Guidelines for Coppice Forest Utilization

Natascia Magagnotti, Janine Schweier, Raffaele Spinelli, Petros Tsioras, David Rossney, Eduardo Tolosana, Abel Rodrigues and Stefan P. P. Vanbeveren

1 Introduction

Coppice management is extremely efficient; it offers the benefits of easy management, prompt regeneration and a short waiting time. Efficiency is also achieved during harvesting, because coppice is often clearcut, which allows concentrated harvest and simple felling arrangements. On the other hand, coppice management has some important limitations, especially the relatively small tree size and the exclusive reliance on hardwoods, which tend to limit future product outputs and productivity.

In recent years, new applications of the coppice concept have been developed for industrial use and/or for a changing agriculture. Today, we may identify three broad types of coppice stands, as follows (Table 1):

Table 1. Three types of coppice stands that have implications for utilization practices

		Conventional Coppice	Short rotation forestry (SRF)	Short rotation coppice (SRC)
Species	(type)	*Quercus* sp. *Fagus sylvatica* L. *Ostrya carpinifolia* L. *Castanea sativa* Mill. etc.	*Populus* spp. *Eucalyptus* spp. *Acacia* spp.	*Salix* sp. *Populus* sp. *Eucalyptus* sp.
Rotation	(years)	15 - 30 / 40	5 - 15	1 - 5
Product	(type)	Firewood	Pulpwood	Chips
Economy	(domain)	Industrial and small-scale forestry	Industrial forestry	Industrial agriculture
Harvest	(technology)	Forest	Forest	Agriculture

Corresponding Author: Natascia Magagnotti, magagnotti@ivalsa.cnr.it

Conventional coppice (Figure 1)
Established with indigenous hardwood species (oaks, chestnut, beech, hornbeam etc.) and occasionally exotic ones (*Robinia*). It is usually harvested on 15-30/40 year rotations for a large variety of products and is managed within the framework of a rural economy, according to local traditional practice. It is harvested using a wide range of techniques and usually uses equipment from small scale agriculture, although the use of specialized forestry machinery is increasing.

Figure 1. Motor-manual felling in a conventional chestnut coppice

Short rotation forestry (SRF) (Figure 2)
Stands are established with exotic fast-growing species (*Eucalyptus, Acacia*) and harvested on 5-15 year rotations to produce industrial feedstock (generally pulpwood). SRF is often developed within the framework of a large-scale industrial economy to supply industrial plants. SRF stands are often (but not exclusively) managed as coppice and they occasionally undergo shoot reduction treatments (thinning). Stands are generally harvested with industrial forestry equipment, but also occasionally with small-scale forestry equipment.

Figure 2. Mechanized industrial felling in a eucalypt SRF plantations managed as coppice (Photo 1 & 2: R. Spinelli)

Short rotation coppice (SRC) (Figure 3)
Stands are established on ex-arable land with fast-growing species, indigenous (willow, poplar) or exotic (*Eucalyptus, Robinia*). They are harvested on 1-5 year rotations to produce industrial feedstock (generally energy biomass) and managed within the framework of small-scale or industrial agriculture. So far, SRC represents a niche sector and it is generally harvested with modified agricultural equipment.

Figure 3. Single-pass harvesting in SRC established with willow (Photo: J. Schweier)

2 Conventional Coppice

The traditional management of conventional coppice forests is quite simple and is based on clear cutting at the end of rotation. Standards may be released in conventional coppice, with a density ranging from 50 to 100 trees per hectare (ha), depending on the species. No standards are released in SRF and SRC plantations. The final harvest of a mature coppice stand commonly yields between 90 and 200 m^3 ha^{-1}, or more, depending on species, age and site productivity. The harvest obtained from thinning (conversion) over-mature coppice generally varies from 40 to over 200 m^3 ha^{-1}. Generally, clear-cutting accrues profits, whereas thinning (conversion) generates losses.

Management has a strong effect on product type and harvesting productivity. Stems are cut before they can become very large and are best suited for conversion into small-size assortments. Mean stem volume typically varies between 0.05 and 0.25 m^3.

