Determining the annual use, service life and value retention of CTL technology

Raffaele Spinelli, Natascia Magagnotti, Gianni Picchi
CNR IVALSA
Via Biasi 75
San Michele all'Adige (TN), Italy
spinelli@valsa.cnr.it

Abstract:
Annual use, service life and value retention are crucial factors in the calculation of machine rates. However, there is little scientific data available to scholars trying to perform such calculations, except for local studies and rule-of-thumb guidelines. Intending to fill such gasp, the authors gathered a large database of second-hand machine sale offers containing over 1000 records for CTL machinery (harvesters and forwarders). Records came from Europe and North America, and contained asking price, year of manufacture and total hours worked. The statistical analysis of this data pointed at a service life in the vicinity of 18000 hours for both harvesters and forwarders, which confirms previous assumptions. The average annual use for the machines in the database is 1424 and 1581 hours year^{-1}, respectively for the harvesters and the forwarders. Nordic users achieve a higher annual use than central European users, and the difference is statistically significant. Data was compared with the figures obtained from local surveys or assumed by the authors of published studies. The average annual use obtained from this study for both groups falls below the levels commonly adopted in current estimates, which may therefore represent ideal reference figures rather than actual averages. Resale price is strongly related to machine age, and the authors calculated some simple functions for estimating it. The study points at a better retention of the original value, compared to the figures reported in previous literature. At 5 years of age the harvesters and forwarders in the study retain respectively 38 and 44% of the new value. The study is also an example of how one can get very useful data with relatively simple research.

Keywords: harvester, processor, forwarder, annual use, cost, value

1 Introduction

Mechanized CTL harvesting has revolutionised forest operations, with strong impacts on value recovery and labour productivity. Harvesters and forwarders are now common in all industrialized countries, far beyond the borders of the Nordic regions where they were first developed. Despite such widespread diffusion, very little data are available on the annual use, economic life and residual value of CTL machinery. Published figures for machine annual use are only available for Austria (Pröll 2005), Italy (Spinelli et al. 2009) and some regions of Germany (Forbrig 2000, Denninger 2002, Findeisen 2002, Nicks & Forbrig 2002, Drewes & Jacke 2005), but the reports are often in the national languages and are not readily available to the larger scientific community. The acquisition of modern CTL technology involves a significant capital investment, much higher than that required by traditional small-scale equipment: that makes the formulation of a correct machine rate even more dependent on a reliable estimate of economic life, annual use and residual value. Such figures play a crucial role in all costing methods

Therefore, the goal of this study was to produce reliable figures for the annual use, economic life and residual value of CTL machinery, based on the analysis of documented, empirical data coming from a large sample of machines on sale on the European and North American markets. A further goal of the study was to determine the relationship between residual value, machine age and machine total use (in terms of total hours worked), which can aid the cross-sectional estimate of cost streams all along the economic life of a machine.

The study only concerned dedicated CTL machinery, and excluded all harvesters and forwarders built on a general-purpose prime mover, such as excavators and farm tractors. Exclusion was justified by the inherent larger variability of the general-purpose equipment category, which risked to generate an unacceptable level of background noise. The versatile character of general-purpose prime movers makes them the ideal solution for part-time loggers, with the risk of introducing a significant bias in the results, if part-time and professional loggers were pooled together.

2 Material and methods

Data were sourced from the advertisements published on the specialised press and on a number of specialised websites, including those managed by the original manufacturers. The authors analysed the 2009 issues of 7 magazines of forest mechanization, considered as the most important titles published in France, Germany, Italy, USA and UK. Furthermore, 19 specialised websites were searched for offers of harvesters and forwarders. Overall, our survey covered the European and North American markets. Together with the machine make and model, most advertisements also reported the year of construction, the hours worked and the request price. Offers containing at least two of the above items were copied into a worksheet database. Entries were then checked for redundancy, and repeat entries were erased. The final version of the database contained 643 harvester and 530 forwarder offers. The data pool only contained dedicated units, excluding all machines based on a general-purpose prime mover.

