SUPPLY CHAIN OPERATIONS IN TEAK PLANTATION

Laddawan Rianthakool, Nopparat Kaakkurivaara, Piyawat Diloksumpun, Wanchai Arunpraparut
Department of Forest Engineering, Faculty of Forestry, Kasetsart University, Bangkok, Thailand - fforlwr@ku.ac.th

Abstract

Teak (*Tectona grandis*) is a valuable wood in Thailand. The suitable sites for teak planting are in the north of country which are mountainous area. The rotation of teak is about 25-30 years. Two or three times of thinning will be implemented along the rotation. Tree length with motor-manual operations are dominated for Teak in Thailand. The objective of this study was to investigate and analyze the teak harvesting to improve the efficiency of wood supply chains. The results explained the combination of logging systems currently used in teak plantation. The appropriate systems are described.

Introduction

Teak (*Tectona grandis*) is the most valuable kinds of timber in Thailand. Teak is a very stability, good strength, elegance and easy workability wood which used for making housing, furniture, as well as other wood products. Teak is most commonly found in the north of Thailand which is humid area (annual rainfall of 1000 to 2000 mm), sandy loam soils, and good drainage (Royal Forest Department, 2010). The rotation of teak is about 25-30 years. There are two or three thinning of the stands. In 2016, the exported teak including logs and sawn timber from Thailand was 213 m³ or equivalent to 0.92 million USD, where the imported teak is more than 360,000 m³ or 23 million USD (Customs Department, 2016). The most of teak plantation areas are belong to Forest Industry Organization (FIO) which is the only forestry state enterprise who plant and harvest teak in country. There are 99,200 ha of teak plantation area with an average annual production 68,000 m³ (Forest Industry Organization, 2016). The harvesting of teak in FIO’s plantation has a long history from manual based to mechanization. Traditional tools such as chainsaw, elephant and a frame truck or wooden frame truck are still in used. Corvanich (1981) explained the elephant can be skidding timbers vary from 150 to 600 m³ a year (July - February) depending on the terrain difficulty. There are various extraction methods by using elephant in logging, but the single skidding or single hauling is the most common. Frame truck or wooden frame truck or sometimes called winch truck is a self-loading truck use for short distance transportation of timber from forest to landing. Manavakun (2008) studied the productivity of this frame truck in teak plantation, results revealed the productivity was 4.029 m³/h and unit cost was 2.24 USD/m³. However, there are not many papers dealing with the efficiency of teak supply chain operations from the forest to the landing. Thus, the aim of this study was to investigate and analyze the teak harvesting to order to improve the efficiency of wood supply chains. Productivity (m³/h) and costs (USD/m³) of each operation were calculated.
Material and methods

The combination of logging systems which used in teak plantation are tree felling with chainsaw, then logs are skidded by elephant and farm tractor, afterwards logs are transport from roadside to landing by frame truck (Fig. 1). The data collection was conducted in Forest Industry Organization (FIO)’s teak plantation in Phrae Province, Northern Thailand. The data was collected from Mae Sroi, Wang Chin, and Khun Mae Kham Mee plantations, all study sites were located between 190 and 350 meters above sea level. The data was collected during January - July in 2017.

![Teak harvesting equipment](image)

**Fig. 1** Teak harvesting equipment a) chain saw b) farm tractor c) elephant d) frame truck and e) branding hammer.

The study applied time study to determine the work cycle in each operation, by using continuous time technique. Stopwatch, handheld GPS, measuring tape, calipers and video recorder have been using for measuring variables including time. Total effective time and log volume per work cycle were calculated, and then estimate the productivity. The cost of supply chain from felling to landing was calculated by FIO’s guideline. A method of estimating the cost was based on machine usage cost in each operation previously (Table1). The cost in Table 1 was calculated for a year. There were two workers in felling operation to fell 10,000 trees or about 3,000 m$^3$ within 143 days. Transportation cost mean worker’s transportation to access the workplace. Due to the lack of labor in forest operation, FIO’s compensation committees has been considered an allowance cost 30% of total basic cost in every operation. The estimated costs per volume were considered by the committees to make a reasonable cost in the area. Fuel cost for elephant skidding means the average cost of food and medicine. The average of working days for elephant was 7.5 month in a year. The cost of transportation with the frame truck and the farm tractor, which used to spread logs in the landing, were estimated together by FIO’s guideline. In this study, the number of sample were 105 work cycles for chainsaw felling, 50 work cycles for elephant skidding, 40 work cycles for tractor skidding, and 20 work cycles for frame truck. Operations in landing started with rearrangement of log pile into line using farm. There were 25 work cycles of this farm tractor operation. The logs were measured, bucked, stamped, and recorded in a log book manually. The number of samples were 57, 62, 48, and 193 work cycles, respectively. Eventually, similar logs size were piled together by farm tractor.
The average effective productivity of felling was 29.81 m³/h (without delay). Average stump diameter, log length, and log volume were 32.39 cm, 13.04 m, and 0.86 m³, respectively (Table 2). The average productivity of primary extraction by elephant was 11.11 m³/h with skidding distance shorter than 100 m. There were average 2.75 logs or 0.68 m³ per work cycle. The productivity of
secondary skidding by farm tractor was 17.52 m³/h. The farm tractor hauled 3 logs or 2.02 m³ per work cycle, with average 353 meters of skidding distance. The average productivity of short distance transportation was 9.23 m³/h, with average 1.77 kilometers of transporting distance.

