# Decline and restoration of a typical silvo-pastoral mountain landscape in the Italian Apennines. The case of Moscheta in Tuscany

Beatrice Fiore [*], Francesco Piras, Antonio Santoro

*Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, via San Bonaventura 13, 50145 Florence Italy*

ARTICLE INFO

ABSTRACT

Mountain cultural landscapes of southern Europe have been affected during the 20th century by significant land use changes, due to depopulation and abandonment of traditional agro-silvo-pastoral practices. In addition, the cessation of traditional forest management led to a homogenization of forest structures and to the loss of habitats. Italy is one of the European countries most affected by the consequences of depopulation of mountain areas. Moscheta is located in the Italian Apennines, in Tuscany, and its economy has been based for centuries on forests (for timber, firewood, charcoal, and chestnuts to produce flour) and livestock. The aim of the paper is to analyze the land use changes occurred in a typical forest mountain landscape of southern Europe in the last 191 years, and to describe the characteristics and the results of the Forest Landscape Restoration project recently implemented. The methodology is based on GIS-based spatial analyses comparing the landscape of 1832, 2013 and 2023. In the period 1832–2013, 45% of the total surface was affected by forestation (average rate of 1.9 ha/year) mainly due to the abandonment of pastures and wooded pastures, but also to direct conifer afforestation. Chestnut groves were abandoned as they were no more economically interesting. From the 2010s, a Forest Landscape Restoration (FLR) project was implemented considering the economical, technical and future management feasibility. It focused on recovering the monumental chestnut groves and the wooded pastures, but also on interventions to increase the touristic attractiveness (paths management, Historical Landscape Museum creation, traditional buildings for chestnut drying restoration). The area was also inscribed in 2016 in the National list of Historical Rural Landscape established by the Italian Ministry of Agriculture. The analyses of the 2013–2023 landscape changes demonstrated that 4 ha of historical chestnut groves and 6.5 ha of wooded pastures have been recently restored, bringing their total surface to 17 ha and to 67 ha, respectively. In addition, results demonstrate that forestation completely stopped in the last 10 years. Other interventions are planned for the future: maintenance of chestnut groves, rehabilitation of other wooded pastures, re-introduction of the traditional practice of pollarding on ten beech trees. This study represents the first assessment of the FLR carried out in Moscheta, and demonstrates that the restoration of open spaces and of cultural forests is possible and could have a big impact on mountain cultural landscapes, contributing to the preservation and enhancement of ecosystem services and of touristic attractiveness, with potential direct benefits on the local economy.

## 1. Introduction

Mountain cultural landscapes provide different goods and ecosystem services, not only to the people living in the mountains but also to the ones living outside mountains (Grêt-Regamey et al., 2012). Mountain ecosystems are in fact crucial for freshwater regulation and water storage and purification, and the abandonment of traditional agro-silvo-pastoral activities in mountain areas can favor floods and hydrogeological problems in the valley bottoms or in the plains (Nadal-Romero et al., 2021). In addition, mountain rural areas are often characterized by high levels of biodiversity and agrobiodiversity (Marchant Santiago, 2023; Foggin et al., 2018), and they represent well-known destinations for rural tourism and recreation activities (Sgroi, 2020; Abellán and García Martínez, 2021; Mele and Egberts, 2023). At the same time, cultural landscapes located in European mountainous areas are probably the landscape typology that have been mostly affected by land use changes in the last century. Rapid depopulation and the abandonment of traditional agro-silvo-pastoral practices

---

have caused significant land use changes, with the loss of important cultural landscapes, of associated traditional knowledge and agro-biodiversity, but also with negative impact on different ecosystem services (Körner, 2000; Faccioni et al., 2019; Sil et al., 2019).

The main change in mountain cultural landscapes is related to the loss of pastures and cultivations with consequent increase of forest surfaces (Anselmetto et al., 2024; Ameztegui et al., 2021; Bebi et al., 2017), that combined with the abandonment of traditional forest management, led to a homogenization of forest structures (species composition, density, vertical and horizontal structures) and to the loss of habitats and of biodiversity at the landscape scale (Agnoletti et al., 2022). The loss of traditional forest management has also negative consequences for the local identity and for sustainable forest management; according to Parrotta et al. (2016), in fact, forest management practices based on traditional ecological knowledge (shifting cultivation, agroforestry systems, management of forests for non-wood forest products) are crucial to preserve forest landscapes, provide food and materials as well as ecosystem services, without jeopardizing the biodiversity and the functional integrity of forests.