The second-hand market offer machines of all ages, from almost new to exceedingly old. Hence, the useful economic life of a machine cannot be assumed as the average age of the machines on sale, nor it can be considered as long as the maximum age of the oldest machines. Therefore, the useful economic life of harvesters and forwarders was considered as falling between the maximum value reported for machine hours at the time of sale and the upper quartile for the same category. The very same process was also repeated for machine age in years, at the time of sale. Machine annual use was simply estimated by dividing the hours of total use by the years of age, for each machine in the database. However, one- and two-year old machines were excluded from the calculation of annual use, because the resulting figures are strongly affected by two uncontrolled factors, and namely: 1) the delay between manufacturing and full commissioning, and 2) the exact month of manufacturing. An attempt was also made to determine if annual use was different in different regions. Machines were grouped by three macro-regions and namely: Nordic Europe, Central Europe and North America. Such attribution was made on the basis of the seller’s address, and not on the place of manufacture. For instance, machines built in Finland but sold by a German owner were considered to be used in Germany and therefore were included in the Central European group. Such groups only contained those records that could be attributed with certainty to any given region, and therefore included a small part of the original data pool used for the study. Residual value was calculated as a percent of the value of a new machine of the same brand and type, after obtaining the current price lists from the manufacturers. When a machine model was no longer in production, the price of its equivalent model (e.g. the same make, capacity, number of wheels etc.) was taken, without attempting to actualize old price lists. If no equivalent model was available, then the entry was excluded from the exercise. Valid data points were then analysed with multiple regression techniques, to determine any significant relationships between residual value at the time of resale, age and total use.

3 Results

Harvesters are generally sold after working between 2800 and 17800 hours (interquartile range), and most often about 10000 hours (Table 1). Economic life can be assumed to reach or exceed the upper quartile level, i.e. 17800 hours. Age-wise, the majority of harvesters are sold at an age between 2 and 14 years (interquartile range), and most commonly at 7.8 years. Some machines are still on the market after over 30 years.

Most forwarders on the second-hand market have worked between 2500 and 19300 hours (Interquartile range), and the average machine is sold at about 11000 hours. Their economic life can be assumed to be around the upper quartile level, i.e. 19300 hours. Like harvesters, most forwarders are re-sold at an age varying between 2 and almost 14 years, and most commonly at 7.6 years of age. Here too, some machines are still on the market after over 30 years in service, having worked more than 30000 hours.

Table 1 – Descriptive statistics for use, age and residual value

	Harvesters				Forwarders			
	Total use	Age	Annual use	Residual	Total use	Age	Annual use	Residual
	Hours	Years	Hours year^{-1}	value %	Hours	Years	Hours year^{-1}	value %
Mean	10371	7.8	1439	31.8	10953	7.6	1617	42.6
S.D.	5564	4.4	540	19.1	6160	4.8	632	20.8
Min.	20	0.5	65	4.8	150	0.5	212	4.9
Max.	30800	33.3	3962	95.8	32650	33.3	4418	100.7
Median	10000	7.3	1372	28.6	10500	6.3	1539	39.2
Mode	15000	5.3	1327	13.0	18000	5.3	1509	NA
IQR	7500	6.0	657	27.7	8400	6.0	799	28.3

After excluding one- and two-years old machines, the average annual use of the harvesters in the database was 1439 hours year^{-1}, with lower and upper quartile values of 782 and 2096 hours year^{-1} respectively. Few machines accumulate an annual use near 4000 hours (Figure 1). The significance of regional differences was tested with the Fisher PLSD test, which indicated a statistically significant difference ($p < 0.0001$) between harvesters coming from Nordic and Central Europe, with values of 1809 and 1355 hours year^{-1}, respectively. The annual use of Northamerican units did not differ significantly from that of the Central European ones, while it was significantly lower than that of Nordic units. However, the number of units unambiguously identified as Northamerican was so limited (56) that such result may not be conclusive. No regional difference was found for the average total use at the time of resale, which was always around 10000 hours regardless of provenance. However, given the more intense annual use, Nordic machines were sold almost 2 years earlier than Central European ones. This difference also proved statistically significant to ANOVA testing ($p = 0.04$).

