Harvesting alternatives and cost factors of delimbed energy wood

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Abstract. The possibilities of harvesting small-diameter energy wood as delimbed instead of whole-trees was studied in the project “Harvesting alternatives and cost factors of delimbed energy wood”. The study focused on comparing the productivity and costs of cutting whole-trees and delimbed trees. The cutting was carried out using the multi-tree-handling technique and only energy wood was recovered. The second aim was to study integrated harvesting of industrial round wood and delimbed energy wood using the conventional single-tree-handling technique. The regional availability, procurement costs and measuring of delimbed energy wood were also estimated in the study.

The productivity of cutting delimbed energy wood was 10–40% lower compared to cutting whole-trees. This was due to the decreased stem volume. However, time consumption per tree was at the same level. The productivity of forwarding delimbed wood was 10–20% higher compared to forwarding whole-trees.

Integrated harvesting of industrial wood and delimbed energy wood was found to be rather costly. The productivity of harvesting energy wood from tops of industrial wood stems was almost three times higher than productivity of harvesting energy wood from small stems not meeting the diameter requirements of pulp wood.

Delimbing lowered the regional energy wood removals by 42–46% and increased the procurement costs by 17–25% compared to whole tree harvesting. Nevertheless, the study showed that the forest energy potential is increased and procurement costs are reduced, if delimbed energy wood is harvested from areas where whole tree harvesting is not acceptable due to nutrient loss or other ecological reasons.

The measuring method of delimbed energy wood was based on estimating the frame volume and the solid volume percentage of the tree bunches by using the harvester’s measuring device. The estimation of both variables was rather inaccurate but the overall accuracy of the measuring method was rather good when the size of the harvested lot was larger than 10 m³.

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Key words: energy wood, thinnings, delimbing, stemwood chips, multi-tree handling, availability

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Introduction

Forests play an important role in the Finnish energy strategies since 20% of the primary energy consumed is derived from wood-based fuels (Hakkila, 2004). Process residues from forest industry are the most important source of wood fuel. Forest chips, logging residues and stumps from clear cuts and small-diameter trees from thinnings, are still relatively modest source of fuel, but have considerable growth potential. Process residues from forest industry are fully utilized at the moment. Therefore, the most important means of increasing the consumption of wood for energy in the future is the utilization of forest chips resources. The goal of the Finnish energy and climate strategies is to increase annual production of forest chips to 5 million m³ by 2010 (Finland’s national…., 1999).

In Finland the use of forest chips was 3.0 million m³ (solid) in 2005 of which 2.6 million m³ was used in heating or power plants and about 0.4 million m³ in households (Ylitalo, 2006). Major share, 78% of chips used in heating or power plants, was produced of logging residues, stumps and large-sized low-quality roundwood. Whole tree chips’ share of the total volume was 17% and delimbed-tree-chips’ (stemwood chips) 5%. In households (farms etc.) the significance of stemwood chips in energy production is remarkably higher. Solmio (2002) has estimated that three-quarters of chips used in households is made of delimbed trees. Delimbed small-diameter trees are also important raw material for chopped firewood the consumption of which in households is estimated to be 5–6 million m³ (solid) per year in Finland (Sevola et al., 2002).

The quality of chips made of delimbed trees is very high. Low size variation of stemwood chips prevents blocks in the fuel receiving and handling systems. The efficient operation of many small-scale heating plants presupposes the use of delimbed wood as a raw material for the chips. Delimbed stems also dry better than undelimbed ones and the nutrient loss is lower, since the nutrient rich branches are left in the stand. The disadvantage is that deliming decreases harvesting productivity and the yield of chips. The cutting of small-diameter delimbed trees was based on manual methods. The continuously increasing price of heating oil has aroused the households’ interest to the utilization of forest chips. Also the national target to increase the annual use of forest chips presupposes that the harvesting volumes of small-diameter wood must be significantly increased. The accelerated loss of nutrients from forest soils must be clearly taken into account in the stand selection and in the development of harvesting methods.

