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RESEARCH ARTICLE

Woody species composition of chestnut stands in the Northern Apennines: the result of 200 years of changes in land use

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Abstract Chestnut stands (orchards and coppices) are among the most typical elements of the southern European mountain landscape and a protected habitat (9260 *Castanea sativa* woods) according to the European Union (Directive 92/43/EEC). As an anthropogenic landscape, they require specific measures to address preservation or to guide their evolutionary trend. In the Northern Apennines, a landscape multi-scalar-multitemporal approach was adopted to highlight factors that have acted on the evolution of this habitat and which still might affect either its preservation or its evolutionary dynamics. Using a diachronic GIS-approach, we analyzed old cadastral maps (drawn up 200 years ago), and aerial photographs. Both the present distribution pattern of the woody species and the incidence of important chestnut diseases were also surveyed. The factors explaining the current extent and species composition of the local chestnut forests confirm their status as an anthropogenic habitat. The present landscape distribution of chestnut woods is heavily linked to past human settlements. Chestnut blight and ink disease are more an indirect reason for past felling activities than an actual direct cause of damage to trees, because of the hypovirulence spread and the limited incidence of the ink disease. Vegetation dynamics of abandoned chestnut forests evolved only partly towards deciduous Beech and Hop Hornbeam stands, thus suggesting both the possibility of a recovery of this cultivation and the need for new criteria for its management.

Keywords *Castanea sativa* · Cadastral maps · Chestnut diseases · Historical ecology · Stratified random sampling · Socio-economic transformation

Abbreviations

SCI	Site of Community Importance
DBH	Diameter Breast Height
NMDS	Non-Metric Multidimensional Scaling

Nomenclature Conti et al. (2005): for higher plants.

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Introduction

Starting from the Middle Ages, chestnut cultivation became a staple resource for fruit and timber production in several European countries, where the chestnut was cultivated up to its ecological limits (Pitte 1986). This cultivation greatly influenced the lifestyle of the mountain populations, giving origin to the so-called "chestnut civilization" (Gabrielli 1994; Arnaud et al. 1997; Conedera et al. 2004).

The traditional European chestnut civilization declined at different times in different countries. The first decline corresponds to the climatic cooling of the eighteenth-century Little Ice Age that caused frost damage on chestnut orchard trees at the exposed sites. The improvement of agricultural cultivation techniques combined with the introduction of alternative crops from abroad (maize, potatoes)—by allowing a greater production of calories with shorter rotation times—also contributed to the progressive substitution of chestnuts as a staple food (Conedera and Krebs 2008). After the mid twentieth century, the depopulation of the mountain countryside (Bonous 2002; Conedera and Krebs 2008) brought about an accelerated decline in chestnut cultivation. At the same time, the appearance and spread of chestnut blight (*Cryphonectria parasitica* [Murr.] Barr) produced severe damage, threatening the chestnut cultivation, as had already occurred in North America (Biraghi 1946; Griffin 2000). Moreover, ink disease (caused by *Phytophthora cambivora* [Petri] Buism.), which appeared in Apennine chestnut forests at the start of the twentieth century (Petri 1918), showed a resurgence in recent decades (Vettraino et al. 2005). In many cases, these factors led to both the complete abandonment of traditional chestnut orchards and a rapid post-cultural evolution toward mixed stands based on climate, soil, stand density, pathogen incidence, and time since abandonment (Mondino 1991; Paci 1992; Romane et al. 1995; Arnaud et al. 1997; Paci et al. 2000; Conedera et al. 2001). In other cases, chestnut orchards were coppiced or planted with conifers in order both to control the spread of diseases (Biraghi 1955) and to overcome the decline in economic values, respectively (Conedera et al. 2004). Similarly, coppice stands underwent either an extension of the traditional rotation time or total abandonment (Conedera et al. 2001; Manetti et al. 2001). Figure 1 shows a general framework illustrating the driving factors which affect the chestnut stand dynamics.

The disappearance of the traditional chestnut groves represents a cultural as well as an ecological loss that may be considered equivalent to the consequences of the natural reforestation of abandoned fields and pastures. In European chestnut areas this disappearence represents one of the most significant changes affecting biodiversity over the last 60 years (Piussi and Pettenella 2000). This has also been recognized by the European Community Natura 2000 network (EU Council Directive 1992), which declared both the *Castanea sativa*-dominated forests and long-established chestnut plantations with semi-natural undergrowth important habitats (9260 *Castanea sativa* woods) for biodiversity conservation (European Commission 2007). This is of particular relevance for Italy, where chestnut woods still dominate the low and middle mountain landscape both in the Southern Alps and the Apennines.

In the meantime, some of the factors that caused the abandonment of chestnut cultivation have changed. Because of the natural spread of chestnut blight hypovirulence (Turchetti and Maresi 2000) and thanks to increasing market prices for their top quality fruits (marrons) and for their derived products with high added values, chestnut orchards and woods are again playing an economic role in some parts of the European mountain regions (Pettenella 2001). The cultivation of high-value chestnut products (fruit or timber) is being intensified in the best chestnut-growing areas, new plantations are being created on potentially good chestnut sites, and traditional old orchards are being restored as part of a multipurpose landscape (Bonous 2002; Conedera et al. 2004). To this aim, the basic knowledge of the factors affecting both the structure and the biodiversity in managed and unmanaged chestnut groves is needed.

Changes in land use, environmental diversity, socioeconomic scenarios, and the impact of plant diseases are the potential driving factors for the present species composition in chestnut stands.

We analysed these factors in the chestnut orchards of Mt. Vigese, a Site of Community Importance (SCI) (IT4050013) in the Northern Apennines, which may well exemplify similar situation throughout the main European chestnut countries.

Using a multi-scalar, multi-temporal, and multi-source approach, our analysis aimed to:

- establish a general understanding of the interaction among changes in land use, biodiversity, socio-economic factors, and plant diseases;
- characterize the structure and typologies of the present chestnut groves;
- identify suitable future management options in protected areas such as SCIs.

