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RESEARCH PAPER

Perception and management of the understorey vegetation by chestnut growers: the study case of the chestnut orchards in the Bologna and Modena Apennines (Italy)

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Abstract

In southern Europe, traditionally managed chestnut orchards are iconic landscapes and habitats rich in biodiversity. They consist of a spaced stand of grafted chestnut trees for fruit production and a herbaceous understorey layer. Management practises play a key role in maintaining and shaping the understorey vegetation layer, which supports most of the vegetation diversity. However, very little is known about thoughts, feelings, and attitudes of growers to the plant species which make up the understorey ground vegetation. To probe further on this issue, we performed qualitative socio-ecological research involving 38 growers to explore their perceptions and attitudes towards the understorey vegetation of selected chestnut orchards of the northern Apennines. Although most of the respondents were in their 60 s, they showed a wide range of cultural backgrounds and shared the common passion for chestnut cultivation. Biodiversity proved to be a difficult concept for the interviewees to understand and deal with. Nevertheless, the interviews based on both closed and open-ended questions made it possible to record 140 plant taxa. Among them, species with conspicuous flowers (e.g., orchids), species requiring management effort, and species providing practical benefits according to local tradition. Understanding and knowing the ecosystem complexity of the chestnut orchards could guide growers towards more adequate and biodiversity-enhancing management practises. There is, however, an urgent need to increase biodiversity awareness among chestnut growers (e.g., through training courses) to enhance and ensure the conservation of the traditional chestnut orchards and related biodiversity.

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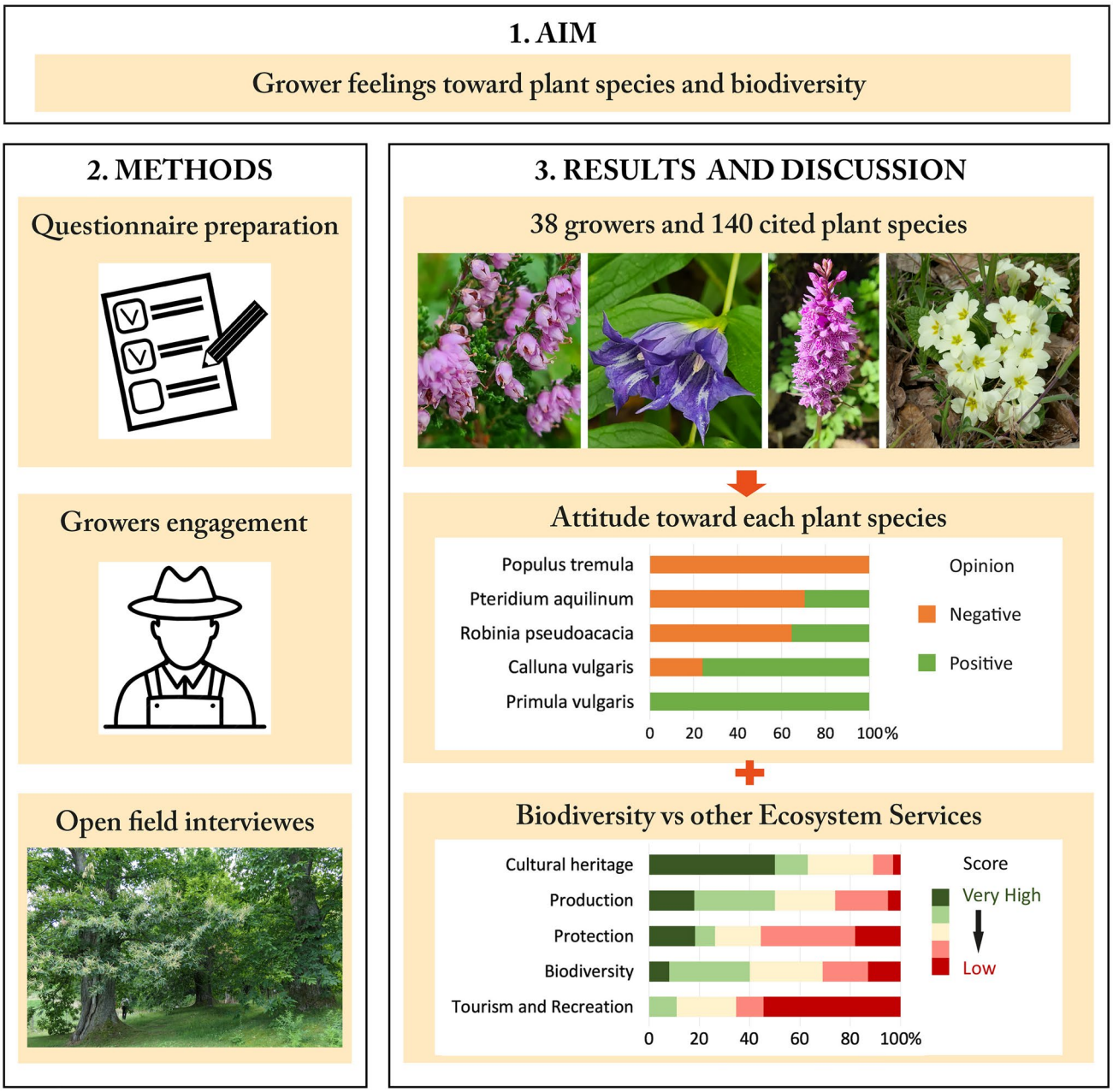
Graphical Abstract



Keywords Biodiversity · *Calluna vulgaris* · Ethnobotany · Natura 2000 · Orchids · *Pteridium aquilinum*

1 Introduction

Traditionally managed chestnut (*Castanea sativa* Mill.) orchards are an open forest habitat of anthropogenic origin characterised by a low-intensity management regime. As a rule, they consist of an upper layer of grafted *C. sativa* trees for fruit production and a semi-natural soil vegetation layer usually intended for hay production or as pastures for farm animals (Mariotti et al. 2019). Since the early Middle Ages, in the mountain areas of southern Europe, chestnut orchards have been a key staple food and environmental resource for local people (Conedera and Krebs 2008). In remote areas, orchards mostly consisted of a high number of different chestnut varieties selected according to their ecological needs, ripening period, and final use (fresh consumption, flour production, and forage for animals) to diversify the