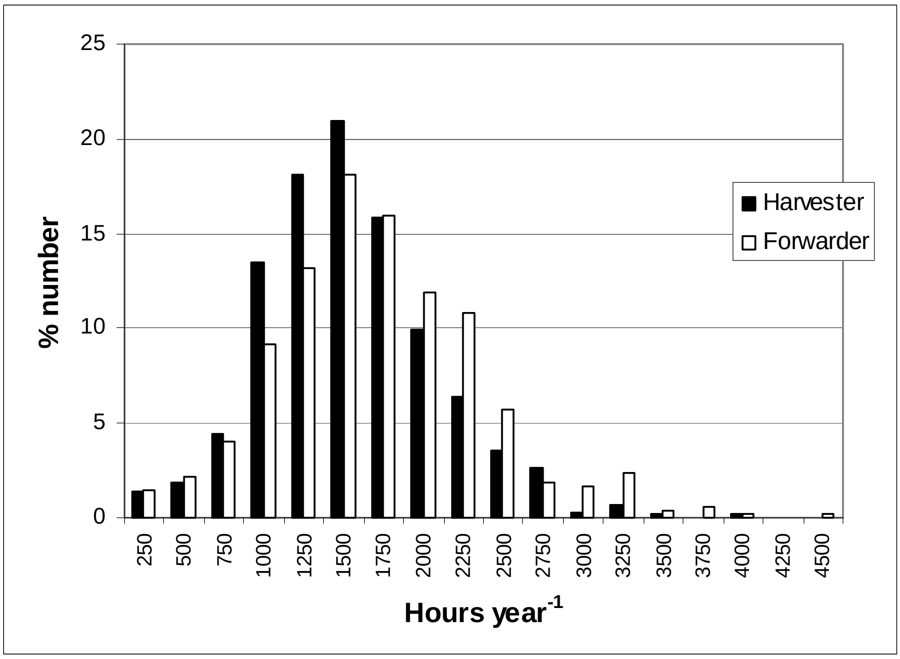

Figure 1: Frequency distribution for the annual use

After excluding one- and two-years old machines, the average annual use of the forwarders in the database was 1617 hours year^{-1}, with lower and upper quartile values of 818 and 2416 hours respectively. Few machines reached an annual use in excess of 4000 hours year^{-1}. Again, Nordic units showed a significantly higher annual use than Central European units, with 1843 hours year^{-1} vs. 1483 hours year^{-1}. This difference resulted significant to Scheffe's test ($p = 0.02$). Hours at the time of resale did not differ on a regional base, but age did, Nordic units being about 2 years younger than Central European units ($p = 0.04$).

The average residual value of harvesters and forwarders was respectively 31.8 and 42.6 % of the new price. These values applied to machines with approximately 10000 hours of work on their hour meters. In fact, the residual value of second hand machines seemed to be related more to their age than to their total use (Fig. 2). Regression analysis was conducted on the valid data pool, separately for harvesters and forwarders. Tested as independent variables, both total use in hours and age in years gave a good fit, but the latter offered a higher coefficient of determination and explained over 70 % of the variability. In all cases, the best fit was a logarithmic curve, where value losses decreased as age or total use increased.