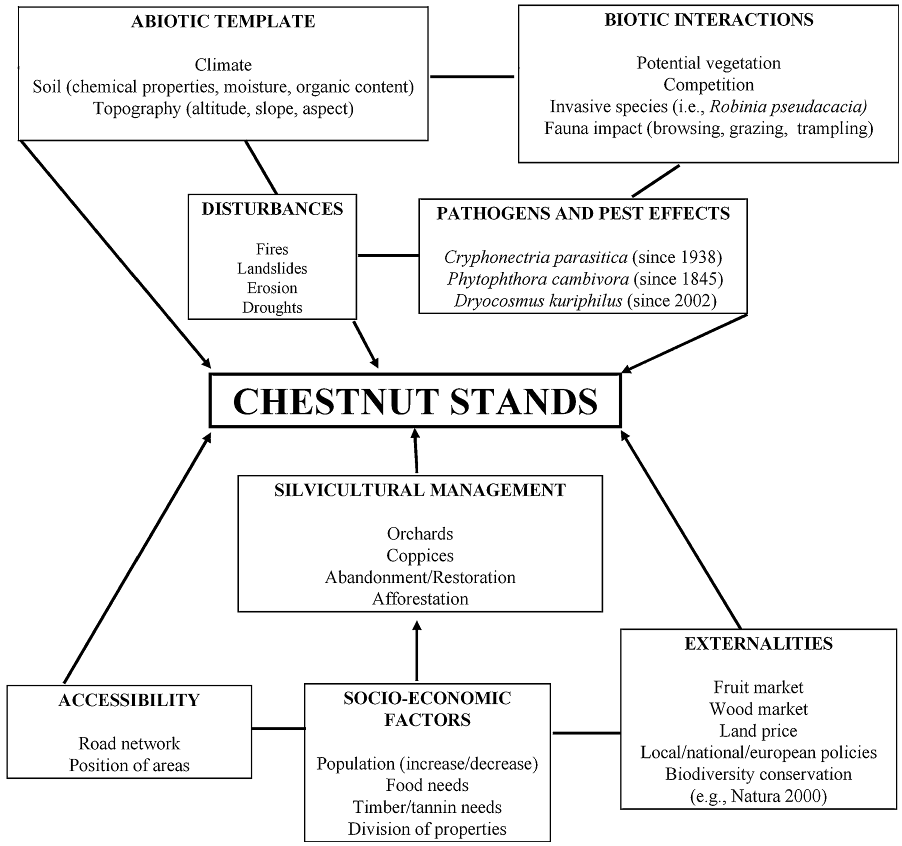


Fig. 1 Conceptual framework of factors affecting chestnut stands. *Arrows* indicate one way relationships, *segments* two way

Methods

Study area

Mt. Vigese SCI (IT4050013; 617 ha), lies in the Northern Apennines (lat. N 44° 12′ 46″; long. E 11° 05′ 38″) with an altitudinal range of 495-1089 m a.s.l. (Fig. 2). In 1995 this area became part of the Natura 2000 network and in 2004 it was also classified as a Special Protection Area (SPA) within the Biogeographic Continental Region. The lithological substrate consists largely of sandstone and marl which "float" on a vast clay base. The area, in general, is subject to landslides, which occurred notably in 1852, 1903, and 1950 (Mazzuoli 1903; Biagetti 1997).

Mixed oak woods largely dominate the vegetation (Pezzi et al. 2005). Long-established chestnut orchards and many chestnut coppices are widespread at an altitudinal range between 495 and 980 m. This Habitat of Community Importance (9260 *Castanea sativa* woods) is characterized by acidophilic undergrowths with *Luzula* (*L. pedemontana*, *L. sylvatica*, *L. forsteri*) and *Geranium nodosum* in the dampest areas. Other Habitats of Community Importance within the SCI (Pezzi et al. 2005; Regione Emilia Romagna 2007) are: 6210 semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*); 6110 rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*; 5130 *Juniperus communis* formations on heaths or calcareous grasslands. From a biogeographic standpoint, a *Quercus ilex* population on sandy outcrops (Cocconi 1883) is of particular interest as it is included in the habitat 9340 *Quercus ilex* and *Quercus rotundifolia* forests.

Land use reconstruction

Data sources on land use consisted of 1:2000 scale geometric-parcel-based cadastres (1807, 1924), panchromatic nadir aerial photographs (1954, 1971, 2000), and a vegetation map (Pezzi et al. 2005) based on the phytosociological approach as proposed by Braun-Blanquet (1964).

Fig. 2 View of the Mt. Vigese SCI (IT4050013; Lat. N 44° 12′ 46″, Long. E 11° 05′ 38″) and its long-established orchards (right)

The earlier data source was the 1807 revised version of the *Boncompagni cadastre* (BC) dating back to 1780–1835. This is the first professionally prepared survey, which provides a fairly reliable picture of local land use (Giacomelli 1987; Salterini and Tura 1995). The 1924 maps belong to the *Cessato Catasto Terreni* (CC) and represent the original geometric-parcel-based cadastre (Bracchi 1956), first established in 1886 for the whole of Italy. Cadastral maps were scanned at 600 dpi and georeferenced by using a number of Ground Control Points (GCPs) recognizable on cadastral maps from the most recent digital orthophotos (IT2000 flight dating back to 1998–1999; 1 m resolution). Selected GCPs produced a co-registration error of about 2 m; bilinear transformation was used as a resampling method. Maps were mosaiced and a vector layer was created by tracing the parcel limits in ArcGIS 9.2 (http://www.esri.com/). The land use of each parcel was identified from the Land Registry (*Brogliardi* for BC, *Tavole censuarie* for CC).

Aerial photos from 1954 and 1971 were digitalized (800 dpi) and orthorectified with an orthogonal projection of all the points in the image to a reference surface in order to correct all types of distortion (Jensen 1996; Novak 1992, see Pezzi et al. 2007 for details). Images were visually interpreted and simultaneously digitized with the ArcGIS software.

The comparison of the oldest cadastral maps to the most recent surveys requires a common classification system of land cover units (Dunn et al. 1991). We adopted the CORINE Land Cover legend (European Environment Agency 2000). Except for cadastral maps, where chestnut orchards and mixed oak coppices are distinct, the forest vegetation cover was detailed (Table 1). The change direction was obtained by overlaying the layers of different years.

In order to test the influence of topographic features on the land use change (see abiotic template in Fig. 1) a Digital Terrain Model (DTM) of the area was implemented by using contours acquired from 1:5000 Regional Technical Cartography (CTR) of the Emilia Romagna Region. Then slope, elevation, and aspect were derived and overlaid with land cover maps.

For the evaluation of demographic and agroforestry trends in a broader context (see socio-economic factors in Fig. 1) we considered the following statistical data referring to the hill and mountain areas of the province of Bologna:

– Resident population according to the Italian censuses: starting from 1861, every 10 years up to 2001 (ISTAT 1994, 2003). Data from the municipalities of Grizzana and Camugnano, in which the SCI is situated, were also extracted.
– Annual surface area (ha) of chestnut woods (orchards and coppices). Local data (ISTAT and the Official Gazette of Italy) were available for coppices from 1947 to 1977, as well as for orchards from 1929 to 1993 with some gaps. The most recent data (2003) derives from a forest map of the province of Bologna.

