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Biodiversity conservation and forest management: the case of the sweet chestnut coppice stands in Central Italy

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Abstract

The ecological and economic relevance of sweet chestnut (*Castanea sativa* Mill.) has long been related to its widespread geographical distribution and multipurpose product potential. In Central Italy, chestnut management represents a paradigmatic example of the potential conflict between landowner targets and biodiversity conservation: options for preserving stand-scale biodiversity are not fully considered as current management is based on monospecific, even-aged coppice stands and clearcutting on wide areas. Relationships between silvicultural treatment and floristic diversity of chestnut coppices are here investigated focusing the attention on rotation length and on the role of thinning. Seven coppice stands were selected in such a way to be of similar size (about 10 ha) and to cover a wide range of ages and a different number of thinnings. Plot sampling was performed across the stands and their floristic diversity was compared and analyzed by means of indicators in order to assess statistical relationships between floristic data and stand structural attributes. The achieved results suggest alternative suitable options for managing chestnut coppice stands in order to enhance biodiversity while maintaining wood production.

Keywords: Plot sampling, rotation length, floristic diversity, thinning, silviculture.

Introduction

Biodiversity monitoring is essential to support management decisions in maintaining multiple forest ecosystem functions at long term (CBD 2001). Under an ecosystem approach, forest monitoring should not be restricted at the assessment of the traditionally measured features related to wood production: it should also assess composition, structure and function of forest ecosystems to provide a better understanding of the roles of the components of biological diversity for supporting the provision of multiple forest ecosystem services (Corona & Marchetti 2007; Corona et al. 2011).

A paradigmatic example of the potential conflicts among services is given by the management of sweet chestnut (*Castanea sativa* Mill.) stands in Italy, where humans have radically modified and controlled the distribution of this species over thousands of years and have long known how to manage it in profitable and diversified ways (e.g. by coppices or orchards) to produce fruit, timber and other goods, mainly by simplifying natural forest stand composition (Krebs et al. 2004). Distinctively, sweet chestnut coppices are characterized by fast-growing features useful to produce a wide range of easily marketable wood assortments for agriculture, constructions, furniture and leather tanning industries (Angelini et al. 2013).

In Italy chestnut forests cover an area of 800,000 ha (Gasparini & Tabacchi 2011): 70% of these are managed as even-aged coppices with release of 30-80 trees per hectare (standards) at the end of rotation, and the remaining 30% as orchards for fruit production. The extensive use of chestnut coppices is justified by landowner benefits: fast growth, short rotation, stumps vitality preserved by periodic clearcut, resilience to stress factors like forest fires and diseases. On the other hand, coppices have less recreational and touristic attractiveness than high stands, due to their higher density and smaller stem size. Coppice clearcuts, which for sweet chestnut are most often larger than 5 hectares, may involve visual and ecological impacts on the landscape (Ciancio et al. 2006), especially in the case of the widest cuts. The domestic production of chestnut wood barely exceeds 0.9 Mm^3 per year (63% being represented by timber assortments), while the current annual increment of chestnut stands is 5 Mm^3 (Gasparini & Tabacchi 2011) meaning that the harvested volume might be significantly increased as claimed by the wood-chain stakeholders (Angelini et al. 2013).

The potential naturalness value of chestnut stands has been recognized by the European Community Natura 2000 network (EU Council Directive 1992), which has declared both the chestnut-dominated forests and the long-established chestnut plantations with semi-natural undergrowth relevant habitats (9260: *Castanea sativa* woods) for biodiversity conservation (EC

2007). In addition, several studies have shown their high ecological importance in supporting a wide variety of flora and fauna (e.g. Gondard & Romane 2005; Gondard et al. 2006; Pezzi et al. 2011; Guitián et al. 2012; Zlatanov et al. 2013). However, actual actions for preserving stand-scale biodiversity of chestnut coppices are, to a certain extent, often neglected by forest managers, even when stands are located within landscapes of recognized naturalistic value and/or designated for conservation purposes.

Various investigations about biodiversity variations of several taxonomic groups have been carried out in coppice stands (e.g. Fuller & Warren 1993; Deconchat & Balent 2001; Joys et al. 2004; Valbuena-Carabaña et al. 2008; Lassauce et al. 2012). Moreover, some results about the correlation between floristic diversity and stand age have been achieved (e.g. Barkham 1992; Boncina 2000; Mason & MacDonald 2002; Bermudez et al. 2007; Bartha et al. 2008; Itô et al. 2012), even focusing on the role of thinning although with contrasting results (e.g. Decocq et al. 2004; Lindgren et al. 2006; Cole et al. 2008). Nevertheless, experimental surveys on relationships between floristic diversity and dendrometric parameters did not clearly lead to silvicultural options to forest managers. This calls for clearer guidelines to assess the potential of chestnut coppice stands with respect to biodiversity conservation purposes.

