International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Cost Analysis of Felling with Chainsaw and Skidding with Farm Tractor in KPH Saradan

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Abstract

The objective of this research was to analyze the productivity and cost of chainsaw felling and skidding with farm tractors in teak plantations of forest management unit (KPH) Saradan, Perum Perhutani. The calculations of cost and efficiency analysis were performed to evaluate the felling and skidding activities in order to do better in terms of technical and organizational systems. The number of felling work cycles recorded in this study was 58 cycles, while skidding ranges as many as 66 work cycles. The results of this study highlight that the average costs of felling with and without delays are IDR 14,515.709 m^{-3} and IDR 13,489.431 m^{-3}. Meanwhile, the respective skidding costs with and without delays are IDR 50,687.582 m^{-3} and IDR 48,499.744 m^{-3}. Based on the results of the linear regression, the variable that affects felling time is the diameter, whereas the variable that affects skidding is the skidding distance.

Keywords: chainsaw; log; harvesting; clear cutting; time study.

1. Introduction

Kesatuan Pemangkuan Hutan (KPH) Saradan teak plantations forest located in East Java, felling is performed by using chainsaws, while skidding is performed by using farm tractors.

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These teak plantations are state-owned forests managed by Indonesia State-Owned Enterprises, Perum Perhutani (State Forestry Public Company). KPH Saradan is a part of forest management areas in Perum Perhutani working unit. The size of Perum Perhutani teak company grade is 1,238,371 ha or approximately 50.65% of the total forest production area [1]. The size of teak plantation in KPH Saradan is around 37,936.6 ha, and approximately 3.06% of the total Perum Perhutani teak company grade [2].

Teak is one of the main commercial timbers in the world, and it is famously recognized because of its color, fine fibers, and high durability [3]. Teak is also well known in the international market with an outstanding reputation in terms of its wood quality [4]. Teak is the first class timber class due to its strength, durability and beauty. Felling, bucking, and skidding in teak plantations are essential, for the wood quality and prices are determined in this process.

Felling activity is essential because the timber quality and price are determined in bucking process. The timber economic value is determined at the bucking stage [5] as a series of felling cycle. In addition, the measurement of felling productivity and cost is important as a basis for planning future felling evaluating these activities to increase the productivity. Reference [6] state that the information of productivity, cost and harvesting system implementation is necessary to evaluate the management plans for forest rehabilitation. Moreover, there has not been any scientific publication regarding research on harvesting productivity and cost in teak plantations by using farm tractors in Indonesia.

A number of researches on felling and skidding producitvity and cost analyses in Perum Perhutani have been conducted. Productivity measurement used to calculate cost analysis. [7] reported that the felling productivity in KPH Purwakarta is 1.559 m^3 h^{-1} with cost analysis of IDR 15,000.00 m^{-3}. Furthermore, [8] revealed that felling productivity in KPH Banten reaches 7.6 m^3 h^{-1}. Meanwhile, [7] reported that the skidding productivity is 0.128 m^3 h^{-1} with cost analysis of IDR 10,000.00 m^{-3}. The data of teak plantation productivity and costs in Indonesia are still uncomplete, and there is no publication in scientific journals; whereas felling activity is a part of important forest harvesting activities in a perspective of technicality [9].

The measurements of felling and skidding productivity are calculated by utilizing time study method. Time study is an analysis of methods, materials and equipment in the production process [10] or the time measurement, classification and analysis of data aiming to increase work efficiency [11]. Harvesting cost analysis covers the analysis of fixed costs and variable costs. Research productivity and cost analysis of felling and skidding by using time study have been conducted in other countries. Authors in [12] used time study in their research in the eastern Amazon jungle and revealed that the productivity data and felling cost are 20.46 m^3 h^{-1} and 0.49 US$ m^{-3}. Authors in [13] conducted a study on productivity and costs in the Caspian forest result in productivities with and without delay of 20.6 m^3 h^{-1} and 26.1 m^3 h^{-1}, while the costs with delay and without delay of $ 1.05 m^{-3} and $ 0.81 m^3. Authors in [9] also conducted a research in Hyrcanian forest in Iran resulting in productivity and costs with or without a delay of 9.7 tree h^{-1} and 11.65 tree h^{-1} and $ 1.21 $tree^{-1}$, and $ 1.45 $tree^{-1}$. On skidding, reference [14] reported the skidding productivity by using a wheeled skidder as much as 11.11 m^3 h^{-1} at a cost of IDR 118,140.00 m^{-3}. Some researches on productivity and cost analysis have been performed; however, the research publication in Indonesia specifically for Perhutani is still uncomplete. In addition, studies on efficiency in the felling and skidding have not been conducted. The objective of this study is to analyze the cost of felling and skidding with harvesting methods utilized in KPH Saradan.