Table 1 Land use/land cover evolution 1807–2005

Land uses	CORINE land cover	Area (ha) for each year of survey				
		1807	1924	1954	1971	2005
Artificial surfaces	1.1 + 1.3.1	1	9	17	16	15
Agricultural areas	2.1.1 + 2.2.2 + 2.2.2 + 2.4.1	79	82	70	51	21
Forests	3.1.1 + 3.1.2					
Chestnut orchards		146	146	151	48	6
Castanea sativa coppices					99	130
Other woods		*190*	*271*	*235*	*288*	*362*
Ostrya carpinifolia woods				75	89	100
Quercus pubescens woods				132	159	180
Quercus cerris woods				28	35	54
Robinia pseudacacia woods				1	4	22
Coniferous plantation					2	6
Scrub and/or herbaceous vegetation associations	3.2.1 + 3.2.4	134	55	85	85	66
Open spaces with little or no vegetation	3.3.2 + 3.3.3	68	55	59	31	17

Characterization of chestnut stands

Twenty-eight randomly selected chestnut forest plots (20 × 20 m) were surveyed by using a design-based probabilistic sampling approach from points placed on a 250 m × 250 m grid (Chiarucci and Bonini 2005). In the summer of 2005, the selected plots were located with a high precision GPS and the total list of woody species was collected. Furthermore, DBH was measured for woody individuals with DBH > 3 cm; the type and frequency of blight infections (*Cryphonectria parasitica*) and the presence/absence of ink disease (*Phytophthora* spp.) were also noted.

Blight incidence was evaluated by the ratio between healing and healed cankers compared to virulent and intermediate ones (Turchetti and Maresi 2000; Turchetti et al. 2008). Lethal blight infections were classified as recent where dead foliage persisted on branches and old where branches were already debarked. Trees or stumps killed by ink disease were classified as old (tissues very degraded) or recent (dead foliage, bark and tissue still present or still suffering trees) attacks.

Statistical analyses at the plot level were carried out using the Vegan package (R version 2.9.2.). Dominant woody species basal areas were analyzed with non-metric ordination (Non-Metric Multidimensional Scaling, NMDS) in order to detect the main features and trends of the plot structure. Following Chiarucci and Bonini (2005), we considered as dominant the species with at least 25% of frequency and 5% of total basal area in each plot. Information on topographical features (elevation, slope, aspect), ink disease, continuity of management, landslides, and presence of orchard vestiges were fitted as variables onto the ordination in order to obtain their correlation to species distribution.

Results

Land use reconstruction

Table 1 and Fig. 3 show changes in land use in Mt. Vigese SCI.

The 1807 map shows that chestnut orchards with agricultural areas and herbaceous vegetation (mainly pastures) cover the largest areas while artificial surfaces are scarce. This map is closely related to extensive human farming activities.

In the 1924 map, the area of chestnut orchards is almost unaltered in extent (24%), with few changes in their distribution. Most changes derive from the extensive landslides registered in 1852 and 1903 (Mazzuoli 1903), which caused the destruction of some orchards and their replacement by open spaces. Unfortunately, there is some confusion between woods and scrubs and herbaceous vegetation cover, probably as a result of the fuzzy criteria used to evaluate the difference between abandoned and wooded pastures.

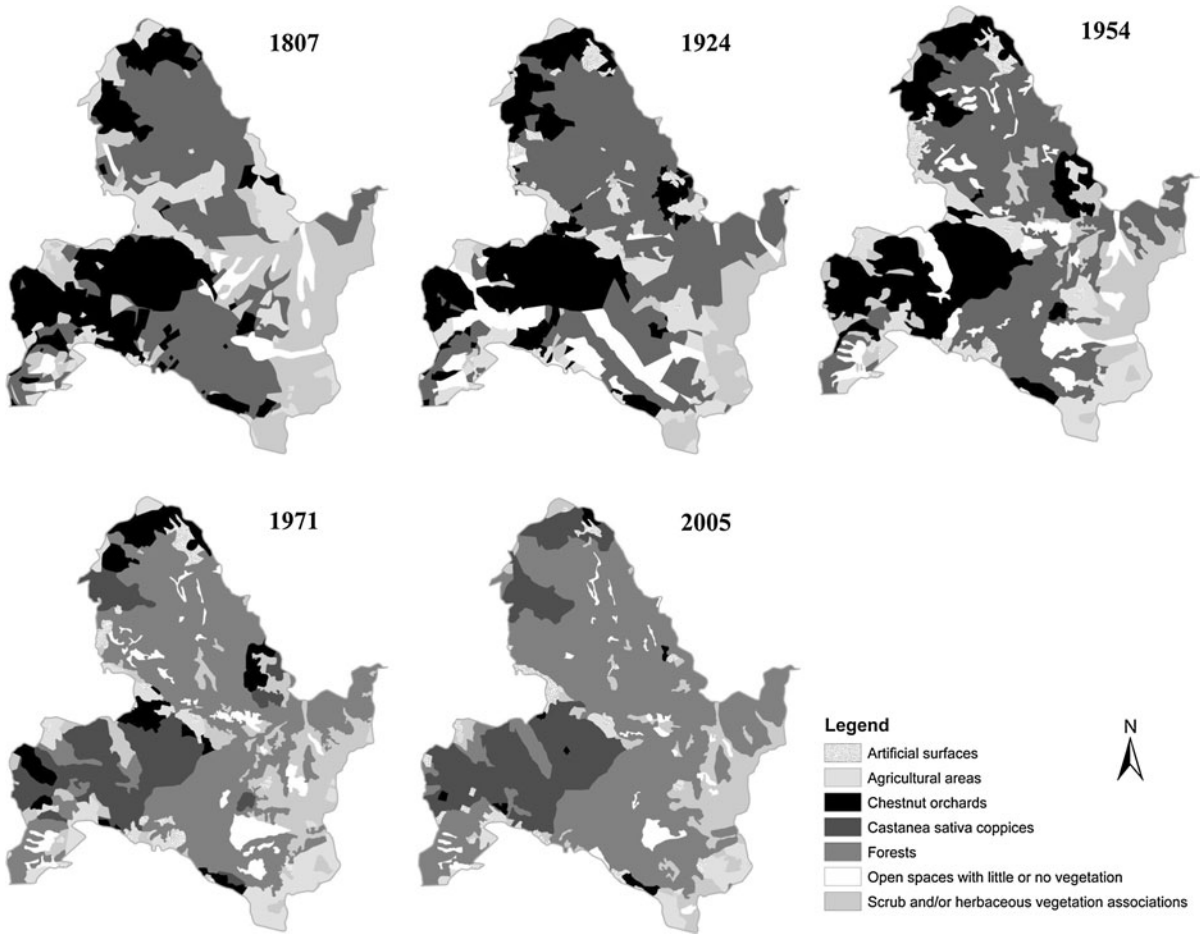


Fig. 3 Changes in land use/land cover of Mt. Vigese SCI, in the last two centuries (1807–2005). Classification follows CORINE Land Cover nomenclature. Further explanations in the text

The largest extent of chestnut orchards was reached in 1954 (151 ha). In the following years the orchard cover decreased to 48 ha in 1971 and to 6 ha in 2005.

