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Stand damage due to mono-cable winch and bulldozer yarding in a selectively logged tropical forest

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Abstract. *Ruslim Y, Sihombing R, Liah Y. 2016. Stand damage due to mono-cable winch and bulldozer yarding in a selectively logged tropical forest. Biodiversitas 17: 222-228.* Timber yarding with bulldozers has substantial unwanted environmental impacts and degrades the quality residual stands. We contrasted the impacts of bulldozer yarding with yarding with a sled-mounted mono-cable winches equipped with 20 and 26 horsepower engines and 100 m of wire in a natural forest timber concession in East Kalimantan, Indonesia. We compared the two systems on the basis of productivity and stand damage in forests that were selectively logged at the same intensity on slopes ≤ 40% for bulldozer and for mono-cable yarding on slopes ≤55%. On slopes ≤40%, bulldozers yarded an average of 10.3 m^3 hm^{-1} $hour^{-1}$ to roadside log landings whereas mono-cable winch productivity was 7.8 m^3 hm^{-1} $hour^{-1.}$ In these areas, mono-cable winching caused 1.2%, 2.0%, 0.6%, and 27.0% less damage to seedlings, saplings, poles, and trees than bulldozer yarding. Our study demonstrates that conventional methods such as bulldozer skidding created damage at seedling, sapling, pole and tree levels of vegetation around 15.3%, 9.9%, 10.8% and 34.5% at slope ≤40%. Winch-yarding is rare in tropical forestry, but the low cost of the mono-cable system we tested ($4,000), its productivity of 20.9 m^3 day^{-1} for yarding distances that averaged 70.5 m, employment opportunities, and reduced environmental impacts indicate that such systems could make a major contribution to reduced-impact logging and promote local development.

Keywords: Kalimantan, log yarding, reduced-impact logging, selective logging, tropical forestry

INTRODUCTION

Sustainable forest management is a global objective for ensuring secure timber supply, protection of forest environmental services (e.g., flood buffering, carbon sequestration), protection of forest wildlife habitats, and protection of safe dwelling places of up to 1.6 billion forest-dependent people (Canadell and Raupach 2008; Chao 2012; FAO 2010; Putz et al. 2012). How to achieve true sustainability in forest management, however, or even how to define it, remains unclear (Sasaki and Putz 2009). What is clear is that most forests, and especially tropical forests, have not had the careful, long-term management required to protect their functional integrity (Edwards et al. 2014). Excessive residual damage to remaining forest stands because of poor planning of timber harvest processes and related infrastructure, and the use of unnecessarily large timber extraction equipment are important aspects of unsustainable forest management (Pinard and Putz 1996; Sist et al. 1998; Iskandar et al. 2006). Reducing residual damage, without incurring major additional costs, would benefit forest management, and increase financial returns from natural forest concessions. This, in turn, could reduce the likelihood that selectively logged natural forests are considered of little economic value, and would become more valuable when converted to mono-cultural crop plantations, such as *Acacia* spp. for pulp and paper production or *Elaeis guinensis* for palm oil.

The primary log skidding equipment used in logging exploitation activities in tropical forests is the bulldozer (Fredericksen and Pariona 2002; Pinard et al. 2000a). The use of bulldozers as timber removal equipment is thought to minimize the environmental impacts (soil compaction and canopy protection) in areas with moderate to heavily contoured topography. Especially following second or third rotation logging, however, remaining forest stands are often in poor ecological condition, because of skidding-related damage (Meijaard et al. 2005). Reducing damage requires the use of alternative removal equipment that match (or exceed) a bulldozer's capacity, but with reduced residual impacts. This includes helicopter yarding, an expensive method that also opens up forests not normally accessible to ground-based equipment (Putz et al. 2001), rubber-tired mini-skidders (Spinelli et al. 2012), and motor-winches (Escobar and García 2013).

