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Full Length Research Article

Time Consumption and Productivity of Motorbike Timber Extraction in Private Forests

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ABSTRACT

Timber extraction in private forests in Indonesia is carried out using appropriate technology. Motorbike extraction is one of the means of timber extraction widely used in private forests in Indonesia. This research aimed to analyze the working time and productivity of timber extraction using motorbikes in private forests. The research was conducted in a private forest in Probolinggo, East Java. The terrain conditions at the study site were partly flat and partly rather steep. The study site can only be accessed through a footpath that is 2 m wide. Observations were made on three motorbikes. The number of trips for each motorbike was 11 trips. The skidding distance was 300 m. Data on timber extraction work time were obtained through video analysis. Production data on timber extraction were obtained through direct measurements in the field. The research showed that the work time spent to transport timber from private forests using motorbikes was 18.18 minutes per trip. The loaded travel spent the highest working time, followed by the empty travel, logs stacking, unloading, and traveling to logs. The efficiency of timber extraction using motorbikes in private forests was 82.11%. The productivity of timber extraction was 0.61 m^3/hour or 0.002 m^3/hour.m.

1. Introduction

Private forests are forests that grow on land that is encumbered with property rights (KLHK 2021). The characteristics of private forests in Indonesia are narrow areas, fragmented, managed by the owners themselves, and limited capital (Apriyanto et al. 2016; Hardjanto 2017). According to KLHK (2015), the area of private forests in Indonesia is 34.8 million ha. There are three types of private forest cultivation in Indonesia: monoculture, mixed forest, and agroforestry (Nadeak et al. 2013). The types of plants developed in private forests consist of forestry plants, multi-purpose tree species, plantation plants, and agricultural plants (Oktaviyani et al. 2017). One species of forestry plant that is most widely planted in private forests in Indonesia is sengon (*Falcataria mollucana*) (Wijayanto and Briliawan 2022; Wijayanto and Tsaniya 2022). The need-cutting system is a common harvesting system applied in private forests (Nugroho et al. 2017). The steps of private forest harvesting consist of tree felling, debranching, bucking, skidding (timber extraction), and hauling (Dalya et al. 2020).

Timber extraction is the process of transporting felled wood from stumps to landing or road sites (Staaf and Wiksten 1984). Timber extraction can be done in various ways, including using

human power, animals, gravity, skidding or yarding, and cables (Dulsalam 2012; Gilanipoor et al. 2012; Kortoci and Kortoci 2021; Qazi and Mirkala 2016; Terinov et al. 2021). The timber extraction system used in private forests differs from that in natural or industrial plantation forests (Stańczykiewicz et al. 2021; Sukadaryati et al. 2018). Factors that influence the choice of timber extraction system are the annual cutting allowance, wood volume, terrain, climate, silvicultural considerations, skidding distance, and the dimension of the wood being skidded (Ghaffariyan 2022; Gilanipoor et al. 2012).

Initially, timber extraction in Indonesia was carried out using human and animal power. Several types of animals have been used for timber extraction in Indonesia, namely cows, horses, buffalo, and elephants (Abbas 2021; Tinambunan 2008; Tinambunan and Sukadaryati 2009). Timber extraction using human power is still used in forest harvesting operations in Indonesia, either in natural forests, plantation forests, or private forests (Endom and Basari 2001; Suhartana et al. 2009). The use of animals in timber extraction in Indonesia is currently rare. As a substitute, the means of skidding are motorbikes, winches, and cable systems (Basari 2010; Dulsalam 2012; Ruslim 2011).

Working time and productivity are measures often used to assess the efficiency of a production process. Working time studies aim to measure working time at work locations, which is then used to improve the efficiency of the working operations (Staaf and Wiksten 1984; Szewczyk and Sowa 2017). Meanwhile, productivity is needed to choose the type of equipment that will be used in a production process. In timber extraction activities, working time and productivity are the main concerns in balancing profitability and sustainability (Kulak et al. 2017; Yoshimura et al. 2023). Many studies have been conducted regarding the working time and productivity of skidding operations and the factors influencing them. Several studies have revealed that the working time and productivity of timber extraction are influenced mainly by skidding distance, slope, volume, and wood size (Berg et al. 2017; Gilanipoor et al. 2012; Kaakkurivaara and Kaakkurivaara 2018).