production risks and maximise benefits. On the other hand, on the most productive sites and in the vicinity of city markets, chestnut orchards were rather populated of commercial high-quality varieties (*marroni* and *marroni*-like) as luxury product for seasonal markets and the nobility (see Piccioli 1922; Conedera et al. 2004; Squatriti 2013). The importance of chestnut orchards was so pervasive to suggest the name of "chestnut civilisation" to describe the society and daily life of such mountain chestnut areas, including the Apennines (Gabrielli 1994). Although with some transitory declines, the cultural and ecological legacy of this civilisation and the link between chestnut orchard cultivation and mountain people have survived for centuries, including a substantial persistence of both chestnut stands and their traditional fruit production. After World War II, however, the situation dramatically changed (Conedera and Krebs 2008). Apart from the population decline due to the war, an exodus towards the industrial cities of the plain caused a further decrease in the population and the younger working class almost completely disappeared in most of the chestnut mountain areas. Besides these aspects, the role of pathogens and new incoming pests influenced the vitality of the chestnut trees, significantly lowering the expectations and motivation of growers towards their cultivation. Particularly, the introduced chestnut blight (*Cryphonectria parasitica* [Murr.] Barr) showed a dramatic spread through the whole chestnut range in the 1950s (Biraghi 1946). Similarly, and although known since the beginning of the twentieth century (Marzocchi et al. 2024), the ink disease (*Phytophthora cambivora* [Petri] Buism.) experienced a recrudescence starting in the early 1990s (Vettraino et al. 2005), whereas the Asian chestnut gall wasp (*Dryocosmus kuriphilus* Yasumatsu) spread into the area in 2008 (Graziosi and Santi 2008) after its first detection in Europe at the beginning of the twenty-first century (Brussino et al. 2002). Despite this general declining trend, some positive signals became evident since the 1980s (Bagnaresi and Giannini 1984). The increasing demand for organic, traditional, and environmentally friendly products highly benefited the marketability of the chestnut fruits, starting from the high-quality *marroni* (e.g., Pezzi et al. 2017). In the following decades, this renaissance extended to the traditional chestnut flour and related innovative products derived (i.e., flavoured craft beers). Consequently, restoring initiatives of chestnut orchards started, which were additionally favoured by the onset, natural spread, and persistence of the chestnut blight hypovirulence (Biraghi 1953; Turchetti et al. 2008) and the effectiveness of the Asian chestnut gall wasp biological control by the introduction of its natural antagonist *Torymus sinensis* Kamijo (Quacchia et al. 2008). Moreover, the ink disease proved so far to have caused localised damage only, being probably counteracted by the soil biome complexity (Venice et al. 2021; Marzocchi et al. 2024).

However, the restoration activities and the management of the chestnut orchards generally suffer from the highly fragmented ownership conditions and the limited marketing potential of the traditional products. This makes the survival of this traditional habitat and landscape element highly dependent on the interest, personal passion, and family cultural heritage of local growers. As a result, present management of chestnut orchards is still rather scattered and very few young growers are willing to take over. A further risk factor is represented by climate change, which causes additional stress on the chestnut trees, thus reducing production, impacting their vitality, and threatening the functioning of the whole ecosystem (e.g., Conedera et al. 2010, 2021).

Managed chestnut orchards are known to support a notable diversity of plants, lichens, mosses, fungi, and animals owing to the contemporaneous presence of trees and open-spaced herbaceous vegetation (e.g., Arnaud et al. 1997; Gondard 2006; Obrist et al. 2011; Morelli et al. 2019). This justifies their inclusion in the list of habitats in need of conservation sensu the Council Directive 92/43/EEC (Natura 2000 code 9260—*Castanea sativa* woods) (Pezzi et al. 2020). In this context, ground vegetation is a key element in terms of habitat, shelter, and food source for the fauna, including various pollinator insects; in addition, it plays a key role in preventing soil erosion. Its current composition and shape are the result of the abandonment and restoring cycles as well as of the present management type and intensity.

Despite such a central role, very little is known about thoughts, feelings, beliefs, attitude, and overall awareness among chestnut growers about ground vegetation and related plant species. Furthermore, most growers are unwilling to take part in such investigations, as they view an unmown chestnut orchard as an obstacle to optimal management of chestnut trees and fruit harvesting.

The aim of this study is to know more on what chestnut growers think about the ground vegetation composition in traditional chestnut orchards. To this purpose, we set up semi-structured interviews among selected chestnut growers of the Bologna and Modena Apennines. In particular, we targeted the following detail questions:

(1)How many plant species are chestnut growers familiar with?

(2)Are any of these species protected or under conservation?

(3)Are they seen as more positive (e.g., aesthetic, nature conservation) or negative (e.g., management effort)?

(4)Does history and present orchard features influence the growers' perception on plant species?

(5)Does the grower's personality (shared beliefs and knowledge, competences, habits, etc.) influence their perception of the orchard flora?

2 Materials and methods

2.1 The study area

The study area (Fig. 1) is located in the chestnut belt between Bologna and Modena Apennines (centroid 44.2561645 N, 10.9453453 E), which extends from 300 to 1100 m a.s.l., thus spanning from the natural range of the deciduous *Quercus*-dominated forests to the *Fagus sylvatica* L. belt (Puppi et al. 2010). The tradition of the chestnut cultivation in this area dates to the Middle Ages but, similarly to other European chestnut-growing regions, experienced mixed fortunes during time as a function of the demographic and climatic fluctuations (Zagnoni 1997). The partial recovery waves starting from the mid-1980s did not counterbalance the drastic drop due to socio-economic evolution after WWII. As a result, of the 12,863-ha registered in the twentieth century, chestnut managed orchards currently only cover about 1641 ha.

Due to highly fragmented ownership, most chestnut orchards are small in size (less than 1 ha, see Pezzi et al. 2022) with highly variable structure and composition as function of ecological constraints (site conditions, such as substrate, slope, aspect, and elevation), past management history (time since and type of restoring), current management stand structure (e.g., canopy cover, age of the chestnut trees), and present biotic interactions (e.g., damage by pest and diseases, propagule pressure of potential vegetation). Orchards may also differ in terms of targeted product between mixed chestnut varieties (i.e., multi-variety structures with ancient local cultivars such as the *Pastonese*) and commercial luxury products basically consisting of a single *marroni* cultivar. For management purposes, the ground vegetation is usually mowed from one to three or more times per season, with the last action just before the fruit ripening to facilitate the chestnut harvest. Mowing has the additional long-term aim of preventing tree and shrub encroachment, whereas hay production or pasture is rare. As a result, most soil vegetation mainly consists of species related to grasslands (*Molino-Arrhenatheretea* Tüxen 1937 or *Festuco valesiacae-Brometea erecti* Br.-Bl. & Tüxen ex Br.-Bl. 1949), together with pre-forestry and fallow land woody species (*Laburno-Ostryion* Ubaldi