Relationships between silvicultural treatment and floristic diversity of chestnut coppices were here investigated by focusing the attention on the rotation length and on the role of thinning. Seven coppice stands in Central Italy with similar size and site conditions but different age and number of thinnings were selected. Plot sampling was performed across the stands and their floristic diversity was compared and analyzed by means of indicators in order to assess statistical relationships between floristic data and forest stand attributes. Distinctively, the main objectives of the paper are: a) to explore correlation of floristic biodiversity with stand structural (dendrometric) parameters; b) to suggest alternative management options with the aim of promoting biodiversity as well as wood production.

Study area

The study was carried out on private sweet chestnut coppice stands located on the Sabatini Mountains (Latium, Central Italy), on smooth volcanic relief (300-700 m a.s.l.), 80 km north of Rome within the municipalities of Bracciano (RM), Oriolo Romano (VT) and Sutri (VT). These woodlands have a high landscape conservation value and are included within the Regional Natural Park of Bracciano-Martignano and the European Commission Natura 2000 site network (Figure 1).

The area is rather homogeneous in terms of vegetation (*Doronico-Fagion* phytosociological alliance, with ingression of acidophilic elements of the *Quercetalia robori-petraeae* phytosociological order), soils (fertile, deep and loose with acid pH, mainly classified as andisols and identified as "black soil") and bioclimate (mesomediterranean sub-humid, with mean annual temperature of 12.8 °C; July as hottest month with an average temperature of 22 °C, and January as the coldest one with 4.2 °C; annual rainfall ranges between 1250 mm and 1550 mm; summer drought does not usually occur thanks to the humid air coming from the Tyrrhenian Sea and the nearby Vico Lake, although a sub-arid period between July and August may occur).

No major natural disturbances, such as forest fires, hurricanes and floods, have been recorded for many years. On the other hand all the forest stands support a certain level of human disturbances besides wood harvesting, like mushroom picking, fodder collection and very moderate grazing.

The current forest management of the sweet chestnut stands is based on short rotation (commonly, 14-16 years, with a single thinning - not always carried out - at half of the rotation age) in monospecific even-aged stands, clearcut on large areas (around 10 ha, on average), with the purpose to profitably yield valuable wood assortments (poles and beams). An average of about 200 ha of chestnut coppices are harvested or thinned per year in the study area.

The monospecificity of the stands is due either to the applied silvicultural practices and to the environmental conditions (specifically, the volcanic soils where chestnut finds optimal growth conditions reaching a maximum yield of 15-20 m^3 ha^{-1} $year^{-1}$).

Materials and methods

Seven coppice stands were selected in such a way to be of similar size (about 10 ha) and cover a wide range of ages (from 6 to 22 years) and a different number of thinnings (from 0 to 2) (Table I). The boundaries of the stands were drawn from the vectorial information provided by the local forest management plans. The stands were used as *strata* for the purposes of statistical analysis.

Seven circular sampling plots of 10-m radius (about 1 plot every 1.5 ha) were established in each stand, with the exception of the stands ID 1 and 2 where the number of plots was reduced to five because of their lower variability concerning dendrometric features. The total number of sampling plots was 45. Plots were randomly located in each stand and reached in the field by means of a GPS with submetric accuracy.

In each sampling plot the following attributes were measured: diameter at breast height (dbh) of the live and dead sprouts and of the standards (minimum dbh threshold 1 cm for sweet chestnut and 5 cm for the other trees species); number of stumps; age of sprouts assessed by a tree corer on those with mean dbh. The following stand attributes were calculated from raw data: number of sprouts (live and dead) per hectare; number of standards per hectare; number of stumps per hectare;

basal area of sprouts and standards; mean basal area increment (stand basal area divided by stand age; Corona 2007).

Floristic surveys were carried out within the sample plots to collect vegetation data according to scheduled campaigns to cover the whole floristic period (one survey every two weeks on average, from April to October, for three years). The collected specimens were dried and stored in the University of Tuscia (Italy) herbarium. Information about Raunkiær life-form (Raunkiær 1934), chorotype (Pignatti 1982) and frequency were recorded for each species. Life-form and chorotype *spectra* were calculated for each stand.