Timber harvesting in fragmented privately owned forests is mostly based on motor-manual technology, with the majority of manual labor used, both at the felling, bucking, and transportation stages. Timber transport in such forests can be done using motorbikes (Stańczykiewicz et al. 2021). Transporting wood using motorbikes has reportedly been used in many countries such as Czech and Poland (Kincl 2022; Stańczykiewicz et al. 2021). Motorbikes began to be used in timber extraction operations in Indonesia in the 1990s, especially in the harvesting of industrial forest plantations and private forests on the island of Java. The motorbikes used are modified motorbikes, which are designed for use on steep and difficult terrain and in areas where there are no adequate transport roads. This modified motorbike has a load support device made of wood or iron (Basari 2010; Sukadaryati et al. 2018). In addition, motorbikes are designated as a mode of long-distance transport for ironwood (locally known as "*ojek ulin*") in Tanah Laut District based on Regional Regulation Number 35 of 2005. The longest allowed size of ironwood transported was 1.5 m (Nugroho et al. 2019).

Working time consumption in timber extraction is needed to determine a working time that meets the requirements following predetermined work standards and improve the effectiveness of using time to extract timber from the felling site to the landing. Previous research had been carried out in industrial plantation forests with pine and private forests where the tree species to be felled was gmelina. The research provided an incomplete distribution of skidding time consumption. (Basari 2010) conducted a study in industrial plantation forests with pine only presented the total

time per cycle of timber skidding using motorbikes. In contrast, Sukadaryati et al. (2018) conducted research that emphasized productivity issues and the costs of skidding wood using motorbikes. On the other side, even though timber extraction using motorbikes has been used widely in private forest harvesting, there is still very little information about the working time consumption and productivity of timber extraction. Therefore, this research aims to comprehensively analyze working time consumption and productivity of timber extraction using motorbikes in private forests.

2. Materials and Methods

2.1. Research Site and Materials

This research was conducted in a private forest partnership between the Bromo Mandiri Private Forest Cooperative and the wood processing industry in Probolinggo, East Java. The research site is located in Patalan Village, Wonomerto District, Probolinggo Regency, East Java. The research is located at an altitude of between 87 and 1,400 meters above sea level. The terrain conditions at the research location are flat (slope < 20%) and rather steep (slope > 20%) (KBM 2022). The private forests observed were monoculture private forests. The types of trees cultivated are sengon (*Falcataria moluccana*) and balsa (*Ochroma grandiflorum*). This private forest was cut using a clear-cutting system. The felled trees were bucked into short wood with a minimum diameter of 10 cm and a uniform length of 130 cm. The area of observed private forest was 0.02 ha. The distance for timber extraction was 300 m. The skidding path was 2 m wide and had a mostly flat slope. This path was muddy and slippery after the rainfall (**Fig. 1**). This research was carried out from January to March 2023.

Fig. 1. Modified motorbike used for timber extraction in private forests in Probolinggo.

The type of tree species cut was sengon. Tree felling was carried out using a chainsaw (Maestro Plus, CS6500L, China). After felling, the stems are bucked directly in the cutting area. The logs are then transported using motorbikes to the landing, which is located on the side of the public road. Three motorbikes were used to transport logs to the research site. The motorbikes used were Japanese-manufactured motorbikes with engine capacities of 100–110 cc, which were

more than 5 years old. The gear and tires of the manufactured motorbike were replaced with a size larger than the standard size. The motorbike's rear is equipped with 2–4 additional shock absorbers. The addition of this shock breaker aimed to increase the capacity of the motorbike's suspension. The modified motorbikes observed in this research were motorbikes that loaded wood on the back. The transported logs were placed crosswise and tightened using rubber straps from used inner tubes.

