Deploying Mechanized Cut-to-Length Technology in Italy: Fleet Size, Annual Usage, and Costs

Raffaele Spinelli
Natascia Magagnotti
Gianni Picchi

Abstract

The authors conducted a survey of mechanized harvesting and processing machinery in Italy, with the purpose of understanding if the close-to-nature small-scale forestry typical of this country may prevent a reasonably intense utilization of modern technology, or entail a significant increase of its operating cost. Despite the challenging work conditions offered by Italian forestry, modern forest technology has already made significant inroads, as witnessed by a small yet substantial harvester and processor fleet, counting more than 80 units, 75% of which are mounted on general-purpose carriers. Usage levels are lower than those reported for northern and central Europe, but still in excess of 1000 machine hours year^{-1}, at least for the prime movers. Insurance, repair, and maintenance costs are significantly lower than generally reported in current literature. However, empirical data on machine costs is very scarce, and most studies report estimates rather than measured values. Such estimates are often obtained with the same basic methods derived from agriculture, thus raising the question of whether their adaptation to forestry use should be further refined.

Keywords: Harvester, processor, technology, logging, mechanization, annual usage.

Introduction

Mechanized cut-to-length (CTL) harvesting brings the industry to the forest, with strong impacts on value recovery and labor productivity (Chiorescu and Grönlund 2001). Even where motor-manual harvesting techniques are still competitive due to cheap labor, there is a general objective to introduce mechanization in order to streamline production and anticipate future labor shortages (Spinelli et al. 2002). Compared to traditional motor-manual technology, advanced mechanization offers the benefits of drastically enhancing worker comfort and safety (Bell 2002). These advantages are so attractive that loggers all over the world have adopted the new technology, applying it to close-to-nature forestry (Hanell et al. 2000), hardwood stands (Jingxin and LeDoux 2005), and steep terrain (Frutig et al. 2007). Such rapid expansion is helped by the remarkable flexibility of the mechanized CTL concept: Cheap, general-purpose prime movers can be converted into reasonably efficient CTL units with the addition of a detached harvester or processor head (Johansson 1995). Earth-moving machinery provides a good alternative to dedicated units, offering a robust, multi-functional, and low-cost base (Jingxin and Haarlaa 2002) — its versatility improves the economics when the harvester function is used for a relatively short proportion of the annual work time (Vaatainen et al. 2004), making it ideal for part-time users. On the other hand, the acquisition of this new technology involves a significant capital investment, much higher than that required by traditional operations (Spinelli et al. 2009). The result is a stronger dependency of mechanized operations on increased machine utilization and a higher annual work flow.

This may be more difficult to arrange in Italy than in other countries, given the prevalence of non-industrial private forestry (NIPF) and the very limited success of owners' associations. In fact, the small scale of most Italian logging firms is likely to reflect their dependence on NIPF sources (Rickenbach and Steele 2006), and results in a limited investment capacity. Nevertheless, mechanized CTL technology has made significant inroads into Italian forestry, and it is increasingly common to encounter logging firms that have just pur-

The authors' affiliation is: CNR IVALSA - Timber and Tree Institute, Via Biasi 75, S. Michele all'Adige (TN), Italy. E-mail: spinelli@ivalsa.cnr.it, magagnotti@ivalsa.cnr.it, picchi@ivalsa.cnr.it.

International Journal of Forest Engineering
Volume 21, No. 2

chased their second machine. Therefore, it may be interesting to characterize the Italian harvester and processor fleet, by describing its composition, development, and usage patterns. This analysis may provide a useful example of how Nordic technology can be introduced to a very different economic, social, and physical environment, indicating the main opportunities, obstacles, and success factors.

