PRODUCTIVITY OF A TRACKED EXCAVATOR-BASED PROCESSOR IN THE NORTH-EASTERN ITALIAN ALPS

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Keywords: processor, excavator, productivity

Abstract: *At moment in the North-eastern Italian Alps four processors based on tracked excavators are operating, mainly used in conjunction with cable yarders. One of the processors (a tracked excavator equipped with a Konrad Forsttecknik Woody 60 processor head) was tested during 2002 harvesting season in order to achieve data useful to determine efficiency limits and application possibilities. The stands to be processed are located in the mountainous areas of Trento Province and are characterized by mixed Coniferous trees (mainly Norwegian spruce). The processor operated closer to the cable crane yarder, usually placed at roadside and running for uphill transport, delimbing and cross-cutting trees or part of them and piling the logs. An established data collection protocol was chosen adapting the one proposed by Stampfer (1999). A statistical analysis has been developed that considers average stem volume, stem diameter, stem length and number of logs obtained by each stem. The results show the productivity of the processor in reaction to stem diameter and number of logs obtained by each stem. Due to the small data set, the results can only be interpreted under the specific circumstances in which the tests were carried out. However they represent the first information about the use of a processor in the North-eastern Italian Alps.*

1. Introduction

In the last few years some processors based on tracked excavators or mounted on tractors have been introduced in North-eastern Italian Alps, mainly for harvesting in Coniferous forests. While the processors mounted on the tractor are generally used in thinning operations on moderate steep terrain (up to 25%), the tracked excavator-based processors are mostly utilized by side of cable yarders in shelterwood cut on steep terrain.

At moment in the North-eastern Italian Alps four tracked excavator-based processors are operating, three of them being equipped with Konrad Forsttecknik Woody processor head (50 and 60 models) and one with Keto processor head.

When processors based on tracked excavators are concerned, the first part of the work cycle consists in motor-manually felling, cross-cutting of the bottom logs of the heavier trees, cable yarding of the full trees or of the cross-cut parts of them; the second part of the working cycle consists of the following functions performed by the processor: picking up the stems from the landing place, moving the stems, delimbing the stems, cross-cutting the stems into logs, piling the cross-cut logs.

Some operators, especially during summer, when the bark can be easily removed by the delimbing knives of the processor head, prefer to adopt a different sequence: after picking up the stems from the landing place, they move them over a free place, e.g. the road downhill shoulder, pass the stems forward and backward across the processor head at least three times, delimbing and debarking them at the same time. Then they cross-cut the stems and pile the logs. This way it is possible to concentrate the branches and the bark in a place where they cannot interfere with the machine operations and from where they can be easily collected.

The goal of the paper is to develop a productivity model for the tracked excavator-based processor, quantifying the effect of some characteristics of the stem[1] on the productivity of the machine.

2. Material and methods

2.1 The tracked excavator-based processor

The tracked excavator-based processor consists of a Konrad Forsttecknik Woody 60 processor head mounted on the Liebherr R 914 B Litronic tracked excavator (Table 1). The carrier is equipped with turbo diesel engine (112 kW) and the total weight of the machine is 25,300 kg. The machine width is 2.765 m and the boom reach at ground level is 10.4 m

Table 1: Technical parameter of the tracked excavator-based processor

Machine	Characteristic	Value	Unit
Liebherr R 914 B Litronic tracked excavator	Engine power	112	kW
	Weight (including processor head Konrad Forsttecknik Woody 60)	25,300	kg
	Width	2.765	m
	Length	9.45	m
	Height	3.80	m
	Boom reach at ground level	10.4	m
	Ground clearance	0.475	cm
Konrad Forsttecknik Woody 60 processor head	Weight	950	kg
	Max. cutting capacity	65	cm
	Delimbing capacity	8-60	cm
	Feeding rolls speed	0-4	m/s
	Feeding rolls force	4,2	kN

2.2 Study sites and working procedures

The stands to be harvested are located in the mountainous areas of Trento Province and their main features are shown in Table 2. They are mixed Coniferous stands located at an altitude ranging from 1,140 to 1,510 m a.s.l. The unit growing stock ranges from 347 to 478 m^3/ha and the current annual increment ranges from 6.34 to 11.74 m^3 ha^{-1} y^{-1}.

[1] Taking into account the working techniques that consider the processing of both full tree and of the remaining part of the full tree, after the removal of the bottom logs, the term "stem" is used all over the paper to cover both the products

The trees were motor-manually felled; if the dimensions of the trees overcame the loading capacity of the cable yarder, one or two bottom logs were cross-cut. The stems and the logs were yarded by a Valentini V500 cable yarder. Once the stems arrived to the landing site they were picked up by the Liebherr R 914 B Litronic tracked excavator equipped with the Konrad Forsttecknik Woody 60 processor head and processed.

