PROCESSING HARDWOOD FROM COPPICED FORESTS

Christian Suchomel[1], Raffaele Spinelli[2], Natascia Magagnotti[2]

[1]Institute of Forest Utilization and Work Science, University of Freiburg,
Werthmannstr.6
79085 Freiburg, Germany
e-mail: christian.suchomel@fobawi.uni-freiburg.de

[2]CNR Ivalsa,
Via Madonna del Piano
50019 Sesto Fiorentino, Italy
e-mail: spinelli@ivalsa.cnr.it - magagnotti@ivalsa.cnr.it

Abstract: *About the half of the italian forest area is classified as coppiced forest. An important species from coppice for sawlogs, poles, fencing, firewood and wood chips is the chestnut tree (Castanea sativa L.). This study deals with four different harvester units used for processing chestnut trees from coppice stands, at the landing. For these four different machines, time studies were conducted in order to estimate productivity and compare the performance of the different units.*

1. Introduction

In Italy, coppice forests are an important landscape element and an important economic factor. 54.5% of the Italian forest area is classified as coppiced forest. In the past, these stands were harvested with short rotation clear cuts, and were managed by leaving between 50 and 90 standards per hectare, to leave seed trees and to improve stand structure. Since regeneration is obtained resprouting, these stands have a multiple stem structure. Despite a general trend towards conversion into high forests, the majority of these stands are still managed through coppicing, due to the high cost of conversion. 21% of the Italian coppice forests are based on mediterranean oaks, 18% on chestnut (*Castanea sativa*), 16% on oaks, 15% on beech (*Fagus sylvatica*), 19% on hornbeam (*Carpinus betulus*), 1% on riparian trees and 10% on other species (INFC 2005, FAO 2005). Chestnut coppice is widespread all over Italy, but is particularly common in the Regions of Piedmont, Tuscany, Latium, Campania and Calabria. Chestnut coppice is seldom converted into high forest, because coppice stands are much less vulnerable to chestnut blight compared to chestnut high forests. Assortments from chestnut coppice are: sawlogs, poles, fencing, firewood and woodchips. Trees from coppice generally have small size and bad form, since they grow as multiple stems from the tree stump. That also entails some problems with mechanical felling and processing. These characteristics reduce the harvesting efficiency of mechanised operations compared to harvesting softwood trees, which normally have straight form, small and horizontal branches, no forks or steep branches. Anyhow, the use of harvester in coppice stems can accrue the economy and safety advantages of full mechanized work. The special conditions of hardwood trees reduce productivity and increase mechanical delays.

This research was conducted on four different harvesting machines in order to evaluate the factors affecting the productivity of processing pre felled chestnut trees from coppiced stands, at the landing. The research was conducted in cooperation between the Institute of Forest Utilization and Work Science of the University of Freiburg and CNR IVALSA.

2. Materials and Methods

The authors studied four different harvesting machines deployed on chestnut coppice in Northern (Piedmont) and Central (Tuscany) Italy. Time-motion studies were carried out, designed to evaluate machine productivity and to identify those variables that are most likely to affect it. Cycle times were split into a number of time elements considered as typical of the working process. Time elements were recorded with a Husky Hunter hand held field computer running Siwork3 timestudy software. The study offers a precious insight into the performance of four different machines used for processing pre-felled chestnut trees into different assortments. The machines were: an Arbro 400S on a JCB 8052 excavator (40 kW, 6t), a Foresteri RH 25 on a CAT 312 L excavator (71 kW, 16 t), a Lako 55 Premio on a JCB JS 180 NL excavator (70 kW, 18 t) and a Timberjack 1270B dedicated harvester (152 kW, 15 t) with John Deere 762C head.