Floristic data were processed in order to compare diversity between and within *strata*. Following Mucina et al. (1993) and Blasi et al. (2004) each observed species was assigned to one of the following phytosociological groups: *Fagetalia sylvaticae*; *Quercetalia pubescenti-petraeae*; *Querco-Fagetea*; *Quercetea ilicis*; *Prunetalia spinosae* s.l.; grass and meadow species; nitrophilous species; other species.

The following diversity indices were computed: β-diversity index; Jaccard and Sørensen similarity indices.

β-diversity was calculated using Whittaker's index (Equation 1):

$$\beta_1 = \frac{\gamma}{\overline{\alpha}} \quad (1)$$

where γ is the total number of species recorded in the stand and $\overline{\alpha}$ = mean of the species richness within plots of each stand. Because in this model β-diversity is dimensionless and is quantified in a manner that is not commensurate with the measurement of α- and γ-diversities, it has been calculated also in accordance to Ricotta & Marignani (2007) (Equation 2):

$$\beta_2 = \gamma - \overline{\alpha} \quad (2)$$

Stands were also compared pairwise by Jaccard (C_j) and Sørensen (C_s) similarity indices (Equations 3 and 4):

$$C_j = \frac{a}{(a+b+c)} \qquad (3)$$

$$C_s = \frac{2a}{(2a+b+c)} \qquad (4)$$

where: a = number of species recorded within plots of both stands; b = number of species recorded only within plots of the 1st stand; c = number of species recorded only within plots of the 2nd stand.

All the stand structural attributes and floristic information (for a total amount of 74 variables) were analyzed by means of correlative statistics and significance tests. Non-parametric Kruskal-Wallis one-way analysis of variance by ranks was applied to find significant differences of the analyzed variables among groups of sample plots (Zar 1996), aggregated by different number of thinnings or by different ages. When a significant difference was found, Mann-Whitney *U* test with Bonferroni correction was conducted.

Results

The number of stems ranges from 1942 to 11,445 n ha^{-1}, mainly composed of live sprouts (1482 to 11,014 n ha^{-1}, with a mean dbh ranging from 4 to 16 cm). The highest value of live sprouts density was found in stands recently treated by thinning or clearcutting. The number of sprouts with dbh larger than 5 cm ranges from 1373 to 2765 n ha^{-1}. Total basal area has a minimum value of 17.54 m^2 ha^{-1} and a maximum value of 41.86 m^2 ha^{-1}. The number of standards per hectare ranges from 36 to 91, with a mean dbh between 24 and 46 cm.

Altogether 165 vascular plant species were found in the study area, with a mean value of 79 species per stand (Table II). It is a high value if compared with the results of similar studies carried out in chestnut stands (Gondard et al. 2001; Gondard & Romane 2005; Gondard et al. 2006). Among the outstanding species deserve to be mentioned: a) the endemic ones as *Digitalis lutea* L. subsp. *australis* (Ten.) Arcang., *Echinops ritro* L. subsp. *siculus* (Strobl) Greuter, *Pulmonaria apennina* Cristof. & Puppi (Pignatti 1982; Conti et al. 2005); b) the rare/endangered ones according to Scoppola (1995) and Conti et al. (1997) as *Galanthus nivalis* L., *Hypericum androsaemum* L., *Iberis umbellata* L., *Lilium bulbiferum* subsp. *croceum* (Chaix) Jan and *Narcissus pöeticus* L. Moreover, eleven species lacking in previous flora studies were found for the first time: one of these, *Rubus scaber* Weihe & Nees, is of great interest because Pignatti (1982) points out that information about its presence in Italy was a mistake.

The richest phytosociological group is *Querco-Fagetea*: about 35% species of the total belongs to it. *Fagetalia sylvaticae* species are present in all the stands, with the highest percentage in stand ID 3 (24 %) and the lowest in ID 4 (14 %). ID 2 is characterized by a great number of species of *Quercetalia pubescenti-petraeae* (almost 20%). *Prunetalia* s.l. species occur with the highest frequency in ID 7 (10%). The meadow and pasture species lack in ID 3 as a consequence of the isolation of this stand from the other. The high value of nitrophilous species in ID 5 and ID 7 (more than 15%) evidences an higher influence of human disturbance on these stands.

A high percentage of phanerophytes is present in ID 6 (42%) and ID 4 (39%); ID 3, the only one with no thinning during the considered rotation, has the highest percentage of nano-phanerophytes. A low value of geophytes is present in ID 2. Therophytes reflect the magnitude of the disturbance: the high value in ID 5 is related to the execution of two thinnings. Euroasiatic species are present in all the stands with values around 60%. Also endemic ones are present in all the stands, but obviously with very low values (from 0.5 to 4.0%).