Starting from 1954, the chestnut orchards decrease corresponds—in both area and distribution—to a chestnut coppice increase, reaching a cover of 130 ha in 2005. Chestnut orchard abandonment and/or coppicing were similar in all the classes of slope, aspect and elevation although orchards at the highest elevations or on the steepest slopes had first been coppiced and then disappeared.

After the first substantial decrease shown on the 1971 map, a second significant decrease in the extent of chestnut orchards is revealed by the 2005 survey. The few remaining chestnut orchards lie in the more accessible and less steep areas. Small groups of grafted trees for domestic use are found near houses. In general, mixed oak woods increased in the abandoned fields and pastures. It should be noticed that no dead trees or damaged crowns were identified by aerial photos throughout the surveying period and forest types.

The trend of population density (Fig. 4) is almost in line with the temporal pattern of the landscape dynamic and shows: a peak in the mid 1930s followed by a decrease starting in the late 1930s, which abruptly accelerated during the second half of the twentieth century. In the last 20 years (1981–2001) resident populations changed in different ways: Camugnano remained substantially stable while a marked increase was recorded in Grizzana as well as in the whole mountain area of the Province.

In the 1930s, both the population size and chestnut orchards reached their greatest extent in the whole province of Bologna. From 1947 until the late ’70s

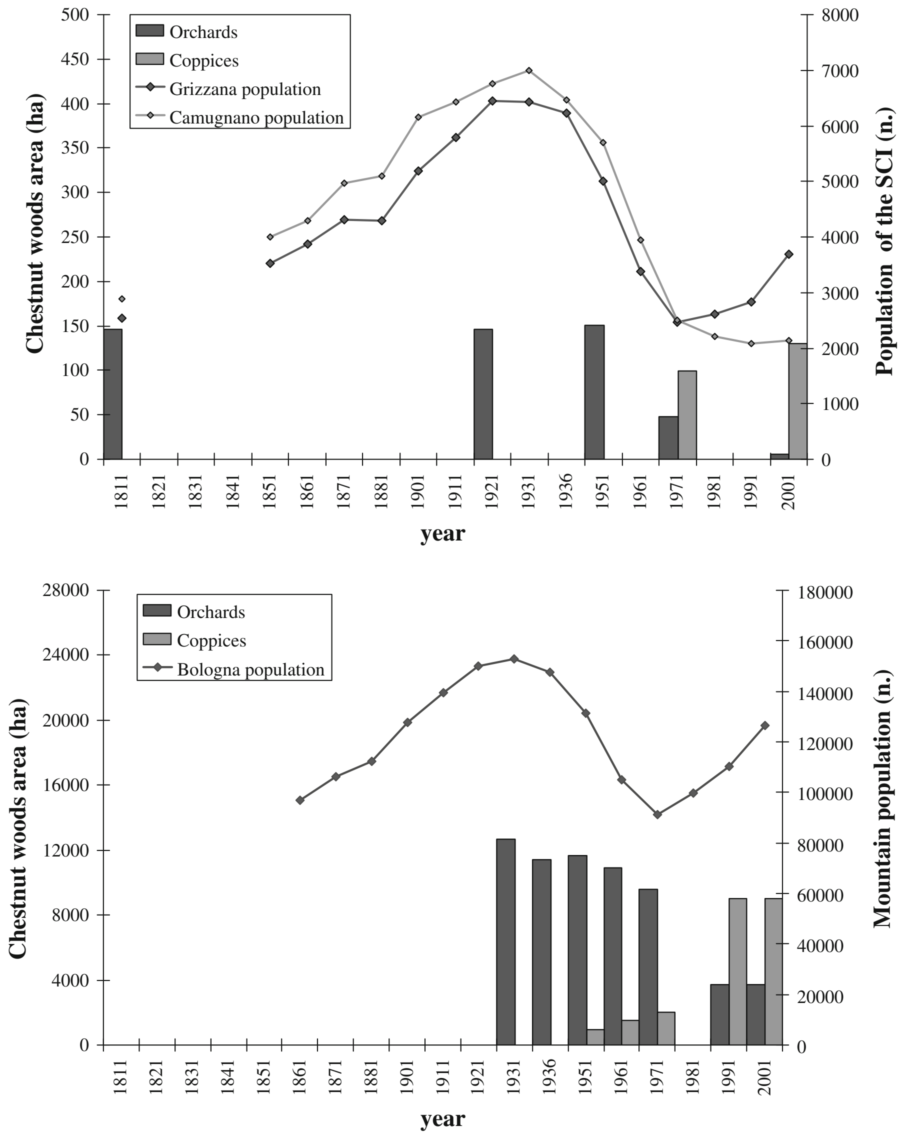


Fig. 4 Trend of population and chestnut woods in the SCI (above) and in a broader context (province of Bologna)

there was a steady population decrease, but the area of the chestnut woods remained unchanged.

Figure 4 clearly shows that when chestnut orchards decrease, coppices increase. However, the percentage of coppices is not equal to that of chestnut orchards lost in the same period, thus indicating that in some cases chestnut orchards were abandoned and naturally reverted to mixed forest stands.

Disease incidence

Chestnut blight was observed in every plot, but damage was limited. Healed and healing infections made up 84% of the 1850 cankers observed on chestnut trees with a further 11% of intermediate, non-lethal infections. Only 5% of attacks were lethal, but they concerned only branches or small and depressed sprouts. The prevalence of healed and healing infections was clear in all but one plot (plot 26), where intermediate infections predominated, together with a low number of normal cankers. Old attacks on branches were found in 14 plots while new lethal infections were found in 9 plots: in all but one (plot 9) they affected only 1 or 2 branches or small and depressed sprouts.

Stumps killed by ink disease were observed in 9 plots. In two plots there was evidence of previous attacks, and just initial symptoms in one. In 6 plots old and recent damage was evident. Only one or two infected stumps in each plot were evident: however, in the whole area, including all 28 plots, two larger issues affecting several trees were observed during the surveys.

Forest structure and woody species

In total, 3746 stems belonging to 31 different woody species were sampled (Table 2): more than 50% (2014) were *Castanea sativa*. *Ostrya carpinifolia* has 592 stems (16%), *Corylus avellana* and *Fagus sylvatica* over 200, *Fraxinus ornus*, *Quercus pubescens*, and *Robinia pseudoacacia* over 100. For the 1.1 ha sampled area, the total basal area is 52.57 m^2: 67% is covered by *Castanea sativa* and 12% by *Ostrya carpinifolia*. Remaining species (with the exception of *Fagus sylvatica*, *Fraxinus ornus*, *Quercus pubescens*, and other few species) cover no more than 0.3%.