High production capacity is only achieved through the increased mechanization of harvest operations, which also helps to compensate for the effects of high labour costs and increasing labour shortages experienced in most industrialized countries (Spinelli and Magagnotti 2011). Technological progress has made the effective introduction of mechanized felling to coppice operations possible, significantly increasing worker safety and productivity. Professional management of mechanized harvesting can prevent or minimize undesired effects, such as soil, stump and stand damage (Cacot et al. 2015). When mechanized harvesting is applied, the scale of the operation and the wood removal must be large enough to offset the high fixed cost of moving machines to the worksite (Väätäinen et al. 2006).

Work safety has become a priority across Europe and the rate and severity of accidents in mechanized felling is much lower compared with the motor-manual option (Albizu et al. 2013).

2.1 Products

Europeans have exploited a wide range of broadleaved tree species in woodlands since the Stone Age. In fact, this prehistoric period of human evolution might more accurately be called the 'Wood Age', reflecting the over-riding importance of wood-based technology at this historic period.

Our ancestors learned to harness the ability of broadleaved tree species to sprout and re-grow when cut. This typically yielded multiple stems, the size of which simply depended on the time they were left to grow. The multiple shoots tended to yield sticks and poles that were straight-grained and relatively branch free; properties that still prove useful to us today.

The lightweight and straight material made good weapons (spears, bows and arrows), tool handles for axes, blades, adzes and ploughs, fencing and building materials (Figure 4). The straight grained wood split easily, yielded

Figure 4. Split chestnut gate hurdles by G and N Marshman Ltd. West Sussex, UK (Photo: D. Rossney)

almost limitless possibilities for strong but lightweight product designs and dried quickly and thoroughly, as is important for firewood.

Traditional products may be categorized as follows:

Building Materials

Includes whole stems (ca. 20 cm +) used in the round, hewn by axes into square sections, riven (split by hammer and wedge) and latterly sawn and jointed into the variety of dimensions required for timber framing.

Dwellings, fencing and weaving

Younger coppice poles have been used from earliest times to construct dwellings and fences, typically with durable species such as sweet chestnut and oak, if these were available. Hazel is less durable, but widespread and capable of producing large quantities of long clean rods. Such characteristics are ideal for a variety of products, such as woven panels used as 'hurdles' for fencing animals; 'wattle and daub', which is an in-filled stick and mud wall in timber framed buildings; and even small, round, skin covered boats called 'coracles', which were used in England during the Iron Age (Figure 5).

Fuel

Firewood for heating or cooking has always been a large consumer of coppice wood, including the use of 'faggots' (or 'slash bundles'; bundled sticks), which give quick heat for bread ovens. Coppice was also turned into charcoal wherever fuel was required for smelting metal, until this practice was superseded by coking coal. In areas with iron ore, where no coal existed, industrial-scale coppicing and charcoal production continued into the 20th century.

Other products

These included bark for leather tanning and weaving, fruits and nuts, such as chestnuts (Figure 6) and hazels, foliage as fodder for animals, pannage (seasonal practice of feeding pigs in woodland on fallen acorns and other nuts) and collected herbs, fungi and medicinal plants growing in coppice woodland ecosystems.

Figure 5. Examples of coracles by Guy Mallinson Woodland Workshop, Hereford, UK (Photo: D. Rossney)

In addition, there are household products that make use of small-dimensioned material, which is 'woven' into small (decorative) creations/objects, for example, small baskets and brooms. These products have been used through the ages, and still are today. An important market now is for tourists or city dwellers purchasing them (mostly) out of nostalgia, which affords an opportunity for some rural communities to earn part of their living from this activity.

Figure 6. Chestnuts, one of many coppice products (Photo: R. Spinelli)

Figure 7. Extraction of firewood with pack mules (Photo: R. Spinelli)

2.2 Harvesting

Traditional harvesting systems

In ancient times, manual work was dominant and it made sense to reduce cut stems to such a size that could be easily handled manually. Firewood was typically cut into one-meter lengths at the stump site, before loading it on pack animals for extraction and transportation (Carette 2003) (Figure 7). With minimal adjustments, animal extraction remained in use until a few years ago in industrial countries such as Italy and France (Baldini and Spinelli 1989) and it is still widespread in the Balkans. Modern adaptations to this ancestral system have been the introduction of chainsaws for felling and processing and of trucks for transportation, so that animal work is limited to extraction. Small stem size, an uncomfortable working position and the need to cut stems into manageable lengths result in a very low productivity of motor-manual felling and processing, which is reported in a range between 0.3 and 1.4 m^3 per scheduled machine hour (SMH) per operator (Spinelli et al. 2016a).