Species richness is higher on the youngest stand (ID 7) and decreases when the stands become older (ID 4 has the lowest value) (Table II).

Pairwise comparison and biodiversity indices showed that ID 2 (five sample plots) has outliers; consequently, this stand was excluded from further statistical analysis that were applied to the remaining 40 sample plots.

Statistically significant relationships ($p<0.01$; $R>0.4$) were found: a significant and positive association exists between the percentage of *Prunetalia* s.l. species and the percentage of living sprouts (with dbh < 5 cm). The percentage of the *Querco-Fagetea* species as well as the percentage of the *Fagetalia* species are correlated with the percentage of dead shoots: in the first case the correlation is negative; in the latter it is positive. The percentage of *Fagetalia sylvaticae* is also positively correlated with the mean basal area increment. In addition, the number of thinnings has a significative and positive correlation both with the percentage of endemic species and with the percentage of *Querco-Fagetea* species: for these two correlations Kruskal-Wallis test points out that plots aggregated by different number of thinnings (0, 1, 2) differ significantly ($p<0.01$); Mann-Whitney *U* test was used to analyze the differences between these groups of plots (Table III).

Discussion

Ground vegetation diversity is a critical component of forest ecosystems, typically supporting the vast majority of total ecosystem biodiversity. Vegetation communities also play a central role in the dynamics and functioning of forest ecosystems by influencing long-term successional patterns. The high number of observed species in the youngest chestnut coppice stands confirms that the greatest species richness can be found in the first years after coppicing (Mason & MacDonald 2002). Then herbaceous species tend to decrease as observed by Bartha et al. (2008) and Kostantinidis et al. (2008). If disturbances occur frequently, richness decreases because species intolerant to disturbance become locally extinct. If disturbances are too infrequent, richness decreases because dominant species occupy resources and eliminate weak competitors. Richness proves to be higher at intermediate frequencies of disturbance, when conditions favor competitive species and those that tolerate stand disturbance (Gondard et al. 2006).

In general, initial vegetation is strongly determined by early successional species characterized by high growth rate but short life span and large amount of small viable seeds dispersed over large distances, whereas late successional species have low growth rates but long life spans and few larger seeds dispersed over shorter distances and with short viability (Baum et al. 2013).

The intensity of cutting, the size of cutting areas and their temporal distribution, as well as the severity of natural disturbance are the key factors that account for changes in species composition and diversity. The variations of the floristic court can be observed also by analyzing the life-form and chorotype *spectra*, which show a growth of the coenosis related to a longer time elapsing since the disturbance (coppicing or thinning). ID 4 and ID 6, which have not been thinned recently, have a denser closure of the canopy caused by the greater presence of phanerophytes. Similarly the high number of nanophanerophytes in ID 3 can be attributed to lack of thinning: the closed canopy and the evergreen shrub layer in the undisturbed stands make survival possible on the forest floor only to shade-tolerant species. In addition, shade-tolerant but disturbance-intolerant species might have disappeared due to long-term human disturbances. This suggests that periodical clearcutting would function as an intermediate frequency disturbance able to prevent dominance of evergreen understory species and would contribute to maintaining rich species abundance in the coppice (Itô et al. 2012).

The impact of the thinning on floristic diversity is shown by the high presence of hemicryptophytes and by the low value of geophytes on ID 2. The fact that therophytes are substituted over time by hemicryptophytes was observed also by Gondard & Romane (2005). The large number of therophytes in ID 5 confirm a higher level of disturbance: in this case, two thinnings.

The analysis of oldest stands (but with different number of thinnings - ID 3, ID 4 and ID 5) showed that thinning, although it constitutes a disturbance (high values of therophytes), has a lower impact on floristic diversity than coppicing, usually performed with release of a rather low number of standards (30-40 per hectare on average). The highest magnitude of disturbance in ID 5 and ID 7 is also underlined by the high frequency of the nitrophilous species which, on the other hand, can depend on higher soil fertility.

The positive correlation between the number of *Prunetalia* species and percentage of live shoots (in particular the smaller ones, with dbh < 5 cm) is related with the fact that there are many smaller shoots when the stand is young and/or disturbed by thinning, creating suitable conditions for the entrance of light-dependent species. Light conditions depend mainly on the number of standard trees retained after coppicing (Joys et al. 2004) as well as on previous density and vitality of the coppice layer (Barkham 1992).