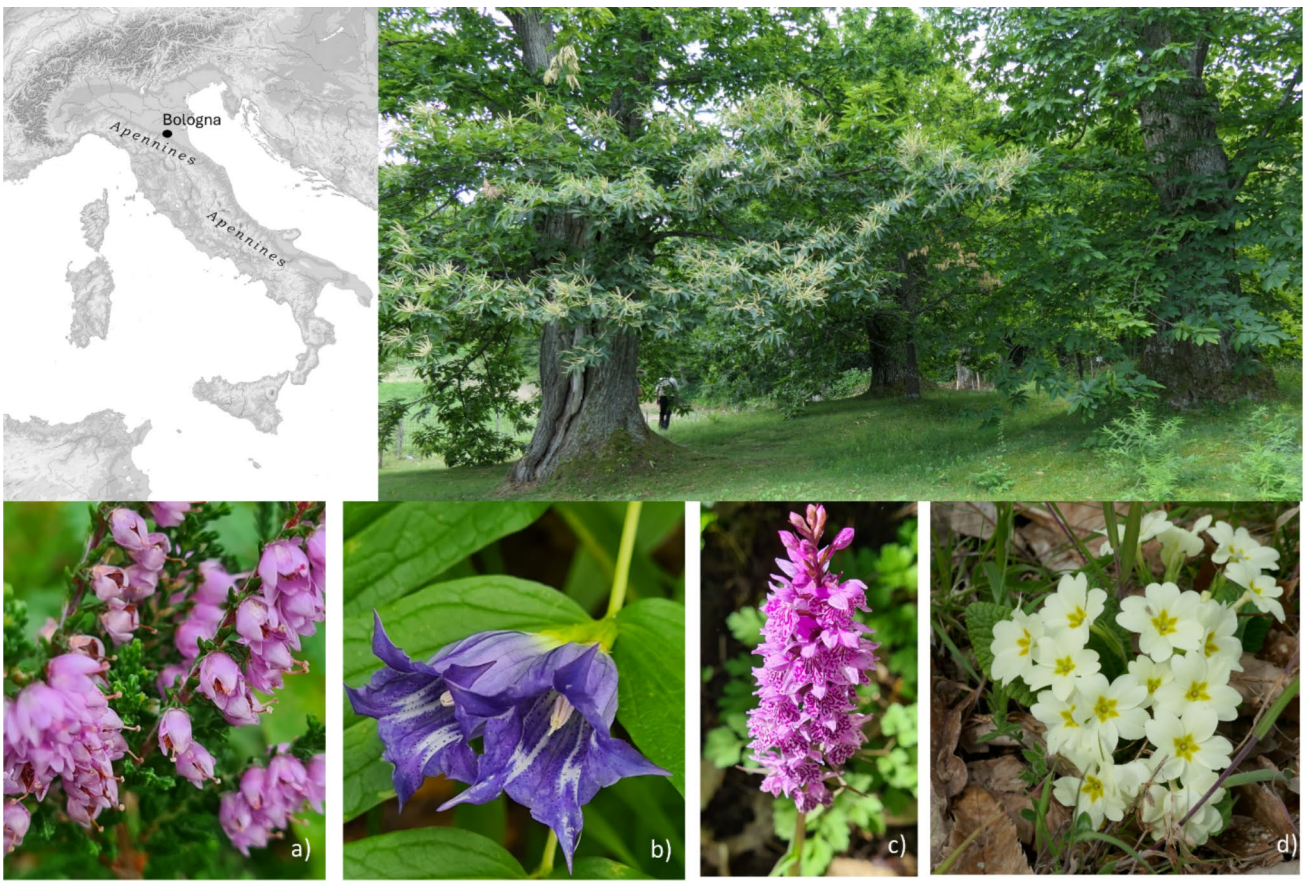


Fig. 1 Above: location of study area (centroid 44.2561645 N, 10.9453453 E) and view of a selected chestnut orchard. Below: examples of mentioned species: **a** *Calluna vulgaris* (L.) Hull; **b** *Gentiana asclepiadea* L.; **c** *Dactylorhiza maculata* (L.) Soó; **d** *Primula vulgaris* L

1980, *Erythronio dens-canis-Quercion petraeae* Ubaldi (1988) 1990 and/or *Fagetalia sylvaticae* Pawłowski in Pawłowski, Sokołowski & Wallisch 1928; see Pezzi et al. 2020).

2.2 Identifying and selecting participants

Conducting semi-structured interviews with the target person directly in the field is a very demanding and time-consuming task. This approach allows, however, to develop a participant-researcher dialogue based on a flexible interview protocol supplemented by follow-up questions and comments deeply delving into the issue. A key point of such study lies in the successful identification of respondents potentially providing the best information on the research questions. On the other hand, a common problem of such semi-structured interviews is given by the difficulty in motivating potential participants, as some individuals are hard to engage in conversation or may be reluctant to share sensitive or personal topics. As a result, the final number of interviews is usually low, which is, however, acceptable, because—unlike quantitative studies—statistical representativeness is not the goal in this kind of research (De Jonckheere & Vaughn 2019). In the study area, local growers are organised in three chestnut growers' associations consisting of 193 members in total, of which 15% are women (R. Panzacchi, D. Medici & S. Fogacci, personal communications).

We applied a snowball sampling approach, starting from the presidents of the local chestnut associations to get further access to potential participants willing to be interviewed. This way, additional potential participants were identified and encouraged to participate. Following this iterative referral "snowball effect" process, we managed to interview 38 chestnut growers.

2.3 Developing an interview guide

Before actually starting the interviews, we first prepared a protocol-blueprint, which we first tested by means of exploratory conversations with key informants (i.e., president of local associations) for obtaining a first picture of the local context and existing concerns. In a second step, we set up a preliminary interview guide and conducted test interviews with some available growers.

The final interview protocol consisted of four parts. In the first section, we collected basic socio-demographic and technical details about the growers (e.g., age, education, main job and experience in managing chestnut orchards, and specific role and responsibilities).

In the second part, we collected information about the selected chestnut orchard (e.g., historical background of the stand, age of the chestnut trees, time since last restoring—if any, target products and related varieties, and management habits of the understorey vegetation).

In the third part, the respondents were asked to list and describe the understorey plants they usually see in the stand, specifying whenever possible in which time of the year and for which reason they notice them. Subsequently, they were invited to assign to each cited plant species one or more of the following appreciations: "beautiful", "useful", "harmful", "requiring management effort", and "attractive/unattractive to animals". The only species whose presence we asked the respondents to recall in case of omission were orchids because of their high conservation interest as habitat quality indicators, as umbrella species safeguarding other species with the same habitat, and as flagship species attracting public awareness about conservation issues.

The last part of the interview concerned the general attitude of chestnut growers towards biodiversity and its perceived importance with respect to other ecosystem services (ES) provided by chestnut orchards, such as fruit production, protection against erosion and other gravitational hazards, tradition and cultural identity (i.e., cultural heritage), recreational activities, and tourism. To this purpose, the interviewed were asked to assign a score to each ES. The interviewees were also invited to give their opinion on the usefulness of being aware about biodiversity when managing their orchard and on the added value biodiversity may represent for their orchards. The last part also included very general questions such as the awareness about the existence of laws concerning biodiversity, their opinion about what a law on biodiversity should deal with, and the general needs to enhance the chestnut culture.

From a methodological point of view, the questionnaire consisted of close-ended answers and answers ordered on a 3-point Likert scale ("yes", "do not know", "no"). Only the scores attributed to different functions of chestnut orchards were measured along a 5-point Likert scale (e.g., very high, medium high, medium, medium low, and low) to allow for greater nuances. Open-ended answers were also present, and growers were further solicited to provide additional comments and feedbacks on missing relevant topics.

2.4 Conducting the interviews

To minimise the effort for the chestnut growers, the interviews took place face to face and directly in the field from July up to mid-October 2020, i.e., when most of them are in the orchards carrying out preparatory activities for the upcoming fruit harvesting season. Available growers owning or managing more than one orchard were asked to select the one they had more information about. All interviews were conducted during the same plant phenological period to guarantee data homogeneity and to facilitate both the memory of plants by the growers and their attribution to

a species, a species aggregate, or at least to a genus by the interviewer (a botanist). People who have no training in biology have a notably different concept of species from that of a professional botanist: the popular idea of species is something like an elementary unit which may be regarded as the smallest easily recognisable discontinuity in the wild based on macro-morphological characters, habitat, and type of use (Berlin et al. 1973). Therefore, the species concept is intended in an ethnobotanical sense (traditional pharmaceutical, food or economic/artisanal uses, legends correlated, etc.) and does not refer to the traditional morphological traits generally considered to define botanical species. As a result, interviewees tend to describe «ethnospecies» using vernacular names, which professional botanists need to convert into botanical species identified with scientific names (Penzig 1921; Lombardini et al. 2006; Signorini et al. 2007).

Interview duration was kept open to allow an interaction with particularly interested and responsive growers.