Table 1. Site and study conditions

Study	Foresteri 1	Foresteri 2	Lako	JohnDeere	Arbro
Area	Gaiole in Chianti (SI)	Abbadia S. Salvatore (SI)	Monzuno (BO)	Armeno - (NO)	Signorino (PT)
Machine	CAT 312 L excavator (71 kW, 16 t)	CAT 312 L excavator (71 kW, 16 t)	JCB JS 180 NL excavator	Timberjack 1270B harvester	JCB 8052 excavator
Head	Foresteri RH 25	Foresteri RH 25	Lako 55 Premio	John Deere 762C	Arbro 400S
Methods	processing at cable yarder landing	processing at landing	processing at landing	processing at landing	processing at landing
Species	chestnut	chestnut	chestnut	chestnut with some birch	chestnut
Assortments	2.2 m long pulpwood; hornbeam and oak: 1.1 m long firewood	Sorts: 6 (2.5 m 15-20 cm; 2 m 8-12 cm; 3 m 10-15 cm; 5 m 15-23 cm; 5 m 23-30; pulpwood), tops for chip production	Poles 3.5, 4.5 and 5.5 m (large end up to 20 cm, small end not smaller than 10 cm), tops for chip production	Process Random lenghts	MDF pulpwood, Poles 3.5, 4.5 and 5.5 m (large end up to 20 cm, small end not smaller than 10 cm), tops for chip production
dbh average	11,9 cm	19,8 cm	15,2 cm	14,0 cm	17,8 cm
dbh st. dev.	4,1	5,0	4,4	3,7	4,3
dbh min	4 cm	12 cm	8 cm	5 cm	8 cm
dbh max	33 cm	33 cm	34 cm	29 cm	38 cm
cycles	528	136	242	840	195
obs. time	9,1 h	2,1 h	9,4 h	13,7 h	5,8 h

For the purpose of the study, the harvested volume was measured directly after processing or it was calculated from the diameter at breast height (dbh), using volume tables. In the latter case, between 10 and 20 tree heights and diameters were measured before processing the trees, in order to estimate a dbh-height curve. Using calculated heights and measured dbh values, tree volumes could be estimated for each tree, using local volume tables. The dbh of each tree to be processed was marked on its stem or butt end, so that researchers could see and note it when recording time study data, during processing. In this study the productivity was estimated for the processed stem volume, excluding the volume eventually converted into chips (tops and branches). Waiting times are also excluded from calculations, because they originated from organizational causes and were not specifically related to the stems being processed or the machines processing them (for instance: waiting for tractor to bring the trees to the harvester).

Table 2. Productive working steps: definitions and breaking points

Move	Machine starts moving – machine stops
Grab	Machine turn into direction of tree – head arms close around the tree
Process	Start debranching and cross cutting – completes debranching and performs the last crosscut, severing the tree top
Stack	Moves the top to the top pile – top falls on the pile, head arms open
Product management	Take assortments and moves them to the appropriate pile – assortments dropped on the pile, head arms open
Other	Other working steps

3. Results

3.1 Foresteri 1

The Foresteri RH 25 mounted on a CAT 312 excavator processed chestnut trees with a dbh range from 4 to 33 cm. The average dbh of all processed trees is 11,9 cm. The harvester has a productivity of 7,7 m³/productive machine hour (PMH). The harvester averages a net productivity of 89 trees/PMH.
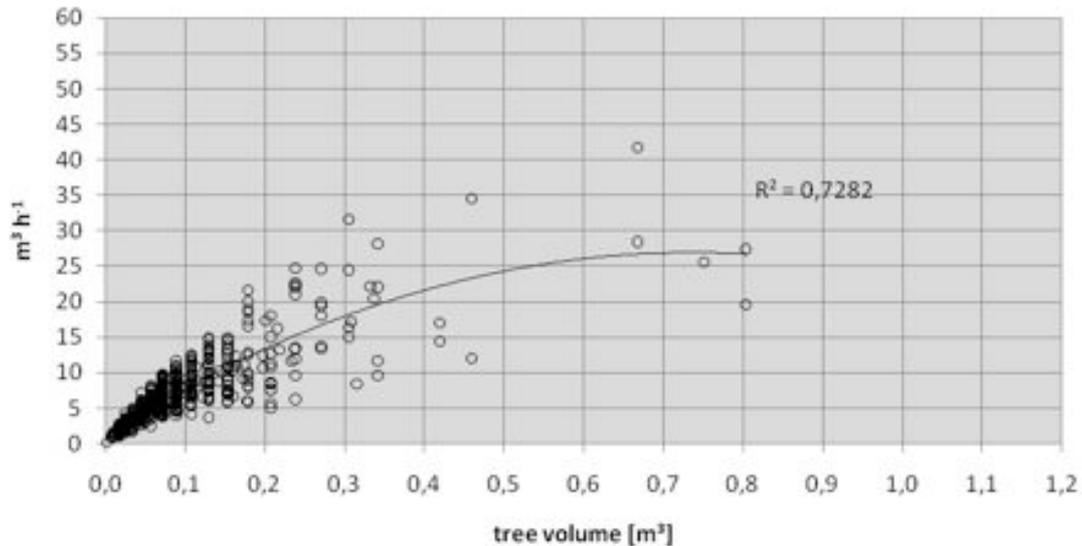