We here focus on the use of motor-winches in reduced impact logging in Indonesian Borneo. These winches are thought to prevent residual damage to forests, because such mono-cable engines are stationed at a particular central point towards which logs are pulled using a sling or a cable. They thus require fewer skid-roads and tracks. A preliminary study by Ruslim (2011) showed that such a system using a 20 horsepower (HP) engine was able to remove 8 tons of logs per day with less damage to top soil and residual stands compared to bulldozer yarding. It also resulted in reduced environmental pollution due to reduced

fuel consumption, in addition to the fact that it was less costly in operation and maintenance due to the involvement of the local community (Ruslim 2011). In this research study, we compared the performance and impacts of two mono-cable winches with 20 HP and 26 HP capacity and also compared with bulldozer, with regard to production capacity (in tons of timber extracted) and impact on residual tree stands after timber removal operation.

MATERIALS AND METHODS

Study area

The study was conducted in two forest concessions at production forest working area, i.e. Ratah Timber Company (114°55' E – 115°30' E;0°2'S – 0°15' N) in West Kutai district of East Kalimantan Province Indonesia and Belayan River Timber Company (115°30'21.60 E – 116°11'38.34" E; 0°32'35.16" N – 0°55' 35.16" N) in Kutai Kertanegara district, West Kutai District of East Kalimantan Province of Indonesia (Figure 1). The total area of Ratah Timber Company is 93,425 ha, which consists of a permanent production forest is 73,420 ha and limited production forest is 20,005 ha. The total area of Belayan River Timber Company is 97,500 ha, which consist of limited production forest. Based on the Schmidt-Ferguson's climate classification, the both forest concession holder belongs to type A climate where the average temperature varies from 22-27°C and average annual rainfall varies at 2,500-4,000 mm. Soil types of the study area include alluvial, latosols, podzolic, litosol, and regosol (Liah 2012). We implemented our study on log skidding using mono-cable winches at both company and bulldozer system only at Ratah Timber company.

Sample plots

To determine the residual stand damage as the result of skidding with mono-cable winch, we built three research plots with average slope below 40% and another three plots with average slope above 40%. We also built three plots with slope below ≤ 40% with similar extent (1 ha each) to determine the damage caused by felling and skidding with bulldozer.

Data collection

We analyzed the vegetation samples collected from both locations and measured forest degradation, which include assessment of forest damage and the depth of soil excavation as the result of mono-cable winch skidding and bulldozer skidding. Pre-logging forest inventory was conducted on seedling, sapling, poles and trees at the sample plots. The measured variables include tree species, diameter and number of trees. After the felling and skidding took place, we did another forest inventory on residual stands of all types of trees with a diameter ≥ 20 cm which were damaged by felling and skidding. The damages of residual stands were noted: (i) broken stems, (ii) broken crowns, (iii) bark scratched, (iv) fallen trees. Within the plots we counted the number of tree with diameter of 20 cm and above before and after harvesting, calculating residual impact.