Modified traditional harvesting systems

The search for a mechanical substitute for the traditional mule started in the late 1980s. Over time, various micro-tractors have been designed and tested (Magagnotti et al. 2012), but none have ever obtained commercial success. Eventually, pack-mules have been replaced by the so-called pack-tractor, i.e. a farm tractor equipped with front and rear bins capable of containing ca. 3 tonnes (t) of one-meter logs (Piegai and Quilghini 1993). Small payload size prevents efficient use of these vehicles on distances further than a few hundred meters, while the limited mobility of an encumbered farm tractor limits its use to relatively easy terrain, or areas with a good network of skid trails. On suitable terrain, productivity is higher than reported for mule teams, varying from 2 to 4 m^3 SMH^{-1} with a crew of two (Spinelli et al. 2016a).

Mechanized cut-to-length harvesting

Mechanized cut-to-length (CTL) harvesting (Figure 8) is based on the introduction of the classic harvester-forwarder combination. While representing a radical technological innovation, CTL harvesting is not a revolutionary system change because it includes the same task sequence followed in the traditional system. The system is adapted to mechanization by increasing log length to 2 or 3 m, since one-meter long logs are too short for efficient mechanical handling. Appropriate machine choice and operator skill are necessary when applying CTL harvesting to coppice stands. The

Figure 8. Mechanized cut-to-length harvesting (Photo: R. Spinelli)

productivity of a modern harvester deployed in conventional coppice operations may vary from 2 to almost 10 m^3 SMH^{-1}, depending on stem size and operator proficiency. The productivity of the forwarder commonly ranges between 5 and 10 m^3 SMH^{-1}, depending on machine model and extraction distance (Spinelli et al. 2016a).

Whole-tree harvesting

Whole-tree harvesting (WTH) consists of felling trees and extracting them whole to the landing, where they are processed into commercial assortments. The main advantages of WTH are the simple in-forest handling, as well as postponement of processing to the landing, where it can be mechanized if terrain constraints make the stand inaccessible to harvesters. Motor-manual directional felling may proceed at a pace between 1 and 4 m^3 SMH^{-1} $operator^{-1}$. If terrain is accessible to mechanical equipment, then feller-bunchers can be introduced and productivity will increase dramatically, reaching values between 4 and over 8 m^3 SMH^{-1} (Schweier et al. 2015). The main operational benefit of mechanized felling is that the better presentation of felled trees boosts extraction productivity. This may range from less than 3 m^3 SMH^{-1} for skidding with a forestry-fitted farm tractor to 5 or even 8 m^3 SMH^{-1} when a dedicated skidder is used. On steep terrain, cable yarding (Figure 9) is the cost-effective alternative to building an extensive network of skidding trails and results in a much lighter site impact compared with ground-based logging (Spinelli et al. 2010). Productivity is somewhat lower than in ground-based operations, varying from 3 to 7 m^3 SMH^{-1} (Spinelli et al. 2014). The main difference with ground-based extraction is crew size, which increases to 3 or occasionally 4 workers, whereas only 1 or 2 workers are required for a skidder.

Figure 9. Cable yarding on steep terrain (Photo: R. Spinelli)

Once at the landing, whole trees are converted into conventional assorted products (i.e. firewood, pulpwood etc.) or thrown straight into a chipper. Whole-tree chipping was tested relatively early on in the Italian coppice stands (Baldini 1973) and has become a widespread commercial activity over the last decade due to a booming demand for biomass chips.

Despite all its many advantages, WTH must be considered with some caution because of the risk of soil nutrient depletion (Helmisaari et al. 2011).