2. Research methods

2.1. Site of Study

The study was conducted from March to August 2016 in a subplot 6A Resort Forest Management (RPH) Sugihwaras, Forest Management Units (BKPH) North Wilangan, KPH Saradan with an area of 10.3 ha. The height range of this area is between 125 meters above sea level up to 650 meters above sea level, and the average rainfall is 2,018 mm/year. The percentage of KPH Saradan slope ranges between 0%−25%. Teak stand has the same age as 80 years.The standing density is 36 trees ha^{-1}, and the total estimated production volume is 636 m^3. Harvesting is conducted by using Stilh 070 chainsaw with clear-cut silvicultural system. Skidding is conducted by using a Massey Ferguson 455 Xtra farm tractor.

2.2. Work Procedure

The time measurement procedure is performed by time study method. Observation of felling coversan activity of bucking. Bucking is conducted by using short sortiment system with pricing and timber quality in accordance with Perum Perhutani. Working elements of felling include walking towards the tree to be felled, clearing the areas around the tree, starting the chainsaw, making sinkcut and back cut, cutting base of the trunk, cutting the buttresses and branchches, determining the length and marking sortiment with teer, bucking, remove the bark, quality marking with paint, measuring the diameter, marking with the slaghammer and forest products administration.

Meanwhile, skidding elements include tractor towards the log, hooking the wire rope, skidding to load point, and taking off the wire rope. Both tree felling and skidding work elements are recorded by using a video camera during the activity. Observation of felling cycle was performed in 58 cycles while skidding in 66 cycles. Observations of felling and skidding cycle are divided into several working elements (Table 1).

Uneffective time is an interruption in an effective process defined as personal, mechanical, and operational delays [15]. Personal Delay occurs because of break activities including eating, drinking, smoking, defecation, using cell phone, and chatting. Mechanical delay is associated with repair and maintenance of harvesting equipment utilized such as filing chain. Operational delay is associated with harvesting cycle such as refueling and operator shifting. Meanwhile, effective time is utilized to carry out activities without delay, and actual time is effective time with an addition of delay time.

The volume data is recorded to calculate the productivity of felling and skidding. The tree volume equity (m^3) divided by the working time of each cycle results in the productivity of felling or skidding.

The distance between trees, tree diameter and slope are recorded to determine their effect onthe felling time. Meanwhile, the distance between skid, timber skidding volume, and slope are recorded to determine their effects on the skidding time.

Table 1: Definition of element and time type in the analyzed activities (Fath 2001)

	Description of element	Time type*	Initial point of timing	Final point of timing
	FELLING			
	Effective elements	EET		
1	Walking towards the tree to be felled	AT	Operator leaves the previous tree	Arrival at next tree to be felled
2	Clearing thea areasaround the tree	AT	End of the previous element	Base of tree is clean
3	Starting the chainsaw	AT	End of the previous element	Engine starts to run
4	Sink-cut and back cut	MT	End of the previous element	Tree top touches the ground
5	Cutting base of the trunk	AT	End of the previous element	Base of trunk is clean up
6	Cutting the buttresses and branches	AT	End of the previous element	Trunk already to bucking
7	Determining length and marking sortimen with teer	AT	End of the previous element	Marking done
8	Bucking	MT	End of the previous element	Bucking done
9	Removes the bark	AT	End of the previous element	Trunk free from bark
10	Quality marking with paint	AT	End of the previous element	Painted finish
11	Measuring the diameter	AT	End of the previous element	Measuring finish
12	Quality marking with Slaghammer	AT	End of the previous element	Marking with sledgehammer finish
13	Forest product administration	AT	End of the previous element	Log already to skidding
	Uneffective elements	UET		
1	Delay mechanic	DM	End of the previous element	Interruption causes maintenance and repair
2	Delay personal	DP	End of the previous element	Interruption causes maintenance and repair
3	Delay operational	DO	End of the previous element	Interruption causes maintenance and repair
	SKIDDING			
	Effective Elements	EET		
1	Tractor towards the log	AT	Tractor leaves landing	Operator arrives at load point
2	Hooking the wire rope	AT	End of the previous element	Sling Already attached
3	Skidding to load point	MT	End of the previous element	Arrives at TPn
4	Taking off the wire rope	AT	End of the previous element	Cable released from tractor
	Uneffective elements	UET		
1	*Delay* mechanic	DM	End of the previous element	Interruption causes maintenance and repair
2	*Delay* personal	DP	End of the previous element	Work resumed
3	*Delay* operational	DO	End of the previous element	Interruption cause remedied