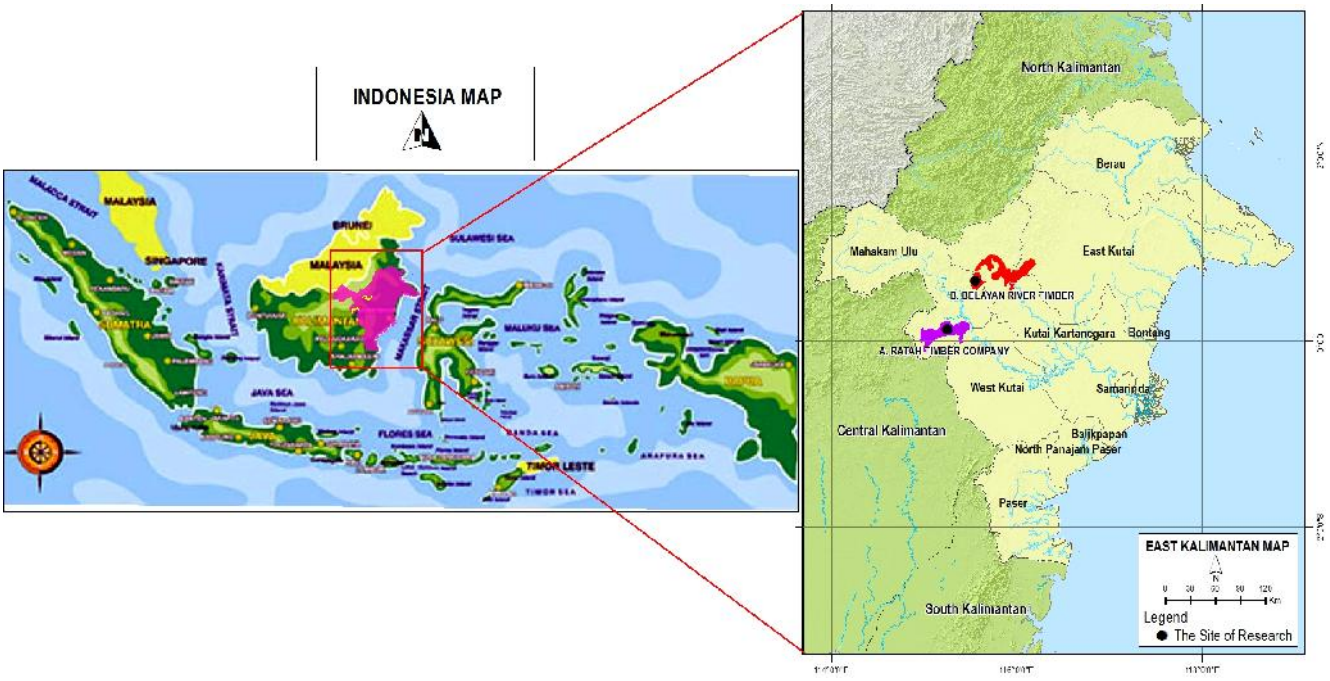

Figure 1. Study area (A) Ratah Timber Company (purple area), West Kutai and (B) Belayan River Timber Company (red area) in Kutai Kertanegara and West Kutai district of East Kalimantan, Indonesia

The time study was typical skidding operations begins with the identification of a set of functional elements comprising of the works cycle of the mono-cable winch machine and bulldozer skidding being evaluated. In performing time study observers watch of these elements as the machine works and note the duration of the event and any other factors that influence the performance of the machine. Mono-cable winch winches logs from stump to the skid trail and moves a maximum of three times to the secondary or main road. Bulldozer skid the logs from stump directly to the log landing. Data were collected continuously throughout each cycle from start to finish.

We estimated labor input using a continuous method in which we measured time allocated to (i) equipment preparation and engine start-up; (ii) access path clearance; (iii) machine fixation on trees or tree stands; (iv) sling directed to logs to be removed; (v) log leading point sharpening and sling fastened to logs using hooks; (vi) log stacking, and (vii) sling winching (sling adjustment, release and winding). These field data were supported by additional information, including trees maps from the company, and fuel consumption.

We estimated the skidding productivity using the Brown (1958) formula:

$$P = V/W$$

With P = removal productivity (m^3 $hour^{-1}$), V = volume removed per trip (m^3 $trip^{-1}$), and W = operating time (hours), i.e, the time needed for preparation, sling carrying to the log, hooking the sling onto the log, yarding, and sling release.

We calculated the volume of logs removed with the following formula:

$$V = \frac{1}{4} \pi d^2 L$$

With V = Volume of logs removed (m^3); d = mean diameter (cm); and L = length of stem (cm).

RESULTS AND DISCUSSION

Forest stands before and after harvesting

Forest harvesting using the mono-cable winch in the area with slope less than 40% and area with slope more than 40% causes damage on the forest vegetation in all living phase, i.e. seedling, sapling, pole and tree. The number of damaged vegetation for seedling, sapling, pole and tree in the area with slope ≤ 40% due to felling operations are 21.0%, 20.6%, 18.9% and 24.5%, respectively. Due to skidding, the seedling, sapling, pole and tree damage were lost 14.1%, 7.9%, 1.2% and 7.6%, respectively. Species-wise, *Shorea johorensis* in all phases (e.g. seedling, sapling, pole and tree) is the one that was mostly damaged during felling and skidding. The only exception was for the poles during skidding, which left the most damage to *Shorea assamica*. The number of damaged vegetation for seedling, sapling, pole and tree in the area with slope more than 40% due to felling operations are 33.6%, 31.4%, 27.4% and 26.0% respectively. Due to skidding, the seedling, sapling, pole and tree were lost 14.1%, 1.9%, 1.7% and 8.0% respectively. Species-wise, *Shorea johorensis* and *Dipterocarpus* spp. in all phases (e.g. seedling, sapling, pole and tree) is the one that was mostly damaged during felling and skidding (Table 1).

