Restoration of selective beech coppices: A case study in the Apennines (Italy)

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Abstract
The coppice selection system is a special type of management of beech (Fagus sylvatica L.) coppice practiced in mountain regions of Italy until the first half of the 20th century. The improvement of social and economic conditions within mountain communities and the progressive shift from an intensive use of the forests towards a protective policy led to the conversion of many beech coppices into high stands. Among abandoned coppices we can still find some that exhibit the typical features of the coppice selection system. Where the locally predominant forest type is beech coppice in transition to high forest, a widespread and fairly homogeneous ecosystem in the Apennines between Tuscany and Emilia-Romagna, the restoration of the coppice selection system can have a role in maintaining and improving both landscape and ecological diversity. This work evaluates the possibility of restoring this silvicultural system on selective beech coppices that are in a state of prolonged silvicultural abandonment. The first cutting treatment of the restoration procedure has been tested in permanent sample plots. Dendrometric characteristics of the stands are analysed and results on the silvicultural and production aspects of this first cutting treatment are presented. Due to the increase of standing volume during the period of silvicultural abandonment, firewood production resulting from this first cut is generally high.

Keywords: Coppice selection system; Beech; Treatment restoration; Traditional management

1. Introduction
1.1. Rationale for restoring selective beech coppices

Only a few years ago the restoration of the coppice selection system would have been considered unworthy of study. However, recent changes in forest management perspectives and objectives favoring development of multifunctional forests and the structural diversification of stands (Wohlgemuth et al., 2002), and the possibility of profitable harvests (von Teuffel, 1999), made possible by the accumulation of biomass in coppices left uncut for decades (Glatzel, 1999), have lately made the idea of selective coppice restoration a legitimate subject for discussion and research.

Restoration of cultural landscapes and traditional forest management practices can have an important role in nature conservation and sustainable forest management (Strandberg et al., 2005; Rotherham, 2006), and for maintaining forest diversity (Bengtsson et al., 2000) and historical characteristics of ancient woods (Peterken, 1999). Research related to the restoration of such practices could help preserve the rural cultural heritage through the study and application of specific techniques and knowledge which could otherwise be lost (Agnoletti, 2002).

In contexts where forests have already been largely converted into high stands and where current managing policies favor the continued development of unproductive coppices into relatively homogeneous high stands, the revival of coppice management could contribute to landscape diversity (Rackham, 1976) and help maintain biodiversity by providing important habitat for those plant and animal species typically found in more open coppice stands which would otherwise not survive in high stands. Restoration of such management systems can be considered an improvement in the context of environmental-biological stability (Andreata, 2006; Joys et al., 2004; Niemela et al., 1996), and a useful diversification of wood production (Piegai et al., 2004) and of forest work and its related professional skills.
Previous experiences on the restoration or introduction of the coppice selection system in beech are unknown. In Sweden, however, a selective coppice regime has been tested for aspen (*Populus tremula* L.) and birch (*Betula pendula* Roth and *B. pubescens* Ehrh.), as a low-impact form of management for urban coppices, chosen for its visual and aesthetic qualities, as shoots are always present on the stool (Rydberg, 2000).

### 1.2. Traditional use of beech coppices

The use of wood for domestic heating and cooking was very common in rural areas and in the small mountain villages in Italy until the Second World War. The bulk of wood used for this purpose was harvested from coppice stands. The most common coppice management was, and still is, the coppice with standards system. In this silvicultural system, clear felling of shoots is carried out at selected rotation ages and a certain number of standards (usually from 50 to 150 per ha), of two or three times the rotation age, are retained. In mountain areas, where beech coppices were widespread, a particular type of harvesting regime known as the coppice selection system (ceduo a sterzo) or ant cut (taglio della formica) was also in use.

This silvicultural system probably originated as a way for people in these often impoverished rural communities to harvest wood from the forest on a more frequent basis without destroying or impoverishing it. It was practiced with great skill by local woodcutters using refined silvicultural techniques that were generally transferred through the generations from father to son (Menicacci, 2002). Some Italian and French authors tried to codify the treatment, assessing dendrometric parameters of the system, cutting rotation periods, and the stock and felling volumes adopted by these traditional managers.