The number of stems (stems $plot^{-1}$; Table 3) ranges between 21 and 232: most of the plots (22) show a stem density >100 (about 40% more than 150); only two plots more than 200. Basal area ranges from 0.86 to 4.90 m^2 $plot^{-1}$. As to *Castanea sativa*, the number of stems ranges from 5 (plot 8) to 190 (plot 20), while basal area from 0.08 (plot 16) to 4.58 m^2 $plot^{-1}$ (plot 21).

Castanea sativa is the dominant species in 24 plots (Table 3), in some stands with *Quercus pubescens*, *Prunus avium*, *Ostrya carpinifolia*, and *Robinia pseudoacacia*. Four plots are clearly dominated by *Ostrya carpinifolia* or *Fagus sylvatica*. Table 3 shows also that all the plots but two were coppiced after 1954.

Figure 5 shows the distribution pattern of plots following NMDS. Most plots are along the first axis; they are chestnut coppices with a different *Castanea sativa* content. Along the first axis the presence of *Castanea sativa* increases (see *Castanea* group of plot in the first positive semi axis), while *Ostrya carpinifolia*, which indicates an evolutionary trend toward mixed deciduous stands, decrease. Plots 2 and 28 have almost completely ousted *Castanea sativa*. Coppices with *Robinia pseudoacacia* (plot 4 and 5), *Quercus pubescens* (plots 7, 9, 11 and 26), *or Fagus sylvatica* (plot 8 and 16) are clearly separated, in accordance with their different ecological features and the altitude. *Q. pubescens* is accompanied by shrubs, indicating more light availability or xeric conditions (e.g. *Cytisophyllum sessilifolium*, *Cytisus hirsutus*, *Genista pilosa*, *G. germanica*, and *Teucrium chamaedrys*), while *R. pseudoacacia* is accompanied by *Sambucus nigra*, *Rubus* spp., *Clematis vitalba*, indicating disturbance. *Fagus sylvatica* plots are located at highest altitude and have almost completely ousted *Castanea sativa*. In addition, the NMDS clearly distinguishes the abandoned chestnut orchard (plot 21) from the cultivated ones (plot 23).

Among the environmental factors considered, only the elevation and slope have a significant relationship with the changes in species composition.

Discussion

Chestnut forest dynamics on the Mt. Vigese SCI are clearly described by the multi-temporal approach based on highly comparable data sources. In addition, medium–high resolution maps allowed the downscaling of the multi-scalar approach, from the landscape to the stand.

Figure 6 summarizes both the historical evolution of chestnut forests in the SCI Mt. Vigese and its relationship with the different constraints identified. The observed trend (1807–2005) can be considered a good example of the general trend in the Northern Apennines chestnut forests: a continuous increase in orchards through the first half of the twentieth century followed by a sharp decrease up to the present time (Agnoletti 2010). Factors shown by the Fig. 6 can be considered almost representative for the most of the Italian districts and applicable to other Mediterranean mountain areas (Pitte 1986; Conedera et al. 2004). However, local factor, especially competition with other more productive coltures (as in France) could have played an effective role (Fauve-Chamoux 2000), but their influence seem reduced in the mountain context as that examined in this work: chestnut forests had and have no economical alternative.

In our study area most chestnut orchards have been coppiced quite abruptly since the late 1950s. This is very much in line with a general trend in the whole Italian Peninsula due to the belief that chestnut orchards had no chance of surviving when attacked by the chestnut blight, whereas managed coppice stands displayed an increase in resistance after several coppicing (Biraghi 1955). What Biraghi very likely observed in the chestnut coppices of first introduction

Table 2 Total number of stems, basal area, and frequency per plot of the woody species in the 28 plots considered

Species	Stems (n.)	Basal area (m^2)	No. of plots
1. *Acer campestre*	17	0.30	4
2. *Acer opulifolium*	51	0.45	6
3. *Acer pseudoplatanus*	3	0.01	3
4. *Alnus glutinosa*	4	0.14	1
5. *Castanea sativa*	2014	35.50	28
6. *Clematis vitalba*	8	0.01	3
7. *Cornus sanguinea*	7	0.01	2
8. *Corylus avellana*	216	0.40	11
9. *Crataegus monogyna*	11	0.02	7
10. *Erica arborea*	1	0.00	1
11. *Fagus sylvatica*	236	2.12	4
12. *Ficus carica*	1	0.00	1
13. *Fraxinus ornus*	138	0.61	11
14. *Juniperus communis*	22	0.07	4
15. *Laburnum anagyroides*	13	0.08	3
16. *Malus domestica*	2	0.15	1
17. *Ostrya carpinifolia*	592	6.42	21
18. *Picea abies*	16	0.09	1
19. *Populus nigra*	1	0.03	1
20. *Populus tremula*	14	0.42	3
21. *Prunus avium*	45	0.59	15
22. *Pyrus pyraster*	2	0.02	1
23. *Quercus cerris*	5	0.12	1
24. *Quercus pubescens*	129	2.24	12
25. *Robinia pseudoacacia*	100	2.41	5
26. *Salix caprea*	14	0.02	1
27. *Sambucus nigra*	17	0.03	3
28. *Sorbus aria*	21	0.17	4
29. *Sorbus domestica*	4	0.04	3
30. *Sorbus torminalis*	41	0.10	5
31. *Tilia platyphyllos*	1	0.01	1

of the disease were the first signs of hypovirulence, that he interpreted as an increased chestnut resistance to the blight (Biraghi 1955). According to the eminent pathologist and researcher, the best way to preserve chestnut stands from disappearing was the repeated coppicing regardless of the type of forest (orchard or coppice). He therefore suggested (and the National Forest Service applied) the systematic coppicing of chestnut orchards to preserve chestnut germoplasm and related forest services (Biraghi 1955). This may be the main reason why people just proceeded to a coppicing before or instead of abandoning stand management where the coppicing of chestnut orchards was related to some local economic benefits (such as money obtained from tannin production). As a result, very few big trees are present in the remaining chestnut woods and very few orchards still lie within the SCI under consideration.

Chestnut is still dominant, thus confirming that surveyed areas are an optimal habitat for this species. Over the past 50 years, *Fagus sylvatica* and *Ostrya carpinifolia* almost replaced *Castanea sativa* only at the edge of chestnut area. *Fagus sylvatica*, *Ostrya carpinifolia*, *Quercus pubescens* and *Robinia pseudoacacia* (these last limited only in disturbed areas) are the invading tree species in our chestnut stands.