2.2. Time Study

Time study is a systematic study of observing and recording the time for each element or cycle using a prepared tool. The time study was carried out based on video images that were taken during timber extraction operations in the field. This did not interfere with the operator's work style. Motorbike activity was recorded by a digital video camera (Canon, EOS M100, Japan). It captured the movements of the motorbikes and the driver when transporting logs from the felling site to landing and returning from landing to the felling site.

Based on observations of the uniform pattern of timber extraction using motorbikes in private forests in Probolinggo, there were five work elements of timber extraction, namely traveling towards timber (Tt), stacking timber on the motorbike (St), loaded travel (Lt), unloading timber from a motorbike (ULt), and empty travel (Et) (**Table 1**).

Table 1. Work elements of timber extraction using motorbikes in private forests

Work element	Start	Finish
Traveling toward logs to be loaded	The operator starts traveling toward the timber	The operator stopped at the timber
Stacking logs on the motorbike	End of previous work element	The operator finished stacking the logs on the motorbike
Loaded travel	End of previous work element	The operator stopped at the landing
Unloading logs from motorbike	End of previous work element	The operator deposited the last log at the landing
Empty travel	End of previous work element	The operator arrived back at the cutting site

The working time structure used was working time at the workplace (WP) (Bjorheden and Thompson 1995), which in this case was at the timber extraction site. WP consisted of time for work (WT) and time not for work (NT). WT was the time used to complete the work cycle, while NT was the time spent on an activity outside the work cycle. WT consisted of productive work time (PW) and supporting work time (SW). PW consisted of main work time (MW) and complementary work time (CW), while SW consisted of preparation time (PT), time related to delays of the means of skidding used (ST), and additional time (AW) (**Fig. 2**).

2.3. Work Sampling

Data adequacy was tested by comparing the minimum amount of data required (N') with the number of preliminary measurements that have been carried out (N). The number of measurements is sufficient if N' $\leq$ N (Sutalaksana 2006). The number of preliminary measurements that have been carried out was 33 cycles. The test showed that with a confidence level of 90%, an N' value of 16 was obtained. Thus, the preliminary measurements were sufficient and can be used for working time analysis.