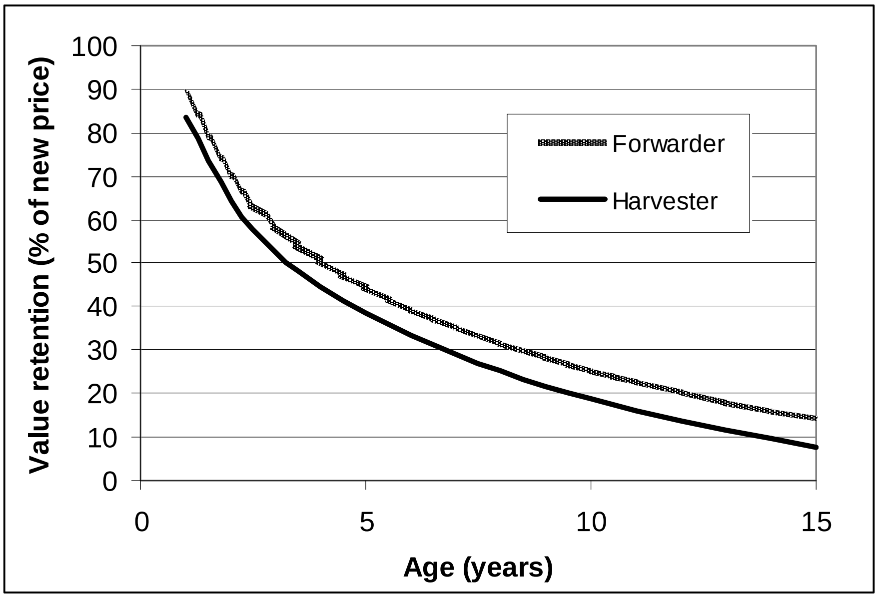

Figure 2: Residual value as a percent of new price

4 Discussion

Dedicated CTL machinery seems to have a very long economic life, and the question arises on the reference values one should use for estimating correct machine rates. We assume that any figure around the upper quartile level would be safe enough for current use, even if some machines can still be on the market many hours and many years beyond those figures. This would bring us to elect economic life figures of about 18000 hours, which correspond with those used, for instance, by Athanassiadis et al (2000) and reported by Strömgren (1999). Eventually, such figures could be considered conservative, and leave some margin for additional use. At any rate, it is important to stress that the use figures deriving from our study refer to meter hours and not to time sheet hours, thus representing productive hours rather than scheduled hours. This is an important distinction and must be remembered when using these figures to calculate machine rates, which should apply to productive work hours and not to scheduled hours (Miyata & Steinhilb 1981). However, it is likely that the machines will be left on also during minor delays, so that meter hours do not correspond to pure productive work hours, but contain a certain amount of delay and preparation time. That fully justifies the Central European and Nordic custom of including delay events up to a certain maximum duration (normally 15 or 30 minutes) into any estimate of productive work time (Spinelli & Visser 2008). Such time is commonly denoted as PMH_{15} and PMH_{30}, as a function of the maximum duration of included delay events.

The machine annual use levels determined by this study are lower than most other estimates available for harvesters, a selection of which is reported in Table 4. A possible explanation is that such estimates are based on time sheets and represent scheduled time, rather than metered productive work time (including some delay). If we assume that an 8-hour scheduled work day corresponds to 7 productive work hours (including some delays), then we can correct our figures by inflating them to 8/7, which would bring our average annual use to about 1600 and 1800 hours $year^{-1}$, respectively for harvesters and forwarders. Even so, it seems that the present study offers lower annual use estimates than those reported by many of the Nordic and Central European sources quoted in Table 2 for harvesters.

Table 2: Annual use of harvesters and processors in some European countries

Hours year^{-1}	Country	Data type	Source
1560	Austria	Published	Pröll (2005)
1435-2277	Austria	Raw Data	Stampfer (2009)
2574	Finland	Estimate	Kärhä (2009)
1725	France	Estimate	Poissonnet (2009)
ca. 1750	Germany	Published	Forbrig (2000)
ca. 1900	Germany	Published	Denninger (2002)
2036-2800	Germany	Published	Findeisen (2002)
1865	Germany	Published	Nicks and Forbrig (2002)
ca. 1300	Germany	Published	Drewes and Jacke (2005)
1328	Italy	Published	Spinelli et al (2009)