2.5 Data preparation

In Italy, people generally instinctively divide plant species into trees, shrubs, flowers (i.e., herbaceous species with showy flowering) and herbs (i.e., herbaceous species without flowers, at least apparently, such as Poaceae—cf. Parlatore 1848, vol I., p. 37 -, Cyperaceae, some Juncaceae etc.); the term '*pianta*' (plant) is used indifferently referring to trees (including grafted chestnut trees, as done by our interviewees), herbs, or vascular species in general (Chiusoli et al. 1983; Ferrari 1983).

To consider such a popular approach, whenever possible species were identified in the field (nomenclature follows Pignatti et al. 2017–2019). We then labelled the plants as herbs (He, including both 'flowers' and 'herbs') and different types of woody plants, i.e., trees (Tr), shrubs (Sh), and lianas (Li). Ferns and horsetails (Fe) were then distinguished from other herbs due to their habitus. Among herbs, we further separated species with showy blossom due to one or more of the following characters: impressive colour or shape of corolla; large flower size (arbitrarily set to single flowers with a mean diameter of 2–2.5 cm or more), high number of individuals in anthesis in a certain period, inflorescence with numerous small flowers with very colourful corollas, and orchids.

2.6 Data analysis

Collected data were anonymised and treated in an aggregate form to guarantee anonymity of the interviewees according to the European Union Regulation 2016/679 (general data protection regulation).

A χ^2 test ($\alpha = 0.05$) was performed to highlight differences among respondents in terms of socio-demographic characteristics (gender, age, level of education, retirement, and relevance of the different functions). Assigned plant attributes (i.e., beautiful, useful, harmful, requiring effort, good for animals, and others) by the chestnut growers have been statistically tested using contingency tables against different grouping variables (i.e., time since stand restoration, age of the respondent, and stand elevation) (Pearson 1904). The independence of each pair of variables has been tested using a χ^2 independence test (Pearson 1900). The grouping variables have themselves been cross tested for independence within each other using Fisher's exact test (Fischer 1935).

A Principal Component Analysis (PCA) was applied to explore relationships among growers' characteristics (age, school years, management experience), stand features (years since management, extent, altitude), and the number of cited plants (total number, orchids number).

All data analyses were carried out in the R free software environment (R—version 4.3.1, Development Core Team 2023. http://cran.r-project.org/), using the R-packages Vegan and Factoextra.

3 Results

3.1 The interviewed growers

We interviewed 38 growers, of which 79% (30) were men. The interview lasted on average 60 min with extreme values ranging from 30 min to 4 h.

Grower's ages range between 26 and 87 years (average: 61.6 ± 14.2). Only three of them were in their 20 s, whereas 63.2% (24) were above 60. About half of them (17) are retired. The women are younger compared to the men ($\alpha = 0.05$), and not one of them are retired. As to the level of education, 16 respondents had attended only elementary and middle school, 17 had attended high school, whilst 5 of them had a university degree.

All respondents are at the same time owners and managers of chestnut stands, except for five who are managers only. Management experience is highly variable ranging from 2 to 80 years (average: 24.6 ± 19.2). Most growers spontaneously list passion for chestnut cultivation and its related culture as their main motivation. As a result, most of them personally carry out not only regular and seasonal work, such as mowing, and fruit harvesting and post-harvesting treatments (90%), but also periodical specialised activities such as grafting (68.4%) and pruning (76.3%).

3.2 Selected chestnut orchards

The 38 selected chestnut orchards are very variable in size (between 0.1 and 5 ha, average = 1.4 ha ± 1.4 ha), lay

in an elevation range from 400 to 1000 m a.s.l. (average: 731.2 m ± 139.6 m), mostly facing north (N, NE, and NW), and on slopes between 0° and 45° (average: 25.7° ± 12.3°). The main product is equally subdivided between high-quality *marroni* and traditional chestnuts varieties. However, single *marroni* trees may be present in traditional chestnut orchards and single traditional chestnut varieties exist in *marroni* stands as well. Among the traditional varieties, the *Pastonese* for chestnut flour production prevails (28 out of 38 stands).

The history of uninterrupted orchard management spans between 3 years to more than a century (average: 47.1 ± 39.7), whereas 11 stands were managed for less than 15 years at the time of the interview. In 27 orchards (71.1%), we found centuries-old chestnut trees in variable numbers and irrespectively of possible periods of management suspension. Mowing is mostly carried out once a year (60.5%), in some cases twice (23.7%) or 3–5 times per year (15.8%). Except in five cases, the mowing residues are released in the chestnut stand. In about half ($n = 17$) of the orchards, leaves and burs are used as compost. Burning of vegetation debris is still practised in 13 stands.

3.3 Mentioned plant species

The interviewed chestnut growers provided 532 citations, although we could assign a precise taxonomic attribution for 516 only. In fact, for 16 plants, a precise identification was not possible, because the interviewees mentioned them with an ambiguous vernacular name, and/or the flowering period was preceding the interview, and/or no traces of a matching plant were found in the stand. These records were, therefore, excluded from the data analysis. Most of the 516 certified citations refer to herbaceous species (i.e., 294 records, corresponding to 56.8%), whereas 221 (42.8%) to woody ones, of which 112 are shrubs.

Vascular taxa cited and identified by the botanist were 140, although with differing taxonomic levels (online resource 1). Most of them were herbs (65.0%), of which 75.8% with a showy blossom, here included 16 orchid taxa and other species of regional conservation interest (Table 2). Graminoid species (i.e., Poaceae and Cyperaceae) are poorly discerned by growers.

Identified taxa per respondent varied from 1 to 36 (average 13.6 ± 8.6). Most chestnut growers (15) cited 10 taxa, seven up to 20 taxa, and three 30 taxa or more (Table 1). Species cited by only one grower prevailed (43%), whereas only 14 species were mentioned by more than a quarter of interviewees (Table 2) and the most cited ones were the fern *Pteridium aquilinum* (29 interviewees) and *Calluna vulgaris* (18).

As for orchids, 15 out of 38 respondents spontaneously mentioned this group of species (calling it simply orchids) during the interviews and 7 of them cited at least one of the species belonging to the family. Of the remaining 23 respondents who did not cite orchids spontaneously, six only mentioned at least one orchid upon request, whereas 17 confirmed to have never seen them or do not know how they look like or not to be interested in orchids. The most cited orchid was *Dactylorhiza maculata*.

Among the ecological functions attributed by the interviewees to the mentioned species, the attractiveness to pollinators prevailed, followed by the food provision to animals, and the role of the species to indicate or affect site conditions (Table 3).

Most plants are referred to as 'beautiful' (32.3%) followed by 'requiring management effort' (21.0%). Among the most cited species, *Pteridium aquilinum* (Fig. 2), the assessment 'requiring management effort' prevails (60.5%), followed by sometimes contrasting points of view (e.g., favouring the maintenance of soil humidity, characterising chestnut orchard flora, causing soil depletion, absorbing a lot of water, and not edible for animals). Among other frequently mentioned taxa, there are positive assessments ("beautiful" and "useful") for *Primula vulgaris*, *Trifolium* spp., *Solidago virgaurea,* and *Sorbus domestica*. Although the positive attributes prevail, *Calluna vulgaris* showed contrasting results. Cited positive characteristics refer to how it looks, the ability to easily resprout after mowing, to keep other weeds away, to act as attraction and nutrition for bees, to enable edible fungi to grow underneath, and to generally be an overall positive indicator for chestnut orchards. Negative counterbalancing statements were the tendency to dominate the ground vegetation, creating a soft coat, acidifying the soil, and being difficult to eradicate (except by wild boar). Concerning mowing, some growers complain that *Calluna vulgaris* makes mowing more difficult, whilst others disagree. Similarly, both positive and negative mentions are reported for *Rubus* spp. and *Robinia pseudoacacia*. Finally, negative assessments (i.e., 'harmful' and 'requiring management effort') are reported for *Populus tremula*. Interestingly, the use of the terms 'useful' and 'requiring effort' is definitely way more frequent among interviewees managing recently restored orchards (i.e. ≤ 15 years), whereas older growers (> 70 years) seem less sensitive to aesthetic or ecological roles for animals or for the cited plants (see online resource 2).

