EFFICIENCY OF MECHANISED STEEP TERRAIN HARVESTING SYSTEMS

Karl Stampfer
University Assistant, Institute of Forest and Mountain Risk Engineering
A-1190 Vienna, Peter-Jordan-Strasse 70/2

Abstract: In Austria there are two rationalization possibilities for timber harvesting in steep terrain: (1) Tracked or hybrid harvesters in combination with cable yarders (cut-to-length system) and (2) Chain saws felling combined with a processor mounted on a cable yarder (whole tree system). The aim of empirical studies and simulation experiments is to compare the productivity and stand damage of these harvesting systems. For the combination harvester and cable yarder different process layouts were investigated.

The results show efficiency advantages for the harvester cable yarder combination in small tree dimensions. The stand damage of both systems are comparable and lower than in motor-manual systems. Harvesters with a boom reach of 15 m are suitable for combining with cable extraction machinery, resulting in 30 m corridor spacing. With a harvester boom reach of approximately 7 m, resulting in 15 m corridor spacing, subsequent cable yarder system is best installed in the middle of three corridors and the bundles extracted through the stand from the neighboring corridors.

INTRODUCTION

Stagnant timber sales and increasing production costs force forestry to make rationalization efforts. While in passable terrain the harvester forwarder combination is a satisfactory solution, equivalent working systems for harvesting in steep terrain are missing. In a mountainous region like Austria where a large amount of the forest area is steeper than 50%, rationalization is necessary to ensure the competitiveness of forestry. This is particularly important for thinning operations.

It is only the technical realization of both the walking platforms and tracked chassis for harvesters that a solution with a high technical innovation potential is available for thinning in steep terrain. Such machines are able, under suitable conditions, to operate up to slopes of 60%. Since the forwarder is to be excluded as practicable extraction machine over approximately 40% (45%) terrain slope, the timber in this slope range must be extracted with cable yarders.

In the past only a few studies dealing with possible productivity increase of cable systems through bunching the logs on the cable corridor have been carried out. With reduced lateral yarding distance and better turn volume preparation the yarder system productivity increases significantly (HEINIMANN et al., 1998; VISSER and STAMPFER, 1998). When using harvesters with a low boom reach (7.5 m) every 15 meters a cable yarder set-up is necessary. In this case the installation costs are too high because of the low total volume of timber to be extracted. So an alternative system layout with pulling the bundles through the stand from the neighboring harvester corridors was proposed by VISSER and STAMPFER (1998). Compared to extracting the pre-bunched logs from only one corridor, the system productivity decrease was significant. The resulting residual tree damage was not investigated.

The alternative harvesting system for thinning in steep terrain is motor-manual felling and extraction of the whole tree to the forest roadside. A processor attached to the cable yarder does the processing of the logs. There are only few international studies about the productivity and negative effects to the environment about this system.

This paper gives an overview about the harvesting possibilities in steep terrain. Results of investigations about productivity of the harvester cable yarder combination and the residual tree damage through this system are pointed out. Comparing the efficiency of different production systems for thinning in steep terrain will be the final step.

HARVESTING IN STEEP TERRAIN

For the mechanization of steep terrain harvesting, the following alternatives exist:

- Combination of steep terrain harvester and cable yarder (cut-to-length system - CTL)
- Motor-manual felling and whole tree extraction. Mechanized processing of the logs on the forest road.

The main characteristics for operating with harvesters on steep terrain are the carrier platform, the boom reach and the harvesting head.

Mechanized harvesting is connected to carrier platforms which are able to pass natural steep terrain. The following locomotion principles are possible: wheels, tracks, legs and hybrids (mostly wheel-legged). Apart
from the characteristics of the vehicles, soil bearing capacity, terrain roughness and slope gradient determine the limits of off-road mobility. Wheeled harvesters today may operate over a wide range of terrain conditions on slopes up to 30%. When the soil bearing capacity is high operations up to 40% (50%) are conceivable. Tracked and hybrid harvesters can pass terrain up to 60%. One requirement for harvesting in steep terrain is the possibility to tilt the cab horizontal.

Since forwarders cannot be used for extraction in terrain slope of more than 40% (45%), wood is extracted by cable yarders. The boom reach of steep terrain harvester determines subsequent cable yarder layout. The critical cable corridor spacing, in which another yarder set up is economically more efficient, is 24 meters. Therefore a boom reach of at least 12 m is a main requirement for steep terrain harvesting. Table 1 shows different steep terrain harvesters and their boom reach. It is significant, that according to the boom reach only a few harvesters fulfil the requirements for a combination with cable yarding systems. When the boom reach is less than 12 m, an alternative central set up of three harvester corridors is necessary (Figure 1). In this case the bundle must be pulled through the stand to the cable corridor.

The tree processing capabilities are dependent on the maximum felling diameter of attachments.

Table 1: Comparison of different steep terrain harvester

<table>
<thead>
<tr>
<th>Carrier platform</th>
<th>Boom reach (m)</th>
<th>Harvesting head (Standard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menzi Muck A 71</td>
<td>8.5</td>
<td>Woody H50</td>
</tr>
<tr>
<td>MHT Robin</td>
<td>9.0</td>
<td>Gangärde GM 928</td>
</tr>
<tr>
<td>Neuson 11002</td>
<td>9.1</td>
<td>Logmax 3000</td>
</tr>
<tr>
<td>Berghibeber</td>
<td>10.5</td>
<td>KETO 100 LD</td>
</tr>
<tr>
<td>Mini-Königstiger</td>
<td>12.4</td>
<td>LAKO 43</td>
</tr>
<tr>
<td>Königstiger</td>
<td>15.0</td>
<td>LAKO 63</td>
</tr>
</tbody>
</table>

Figure 1: System layout for cable yarding following harvester operation with short boom reach

Motor-manual felling and extraction in whole tree system is followed by mechanized processing of the logs on forest road. Combining cable yarder and processor should have the following technical requirements: (1) radio controlled carriage with "goal automatic", and (2) a powerful crane with processor attachment.

