TECHNIQUES, PRODUCTIVITY AND COSTS OF LOGGING OPERATIONS IN INDUSTRIAL PLANTATION FOREST

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Abstract

The study was carried out to promote environmentally sound, economically feasible and socially acceptable logging operations in Indonesia. It was a case of logging operations in industrial plantation forest by implementing a cut to length method to harvest stands of *Acacia mangium* at the age of eight years with an average tree size of about 0.30 m3 per tree. It was stressed to present organisation and quality of operations and to analyse efficiency of operations in terms of productivity and costs. The results showed that the logging operations had taken care of environmental considerations and were well organised even though they might offer for improvements. In felling, delimbing, bucking and bunching activities, the total costs were 1.82 USD/m3 and the productivity was 4.92 m3/hour with the total working time of 3.66 minutes per tree at the mean volume of 0.30 m3 per tree. In forwarding activity, the total costs were 1.88 USD/m3 and the productivity was 18.60 m3/hour with the total working time of 30.76 minutes per load at the mean volume of 9.53 m3 per load and the mean distance of 378 meters. In transport activity, the total costs were 2.68 USD/m3 and the productivity was 6.42 m3/hour with the total working time of 379.17 minutes per load at the mean volume of 40.57 m3 per load and the mean distance of 64 km. It must be acknowledged that the logging operations provided social advantages to the local people such as job opportunities, agroforestry programs and the fulfilment of other needs.

Key words : logging operations, sustainable forest resources management, productivity and costs, environmental considerations, social advantages.

1. Introduction

Degradation of forest resources is increasing and becoming a major problem in Indonesia. On the other hand, the demand for wood products is rising with the growing population. One way to cope with this problem is by developing a program of large-scale plantations for industrial timber production. The purposes of this program are to increase productivity of degraded forest areas and to provide a continuous supply of raw material for wood-based industries.

Indonesia started regular forest plantations in 1873, mostly in Java with *Tectona grandis* and in 1916 with *Pinus merkusii* in Sumatra. The total area of plantations in 1980 was 2.669.000 ha (FAO, 1981), with the major portion in Java. In 1988, the Ministry of Forestry decided to establish 6.200.000 ha of additional industrial plantation forests in the long run (about 25 years) with an annual planting rate of 2.507.000 ha by state and private companies (MoF, 1996).

The efficiency of the logging operations is very important in the industrial plantation forests. A higher efficiency leads to a higher productivity and lower costs of logging operations. In addition, it should minimise the environmental damages and maximise the advantages of the forest to the local people.

The objectives of study were to investigates and presents the logging operations of an industrial plantation forest in terms of sequence, preparation, organisation and quality of operations as well as in term of employment of workers and occupational safety and health, to analyses the efficiency of logging operations in terms of productivity and costs, and to records shortcomings and provides recommendations in order to improve the quality and the efficiency of the logging operations.

2. Study Area

The company has managed a plantation forest with a total size of 193.500 hectares since 1990. Harvesting was scheduled to start in February 1999. All the wood will be supplied to Pulp and Paper Industry, which started construction in 1996. The mill site is 10

km from the nearest plantation. The mill was fully operational in early 1999 producing 450.000 tons of bleached craft pulp per year.

Logging operations in the industrial plantation forest consist of logging planning, road construction, harvesting and transportation of wood. The logging division is responsible for all logging operations. Logging planning consists of forest inventory, harvesting time scheduling and mapping. Road construction is responsible for constructing, maintaining and upgrading roads, bridges and landings. Wood production covers felling the trees in the stand and extracting (forwarding) the wood to the landing point. Wood transportation consists of loading the wood on the truck at the landing point, transporting it to the mill and unloading it there.

The industrial forest plantation areas are in a lowland humid environment with elevations ranging from 60 to 200 meter above sea level. The terrain of the plantation area varies mostly from flat to undulating and some parts are quite rolling. The daily temperature ranges from 22 ^{o} C to 31 ^{o} C and the average daily temperature is around 27 ^{o} C. The annual rainfall in the last ten years varied between 1.890 to 3.585 mm, the average rainfall was 2.700 mm/annum. The average relative humidity varies from 70% in the dry season to 84% in the rainy season.

The tree species planted are mostly fast growing ones suitable for pulping. *Acacia mangium* is the main species in the company and covers more than 90% of the total plantation area and the other species cover 10%, i.e.: *Paraserianthes falcataria, Eucalyptus spp and Gmelina arborea*.