The percentage of *Fagetalia sylvaticae* species tends to increase when stands become older without thinning. As the stand ages, there is a higher number of dead sprouts, larger tree stems and higher basal area, indicating how a forest evolves if left undisturbed: the conditions for hosting nemoral species increase, a mesophilous micro-climate is created together with a soil with higher water retention. Moreover, bigger tree stems provide habitats for saproxylic insects that typically inhabit mature trees, such as endangered cavity-dwelling species. In this case, saproxylic biodiversity would benefit from these trees (Bouget et al. 2012). Conversely, when coppicing and/or, to a lesser extent, thinnings interrupt or disturb the stand development process, the species of *Querco-Fagetea* can spread.

The full abandonment of chestnut stand cultivation does not automatically induce higher plant diversity, and the management intensity modulates the effect on species richness (Guitián et al. 2012). However, lower levels of species richness do not mean lower quality of biodiversity (Boncina 2000).

Implications for chestnut coppices management

Optimal rotation age is a topical decision for multifunctional management of even-aged stands in order to exploit potential trade-off between the benefits of harvesting for forest owners and other ecosystem services such as biodiversity conservation. The development of "environment friendly" silvicultural treatments may be crucial to the preservation of the functional biodiversity also in sweet chestnut stands.

The investigated stands do not appear seriously at risk either in terms of species richness or the presence of endemic, rare and endangered ones, despite the fact that short rotation (14-16 years) and medium-to-high intensity thinning are the common silvicultural practices used so far in the study area. Moreover, this practice is applied in all conditions, without taking into account the need to conserve/enhance biodiversity while maintaining/improving wood production. These are the key elements for the following management proposals.

A 20-22 (25) years rotation without thinning should be applied to small coppice stands within areas of high naturalistic value because it allows the evolution towards a higher quality of floristic diversity, at least on fertile soils. This management scheme reduces the frequency of disturbance and the impact of coppicing in terms of soil erosion, compaction and rutting. This physical disturbance could in turn affect floristic assemblages by decreasing the rooting space (Wilpert & Schäffer 2006), encouraging species adapted to hypoxic conditions in dense soils (Godefroid & Koedam 2004) and reducing the density and diversity of soil fauna or their biological activity (Merino et al. 2004). This kind of management is not exceptional in the study area: it is applied in small landownerships where the limited stand area to be managed (usually less than 3 ha per land owner) may make thinnings unprofitable.

Otherwise, and especially for sites with low to fair fertility, it could be useful to lengthen the rotation to 25-30 (35) years and to execute more (2-3) thinnings. Longer rotations and reduced competition for released trees allow to obtain larger average stem diameter at the end of a rotation and therefore compensate higher management costs. A gradual reduction of tree density allows a better soil protection and minimizes the effect of the disturbance on the natural evolution of the floristic court. Periodical thinnings would function as an intermediate intensity disturbance to prevent the dominance of evergreen understory species in the coppice. Moreover, according to recent research (Spina & Romagnoli 2010), this kind of density management can be effective in preventing or reducing the incidence of the ring shake that severely affects the quality of the timber harvested in this area.

Conclusions

Forest ecosystems have the potential to harbor high levels of biological diversity, more than any other terrestrial ecosystem (Lindenmayer & Franklin 2002). During the last years, the continuous loss of biodiversity has led to focus onto ecosystem management aimed at nature conservation through the safeguarding of habitat and species. The conservation and, if possible, the improvement of biodiversity are key-factors for a sustainable forest management (Corona et al. 2011), especially in the framework of stand-level forest type approach (Corona et al. 2004; Barbati et al. 2007; Barbati et al. 2014).

Habitat conditions, such as spatial structure, tree stems density, shade and humidity, and deadwood profiles change as the coppice ages. These changes impact on biodiversity.

Coppicing may emulate, to a certain extent, the natural dynamics of the *gaps*, increasing species richness. The size of cutting areas, their temporal distribution, and the severity of disturbance are the main influential factors on floristic composition, structure, species diversity and regeneration. Taking into account uniquely species richness allows to evaluate biodiversity variations only from a quantitative point of view (higher richness is often related to disturbance occurrence). When addressing biodiversity it is important to use an integrated approach with qualitative considerations.

This study gives a positive indication about the evolution of forest stands when left undisturbed. In absence of thinning, the floristic court established after coppicing tends to develop into homeostatic communities associated with various *Fagetalia sylvaticae* species, with increase of geophytes and decrease of therophytes.

Present results provide two management models for managing chestnut coppice stands that may help to develop guidelines to preserve biodiversity while maintaining wood production.

The effectiveness of the proposed management systems warrants further investigation under various geographic, structural and silvicultural conditions.