Finally, several traditional uses were also attributed to 26 out of 140 species (Table 4). Beside vascular plants, bryophytes were also cited in about half of the cases (but never with terms different from the generic *muschio*—moss, in English) and several positive aspects (as food in particular) were attributed to them (see online resource 1).

The PCA (Fig. 3 and online resource 3; PC1 32.0%; PC2 21.3%) show that the number of species mentioned (as well as the number of orchids) is positively correlated

Table 1 Main characteristics of the interviewed chestnut growers ($N=38$) and the 38 selected chestnut orchards

Category	Question	Answer	N
Demographic data	*Gender*	*Female*	8
		Male	30
	Age	*26–59*	14
		60–69	15
		70–87	9
	Education	*Primary/secondary school*	14
		High school	19
		University	5
	Management experience	*2–20*	22
		21–35	7
		36–80	9
	Management responsibilities	*Owner/manager*	33
		Manager	5
	Grower type	*Farmer*	20
		Hobbyist	18
Chestnut orchard characteristics	*Area (ha)*	*0.1–1.0*	19
		1.1–3.0	15
		3.1–5.5	4
	Altitudinal range (m)	*400–749*	17
		750–1000	21
	Management purpose	*Nut*	19
		Marroni	19
	Managed since	*≤ 15*	11
		16–45	10
		46–170	17
	Mowing frequency (per year)	*1*	24
		2	10
		3+	4
	Mowing month	*AMJ*	13
		JASO	49

Table 2 Cited taxa by chestnut growers: most cited species (more than 25% of interviewees), orchids, and other species of conservation interest. Tr: trees; Sh: shrubs; Fe: ferns and horsetails; He: herbs

Group	Plant list
Most cited plant species	**Tr:** *Quercus pubescens* Willd., *Populus tremula* L., *Prunus avium* (L.) L., *Sorbus domestica* L., *Robinia pseudoacacia* L.; **Sh:** *Calluna vulgaris* (L.) Hull, *Rubus* spp. (i.e. *Rubus ulmifolius* Schott, *R. hirtus* Waldst. & Kit. group); **He:** *Primula vulgaris* Huds., *Solidago virgaurea* L., *Trifolium* spp., Poaceae; **Fe:** *Pteridium aquilinum* (L.) Kuhn
Orchids	**He:** *Anacamptis morio* (L.) R.M. Bateman, Pridgeon et M.W. Chase, *A. pyramidalis* (L.) Rich., *Cephalanthera rubr*a (L.) Rich., *Dactylorhiza maculata* (L.) Soó, *D. sambucina* (L.) Soó, *Epipactis helleborine* (L.) Crantz, *Gymnadenia conopsea* (L.) R. Br., *Himantoglossum adriaticum* H. Baumann, *Listera ovata* (L.) R. Br., *Ophrys* spp., *Orchis provincialis* Balb. ex Lam. et DC., *O. purpurea* Huds., *O. simia* Lam., *Platanthera* spp. (*P. bifolia* (L.) Rich. and *P. chlorantha* (Custer) Rchb.), *Serapias* spp.
Other species of conservation interest	**He:** *Aquilegia dumeticola* Jord., *Crocus neglectus* Peruzzi et Carta, *Dianthus* spp. (*D. armeria* L., *D. balbisii* Ser., *D. carthusianorum* L., *D. seguieri* L.), *Dianthus monspessulanu*s L., *Gentiana acaulis* L., *G. asclepiadea* L., *Leucojum vernum* L.

Table 3 Ecological functions attributed by the interviewees to the understorey plant species of chestnut orchards

Function	Species
Indicating or affecting site conditions	*Calluna vulgaris* (L.) Hull [27]; *Carex pendula* Huds. [04]; *Cichorium intybus* L. [24, 32]; *Colchicum lusitanum* Schott [18]; *Crocus neglectus* Peruzzi et Carta [25]; *Cyclamen hederifolium* Aiton [31]; *Equisetum telmateia* Ehrh. [01, 03, 04]; *Onobrychis viciifolia* Scop. [06]; Poaceae [38]; *Populus tremula* L. [09, 33]; *Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum* [01, 02, 17, 18, 27, 28]; *Salix caprea* L. [01]; *Urtica dioica* L. subsp. *dioica* [18]; *Trifolium* spp. [10] Mosses [18, 20, 30]
Structuring or affecting the species composition	*Calluna vulgaris* (L.) Hull [19, 27, 32, 36]; *Cuscuta epithymum* (L.) L. [01]; *Hedera helix* L. [04]; *Populus tremula* L. [09; 24, 31, 33]; *Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum* [18, 36]; *Robinia pseudoacacia* L. [03, 04, 18] Mosses [33, 36]
Food provision to animals (bulbs, fruits, forage)	*Astragalus glycyphyllos* L. [09]; *Carlina acaulis* L. subsp. *caulescens* (Lam.) Schübl. et G. Martens [23]; *Cirsium vulgare* L. [29]; *Corylus avellana* L. [29, 32]; *Crataegus monogyna* Jacq. [03, 27]; *Fragaria vesca* L. [18]; *Hedera helix* L. [18]; *Juniperus communis* L. [27]; *Lilium bulbiferum* L. subsp. *croceum* (Chaix) Jan [18, 27]; *Lilium martagon* L. [27]; *Lotus corniculatus* L. [15]; Poaceae [18]; *Prunus avium* (L.) L. [32]; *Sambucus ebulus* L. [03: cows]; *Sorbus domestica* L. [29]; *Trifolium* spp. [10]; *Vicia* spp. [03]
Shelter (animal)	*Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum* [02, 16]; *Rubus* spp. [19]
Attractiveness to pollinators (*)	*Calluna vulgaris* (L.) Hull [01, 28]; *Cyanus segetum* Hill [04]; *Cytisus scoparius* (L.) Link [01]; *Dianthus* spp. [01, 17]; *Erica arborea* L. [01]; *Equisetum telmateia* Ehrh. [01]; *Eupatorium cannabinum* L. [22]; *Fraxinus ornus* L. [34]; *Genista* spp. [34]; *Lavandula angustifolia* Mill. [28]; *Ononis spinosa* L. [28]; *Prunus avium* (L.) L. [05, 19], *Ranunculus* spp. [10]; *Robinia pseudoacacia* L. [05]; *Rubus* spp. [04]; *Solidago virgaurea* L. [29]; *Trifolium* spp. [10, 15, 17]; *Vicia* spp. [17]
Species under which edible fungi usually grow	*Calluna vulgaris* (L.) Hull [01, 32, 36, 37]; *Erica arborea* L. [01]; *Genista* spp. [31]; *Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum* [01, 29] Mosses [02]