A correct estimate of operating costs is a first crucial step when gauging the capacity of CTL technology to compete with traditional harvesting systems. Such an estimate can be done with widely-known costing methods (Miyata 1980), but requires reliable input data. Most of these data are site-specific, and must be collected locally. That applies for instance to annual usage, insurance, relocation, repair, and maintenance. Borrowing figures from other countries may produce inaccurate estimates. Besides, the data available from the international scientific bibliography are remarkably scarce. While solid figures are available on fuel consumption (Athanassiadis et al. 1999), no recent scientific studies have specifically addressed the determination of cost components in the operation of harvesters and processors, with the possible exception of local works published in the national languages, and therefore they are inaccessible to the larger scientific community. Therefore the need exists for a specific study, answering the question of how the local economic, social, and physical conditions of Southern European NIPF can affect the usage patterns and the costs of mechanized harvesting technology. In this respect, Italy represents an ideal case study, due to the prevalence of NIPF and the existence of a sizable machine fleet. Both the Italian machine users (actual and prospective) and the foreign producers have an interest in understanding if such conditions may affect the composition of the Italian machine fleet and cause significant deviations from the mainstream European trends. Similarly, both may want to know if the close-to-nature small-scale forestry typical of this country prevents a reasonably intense usage of mechanized harvesting and processing technology, or entails a significant increase of operating costs through the excessive incidence of machine relocation expenses. Furthermore, it may be worth checking if the costs of repair and maintenance are made particularly high by the taxing work conditions presented by mountain terrain, hot summer climate, heavy branching, and hardwood trees – all typical of Italian forestry.

Therefore, the goals of this study are: A) to characterize the Italian harvester and processor fleet, describing its usage pattern and its development over the past 10 years; B) to determine the annual usage level of mechanized CTL technology in Italy, and to compare it with the usage levels commonly reported for other European countries; C) to determine the costs sustained by the Italian logger for the insurance, relocation, repair, and maintenance of their harvesters and processors.

Materials and methods

A general survey was conducted in order to identify and locate mechanized operators using CTL technology either for felling and processing (harvesting) trees at the stump site, or for processing pre-felled trees at the landing, after extraction. This was done by contacting the many mechanized firms with which the National Council for Research (CNR) has been working for about a decade, since the first harvesters were introduced to Italy. This provided, the authors counted on a large and established network of mechanized firms through which they could be introduced to further operators. A similar search was also launched through the many forest administrations that cooperate with CNR. Once a list of machines had been gathered, users were grouped by machine make and the dealers were asked to confirm or update their respective lists.

The final list contained 87 units, six of which were owned by foreign firms and excluded from the count, since operation in Italy occupied only a minor part of their annual schedules. Furthermore, seven of the Italian machines were too recent for obtaining reliable data about annual usage and costs. The remaining 74 machines were considered representative, and their owners were contacted in order to obtain annual usage and cost figures. In most cases they also were visited in the field as they were working. Each was given an interview form asking data about machine age, total machine hours, annual insurance costs, and annual repair and maintenance costs. Furthermore, data was asked about relocation method, frequency, and costs. The form was left with the owners so that they could check their books and provide accurate figures. Valid data were obtained for 53 machines, i.e. over 70% of the surveyed pool. Thirty-four of the respondents could actually provide annual lists of the repair, maintenance, and relocation expenses, whereas the others only offered average annual figures.

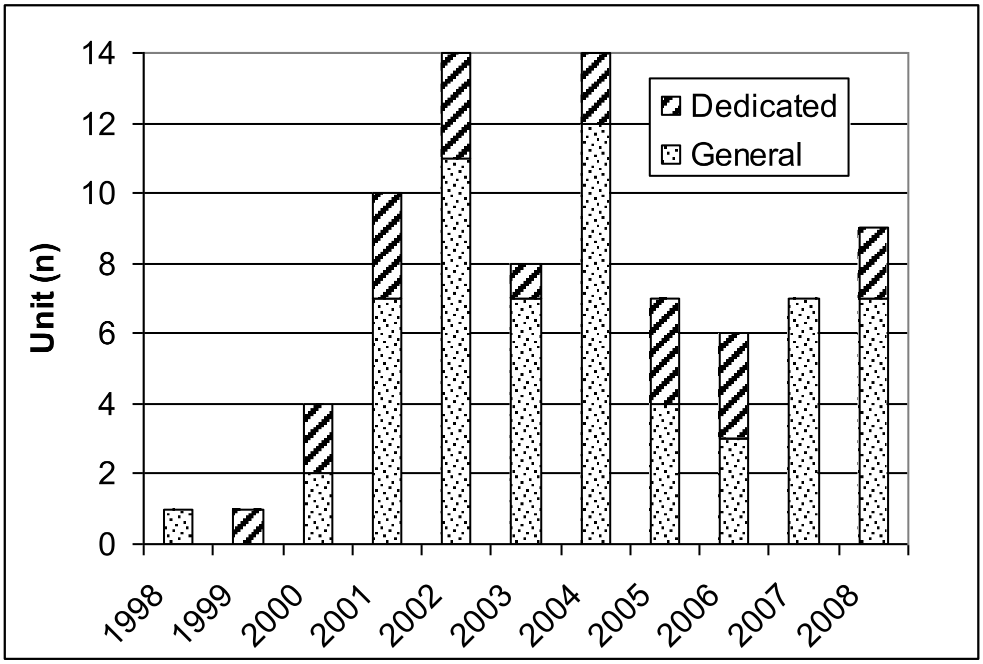
Data processing was relatively simple and consisted of calculating the basic descriptive statistics for the valid pool of data. Regression analysis was applied to the repair and maintenance cost time series in order to check whether annual repair and maintenance costs varied over time (SAS 1999). All cost figures in annual series were adjusted to 2009 values using the living cost index list published on the national statistics website (ISTAT 2009).