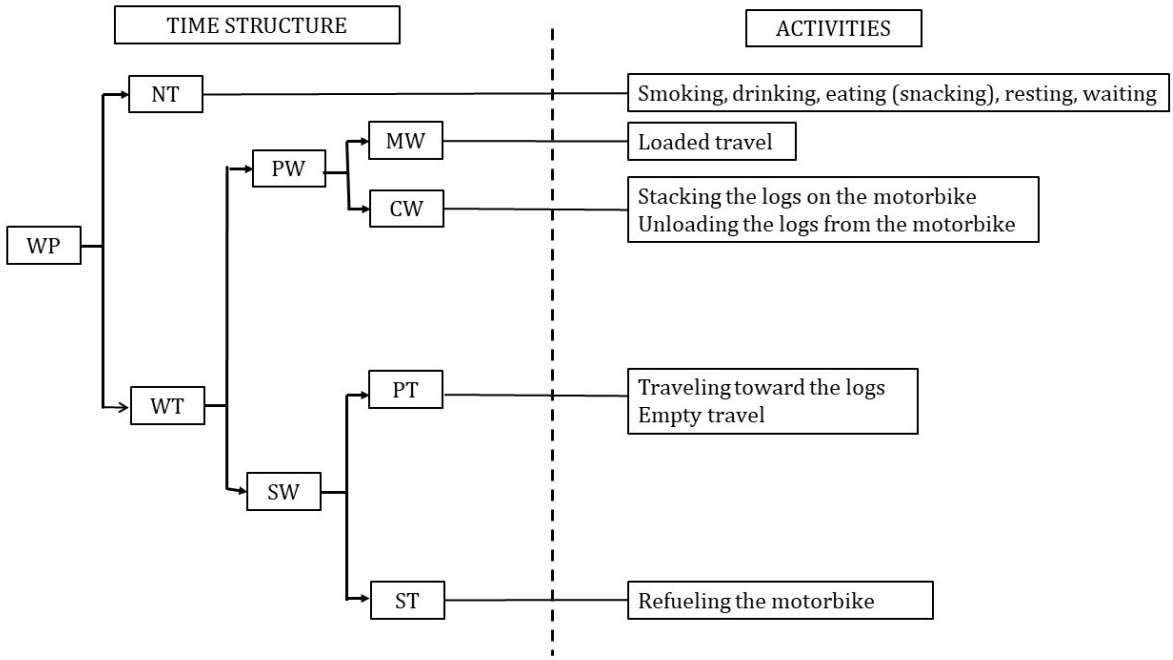

Fig. 2. Time structure and timber extraction activities using motorbikes in private forests (Bjorheden and Thompson 1995).

2.4. Productivity

Production of timber extraction was calculated based on the total volume of logs skidded from the cutting site to the landing. Measurement of diameter and length of logs referred to Indonesian National Standard number 7533.2.2011 concerning the measurement and volume table of logs. The volume of logs was determined based on the volume table for species other than teak (known as "*Kayu Rimba*") (BSN 2011). The productivity of timber extraction was the ratio between timber extraction production (m^3) and the time spent on timber extraction (hours) (Borz et al. 2023).

2.5. Data Analysis

This research used descriptive data analysis. Descriptive analysis is a statistical analysis method that provides a description or overview of research subjects based on variable data obtained from certain subject groups (Hastono 2006). Data from the research were presented in the form of tables, histogram tables, and average and percentage values. Data on the working time were grouped based on working elements and working time structure.

3. Results and Discussion

3.1. Results

The total number of timber extraction cycles by motorbike in the sengon private forest was 33 cycles, and the total volume was 6.08 m^3. The total working time for timber extraction by motorbike was 599.88 minutes, consisting of a working time of 487.33 minutes and a non-working time of 112.55 minutes. Thus, the efficiency of extracting sengon with a motorbike was 81.22%. The non-working time of timber extraction included chatting, eating, drinking, resting, and

waiting. Of the total working time, 324.87 minutes was productive time and 162.10 minutes was supporting time. The working time consumption for skidding sengon wood using a motorbike based on the time structure is presented in **Table 2**.

Table 2. Distribution of timber extraction working time using a motorbike based on time structure

Motorbikes	Number of trips	Working time (minutes)					
		PW		SW		NT	WP
		MW	CW	PT	ST		
1	11	62.57	46.90	43.07	7.65	41.85	202.04
2	11	61.73	47.00	48.66	6.20	32.80	196.39
3	11	60.67	46.00	49.78	7.10	37.90	201.45
Total	33	184.97	139.9	141.51	20.95	112.55	599.88
Total PW and SW		324.87		162.10		-	-
Average per trip		5.61	4.24	4.29	0.61	3.41	18.18
Percentage (%)		3.83	23.32	23.59	3.49	18.76	100

Notes: PW = productive work time, SW = supporting work time, MW = main work time, CW = complementary work time, PT = preparation time, ST = skidding used, NT = time not for work, WP = workplace.

Based on the work elements, the loaded travel spent the highest working time (184.97 minutes), followed by the empty travel (104 minutes), stacking timber on the motorbike (94.33 minutes), unloading the log from the motorbike (45.57 minutes), and finally traveling to logs (37.51 minutes) (**Fig. 3**). The average working time for timber extraction using a motorbike with a skidding distance of 300 m was 18.18 minutes per cycle. Traveling to the logs took an average of 1.14 minutes per cycle (7.70% of the total work time). Stacking logs on the motorbike required 2.86 minutes per cycle (19.36%). On average, it took 5.61 minutes per cycle (37.96%) to carry logs using a motorbike from the cutting site to the landing. Unloading logs from a motorbike took 1.38 minutes per cycle. The time required to return to the cutting site without a load is 3.15 minutes per cycle. Refueling the motorbike took approximately 0.63 minutes per cycle. The average speed of a motorbike was 3.18 km/hour when loaded and 5.7 km/hour when empty.