Figure 1. Productivity of Foresteri – study 1

In most cases (457 cycles) the operator processed one tree at a time. In some other cases 2 (61 cycles), 3 (27 cycles) or 4 (1 cycle) trees were processed in the same cycle. A calculation of different productivity functions for total processed tree volume by cycles could not reveal a difference in total productivity when processing more than one tree at a time. However, the productivity is higher when processing several small trees at a time, compared to processing them one by one.

3.2 Foresteri 2

Foresteri productivity reaches 19,8 m³ or 70 trees per productive machine hour. The Foresteri on a CAT 312 excavator has a higher productivity than in the first study with the same machine, because trees were in the second study of the substantially larger, with an average dbh of 19,8 cm (compared to 11,9 cm in the previous study). The dbh range of the processed trees is between 12 and 33 cm.

Tree quality also varied between the two different Foresteri studies. In the second study the processed trees had a better quality than in the first one, being larger and straighter. Furthermore, the first study was conducted at a cable yarder landing, where the machine had to move with much care in order to avoid damage to the tower, the guy lines and other surrounding people and equipment.
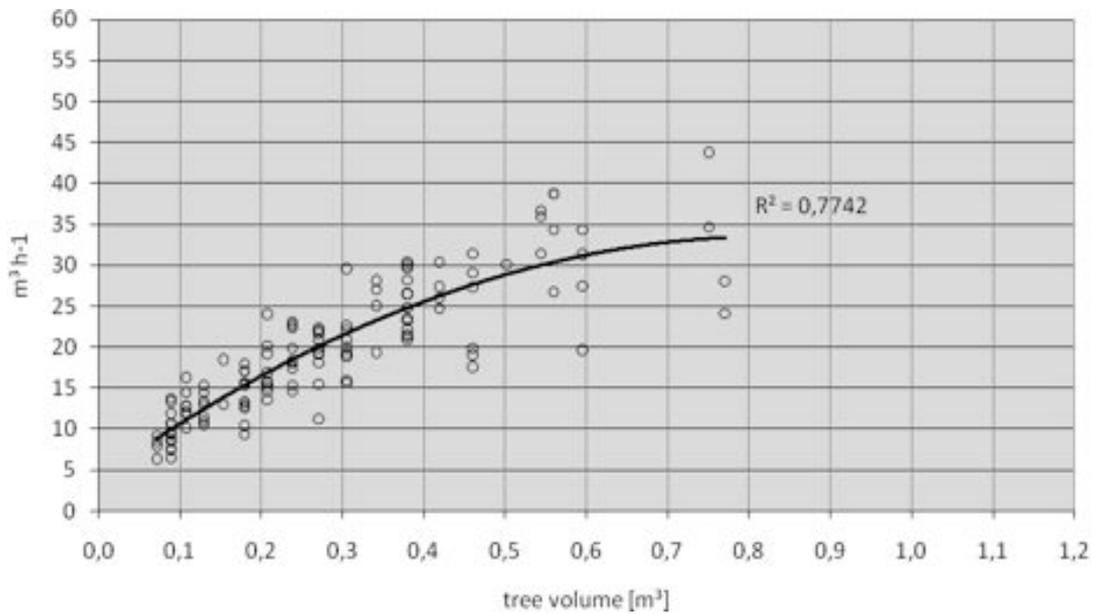
Figure 2. Productivity of Foresteri – study 2