The silvicultural system commonly used to manage the industrial timber plantations of fast-growing species is clear cutting with artificial regeneration. The logging method commonly applied in industrial plantation forests is the cut to length method.

The stands are harvested at the age of 8 to 10 years. At this age, they have an average diameter at breast height (DBH) of 21 cm and an average total height of 19 meters. The average merchantable height is 16 meters (85% of average total height) until the top diameter of 8 cm. According to the experience of the company, it is assumed that the form factor of *Acacia mangium* is 0,45 so that the average volume per tree is around 0,30 m^3.

The length of the logs supplied to the pulp mill should be 2,50 meter with a minimum diameter of 8 cm. According to data supplied by the company, the average diameter of logs is 14 cm so that the average volume of logs is 0,04 m^3.

3. Materials and Methods

This study focuses on the logging operations which include felling, delimbing and bucking the trees in the stand, forwarding the timber to the landing point and transporting it to the pulp mill. It concentrates on the measurement and analysis of each working element, including time, volume, costs and productivity.

The working time of each element was measured by using stopwatches. All measurements in the field were documented on tally sheets. The tally sheets were designed before the field study and were based on the literature and past experience taking into account field conditions, equipment and logging method. They were redesigned during the study to suite the actual conditions in the field.

The statistical analysis of the data focuses mainly on a computation of descriptive statistics and a regression analysis. The basic descriptive statistics are defined by sample size, mean value, standard error and standard deviation. In the case of the regression analysis, the linear regression technique is used to determine the relationship between the dependent variable (Y) and the independent (explanatory) variable (X).

4. Results and Discussion

4.1 Felling Operations

There are several stages of felling operations: felling preparation, tools preparation, felling, delimbing and bucking, bunching and auditing. The chain saw type used was husqvarna 365 which has an engine power of 3,4 kW (it equals to 4,6 PS) and a weight of 7,6 kg with a bar length of 885 mm.

The supervisor checks the felling crew and tools. The felling crew consists of an operator who passed training and two or three helpers. They should have good health when they work in the field. The felling tools consist of a chain saw, a measure tool, i.e. a wood stick with 2,50 meter in length, and a chopping knife, which is used to clear the undergrowth. The safety devices consist of safety helmet, boots and box.

The felling operation as such consists of clearing the undergrowth, walking to the tree, determining the felling direction and felling the tree. One helper measures the felled tree, starting from the foot of the trunk up to the diameter of 8 cm. The operator delimbs it properly and, at the same time, bucks it into logs with a length of 2,50 meters.

The helpers bunch the logs at both sides of the skidding line. All bunches must be in round shape with 10-12 logs to facilitate the forwarder operation. They must also be cleared of all slash so that bunches are not burned in case of fires.

The skidding lines are 4 meters wide and covered by the slash, i.e. branches, twigs, leaves and waste timber are put on them in order to reduce soil disturbances. The slash must not be piled higher than 1,5 meters so that the movement of the forwarder is not impeded.

According to the result of the statistical analysis with a sample size of 24 trees, the mean height of trees is 19,00 meters, the mean dbh of trees is 0,21 meters, and the mean volume of trees is 0,30 m^3. The total working time of felling is 3,66 minutes per tree, consisting of 2,58 minutes of productive time (70,5%) and 1,08 minutes of delay time (29,5%).

There is a positive relationship between felling time and size of trees, either expressed by dbh or trees volume. As the correlation coefficient of the regression analysis indicates, this relationship is rather strong. Since delays occur irregularly and do not depend on tree size, the relationship is stronger for the working time without delays than for the working time with delays. There is a significant influence of dbh and tree volume (variables X) on the working time of felling (variable Y) that is indicated by p-value < 0,05 at a confident level of 95%.

The felling productivity is 4,92[1] m^3 per hour, based on the mean volume per tree of 0,30 m^3 and the mean time per tree of 3,66 minutes. The bunching productivity of both helpers is 4,74[2] m^3 of logs per hour. It is lower than the productivity of felling because the volume of logs must be less than the volume of tree.

The cost calculations are based on the following assumptions. The day has 7 working hours and the month 25 working days. With 11 working months per year, there are 275 working days and 1.925 working hours per year.