Results

The annual sales of harvesters and processors show an overall growing trend, with cyclic peaks in 2002 and 2004, reflecting the cyclic release of state subsidies for the purchasing of agricultural and forestry equipment (Figure 1, next page). The overall annual average amounts to seven new units per year. This figure swells to almost nine units if one starts the count from the new century and excludes years 1998 and 1999. These first two years can rightly be regarded as a “test” period, during which very few machines in Italy were being given much attention by potential users, who still had to overcome initial diffidence.

Three quarters of the harvester or processor heads sold in Italy are mounted on general purpose prime movers, especially excavators. Dedicated harvesters are much less popular and represent the remaining quarter. Regardless of type, 27% of the prime movers are pre-owned, but almost half of them have been fitted with new heads.

Figure 1. Harvesters and processors sold in Italy from 1998 through 2008.



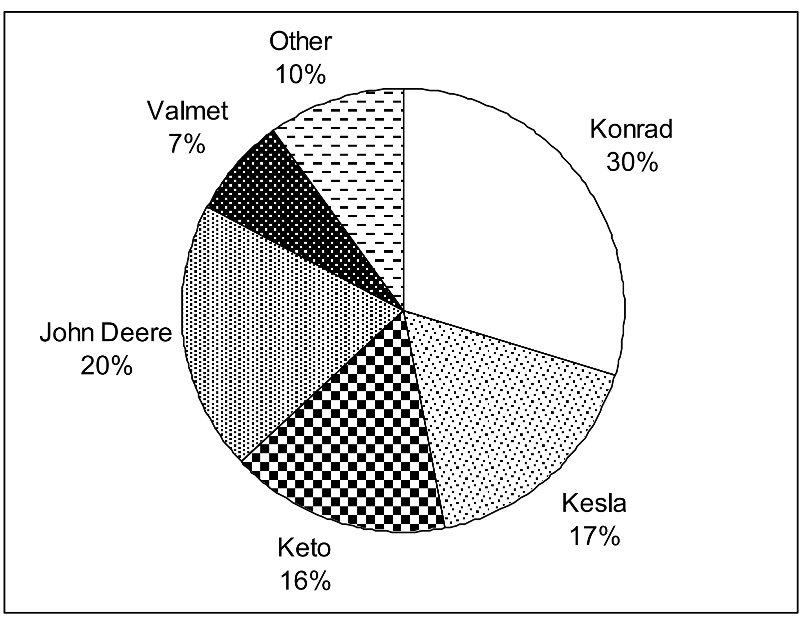
Note: Sales are subdivided between dedicated forestry harvesters (i.e. Dedicated) and harvesters and processors mounted on a general-purpose carrier, such as an excavator or a farm tractor (i.e. General).

Sizewise, 70% of the heads fall into the heavy harvester class, with a nominal cutting capacity of 60 to 70 cm. Another 16% have a cutting capacity between 40 and 50 cm and are classed as medium size. Nine heads (11%) have a cutting capacity of 35 cm and are typical thinning machines. These are mounted exclusively on small excavators or, more rarely, on modified farm tractors. Two units (3%) mount extra-heavy harvester heads, with a cutting capacity of 80 cm or more.

Figure 2 shows the market shares of the main brands. Konrad is by far the most popular, followed at a distance by John Deere, Kesla, and Keto. A number of other brands are also present on the Italian market, often with just one or two units. This list includes AFM, Arbro, Caterpillar, Lako, Loglogic, and SP. Curiously enough, Ponsse is totally absent from Italy, despite their large and increasing success on the neighboring French market. Not all machines were purchased from the official Italian dealers, as some companies bought pre-owned units from foreign dealers just across the border.

