PRODUCTIVITY OF THE SUPPLY SYSTEM BASED ON WHOLE-TREE BUNDLING

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ABSTRACT: In the present study, time consumption models for bundle harvesting and forwarding were created by applying regression analyses. The time studies related to on-road transportation were focused on comparing the terminal times spent on handling of whole-tree bundles and conventional 5-m pulpwood. The number of whole-tree bundles per truck load and the weights of the payloads were also recorded. The forwarding productivity of whole-tree bundles was about double compared to conventional pulpwood and whole-trees. In on-road transportation, the mean loading and unloading time of whole-tree bundles per truck load was 46% higher compared to that of conventional 5-m pulpwood. The second prototype of the bundle harvester is under construction, and the time studies are to be continued after accomplishing the machine in the spring 2009.
Keywords: Transporting, whole-tree bundles, integrated harvesting.

1 INTRODUCTION

1.1 Background

The harvesting of industrial roundwood and energy wood from early thinnings is costly due to small stem size and low removal. Integration of energy wood harvesting into that of pulpwood is seen as a means for reducing procurement costs. Increased recovery in the form of tops and branches compensate the high harvesting cost of pulpwood. However, high transportation costs of bulky whole-tree material are a problem.

The cost-efficiency of the harvesting of pulpwood and energy wood from early thinnings can be improved by applying a newly-developed integrated procurement system based on whole-tree bundling [1, 2, 3]. With the newly-developed “Fixteri” bundle-harvester the trees are compacted into cylindrical bundles with a length of 2.7 m and a diameter of about 60 - 70 cm [4]. Their solid volume varies between 0.3 m³ and 0.5 m³, depending on the bundle assortment and stand properties [5]. The whole-tree bundles are transported using standard forwarders and timber trucks to the end-use facility. Cost savings are expected especially in off-road and on-road transportation due to increase in load sizes [6]. The greatest cost reduction potential lies in small-diameter ($d_{1.3}$=7–10 cm) first-thinning stands, which are relatively unprofitable sites for conventional pulpwood procurement [6]. The pulp and energy fractions are separated from each other in the debarking drum of the chemical pulp mill, and separate crushing of the energy fraction can be eliminated [1, 7, 3]. Under-sized trees and tree species undesirable for pulp production can be accumulated into separate energy wood bundles, which are transported to be comminuted for combustion at heating and power plants [1, 3].

Based on the Finnish Energy and Climate strategy, there is a need to triple or even quadruple the production of forest chips from small-diameter material by 2020 [e.g. 8, 9]. In Finland, the forest industries are the largest producer and consumer of wood-based energy. Integration of energy wood procurement into that of industrial roundwood is a rational way to organize the raw material supply for pulp production and energy generation. Whole-tree bundling enables cost-efficient procurement of bulky whole-tree material from remote thinning sites.

1.2 Aim of the study

The absence of the empirical time study models and parameters for whole-tree bundle harvesting, bundle forwarding and truck transportation has been problem when comparing alternative supply systems for integrated pulpwood and energy wood procurement. The present study was aimed at constructing time consumption models and parameters for harvesting, forwarding and trucking of whole-tree bundles. The time consumption models were created by applying regression analyses to empirical time study data. The time studies related to on-road transportation were focused on comparing the terminal times spent on handling of whole-tree bundles and conventional 5-m pulpwood.

2 MATERIAL AND METHODS

2.1 Time studies of whole-tree bundling

The time studies on bundle harvesting with the second prototype of the “Fixteri” bundle harvester are ongoing, and thus results are not available. The productivity of felling and bundling of whole-trees will be studied in 32 young thinning stands. Relationships between stand properties and bundle size and composition will also be examined.

2.2 Time studies of forwarding

The time study data was comprised of 50 forwarder loads of whole-tree bundles harvested from two first-thinning stands. The total number whole-tree bundles transported during the time study was 1113. The data was collected in winter conditions in February 2008. The time study was carried out using a 6-wheeled Timberjack 1010B forwarder. The forwarding data was collected using continuous time registration. Driving distances unloaded, during loading and loaded was measured using a thread meter. Effective working time, including auxiliary time of each work phase (e.g. planning of work and preparations), was divided into working phases as follows:

- Driving unloaded, distance m
- Loading. The number of the bundles in the grapple and the number of the grapple loads per load were recorded.
- Driving during loading, distance m
- Reversing and turning around in the stand
- Driving with load, distance m
- Unloading. The number of the bundles in the grapple and the number of grapple loads per load were recorded.
- Sorting and handling of the bundle assortments in the bunk
- Moving during unloading at the roadside storage
- Cleaning of the roadside storage.