Tree-length harvesting

In tree-length harvesting (TLH), trees are delimbed and topped before extraction, but not cut to length. It reduces inefficient stump-site work compared with traditional short wood harvesting, but increases the retention of biomass on-site, helping to mitigate possible adverse effects and making it suitable for site of low fertility (Mika and Keeton 2013). TLH operation determines a large (>50%) increase of stump-site work compared with WTH, whereas landing work is reduced only slightly. Decreased work efficiency leads to a general increase of logging cost, which has been estimated at 10-15% over WTH (Spinelli et al. 2016b).

3 Short Rotation Forestry

In Europe, short rotation forestry (SRF) stands, planted with exotic, fast-growing species and managed as coppice, are mainly located in the Iberian Peninsula. Among these fast-growing species, *Eucalyptus* is the most prominent and is cultivated for pulp and paper industry; it will be the focus of this chapter.

Eucalyptus was first planted in the Iberian Peninsula in Vila Nova da Gaia (Portugal) in 1829, while the first eucalypts planted in Galicia (Spain), around 1850, were likely *E. globulus*. Nowadays, the estimated surface of eucalypt plantations is approximately 0,8 Mha in Portugal and 0,6 Mha in Spain. The Iberian eucalypt industrial wood production was estimated at 10,9 Mm^3 in 2009, which represented 47% of the industrial wood fellings, but only 6% of Iberian forest surface.

3.1. Products

The main planted *Eucalyptus* species is *E. globulus*. It is very efficient in cellulose fiber production, so the main destination of its wood is the pulp industry. There are several pulp mills of different companies operating in Spain and Portugal and in 2009 they had a demand of nearly 12 Mm^3. Nowadays, *E. globulus* occupies the largest forest area in Portugal with 812.000 ha, mainly allocated for pulp production under an intensive coppice system, with a full year growing cycle. *E. globulus* is the only significant eucalypt species in Portugal.

Other uses of eucalypt forests are less frequent, but there are some smaller mills producing veneer, laminated panels and beams used for farming mussels beneath sea water. In addition, essences and honey are widely obtained from these cultivated forests.

3.2. Harvesting

E. globulus is a sprouting species and is thus traditionally coppiced. In the past, the more drought-resistant *E. camaldulensis* was widely planted in the southwest of Spain, but in the past decades most of its plantations have been removed or substituted by more productive *E. globulus* clones. Lastly, from the beginning of 21st century, the more freeze, pest and diseases resistant species *E. nitens* has become more frequent in the northwest of Spain, especially in Galicia.

The most productive Spanish eucalypt plantation area is located within Galicia and the Cantabrian region. A constraint on these plantations is the very fragmented forest ownership (average ownership size of less than 2 ha, divided into several plots), which limits the harvesting systems and the plantation profitability. Accordingly, most of the Spanish harvesting contractors are small-sized enterprises that have had trouble to adapt to a proper mechanization due to lack of investment capability and, in many cases, lack of adequate training and entrepreneurial culture.

In Spain, the usual plantation frame ranges from 2x3 m to 3x3 m (final density; there are no thinnings) and the rotation age varies from 12 to 15 years, although it could eventually be longer. Fertilizing and cleaning of competing vegetation are usual practices. Treatments against pest and diseases are quite common. Fire risk and fire protection are of high importance for eucalypt management.

When a *E. globulus* plantation is coppiced, felling and sprouting are followed by the selection of the best sprouts: 1 to 3 per stump, after 1 or 2 years. The second rotation is thought to produce some 10-15% more volume

Figure 10. Felling by chainsaw (Photo: E. Tolosana)

compared to the original plantation, while the next rotations continue to decrease in yield to the point at which it is more productive to plant again. During the past decade, many coppices have been uprooted and re-planted again using genetically improved material.

Eucalypt coppices in Portugal are characterized by a 12 year rotation cycle and that growth continues throughout the year. The average biomass productivity ranges from about 14 to 16 t ha^{-1} $year^{-1}$, which is equal to about 14 to 15 m^3 $year^{-1}$. Recent data shows a high dependence between biomass productivity and rainfall, reflected by a sharp decrease in the second year of a two year draught period (2004 - 2005), characterized by half yearly precipitation values. The decrease of above ground biomass productivity in the second year was half the order of magnitude compared to usual values.