Almost two-thirds of the Italian mechanized CTL fleet is concentrated in the northern regions, especially in the autonomous provinces of Trento and Bolzano (respectively 15 and 12 units). Another quarter of the fleet is deployed in central Italy, with the highest concentration in Tuscany and Emilia-Romagna. Only six units are owned by southern companies, with at least two of them actually working in central Italy (Figure 3, next page).

Figure 2. Market shares (number of units) for the main brands selling mechanized CTL technology.



Concerning the prevalent job type, one-third of the machines work in alpine conifer stands, a quarter in lowland poplar plantations, 20% in chestnut coppice, and the remaining 20% in the many pine plantations scattered across central and southern Italy, and often treated with urgent salvage cuts following fire and/or insect damage. Over half of the thinning heads are used for processing pre-felled chestnut stems, whose diameter seldom exceeds 35 cm. Under these conditions, a thinning head represents a cheap and effective substitute for motor-manual power and can reach a much higher productivity level than normally achieved in thinning jobs (Spinelli et al. 2009).

The average annual usage for the 53 sampled units is 1328, 753, and 382 machine hours year^{-1}, respectively, for dedicated, excavator-base, and tractor-mounted units (Table 1, next page). About 20% of the owners of excavator-base and tractor-mounted units in the sample declared that their base machines are often used for jobs other than harvesting and processing, such as bunching, loading, and digging. Tractors are also used for extraction, after attaching a trailer and exchanging the

Figure 3. Geographic distribution of mechanized CTL units.

harvesting head for a grapple, as already recorded by Johansson (1996) for Sweden. That allows doubling the annual usage of the prime mover, which can thus reach or exceed the 1000 machine hours year^{-1} level. Overall, 75% of the Italian harvester and processor fleet actually sampled has a usage level above 500 machine hours year^{-1} (Table 2, next page). Statistical analysis could not detect any significant difference in the annual usage of new and pre-owned units.

Insurance costs range between 100 and 2600 € year^{-1}. Over half of the machines are included in an overall insurance policy covering all the company's fleet for liability against damage to third parties. The average cost of such a policy goes from 1900 to 2600 (mean 2200) € year^{-1}, and it is very difficult to disaggregate the total figure and calculate the insurance costs of the harvester or the processor only. The remaining companies have stipulated individual insurance contracts for their mechanized CTL machines, at an average cost of 712 and 2060 € year^{-1} depending on whether the machine is only insured against damage to third parties, or also against fire, theft, and vandalism. The cost of single-machine insurance contracts presents a wide range of variation, with minimum and maximum values equal to half and to twice the mean figures shown above respectively.

The costs reported for repair and maintenance (R&M) average 4097 € year^{-1}, ranging from as little as 258 € year^{-1} to a more substantial 22371 € year^{1}. (Table 3, next page). Dedicated harvesters carry a higher annual maintenance cost than excavator-base and tractor-mounted units, but that results from their higher annual usage. In fact, no significant differences can be found between machine configuration classes when analyzing hourly R&M costs, which average 4 € hour^{-1}. Similarly, no such differences are found between new and pre-owned machines. A weak but significant correlation is found between average annual R&M costs and machine age expressed in hours (Figure 4, next page). It must be stressed that the R&M costs reported in Figure 4 are the average annual value calculated over the whole machine life for the total hours indicated, not the value for the specific year when the machine reaches the x hours. R&M costs in the final year of the machine life should be significantly higher and result in a higher coefficient of determination for the regression. In general, the majority of interviewed owners are satisfied with their machines, which they consider reliable and low-maintenance. Some have minor complaints about electronic components, deemed as failure-prone and generally short-lived. A few owners are very dissatisfied with service, having waited for weeks in order to get some vital spare part that often ends up being very simple and cheap.

Two-thirds of the harvesters and processors used in Italy are compact enough to be transported on public roads without any specific authorizations. The remaining third exceeds the legal road limit for width, and the transport must be authorized by the road administration, often on an annual basis. Only five units are so wide as to require an escort when trans-

Table 1. Annual usage (machine hours year^{-1}) of the Italian harvester and processor fleet.