This articles’ findings are based on the results of the project: “Harvesting alternatives and cost factors of delimbed energy wood” (Heikkilä et al., 2005). The project was part of The National Wood Energy Technology Programme (Hakkila, 2004) and was funded by Tekes, the Finnish Funding Agency for Technology and Innovation, Komatsu Forest Oy, Sampo-Rosenlew Oy and Waratah-OM Oy (joint venture of Outokummun Metalli Oy and John Deere Forestry). The research was carried out in the Finnish Forest Research Institute and in the TTS Institute. The project was divided into four subprojects. The first subproject focused on comparing the productivity, costs and silvicultural results of cutting whole trees and delimbed trees. The cutting was carried out using the multi-tree-handling technique and only energy wood was recovered. The second subproject dealt with integrated harvesting of industrial roundwood and delimbed energy wood using the single-tree-handling technique. The regional availability and procurement costs of delimbed energy wood were estimated in the third subproject. In the fourth subproject the measuring of delimbed energy wood using the harvester’s measuring device in multi-tree-handling was studied.
Material and methods

Cutting of delimbed energy wood and whole trees by Timberjack 745 and Valmet 945 “shear head” harvester heads were compared in four stands. In each stand both harvesting methods were applied and all removal including industrial-sized stemwood was harvested as energy wood. The total amount of harvested trees was 6700 of which half were harvested as whole trees and half as delimbed trees. The forwarding productivity of delimbed energy wood and whole trees was studied in two stands and the study material consisted of 12 loads. The cost calculation of the studied harvesting methods was based on time studies. The productivity per effective hour ($E_0$ hours) was converted to gross-effective productivity using coefficient of 1.3 for harvesting and 1.2 for forwarding. The gross-effective productivities were converted to harvesting costs using an operating cost of 70 € per $E_{15}$ hours for harvester and 50 € per $E_{15}$ hours for forwarder.

In the integrated harvesting, delimbed energy wood consisted of industrial roundwood tops and small trees with diameter below the requirements of pulpwood. The thinning was carried out by Keto 51 harvester head and the base machine was Sampo Rosenlew 1046X harvester. The integrated harvesting was studied in three stands and the total amount of harvested trees was 900. The cost calculation of integrated harvesting also based on time study and the same parameters presented in previous paragraph were used in cost calculation except for operating cost of light thinning harvester which was 65 € per $E_{15}$ hours.

The regional availability estimation of delimbed energy wood and whole trees from young forests was based on sample plot data from the 8th and 9th national forest inventories (NFI 8 & 9) of Finland (e.g. Tomppo et al., 2001). Forestry district level NFI data was converted to the municipal level by using multi-source NFI data (Tomppo et al., 1998). Calculations of forest fuel resources were made for the advanced seedling stands and young thinning stands needing improvement felling within a five-year period. The availability study was made around the city of Vaasa. The radius of energy wood procurement area was 100 km along the existing road network. In the availability analysis the minimum top diameter of delimbed energy wood was set to 4 cm and the length of stems was either 3 m or 5 m. The availability of whole trees was based on earlier study (Laitila et al., 2004).

The accuracy of the measuring method for delimbed energy wood was tested with Timberjack 745 harvester head, which was able to multi-stem processing. The method was based on estimating the frame volume and solid volume percentage of tree bunches using the harvester’s measuring device.

Results

The productivity in cutting of delimbed energy wood using the multi-tree-handling technique was 10–40% lower compared to cutting of whole trees due to lower average stem volume. The handling time per tree was at the same level (Figure 1). The forwarding productivity of delimbed wood was 10–20% higher than forwarding of whole trees (Figure 2). Main reasons were the improved efficiency in the loading and unloading work and especially the increase in average load size. The harvesting cost of delimbed wood in the studied stands was 29.3 €/m³ on average whereas the cost of whole tree harvesting was 23.8 €/m³. The main reason for the cost difference was the lower productivity in cutting of delimbed wood. The average cutting cost of delimbed energy wood was 25.8 €/m³ and cutting cost of whole trees 19.7 €/m³.
Figure 1. Time consumption by working elements and cutting methods.

Figure 2. Forwarding productivity of delimbed energy wood and whole trees.

Figure 3. The productivity of cutting in integrated harvesting by assortments.
Average forwarding cost of delimbed energy wood was 3.5 €/m³ whereas forwarding cost of whole trees was 4.1 €/m³.

In the integrated harvesting of energy and industrial wood the average productivity in industrial roundwood cutting was 8.5 m³ per effective hour and the productivity of energy wood cutting was 3.2 m³ per effective hour. The productivity of cutting energy wood from roundwood tops (5.8 m³/Eoh) was almost three times higher than that of cutting small standing stems (2.1 m³/Eoh) (Figure 3). The combined cutting productivity of roundwood and energy wood was 6.8 m³ per effective hour (Figure 3). Cutting cost of delimbed energy wood was 27.4 €/m³ on average and forwarding cost was 5.2 €/m³. The accumulation of energy fraction per hectare was low when both roundwood and energy wood was recovered. In studied stands it was between 5–20 m³/ha.