Table 3 The topographic and chestnut stand features considered in the 28 plots sampled

Plot (*n*)	Slope (°)	Elevation	Aspect	Castanea orchard					Species	Stems		Basal area		Dominant woody species
		(*m*)		1807	1924	1954	1971	2005	(n)	Total (n)	Chestnut	Total (m^2)	Chestnut	
1	27	805	SW	x	x	x	x	–	21	119	77	1.79	1.63	*Castanea sativa*
2	27	804	SE	x	–	–	–	–	23	232	7	1.31	0.12	*Ostrya carpinifolia*
3	33	760	NW	x	x	x	–	–	17	106	69	2.88	2.1	*Castanea sativa*
4	17	565	W	x	x	x	–	–	17	110	61	1.6	0.82	*Castanea sativa*, *Robinia pseudacacia*
5	16	574	W	x	x	x	–	–	19	103	52	1.35	0.79	*Castanea sativa*, *Robinia pseudacacia*
6	18	630	W	x	–	–	–	–	25	92	37	1.2	0.42	*Castanea sativa*
7	23	765	SW	x	–	–	–	–	26	99	49	1.49	0.99	*Castanea sativa*
8	44	1027	NW	–	x	–	–	–	7	153	5	1.9	0.16	*Fagus sylvatica*
9	22	566	W	x	x	–	–	–	22	111	63	1.34	0.59	*Castanea sativa*, *Quercus pubescens*
10	20	558	N	x	x	x	–	–	21	165	139	1.4	1.26	*Castanea sativa*
11	31	613	SW	x	x	x	–	–	22	109	64	1.8	1.11	*Castanea sativa*
12	23	661	W	x	x	x	–	–	12	120	119	2.24	2.24	*Castanea sativa*
13	22	799	N	x	x	–	–	–	14	130	50	1.49	0.74	*Castanea sativa*
14	27	793	N	x	x	x	–	–	9	138	105	1.92	1.78	*Castanea sativa*
15	39	906	N	x	x	x	–	–	15	226	93	1.89	0.79	*Castanea sativa*, *Ostrya carpinifolia*
16	36	865	NE	x	x	x	–	–	8	199	6	1.84	0.08	*Fagus sylvatica*
17	16	625	NW	x	x	x	–	–	15	91	52	2.63	1.95	*Castanea sativa*
18	20	687	W	x	x	x	x	–	23	114	103	2.04	1.92	*Castanea sativa*
19	26	785	NW	x	x	x	–	–	13	190	186	1.53	1.53	*Castanea sativa*
20	21	825	N	x	x	x	–	–	9	193	190	2.01	1.96	*Castanea sativa*
21	22	675	NW	–	x	x	x	x	19	72	30	4.9	4.58	*Castanea sativa*
22	17	691	N	–	x	x	x	–	19	168	108	2.14	1.72	*Castanea sativa*
23	15	636	NE	x	x	x	x	x	10	21	8	0.86	0.35	*Prunus avium*, *Castanea sativa*
24	24	566	N	x	x	x	–	–	21	157	85	1.81	1.04	*Castanea sativa*
25	48	645	NW	–	x	x	–	–	18	106	54	1.62	1.38	*Castanea sativa*
26	29	592	W	–	x	x	–	–	23	79	51	1.69	1.21	*Castanea sativa*
27	27	523	W	–	x	x	x	–	16	157	116	2.18	1.77	*Castanea sativa*
28	27	624	NE	x	x	x	–	–	16	186	35	1.72	0.49	*Ostrya carpinifolia*

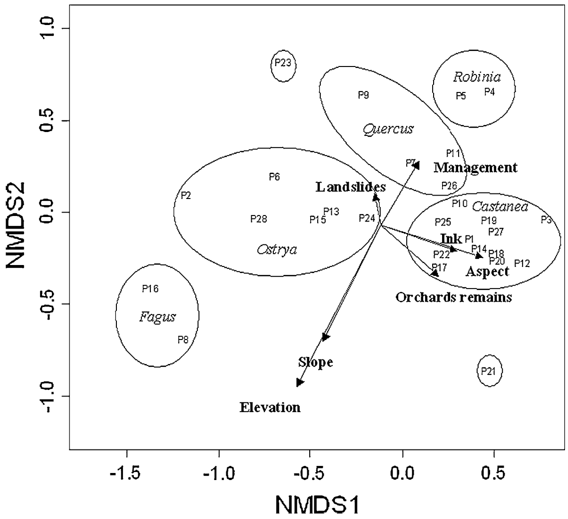


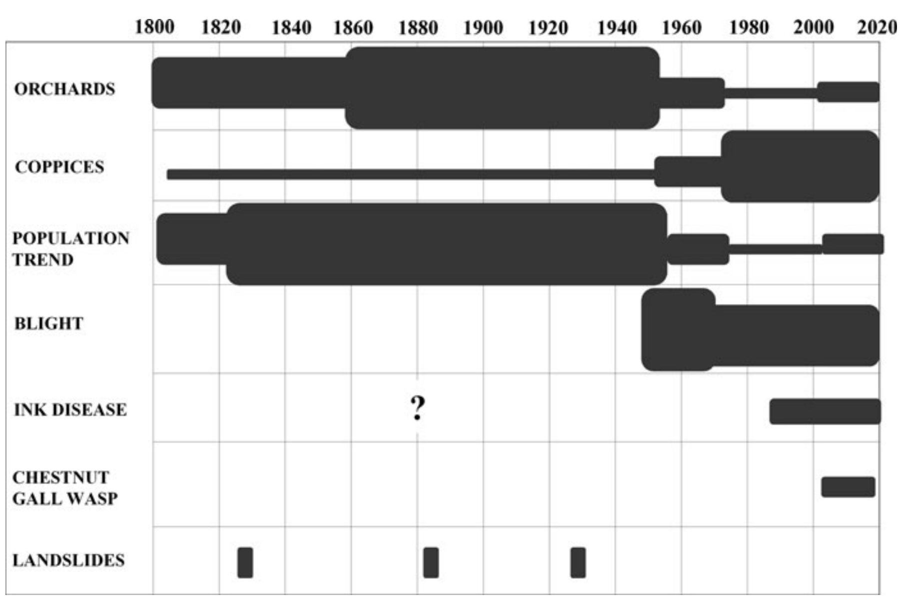
Fig. 5 NMDS (Non-Metric Multidimensional Scaling) Ordination diagram of basal areas showing the gradient and the correlation to topographical features (elevation, slope, aspect), ink disease, continuity of management, landslides, presence of orchard vestiges. *Vectors* show the direction of the gradient, length of the arrow is proportional to the correlation between the variable and the ordination. *Circles* indicate group of plot and the main invading tree species (*Ostrya carpinifolia*, *Robinia pseudoacacia*, *Quercus pubescens*, *Fagus sylvatica*). Stress: 9.738; P = plot

However, our study shows that in the study area *Ostrya carpinifolia* may be locally considered the main indicator of *Castanea* forest dynamics toward mixed deciduous woods. Although the two species show different ecological needs in term of soil acidity and lime content of the soil, the particular characteristics of the sandstone and marl substrate present in the study area allow the coexistence of both species. Elevation and slope seem to act as the most effective site factors. It is likely that they have been immediately affecting the choice between management and abandonment.