	Dedicated	Excavator	Tractor	All
Mean	**1328^{a}**	**753^{b}**	**382^{b}**	**927**
Std.Dev	598	423	221	563
Min	240	67	133	67
Max	3085	2125	552	3085
Valid obs.	18	32	3	53

Note: Different letters on the mean values for annual usage indicate that differences are significant to Anova testing at the 5% level.

Table 2. Number of units by annual usage class.

machine hours $year^{-1}$	n°	%
< 500	13	25
500 to 999	19	36
1000 to 1499	14	26
1500 to 2000	5	9
> 2000	2	4

Table 3. Repair and maintenance cost.

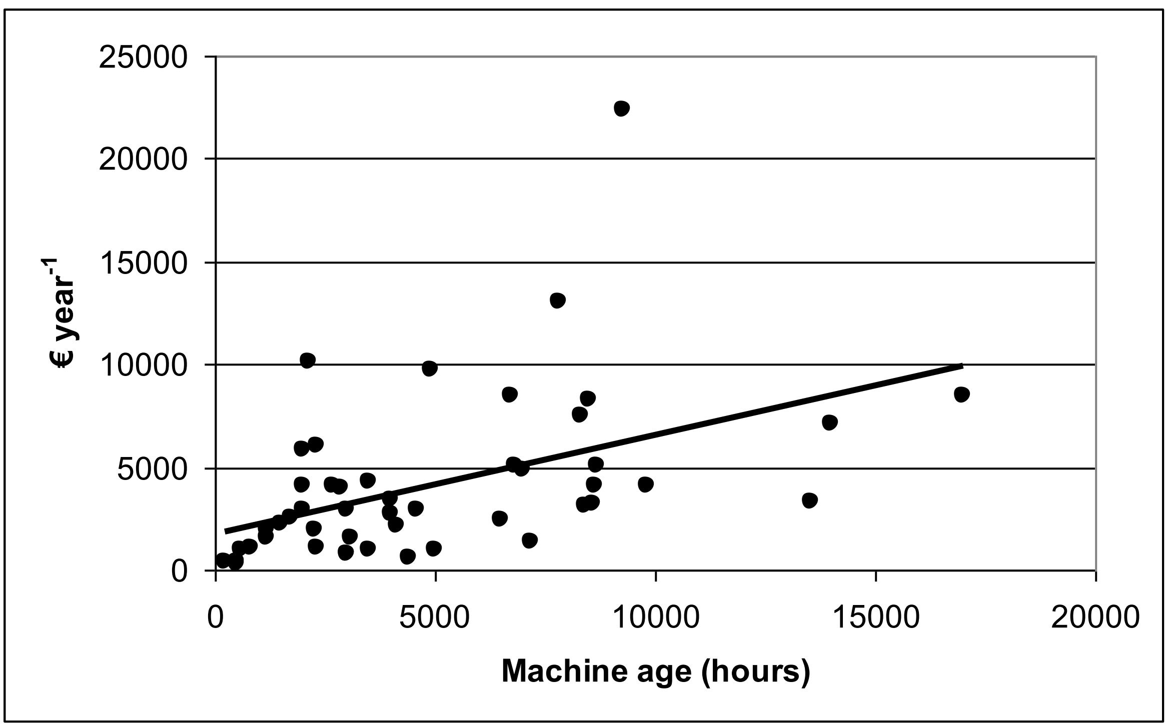
	R&M € $year^{-1}$	R&M € machine $hour^{-1}$	Age machine hours
Mean	4097	4.2	5064
Std. Dev.	3987	3	4049
Min.	258	0.8	210
Max.	22371	13.4	17000
Valid obs.	48	49	53

ported on public roads. Tractor-mounted units are the only ones authorized to drive on public roads and are often relocated without the need for a transport truck, at least on short distances (generally up to 30 km).

Over half of the companies are equipped for relocating their harvesters and processors on their own. They often use a second-hand low-bed trailer hitched to one of their log trucks. At times, the trailer is also used for transporting short -wood, loaded cross-wise. Cost reduction is only one reason for internalizing machine relocation, the other being operational flexibility. Confronted with the unpredictability of logging jobs and intent on maximizing the usage of their machines, most operators find it difficult to plan their relocation with enough accuracy to book their transport, and they do not want to wait too long before a transport is available. Independent relocation is therefore considered the most desirable choice by the majority.