The availability analysis revealed that delimbing lowered the regional cutting removal by 42–46% compared to whole tree harvesting, when the minimum accumulation for the energy fraction was set to 25 m³/ha. Around the town of Vaasa (Western coast of Finland) the availability of whole trees was 173 000 m³ per year (Figure 4) and delimbing of trees decreased the accumulation to 93 000 m³ per year. According to current recommendation whole tree harvesting should be avoided in peatlands and infertile mineral soils to decrease the effect of nutrient loss (Koistinen & Äijälä, 2005). When the whole tree method was limited to fertile mineral soil stands, excluding spruce dominant stands, the accumulation of energy wood was 72 000 m³ per year (Figure 4). When harvesting energy wood as delimbed from peatlands, barren mineral soil stands (poorer than Myrtillus-type) and spruce dominant stands the annual availability was 53 000 m³. The annual total availability of whole trees from fertile mineral soil stands and delimbed energy wood from peatlands and barren mineral soil stands was 125 000 m³ (72 000 + 53 000) (Figure 4).

At regional level the effects of alternative stand selection criteria and cutting methods on procurement cost of energy wood were estimated around Vaasa (Figure 5). In the calculation the cutting was based on multi-tree-handling technique and the procurement chain was based on chipping at the roadside storage. Costs at the power

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**Figure 4.** Accumulation of energy wood around Vaasa when using different stand selection criteria and by alternative cutting methods.
plant were expressed as relative values. Procurement costs were at the lowest when trees were harvested as whole trees and there were no stand restrictions. Procurement cost of delimbed energy wood was 17% higher compared to whole tree harvesting, when the annual harvested volume was 60,000 m³ (Figure 5). When the whole tree harvesting was limited to fertile mineral soil stands, procurement cost was 9% higher. When the harvesting was based both on whole tree method and delimbed energy wood method on peatland and barren mineral soil stands, procurement cost was only 4% higher (Figure 5).

The estimation of both the frame volume and the solid volume percentage of tree bunches using the harvester head’s measuring device was rather inaccurate. However, the overall accuracy of the measuring method was relatively good when the harvested volume in stand was over 10 m³ thus consisting of hundreds of tree bunches (Figure 6).

Figure 5. Procurement cost of energy wood by alternative stand selection criteria and cutting methods around Vaasa.

Figure 6. Accuracy for measurement of total volume of timber lot.
Discussion and conclusions

Time consumption per harvested tree is almost the same in compared cutting methods when using multi-tree-handling, but recovery of energy wood is lower when the trees are delimbed. The productivity in forwarding delimbed trees is higher than that of whole trees. In the studied stands harvesting costs of delimbed energy wood were 5.5 €/m³ (23%) higher than those of whole trees. There are little previous studies on mechanized harvesting of delimbed energy wood. Rahikainen (2005) found that cutting costs of delimbed energy wood were 4 €/m³ higher than cutting costs of whole trees when using single-tree-handling. The presented results are also on line with the previous studies on mechanized whole tree harvesting (Kärhä, 2004; Laitila et al., 2004).

The quality characteristics of chips made of delimbed trees are good and the material is also suitable for small-scale use and the production of chopped firewood. Also nutrient losses out of forest are lower when harvesting delimbed energy wood (Nurmi et al., 2001). According to current forestry recommendations whole tree harvesting should be avoided in ecologically sensitive sites. However, harvesting of delimbed energy wood is possible also in these sensitive sites since the nutrient rich branches are left to the site. As a result the regional forest energy potential actually increases when applying both the delimbed energy wood and the whole tree harvesting and when this is compared to situation where trees are harvested as whole trees and harvesting is limited only to fertile mineral soils. Intelligent selection of harvesting methods for different stands enables minimizing of transport distance and controlling of procurement costs.

In the integrated harvesting of industrial and energy wood the relatively low minimum diameter of pulpwood which is currently applied (6–7 cm) decreases the profitability of harvesting of delimbed energy wood. In principle, it takes a very short time to operate one energy wood section, but the costs rise sharply because of very small handling unit. In the integrated harvesting, recovery of energy wood from tree tops caused less extra work than cutting it from small stems. When applying integrated harvesting the removal and stem size of both assortments should be adequate.

The results from the measurement method, which was based on frame volume and solid volume percentage of tree bunches, were promising. The method is applicable also for measuring pulpwood when cutting is carried out with multi-tree-handling technique. However, more studies would be needed before the implementation of the measurement method.

References


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