3.3 John Deere

The productivity of the John Deere 762C on a Timberjack 1270B harvester is 16,8 m³/PMH. The Harvester processes 77 trees/PMH. The function shown below presents a rather weak correlation, due to a number of factors, and especially to the important effect of assortment type and tree form, which was not included in the simple regression. Nevertheless, the significance of this function is very high, due to the very large number of observations used to calculate it.
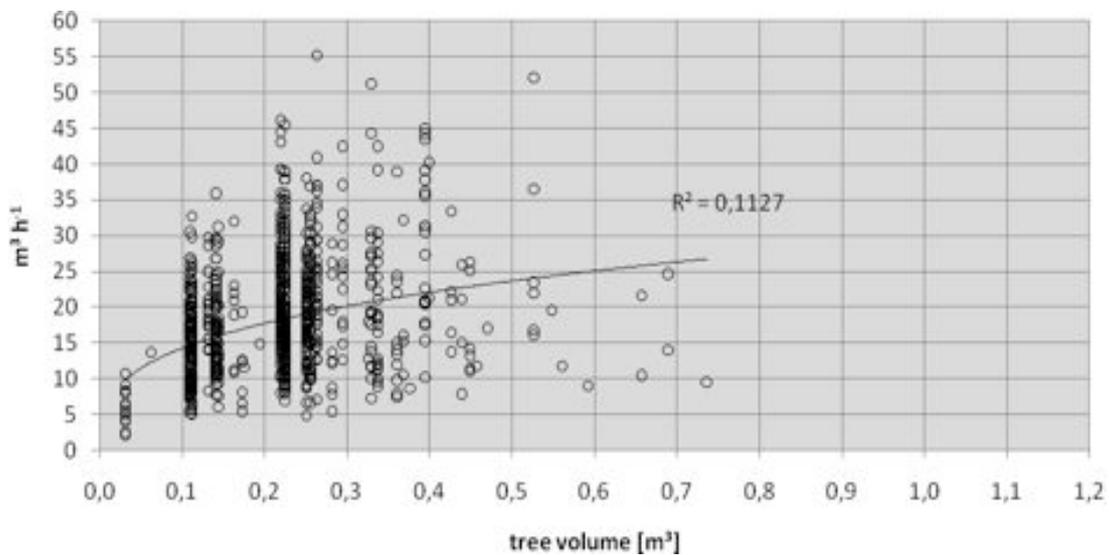

Figure 3. Productivity of John Deere

3.4 Lako

The dbh of processed trees range from 8 to 34 cm, with an average value of 15,2 cm. Average tree volume is 0,13 m³. The productivity of this unit is 5,4 m³ or 41 trees per productive machine hour.
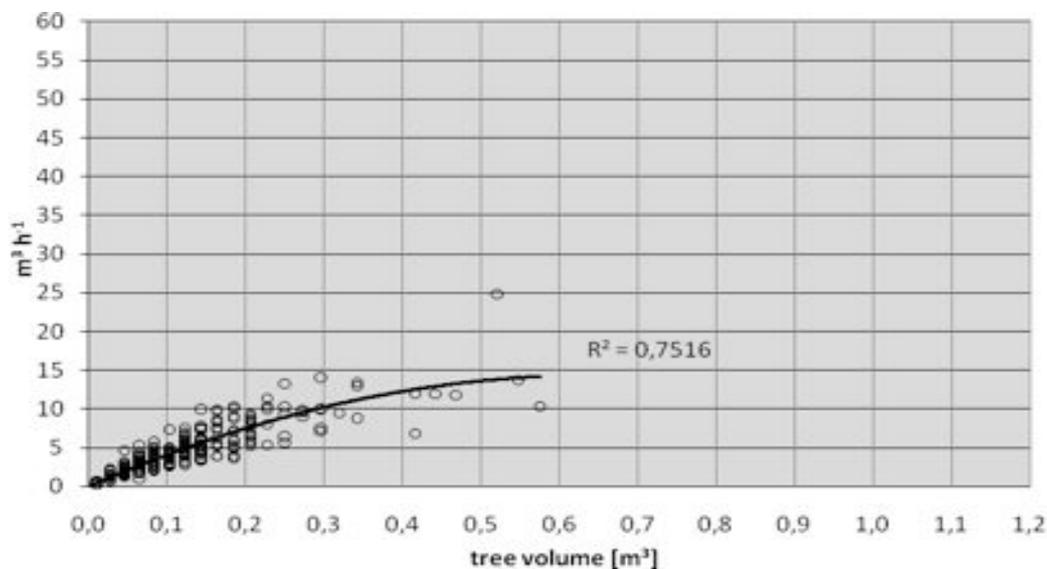