In 1999, the company used its own workers in the felling operations. It paid them 1,14 USD/m^3 per crew. The cost of the chain saw was 1,46 USD/hour. The company assumed that the productivity of the felling operation was 2,14 m^3/hour. Then, the total costs of the felling operation are 1,82 USD/m^3 and consist of machine costs of 0,68 USD/m^3 (37%) and labour costs of 1,14 USD/m^3 (63%).

In the year 2000, the company shifted in the felling operations from own employees to contractors. But it paid the contractors just 2,00 USD/m^3 as a flat piece

[1] 0,30 x 60/3,66 = 4,92

[2] 1,91 + 2,83 = 4,74

rate. This means that the contractor had to use this sum to pay the workers as well as to cover the costs of the chain saws that he supplied and his overhead costs.

As a consequence, he paid the workers only 0,93 USD/m³ per crew (as compared to 1,14 USD/m³ per crew that was paid by the company before). If the assumed productivity of 2,14 m³/hour were still valid, the workers would only earn 1,99 USD/hour per crew. At machine costs for the chain saw of 1,46 USD/hour, the contractor would have total direct costs of 1,61 USD/m³ that means that he enjoys 0,39 USD/m³ as profit and/or contribution to his overhead costs

The felling crews mostly applied an unsafe technique of felling, i.e. felling more than one tree (up to seven trees) in a sequence before delimbing and bucking them. This method causes a lower quality of felling and subsequent operations (delimbing and bucking) and it also increases the risk for accidents of the workers. To avoid this, the company must increase the supervision intensively and also reorganise the piece rate system.

4.2 Forwarding Operations

The phases of forwarding operations are forwarding preparation, tools preparation, forwarding, supervising and auditing. The forwarder type used was timber jack 1010B, which has 6 wheels, an engine power of 82 kW (it equals to 110 hp) and a load capacity of 11 tons (it equals to 11 m^3) with a grapple capacity of 0,95 to 2,10 tons.

In one setting, there are two forwarders operated by five operators. The operators work on a shift time system. Not more than one forwarder should operate in one skidding line. The forwarding starts from the backside of the settings. The forwarder must not leave the skidding line.

According to the results of the statistical analysis with a sample size of 28 cycles, the mean total time per cycle is 30,76 minutes at a mean forwarding distance of about 378 meters. There was no delay time observed during the time study since no mechanical failures of the forwarder happened. Personal delays were concentrated into one scheduled break, which was not included in the time study, in the middle of the shift.

The regression analysis indicates, that there is a positive relationship between forwarding time and distance with a very strong correlation. However, there is no relationship between forwarding time and load volume as is shown by the correlation coefficient, which is close to zero. There is a significant influence of forwarding distance (variable X) on the working time of forwarding (variable Y) that is indicated by p-value < 0,05 at a confident level of 95%. However, there is no significant influence of load volume (variable X) on the working time of forwarding (variable Y) that is indicated by p-value > 0,05 at a confident level of 95%.

The work efficiency of the forwarding operation is influenced by the quality of the felling and bunching operations. Poorly stacked bunches will increase the time for loading the logs on the forwarder. A stump height of more than 10 cm will increase the probability of damages of the tires and will decrease the speed of the forwarder. Insufficient coverage of skidding lines by slash may create ruts, slow down the forwarder and lead to soil compaction.

The productivity of the forwarder is 18,60 m^3 per hour at the average forwarding distance of 378,04 meters, depending on the mean volume per cycle of 9,53 m^3 and the mean time per cycle of 30,76 minutes.

The cost calculations are based on the following assumptions. The working day has 14 hours and the working month 25 days. With 11 working months per year, there are 275 working days and 3.850 working hours per year. It might be stressed that the costs given here cannot be generalised, according to the specific conditions of the study (e.g. sample size, set of conditions, and no delay time).

The machine costs of the forwarder were 33,46 USD/hour. Then, they were multiplied by total time of 0,51 hours per trip and divided by load volume of 9,53 m^3 per trip in order to obtain the machine costs of 1,80 USD/m^3. If the labour costs of 0,08 USD/m^3 are added to the machine costs, it will be obtain the total forwarding costs of 1,88 USD/m^3.

In forwarding, environmental aspects are properly considered. All forwarders should move on pre-determined skidding lines. These skidding lines are piled up with slash, i.e. small timber, branches, twigs and leaves, to reduce ground disturbance. So, the company expects to maintain the productivity of the forestlands in order to reach sustainability of its plantations. It must be kept in mind, however, that a great deal of the biomass is concentrated on the skidding lines. But it is still left on the forestlands.