Forest harvesting using the bulldozer in the area with slope less than 40 causes damage on the forest vegetation in all living phase, i.e. seedling, sapling, pole and tree. The number of damaged vegetation for seedling, sapling, pole and tree in the area with slope ≤ 40% due to felling operations are 9.3%, 7.2%, 8.6% and 10.9%, respectively. Due to skidding, the seedling, sapling, pole and tree were lost 15.3%, 9.9%, 10.8% and 34.5%, respectively. The tree species most damaged by felling and skidding at level poles and trees are *Dipterocarpus* spp and *Shorea johorensis* (Table 2).

Skidding labor input, timber volume, skidding distance and skidding productivity

The use of the larger (26 HP) engine reduced skidding time and increased log removal volume, and thus increased productivity. The skidding productivity using bulldozer is 10.3 m^3 hm^{-1} $hour^{-1}$, greater than mono-cable winch is in average 7.8 m^3 hm^{-1} $hour^{-1}$ (Table 3). The mono-cable winch system is more time consuming, more labor intensive and less productivity under the RIL method. This is reflected by results of the study that shows the reduced degree of destruction induced by removal as per the RIL procedure and efforts of releasing and un-releasing hooks where stem destruction induced by frictions became avoidable. Consequences of releasing and un-releasing hooks on site, however, was slower work performed by the mono-cable winch operator as he had to be more careful when doing his removal work, resulting in the reduced overall removal performance. On the other hand, stem destruction induced by removal was very small due to the slow friction with the stems.

Discussion

The analysis of collected data showed that by using a mono-cable winch with a winching process with distance between 30–100 meters , will be able to avoid damage to remaining trees. The result showed that around 8% of trees were destroyed by skidding operation with mono-cable winch and compared to bulldozer the damage to remaining stands reached 35% (Figures 2 and 3).

The skidding machines, winching distance are the important factors to influence on amount of ground based skidding to the residual stand in the forests. Directional felling is important techniques to reduce skidding damages to residual stand. Tavankar et al. (2012) reported with directional felling, trees were felled to reduce damage to the residual stand, to facilitate chocker hookups in preparation for skidding and to without creating unnecessary large forest disturbance. The main benefit of winching with mono-cable winch system was to reduced skidding damage around 26.9% (Figure 2a) compared to a bulldozer system (Figure 2b).

Table 1. Felling and skidding damage after logging with a mono-cable winch on slopes ≤ 40% and≥ 40% at Belayan River Company at ha^{-3}

	Felling damage		Skidding damage		Residual stands (n)	Total (n)
	(n)	(%)	(n)	(%)		
			Slope ≤ 40%			
Seedling	73	21.0	49	14.1	225	347
Sapling	34	20.6	13	7.9	118	165
Pole	49	18.9	3	1.2	207	259
Tree	13	24.5	4	7.6	36	53
			Slope ≥ 40%			
Seedling	93	33.6	39	14.1	145	277
Sapling	49	31.4	3	1.9	104	156
Pole	65	27.7	4	1.7	166	235
Tree	13	26.0	4	8.0	33	50

Table 2. Felling and skidding damage after logging using bulldozer with slope ≤ 40% at Ratah Timber Company at ha^{-3}

	Felling damage		Skidding damage		Residual stands	Total
	(n)	(%)	(n)	(%)	(n)	(n)
Seedling	29	9.3	48	15.3	236	313
Sapling	8	7.2	11	9.9	92	111
Pole	8	8.6	10	10.8	75	93
Tree	6	10.9	19	34.6	20	55

Table 3. Average productivity of logs skidding using 20 HP and 26 HP engines with mono-cable winch and bulldozer on an inclination ≤ 40%