Table 2: Stand characteristics

Characteristic	Stand 1	Stand 2	Stand 3
Tree species	spruce/fir/larch	spruce/larch/scots pine	spruce/fir/larch
Altitude (m a.s.l.)	1,140	1,510	1,440
Slope (%)	52	47	48
Unit growing stock (m^3/ha)	478	347	372
Current annual increment (m^3 ha^{-1} y^{-1})	11.74	9.75	6.34
Tree height (m)	21	21	23
Harvesting intensity (%)	18.3	24.8	13
Location	Levico	Palù del Fersina	Roncegno

2.3 Model

The following hypothesis has been assumed for constructing a productivity model for processor:

Time for stem processing = f (DBH of the individual stem, length of the individual stem, volume of the individual stem, number of logs per individual stem)

2.4 Data collection and statistical analysis

For the data collection an established protocol developed by Stampfer (1999) was adapted to the study. The working cycle of the processor was divided into the following functions:

Grabbing: after piled the last log the excavator moves towards the landing site and grabs a stem;

Moving: the excavator moves away from the landing site and positions the stem over a place where the delimbing and the cross-cutting steps can be easily carried out;

Delimbing: the stem is moved through the processor head by the feeding rolls and the branches are delimbed (the "Delimbing" function includes also the ejection of the stem top);

Cross-cutting: the stem is stopped and the chain saw is activated in order to cross-cut the log;

the "Delimbing" and "Cross-cutting" functions are repeated until all the stem has been delimbed and cross-cut

Piling: the logs are picked up and piled.

The individual stem was chosen as observation unit and the variables and the times measured are presented in Table 3. The statistical analysis was carried out on the productive system hours (PSH_0). To determine the productive system hours including delays shorter than 15 minutes (PSH_{15}) a conversion factor (k) equal to 1.4 was adopted.

A total of 265 stems were processed from all over the sites.

The statistical analysis was carried out using SPSS 11.5 for Windows (2003). For developing the model the following analysis strategy, adapted from Heinimann et al. (1998), was chosen:

- development of a linear model with all the co-variables from Table 3;
- evaluation of the non-linearity of the co-variables;
- estimation of a model through the removal of the variables that were not significant.

Table 3: Numerical variables and time components

Type	Name	Description	Unit
Dependent variable	$\text{cycle}_{\text{process}}$	Total time for processing a single stem	cmin
Co-variables	Stemdiam	DBH of the individual stem	cm
	Stemlength	Length of the individual stem	m
	Stemvol	Volume of the individual stem	m^3 without bark
	Logs	Number of logs per individual stem	n
Time	PSH_0	Sum of total time components related to the working cycle of the processor	cmin
	Less<15	Delays in the working cycle up to 15 min	cmin

3. Results and discussion

Table 4 shows the statistical values of the numerical variables.

Table 4: Statistical values of the numerical variables

Variable	Mean	Standard deviation	0.05 quantile	0.95 quantile	Unit
$\text{cycle}_{\text{process}}$	171.88	64.42	82.3	287	cmin
Stemdiam	36.9	11.4	19	56	cm
Stemlength	15.84	5.44	6.73	24.34	m
Stemvol	1.3	0.89	0.19	3.05	m^3 without bark
Logs	3.38	1.27	1.3	5	n

On average, the processor processed one stem in nearly two minutes; the stem volume was relatively high with a mean value of 1.3 m^3.

The statistical analyses resulted in the model presented in the following equation (1):

$$\text{cycle}_{\text{process}} = 1.9042\ \text{Stemdiam} + 29.9764\ \text{Logs} \quad (1)$$

where:

$\text{cycle}_{\text{process}}$ total time for processing a single stem (cmin)

Stemdiam DBH of the individual stem (cm)

Logs Number of logs per individual stem (n)

Around 95% of the total variation in time required for processing can be explained by the regression, i.e. through the co-variables stem diameter and number of logs per individual stem. For the data set obtained through the study the co-variables representing the volume and the length of the individual stem did not have any influence on the time required for processing.