The importance of traditional forest management and of mountainous cultural landscapes is also recognized by the largest program of the United Nations specifically aimed at the protection of traditional agro-silvo-pastoral systems, the GIAHS (Globally Important Agricultural Heritage Systems) Programme established by the Food and Agriculture Organization (FAO). This FAO Programme, that today accounts 86 systems in 26 countries, focuses on the identification and protection of agro-silvo-pastoral sites and on the application of dynamic conservation principles to promote their sustainable development and, at the same time, for maintaining traditional landscapes, agrobiodiversity, traditional ecological knowledge, cultural and social values (Koohafkan and Altieri, 2011). Among the sites inscribed in the GIAHS Programme, forests and agroforestry systems have a crucial role, providing timber, fuelwood and non-wood forest products according to sustainable and traditional management practices, contributing to hydrogeological protection, water regulation and biodiversity conservation (Santoro et al., 2020). These forests, managed through the application of traditional techniques for centuries, can be considered cultural forests, and their current characteristics in terms of species composition, tree density, vertical and horizontal structures, are the result of human interventions that can be also effective for the preservation of the ecological value and not only of the cultural ones (Piras et al., 2022).

Considering that 35% of the Italian terrestrial surface is classified as mountain, Italy represent one of the European countries most affected by the consequences of depopulation of rural areas during the 20th century (Amodio, 2022). The economy of the Italian Apennine Mountain range has been based for centuries on the integration of forest, livestock and small cultivations. Forests provided timber, firewood, charcoal, and fruits (especially chestnuts used to produce flour); livestock provided proteins and was based on seasonal transhumance, while cultivations were limited to few suitable areas. Moscheta, in Tuscany, represents a typical mountain cultural landscape, resulting from the aforementioned activities that shaped the local environment according to the needs of the local population. Despite the abandonment process occurred in the last century, the area still preserves an important cultural landscape, that was recently the subject of a forest landscape restoration project. The term Forest Landscape Restoration (FLR) was initially coined in 2000 at a workshop in Segovia (Spain) organized by WWF and IUCN (Mansourian, 2021) and in the last decade has received a lot of interest by researchers and public administrations, as a way to re-establish cultural landscapes and ecosystem services related to forests, but also as a way to differentiate the local economy of mountain areas (i.e. increasing rural tourism) and to strengthen the local cultural identity (Lake et al., 2018; Mansourian et al., 2020; César et al., 2020).

The aim of the paper is to analyze the land use changes occurred in a typical forest mountain landscape of southern Europe in the last 191 years, and to describe the characteristics of the Forest Landscape Restoration project carried out and its results, evaluating its effectiveness and the possibility to replicate this type of FLR project in similar forest mountain landscapes.

## 2. Materials and methods

### 2.1. Study area

The study area of Moscheta extends for about 750 ha in the municipality of Firenzuola, in the Apennines mountains (Fig. 1). The average altitude is around 700 m a.s.l., while the highest altitude is reached by Monte Acuto with its 1040 m a.s.l. and the lowest one corresponds to Molino di Moscheta (550 m a.s.l.). The climate is of the Mediterranean-submountain type with very limited summer aridity.

Moscheta features the typical forest mountain landscape of the Apennines, characterized by a rugged morphology and a dense forest interspersed with wooded or bare pastures. The most common forest type is the broadleaf forest predominantly consisting of *Quercus cerris, Ostrya carpinifolia, Fagus sylvatica*, and *Castanea sativa*. Within the area, there are artificial reforestations of conifers, mainly *Pseudotsuga menziesii* and *Pinus nigra*, planted around the 1960s. As evidence of a rather significant past anthropic presence, there are several cultivated surfaces designated as chestnut orchards, some currently restored and others slated for restoration.

The area is almost entirely included in the Site of Community Importance Giogo-Colla di Casaglia (IT5140004), established in 1995 and part of the Natura 2000 network. Among the protected habitats under the EU Habitat Directive present in the site, the most common are the "Asperulo-Fagetum beech forests (9130)", the "Castanea sativa woods (9260)", and the "Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (6210)". According to the official documentation, in addition to the effects of the tunnel construction for the Florence-Bologna high-speed train line, the main threats listed are the abandonment of crop production and of the pastoral systems with consequent reduction of chestnut groves and of open areas. According to the regional Landscape Plan, most of the study area is classified as *Morphotype of prairies and medium mountain pastures* (Venturi et al., 2021).