Specialized moving firms charge their services by the hour or by the km. According to interviews, hourly rates range between 75 and 135 € $hour^{-1}$, with most responses clustering

Figure 4. Relationship between annual R&M costs and machine age in hours.



R&M costs, € $year^{-1}$	n = 48	R^2 = 0.215	F-Value	12.573
	Coefficient	Std.Error	t-Value	p-Value
Intercept	1719.584	845.148	2.035	< 0.0477
Machine age, hours	0.484	0.136	3.546	< 0.0009

Table 4. Relocation cost, frequency and distance.

	Transport	Mean	Std.Dev.	Min.	Max.
€ year^{-1}	Own	3167^{a}	2358	240	7500
	Rented	4342^{a}	3877	158	13621
Trips year^{-1}	Own	11.1^{a}	6.2	2	20
	Rented	6.3^{b}	5.5	1	21
€ trip^{-1}	Own	306^{a}	160	100	605
	Rented	790^{b}	651	158	2313
% Long	Own	2.2^{a}	5.3	0	18
distance	Rented	23.1^{b}	24.2	0	67

Note: Different letters on the mean values indicate that differences between transport with rented and owned vehicles are significant to Anova testing at the 5% level; % Long Distance is the % of trips covering distances in excess of 100 km.

around 85-90 €. Reported kilometer rates vary between 1 and 1.5 € km^{-1}. However, operators can strike special deals with movers and pay considerably less than that. This is the case for package deals (so many transports per year) or for service returned (e.g. loading the log trucks owned by the same transport firm as soon as they appear, interrupting any other ongoing tasks).

The average annual costs for the relocation of a harvester or a processor are 3167 and 4342 € year^{-1}, respectively, for the companies that use their own trucks and those who contract a professional mover (Table 4). The latter relocate their machines less frequently (six times per year vs. 11), but more often on distances longer than 100 km. Seeking work outside the region of origin is not rare, and two companies occasionally work abroad, in Austria, France, and Germany. In general, the average cost of a single move is estimated at 306 € if the job is done with their own trucks, and 790 € if a professional mover is contracted. The higher cost of using a professional mover also depends on the longer distance covered in that case.

Discussion

The Italian harvester and processor fleet is still small compared to those deployed in neighboring states such as Austria (237 units, Pröll 2005), Bavaria (177 units, Borchert and Kremer 2007), and France (ca. 500 units, Nguyen The et al. 2005). In fact, the Italian forests offer challenging work conditions due to a peculiarly unfavorable combination of rough terrain, ownership fragmentation, and low product value. Besides, the traditional, close-to-nature, continuous-cover forestry generally adopted in Italy may not encourage the use of modern industrial equipment (Mason et al. 1999) unless these same silvicultural prescriptions are applied with some flexibility (Price and Price 2006). A major technology shift is occurring in Italy, propelled by such vital needs as cost reduction, increased work safety, and labor shortage. Mechanization offers significant benefits in all these fields, and is getting established in Italy as well, even without the unwanted help of catastrophic storms, which had a significant role in boosting sector modernization further north, in Germany, France, and Austria. Significant fluctuations in the number of units purchased every year are often related to the periodic availability of public grants for technology modernization, derived from National and European funding schemes. Depending on company type, regional localization and year, grants can be obtained for up to 40% of the initial investment, and a number of machines have been purchased under such schemes.

The introduction of mechanized CTL technology to the Italian market is a work in progress, as witnessed by the dominant role of excavator-base units. These are indeed the first choice when the new technology is being introduced to a developing market, whereas mature markets prefer high-output dedicated units (Gellerstedt and Dahlin 1999). Most Italian loggers are relatively new to mechanized CTL harvesting and are not ready for the strong financial commitment required by the purchase of a dedicated harvester. Besides, the superior agility of such units might be wasted if they are to be deployed in flatland row plantations, or parked under a yarder at the landing site. These very same reasons can explain the remarkable success of Konrad, further assisted by the close proximity of their plant and headquarters to the Italian border. The Austrian manufacturer offers a uniquely versatile combi-head, capable of transforming into an effective log grapple at the touch of a button. These machines are ideally suited to landing work, where a CTL-unit must alternately process the trees, stack the logs, and pile the slash.