This is especially true for the Nordic estimates, which are always above 2000 hours year^{-1}. However, most of these estimates were collected in 2009, whereas the data obtained with the present study refer to average values centered about 7 to 8 years ago, which is the average age of the pre-owned machines on sale. Pre-dating is the inherent characteristic of a study using second-hand market data, and the discrepancy between our estimates and those of the best Nordic experts could depend on a growing trend of machine annual use over time, which may have brought machine annual use from the 2000 hours year^{-1} of 2002 to the current 2500-2700 hours year^{-1}. However, regressing annual use figures with machine age in years did not return any significant decreasing trend (i.e. lower annual use with longer age), since all functions tested were associated with a coefficient of determination always below 0.1. Such result also seems to disprove any assumptions about a decrease in annual use along a machine's economic life. It is indeed very likely that many machines are bought new by large contractors, utilized very intensively earlier on in their economic life and then sold after few years to less intense users. However, if this was the general and dominant trend, then regression analysis should return a much higher coefficient of determination, which was not the case. Therefore, we may infer that an annual use above 2000 hours year^{-1} represents an ideal target rather than the norm, and it only describes elite industrial users. Such a high level of annual use only applies to 14 % of the harvesters represented in our study, the majority of which (55%) are utilized between 1250 and 1750 hours year^{-1}.

Statistical analysis shows that machine age in years is a stronger predictor of residual value than machine total use in hours. Such result is corroborated by many other studies addressing the residual value of forest machinery (Bright 2004, Brinker et al. 2002, Cubbage et al. 1991). Compared to these studies, however, our research highlights a better retention of the original value over time. At 5 years of age the harvesters and forwarders in our study keep respectively 38 and 44% of the new value, versus the 30 and 36 % indicated by Bright (2004). Brinker et al. (2002) take value retention to an even lower level, assuming a residual value of 20% of the original price after only 4 years. Of course, our regressions explain only 75% of the variability, leaving a quarter of the total variation in the data unaccounted for. However, this can be considered a good result, in the light of the significant background noise generated by differences in machine conditions, by the presence (or lack) of accessories and options, and by the effect of machine make and models – some necessarily more popular than others. Furthermore, we have calculated residual value as the difference between list price for the new machine and ask-price for the used one, without considering the actual prices after the eventual negotiations. However, since we are trying to estimate a difference rather than an absolute value, the most important thing is that the bias of both estimates is consistent. In fact, the inclusion of further attributes among the independent variables does not necessarily improve the accuracy of the estimate, as demonstrated by Cubbage et al. (1991), who could not explain more than 50% of the variability in residual values for whole-tree harvesting equipment, despite the inclusion of "machine conditions" in their regressions. Further variability is introduced by the rapid evolution of CTL machinery, which implies constant and significant technical improvements (Nordfjell et al. 2010). New models and new versions of the old models appear every few years and offer superior specifications and performance. Hence, the price of the new equivalent model is different from the actualized original price, because the machine is also different. However, our calculation may be more realistic: if depreciation is the amount of money that must be saved to buy a new machine when the old one is worn out, then by the time the machine is worn out one will not find exactly the same machine on the market, and will have to buy the new model – likely an improved version.

Forwarders seem to have a longer economic life, a higher annual use and a better value retention than harvesters, which may depend on their lower complexity, resulting in less wear and higher operational flexibility. Even when conditions are not suitable to the use of a harvester (malformed trees, large-diameter stems etc.) and trees are felled and processed motor-manually, one can always use a forwarder for extraction. That may favour the acquisition of a few hundreds extra work hours per year on odd-jobs, and explain the higher annual use of forwarders. Another possible explanation is the slightly lower productive potential of forwarders when extraction distances are long, which may impose longer shifts on the extraction machines in order to achieve operation balance (Brunberg 2004).