2.3 Time studies of truck transportation

In the truck transportation study, the loading and unloading times of whole-tree bundles were compared to those of conventional 5-m pine pulpwood. The timber was transported by a Volvo FH 16 timber truck of the 2004 model, composing of a three-axle tractor and a four-axle trailer (Weckman) with fixed length and movable load-bunk frames. The truck was equipped with a detachable Jonsered 1020 hydraulic timber crane, which was not removed from the truck during the time studies.

Both loading and unloading were done using the crane of the timber truck. The empirical data was comprised of five timber truck loads, of which four were whole-tree bundle loads and one was a pulpwood load (Table 1). All truck loads were unloaded directly to railway wagons. The studies were carried out in the daylight in February 2008. The volumes and payloads of the timber lots were based on the scaling at the Wisaforest pulpmill in Pietarsaari.

Table 1. Characteristics of the timber truck loads

Assortment	Payload, kg	Load size m³	Load size pieces	Mean size of the bundles m³	Mean size of the bundles kg
Energy wood bundles	26 300	30.2	78	0.39	337
Energy wood bundles	28 050	32.1	86	0.37	326
Pulpwood bundles	32 569	35.0	90	0.39	362
Pulpwood bundles	25 331	27.2	70	0.39	362
Pine pulpwood, 5 m	35 650	37.9	-	-	-

Effective working time of the trucking was divided into the following work phases:

Loading
- Preparing of the crane
- Handling of the trailer and bunks
- Loading. The number of the bundles in the grapple and the number of grapple loads per load were recoded.
- Sorting of the logs or bundles within the piles or in the load bunk
- Moving of the truck at the roadside storage during loading
- Binding of the load
- Cleaning of the residues from the roadside storage.

Unloading
- Opening of the load binders
- Preparing of the crane
- Unloading. The number of bundles in the grapple and the number of grapple loads per load were recorded.
- Sorting of the logs or bundles in the load bunk
- Moving of the truck during unloading
- Handling of the trailer and bunks
- Cleaning of the delivery point.

3 RESULTS

3.1 Forwarding

Loading consumed 22% of the forwarder’s effective working time (E_0h) while the proportion of unloading was 21%. Driving unloaded and with load took 21% and 17% of (E_0h), respectively. Driving during loading accounted for 16%. Reversing at the stand, sorting and handling the bundle assortments in the bunk and moving during unloading and cleaning of the roadside storage represented about 1 % of (E_0h) each. The average driving distance unloaded was 342 m, 235 m loaded, and 123 m during loading. One forwarder load contained on average 22.3 whole-tree bundles, ranging from 8 to 31 bundles per load.

Compacting of whole-trees into dense bundles improves the efficiency of forwarding timber from young stands markedly (Fig. 1). The forwarding productivity of whole-tree bundles is about double compared to conventional pulpwood and whole trees when the forwarding distance is 300 meter and the solid volume of the bundle is 0.5 m³. Even if the solid volume of the whole-tree bundle was reduced to 0.3 m³, the forwarding productivity would still be 20-40 % higher compared to conventional pulpwood or whole-trees. In the comparisons, the cutting removal was assumed to be 60 m³/ha and the load size 6.5 m³ for whole-trees, 11.0 m³ for pulpwood and 24 pieces for whole-tree bundles. In the comparison, the forwarding productivity of whole-trees (m^3/E_0h) was computed using the models of Laitila et al. [10]. In the case of forwarding pulpwood, the models of Kärhä et al. [11] were used.