In the coppice selection system, the coppice stand is organised into three age classes with shoots of different age and diameter coexisting on the same stool. At each coppicing time (from 8 to 12-year rotation) the larger and older shoots are cut and the others are lightly thinned (Buffolo, 1936; Patrone, 1944; Mannozzi-Torini, 1949; Poggi, 1960; Hermanin and La Marca, 1985; Bernetti, 1995; Camia et al., 2002). If \( t \) is the average life span of mature shoots for a determined assortment (also defined by a fixed cutting diameter) and \( \lambda \), the rotation period \( (=1/3t) \), at each felling, shoots that have reached age \( t \) are removed, and younger shoots, i.e. shoots at the end of their second rotation period \( (2\lambda) \) and if necessary shoots at the end of their first rotation period \( (1\lambda) \), are selectively thinned, creating conditions favoring the growth of a new generation of shoots (Fig. 1). Thus, the main differences from other coppice systems is the continuous presence of live shoots on stools.

The rotation period, the felling diameter and the age of mature shoots depend upon the assortments to be obtained and the fertility of the site. Buffolo (1936) described two kinds of coppice selection system (moderate with short rotation, or strong with long rotation) with rotation periods \( (\lambda) \) of 6 and 10 years and full cycle \( (t) \) of 18 and 30 years, respectively. Patrone (1944) described rotation periods ranging between 6 and 8 years and full cycle lengths between 18 and 24 years. According to Mannozzi-Torini (1949) rotation periods vary from 6 to 8 years and full cycle lengths between 18 and 24 years. Hermanin and La Marca (1985) indicated 36 years as the maximum cutting age with a rotation of 12 years. Finally, according to Bernetti (1995), rotation periods vary between 9 and 12 years with full cycle lengths ranging from 27 to 36 years.

Short rotation periods and a low cutting diameter, usually between 8 and 10 cm, were typical of coal production (Mannozzi-Torini, 1949; Servant et al., 2006) which was the main produce of the coppice selection system.

Simplified versions of this system were also used in Italy and elsewhere in Europe. In some Italian mountain regions, a more simplified treatment yielded shoots of two (rather than three) age classes on each stool (Hermanin, 1981). Beech selective coppices were common in the Pyrenees as well and were mostly managed in a simplified form with two shoot age classes (Perrin, 1954). In the Chilterns (England) beech woods have been treated in a slightly different way than other coppices, and where beech wood was to be coppiced for poles and firewood,
no beeches less than 9 years of age were to be cut. (Clements et al., 2001). In mountain regions of France, beech coppices were usually treated according to a selection system (furetage) defined as a cut which removes only larger shoots, leaving the others for future exploitation (Bastien, 2002).

1.3. Selective beech coppice advantages

Limitations on the application of the coppice system for beech are the species’ relatively poor ability to produce new shoots, their slow initial growth, and the need for protection from adverse weather conditions, at least when they are young (Crivellari, 1955; Bernetti, 1995). Recurrent interventions and the permanence of living shoots on the stool, typical of selective coppice, help to overcome these limitations. Clements et al. (2001) suggests leaving beech stools with a single stem after coppicing to promote their regrowth, while other authors have suggested stimulation of root shoots using special cutting techniques (Mannozzi-Torini, 1949; Ciancio and Nocentini, 2004, p. 149).

The preference of beech for deep, fertile, soils (Hofmann, 1991) can be considered a further limitation to the application of the coppice system. In the Apennines, intense periods of rainfall and drought are typical of the region’s Mediterranean mountain-climate regime; the thick litter layer of beech forests has an important role in maintaining adequate soil moisture. With simple coppice or coppice with standards management regimes, the soil is often totally or partially uncovered following coppice harvests due to complete or near-total loss of canopy cover, and on these sites, particularly on steep slopes, rapid litter mineralization and soil erosion can occur. Selective coppice reduces these harmful effects by the retention of live shoots on each stool, which provides a diffuse, if light, shade and soil cover (Piussi, 2006).