References

Angelini A, Mattioli W, Merlini P, Corona P, Portoghesi L. 2013. Empirical modelling of chestnut coppice yield for Cimini and Vicani mountains (Central Italy). Ann Silv Res 37 (1): 7-12. http://dx.doi.org/10.12899/ASR-749

Barbati A, Corona P, Marchetti M. 2007. A forest typology for monitoring sustainable forest management: the case of European Forest Types. Plant Biosyst 1: 93-103. http://dx.doi.org/10.1080/11263500601153842

Barbati A, Marchetti M, Chirici G, Corona P. 2014. European Forest Types and Forest Europe SFM indicators: tools for monitoring progress on forest biodiversity conservation. Forest Ecol Manag 321: 145-157. http://dx.doi.org/j.foreco.2013.07.004

Barkham JP. 1992. The effects of coppicing and neglect on the performance of the perennial ground flora. In: Buckley GP, editor. Ecology and Management of Coppice Woodlands. Chapman & Hall, London. pp. 115-146.

Bartha S, Merolli A, Campetella G, Canullo R. 2008. Changes of vascular plant diversity along a chronosequence of beech coppice stands, central Apennines, Italy. Plant Biosyst 142 (3): 572-583. http://dx.doi.rg/10.1080/11263500802410926

Baum S, Weih M, Bolte A. 2013. Floristic diversity in Short Rotation Coppice (SRC) plantations: comparison between soil seed bank and recent vegetation. Appl Agr Res 63 (3): 221-228. http://dx.doi.org/10.3220/LBF_2013_221-228

Bermudez AM, Fernandez-Palacios JM, Gonzalez-Macebo JM, Patiño J, Arèveloa JR, Otto R et al. 2007. Floristic and structural recovery of a laurel forest community after clear-cutting: a 60 years chronosequence on La Palma (Canary Island). Ann For Sci 64: 109-119. http://dx.doi.org/10.1051/forest:2006094

Blasi C, Di Pietro R, Filesi L. 2004. Syntaxonomical revision of *Quercetalia pubescenti-petraeae* in the Italian Peninsula. Fitosociologia, 41 (1): 87-164.

Boncina A. 2000. Comparison of structure and biodiversity in the Rajhenav virgin forest remnant and managed forest in the dinaric region of Slovenia. Global Ecol Biogeogr 9: 201-211.

Bouget C, Lassauce A, Jonsell M. 2012. Effects of fuelwood harvesting on biodiversity - a review focused on the situation in Europe. Can J Forest Res 42: 1421-1432. http://dx.doi.org/10.1139/X2012-078

CBD. 2001. Sustainable management of non-timber forest resources. Convention on Biological Diversity. Montreal. Technical series 6: 1-28.

Ciancio O, Corona P, Lamonaca A, Portoghesi L, Travaglini D. 2006. Conversion of clearcut beech coppices into high forests with continuous cover: a case study in central Italy. Forest Ecol Manag 224 (3): 235-240. http://dx.doi.org/10.1016/j.foreco.2005.12.045

Cole HA, Newmaster SG, Lanteigne L, Pitt D. 2008. Long-term outcome of precommercial thinning on floristic diversity in north western New Brunswick, Canada. iForest, 1: 145-156. http://dx.doi.org/10.3832/ifor0470-0010145

Conti F, Abbate G, Alessandrini A, Blasi C. 2005. An annotated checklist of the italian vascular flora. Palombi Editori, Roma.

Conti F, Manzi A, Pedrotti F. 1997. Liste Rosse Regionali delle piante d'Italia. WWF - SBI. Camerino, 139 pp.

Corona P. 2007. Metodi di inventariazione delle masse e degli incrementi legnosi in assestamento forestale. Aracne Editrice, Roma.

Corona P, Chirici G, McRoberts RE, Winter S, Barbati A. 2011. Contribution of large-scale forest inventories to biodiversity assessment and monitoring. Forest Ecol Manag 262: 2061-2069. http://dx.doi.org/10.1016/j.foreco.2011.08.044

Corona P, Del Favero R, Marchetti M. 2004. Stand-level forest type approach in Italy: experiences from the last twenty years. In: Marchetti M, editor. Monitoring and indicators for forest biodiversity in Europe. From ideas to operationality. EFI Proceedings, 51. pp. 143-152.