The area has also an historical relevance, as the Badia di Moscheta was founded by San Giovanni Gualberto in the first half of the 11th century. Characteristic of San Gualberto was the intent to improve the living conditions of the local populations through work in the fields, setting an example with his lay brothers; thus the lands around the Badia were cleared to obtain some arable land and, above all, pastures for livestock grazing. The Badia became increasingly richer, possessing both arable land and pastures even in distant areas, and in the 13th century it appeared as one of the most prosperous in the region. Beside cultivating and raising animals, local monks started to extend chestnut cultivation: in a drawing probably from the 18th century, the Moscheta abbey was depicted surrounded by chestnut and beech trees, and also by a smaller number of fir trees. From the 16th to the 17th century began a period of decline as a religious center, and Moscheta lands were given in use also to non-members of the church, and then suppressed during the reforms of Pietro Leopoldo (1748), when the property was sold. The new owners, the Martini family, reorganize the property into a large farm, where the main income was given by livestock breeding, the production of wood, and of chestnut flour (Agnoletti et al., 2006). As regards the demographic evolution, the hamlet of Moscheta undergoes some fluctuations until the end of the WWII, when started a sudden depopulation, as in the rest of the Apennines Mountain range. The area is now owned by the Tuscan Region and is managed by the Mountain Union of Mugello Municipalities.

### 2.2. Materials

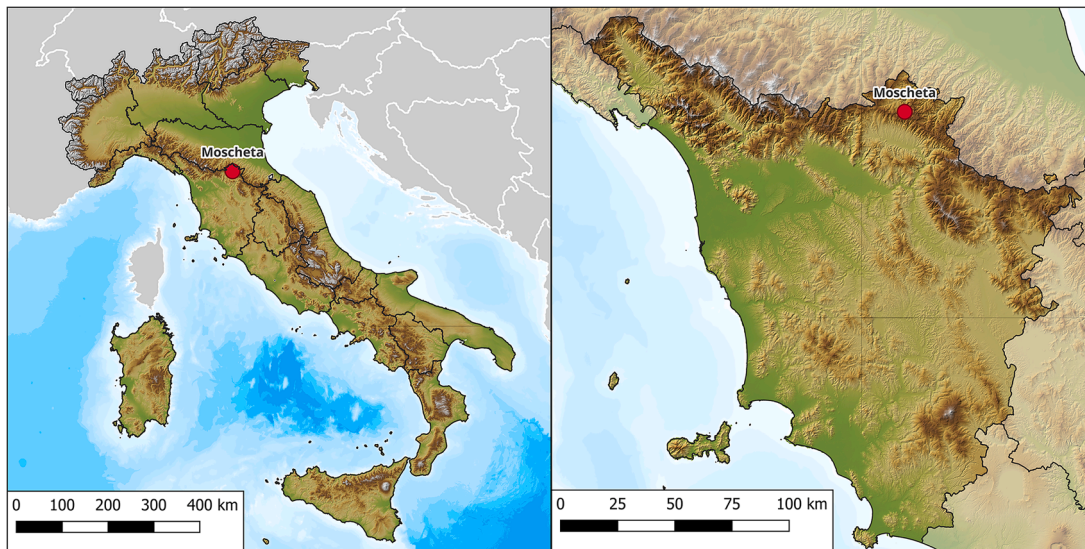The materials used for the analyses are the following:

**Fig. 1.** Moscheta is located in Tuscany (central Italy), along the Apennines Mountain range.

- General Cadastre of Tuscany of 1832. All the original maps have been georeferenced and are freely consultable through the WMS of the Tuscan Region, while the original cadastral records are preserved in the National Archive of Florence. Maps and registers have been consulted to reconstruct the land use map of 1832. . The choice of