<u>The traditional logging systems are based on:</u>

Motor-manual felling and processing

With chainsaw; where forest harvesters are not available and/or the terrain conditions are unfavorable for mechanization (Figure 10).

Semi-mechanized felling and processing

Felling by chainsaw and processing using forest CTL-harvesters, frequently based on tracked excavators but also specialized Nordic machines. One of the reasons felling often has remained to be motor-manual is the interest of the forest owners in keeping the stump height as low as possible and getting a good cut quality. In steep terrains, felling is always performed by chainsaw. Whole trees are then slipped or winched to temporary forest roads where they are processed by machines.

The most common equipment for extraction is an adapted farm tractor or local small to medium-sized forwarder, using the CTL harvesting system.

The use of residual biomass in Spain has changed over the years. In the past, the logs were debarked at the harvesting site and branches, tops and bark left on the terrain. From the 1990s onwards, the trend has been to transport the wood with bark to the mill (Figures 11) and use stationary drum debarking machines to separate the bark, which is burnt for combined heat and power (CHP) generation at the mills.

Felling mechanization in eucalypt plantations has been encouraged in the past years.

Figure 11. Transportation of wood with bark to the mill (Photos: E. Tolosana)

Figure 12. Mechanized felling and processing

Figure 13. Mechanized felling (Photos: E. Tolosana)

Besides the traditional systems mentioned above, companies are trying to implement two new harvesting systems:

- Fully mechanized felling and processing with specialized forest harvesters (Figures 12 and 13)
- Fully mechanized felling with disc saw or knife feller-buncher, followed by processing with forest processors

To haul the logs off, the trend is to use larger, increasingly Nordic, forest forwarders.

Regarding eucalypt residual biomass harvesting in Spain, the prevalent system is based on bundlers (Figure 14); Portuguese or Nordic machines equipped with knives - instead of chainsaws - to cut the biomass bales. This allows the use of the same machinery to handle the logs and the bundles and avoids the preparation of landings to organize chipping operations, which is often difficult in the typically small plantations.

Besides this, one of Spain's leading forest management companies, ENCE, is trying to improve forest harvesting operations by providing their logging contractors with Total Quality Management (TQM) instructions, in order to increase the utilization rate and productivity. To this end, ENCE has developed apps that communicate daily reports by the contractors through mobile phones and they are providing their contractors with technical and managerial support to optimize their operational efficiency. Despite the inclusion of a GPS tracking system, the road transport optimization still has much room for development.

There is a recent strong trend to substitute *E. globulus* with *E. nitens* in some Galician forest areas despite the fact that the latter is less efficient in producing cellulose fiber and does not resprout well, which limits coppicing. The main drivers are the threats by pest and diseases, towards which *E. globulus* is more sensitive, and the much higher growth potential of the *E. nitens* in many climate and terrain conditions.

Besides this species change, in Spain there is a trend to abandon coppicing in some areas; mainly where *E. nitens* is planted, but also other areas. Some reasons are: coppicing requires a more intense management than first plantation at final density; pulpwood quality is worse in coppice; coppice harvesting presents some mechanization difficulties; there is a decrease in yield after multiple coppicing; and new technologies allow the production of pulp from removed stumps.

In Portugal, the main trends of pulp production follow a consequent forest biotechnological breeding program of *E. globulus*, which aim at improving the biomass productivity and resistance to biotic and abiotic agents, such as drought.

Figure 14. Bundler, often used for eucalypt in Spain (Photo: E. Tolosana)

4 Short Rotation Coppice

Short rotation coppice (SRC) is a dedicated crop, mainly planted on agricultural land and designed to produce large quantities of raw materials at regular intervals.

Fast-growing tree species considered for SRC can be indigenous (willow, poplar) or exotic (eucalypt, black locust).

The planting density ranges from about 6,000 to 15,000 plants (usually unrooted cuttings) per ha, planted in single or twin rows, according to the species and the rotation lengths. The tree growth is influenced by site characteristics (such as soil and climate) and genotype selection should be made accordingly. SRCs are harvested in rotations of 1-5 years for the production of industrial feedstock (generally energy biomass).