To determine the productivity of the system an equation (2) was developed including the volume of the stem; furthermore to include delays less than 15 min, increasing the time required per cycle and passing from PSH_0 to PSH_{15}, a correction factor k was used. For the conversion from centesimal minutes to hours a factor 1:6000 was introduced in the equation.

$$prod_{process} = \frac{6000 \cdot Stemvol}{k \cdot cycle_{process}} \tag{2}$$

where:

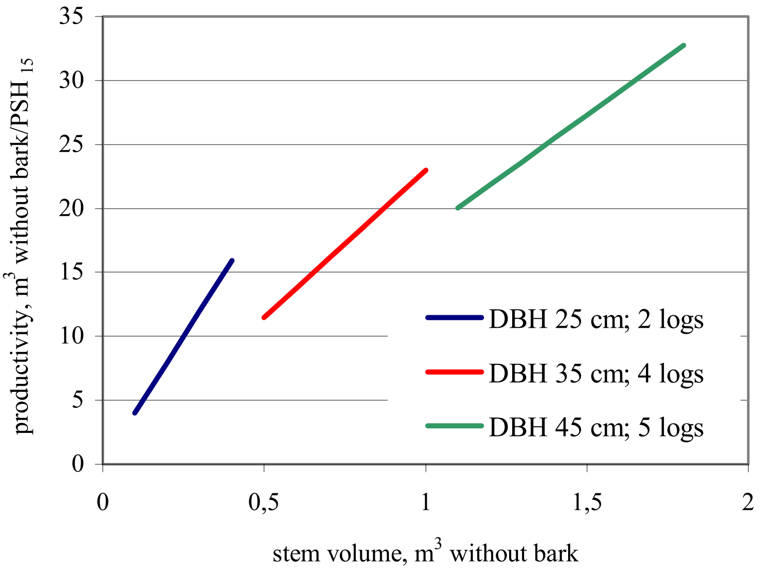
$prod_{process}$ system productivity (m^3/PSH_{15})

$cycle_{process}$ total time for processing a single stem (cmin)

Stemvol volume of the individual stem (m^3 without bark)

Figure 1 shows the productivity of the processor (Liebherr R 914 B Litronic tracked excavator equipped with the Konrad Forsttecknik Woody 60 processor head) in relation to stem volume and for three different combinations between stem DBH and number of logs cross-cut from the stem.

Figure 1: System productivity (m^3 without bark/PSH_{15}) of the processor in relation to stem volume for three different combinations between stem DBH and number of logs



The marginal increment of the productivity, pointed out by the gradients of the three segments, tends to reduce increasing the volume of the stem. In fact for the first combination, when the stem volume increases by 0.1 m^3, the productivity increases of about 3.9 m^3/PSH_{15}; for the third combination the increment of productivity, for the same increase in stem volume, is about 1.8 m^3/PSH_{15}.

The key role is played by the number of logs that are cross-cut by each stem: actually, when high volume trees are concerned, incrementing the number of logs, i.e. shifting from long to shorter assortments, the time for cross-cutting and piling increases, limiting the effect of stem volume on productivity.

4. Conclusions

In order to analyze the parameters that influence the productivity of a tracked excavator-based processor an empirical study was carried out. The study has concerned the use of a Liebherr R 914 B Litronic tracked excavator equipped with the Konrad Forsttecknik Woody 60 processor head, working at the landing site of a Valentini V500 cable yarded used for uphill transport.

A data set, considering the characteristics of the processed stems and the time occurred for the different functions performed by the processor, was obtained; through a statistical analysis, a productivity model was defined that includes delays shorter than 15 min.

The time required to process the stem is function of the stem diameter and of the number of logs that are cross-cut from each stem. With an average stem volume of 0.4 m^3 (average stem diameter 25 cm) and producing 2 logs per stem, the processor achieves a productivity of around 16 m^3/PSH_{15}; with an average stem volume of 1.2 m^3 (average stem diameter 45 cm) and producing 5 logs per stem, the processor achieves a productivity of around 21 m^3/PSH_{15}.

It must be emphasized that the major influence on the increment of productivity is due to the number of logs that are cross-cut from the stem and hence by the assortment method adopted.

On the basis of the small data set the results can only be interpreted under the specific circumstances in which the study was carried out. However they represent the first information about the use of a processor in the North-eastern Italian Alps.

Due to the interest that day by day the processor system is gaining in forest utilization in North-eastern Italian Alps, further studies should be carried out in order to validate the model better and to obtain a useful tool for harvesting planning.

5. References

Heinimann, H. R.; Visser, R. J. M.; Stampfer, K. (1998) Cable yarder system evaluation on slopes – a Central European study in thinning operations, Proceedings of the Annual Meeting of the Council on Forest Engineering, Harvesting Logistic: form woods to market, Portland OR, 39-44.

SPSS for Windows Rel. 11.5. (2003) Chicago, Illinois: SPSS Inc.

Stampfer, K. (1999) Influence of terrain conditions and thinning regimes on productivity of a track-based steep slope harvester, Proceedings of the International Mountain Logging and 10th Pacific Northwest Skyline Symposium, Corvallis OR, 78-87.