The annual usage figures found in our survey are compatible with the different intensity of use expected for the dedicated and general-purpose units and are significantly lower than those reported in bibliography for other countries. However, it must be stressed that international scientific bibliography offers very little hard data about annual machine usage. Most studies report assumptions instead of actual figures. Annual usage data obtained from direct machine surveys are only available for Austria and Germany (the latter on a regional base only) and are published in German. Table 5 (next page) was compiled from these materials and integrated through direct interviews with competent foreign colleagues. Dedicated harvesters dominate all the national fleets in the table, except for the Austrian one, where steep terrain conditions determine a significant incidence of yarder-processor operations. As a result, direct comparisons between usage levels are most appropriate only when using the average usage data obtained in Italy for the dedicated units, and equal to 1328 machine hours year^{-1}. This figure still represents half of the annual usage obtained in Finland and Sweden, but already about 75% of the level reached in France and Germany. In any case, readers must be warned against a strict interpretation of these comparisons, whose accuracy may suffer from differences in the data collection methods. Many reports do not specify whether the data for machine usage comes from the machine's own hour meter or from the operator time sheets, the two al-

Table 5. Annual usage of harvesters and processors in some European countries.

Hours year^{-1}	Country	Data type	Source
1560	Austria	Published	Proll (2005)
1435-2277	Austria	Raw Data	Stampfer (2009 Personal communication)
2574	Finland	Estimate	Kärhä (2009 Personal communication)
1725	France	Estimate	Poissonnet (2009 Personal communication)
ca. 1750	Germany	Published	Forbrig (2000)
ca. 1900	Germany	Published	Denninger (2002)
2036-2800	Germany	Published	Findeisen (2002)
1865	Germany	Published	Nick and Forbrig (2002)
ca. 1300	Germany	Published	Drewes and Jacke (2005)
1700-2000	Ireland	Estimate	Lyons (2009 Personal communication)
2000-2700	Sweden	Estimate	Bergkvist (2009 Personal communication)

ways returning different figures.

The average cost of 4 € hour^{-1} sustained for the repair and maintenance of Italian CTL units seems very small compared to the figures reported in foreign studies. This value is three and four times smaller than those obtained respectively from Finland (12 € hour^{-1}, Kärhä 2009 personal communication) and Sweden (16 € hour^{-1}, Bergkvist 2009 personal communication). Much higher figures are calculated in Germany by Bodelschwingh (2005, 16 to 26 € hour^{-1}), Korten and Matthies (2003, 35 to 50 € hour^{-1}) and Weise et al. (2006, 49 € hour^{-1}), among others. It seems difficult to reconcile our figures with those obtained elsewhere in Europe, but there are two possible explanations. First, the majority of Italian machine owners perform most maintenance and repair on their own and generally do not account for the cost of labor, but only for the expenses sustained to acquire spares and consumables. This also happens in Austria, where Pröll (2005) estimates that over 90% of mechanized contractors service and repair their machines on their own. The second explanation is simply that the calculation methods currently used to estimate the cost of machine repair and maintenance are inaccurate and tend to overestimate real costs. In fact, all the figures found in bibliography have been estimated by the respective authors and not actually measured. Besides, most cited authors have used the same method to produce their estimates based on applying a simple coefficient to depreciation cost. In fact, such is the official method proposed by Miyata (1980) and implemented by Brinker et al. (2002) in their important reference work, which in fact reports a figure of $10US hour^{-1} (2002 figure, needing substantial re-evaluation) for the R&M cost of a popular CTL harvester model. In no way do we intend to criticize the working principles of this most accepted and expedient method for estimating R&M costs, yet we think it may be worth checking the coefficients and possibly decreasing their values below the actual suggested ratios of 0.8 to 1.1. Applying the more articulate method suggested by Bright (2004) also returns higher values than obtained in this survey, and closer to those offered for the Nordic countries. Again, this method bases its estimates on initial investment and, like Miyata's, is derived from agriculture (cfr. Lazarus and Selley 2002), which may simply mean that the ratio between capital and R&M costs is significantly different for agricultural and forestry equipment, calling for an adjustment of the conversion coefficients used in the respective equations.