Corona P, Marchetti M. 2007. Outlining multi-purpose forest inventories to assess the ecosystem approach in forestry. Plant Biosyst 2: 243-251. http://dx.doi.org/10.1080/11263500701401836

Decocq G, Aubert M, Dupont F, Alard D, Saguez R, Wattez-Franger A et al. 2004. Plant diversity in a managed temperate deciduous forest: understorey response to two silvicultural system. J Appl Ecol 41 (6): 1065-1079. http://dx.doi.org/10.1111/j.0021-8901.2004.00960.x

Deconchat M, Balent G. 2001. Vegetation and bird community dynamics in fragmentated coppice forests. Forestry 74 (2): 105-118. http://dx.doi.org/10.1093/forestry/74.2.105

EU Council Directive. 1992. Natura 2000 network on the conservation of natural habitats and of wild fauna. Council Directive 92/43/CEE of 21 May 1992. The Council of the European Communities.

European Commission. 2007. Interpretation manual of European habitats - EUR27. DG Environment, Nature and Biodiversity.

Fuller RJ, Warren MS. 1993. Coppiced woodlands: their management for wildlife. 2nd ed. Joint Nature Conservation Committee, Peterborough.

Gasparini P, Tabacchi G, editors. 2011. L'Inventario Nazionale delle Foreste e dei serbatoi forestali di Carbonio INFC 2005. Secondo inventario forestale nazionale italiano. Metodi e risultati, Ministero delle Politiche Agricole, Alimentari e Forestali; Corpo Forestale dello Stato;

Consiglio per la Ricerca e Sperimentazione in Agricoltura, Unità di ricerca per il Monitoraggio e la Pianificazione Forestale. Edagricole - Il Sole 24 Ore, Bologna.

Godefroid S, Koedam N. 2004. Interspecific variation in soil compaction sensitivity among forest floor species. Biol Conserv 119 (2): 207-217. http://dx.doi.org/10.1016/j.biocon.2003.11.009

Gondard H, Romane F, Grandjanny M, Li J, Aronson J, 2001. Plant species diversity changes in abandoned chestnut (*Castanea sativa*) groves in southern France. Biodivers Conserv 10: 189-207. http://dx.doi.org/10.1023/A:1008997625523

Gondard H, Romane F. 2005. Long-term evolution of understorey plant species composition after logging in chestnut coppice stands (Cevennes Mountains, southern France). Ann For Sci 62: 333-342. http://dx.doi.org/10.1051/forest:2005028

Gondard H, Romane F, Santa Regina I, Leonardi S. 2006. Forest management and plant species diversity in chestnut stands of three Mediterranean areas. Biodivers Conserv 15: 1129-1142. http://dx.doi.org/10.1007/s10531-004-3103-8

Guitián J, Guitián P, Magrach A, Docampo C, Domínguez P, Guitián L. 2012. Effect of management and spatial characteristics on plant species richness of *Castanea sativa* Mill. Woodlots in the NW Iberian Peninsula. J For Res 17: 98-104. http://dx.doi.org/10.1007/s10310-011-0261-x

Itô H, Hino T, Sakuma D. 2012. Species abundance in floor vegetation of managed coppice and abandoned forest. Forest Ecol Manag 269: 99-105. http://dx.doi.org/10.1016/j.foreco.2011.12.017

Joys AC, Fuller RJ, Dolman PM. 2004. Influences of deer browsing, coppice history, and standard trees on the growth and development of vegetation structure in coppiced woods in lowland England. Forest Ecol Manag 202: 23-37. http://dx.doi.org/10.1016/j.foreco.2004.06.035

Kostantinidis P, Tsiourlis G, Xofis P, Buckley GP. 2008. Taxonomy and ecology of *Castanea sativa* Mill. forests in Greece. Plant Ecol 195: 235-256. http://dx.doi.org/10.1007/s11258-007-9323-8

Krebs P, Conedera M, Pradella D, Torriani M, Felber M, Tinner W. 2004. Quaternary refugia of the sweet chestnut (*Castanea sativa* Mill.): an extended palynological approach. Veg Hist Archaeobot 13: 145-160. http://dx.doi.org/10.1007/s00334-004-0041-z

Lassauce A, Anselle P, Lieutier F, Bouget C. 2012. Coppice-with-standards with an overmature coppice component enhance saproxylic beetle biodiversity: a case study in French deciduous forests. Forest Ecol Manag 266: 273-285. http://dx.doi.org/10.1016/j.foreco.2011.11.016

Lindenmayer DB, Franklin JF. 2002. Conserving forest biodiversity: a comprehensive Multi-Scaled Approach. Island Press, Washington, DC.

Lindgren PMF, Ransome DB, Sullivan DS, Sullivan TP. 2006. Plant community attributes 12 to 14 years following precommercial thinning in a young lodgepole pine forest. Can J Forest Res 36: 48-61. http://dx.doi.org/10.1139/x05-228

Mason CF, MacDonald SM. 2002. Responses of ground flora to coppice management in an English woodland - a study using permanent quadrats. Biodivers Conserv 11: 1773-1789.

