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Assessing Timber Extraction by Using the RIMBAKA R2020-A Timber Harvester on a Steep Terrain in Ulu Jelai Forest Reserve, Peninsular Malaysia

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ABSTRACT

In this study, the extraction operation of a RIMBAKA Timber Harvester R2020-A on steep terrain was investigated. A continuous time study was carried out to estimate the operational efficiency of the RIMBAKA timber harvester. Four dependent variables were observed to investigate their impacts on the extraction phases: skidding distance, hauling distance, volume and slope. A total of 48 working cycles were time studied. During the operation, RIMBAKA extracted 3.55 m^3 of logs per cycle and had a machine utilization rate of 78%, with a corresponding productivity of 45.92 m^3/PMH_{15}. The unit cost of RIMBAKA was RM 4.64/m^3. Meanwhile, hauling distance and log volume had a major effect on the productivity of the harvester during the extraction phase. Thus, a better understanding of the integrated effect on the productivity of the RIMBAKA extraction operation, in combination with the rest of machines of the harvesting system, will better help predicting the efficiency and productivity of the whole system.

Keywords: Cost estimation, cycle time, production rate, RIMBAKA, timber extraction

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INTRODUCTION

Decisions regarding the type and configuration of the machines used in timber harvesting operation must be considered during the planning phase to assess their impacts on the economic returns of the harvesting system. An application of reduced impact logging (RIL) machinery in Peninsular Malaysia forest harvesting

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showed that the overall harvesting cost was increased by 57.4% (Abdul Rahim *et al*., 2009). This high cost precluded the use of RIL equipment and favoured the use of conventional ground base skidder machinery, regardless of the environmental constraints, due to their low investment cost and the larger productivity achieved by the more experienced operator (Pinard *et al*., 2000).

The deforestation rate in Peninsular Malaysia increased by 69% from 19.01 million ha in 1999 to 5.89 million ha in 2010. This situation resulted in timber harvesting operations moving from lowland forests to hilly forests. Due to the impacts of harvesting operations on sensitive sites, a number of efforts have been made by forestry agencies to sustainably harvest forest management units (FMU). Consequently, guidelines have been developed to conduct harvesting operations in the production forest areas (Kamaruzaman & Dahlan, 2008). Since the early 1990s, such efforts have included the introduction of low impact timber harvesting practices particularly for log skidding (Wan Mohd & Mohd Paiz, 2003).

The RIMBAKA Timber Harvester R2020-A (RIMBAKA) was developed and introduced in 2001 to skid logs from rocky and deep narrow corridors, which were difficult and dangerous to operate for conventional ground base skidders. RIMBAKA is a cable skidder machine (Fig.1) operated on steep terrain, and it is

Fig.1: The RIMBAKA Timber Harvester R2020-A

equipped with a winch system and chocker to haul logs from the stump to roadside landings, where conventional ground base skidders cannot operate. The machine is a modified excavator with an added winch set that acts as a cable skidder for log hooking using the ‘fishing’ concept. Thus, it is a ground base machine that uses a cable extraction system that helps diminish the environmental impacts during the timber harvest operation (Baker *et al*., 2007). Yet, RIMBAKA has its own criterion to be chosen as an acceptable skidder machine in timber harvesting operation such as the operational efficiency of its application in terms of economic profits.

The efficiency of machine can be obtained from previous productivity and cost studies (Bavaghar *et al*., 2010). According to Palmroth and Holtta (2004), it is necessary to calculate the efficiency of the machine operating in various topographic and stand conditions. Effectiveness, flexibility and ease of use for operators have been considered in some previous studies for the calculation and analysis of machine costs (Parsakhoo *et al*., 2009). The three factors mentioned above are pivotal when selecting the most suitable machinery in timber harvesting operations (Acar & Yoshimura, 1997). This paper, which is based on time study data collection, was carried out to analyse and examine the production rate and cost of the RIMBAKA operation on a steep terrain timber harvesting operation.

MATERIALS AND METHODS

Study area

The study was carried out at compartment 484 of the Ulu Jelai Forest Reserve (UJFR), located in the Kuala Lipis district of the Pahang state within a 71 ha concession area (see Fig.2). Approximately 4703 m^3 of logs were extracted. This harvesting area was predominantly composed of dipterocarp species such as *Shorea leprosula, Shorea parvifolia* and *Shorea curtisii.* The elevation ranged from 180 m to 680 m, with a maximum slope of 81 degree. The annual precipitation ranged between 150 mm-200 mm, whereas the minimum and maximum temperatures recorded were 15.5^0C and 24.4^0C, respectively. Typically, RIMBAKA and excavator machines used for road work excavation are employed as extraction machines.