It is worthy of note that all the original orchards in this area consisted of local varieties used for chestnut nut and flour production, mainly for self-sufficiency or to exchange with other products. Owners were discouraged from maintaining this cultivation because of its lack of profitability, which can in no way compare to the income possible from wood and timber sales. Probably, parts of nuts were commercialized and could be involved in commercial channel towards cities and foreign countries, but the bulk of the production and especially flour, as everywhere on the Apennines, just covered the family needs. Still now, flour is a secondary product and orchards with flour varieties are mainly abandoned or coppiced due to the very high production costs with respect to the market prices (Pettenella 2001; Conedera et al. 2004). As a consequence, most restoring activities of productive orchards are strictly related to possibility of cultivating the high quality varieties of "marrons", mainly for the fresh consume (Conedera et al. 2004).

The demographic trend seems to have been the main driver of the landscape changes over the last two

Fig. 6 Summary of historical evolution of chestnut woods within the Mt Vigese SCI and its relationship with the different constraints considered



centuries: chestnut woods were affected in extent, management, and structure. Population increase meant more orchards; its decrease meant either its abandonment or replacement by coppices. The recent slight mountain repopulation observed in both municipalities considered, as in some other Apennine areas, has not affected chestnut cultivation: the incoming population is not involved in woodland ownership and has no economic interest in chestnut cultivation. Most of the new inhabitants are either from cities or from different cultures and traditions. They have no links to the "chestnut culture" and they cannot contribute to the related cultural landscape. Only one single coppice conversion into a new orchard for "marrons" chestnut production was observed in the study area! It appears highly improbable that all the former orchards will be recovered in the near future. The maintaining of the few old grafted trees close to houses is more plausible.

The predominance of hypovirulence in all the surveyed plots is clear, and the small number of old attacks observed suggests that, probably, the equilibrium between host and parasite was reached early on. At present, in the area considered as well as in the whole Italian chestnut range, blight is not a threat to chestnuts and does not seem to influence forest changes, except as a secondary agent during periods of stress (droughts or windstorms or other climate stress), as observed by Davini et al. (1998) and Turchetti et al. (2008). The greatest negative impact on the landscape dates back to the 1950s, when chestnut coppicing was extensively pursued in order to constrain the blight spread (Biraghi 1946, 1953). It is important to note that oldest trees survive epidemic outbreaks, thus confirming the early appearance of hypovirulence also in this area. There was no historical record of ink disease in the area and, like blight damage, it did not show up in 2003 aerial photographs. It is suggested that only small but widespread attacks appeared during the 1990s, as in other areas of the Apennines (Turchetti and Maresi 2000; Vettraino et al. 2005), without immediate and significant effects on chestnut presence. A more effective action might manifest itself in the future, especially in the two largest foci that were observed in the area. The recent appearance of the chestnut gall wasp (*Dryocosmus kuriphilus* Yasumatsu) in the Northern Apennines could act as a new disturbance factor but its effects are not yet known or foreseeable (Graziosi and Santi 2008). In addition, dated and recent chestnut parasites and diseases may interact increasing the pressure on the phytosanitary conditions of the stands (Turchetti et al. 2010).

In the near future, the management scenarios may be summarized as follows either for Mt. Vigese or for most of chestnut woods on Mediterranean mountains:

1. maintenance of chestnut coppices by regular coppicing. This solution requires a market for chestnut wood. Up to now, the absence of recent coppiced area suggests that no or limited economic values are involved in this kind of product.
2. natural dynamics from abandoned coppices to mixed woods. At present, the sampled plots are mainly old abandoned coppices. Increasing changes in the species composition of the abandoned coppices toward mixed oak woods can be foreseen but, as shown by our data, this process has not yet begun and seems to be a long-term process.
3. conversion to new orchards—this scenario might involve only small areas, as it is connected mainly to the local population size as well as to market development. In any case, the preservation, as well as the recovery, of big old grafted trees may greatly affect the stability in the local biodiversity.

The Natura 2000 programme offers new resources for maintenance of Mt. Vigese old chestnut woods in the near future. However, without a change in the social and economic context, different appropriate management choices must be sought.

As in many other chestnut areas of Europe, the most promising strategy for enhancing conservation and active management of the chestnut forests includes their marketing as a multipurpose forest type where outputs are not only organic fruits and fruit-derived products, as well as woody products, but also other non-woody products (honey, mushrooms, herbs, etc.) as well as the chestnut landscape, their biodiversity, cultural heritage and eco-touristic potential.

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References

Agnoletti M (2010) Paesaggio rurale. Strumenti per la pianificazione strategica. Edagricole—Edizioni Agricole de il Sole 24 ORE Spa, Bologna

Arnaud MT, Chassany JP, Dejean R, Ribart J, Queno L (1997) Economical and ecological consequences of the disappearance of traditional practices related to chestnut groves. J Environ Manage 49:373–391

Biagetti M (1997) Evoluzione dei movimenti franosi nell'area di M. Vigese e M. Ovolo. Degree thesis in Geological Science, academic year 1996–1997. University of Bologna

Biraghi A (1946) il cancro del castagno causato da *Endothia parasitica*. L'Italia Agricola 7:406

Biraghi A (1953) Possible active resistance to *Endothia parasitica* in *Castanea sativa*. Proc Cong Int Un For Res Organ 11:643–645

Biraghi A (1955) Il "cancro della corteccia" ed i suoi riflessi sulla crisi del castagno. Italia Forestale e Montana 10:3–11

Bonous G (2002) Il castagno. Coltura, ambiente ed utilizzazioni in Italia e nel mondo. Edagricole Bologna

Bracchi G (1956) Il catasto. Norme fondamentali sulla formazione del nuovo catasto terreni e del nuovo catasto edilizio urbano e sulla conservazione dei catasti terreni e dei fabbricati vigenti in Italia. Manuale tecnico-amministrativo. Rome

Braun-Blanquet J (1964) Pflanzensoziologie. Grundzüge der Vegetationskunde, 3rd edn. Springer, Berlin

Chiarucci A, Bonini L (2005) Quantitative floristics as a tool for the assessment of plant diversity in Tuscan forests. Forest Ecol Manag 212(1–3):160–170

Cocconi G (1883) Flora della provincia di Bologna: vademecum per una facile determinazione delle piante incontrate. Zanichelli, Bologna

Conedera M, Krebs P (2008) History, present situation and perspective of chestnut cultivation in Europe. In: Abreu CG, Peixoto FP, Gomes-Laranjo J (eds) Proceedings of the second Iberian Chestnut Congress, Vila Real (P), June 20–22th 2007. Acta Hort 784:23–27

Conedera M, Stanga P, Oester B, Bachmann P (2001) Different post-culture dynamics in abandoned chestnut orchard and coppices. For Snow Landsc Res 76(3):487–492