Figure 4. Productivity of Lako

3.5 Arbro

The Arbro 400S is a stroke harvester, which feeds processed stems with an alternating slide boom rather than with rollers, like the other units observed so far. The average productivity recorded in the study is 9,2 m³ and 39 trees per productive machine hour. The range of tree dbh varies between 8 and 38 cm, with an average of 17,8 cm.
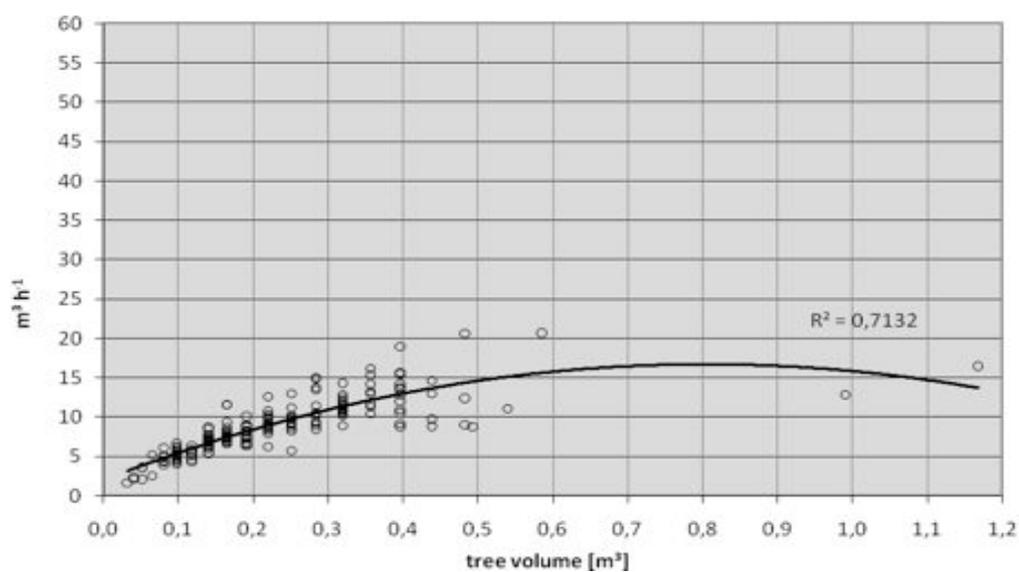

Figure 5. Productivity of Arbro

3.6 Comparision of all studies

Figure 6 compares the productivity functions already presented above, and shows the Foresteri as the best performer, outproducing even the dedicated harvester, However, one must keep in mind the very wide spread of the data recorded for the dedicated harvester, which leaves significant room for adjustments. The Lako on a JCB JS 180 NL and the Arbro on a JCB 8052 excavator had the same productivity, despite the very different size and mechanical characteristics.
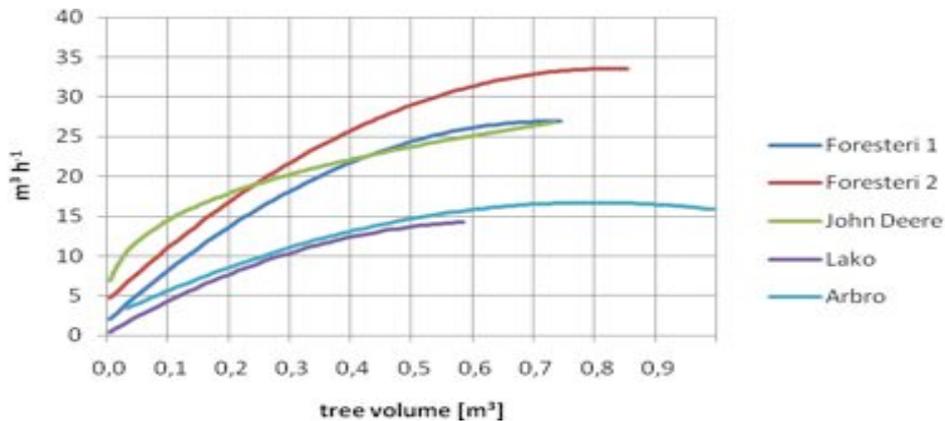

Figure 6. Productivity of all 4 machines

Regression equations for estimating productivity (m³ PMH^{-1}) as a function of stem volume (m³):

$$\text{Prod. Foresteri 1} = -47{,}064x^2 + 69{,}931x + 1{,}3543 \tag{1}$$
$$\text{Prod. Foresteri 2} = -42{,}782x^2 + 71{,}15x + 3{,}9575 \tag{2}$$
$$\text{Prod. John Deere} = 29{,}428x^{0{,}3152} \tag{3}$$
$$\text{Prod. Lako} = -48{,}057x^2 + 55{,}324x \tag{4}$$
$$\text{Prod. Arbro} = -22{,}744x^2 + 36{,}574x + 2{,}0098 \tag{5}$$