Skidding system	Operating time (hours)	Volume (m^3)	Skidding distance (m)	Productivity ($m^3\ hm^{-1}hour^{-1}$)
Mono-cable winch				
20 HP Engine	0.8	8.3	69	7.0
26 HP Engine	0.8	8.9	72	8.5
Bulldozer	1.2	7.6	153	10.3

The proportion of trees injured because of felling activity were bigger at Belayan River Company, it is dependent on height of the tree, the size of its crown and the topography. Mono-cable winch system mostly damaged *Shorea johorensis*, followed by *Shorea assamica*, *Shorea pinanga* and *Dipterocarpus* spp. respectively, while bulldozer system mostly damaged *Shorea laevis*, followed *Dipterocarpus* spp. Skidding with bulldozer has considerable impact on biodiversity conservation, forest structure and species composition. In average with mono-cable winch system were relatively small destruction towards forest floor induced by logs skidding as top soil is not even stripped down to 11 cm and 1 m width of skidding road. Another major impact of ground base skidding with bulldozer is removal of the top soil, very high destruction of forest soil during skidding, as soil is stripped down more than 30 cm and more than 4 m width of skidding road. Ruslim (2011) reported the application of the mono-cable winch system in reduced impact logging is an effort to reduce economical and environment damages when compared to conventional system of ground based skidding with bulldozer system. The mono-cable winch system was most efficient (operational cost) and reduced the soil damage by as much as 8% ha^{-1}.

Removal activities using a bulldozer requires sufficiently high cost per hour of operation due to its 8-hour work fuel consumption requirement, which can reach 250 L, in addition to high cost of parts replacement (Ruslim 2011). An experienced expert would require at least one full day to install the equipment depending on the site condition. It is all different when being compared to operating costs of a mono-cable winch with the lowest fuel consumption (5 L $days^{-1}$) for an eight hour operation resulting in a positive impact on global warming due to the reduced carbon emission induced by low fuel consumption. Bulldozer requires higher operating costs. This is because it needs more diesel fuel, i.e. in addition to more spare parts; it requires 250 liters for 8 hours of work. Healey et al (2000) also stated that the implementation of RIL will reduce carbon emissions and reduce other losses from harvesting activities.

Figure 2. A. The view of stand and soil damage after skidding with mono-cable winch, and B. with bulldozer

Figure 3. A. Small destruction towards forest floor induced by logs skidding as top soil with mono-cable winch, and B. very high destruction with bulldozer

This was backed up by previous research (Ruslim 2011), where, when viewed from the environmental, economic, engineering and even social aspects, the use of the mono-cable winch is an alternative that can be employed in the removal operation and is eligible to be used by the work area of forest timber products utilization business licensed concession holder (Table 3). Putz et al (2000) state lack of governmental incentives to change logging practices for not adopting RIL methods in the field.

Limbang Ganeca company has been using a bulldozer resulting in uncovered land in a conventional way 16.3% ha^{-1} (Ruslim et al. 2000). The application of RIL in Sabah, Malaysia has been able to reduce destruction of the remaining tree stands from 50% down to 28% when compared with conventional logging where the soil destruction has been able to reduce from 13% to 9% (Pinard et al. 2000b). Sist et al. (1998) state that using the RIL technique in Berau (East Kalimant**a**n) has been able to reduce destruction induced by logging down to 50% when compared with the conventional system. A study at Narkata Rimba Company (East Kalimantan) mentions that the degree of remaining tree stands induced by conventional harvesting system is 28–45% (Elias 2002). John et al. (1996) also state that a well-planned RIL application in the Amazon, managed to reduce destruction of the tree stands around 25–33%. The damage level of residual stands caused by tree cuttings with the selective cutting system was influenced by cutting intensity, forest harvesting techniques, and forest management types. Bertault and Sist (1997) reported that conventional logging by 87 m^3 ha^{-1} had damaged trees with a diameter > 10 cm as much as 40%, whereas the reduced-impact logging (RIL) techniques had caused damages of only 30.5%. Sist et al. (1998) reported that the cutting intensity of 8 trees ha^{-1} or less using the

Table 3. Comparison between environmental, economic, engineering and social aspects between a mono-cable winch and a bulldozer (Ruslim 2011)