Data Collection

A continuous time study for each of the RIMBAKA’s work elements was conducted on 48 extraction cycles. The work elements recorded were travel empty, releasing winch, hooking and unhooking, hauling, travel loaded, sorting and positioning. The times were measured manually using a stop watch and transcribed into hard copy form at the study area. The operation was also filmed using a video camera, and the footage was reviewed in the office in case the manual time records were incomplete (Nakagawa *et al*., 2010). The variables recorded for the extraction operation were hauling distance, skidding distance, log volume and slope.

Estimating Production Rates and Costs

Production rates and costs were estimated by cycle time and variables input recorded in the field. In addition, interviews were conducted with the machine operator and contractor. Productivity was obtained by dividing the volume of log extracted and the time per cycle, and it is expressed in m^3/PMH_{15} (where PMH corresponds to productive machine hour, including delays that do not exceed 15 minutes). Machine rate was calculated from fixed and variable costs (including operator wage) and expressed in Ringgit Malaysia (RM), as shown in Table 1. The RIMBAKA unit cost was calculated following the methodology proposed by FAO (1992).

TABLE 1
Cost calculation for the RIMBAKA operation

Machine Information	Value
Purchase price (RM)	750,000
Salvage value (RM)	150,000
Life in years (yrs)	10
Scheduled hour / yr (SMH)	1,589
Repair & Maintenance (% of Depreciation)	80
Labour fringe benefit factor (% of wage)	30
Expected utilization (%)	70

RESULTS AND DISCUSSION

The production rate of the RIMBAKA ranged from 9.8 to 129.7 m^3/PMH_{15}. From the regression analysis carried out, hauling distance and volume were found to have a significant effect on the Residual Mean Squares (RMS) of the response variable productivity. The following productivity equation was developed from the RIMBAKA's time study data:

Productivity (m^3/PMH_{15}):
$$50.3846 - 1.0186_{hauling\ distance} + 6.2198_{volume}$$
R^2: 0.4203

The correlation coefficient (R^2) of 0.4203 indicates that hauling distance and log volume explain 42% of the variability of productivity. The ANOVA table (Table 2) shows that the estimated productivity equation is significant at $\alpha < 0.05$.

These results indicate that a larger extraction log volume and shorter extraction distance result in an increase of productivity. These results are consistent with those of Wang and Haarlaa (2002) who found that the time variation and productivity varied roughly in a linear fashion with log size. In addition, variation in the slope condition impacts the time required for hauling and subsequently reduces the production rate (Akay *et al.,* 2004). In comparison

TABLE 2
ANOVA table for production rate estimation- Overall goodness of fit

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	18867.841	2	9433.920	18.037	.000(a)
Residual	23536.917	45	523.043		
Total	42404.757	47			

