduced to increase harvesting productivity.

Compliance with ethical standards

Acknowledgments

The authors gratefully acknowledged to staff and field workers of Perhutani company in the Pati District Central Java, Indonesia.

Disclosure of conflict of interest

All the authors declare that there are no conflicts of interests.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Perhutani (2022). Company Profile https://www.perhutani.co.id/ ;accessed on April 7th 2023.

[2] Sunandar R. Effect of temperature induction and concentration of rootone-f by immersion method on the formation of roots and shoots of rosewood root cuttings. [thesis]. Bogor: Institut Pertanian Bogor; 2006. [in Indonesian].

[3] Mandang YI, Pandit IKN. Guidelines for Identification of Wood Species in the Field. Bogor: Prosea Indonesia; 2002 [in Indonesian].

[4] IUCN (International Union for Conservation of Nature). Red List of Threatened Species; 2022.

[5] Lakhey P, Pathak J, Adhikari B. Dalbergia latifolia. The IUCN Red List of Threatened Species, e. T32098A 67777757; 2020. https://dx.doi.org/10.2305/IUCN.UK.2020-3.R

[6] Matangaran JR. Soil Compaction by Valmet Forwarder Operation at Soil Surface with and without Slash. Jurnal Manajemen Hutan Tropika. 2012; XVIII: 52–59. DOI: 10.7226/jtfm.18.1.52

[7] Matangaran JR, Rishadi H. Quantification of Logging Residue and Biomass Generated by an Industrial Plantation Forest in Indonesia. International Journal of Ecology and Development. 2014; 27:77–88.

[8] Danquah JA, Appiah M, Pappinen A. Effect of African Mahogany Species on Soil Chemical Properties in DegradedDry Semi-deciduous Forest Ecosystem in Ghana. International Journal of Agriculture and Biology. 2012; 14:321–328.

[9] SNI (Standar Nasional Indonesia). Measurement and determination of the volume of round wood, SNI 8911:2020 Jakarta: Badan Standarisasi Nasional; 2020 [in Indonesian].

[10] Mujetahid A. Logging productivity in smallholder teak (Tectona grandis) forests in Bone District. Jurnal Penelitian Hasil Hutan. 2008; 5(1): 53–58 [in Indonesian].

[11] Retno I. Evaluation of elements and work performance of harvesting in teak forest (case study of teak wood harvesting at BKPH Sadang KPH Purwakarta Perum Perhutani Unit III West Java). [thesis]. Bogor: Institut Pertanian Bogor; 2001 [in Indonesian].

[12] Setiani NH. Productivity and cost of harvesting teak at KPH Randublatung. [thesis]. Bogor: Institut Pertanian Bogor; 2016 [in Indonesian].

[13] Sulistianto A. Productivity, cost of logging, and distribution of teak logs in KPH Ciamis. [thesis]. Bogor: Institut Pertanian Bogor; 2016 [in Indonesian].

[14] Barokah SM. Harvesting efficiency and productivity of teak plantations in KPH Saradan. [thesis]. Bogor: Institut Pertanian Bogor; 2016 [Indonesian].

[15] Alsyakirin FA. Productivity of logging using chainsaws and skidding of teak using hardtops at KPH Ciamis. [thesis]. Bogor: Institut Pertanian Bogor; 2018 [in Indonesian].

[16] Matangaran JR, Priyonggo PB. Chainsaw part damage of harvesting teak forest in Madiun East Java. GSC Advance Research Reviews 2022; 11:27–31. https://doi.org/10.30574/gscarr.2022.11.3.0147

[17] Suhartana S, Yuniawati, Dulsalam. Cost and productivity of skidding and construction/ maintenance of canals in the Rawa Gambut HTI in Riau and Jambi (in Indonesian). Jurnal Penelitian Hasil Hutan. 2013; 31:36–48

[18] ILO (International Labour Office). Guide to developing balanced working time arrangements. Geneva ILO; 2019.