*EET: Effective time, UET : Uneffective Time, AT: Auxiliary time, MT: Main time, DM: Delay mechanic, DP: Delay personal, DO: Delay operational

Data analysis was performed using Minitab 14.0 statistical program for developing a regression equation of time consumption.

2.3. Cost analysis

The variable cost is summary of maintenance and repairs, fuel and lubricants, while fixed is summary of capital interest, depreciation and insurance. Total variable costs and fixed costs are machine cost. Total system costs were calculated by summarizing the machine and labour cost. Felling cost is total felling cost divided felling productivity. Skidding cost analysis as well as felling cost. Table 2 shows the cost factors information of felling and skidding**.**

Table 2: Cost information of felling and skidding

Cost factors	Felling	Skidding
Purchase price (IDR)	5,000,000.00	600,000,000.00
Salvage value (IDR)	0	300,000,000.00
Economic lifetime (year)	5	5
Chain life (h year^{-1})	1,491.00	1,491.00
Interest (IDR-h^{-1})	20	20
Depreciation (IDR-h^{-1})	670.69	40,241.45
Repair and maintenance cost (IDR-h^{-1})	2,211.11	34,716,500.00
Total labor cost (IDR-h^{-1})	20,000.00	40,000.00
Fuel cost (IDR-h^{-1})	9357.14	26,062.00
Total fixed cost (IDR-h^{-1})	1,180.41	20,120.72
Total variable cost (IDR-h^{-1})	14,068.254	87,843.02
Total machine cost (IDR-h^{-1})	15,248.67	202,933.57
Total system cost (IDR-h^{-1})	35,248.67	242,933.57

3. Result

3.1. Time felling and skidding

Felling undertaken in KPH Saradan system uses full tree harvesting and silviculture systems clearcutting. The measurement of time to do the work of felling and skidding cycles is required to perform the calculation of productivity. Measurement time of one working cycle of logging includes walking towards the tree to be felled, clearing the areas around the tree, starting the chainsaw, making sinkcut and back cut, cutting base of the trunk, cutting the buttresses and branchches, determining the length and marking sortiment with teer, bucking, remove the bark, quality marking with paint, measuring the diameter, marking with the slaghammer and forest products administration. Table 3 shows the statistical description of the work cycle elements of felling and skidding. The results showed that on average felling cycle time required to perform the cutting cycle is 2,423 seconds, or within 40 minutes a felled tree to be cut into short sortimen was conducted. If it is calculated up to the elements of creating sinkcut and backcut or before the distribution of the trunks,it takes 281 seconds, or 12 trees can be cut downper hour, sothe total cutting cycles of each working element is 58 cycles.

Table 3: Statistical description of the felling and skidding work cycle

Elemental times of working cycles	Average (Second)	Std. dev	(N)
FELLING			
Walking towards the tree to be felled	63	58	58
Clearing thea areas around the tree	34	32	58
Starting the chainsaw	3	1	58
Sink-cut and back cut	181	143	58
Cutting base of the trunk	81	85	58
Cutting the buttresses and branches	80	40	58
Determining length and marking sortimen with teer	246	63	58
Bucking	358	66	58
Removes the bark	239	47	58
Quality marking with paint	199	34	58
Measuring the diameter	201	83	58
Quality marking with Slaghammer	220	75	58
Forest product administration	311	121	58
SKIDDING			
Tractor towards the log	270	67	66
Hooking the wire rope	116	40	66
Skidding to load point	409	113	66
Taking off the wire rope	47	12	66