Conedera M, Manetti MC, Giudici F, Amorini E (2004) Distribution and economic potential of the Sweet chestnut (*Castanea sativa* Mill.) in Europe. Ecol Mediterr 30(2): 179–193

Conti F, Abbate G, Alessandrini A, Blasi C (2005) An annotated checklist of the Italian vascular flora. Palombi, Rome

Davini G, Gervasini E, Maresi G, Rapella A, Ronchi L, Tagliaferro A, Turchetti T (1998) Il castagno in Lombardia: prime indagini fitosanitarie. Quaderni di Ricerca e Sperimentazione. ARF ed

EU Council Directive (1992) Natura 2000 network on the conservation of natural habitats and of wild Fauna. COUNCIL DIRECTIVE 92/43/EEC (1) of 21 May 1992. The Council of the European Communities

Dunn CP, Sharpe DM, Guntenspergen GR, Stearns F, Yang Z (1991) Methods for analyzing temporal changes in landscape pattern. In: Turner MG, Gardner RH (eds) Quantitative methods in landscape ecology. Springer, New York, pp 173–198

European Commission (2007) Interpretation manual of European habitats—EUR27. Published by the European Commission, DG Environment, Nature and Biodiversity

European Environment Agency (2000) CORINE land cover technical guide—addendum 2000. EEA, Copenaghen

Fauve-Chamoux A (2000) II.D.1.Chestnuts. In: Kiple KF, Ornelas KC (eds) The Cambridge world history of food. Cambridge University Press, Cambridge

Gabrielli A (1994) La civiltà del castagno. Monti e boschi 65:3

Gazzetta Ufficiale del Regno d'Italia (several years) Supplemento straordinario, Bollettino di statistica agraria e forestale. Rome

Giacomelli A (1987) Carta delle vocazioni agrarie della pianura bolognese desunta dal catasto Boncompagni (1780–1786). Historic Disciplines Dept. University of Bologna, Bologna

Graziosi I, Santi F (2008) Chestnut gall wasp (*Dryocosmus kuriphilus*): spreading in Italy and new records in Bologna province. Bull Insectol 61(2):343–348

Griffin GJ (2000) Blight control and restoration of the American chestnut. J For 98(2):22–27

ISTAT (1994) Popolazione residente dei Comuni. Censimenti dal 1861 al 1991. Istituto Nazionale di Statistica, Rome

ISTAT (several years) Annuario di statistica forestale. Istituto Nazionale di Statistica, Rome

ISTAT (2003) 14° Censimento generale della popolazione e delle abitazioni. http://dawinci.istat.it/. Accessed 22 Dec 2008

Jensen JR (1996) Introductory digital image processing: a remote sensing perspective, 2nd edn. Prentice-Hall, Upper Saddle River, NJ

Manetti MC, Amorini E, Becagli C, Conedera M, Giudici F (2001) Productive potential of chestnut (*Castanea sativa* Mill.) stands in Europe. For Snow Landsc Res 76(3): 471–476

Mazzuoli L (1903) La relazione ufficiale sulla frana di Vigo. L'Alpe 11–12:136–138

Mondino PG (1991) Caratteristiche dei boschi di sostituzione e loro tendenze evolutive. In: Atti del Simposio: I boschi italiani. Valori naturalistici e problemi di gestione, pp 53–61. Castiglione dei Pepoli (Bologna, 9 October 1989)

Novak K (1992) Rectification of digital imagery. Photogramm Eng Remote Sens 58(3):339–344

Paci M (1992) Note sull'ecologia del castagno. Economia Montana 24(6):15–17

Paci M, Maltoni A, Tani A (2000) I castagneti abbandonati della Toscana: dinamismo e proposte gestionali. In: Bucci G, Minotta G, Borghetti M (eds) Applicazioni e prospettive per la ricerca forestale in Italia, Atti II congresso SISEF (Bologna, 20–23 October 1999), pp 9–16

Petri L (1918) Studi sulla malattia del castagno detta 'dell'Inchiostro'. Annali del R. Istituto Superiore Forestale Nazionale 3:1–34

Pettenella D (2001) Marketing perspectives and instruments for chestnut products and services. For Snow Landsc Res 76(3):511–517

Pezzi G, Bordò L, Ferrari C (2005) Carta della vegetazione del SIC "Monte Vigese" (IT4050013, Appennino settentrionale, Bologna). Braun-Blanquetia 40:1–24

Pezzi G, Bitelli G, Ferrari C, Girelli VA, Gusella L, Masi S, Mognol A (2007) Pattern temporale del limite altitudinale dei boschi di faggio nell'Appennino settentrionale. Un'analisi di dati fotogrammetrici. Forest@ 4(1):79–87. [Online 2007-03-21] URL: http://www.sisef.it/forest@/. doi:10.3832/efor0440-0040079

Pitte JR (1986) Homme et paysage du chtaignier de l'Antiquit nos jours. Librairie A Fayard, Paris

Piussi P, Pettenella D (2000) Spontaneous afforestation of fallows in Italy. In: Weber N (ed) NEWFOR new forest for Europe: afforestation at the turn of the century. Proceeding of the scientific symposium, Freiburg, 16–17 February 2000, pp 151–163

Regione Emilia Romagna (2007) Cartografia interattiva dei SIC, delle ZPS e delle Aree protette della Regione Emilia Romagna. http://www.regione.emilia-romagna.it/natura2000/indice/gisweb.html. Accessed 02 Jan 2009

Romane F, Hauter S, Valerino L (1995) Factors affecting biodiversity in chestnut (*Castanea sativa* Mill.) ecosystems along a gradient from coppice to orchard in the Cevennes Mountains (Southern France). In: Romane F (ed) Sustainability of mediterranean eco systems. Case study of the chestnut forest. Ecosystem Research Report 19, EUR 15727 EN, pp 103–109

Salterini C, Tura D (1995) Catasto Boncompagni. Libri censuari. Bologna State Archives

Turchetti T, Maresi G (2000) Effects of diseases on chestnut orchards and forest ecosystems. Ecologia Mediterranea 26(1–2):113–121

Turchetti T, Ferretti F, Maresi G (2008) Natural spread of *Cryphonectria parasitica* and persistence of hypovirulence in three Italian coppiced chestnut stands. Forest Pathol 38(4):227–243

Turchetti T, Addario E, Maresi G (2010) Interazioni tra cinipide galligeno e cancro della corteccia: una nuova criticità per il castagno. Forest@ 7(1):252–258. [online: 2010-12-02] URL: http://www.sisef.it/forest@/. doi:10.3832/efor0642-007

Vettraino AM, Morel O, Perlerou C, Robin C, Diamandis S, Vannini A (2005) Occurrence and distribution of *Phytophthora* species in European chestnut stands, and their association with Ink Disease and crown decline. Eur J Plant Pathol 111:169–180