using the General Cadastre of Tuscany of 1832 is due to the fact that this document is particularly detailed concerning the description of the land use of each cadastral unit and it refers to a period where the territory was traditionally managed through the sharecropping system, that dominated the central part of Italy until the mid-20th
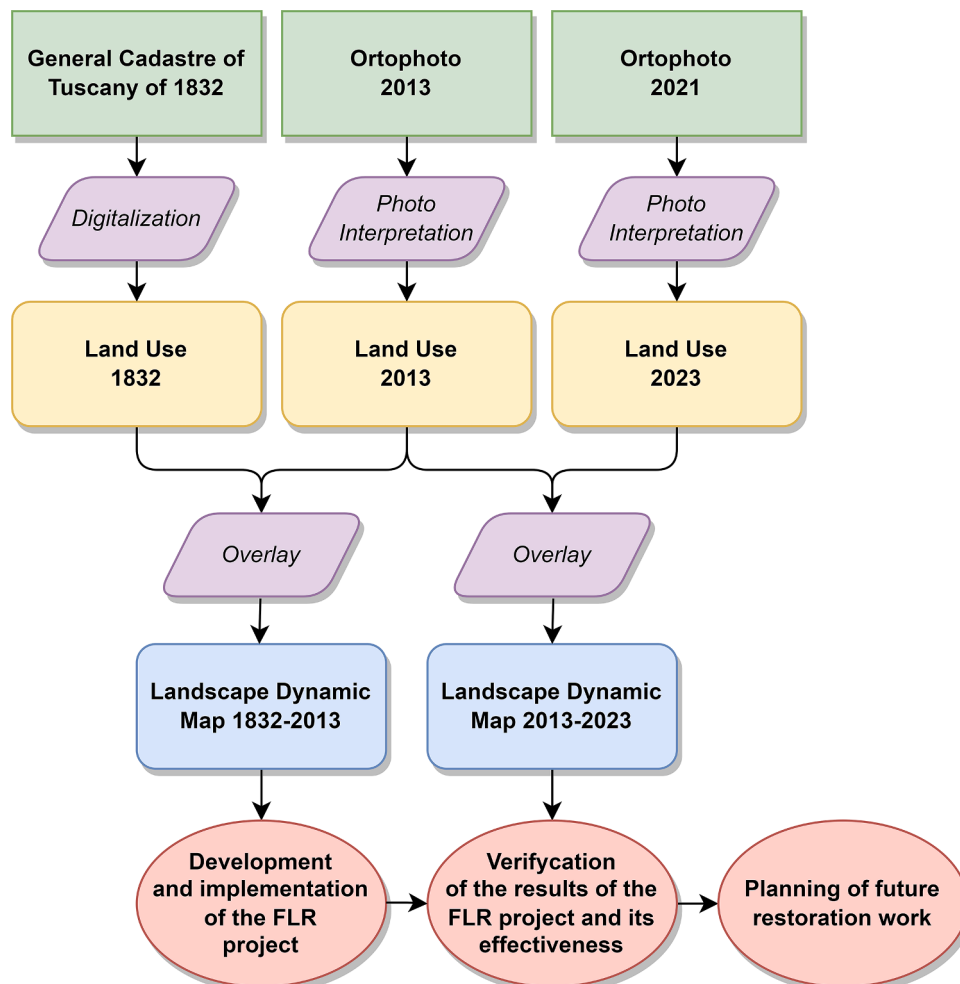


**Fig. 2.** Scheme of the methodological approach.

century. Therefore, this historical document is a key document to study the historical landscape structure of Tuscany. Since the description of the land uses is too detailed to allow comparison with the following layers, they have been reclassified to obtain a comparable legend.

- Orthophotos of 2013. High-resolution (50 cm) orthophotos of 2013 have been consulted through the WMS of the Tuscan Region and photointerpreted to produce the land use map of 2013. The year 2013 has been chosen since it since it is immediately prior to the beginning of the restoration plan, allowing to describe and measure the effects of the first long phase of abandonment (1832-2013).
- Orthophotos of 2021. High-resolution (20 cm) orthophotos of 2021 have been consulted through the WMS of the Tuscan Region. The 2021 orthophotos were the most recent ones available at the time of the study. Their photointerpretetation together with field surveys conducted in the month of May 2023 to update and verify the land uses classification, allowed to produce the land use map of 2023.

### 2.3. Methodology

The methodology is based on four steps (Fig. 2).

1. Analyses of the landscape changes for the period 1832–2013, to identify the main landscape transformation trends, the location of land use changes and the priority areas for the restoration project.
2. Development and implementation of the FLR project carried out in Moscheta.
3. Analysis of the land use changes for the period 2013–2023, to verify the results of the restoration project and its effectiveness.
4. Description of the restoration works planned for the future.

All the spatial analyses have been performed with the use of QGIS 3.22.3 software.