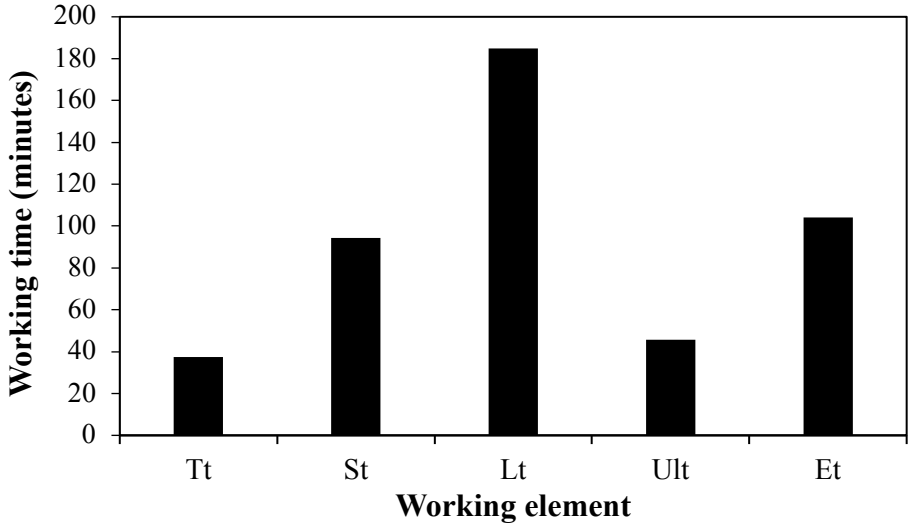

Fig. 3. Distribution of timber extraction time using a motorbike based on work elements (Notes: Tt= traveling toward logs to be loaded, St= stacking logs on the motorbike, Lt= loaded travel, ULt= unloading logs from a motorbike, and Et= empty travel).

The average diameter of the logs transported was 15 cm, varying between 7–22 cm. The length of the logs transported was uniform, namely 1.30 m. The number of logs transported per motorbike varied from 6 to 15, with an average of 10. The average volume of wood transported per cycle was 0.18 m^3, varying from 0.10 to 0.28 m^3. The average productivity of timber extraction using a motorbike was 0.61 m^3/hour, varying from 0.55 to 0.72 m^3/hour (**Table 3**).

Table 3. Productivity of timber extraction using motorbikes in the private forest in Probolinggo

Motorbike	Number of trips	Working time (minutes)	Number of logs (pieces)	Volume (m^3)	Productivity (m^3/hours)
1	11	202.04	103.00	2.42	0.72
2	11	196.39	123.00	1.80	0.55
3	11	201.45	113.00	1.86	0.55
Average		199.96	113.00	2.03	0.61
Average per trip		18.18	10.00	0.18	0.61

3.2. Discussion

Research on timber extraction using motorbikes in private forests in Indonesia that discusses working time consumption is very limited. This research is the first to discuss the distribution of work time for timber extraction in private forests in Indonesia in detail. The study showed that 18.78% of the total work time was spent on activities unrelated to timber extraction, such as chatting, waiting, eating, drinking, and resting. A potential cause for this situation included the fact that the previous stages of forest harvesting, such as tree felling or wood processing (bucking), have not been completed. At the same time, the skidding operators have arrived back at the cutting site after transporting the logs to the landing. Previous research showed that the amount of non-working time on wood extraction varies, depending on the location, nature of the terrain, skidding distance, and extraction system. The non-working time of wood extraction using a traditional cable car in Albania was 18.50% (Kortoci and Kortoci 2021), while wood extraction using a forwarder in Argentina varied from 24–40% (Hildt et al. 2020).