Merino A, Fernández-López A, Solla-Gullón F, Edeso JM. 2004. Soil changes and tree growth in intensively managed *Pinus radiata* in northern Spain. Forest Ecol Manag 196 (2-3): 393-404. http://dx.doi.org/10.1016/j.foreco.2004.04.002

Mucina L, Grabherr G, Wallnöfer S. 1993. Die Pflanzengesellschaften Österreichs. Teil III Wälder und Gebüsche. Austrian Science Fundation. Gustav Fischer Verlag Jena. Stuttgart. New York.

Pezzi G, Maresi G, Conedera M, Ferrari M. 2011. Woody species composition of chestnut stands in the Northern Appennines: the results of 200 years of changes in land use. Landscape Ecol 26: 1463-1476. http://dx.doi.org/10.1007/s10980-011-9661-8

Pignatti S. 1982. Flora d'Italia. Ed agricole, Bologna.

Raunkiær C. 1934. The Life Forms of Plants and Statistical Plant Geography, being the collected papers of C. Raunkiær. Oxford University Press, Oxford. Reprinted 1978 (ed. by Egerton FN), in: "History of Ecology Series". Ayer Co Pub. ISBN 0-405-10418-9.

Ricotta C, Marignani M. 2007. Computing β-diversity with Rao's quadratic entropy: a change of perspective. Divers Distrib 13: 237-241.

Scoppola A. 1995. Piante minacciate, vulnerabili o molto rare della Provincia di Viterbo. Amm. Prov. di Viterbo. Ass. all'Ambiente. 159 pp.

Spina S, Romagnoli M. 2010. Characterization of ring shake defect in chestnut wood in Lazio region (Italy). Forestry 83 (3): 315-327. http://dx.doi.org/10.1093/forestry/cpq014

Valbuena-Carabaña M, González-Martínez SC, Gil L. 2008. Coppice forests and genetic diversity: a case study in *Quercus pyrenaica* Willd. from Central Spain. Forest Ecol Manag 254: 225-232. http://dx.doi.org/10.1016/j.foreco.2007.08.001

Wilpert K, Schäffer J. 2006. Ecological effects of soil compaction and initial recovery dynamics: a preliminary study. Eur J Forest Res 125 (2): 129-138. http://dx.doi.org/10.1007/s10342-005-0108-0

Zar JH. 1996. Biostatistical analysis. 3rd ed. Prentice-Hall International, New York, USA.

Zlatanov T, Schleppi P, Velichkov I, Hinkov G, Georgieva M, Eggertsson O et al. 2013. Structural diversity of abandoned chestnut (*Castanea sativa* Mill.) dominated forests: implications for forest management. Forest Ecol Manag 291: 326-335. http://dx.doi.org/10.1016/j.foreco.2012.11.015

Tables

Table I. Characteristics of the surveyed chestnut coppice stands and number of sampling plots.

Stand ID	Area [ha]	Altitude [m a.s.l.]	Slope [%]	Exposure	Age [years]	Thinnings	No. plots
1	13.3	430	15	NE	12	0	5
2	12.8	410	20	SE	14	1	5
3	12.5	435	0	SW	20	0	7
4	10.6	420	5	S	22	1	7
5	9.1	425	10	E	22	2	7
6	8.1	425	5	SE	16	1	7
7	11.2	455	10	SE	5	0	7

Table II. Values of α, β, γ diversity, median and variance for each stand.

Stand ID	1	2	3	4	5	6	7
Number of species (γ diversity)	82	84	80	73	77	74	86
$\overline{\alpha}$ (mean number of species)	38.2	39.8	36.1	34.6	38.1	35.0	40.1
Median	39	39	37	33	39	36	41
Variance	21.7	99.2	6.5	13.3	13.5	8.0	9.1
$ß_1$	2.15	2.11	2.21	2.11	2.02	2.11	2.14
$ß_2$	43.8	44.2	43.9	38.4	38.9	39.0	45.8

Table III. Mann-Whitney *U* test results for *Querco-Fagetea* species and Endemic species with respect to the number of thinnings (values with different letters are statistically different at $p < 0.05$).

No. of thinnings	Percent of *Querco – Fagetea* species (median)	Percent of Endemic species (median)
0	41.18 a	1.19 a
1	46.06 b	3.08 b
2	48.48 b	2.94 b

Figures

Figure 1. Study area and location of the sampled chestnut coppice stands.