Working element to be measured for one skidding cycle of work includes tractor towards the log, hooking the wire rope, skidding to load point, and taking off the wire rope. On skidding cycle, time required to perform the extraction cycle is 842 seconds, or 4 trees per hour can be skidded. In this study, skidding a tree trunk with a large size is divided into two for easy extraction. Number of working cycles skidding recorded in this study is 66 cycles. The greatest time used in a felling cycle is working element of bucking that is equal to 14.77% of total actual time. Distribution of the use of the actual time of felling cycle can be seen in Table 4. The delay time is equal to 8.54% of total actual time. Uneffective time or the delay time at the most is the personal delay amounted to 50.72% of the total delay time. The personal delay time occurs because many operators take a lot of breaks for private purposes such as chatting, using a cellular phone and smoking. The results showed the time of each element of the skidding work cycle can be seen in Table 4. The most time in the cycle is the element of skidding to the load point amounted to 46.58% of total actual time. Delay time is 4% of the actual total time of extraction. The period of resting (drinking and smoking) and chatting by the operators is included in the personal delay, and this is most frequently conducted, reaching 77.77% of the total delay time. If there is a mechanical delay on the skidding tractor, the activity is stopped or no activity is carried out. In this study, no mechanical delay is included in the extraction cycle so that the delay time due to a mechanical delay does not exist. Operational delay time is equal to 22.22% of the total time delay.

Table 4: Distribution of time and delay in felling and skidding

Element and delay of working cycle	Times	
	(minutes)	(%)
PENEBANGAN		
Walking towards the tree to be felled	63	2.60
Clearing thea areas around the tree	34	1.40
Starting the chainsaw	3	0.12
Sink-cut and back cut	181	7.47
Cutting base of the trunk	81	3.34
Cutting the buttresses and branches	80	3.30
Determining length and marking sortimen with teer	246	10.15
Bucking	358	14.77
Removes the bark	239	9.86
Quality marking with paint	199	8.21
Measuring the diameter	201	8.29
Quality marking with Slaghammer	220	9.07
Forest product administration	311	12.83
Delay	207	8.54
Total	2,423	100
Delay mekanik	34	16.42
Delay personal	105	50.72
Delay operational	68	32.85
SKIDDING		
Tractor towards the log	270	30.75
Hooking the wire rope	116	13.21
Skidding to load point	409	46.58
Taking off the wire rope	47	5.35
Delay	36	4.10
Total	878	100
Delay mechanic	0	0
Delay personal	28	77.77
Delay operational	8	22.22

Delay and productivity are affected by several things, among others, the stand condition, skills of workers, working techniques, and characteristics of the machine or tools used [16]. Many factors affect the productivity of harvesting including the harvesting time per tree of DBH (diameter at breast height), distance between trees and harvesting intensity [17]. Felling and skidding time required in performing the work cycle in this research is affected by DBH for felling and skidding distance for skidding. The results of this study showed that the use of time for a felling cycle is not affected by the distance between trees felled. It is caused by the same spacing as they are plant forests and the location of felling has a flat contour to facilitate the logging. The skidding distance activity affects the time of skidding.

The correlation coefficient (R^2) is 53.91% of the total variability, which is explained by the regression equation. ANOVA table can be seen in Table 5 with a 95% accuracy rate. Figure 1 illustrates the relationship of time used for felling in various diameters. These results indicate that the time consumtion of felling increases as the diameteris wider. Similarly, the research of [14] reveals that the larger the diameter, the more time is needed for felling. Authors in [17] reported that many factors affect the productivity of harvesting including the harvesting time per tree that is DBH, distance between trees and harvesting intensity. The factors that most affect the use of time on the logging include the diameter and distance between trees [18].