In square brackets, interviewee codes. For further details, see online resource 1

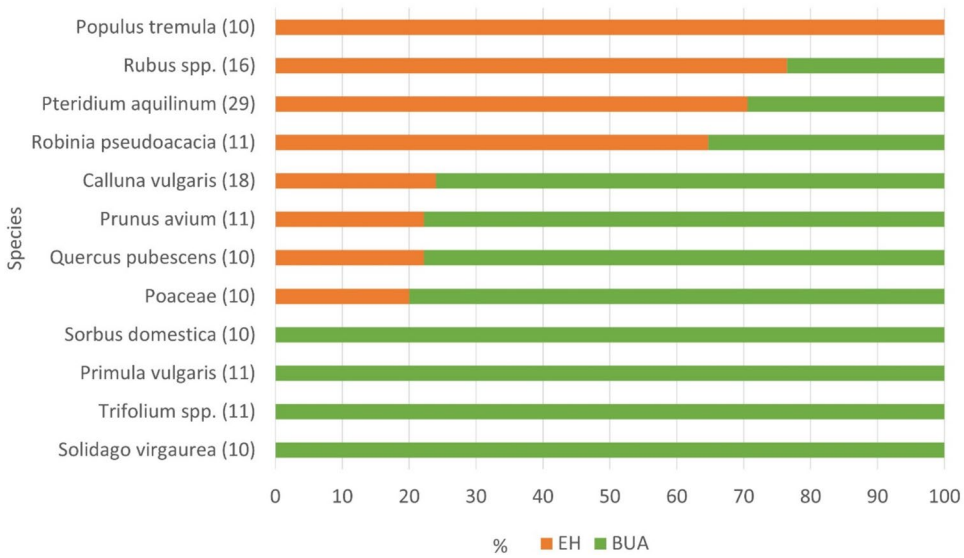


Fig. 2 Perceived attributes for the most cited species. *BUA* Percentage of counts for Beautiful, Useful and Attractive to animals' opinions, *EH* Percentage of counts for requiring management effort and Harmful opinions

Table 4 Traditional uses of the plants cited by chestnut growers

Species	Uses
Carlina acaulis L. subsp. *caulescens* (Lam.) Schübl. et G. Martens	OUI: flowers to adorn holy shrines [15]; flowers for weather forecast (if it closes it is going to rain) [23]
Cistus salvifolius L.	COSM: to make essential oils [34]
Clematis vitalba L.	FOOD: shoots eaten [09]
Cytisus scoparius (L.) Link	DOM: for tying graft [09]; for making bundles for fire [36]; for making brooms (it. *granate*) [36]
Dianthus spp.	FOOD: to eat [23]
Dryopteris filix-mas (L.) Schott	DOM: aerial part put in the basket, where strawberries are put (to protect it) [06]
Equisetum telmateia Ehrh.	MED: for medicinal functions [09]
Erica arborea L.	DOM: to make brooms (it. *granate*) [36]; to light the fire [36]
Fragaria vesca L.	FOOD: fruits to eat [09, 18, 19, 29, 34], to make strawberry liqueur [09]
Gentiana asclepiadea L.	FOOD to make liqueur [06] MED: root liqueur aids digestion [06]; root boiling water against fever; as penicillin [13]; root infusions for varicose veins [14]
Hedera helix L.	FOOD: solid honey production [04]
Hypericum perforatum L.	MED: medicinal functions [17, 21]
Lotus corniculatus L.	AGROPA: to feed sheep
Mentha spp.	FOOD: to make tea [05]; to make mojito [05]
Mespilus germanica L.	FOOD: fruits [02, 17, 28]; CRAFT: wood for handles [03]
Polypodium vulgare L.	FOOD: roots eaten [12, 22, 24], liquorice-like taste [12,22,24]
Primula vulgaris Huds.	FOOD: flower and leaves (when tender) eaten [03]; OUI: corolla detached from the calyx and whistles if placed between the lips [09]
Prunus avium (L.) L.	FOOD: Fruit [09]
Pteridium aquilinum (L.) Kuhn subsp. *aquilinum*	AGROPA: It was used to make beds for cows [28], and sheep [36]
Robinia pseudoacacia L.	FOOD: Flowers [03]
Rosa spp.	FOOD: Fruit: high amount of ascorbic acid [19]
Sorbus domestica L.	FOOD: fruits [05, 27, 28]; CRAFT: from wood a mallet (it. *mazzetto*) was made to carve wood [34]
Taraxacum gr. *officinale* Weber	FOOD: leaves [04, 21]
Urtica dioica L. subsp. *dioica*	FOOD: green tip for food purposes [04], to make pasta [23] and noodles [31]
Vaccinium myrtillus L.	FOOD: Fruit [20]

The traditional uses have been referred to the following categories according to Chiocchio et al. (2024): *COSM* cosmetic, *CRAFT* craft, *DOM* domestic, *FOOD* food, *GAME* games, *MED* medicinal, *TOXIC* toxic, *OUI* other uses. The respondent code is reported in brackets

with an increasing education level of the growers and negatively correlated with their age. In turn, grower's age is positively correlated with management experience and managing duration of the stand. Finally, the number of cited species is independent from canopy cover and stand features (extent, slope, and elevation).

3.4 Biodiversity and other ES outlook

As reported in Fig. 4, the highest scores (very high and high) were attributed to the cultural heritage (63%) with 50% of the interviewees attributing a very high importance to this ES. Further, there is a balance between highest score and medium-to-low scores for production, whereas the highest scores are shared by both *marroni* orchards and multivariate orchards. Medium-to-low scores prevail for tourism and recreation (90%) and protection (73%). It should be noted that half of interviewees attributed the score "very low" to tourism and recreation.

As for biodiversity, only three respondents attributed the score "very high", whereas medium-to-low scores prevailed (60%). In any case, on average, the values of biodiversity scores for women are higher than for men. Nevertheless, about 80% of the growers considered knowing biodiversity important (it would be useful") and thought biodiversity is an advantage for chestnut orchards (online resource 4). However, difficulties emerge according to the growers on the necessity to become passionate and trained on plant knowledge in chestnut orchards. As pointed out by one respondent, "the chestnut orchard has a high biodiversity, which is greater in a cultivated stand than in abandoned ones,

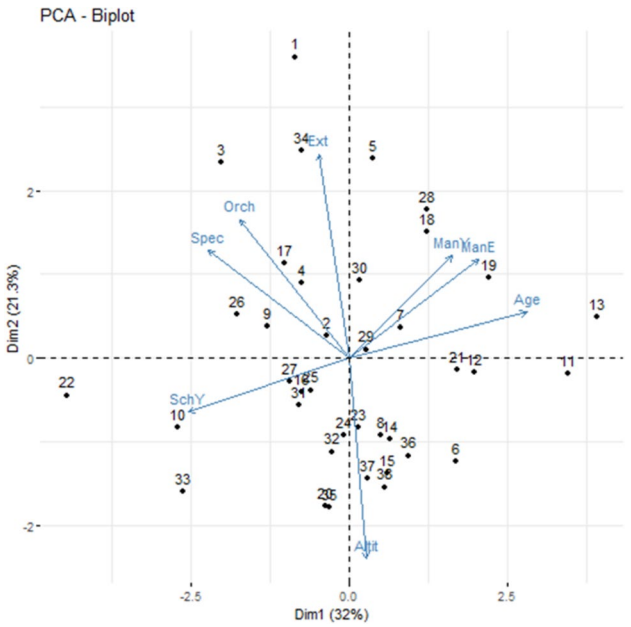


Fig. 3 PCA plot showing the relationship among growers, chestnut stand, and mentioned species. *Age* grower's age, *Altit* stand altitude (m), *Ext* stand extent (ha), *ManE* grower management experience (years), *ManY* stand years since management, *Orch* number of orchids cited by a grower, *SchY* grower's school years, *Spec* number of species mentioned by a grower