1.4. Abandonment of selective beech coppices

Although, still in the 1960s, the transformation of simple coppice into selective coppice was considered as an improvement in beech coppice management (Poggi, 1960), the coppice selection system has been progressively abandoned over the past 50 years for several reasons: reduction of demand for firewood, high cost of felling operations in remote areas lacking roads, difficulty in shoot selection and in felling operations, badly executed cuts and bad selection of shoots from the various age classes (quality and number) that may cause a slow but progressive heightening of the stump.

The abandonment of this type of silvicultural management has apparently accelerated with improvements in social and economic conditions of people living in the mountains. Over time, with changing socioeconomic conditions in rural areas and forest policies increasingly discouraging intensive forest management, many beech coppices, including selective coppices, have progressively been converted to high stands (Bürgi, 1999). The idea that conversion to high stand was the most appropriate silvicultural management strategy for abandoned beech coppices, considering the physiological and ecological requirements of the species, has become the prevailing view among foresters. Many studies have been carried out on this subject in order to better define silvicultural and production options for beech (Amorini and Gambi, 1977; Bianchi and Hermanin, 1988; Padula et al., 1988; Amorini and Fabbio, 1991; Amorini et al., 1995; Ciancio et al., 2006) and numerous public campaigns have promoted conversion of these coppice systems to high stand over extensive areas of Tuscany and Emilia-Romagna (Premuda, 1957; Hofmann, 1963; Gambi, 1968; Bianchi, 1976).

1.5. Current condition and management of selective beech coppices

According to the Italian National Forest Inventory, beech woods in Italian mountain areas cover an area of about 700,000 ha. In 1985 (the year the inventory was taken) beech coppice was still the most common type of management, extending over a surface of more than 400,000 ha, mainly in the northern Apennines and in the Alps. Of this, about 10% was selective coppice. But in recent times, as discussed above, there has been a decline in management intensity in this type of forest. Already in 1985, about 45% of beech coppices had an average life span of more than 30 years (Castellani et al., 1988).

In Emilia-Romagna coppices are found over 316,578 ha, of which 73,790 ha are beech coppices and 9937 ha (about 14%) are managed under the coppice selection system (Bassi and Bassi, 2000). In Tuscany, coppice forests cover an area of 670,096 ha, of which 54,960 ha are beech coppices, with selective coppices representing less than 6% (3184 ha). However, an additional 28,000 ha of aged coppices, most of which were selective coppices, should be added to this figure. It should also be noted that converted high stands presently total 13,200 ha; these are mainly derived from selective coppices (Hofmann et al., 1998).

At the present time, most selective beech coppices are in a state of prolonged silvicultural abandonment, neglected particularly since the 1960s and 1970s. This study aims to evaluate whether or not selective beech coppices presently in a state of silvicultural abandonment could be restored and if the restoration treatments could be productive and economically sustainable. The objective is to provide a scientific basis to support silvicultural management decisions, by establishing and evaluating a replicable procedure for restoring selective coppices that may be, in particular socioeconomic and geographic situations, a feasible alternative to conversion to high stands.

2. Description of the study sites

The experiment included sites on both sides of the watershed of the Tuscan-Emilian Apennines. In 2004, three permanent sample plots were set up: A and B located at 44°17' N, 10°16' E, in the high Val Secchia (Emilia-Romagna) at 1250 m above m.s.l., with total areas of 6000 and 4000 m², respectively, and C located at 44°12' N, 10°27' E, in Garfagnana (Tuscany) at 1200 m above m.s.l., being 1750 m² in size (Fig. 2). The Emilian site faces North-East while the Tuscan site faces
South-West; the climate regime is Mediterranean mountain with higher annual precipitations on the Tuscan site (2000 mm) than on the Emilian site (1600 mm). Annual average temperature is 5 and 7°C, respectively. The soil is an Eutric Regosol on arenaceous flysch bedrock.