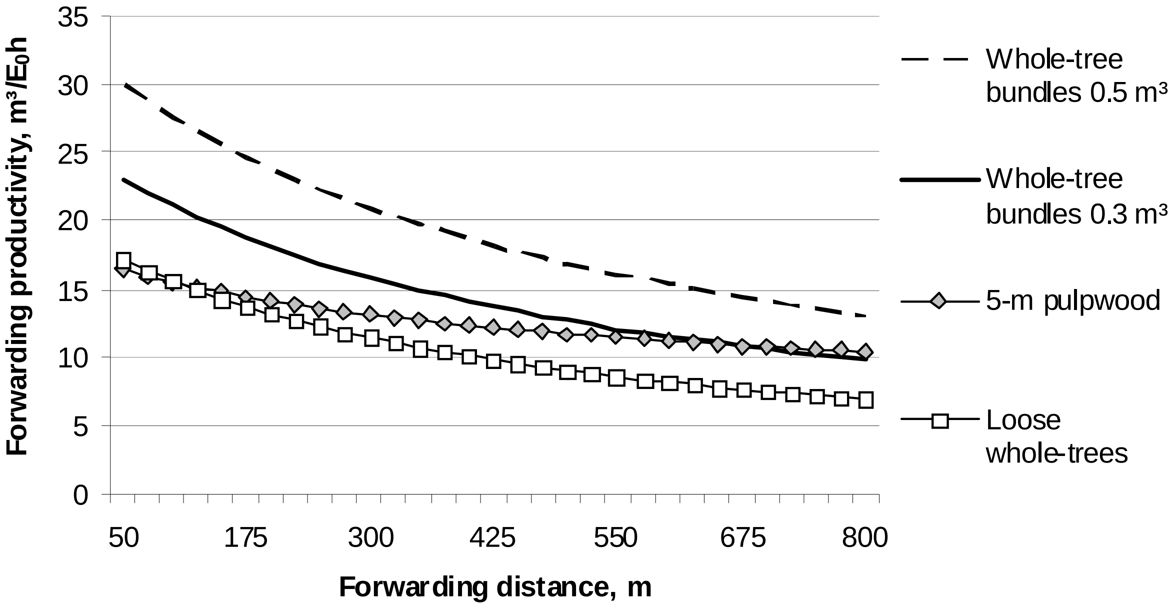

Figure1. Effect of forwarding distance on the productivity of forwarding loose whole-trees, 5-m pulpwood and whole-tree bundles (cutting removal 60 m³/ha)

3.2 On-road transportation

In this study, one bunch of the 5-m pulpwood was loaded on the tractor and two bunches on the trailer, whereas the bundle loads consisted of two bunches on the tractor and three bunches on the trailer. Consequently, the driver had to move the timber truck while loading and unloading of the bundles in order to get the load full or empty within the crane reach. With 5-m pulpwood, the driver was able to load and unload from one working point without a need for relocation at a storage pile or a railway wagon. The conventional pulpwood was free of slash and thus there was no need for cleaning the storage.

The mean time consumptions of the work elements in the comparative time study are shown in Table 2. The preparation time of the crane, the handling time of the bunks and the trailer, the handling time of the load, translocation time during loading and unloading, the binding and opening time of the load, and the cleaning time of the storage and delivery sites were given as the mean value per a whole-tree bundle load. The loading and unloading time of whole-tree bundles was calculated using a load size of 90 bundles. The load size of the 5-m pulpwood as well the time consumption of working elements were derived from the results of the comparative time study. Following the procedure described above resulted in a total effective handling time of the whole-tree bundles of 3958 seconds and 2724 seconds for the 5-m pulpwood (Table 2).

Table 2. The mean time consumption (E0h) of work elements per timber truck load of whole-tree bundles and pulpwood in seconds

Work element:	Whole-tree bundles, 90 pieces per load	5-m long pulpwood, 38 m³ per load
Preparing of the crane, s	134	83
Handling of the bunks and trailer, s	112	84
Loading, s	1464	969
Handling of the load, s	90	192
Translocations, s	196	0
Binding and openening the load, s	626	593
Unloading, s	1125	803
Cleaning, s	238	0
Total time per load, s	3985	2724

4 DISCUSSION AND CONCLUSIONS

From the methodological point of view, the present forwarding study was a relationship study while the truck transportation study was a comparative time study with a very limited data, aimed at comparing the handling times of pulpwood and whole-tree bundles and thereby generalizing and making the results more comparable with the earlier studies. The results reported in this paper were based on the output of only one forwarder operator and one timber truck driver, and therefore they do not cover the whole range of the productivity. However, it is evident that the number of experienced operators available for the study dealing with transportation of an entirely new assortment is limited. The study was focused on the effective time (E_0h), which is only a part of the total working time. Nevertheless, the results give new estimates for the performance in terrain and road transportation of the whole-tree bundles. The workers involved in the studies were skilled and the machinery represented the current fleet.

Knowledge of the productivity of the machinery and the cost factors associated with cutting and transporting are crucial when designing a new procurement system. The parameters and models constructed in this study will be used for comparing supply systems applicable to pulpwood and energy wood procurement from young stands in a R&D project coordinated by Metsäteho Oy [12]. The project is funded by the National Technology Agency (Tekes), the Finnish forest industries, and Finnish Forest Research Institute. Productivity models for the second prototype “Fixteri” bundle harvester will be finished during the autumn 2009.

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