especially at the herbaceous level" [09]. The advantages provided by biodiversity to chestnut stands and reported by growers are highly diversified and span from aesthetic to functional value (see online resource 3 for the complete list of comments). Here, just few examples: "a chestnut orchard without a nice meadow doesn't say much" [15]; "the more plants there are in the undergrowth, the more they protect the chestnut roots" [02]; "understorey plants create a meadow. They prevent the rainwater to drain" [15]; plants are "useful from a phytosanitary viewpoint. Strawberry trees, on the other hand, are useful from a production viewpoint" [33]; understorey vegetation layer "is an inconvenience from a production viewpoint, but in the long term it is positive" [22]; plants "keep the soil cooler" [31]; "the chestnut orchard works best" [38].

When considering biodiversity-related legislations, only 23.6% of the interviewees were aware of their existence and the percentage of respondents who know a law or know what a biodiversity law looks like is the same. However, apart from a few respondents, most have a precise opinion regarding what a biodiversity law should deal with: land conservation [05], plant protection [10, 23], support farmers [26], education, and communication [22]. In any case, respondents think that: laws should be made according to territory specificity [02, 25]; there are laws, but the application sometimes fails [16]; clear rules are necessary [23]; involvement of stakeholders is needed [02]. See online resource 5 for further comments.

3.5 What would be needed and what could be done to spread chestnut culture?

Chestnut culture and cultivation (online resource 6) is referred to as a personal vocation [03], which needs passion [13] being a not profitable business [03]. It is a niche

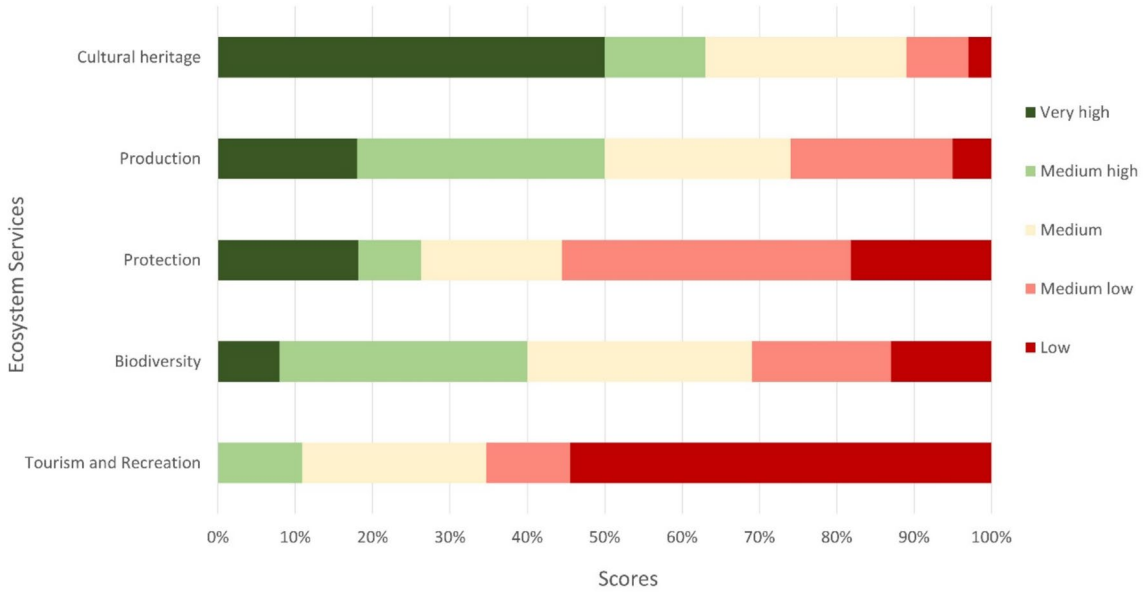


Fig. 4 Ecosystem services as perceived by chestnut growers

cultivation and a niche fruit, limited in terms of both territory and seasonality [20]. However, the chestnut orchard is the life of the mountain people and their history [23]. The chestnut tree has secrets [30], and its cultivation is not an easy thing [19].

According to the growers, major needs for preserving and enhancing the chestnut culture are:

- to make the chestnut culture better known and publicised [e.g., 02, 02, 06, 08, 26];
- to involve more people, especially younger generations (students who get their hands dirty), and with passion [e.g., 03, 13, 14, 33, 34];
- to move from abandoned land to designated agricultural/land/forest/natural heritage [e.g.,02];
- that growers pass on their personal experiences [e.g., 34].

Several responses emphasise the need of educational training for chestnut growers and of a revised legislation: "not too many laws, trees do not know politics" [05]; but few targeted rules that provide incentives for the recovery and maintenance of a traditional chestnut orchards, also for hobbyists.

Some key words emerge, such as education, production, forest-nature-agri-food, research, awareness, food possibilities, and support policies [09].

4 Discussion

4.1 Understorey vegetation

The growers interviewed show difficulties in fully perceiving biodiversity. The growers' knowledge of plant species is in line with the low value they place on biodiversity in relation to other functions of chestnut orchards (in particular "cultural heritage") and their level of perception is negatively related to the increasing age of the growers. In any case, people who do not care about biodiversity (in this case all but the chestnut trees) are very rare: opinions like «Ground plants must all be removed» or «only chestnut trees should be in the chestnut orchard» are very rare. As a result, only three growers indicated to us more than 30 understorey plant species. However, with 38 interviews, 140 "ethnospecies" were mentioned, which are commonly found in the northern Apennines and on acid soils (Puppi et al. 2010).

The repeated citation of *Pteridium aquilinum* in relation to management efforts (80% of respondents) is not surprising. This species is widespread over large areas of all continents (except Antarctica) and is particularly common in chestnut-dominated formations (Fenaroli 1945; Arrigoni & Viciani 2001; Zaccone et al. 2014; Pignatti et al. 2017–2019). In fact, this species is found in acidic or subacidic soils with moderate soil moisture. It is characterised by an extensive rhizome system, a high cover capacity during the vegetation season, and an accumulation of litter rich in allelopathic compounds making it 'over-dominant' in case of prolonged depleting exploitation or fire. These factors influence species composition of habitats and consequently displace plant communities of much higher conservation value. As a result, it also causes problems for nature conservation and livestock. As noted by other authors (Alday et al. 2023; Ghorbani et al. 2025), in some cases, our respondents also reported positive benefits for the species (e.g., aesthetic value or provision of shelter for animals).

Furthermore, *Robinia pseudoacacia* is linked to management effort. In fact, chestnut-dominated stands are under pressure from this invasive non-native species, which easily colonises open forest stands thanks to its pioneer character (Lazzaro et al. 2020; Campagnaro et al. 2023). However, many positive values were reported also to our respondents due to its flowers and its melliferous value.