Forest stands are dominated by beech with few other tree species (Ostrya carpinifolia Scop., Salix caprea L., Acer pseudoplatanus L., Sorbus aria (L.) Crantz, Sorbus aucuparia L., Laburnum anagyroides Medicus). Ground vegetation is represented mostly by Geranium nodosum L., Anemone nemorosa L., Oxalis acetosella L., Galium odoratum (L.) Scop., Cardamine heptaphylla (Vill.) O. E. Schulz, and Luzula nivea (L.) Lam. et DC.

In these forests selective coppice management was historically very popular for firewood production (Fornaciari Chitoni, 1964; Bianchi, 1976). Many coppices have been converted into high stand in recent decades, although some unconverted coppices are still found, especially in sites where harvesting was not profitable.

A coppice not regularly cut nor converted into high stand, that is not biologically old but where the abandonment of management (and utilization) has exceeded the ordinary rotation age, is commonly defined as “aged coppice” (Clauser, 1982). These coppices can remain in a state of silvicultural abandonment, the sprouting capacity of the stumps maintained for a period of time that varies among tree species and with site fertility (Perrin, 1954, p. 201).

Defining ”cultivation abandonment classes” for the coppice selection system as proposed in Table 1, most selective beech coppices still found in the Apennines can be considered in the third class (“prolonged abandonment”), in which trees exhibit decrease in resprouting ability, reduction in the number of live shoots and progressive selection of the dominant individuals of the stand. As it is relatively difficult to find younger selective coppices, and considering that those in a prolonged state of abandonment are the most difficult to be restored, our study focuses on stands belonging to the third abandonment class.

Table 1
Definition of cultivation abandonment classes in relation to the number of years since the last selection cut (compared to the ordinary utilization limit that commonly is at least 36 years), likely silvicultural-abandonment process and suggested restoration procedures

<table>
<thead>
<tr>
<th>Cultivation abandonment class</th>
<th>Utilization delay beyond the ordinary limit</th>
<th>Likely silvicultural-abandonment process</th>
<th>Possible restoration procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delayed utilization</td>
<td>Utilization is delayed up to 10 years</td>
<td>No decrease occurs in stand vitality nor in resprouting capacity</td>
<td>With a strong selective cut the stand could return to selection coppice regime</td>
</tr>
<tr>
<td>Abandonment</td>
<td>Utilization is delayed 10–20 years</td>
<td>Larger shoots become dominant and standard crowns enlarge</td>
<td>A first moderate cut of dominant shoots is needed to promote stool resprouting, a second cut will remove all bigger shoots</td>
</tr>
<tr>
<td>Prolonged abandonment</td>
<td>Utilization is delayed for more than 20 years</td>
<td>Stools around standards and smaller dominated shoots could die</td>
<td>Two or three subsequent cuts could be necessary in order to promote resprouting capacity of living stools; caution is required</td>
</tr>
</tbody>
</table>
3. Material and methods

To describe the state of the stands before intervention, dendrometric surveys were carried out. The diameter at breast height (dbh) of all shoots in the plots and a sample of shoot heights for each plot were measured to determine shoot diameter distributions, vertical structure and standing volumes. Dominant values of dbh and height of shoots were calculated for each plot as mean dbh and height of the 400 largest shoots per ha. The total volume prior to silvicultural intervention (i.e., cutting) and the volume of the shoots harvested were estimated using volume equations for beech coppices in Emilia-Romagna (Bassi et al., 2000). Current volume increments of shoots were calculated in plots A and B as mean annual growth over the last 10 years.

Vitality of the stands was evaluated by counting live and dead stools. To determine the age of the stands, and the age distribution of the shoots, tree rings were counted in each plot on nearly 10 live shoots of different sizes. These data were used to estimate the length of time that had passed since the stands had been subject to their last coppicing cut. Shoot diameter distribution data were used to classify coppice shoots into two groups – < 12 cm dbh (smaller) and > 12 cm dbh (larger) – as a basis for design of the restoration treatment.