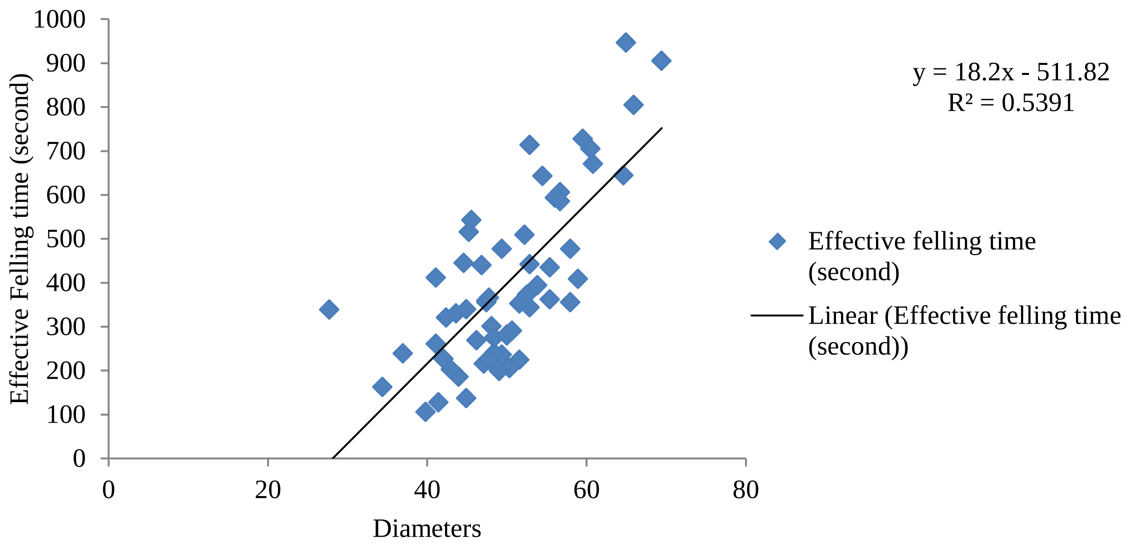

Figure 1: Effective time (without delay) logging in various diameters

Table 5: ANOVA model

Source	df	Sum of Squares	Mean Square	F	Sig.
Regression	2	329.03	164.52	32.85	0.000
Residual	55	275.45	5.01		
Total	57	604.48			

Figure 2 shows the linear regression between skidding distance and effective time for skidding. The chart shows a 56.92% rate of effective time diversity which can be explained by the distance of the skid, and the rest is influenced by the other factors. ANOVA table can be seen in Table 6 with a 95% accuracy rate. According studies of [19] [6] [20]; skidding is influenced by a number of factors, among others,the skidding distance, timber volume, number of stems, and slopes. In these studies,the skidding tool used is Timberjack usually used for timber extraction. Authors in [21] reported that skidding uses of tractors farm are influenced slope and skidding distance. According to studies of [22] [23] the skidding distance is the most effective variable on skidding time. In this study, skidding is conducted with farm tractor of Xtra Massey Ferguson 455 with almost the same slope that is 0−10%. The number of rods on each cycle of skidding is the same as one rod and with an average volume of 1.148 m^3 $cycle^{-1}$. Therefore, the slope and skidded number of stems do not affect the time of skidding; however, skidding is most affected by the skidding distance.