[19] Campu VR, Ciubotaru A. Time consumption and productivity in manual tree felling with a chainsaw – a case study of resinous stands from mountainous areas. Silva Fennica. 2017; 51:1657. 19 p. https://doi.org/10.14214/sf.1657

[20] Abbasi E, Lotfalian M, Hosseini SAO. Productivity and cost of tree felling crew with a chainsaw in Caspian forests. Journal Biodiversity and Environmental Science. 2013; 3:90–97.

[21] Behjou FK, Majnounian B, Dvořák J, Namiranian M, Saeed A, Feghhi J. Productivity and cost of manual felling with a chainsaw in Caspian forests. Journal of Forest Science. 2009; 55: 96–100. https://doi.org/10.17221/69/2008-JFS

[22] Marceta D, Kosir B. Comparison of Two Felling & Processing Methods in Beech Forests. Croatian Journal of Forest Engineering. 2016; 37:163–174.

[23] Galezia T. Analysis of the duration of basic logging operations performed using a chainsaw. Leśne Prace Badawcze (Forest Research Papers). 2014; 75:25–30. http://doi: 10.2478/frp-2014-0003

[24] Erber E, Stelzer S, Stampfer K. Evaluation of a novel mobile device app for value-maximized Bucking by chainsaw. International Journal of Forest Engineering. 2021; 32: 63–73. https://doi.org/10.1080/14942119.2021.1927362

[25] Kaakkurivaara N, Kaakkurivaara T (2018). Productivity and cost analysis of three timber extraction methods on steep terrain in Thailand. Journal of Forest Engineering. 2018; 39: 213–221.

[26] Nagao M, Yamada Y. Physical effects of hinges shape on chainsaw felling direction in Japanese Cypress. International Journal of Forest Engineering. 2019; 30:182–189. https://doi.org/10.1080/14942119.2019.1613611

[27] Gendek A, Aniszewska M, Nurek T, Moskalik T. Training and Equipping Chainsaw Operators and Occupational Safety in Polish Forest. Environmental Science Proceeding 2021; 3: 55–57. https://doi.org/10.3390/IECF2020-08057

[28] Ferreira MCP, Caparrós FS, Castrillo JAC, García AIM, Romero JCR. Assessment of Chainsaw Operators Training in Andalusia (Spain). Croatia Journal of Forest Engineering 2022; 43:123–135. https://doi.org/10.5552/crojfe.2022.1204

[29] Hoffman S, Jaeger D. Insights on motor-manual tree felling in Germany, recent developments to ensure efficient operations in singletree selection harvest. European Journal of Forest Engineering. 2021; 7: 39–44 https://doi.org/10.33904/ejfe.953226

[30] Campu RV, Bratu MA, Ciocirlan M. The Felling of Hung-Up Trees. A Work Safety and Productivity Issue. Forests 2020; 11: 1225: 1–19. https://doi.org/10.3390/f11111225

[31] Gulci N, Akay AE, Erdaş O. Investigation of timber harvesting operations using chainsaw considering productivity and residual stand damage: The Case of Bahçe Forest Enterprise Chief. Journal of Faculty of Forestry Istanbul University. 2016; 66:357−368 http://dx.doi.org/10.17099/jffiu.11250

[32] Matangaran JR, Putra EI, Diatin I, Mujahid M, Adlan Q. Residual stand damage from selective logging of tropical forests: A comparative case study in central Kalimantan and West Sumatra, Indonesia. Global Ecology and Conservation. 2019: 19 e00688. https://doi.org/10.1016/j.gecco.2019.e00688 2351-9894

[33] Diatin I, Mujahid M, Teduh A, Matangaran JR (2018). Ornamental Carp Fish Cultured in Settling Pond after Revegetation of Ex-Silica Mining Area. Pertanika Journal of Tropical Agricultural Science. 2018; 41:1071−1084.

[34] Matangaran JR, Putra EI, Mashitha MW, Diatin I, Mujahid M, Adlan Q. Soil Disturbance by Logging Operation of Industrial Plantation Forest in Indonesia. IOP Conf. Series: Earth and Environmental Science 2019; 394: 012064. http://doi.org/10.1088/1755-1315/394/1/012064