5 Conclusions

This study suggests that the machine rate for a harvester can be calculated by assuming resale at 10000 hours and after 8 5. years, with a 30% residual value over the new price of an equivalent machine. Similar assumptions could be used for a forwarder, while taking care to increase residual value to 40% of the new price. The actual economic life of both machines is likely to be much longer than 10000 hours, and may approach or exceed 18000 hours. One may also use the latter figure to calculate machine rate, but in this case residual value would need to be decreased to 13 and 20%, respectively for the harvester and the forwarder, based on the longer age of resale (11 and 12 years respectively). At any rate, our study provides the elements needed for machine rate calculation, and each can use his/her own preferred format. Its main benefit is that of offering empirically validated figures, extracted from a large pool of data.

6 References

Athanassiadis D., Lidestav G., Wasterlund I. (2000) Assessing material consumption due to spare part utilization by harvesters and forwarders. *Journal of Forest Engineering* 11: 51-57.

Bright, G. (2004) Calculating costs and charges for forest machinery use. *Forestry* 77: 75:84.

Brinker, R., Kinard, J., Rummer, B., Lanford, B. (2002) Machine rates for selected forest harvesting machines. Circular 296 (Revised). Alabama Agricultural Experiment Station, Auburn University, AL. 32 p.

Brunberg, T. 2004. Productivity norm data for forwarders. Skogsforsk Redogörelse n.3. 12 pp (In Swedish, with English summary).

Cubbage, F., Burgess, J., Stokes, B. (1991). Cross-sectional estimates of logging equipment resale value. *Forest Products Journal* 41: 16-22

Denninger, W. (2002) Stand der hochmechanisierte holzernte in Niedersachsen. Forst & Technik 7: 14-17 (In German).

Drewes, D., Jacke, H. (2005) Einsatzzeiten – Die nutzung von selbstfahrenden forstmaschinen (auch) in Deutschland. KWF Forsttechnische Informationen 4: 47-49 (In German).

Findeisen, E. (2002) ThüringenForst: erfahrungen zur teilautonomen gruppenarbeit in der hochmechanisiert holzernte. KWF Forsttechnische Informationen 4: 37-44 (In German).

Forbrig, A. (2000) Konzeption und anwendung eines informationssystems über forstmaschinen auf der grundlage von maschinenbuchführung, leistungsnachweisen und technischen daten; KWF-Bericht 29: 119-125 (In German).

Miyata, E. S., Steinhilb, H. (1981) Logging system cost analysis: comparison of methods used. Research Paper NC-208. Forest Service North Central Forest Experiment Station, St. Paul, MN. 15 pp.

Nick, L., Forbrig, A. (2002) Forsttechnikerhebung – Stand, bewertung, bedarf, entwicklung; zwischenergebnis. KWF Forsttechnische Informationen 9: 93-99 (In German).

Nordfjell, T., Björheden, R., Thor, M., Wästerlund, I. (2010) Changes in technical performance, mechanical availability and prices of machines used in forest operations in Swedenfrom 1985 to 2010. Scandinavian Journal of Forest Research 25: 382-389.

Pröll, W. (2005) Harvestereinsatz steigt. Forstzeitung, Arbeit im Wald. 116: 4-6 (In German).

Spinelli, R., Visser, R. (2008) Analysing and estimating delays in harvester operations. *International Journal of Forest Engineering* 19: 35-40

Spinelli, R., Magagnotti, N., Picchi, G. (2009) Deploying mechanized Cut-to-Length technology in Italy: fleet size, annual usage and costs. *International Journal of Forest Engineering* 21: 23-31.

Stampfer, K. (2008) Personal communication. Data on machine utilization from 2001to 2006 for 9 units managed by Forsttechnik Steinkogl ÖBf AG

Strömgren, A. (1999) Productivity and economy in thinning and final felling for a combined Harvester-Forwarder. Swedish University of Agricultural Sciences, Dept. of Silviculture, Section of Forest Technology. Student Report 23 (In Swedish, with English summary).