Initially, teak logging operation was time-consuming because of the different performance of tools used in each operation. The result showed that the high productivity in felling stage but low productivity in extraction and primary transportation stages. Low productivity rate in the extraction and the short distance transportation lead to logs stored in the plantation or bottleneck problem. Although elephant skidding provides lower productivity compared to mechanization such skidder, but elephant cause less damages to the ecosystem (Food and Agriculture Organization, 2016).

The ways to reduce a waiting time of logs in the forest is to improve the work efficiency, especially in the extraction and the transportation process. The skidding time with load and without load of elephant were greater than eighty percentage of total productive time. The transporting time with load and without load of frame truck were 21.63 and 21.53 percentage of total productive time, respectively. This result explained that these stages of the supply chain should be considered an optimum transportation distance to reduce the transportation time (Ozturk, 2014). An optimum forest road network and suitable roadside landing may be able to tackle this problem.

Another part of the supply chain which consumed a lot of time is at the landing area. The average productivity of spreading logs by farm tractor was 19.16 m³/h for 4 logs or 1.31 m³ per work cycle. The workers were measure diameter and length of the logs by manual. Average productivity of this process was 330 logs/h. The average productivity of bucking by using chainsaw was 170 logs/h with averaging 20.94 cm of log diameter. There were two stamp hammers; plantation’s identification and serial number of logs. The average productivity of stamping for log identity was 207 logs/h. Average productivity of log recording was 221 logs/h without delay.

Table 2 Summary of productivity and cost of all operations.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Equipment</th>
<th>Number of sample</th>
<th>Productivity</th>
<th>Unit cost USD/m³</th>
<th>Characteristics of related factors</th>
</tr>
</thead>
</table>
| **Felling**     | Chainsaw       | 105              | 29.81 m³/h   | 1.09             | - Avg. stump diameter 32.39 cm  
- Avg. log length 13.04 m  
- Avg. log vol. 0.86 m³ |
| **Extraction**  | Elephant        | 50               | 11.11 m³/h   | 1.38             | - Avg. number of logs/trip 2.75 logs  
- Avg. log vol./trip 0.68 m³  
- Skidding distance < 100 m |
|                 | Farm tractor    | 40               | 17.52 m³/h   | 0.96             | - Avg. number of logs/trip 3 logs  
- Avg. log vol./trip 2.02 m³  
- Avg. skidding distance 353 m |
| **Transportation** | Frame truck  | 20               | 9.23 m³/h    | 4.99             | - Avg. number of logs/trip 9 logs  
- Avg. log vol./trip 4.10 m³  
- Avg. transporting distance 1.77 km |
| **Landing**     |                |                  |              |                  |                                    |
| Dragging logs   | Farm tractor    | 25               | 19.16 m³/h   |                  | - Avg. number of logs/trip 4 logs  
- Avg. log vol./trip 1.31 m³ |
| Log measurement| Manual          | 57               | 330 logs/h   |                  | - Avg. log diameter 17.21 cm  
- Avg. log length 7.76 m |
| Bucking         | Chainsaw        | 62               | 170 logs/h   |                  | - Avg. log diameter 20.94 cm |
| Stamping        | Manual          | 48               | 207 stamps/h |                  |                                    |
| Log accounting  | Manual          | 193              | 221.15 logs/h|                  |                                    |
| Piling          | Farm tractor    | 36               | 10.91 m³/h   |                  | - Avg. number of logs/trip 3 logs  
- Avg. log vol./trip 0.85 m³ |
The unit cost in Table 2 were calculated using the cost per volume from FIO’s guideline and based on the actually productivity from the fields data. The cost of transportation with the frame truck and the farm tractor was 4.99 USD/m³ which the large financial effect on the teak harvesting process. Manavakun (2008) found that the unit cost only the frame truck was 2.24 USD/m³. Although it seems cheaper than the cost of timber haulage in other country, but it could be improving the productivity by applying another machine such as a crane truck with a hydraulically-powered crane that use in other work in Thailand. On the other hand, the cost of manual work in landing was cheaper than other operation while there were many workers worked in this process. According to the innovative technology such as smart applications, new label technology may be the solution to reduce the number of workers and to improve the productivity in the landing.

Conclusions

The results of study showed that the productivity and cost of the most common supply chain in the teak plantation in Thailand. Bottleneck was found between felling and extraction process. Waiting time, non-effective process and transportation were wastes according to the lean concept. These problems can be tackle by increase resource, i.e. machine. Moreover, there are two methods to increase high productivity in the extraction process. Firstly, introduce higher efficiency machine make high production at the same time. Second, reprocessing is to change the process such as extraction by elephant only from the forest to a suitable roadside landing and then move to the landing by the frame truck. In conclusion, to improve the efficiency of the supply chain should be consider the other timber method such as cut-to-length.

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