The first restoration treatment (cutting) was carried, the intensity of the operation based on dendrometric characteristics, condition of the coppice shoots, vitality of the stand and fertility conditions of the site (Fig. 3). The restoration procedure included the removal of some of the standards depending on their dominance in the coppice stand. The objective was the re-establishment of the stools in order to encourage their resprouting.

Silvicultural criteria for shoots and standards removal were:

- for stools with only dominant shoots, at least one of these shoots was to be removed;
- for stools with both dominant and suppressed shoots, at least one of the dominant and, if necessary, some suppressed shoots were to be removed;
- for stools with only suppressed shoots, these were to be thinned if necessary;
- dominant standards with large crowns surrounded by only dead stools were to be left in order provide soil coverage (shading);
- dominant standards that still had living stools nearby, could be removed in order to promote stool growth.

4. Results

The study stands had a high number of live shoots per ha, with a mean density of approximately 3900 ha⁻¹, with a large variation among plots (from 2846 ha⁻¹ in plot C to 5608 ha⁻¹ in plot A). The number of standards per ha averaged 65 (from 52 in plot A to 80 in plot C) (Table 2). The average numbers of live and dead stools per ha (excluding standards) were approximately 1280 and 410, respectively (Table 3).

The range of recorded shoots ages in the plots was wide, from 30 to nearly 70 years. The average age of smaller shoots (<12 cm dbh) was approximately 40 years while the average age of the larger shoots (>12 cm) was nearly 60 years (Fig. 4). The dbh and total heights of dominant shoots were 21 cm and nearly 18 m respectively, while mean values of all shoots were 11 cm and 13.5 m respectively. Total values of basal area and volume are in average 42 m² and 314 m³.

Fig. 3. Example of the procedure for the restoration of coppice selection system; (a) coppice before felling; (b1) moderate removal of two mature shoot; (b2) strong cut with the removal of nearly all dominant shoots.
Current increment of shoots volume amounts to 10 m$^3$ ha$^{-1}$ year$^{-1}$.

With the first restoration cut, 30–50% of individuals and 40–60% of the basal area were removed. The ratio was higher for higher dbh classes: 40–70% of shoots with dbh $>$ 12 cm were removed (Fig. 5). The removal of standards involved 44–68% of their total number, and was done mainly by choosing those standards which have around them a certain number of stools that are still alive even if strongly dominated, as discussed above. The wood volume removed with the cut amounts to 150 m$^3$ ha$^{-1}$ approximately, between 40 and 60% of the initial volume of the stands (Fig. 6).

5. Discussion

5.1. Stand structure

The distribution in dbh classes before intervention was typically uneven aged, tending towards larger dbh classes (>12 cm) when compared to actively managed selective coppice stands (Fig. 5) for which felling diameters described in literature amount to 8–10 cm (Buffolo, 1936; Patrone, 1944; Mannozzi-Torini, 1949; Camia et al., 2002).

The number of dead stumps (excluding standards) gives an indication of the reduction of coppice density compared to the original number (before abandonment); this reduction amounts to about 20–25% of the original value (Table 3). However the density of stools remained relatively high compared to those described for younger beech coppices in state of silvicultural abandonment: Piovesan et al. (1995) found, in a naturally developing 34 years old beech coppice nearly 900 live stools per ha with a reduction of about 30% of the original value after 20 years.

The stands in this study had been abandoned for about 40 years, as the average life span of the smaller shoots indicates. In this period competition for light among shoots led to a differentiation in growth rates among stools (Bernabei and Piovesan, 1997). This structural differentiation is notable in a period of 10 years of observation; Amorini et al. (1995), reporting on a 47 years old beech coppice in a state of silvicultural abandonment, found 824 live stools per ha with a reduction of about 30% of the original value after 20 years.