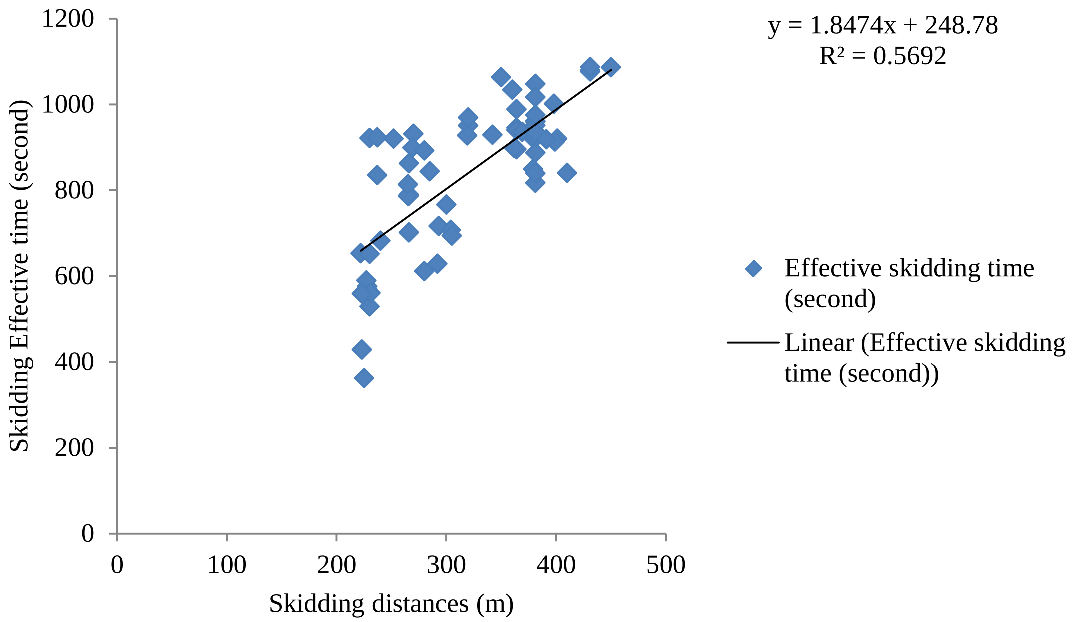

Figure 2: Effective time skidding in various skidding distances

Table 6: ANOVA model

Source	df	Sum of Squares	Mean Square	F	Sig.
Regression	1	1,030,533	1,030,533	84.85	0.000
Residual	64	779,811	12,185		
Total	65	1,810,344			

3.2. Productivity of felling and skidding

Measurement of felling and skidding is conducted to calculate the fees required in accordance with the activities that take place in the field. The calculation of productivity is the ratio between the production that is obtained by the required time. Table 7 shows the use of time, volume and productivity at the effective time and duty time of cycle of felling and skidding. Productivity is measured by the volume of production per hour. The average volume harvested amounted to 1.947 m^3. The average productivity of felling effetive time is 2.613 m^3 h^{-1} while the average productivity of harvesting to the actual time is 2.428 m^3 h^{-1} . In this study, a decrease in productivity can lead to an increased cost of IDR 1,026.28 m^{-3} or 7% of the total cost. The decline in productivity is caused by delay in harvesting or less efficient use of time.

Table 7: Time, volume and productivity felling and skidding

Time consumption, volume and productivity	Effective time	Actual time
FELLING		
Average of time consumption (second $cycle^{-1}$)	2,216	2,423
Minimum of time consumption (second $cycle^{-1}$)	1,231	1,231
Maximum of time consumption (second $cycle^{-1}$)	3,473	3,722
Average of volume (m^3)	1.947	1.947
Minimum of volume (m^3)	0.494	0.494
Maximum of volume (m^3)	4.735	4.735
Average of productivity (m^3 h^{-1})	2.613	2.428
Minimum of productivity (m^3 h^{-1})	0.865	0.688
Maximum of productivity (m^3 h^{-1})	5.061	4.996
SKIDDING		
Average of time consumption (second $cycle^{-1}$)	842	878
Minimum of time consumption (second $cycle^{-1}$)	362	362
Maximum of time consumption (second $cycle^{-1}$)	1,087	1,185
Average of volume (m^3)	1.148	1.148
Minimum of volume (m^3)	0.07	0.07
Maximum of volume (m^3)	3.35	3.35
Average of productivity (m^3 h^{-1})	5.009	4.793
Minimum of productivity (m^3 h^{-1})	0.244	0.226
Maximum of productivity (m^3 h^{-1})	11.845	11.519

Skidding in KPH Saradan in this study was performed using a farm tractor with Massey Ferguson Xtra 455 brand. This is done because the implementation of harvesting coincides the rainy season. Distance from compartment to land is not possible if the extraction is done manually by human power. Skidding in plantations usually uses agricultural tractors, rubber-tired skidder or forwarder [24]. The average productivity of skidding effective time and actual time is 5.009 m^3 h^{-1} and 4.793 m^3 h^{-1} respectively. Difference productivity of effective time and actual time is 0.216 m^3 h^{-1} or decrease in the time of delay of skidding productivity is 2.2%. The average volumeof skidding is 1.148 m^3. Compared to research by [21] who conducted in the forest tamperate using agricultural tractor, the skidding productivity was 2.6 m^3 h^{-1} which is lower than the result of this study. [25] reported skidding productivity of plantations in Indonesia using CAT Skidder 525 is equal to 6.758 m^3 h^{-1}, higher than the result of this study. If compared to the studies, the result is relative and depends on various factors.

Various factors can affect the productivity of forest harvesting. Reference [26] reported the productivity of timber harvesting is influenced by several factors, among others, labor, methods, production, and work environment. [16] also reported the delay and productivity are influenced by several things, among others, the stand condition, workers' skills, working techniques, and characteristics of the machine or device used. Reference [27] stated that the proper planning on logging activities would increase productivity by 15% if compared with that of logging without planning.