Similar appreciations linked to the management effort concerned *Populus tremula*, a boreal species with a vast Eurasian range (up to North Africa) often growing on soils with pH values ranging from 3.7 to 6.4 and with a strategy to tolerate aluminium, frequent element in acid soils (Böhlenius et al. 2018). The species colonises open landscapes thanks to its high ability to form root suckers and often acts as a pioneer invader of chestnut orchards (see Pignatti et al. 2017–2019).

Regarding the shrub *Calluna vulgaris* positive aspects prevails on management effort and comments of grower's indicate the strong relationship among the growers and the species with the chestnut (Fenaroli 1945).

As to herbaceous Angiospermae, many mentioned species were those producing showy flowers with a particular aesthetic aspect (which sometimes the growers even preserve from mowing). The case of *Primula vulgaris* serves to illustrate this point. In spring, this species forms a monochrome carpet of yellow beneath the chestnut canopy, thereby conferring a high aesthetic value upon the orchard. An additional example is that of *Solidago virgaurea*, which flowers from August to September, precisely at the time of mowing activities.

In the case of species of conservation interest, all have large flowers or showy inflorescences, as for example, *Gentiana asclepiadea*, for which also traditional uses were cited.

About half of the growers cited orchids and 16 species were mentioned. The most cited (*Dactylorhiza maculata*) displays a typical stained leaf (*maculata*) and is widespread in chestnut orchards (as well as in European mountains). Not surprisingly, the unobtrusive graminoid species (i.e., Poaceae and Cyperaceae) are poorly discerned by growers, further highlighting the importance of considering also

human emotional perception when engaging people on conservation issues (Tribot et al. 2018).

In line with the high value attributed by growers to cultural heritage, several traditional uses already cited by other authors emerged (e.g., Ungarelli 1921; Dente and Mariotti 2014; Chiocchio et al. 2024).

Interestingly, there is a recognition among chestnut growers of the different post-mowing reactions of the ground vegetation. Whilst some plants copiously regenerate after management, others weaken and disappear over time because of mowing.

Finally, sometimes, growers would like to have a deeper knowledge of biodiversity (flowers, essentially), intended as a potential source of good health for the chestnut orchard microcosm (a sort of ecological vision, we could say, even if not formalised and not framed in an academic formation).

4.2 The growers

The interviewed chestnut growers' age and culture vary considerably, but most of them were men over 60 (chestnut orchard management is a field historically dominated by men). The interviewees have a very varied but also very long experience of chestnut cultivation and their susceptibility with respect to the vegetation and its diversity may vary with age (especially in the case of senior growers above 70) and the management history of the concerned orchard (recently restored stands vs. continuously managed ones). One noteworthy example is an 86-year-old interviewee who has managed an orchard for 80 years. His deep connection with the chestnut orchard and its associated culture began during his childhood. This shows a clear example of intangible cultural heritage, as defined by the UNESCO Convention, and suggests considering the potential role of chestnut orchards in reducing the nature-deficit disorder in new generations (i.e., children: Louv 2008; Driessnack 2009). In this respect, *Castanea sativa* may become an 'experimental key (plant) species' for children (see Battisti 2016) together with chestnut orchard habitat. According to many growers, the component of well-being (the so-called cultural ES) associated with the management and even simple frequentation of chestnut groves has a very high importance. This is accompanied by a common trait among growers, i.e., the deep passion for their work, which is, in various cases, the only reason to maintain a traditional form of agriculture that is no longer able to guarantee a steady source of income. A frequent complaint in this respect is in fact the lack of appropriate financial support from government institutions. Italian subventions for agriculture are reserved to much more widespread and more profitable cultures, whereas the chestnut cultivation seems to be only supported by the passion of single growers, or the continuation of a family or local tradition (Pezzi et al. 2017). In this sense, in various growers, one can perceive a notable sense of belonging to the local community and a profound knowledge of their territory, especially of the chestnut orchard, which is regarded as a sort of microcosm populated by numerous living beings that are not easy to know and identify. «Make people fall in love with chestnut orchards», many say to propose a way to encourage the recovery of this culture, because «the chestnut tree has secrets» that must be known if one wants to cultivate it effectively. Although older growers complain about the low number of young people in this niche cultivation, the number of "new growers" and the presence of women in the group of managers indicate a possible new potential for maintaining and possibly increasing the area under cultivation.

4.3 The effectiveness of socio-ecological research

The adopted method, consisting of a face-to-face dialogue with a flexible interview protocol and carried out directly in the chestnut orchard, confirmed to bring several advantages. It enables the interviewer to support the growers' memory of the plants, to proceed to direct plant identification, and to deepen subjects of interest on need. As is normal in such socio-ecological qualitative research, the number of participants remains usually limited (e.g., Muratet et al. 2015; Colvin et al. 2016; De Jonckheere and Vaughn 2019; Bardsley et al. 2023). In addition, if the number of participants is higher, the sample of respondents may be biased, as only interested people take part in the survey (Thiemann et al. 2022). In our case, many growers are reluctant to take a part in the discussion of such a topic for several reasons: their interest is focused mainly on the chestnut tree (the plant *par excellence*) and an unmown chestnut orchard is considered "dirty". From this point of view, the help of the gatekeepers in contacting the growers was essential. Anyway, the survey allowed to cover the whole age range of chestnut growers and consider a representative choice of chestnut orchards in terms of altitude range and management purpose (multivariate vs. monovarietal) within the chestnut belt in this part of the Apennines.

This allowed us to partially contribute to fill the lack of research that explores in depth people's perceptions of biodiversity at the taxa level and their attitudes towards biodiversity (Muratet et al. 2015).

5 Conclusions

Overall, the interviewed chestnut growers confirmed to be aware of the multifunctionality of the chestnut orchards (with cultural services having a central role in this agroecosystem: e.g., cultural heritage, local knowledge and other forms of historical legacy, sense of attachment to the cultivation, and sense of identity). Furthermore, even if

growers do not fully understand it, they are also aware of the existence of a complex biodiversity linking the numerous taxonomic groups present in the chestnut orchard (vascular plants, bryophytes, fungi, insects, ungulates, etc.) with each other, with the management practises, and eventually to the stand structure and the provided ecosystem services. This implies the need to better inform chestnut growers about the different aspects of biodiversity (including legislation protecting biodiversity) and to create a common knowledge base among managers. From a policy point of view, biodiversity should be considered as an additional asset for the conservation of this very specific agroforestry ecosystem, placing the growers as custodians of these habitats where the link between man and the ecosystem is particularly strong. Efforts to increase knowledge of biodiversity among chestnut growers (e.g., through training courses) must be made in collaboration with associations of existing chestnut growers, with growers who are more interested in biodiversity and who, given the passion that motivates them, can be promoters of knowledge among other growers. Finally, biodiversity could be used to support the recovery of chestnut cultivation, together with a new set of tangible and intangible assets (landscape, land management, flour, nuts, *marroni*, young people, and women's work). This would be an additional added value consisting of engaging growers in biodiversity improvement and conservation.

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Author contributions G.P. ideated the project. G.P., Gi.M., and F.F. contributed to the study conception and design. G.P. contacted the interviewees and conducted the interviews in the field. Gl.M. performed data preparation. M.C. and F.B. critically read, amended, and commented manuscript, contributing validly to data interpretation. All the authors approved the final version of the manuscript.

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Data availability Due to human ethical reasons, the dataset derived from the current research is not publicly available, but is available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare no competing interests.

Ethics approval Not applicable

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