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Fig. 4. Relation between age (years) and dbh (cm) on a sample of shoots in the plots.
Fig. 4 where shoots with nearly the same age (50–60 years) have very different diameters. However some age groups of shoots are recognizable in these stands, indicative of the selective system practiced in the past.

Due to the long period of time since these stands were abandoned, during which there was considerable biomass accumulation, the growing stock in the sample plots was extremely high (314 m$^3$ in average), higher in fact than any value recorded in yield tables for beech coppices (Giordano, 1949; Bernetti, 1980; Castellani, 1982). Such values are found only in high stands converted a long time ago (Amorini et al., 1995). As has been found in other coppices (Hermanin and Pollini, 1990) lengthening of the rotation periods results in increased wood production.

The estimated current shoot volume increment (10 m$^3$ ha$^{-1}$ year$^{-1}$) is equal or higher than that recorded for 60 years old even-aged high stands of beech (Cantiani and Bernetti, 1963; Bianchi, 1981) and nearly double the values recorded for beech coppices at their maximum current volume increments (Giordano, 1949; Castellani, 1982) but similar to the values reported by Buffolo (1936) who indicated sustained yields of 6–7 to 9–10 m$^3$ ha$^{-1}$ year$^{-1}$.

5.2. Effects of the restoration treatment and future prospects

The main shoot removal treatment, which was concentrated on the larger shoot size class, led to a reduction of 1–2 cm of the dominant dbh of the stands. Nearly half of the shoots of the larger class (>12 cm dbh) and 30% of the smaller shoots (<12 cm dbh) were removed (Fig. 5). After this cutting treatment, nearly 350 shoots per ha of the larger (>12 cm dbh) dbh were left, maintaining adequate protection to the smaller, younger, shoots. Additional larger shoots could be gradually
removed in the succeeding cuts after evaluation of the stumps resprouting responses.

In fact, there is no certainty that stumps will respond to the cut with an adequate production of shoots. On this subject, no previous specific experimental data exists, probably due to the fact that the main aim of forest scientists and managers interested in coppice management has been to regulate the minimum age for cutting, whereas problems concerning old or abandoned coppices were not considered important. Authors who have dealt with this subject, have done so in the context of coppice conversion to high stands. They generally agree that beech resprouting ability decreases with the age of stools (Perrin, 1954, pp.320; Crivellari, 1955; Hofmann, 1963; Brun and Furlan, 2000). However, Ciancio and Nocentini (2004) reported that resprouting capacity first increases with age and then decreases until it ceases altogether and that this pattern is considered a function of the species’ longevity.

The restoration treatment also included removal of standards. In a coppice stands, standards are usually retained in the stand as seed trees, and for timber production and soil protection and cover. In a selective coppice, the soil protection and cover functions are already fulfilled to some extent by the permanent presence of shoots. So the number of standards of a coppice selection system may be limited. According to Ciancio and Nocentini (2004) standards are not indispensable in selective coppices as they do not carry significant advantages, and have some negative effects such as competition and suppression of dominated shoots, a view supported by Perrin (1954), who indicated that standards over a selective coppice stand can restrict stool resprouting. The number of standards should therefore not exceed 50 per ha and it would be appropriate if they were neither very large nor forming broad canopies, as they would otherwise occupy an area available for coppice development.

However, shoots of shade-tolerant species can remain viable for quite a long time under closed canopy conditions (Canham, 1988; Bernabei and Piovesan, 1997), so the removal of some standards, as tested in this study, may be useful if these are still surrounded by some live stools. This is quite a complicated operation because of the large dimension of standards stems but it is possible when the stools that are around them have thin and flexible shoots. When the damage caused by removal was judged to be too great in this study, the standard was left standing, but was girdled as part of the restoration treatment.