3.3. Cost Analysis

Analysis of the cost of felling and skidding is calculated and it is based on fixed costs and variable costs tools used. Table 8 shows the cost of felling and skidding. Cost felling is influenced by operator costs by 57%, while the cost of the machine is only 47%. Based on the cost components, the cost cutting is IDR 14,515.00 m^{-3} while the cost of logging operation IDR 35,248.00 h^{-1}. The cost of this business is the result of calculations with operator wages amounted to 2 people. The skidding cost is IDR 48,499.74 m^{-3} while the system cost is in IDR 242,933.57 h^{-1}. The system cost is the result of the calculation with the wages of 2 operators.

Table 8: Cost analysis of felling with chainsaw and skidding with tractor

Komponen biaya	*Chainsaw*	Tractor
Fixed cost (IDR h^{-1})	1,180.41	115,090.54
Variable cost (IDR h^{-1})	14,068.25	87,843.02
Machine cost (IDR h^{-1})	15,248.67	202,933.57
System cost (IDR h^{-1})	35,248.67	242,933.57
Total cost (Rp m^{-3})	14,515.71	48,499.74

The payment system of felling and skidding that has been done by Perhutani is the wholesale system with the calculation based the cubication of timber harvested. Cost cutting in Perhutani is based on the rate of pay for the contract i.e. IDR 30,100.00 m^{-3}. Table 9 shows that the minimum and maximum costs of felling and skidding on average. The results showed that the average cost of felling in the KPH Saradan is IDR 13,489.43 m^{-3} for an effective time and IDR 14,515.71 m^{-3} for the actual time. The actual extraction cost is higher than IDR 1,026.28 m^{-3} compared to the cost of the effective time (without delay). The delay increases the cost of production by 7%. The cost based on the Perhutani wage rate is higher by 51.77% than the result of the cost analysis for the actual time in this study.

Skidding cost in Perhutani is based on the Perhutani wage rate or based on a contract system that is IDR

65,000.00 m^{-3}. The result showed that the average cost of skidding is IDR 48,499.74 m^{-3} for an effective time and IDR 50,685.07 m^{-3} for the actual time. This shows that the payment rate of skidding by Perhutani is 22% higher than the cost based on the cost analysis for the actual time in this study.

4. Conclusion

The results of this study showed that the average costs of logging with or without a delay are IDR 14,515.709 m^{-3} and IDR 13,489.431 m^{-3} respectively. The average costs of skidding with or without a delay are IDR 50,687.582 m^{-3} and IDR 48,499.744 m^{-3}. The result of the cost analysis in this study is lower than the existing rate at Perhutani. The results of this study can be used for evaluation in logging activities, work planning and subsequent extraction costs.

References

[1]. [Perum Perhutani] State Forestry Public Company of Indonesia. “Rencana Pengaturan Kelestarian Hutan (RPKH) Kelas Perusahaan Jati Kesatuan Pemangkuan Hutan Saradan”, 2012.

[2]. [Perum Perhutani] State Forestry Public Company of Indonesia. “Buku Statistik Perum Perhutani Tahun 2009-2013”, 2014.

[3]. D. Pandey and C. Brown.”Teak: a global overview”. An International journal of forestry and forest industries, vol. 51(201), pp. 3–13, 2000.

[4]. R.M. Keogh. “The future of teak and the high-grade tropical hardwood sector”. Planted Forests and Tress Working Paper Series. Rome (IT): FAO, 2009.

[5]. A. Budiaman, R.H. Prabowo. ”Simulasi pembagian batang sistem kayu pendek pada pembagian batang kayu serat jenis mangium”. Journal Manajemen Hutan Tropika,vol. 14(2),pp. 61–65, 2008.

[6]. F.K. Behjou, B. Majnounian, M. Namiranian , J. Dvorak. “Time sttudy and skidding capacity of the wheeled skidder Timberjack 450C in Caspian forests”. Journal Forest Science, vol. 54(4), pp. 183–188, 2008.

[7]. I. Retno. “Evaluasi elemen dan prestasi kerja pemanenan di hutan jati (studi kasus pemanenan kayu jati BKPH Sadang KPH Purwakarta Perum Perum Perhutani Unit III Jawa Barat)”. thesis, Bogor Agricultural University, Indonesia, 2001.