Aspect	Variable	Skidding equipment	
		Mono-cable winch	**Bulldozer D7G**
Environment	Destruction to forest floor	Relatively small destruction towards forest floor induced by logs skidding as top soil is not even stripped down to 15 cm and 1 m width of skidding road.	Very high destruction of forest soil during skidding, as soil is stripped down more than 1 m and more than 4 m width of skidding road
	Soil erosion	Relatively small soil erosion	Very high soil erosion
Economical	Investment cost	Purchase price US$4,000 ,- unit^{-1} US$9.5 m^{3}	Purchase price . US$184,500 unit^{-1} US$16.5
	Skidding cost including felling	Skidding cost is 42% cheaper than that of bulldozer	
	Fuel consumption	Fuel consumption is 0.625 L hour^{-1}	Fuel consumption is 30 L hour^{--1}
	Productivity	Skidding capacity is on average 5 logs a day $^{-1}$ with 100 m skidding distance	Skidding capacity is on average 10 logs a day $^{-1}$ with 300 m skidding distance
Technical	Topography	Can be used on slopes up to 60%	Can be used on slopes up to 40%
	Cable length	Can skid logs with winching distance 100 m	Can skid with winching distance 32 m
	Skidding capacity	8-12 ton	15 ton
	Spare parts	Cheap, easy to order in Samarinda	Takes a long time to order (import)
Community impact	Work force (Chainsaw operator and mono-cable/bulldozer operator)	More employment from local people (5 people unit^{-1})	Commonly the employment is from Java and local people (4 people unit^{-1})

RIL techniques resulted in tree damages to 25%, while the conventional logging technique had caused damages to 50%. TNC (2010) reduced-impact logging method can directly decrease emissions by about 30-50% per unit of wood extracted. Furthermore, the requirements for special management of high conservation value forest HCVFs and other conservation zones provide greater carbon storage in those areas. Putz et al. (2008) stated that, the carbon lost due to harvesting through the conventional system using a bulldozer in Sabah Malaysia within a period of 30 years was 108 tons ha^{-1}, while the carbon lost using a bulldozer with RIL system was only 78 tons ha^{-1}. When compared to the conventional logging system, carbon stocks using RIL system will store more carbon reserves of 30 tons ha^{-1}. Bulldozer operation in logs removal will always bring negative impacts for the environment and forest ecosystems, such as the forest floor and canopy destruction. The application RIL is expected to reduce the negative impacts of logging operation using bulldozers in land clearing and forest canopy. The application of RIL method using bulldozers through intensive supervision produces a removal trail of around 5 m. Muhdi (2008) states that losses inflicted by removal using bulldozers results in destruction towards forest vegetation and soil physical condition, that is, soil compaction that will, in turn, destroy the soil structure. Efforts to reduce soil uncovering have been conducted by sharpening the log stems/edges (round shaped) to enable them to get through the standing trees during removal operations. This, in turn, will give positive impacts as the uncovered line using the mono-cable winch is much smaller than that using a bulldozer (sized just a log diameter wide). Expansion of the removal access road only occurs at the final stage located on the primary logging road, crossing or branching roads where all logs are stacked, up to five meters (Ruslim 2011). Using innovative equipment such as, mono-cable winch systems, that slides logs along the forest floor with long cables, reducing the damage to the soil and residual stands (TNC 2010).

In conclusion, Increase of the mono-cable winch engine capacity from 20 HP to 26 HP resulted in increasing of logs skidding productivity around 20.3%. Relatively small damages using mono-cable winch on forest floors induced by logs skidding on top soil and injured with bark scratched intensity for residual stands. Simple innovations on the utilization of used and waste material into bulldozer maybe applied as skidding machine. Uses of this technology are cost efficient, locally made and have environmental benefits. Future effective use of mono-cable winches implements cost effective ways for RIL. The use of timber products will only increase so the development of more effective ways for RIL is paramount to continued protection of diversity in tropical rain forests. With improvements from the mono-cable winch, improving productivity while reducing damage to the logging area, we have started on a better path to finding an amicable solution for conservationists and the needs of an ever growing population.

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