Regression equations for estimating productivity (m³ PMH^{-1}) as a function of dbh (cm):

$$\text{Prod. Foresteri 1} = 0{,}0042x^2 + 0{,}938x - 4{,}8299 \tag{6}$$
$$\text{Prod. Foresteri 2} = 0{,}0212x^2 + 2{,}2443x - 16{,}068 \tag{7}$$
$$\text{Prod. John Deere} = 2{,}9455x^{0{,}6486} \tag{8}$$
$$\text{Prod. Lako} = -0{,}0084x^2 + 0{,}9323x - 7{,}0962 \tag{9}$$
$$\text{Prod. Arbro} = -0{,}0187x^2 + 1{,}3829x - 9{,}4974 \tag{10}$$

In all five studies the time of "moving" the machine is very low with a percentage part from 2,2% (Foresteri 1) to 8,5% (John Deere). The highest absolute time is 8 100/min. (100 parts of a minute) per cycle and pertains to the Arbro: this is the smallest machine in the study, with the shortest boom reach, and has more need to change positions during work.

The time for "grabbing" trees represents between 15% and 24% of the total net work time. In this respect, all studies are very close together. The time element grab for pre felled and pre extracted trees shows only a small difference between the machines. Presented as absolute times, the range is between 12 and 23 100/min, with the Arbro and the Lako need the longest time (23 100/min).

"Processing" time represents the largest proportion of the cycle, in all studies. The percent contribution of processing time to total cycle time increases with tree dbh. In absolute terms, processing requires an

average time consumption of: Foresteri 1: 40 100/min. (with a average dbh of 11,9 cm), Foresteri 2: 49 100/min. (avr. dbh 19,8 cm), Lako: 96 100/min. (avr. dbh 15,2, John Deere: 34 100/min (avr. dbh 14 cm , Arbro 78 100/min. (avr. dbh 17,8 cm).
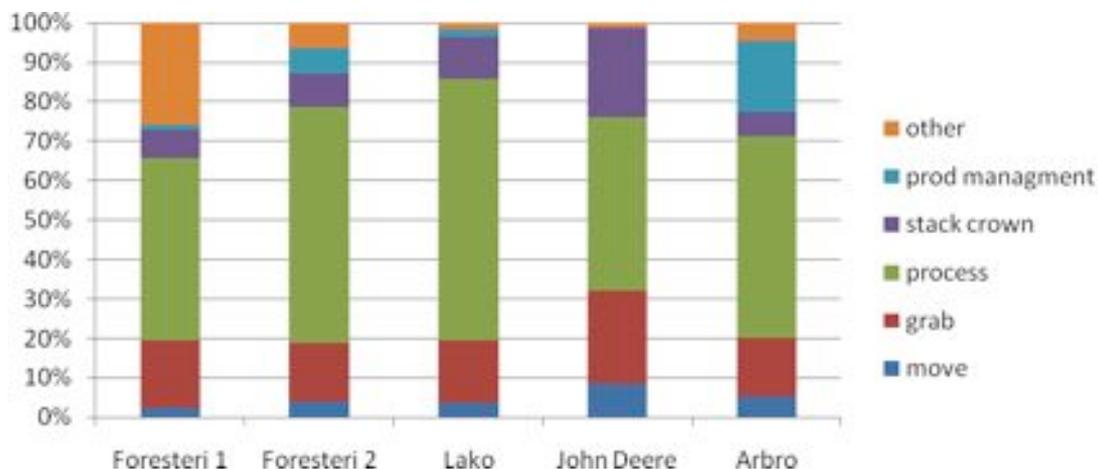

Figure 7. Breakdown of net time among working steps, excluding waiting times

"Stacking" tops after processing takes between 6 and 11% of total cycle time with the Foresteri, Lako and Arbro machines, but grows up to 23 % with the John Deere dedicated harvester (18 100/min). The Lako also needs 15 100/min for stacking tops after processing.

"Product management" includes moving processed assortments to different stacks and cleaning the work place. The contribution of this work step to total cycle time is highest with the Arbro, where it amounts to 18% (28 100/min. absolute time per cycle). In that case, the operator often grabbed the stems multiple times to "organize" the woodpile.

Foresteri 1 has the highest contribution of "other" times, because it worked under the cable yarder, which required the additional handling of stems before and after processing.