The plantations are generally harvested with modified agricultural equipment that can harvest small stems. Forest equipment is only used if stems are too large and too close to one another. Planting is done with vegetative material (uprooted cuttings), whereas resprouting after harvest happens naturally from the existing root systems.

4.1 Products

The main purpose is to grow wood for energy (Figure 15), but it also can be used for other products, such as industrial feedstock or in the bio-refinery industry. In most cases, stems are chipped immediately after the cutting and blown into a tractor-trailer unit that accompanies the forage harvester. These chips have a moisture content of 50-60% (Spinelli et al. 2008, Vanbeveren et al. 2015) and a low heating value. Chips can be dried (naturally or

Figure 15. Short rotation coppice crops are mainly chipped and used for energy (Photo: J. Schweier)

Advantages of SRC

- High biomass yields
- Regular incomes in short intervals
- Groundwater protection
- Ecological planning
- Phyto-remediation
- Increase of value added in rural areas
- Diversification of landscape
- Higher biodiversity compared to agricultural fields

Disadvantages of SRC

- High moisture content of freshly cut chips (poplar 50-60% wet weight basis)
- Difficult storage of wet chips
- Technical limitations on difficult terrain (slope)
- High costs on small sites
- Dependence on harvester availability
- Lower biodiversity compared to forests and uncultivated grass/shrublands

Figure 16. Unloading of chips; the chips should be used immediately if possible (Photo: J. Schweier)

artificially) to reach a desired moisture content. However, during the storage there is a dry matter loss of 10 - 20% (Schweier et al. 2017) due to microbiological activities, which reduce the chip quality and can create self-ignition and health problems. The latter are caused mainly by fungi, especially when their spores become airborne during fuel handling. Therefore, chips should be used immediately (Figure 16). If this is not possible, chips should be stored at a proper distance from residential areas and should be handled with appropriate precautions.

If the market recognizes the added value, the use of surplus heat, when available, could be a good and efficient option for drying chips (Schweier and Becker 2013).

Chips from SRC have a relatively high bark content, which is important because bark has higher elemental concentrations and a lower density compared to wood (Tharakan et al. 2003). During the combustion of material with a high bark percentage, problems arise from damage to the boilers (Guidi et al. 2008) and fouling can occur. Bark ratio is reduced in biannual systems, where harvesting is done at minimum 2 - 3 year intervals, which produces more favorable chip quality than annual harvesting. Therefore, clones with a lower bark percentage should be selected and trees should not be cut before an acceptable fibre-to-bark ratio is obtained (Spinelli et al. 2009).

4.2 Harvesting

There are two dominant harvesting systems used for SRC: the single pass cut-and-chip and the double pass cut-and-store technique.

Single pass cut-and-chip technique

Stems are cut, chipped and discharged into accompanying tractor-trailer units in one single pass, using only one harvesting machine (Figure 17). Generally, the system is based on a prime mover equipped with a header and 2 - 4 tractor-trailer units to move the chips to a collection point. There, the wood chips can be reloaded onto road transportation vehicles, or used directly as feedstock if an energy plant is close-by.

The coppice header can be placed on the front of the mover or on the side. Headers for SRC can be modified maize choppers (e.g. the Claas HS-1) or purpose-built (e.g. Claas HS-2 or the Italian GBE). According to site characteristics, these machines can reach very high productivities with peak values up to 80 green tonnes per hour (Spinelli et al. 2008) and guarantee consistent chip sizes. An additional advantage of modified forage harvesters is that they allow the farmer to run their machines in winter as well, when agricultural field work is not possible. The main disadvantage is the machines' weight, as this limits their use to flat and solid terrain. Modified forage harvesters require stems of a particular size and row spacing. Cut stems usually enter the chopper horizontally, but if stems are too close to each other, or too long, the cut stems can become entangled with standing stems and jam the header (Spinelli et al. 2009).

Figure 17. Examples of single pass cut-and-chip system: the harvesting machine cuts and chips the stems and the chips are discharged directly into a tractor-trailer units. (Photos: J. Schweier)

Mower-chippers can be a good alternative for dense plantations and larger diameters due to their capability to chip the stem in an upright position (Pecenka and Hoffmann 2015).