4.3 Transport Operations

The phases of the transport operation include preparation, unloaded travelling from the industry to the landing, loading at the landing, loaded travelling from the landing to the industry, unloading in the industry. The company uses trucks of the type Mercedes Benz 2631. They have a full log trailer, an engine power of 310 hp (it equals to 250 kW) and a load capacity of 36,75 m^3.

The truck travels with the load from the landing to the industry by using forest roads and public roads. The company allows the drivers to pick up and take off passengers. This policy provides advantages for the local people, but it increases the transport costs because of the delays related to it.

Unloading at the wood yard is used for fresh wood in order to let it dry before processing. A “Sisu” loader is used at the chipping machine and a “Volvo” loader at the wood yard. Unloading into the chipping machine is applied to wood, which is already dry. If the wood yard is already used to its full capacity, all the arriving wood is directly unloaded into the chipping machine. But this is not the normal case.

According to the results of the statistical analysis with a sample size of 11 cycles, the mean total time per cycle, including the waiting time, is 516,63 minutes at a mean transport distance of about 64,27 km. In addition, without the waiting time (137,46 minutes per cycle), the mean total time per cycle is 379,17 minutes at the same distance.

The regression analysis indicates, that there is a positive relationship between transport time and distance with a very strong correlation. However, there is no relationship between transport time and load volume as is shown by the correlation coefficient, which is close to zero. There is a significant influence of transport distance (variable X) on the working time of transport (variable Y) that is indicated by p-value < 0,05 at a confident level of 95%. However, there is no significant influence of load volume (variable X) on the working time of transport (variable Y) that is indicated by p-value > 0,05 at a confident level of 95%.

The productivity of the transport is 6,42 m^3 per hour at the average transport distance of 64,27 km, depending on the mean volume per cycle of 40,57 m^3 and the mean time per cycle of 379,17 minutes.

The cost calculations are based on the following assumptions. The working day has 14 hours and the working month 25 days. With 11 working months per year, there are 275 working days and 3.850 working hours per year. It might be stressed that the costs given here cannot be generalised, according to the specific conditions of the study (e.g. sample size and set of conditions).

The machine costs for the truck were 15,85 USD/hour. If they are multiplied by the total time of 6,32 hours per trip and divided by the load volume of 40,57 m^3 per trip, the machine costs are 2,47 USD/m^3. If the labour costs of 0,21 USD/m^3, the rate paid by the company, are added to the machine costs, the total costs of the transport are 2,68 USD/m^3 at the average travelling distance of 64,27 km.

In the transport operations from the forest to the pulp mill, the company allows all drivers of logging trucks to pick up and drop off passengers who want to enter and leave the forest. Although this means higher costs, the company accepts them and provides this service according to the needs of the local people.

5. Conclusion

Basically, the logging operations of the company are well organised though the structure of the logging division seems to be rather complicated and might offer room for improvements (streamlining in the sense of "lean management").

The logging operations follow standard operating procedures. The workers are trained before they go to the field. But it seems that the standard operating procedures are later not applied in the field and that safety regulations are not obeyed. This might be due to a lack of supervision that might have to be improved in various ways (e.g. greater number of supervisors and/or smaller area per supervisor, better concentration of work areas per year, tasks of supervisors) in order to improve the effectiveness and the efficiency of operations. The piece rate system that is presently used by the contractors might be an additional reason for the deviation from the safety rules.

It might also be checked if the mean diameter of logs of 14 cm could be generally used because it rather seems that the various settings have a different volume per tree. In addition, the volume to be harvested per hectare might also differ from setting to setting.

The high waiting time of trucks also offers room for improvement. Of course, the wood supply from the forest has to meet the demands of the pulp mill in time taking into account the density and quality of roads as well as the prevailing weather conditions. But a better scheduling of the trucks might decrease the waiting times in the forest and at the pulp mill without harming the sustainable and timely supply of wood.

It must be acknowledged that the company provides valuable advantages to the local people, i.e. job opportunities, agroforestry programs or the fulfilment of other needs, in order to increase the welfare of the local people. This, on the one side, improves the situation of the local people and, on the other side, gives the company a good image and good relationships with the local communities. There is no question, that these activities of the company should be continued.

6. References

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