The computerized system allows the operator to return the carriage to the point it last came from at the push of a button. This means that after the carriage has commenced its travel outwards the operator is free to handle the processor. Equally the choker-setter who has a radio control unit for operating the carriage can send the carriage with the turn back towards the yarder. There it will stop automatically until the operator once again takes control.

MATERIAL AND METHODS

Productivity and efficiency models

Productivity models make it possible to predict the system productivity depending on different variables. The methodical approach to developing productivity models is the experiment. The central concept of experimental investigations is the observation unit. The classical productivity study works with the single tree (or turn) as observation unit. In North America the shift level is the observation unit.

In the existing case the productivity models are based on empirical studies with single tree or turn as observation unit. Since the work system is the focus, further division into individual work components was omitted. The productive time (resulting in productive system hour, $PSH_0$) and breaks lower and greater than 15 minutes were recorded. Different stand, terrain and machine parameters were measured. In a first step the data are analyzed with variance analyses, after that the parameters, which are quantifying the productivity under
different conditions, are estimated. The detailed procedure for this kind of work studies is described by STAMPFER (1999) and STAMPFER and DAXNER (1998).

When the hourly costs of the different machines are known they can be divided by system productivity to get the efficiency in Euro per m$^3$. The different personal and machine costs for this investigation are listed in Table 2.

Table 2: Personal and machine costs

<table>
<thead>
<tr>
<th></th>
<th>EURO/PSH15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syncrofelke with processor</td>
<td>199</td>
</tr>
<tr>
<td>Syncrofelke with grapple</td>
<td>102</td>
</tr>
<tr>
<td>Königstiger</td>
<td>102</td>
</tr>
<tr>
<td>Neuson</td>
<td>69</td>
</tr>
<tr>
<td>Forest worker</td>
<td>25</td>
</tr>
</tbody>
</table>

Stand damage

To quantify the residual stand damage through the harvester cable yarder system, a tree damage analyses after MENG (1978) was carried out. The damage is addressed by extent and size as well as location on the tree and in the stand.

Extent of damage

1. The bark is damaged in the outer layers, but the cambium remains without damage. The tree reacts with low resin flow, but fungal infection rarely affects this area.
2. The bark is crushed, but remains on the stem. That kind of damage is only seldom infested by fungus (MENG, 1978).
3. The bark is removed; the wood is visible but is without damage. That kind of damage results mostly in fungal infections and rotting, which is influenced by damage type, size and season.
4. The bark is removed; the wood is lightly (4) or heavily (5) damaged.

Location of damage

(1) Root  (2) stock  (3) 0.3 – 1 m height  (4) higher than 1 m

Size of damage

(1) <10cm$^2$  (2) 10-50cm$^2$  (3) 50-200cm$^2$  (4) >200cm$^2$

Cause of damage

(1) Felling and processing  (2) extraction  (3) others

Location of damaged tree

(1) Distance to the harvesting corridor in meters

RESULTS

Cable yarder productivity

Figure 2 shows the results from a cable yarder productivity study. The productivity is dependant on the piece volume and the bunching strategy. By an average piece volume of 0.15 m$^3$ pre-bunching leads to a productivity increase of 33%. This can be explained by the increase in average load volume and the reduced lateral yarding distance. When the bundles are pulled through the stand the productivity advantage is only reduced by approximately 6%.

Figure 2: Cable yarder productivity depending on piece volume and bunching strategy

Residual stand damage

Investigations were carried out to determine the residual stand damage from pulling bundles through the stand. Figure 3 shows that 14% of the remaining stand had new tree damage through the whole system. Of this damage, 55% is caused by the harvester, the rest due to the cable yarder. 8% of the trees are with old damage. 78% of the residual trees are without damage which is comparable to other working systems. FRUTIG and TRÜMPI (1990) indicated residual tree damage of between 5 and 25% for motor-manual felling and cable extraction. The damage for cable yarding in whole tree system was between 10 and 14%. Whole tree downhill yarding leads to damage on 40% of the remaining stand, which is unacceptable.
Efficiency of steep terrain harvesting systems

Figure 4 shows the efficiency in Euro per m³ depending on tree volume and steep terrain harvesting systems. The results indicate very clearly: Mechanization is the only possibility to complete thinning operations in a cost-effective way. Motor-manual systems are too expensive. Comparing harvester-yarder with yarder processor systems in small timber, the whole tree system is less competitive. With a tree volume of approximately 0.2 m³ the disadvantage swaps to the harvester yarder combination. Nevertheless, this system is the only one which can operate downhill because the whole tree system leads to unacceptable residual tree damage.

CONCLUSIONS

The present paper analyzed different harvesting systems for thinning on steep slopes. The investigations resulted in the following main findings:

- The harvester yarder system combination (cut-to-length) and the processor attached to a cable yarder (whole tree) are efficient on steep slopes.
- When multiple harvester corridors are extracted from a single yarder set up the productivity is still very high and the residual tree damage is acceptable.
- In small timber the CTL-yarder system has advantages. In large timber the tree length yarder processor is more efficient. Downhill extraction with this system is not acceptable at the moment. The reason is the residual tree damage.

REFERENCES