Double pass cut-and-store technique

With the double pass cut-and-store technique, the processes of cutting and chipping are split into two steps: one machine first cuts and windrows the stems (Figure 18) and a second picks them up and chips them (usually some weeks to months later), blowing the chip into conventional silage trailers. The main benefits are the capacity to concentrate the cutting within a short period of time (thus exploiting good weather windows) and the possibility to chip the material according to market demand or required moisture content.

Until now, single pass cut-and-chip harvesting is the most common technique used in SRC, due to the technological progress and research that it underwent. Other techniques do exist, such as the singe pass cut-and-bale and the single pass cut-and-billet technique, which produce wood bales in the first case and billets in the latter (Vanbeveren et al. 2017), but they do not yet reach market value. Thanks to their more powerful engine, cut-and-chip harvesters have a higher average productivity (30 green tonnes per hour) than whip harvesters (19 green tonnes per hour) (ibid.).

Conclusions

Among possible sources of energy biomass, SRC has a high potential to contribute to the renewable energy mix.

Since harvesting costs are estimated to be above 50% of the total cost of the biomass produced from SRC, the optimization of these operations is required.

Good performance can be obtained when several factors concur, such as: good terrain and weather conditions, adequate machine selection, appropriate crop density and exact row spacing.

Figure 18. Example of the cutting in the double pass cut and store techniques. The stems will be chipped later (Photo: J. Schweier)

5 Conclusion

Despite some decades of decline, the current economic trends point to a good future for coppice forests (Figure 19).

Coppice management can be applied in many ways, according to different species, level of mechanization and specific local condition; it can also be aimed at different products.

Active coppice management already plays a vital part in rural economies, but can increase its potential when a certain level of modernization is acquired.

Mechanization is a possible solution to make coppice management a modern industrial business instead of a part-time activity. Modern harvesting systems, of different scales, can compensate for the difficulty in acquiring sufficient rural labor and maintaining young workers in the forestry sector.

It is important to select or, in some cases, further develop the right felling technology to guarantee the rejuvenation of the coppiced stands. Stump crowding and small stem size can be considered common elements that have an impact on operational choices in many coppiced stands. The presence of multiple stems on the same stump offers a serious challenge to mechanized felling in coppice harvesting operations, because stem crowding hinders felling head movements. Small stem size affects the type of products one can obtain from coppice stands, while limiting work productivity.

An effective introduction of mechanized felling requires the selection of a suitable machine but also a skilled and professional operator who can prevent or minimize undesired effects, such as soil, stump and stand damage.

Figure 19. Coppice provides a wide range of products and is important for rural economies (Photos: upper left C. Suchomel, lower middle R. Spinelli, lower right J. Schweier, rest A. Unrau)

It is also necessary to promote a certain level of mechanization to improve safety. Manual work is associated with the highest accident risk and severity, and it accounts for most of the fatal accidents recorded in forest operations.

Silvicultural practices may need to be adapted to new harvesting technology and to favor, whenever possible, proper removals and the use of machines. In many cases coppice forests are situated in difficult terrain with poor access. The improvement and adaptation of the existing infrastructure (road density and quality) to the requirements of mechanized operations is one important prerequisite for successful mechanization.

Although much progress has already been made, the introduction of mechanized operations still encounters resistance.

Better knowledge concerning the techniques of mechanized harvesting in coppice forests is required. International initiatives such as the COST Action FP1301 EuroCoppice may help to bridge gaps in such areas.

Rural development policies should encourage coppice management in order to promote the diversification of rural activities.

It is important to continue the regular utilization of coppice in order to preserve it as a system of forestry. This utilization will promote ecological, protection and aesthetic functions of coppice forests and can guarantee income to owners, loggers and rural communities.

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Editors: Alicia Unrau, Gero Becker, Raffaele Spinelli, Dagnija Lazdina, Natascia Magagnotti, Valeriu-Norocel Nicolescu, Peter Buckley, Debbie Bartlett and Pieter D. Kofman

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