The effect of tree quality on productivity was calculated by correlation test for the Arbro study. The quality of trees was measured by five different form factors (Table 3), which proved to have a significant effect on productivity (Kendal-Tau and Spearman-Rho test on level 0,01). Used an independent variable in multiple regressions, the form factors also shows to have a significant effect, together with tree size or combined with it (i.e. interaction variable form * dbh).

Table 3. Characteristics of form factors

1	Small branches, straight stems
2	Big branches or bad form
3	Big branches and bad form, or very big branches
4	Very big branches and bad form, or fork and big branches
5	Forked several times, or many big and very big branches

4. Discussions

The study confirms that processors can reach a high productivity when handling whole chestnut trees. Therefore, CTL technology can be a good alternative to motormanual work in chestnut stands.

Moving time when working was very small because all machines worked from piles, which reduced the number of work sites. Furthermore, all machines worked in coppice clearcuts (the most common treatment in coppice stands), with the advantage coming from concentrated volume removal.

On the other hand, coppice harvesting presents all the disadvantages related to small tree harvesting. Stem quality of trees is another significant factor affecting productivity, as shown in the Abro study.

Readers must be particularly aware of the different product strategies followed in the different studies, and that a more accurate comparison of machine productivity between tests could only be made if all machines were used to produce the same assortment range. The effect of assortment type on harvester productivity has already been shown by other studies, reporting productivity differences between 12 and 34% as a result of different product strategies (Emeryat et al. 1996 and 1997, Martin et al. 1996, Sauter and Grammel 1996, Spinelli and Spinelli 2000). Furthermore, productivity differences could be partly derive from different operator skills. The 5 machines used for the study were operated by 5 different professionals, and not by the same test operator. Hence, each operator, however, was a potential source of individual variability, which must be taken into account when evaluating the results (Gellerstedt 2002), since operator effect has already been shown to affect machine productivity up to 40% (Ovaskainen et al. 2004). However, no attempts were made to normalize individual performances by means of productivity ratings (Scott 1973), recognizing that all kinds of normalization or corrections can introduce new sources of errors and uncontrolled variation in the data material (Gullberg 1995).

Therefore, the results of this studies must be interpreted with caution, avoiding categorical conclusions.

References

Emeryat, R., Picorit, C. and Reuling, D. (1996). L´allonegement des longueurs de billions du pin maritime. AFOCEL Fiche Information-Forêt, n. 531. 6p.

Emeryat, R., Picorit C. and Reuling D. (1997). Perspectives de la mecanisation du bûcheronage du pin maritime. AFOCEL Fiche Information-Forêt, n. 561. 6p.

FAO (2005). Global Forest Resource Assessment. http://www.fao.org/forestry/static/data/fra2005/global_tables/FRA_2005_Global_Tables_EN.xls

Gellerstedt S. (2002). Operation of the single-grip harvester: motor-sensory and cognitive work. International Journal of Forest Engineering, 13 (2), 35-47

Gullberg T. (1995). Evaluating operator-machine interactions in comparative time studies. International Journal of Forest Engineering, 7 (1), 51-61

INFC (2005). Ministere delle Politiche Agricole, Alimentari e Forestali. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. Trento. http://www.sian.it/inventarioforestale/jsp/home.jsp

Martin, P., Lapeyre, D., Restoy, G., Martinez, F. and Guegand, G. (1997). Bûcheronage mécanisé en eclaircie de feuillus. Chantier de Tournay (65). AFOCEL Note technique CW 02/97. 22p

Ovaskainen H., Uusitalo J., Väätäinen K. (2004). Characteristics and Significance of a Harvester Operators' Working Technique in Thinnings. International Journal of Forest Engineering, 15 (2)

Sauter, U. and Grammel, R. (1996). Konkurierende Aufarbeitung von Nadelschwachholz in langer und kurzer Form mit Kranvollerntern in der Durchforstung. Forsttechnische Informationen, 6/7, 68-76

Scott A. (1973). Work measurement: observed time to standard time. In: Wittering, W. (1973). Work study in forestry. Forestry Commission Bulletin, n. 47: 26-39

Spinelli, R. and Spinelli, R. (2000). L´allestimento meccanizzato del ceduo di castagno. Monti e Boschi, 1, 36-42

Tella, G. di (1982). Castangno di Valombrosa. Istituto Sperimentale per l`Assestamento Forestale e per l`Alpicolura Tavole stereometriche ed alsometriche costruite per boschi italini, 369-372