The wood volume removed with this first restoration cut was high, though a good volume of growing stock still remained, between 130 and 180 m³ ha⁻¹ (Table 2). This may sustain the production of wood during the following years. Even after this intervention, sample plots showed values of growing stocks higher than those recorded in the literature for selective coppice; these values are usually low, ranging from 30–40 to 70–80 m³ ha⁻¹ before felling, depending on the fertility of the site (corresponding to 5–6 and 15–20 m³ ha⁻¹ after felling) (Patrone, 1944). Thus, compared to typical values, there appears to be a good safety margin to the intervention in terms of growing stock reserves. We assume that since the first cut maintain a certain number of large shoots in the stand, the restoration process might require a second (or even a third) cutting treatment. In practice we plan to accomplish this in phases, passing through a time of transition, monitoring stand development, and calibrating the next procedure steps on the basis of stools resprouting response.

We expect that the silvicultural setting of the restored coppice should be no longer the classic one described in literature for the coppice selection system but a formation with a higher minimum level of growing stock capable of producing enough biomass, so as to make the continuation of the treatment economically viable (Fig. 7). For this longer rotation periods than the ones commonly recorded (8–12 years) will be necessary, eventually leading to stands with only two age classes. While this needs to be tested and confirmed through research, it might offer the advantage of even simplifying the cutting procedures and consequently reduce management costs, as described by Perrin (1954) in the Pyrenees.

In fact the problem of effective cutting practice remains, and is a key to good outcomes and for the continuance of the treatment itself. The use of chain saws may also be problematic for the application of these selective cuts (as opposed to the use of manual cutting tools, such as hatchets), but with particular care mechanized cutting may work well, for example if light chain saws are used that allow cutters to work easily even within a thick stool without damaging the remaining shoots (Menicacci, 2002).

Many authors agree that a good outcome depends mainly on the skills of specialized workers who should be very experienced in this type of cut. Some even advise that workers with these skills should be transferred to those places where the treatment has been used unsuccessfully (Poggi, 1960; Ciancio...
and Nocentini, 2004). Nowadays there is a lack of such specialized personnel, so if there is a real determination to proceed with the restoration of this traditional silvicultural system, it would be necessary to provide a good training on the correct application of the method.

In planning the restoration of selective beech coppice systems, managers should also carefully consider the best ways to define and execute coppice selection system field operations, and also consider the definition of aged coppices, in accordance with regional law. In Italy, there are lower and upper age limits for fellings in selective coppices: the cut is allowed between 24 or 30 years, in Tuscany and Emilia-Romagna respectively, to 36 years, when they are considered “aged coppice”; delayed utilization up to 50 years of age is allowed only with special permission (Regione Toscana, 2003; Regione Emilia-Romagna, 1995).

6. Conclusions

This experiment shows that if stools density and the total number of shoots in abandoned selective beech coppice stands is sufficiently high, a first restoration cutting treatment can be profitable in terms of firewood production without severely reducing the number of shoots remaining in the stand. From a productive point of view, the quantity of optimal growing stock, and estimates of future biomass and utilizable wood production, are unknown at present, and will have to be estimated on the basis of future stand development.

According to regional policies, the possibility of restoring selective beech coppices in state of silvicultural abandonment is limited but, if confirmed by a positive response of the stands in this study, the present experiment could show how restoration treatments can be applied to selective beech coppices in state of prolonged silvicultural abandonment that have maintained a good structural features and uneven age distribution of coppice shoots.

As this study has shown, firewood production from restored stands can also be high, especially during the first phase of the restoration process. This might support local economic development particularly where young converted stands or non-mature high stands are dominant, which are typical uneconomic phases of high stand management cycles. In fact, compared to the first cut of conversion to high-stand procedure (Amorini and Fabbio, 1991) the first restoration cut in this study was much more profitable.

The development of new technologies for the use of forest biomass for energy production (Bernetti et al., 1998; Hellrgl, 2003; Jansen and Kuiper, 2004) also suggests a reconsideration of coppice selection system in the context of forest management planning. However, a restoration of this system for the purposes of forest-based energy production would probably require improvement of road networks in forested regions; at present, in those forests where beech coppices have been neglected, their distance from existing roads makes exploitation for the purpose of firewood production unprofitable.

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