The completion of timber extraction in private forests in Probolinggo was not determined based on a time-based system but on a piecework system. Timber buyers of private forests set wages for timber skidding based on the volume of logs to be extracted at a certain price, and it will be paid if all the logs at the cutting site have been transported to the landing. Mujetahid (2009) reported that the piecework system is a wage system that generally applies to private forest management activities, including timber extraction. Wages for forest harvesting workers are calculated using a piece rate system according to the volume of felled trees. Wages for piecework in timber extraction are expressed in IDR/m^3.

The research showed that the average time for loaded traveling was 40%, and the remaining time (60%) was for other work elements such as empty travel, traveling to the logs to be loaded, stacking the logs, and unloading the logs. This study obtained data on the distribution of timber extraction similar to that of the research conducted in the Czech Republic. Kincl (2022) researched the working time of timber extraction using four-wheeled motorbikes (known as all-terrain vehicles (ATVs)) in areas with slope < 10 in the Czech forests bordering Poland. The research results showed that the total average skidding time per cycle was 22.53 minutes, of which an average of 40% was loaded traveling time and 60% was loading and unloading the logs. The

skidding distance was 480 m. The research also showed that the total skidding cycle time is influenced mainly by the skidding distance and the number of logs loaded.

The productivity of timber extraction using motorbikes in private forests in Probolinggo was 0.61 m^3/hour for a skidding distance of 300 m or 0.002 m^3/hour.m. The results of this research were smaller than the results of Basari (2010) and similar to the results of Sukadaryati et al. (2018). Basari (2010) reported that the average productivity of pine timber extraction using a motorbike was 1.58 m^3/hour for every 100 m skidding distance or 0.02 m^3/hour.m, while Sukadaryati et al. (2018) reported that the average productivity of skidding gmelina using a motorbike was 0.85 m^3/hour with a skidding distance of 400 m or 0.002 m^3/hour.m. Differences in the productivity of wood extraction were mainly influenced by wood diameter and skidding distance. The diameter of the extracted wood in the research of Basari (2010) of 17 cm, was greater than in this study (15 cm), as well as the skidding distance. Meanwhile, the diameter of extracted wood in Ciamis was not much different from that of this study. Previous studies revealed that increasing the wood diameter and skidding distance causes a decrease in the productivity of timber extraction (Borz et al. 2023; Kulak et al. 2017; Nikooy et al. 2013).

Wood extraction in private forests has been carried out manually using human power. Using motorbikes is a new way of extracting wood in private forests. However, the use of motorbikes has proven to be a helpful way to facilitate wood extraction in private forests. The results of this research are expected to contribute to the development of forest harvesting science, especially the development of appropriate wood extraction systems in private forests under socioeconomic, environmental, and resource conditions around private forests. Private forest harvesting, including wood extraction, is generally carried out by harvesting contractors based on a piece rate system. Using motorbikes for wood extraction is more practical than using human power. The results of this research can be used as consideration in selecting wood extraction systems that are cheap, efficient, and environmentally friendly in areas that have low accessibility and limited road network infrastructure.

4. Conclusions

This research was the first to collect detailed time consumption and productivity data on timber extraction using motorbikes in private forests in Indonesia. The research found that the average skidding time per cycle using a motorbike was 18.18 minutes, of which 40% was loaded travel time and 60% was unloading, wood stacking, and empty travel time. The estimated productivity of wood extraction using a motorbike was 0.61 m^3/h. The research was carried out in private forests managed with an agroforestry system with an average slope of < 20%, a skidding distance of 300 m, and the diameter of the wood extracted was small. Meanwhile, private forests vary in silviculture system, terrain condition, wood diameter, skidding distance, and timber species. Developing future studies on the effects of these factors on the time consumption and productivity of wood extraction using a motorbike is necessary. Results of future studies will make it possible to generalize the model of the time consumption and productivity of wood extraction using a motorbike under different operating conditions.

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