[8]. M.G. Mahendra. “Pengukuran waktu standar dan prestasi kerja penebangan jati (Tectona grandis) di Perum Perhutani Unit III Jawa Barat”. M.A. thesis, Bogor Agricultural University, Indonesia, 2003.

[9]. R. Mousavi. “Time consumtion and productivity and cost analysis of the short-log and long-log skiddding in the hyrcanian forest in Iran”. Univrsity of Urmia, Faculty of Forestry, Iran, 2011.

[10]. Barnes RM. “Motion and Time Study: Design and Measurement of Work”: New York (USA): John Wiley & Sons, Inc,1968.

[11]. R. Björheden and M.A. Thompson. “An international nomenclature for forest work study”. In: Proc of Caring for the Forest: Research in Changing World. XX World Congress; Tampere, Finland, Agust 6−12, 1995, pp. 191–215, 1995.

[12]. T.P. Holmes, G.M. Blate, Zweede, Jr.R. Pereira, P. Barreto, F. Boltz, R. Bauch. ”Financial and ecological indicators of reduced impact logging performance in the eastern Amazon”. Journal Forest ecology and Management, vol. 163, pp. 93–110, 2002.

[13]. F.K Behjou, B. Majnounian, J. Dvorak, M. Namiranian, A. Saeed, J. Feghhi. “Productivity and cost of manual felling with a chainsaw in Caspian Forest”. Journal Forest Science, vol. 55 (2), pp. 96–100, 2009.

[14]. R. Mousavi. “Comparison of productivity, cost and environmental impacts of two harvesting methods in Nothern Iran: short-log vs. long-log” . disertation, University of Joensuu, Finland, 2009.

[15]. H. Fath. “Commercial timber harvesting in natural forests of Mozambique”. Forest Harvesting Case-Study. Rome (IT): FAO, 2001.

[16]. T. Nurminen, H. Korpunen and J. Uusitalo. “Time consumption analysis of the mechanized cut-to-length harvesting system”. Silva Fennica, vol. 40 (2), pp. 335–363, 2006.

[17]. D. Lortz, W. McCoy, B. Stokes, J. Klepac. “Manual felling time and productivity in Southern Pine Forest”. Forest Product Journal, vol. 47 (10), pp. 59–63, 1997.

[18]. J. Wang, C. Long, J. McNeel, J. Baumgras. “Productivity and cost of manual felling and cable skidding in central Appalachian hardwood forests”. Journal Forest Product. vol.54(12), pp. 45–51, 2004.

[19]. M. Lotfalian, E.H. Zadeh, Hosseini. “Calculating the correction factor of skidding distance based on forest road network”. Journal Forest Science,vol. 57(11),pp. 467–471, 2011.

[20]. M. Nikooy, A. Esmailnezhad, R. Naghdi. “Productivity and cost analysis of skidding with timberjack 450C in Forest plantations in Shafaroud watershed, Iran”. Journal of Forest Science, vol. 59 (7), pp. 261–266, 2013.

[21]. N. Gilanipoor, A. Najafi, S.M.H. Alvaezin. “Productivity and cost of farm tractor skidding”. Journal of forest science, vol. 58 (1),pp. 21–26, 2012.

[22]. A.F. Egan, J.E. Baumgras. “Ground skidding and harvested stand attributes in appalachian hardwood stands in West Virginia”. Forest Product Journal, vol. 53 (9), pp. 59−63, 2003.

[23]. M.R. Ghaffarian, K. Stampfer, J. Sessions. ”Forwarding productivity in Southern Austria”. Croatian Journal of Forest Engineering, vol. 28, pp. 169−175, 2007.

[24]. J. Sessions. “ Harvesting Operations in the Tropics”. Berlin (DE): Springer, 2007.

[25]. B. Sulistiyanto B. “Prestasi kerja dan biaya pemanenan pada hutan tanaman industri studi kasus di HPHTI PT Tanjung redep Hutani, Barau Kalimantan Timur”. thesis, Bogor Agricultural University, Indonesia, 2001.

[26]. M. Sinungan.. “Produktivitas: Apa dan Bagaimana”. Jakarta: PT. Bina Aksara, 1987.

[27]. P. Barreto, P. Amaral , E. Vidal, Uhl. “Costs and benefits of forest management for timber production in eastern Amazonia”. Journal Forest Ecology and Management, vol. 108,pp. 9–26, 1998.