Very much the same can be said about insurance costs. The 4% coefficient applied to depreciation costs by Brinker et al. (2002) returns an insurance cost of $10,800US year^{-1} (again 2002 figures), which may be appropriate for the United States, but certainly not for Italy, where our survey returned a maximum figure of 2600 € year^{-1}. This value seems representative of a general European cost level, because it matches those reported for other European countries, such as Finland (2600 € year^{-1}, Kärhä 2009 personal communication), France (1525 € year^{-1}, Poissonnet 2009 personal communication) and Germany (4000 € year^{-1}, Korten and Matthies 2005).

The relocation rates charged by Italian professional movers are in line with those charged in Austria (70 € hour^{-1}, Friedl et al. 2004), Finland (1.0-1.5 € km^{-1}, 69 € hour^{-1} and 171 € trip^{-1}, Väätäinen et al. 2006), Germany (72 € hour^{-1} and 216 € trip^{-1}, Bodelschwingh 2005), Ireland (80 € hour^{-1} and 400 € trip^{1}, Lyons 2009 personal communication) and Sweden (300 € trip^{-1}, Bergkvist 2009 personal communication). The preference of Italian companies for carrying out relocation with internal resources is shared at least by their Finnish colleagues, 80% of which are equipped with low-bed trailers, also seeking operational flexibility (Väätäinen et al. 2006). Contrary to expectations, the incidence of relocation costs is lower in Italy than in the Nordic countries, where it can range from 5000 to over 10000 € year^{-1} (respectively Kärhä et al. 2008, Väätäinen et al. 2006). A possible explanation is offered by the relatively small number of Italian mechanized operators, who can still pick the best and largest sales by outbidding their competitors, who resort to traditional motormanual technology and are no match for the mechanized logger. This inference is supported by the average number of annual relocations of the Italian harvesters and processors, which is 10 times smaller than what has been reported for Finland (Väätäinen et al. 2006). Even if the Finnish machines are utilized twice as intensely as the Italian ones, the latter still spend five times the same amount of hours on a single site. Of course, the amount of empirical data available for the frequency and the cost of machine relocation is still too limited for drawing any conclusive statements, and further research may help in defining the actual obstacles to the further development of mechanized CTL technology in Italy and in Europe.

Conclusions

Despite the challenging work conditions offered by Italian forestry, modern forest technology has already made significant inroads in our country, as witnessed by a small yet substantial harvester and processor fleet, counting more than 80 units. The current picture is that of an initial stage, where a pioneering elite is venturing into the new technology with some caution, as shown by the prevalence of single-machine firms, often resorting to excavator-base or pre-owned dedicated units. The growing trend in sales of mechanized CTL technology may indicate the beginning of a major technology shift. How long it will take to complete this shift and what size a saturated Italian market will be is a matter of debate. The answer will depend on a number of factors, including the acceptance of modern forest technology from forest owners who are often prejudiced against industrial forest machinery, even if recent studies have demonstrated that the latter does not cause any more damage than motor-manual crews (Stokes et al. 2009). In this respect, it will be crucial to develop, adopt, and enforce a clear set of environmentally safe working practices. In any case, the information contained in this study may assist forest machine manufacturers in developing an adapted product that may best suit the needs of the Italian market – and possibly any markets where mechanized CTL technology is not as well-established as in northern and central Europe.

This study represents one of the very few scientific efforts to conduct a survey of mechanized CTL operations in a given country and to provide empirical data on actual machine usage and on crucial cost items, such as R&M and relocation. Our figures are generally lower than those reported in most other studies, but many studies adopt assumptions yet unavailable in the international scientific press and likely represent rule-of-thumb estimates (Cubbage et al. 1991). While the lower usage levels can be explained by the specific constraints of close-to-nature forestry conducted in rough terrain and on small tracts, the lower costs require a different explanation, which may open a fundamental debate on methodology. It is possible that the methods currently used to estimate insurance and R&M costs need some refining. The results of just one empirical study cannot provide conclusive evidence of the potential inaccuracy of commonly used methods, but they send a warning sign that can be neither confirmed nor refuted in the absence of further such studies. Similarly, our study discloses the general absence of a recognized standard methodology to measure machine usage, each of the few studies yet available returning data recorded with different and/or unspecified methods. In order to produce accurate cost estimates and comparisons, forest engineers need a larger corpus of empirical data on machine usage and cost, as well as a new reference standard on the methods for recording these data.

Funding

This work was supported by the Provincia Autonoma di Trento, within the scope of the research projects "SOFIE" and "Pibasem" (2006 post-doc program).

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