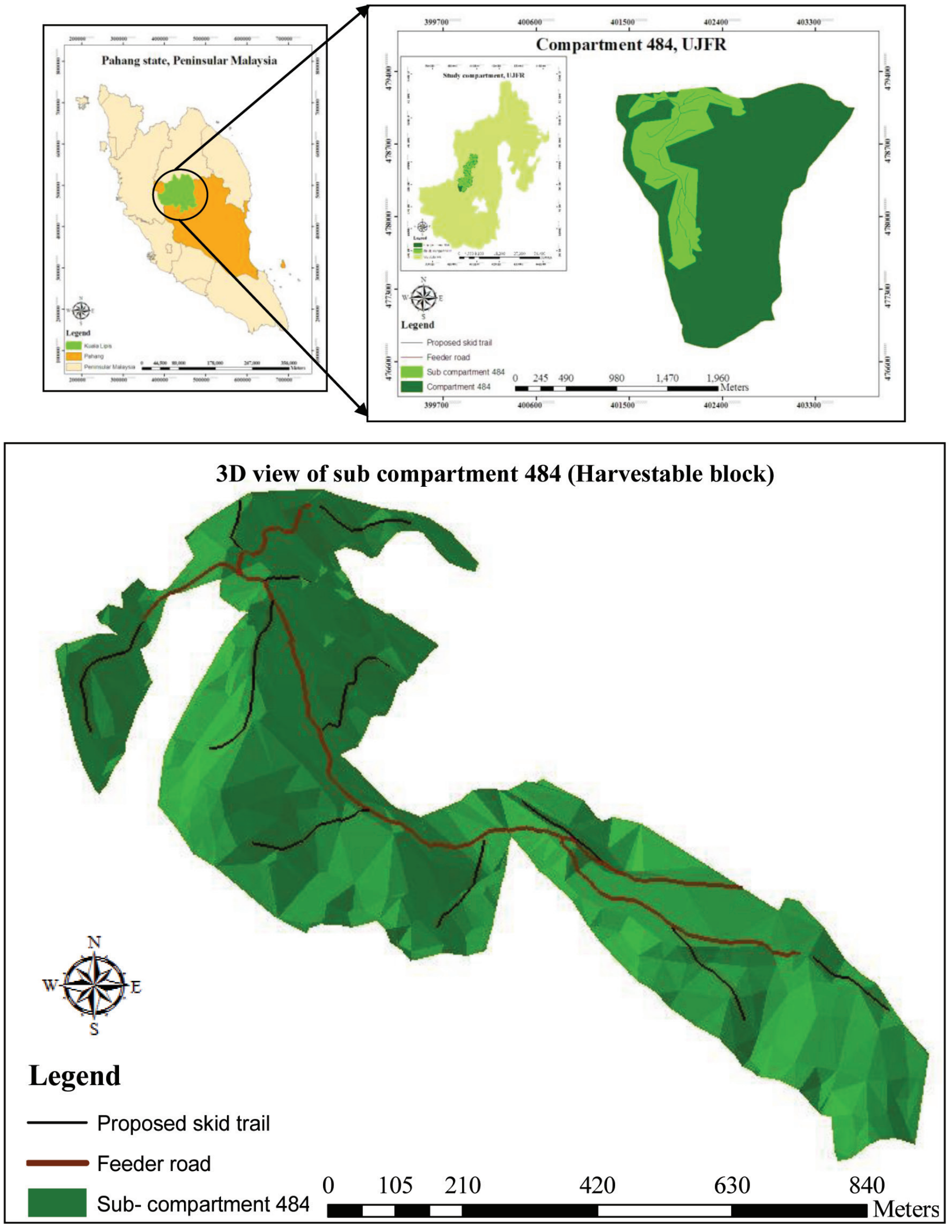

Fig.2: The field study of Compartment 484 located at UJFR, Kuala Lipis, Pahang

to conventional ground based skidding systems working on steep terrain, the productivity of RIMBAKA is averagely bigger than those reported in the previous studies. For example, Saharudin *et al.* (2004) reported a productivity of 45.88 m^3/ PMH_{15} for ground based skidders working in similar conditions. The large production rate and efficient working operation of the RIMBAKA in this study can be explained by the improved technology and machine performance, as well as by the experience (more than 10 years) of the operator (Spinelli & Magagnotti, 2010; Barreto *et al.,* 1998). With a weight of up to 26 tonnes and track width of 3.5 m, RIMBAKA is able to operate efficiently and perform better in log skidding even in undulating slope conditions. This can be explained by the increment of rolling resistance and total load which is evenly distributed to the bogie track over the total contact area, resulting in improved machine traction (Rieppo *et al*., 2002). Eventually, the productivity equation derived from this study may be used to predict the productivity of RIMBAKA and to determine the best practice of machine operation in different harvest areas. However, given that the study results are based on just one trial, the production equation derived may have a limited use when applied to different forest stands with different topographical condition and stand composition. A further investigation should be conducted in different timber harvesting operation areas in order to capture enough variability from the outcomes derived when using different predictive variables (Bavaghar *et al*., 2010).

The operation with RIMBAKA resulted in an hourly and unit cost of RM 213.14/ SMH, and RM 4.64/m^3, respectively. This unit cost value is substantially larger than RM 0.58/m^3 reported by Saharudin *et al*. (2004). This situation is explained by the high initial investment cost, as well as the operational costs associated with higher rate fuel consumption, and more frequent maintenance of bogie tracks, winch drum and winch wire. Akay *et al.* (2004) and Barreto *et al.* (1998) pointed out that harvesting operational and investment costs could be recovered when the equipment operate efficiently. In a study conducted by Holmes *et al*. (2002), it was found that the RIL practice resulted in reduced costs and a 45.7% net profit margin, as compared to only 38.6% net profit margin of a conventional operation. In summary, it is expected that the extended application of advanced RIL technology on steep terrain timber harvesting will result in cost reduction and help protecting other forest values and maintain the forest stand composition.

CONCLUSION

The production rate was found to be primarily affected by hauling distance and log volume. With a rough production rate of 45.92/PMH_{15}, the study conducted on RIMBAKA has shown that the application of improved technology in conjunction with RIL practices can lead to more sustainable forest management during timber harvesting operations. Extraction hourly and unit costs of RIMBAKA were RM213.14/ SMH and RM 4.64/m^3, respectively, and these costs can be reduced with a higher production rate. Among other advantages, the RIMBAKA harvester is more eco-friendly while working on steep terrain and this can help preserve the forest resources for the benefits of future generations. With its capability to haul logs much further from the stump area, a reduced optimum density of forest road and minimum forest canopy opening is anticipated to be attained with RIMBAKA. Consequently, this saving in site preparation planning can contribute towards the overall cost reduction in forest operations. A comprehensive study of all the machines in the whole timber harvesting system may strengthen the predictive equation derived in this study, whilst cost constraints assumption can be verified according to the best management practice applied and may be useful for helping forest manager to make the best decision according to the type of machines and harvesting practices that are chosen.

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