Points 1 and 3 of the methodology are based on a multitemporal approach called VASA, originally developed inside the DAGRI Department of the University of Florence for different landscape studies and for establishing a monitoring system of the rural landscape in Tuscany (M. Agnoletti, 2007). This methodology is based on a multitemporal analyses of the landscape of the same area through the use of GIS software and the performing of different spatial analyses, and in 2012 has been selected by the Italian Ministry of Food, Agricultural and Forest Policies (now Ministry of Agriculture, Food Sovereignty and Forests) as the reference methodology for the assessment of the landscapes that requested to be included in the "National Register of Rural Landscapes, Agricultural Practices and Traditional Knowledge" (Agnoletti and Santoro, 2022).

After producing maps and databases for every year (1832, 2013, 2023), these datasets were intersected using QGIS software to obtain a new dataset, called analysis of the dynamics, in which each polygon is classified according to a standard classification based on both the previous and the actual land use. These categories are:

- Unchanged: the main type of land use remains constant on the same polygon over time, or when there is a change, but between similar land uses, as occurs for examples between two types of woods or between a specialized vineyard and an olive grove.
- Anthropization: replacement of natural or seminatural land uses with urban areas, infrastructures, or buildings.
- Intensification: the passage from low-consumption land uses (in terms of biomass removal, mechanization, fertilizer, and crop protection products), such as meadows, pastures or traditional crops, to land uses characterized by high specialization and by a high need of energy supplies, such as monocultures.
- Extensification: the opposite of intensification, which is only rarely linked to a return to traditional land uses, but more often occurs in the presence of the phenomenon of abandonment of agricultural land or pastures.
- Deforestation: removal of woodlands or shrublands for obtaining pasture or agricultural lands.
- Forestation: natural process that occurs by secondary succession, in which trees or shrubs occupy patches once used as pastures or cultivations.
- Conifer afforestation: process that is directly related to human intervention, such as reforestation with conifers.

Forestation and conifer expansion are two similar processes, but they are kept separate because they have different origins, although they always identify the expansion of the forest on former agricultural areas or pastures. Forestation is a natural process, which occurs by secondary succession, while conifer expansion indicates the planting of conifer trees by men, an activity that has impacted the Italian rural landscape especially during the 1960s. (Agnoletti et al., 2019).

Respect to the original VASA methodology, two new dynamics have been added to better describe land use changes that are specific of the study area:

- Abandonment of chestnut groves.
- Restoration of chestnut groves.

## 3. Results

### 3.1. The abandonment of the traditional agro-silvo-pastoral landscape: 1832–2013

At the time of the 19th century land Cadaster, the territory of Moscheta was organized as a large agricultural property with a series of farms, each of which hosted a farm family according to the typical sharecropping structure. Because of this organizational structure, the landscape of 1832 was dominated by wooded pasture (46.8% of the total area) and then by woods (33.4%) (Fig. 3). Grazing was located throughout the area, from areas at higher altitudes to those at lower altitudes; in most cases these were wooded pastures, in fact, bare pastures were only present in 74 ha (9.9%). According to the cadastral register of 1832, wooded pastures were divided into 50 different categories, which differed due to the presence of different tree species, which constituted many pieces of a complex landscape mosaic, corresponding to different habitats expression of the great biodiversity of environments; the most extensive type was the "pasture with beech trees". Forests were mainly represented by beech forests, with 115 ha, corresponding to 15.3% of the total surface. Beech forests were used to produce firewood and coal, but also leaves were regularly used for feeding and housing livestock. 35% of the woods were instead made up of chestnut groves, an important symbol of the cultural identity of this area, above all for its links with the life of the populations, as chestnuts represented one of the main sources of flour in mountainous areas of Southern European countries. In 1832, conifers were not mentioned in the cadastral register, probably because with the end of the monastic property the cultivation and selling of conifer wood was no more economically profitable. Arable land covered only 5.5% of the territory, distributed mainly in the valley floor along the stream, and included 14 different types, almost all characterized by the presence of tree species.

The landscape of 2013 was characterized by a dominance of the forest surfaces which, also considering the chestnut grove and conifer reforestation, occupy over 618 hectares, 82.3% of the territory. The most widespread forest type remained that of the beech forest (31.3% of the total surface) followed by other broad-leaved forests (24.7%), forests with prevalence of chestnut (13.7%), and conifer reforestation (6.7%); chestnut groves have almost disappeared, being limited to only 14 ha (1.9% of the entire surface). Meadows and pastures were found on a total of over 130 hectares (17.3%), mainly represented by simple pastures (67 ha) and by wooded pastures (57 ha). Agricultural activities
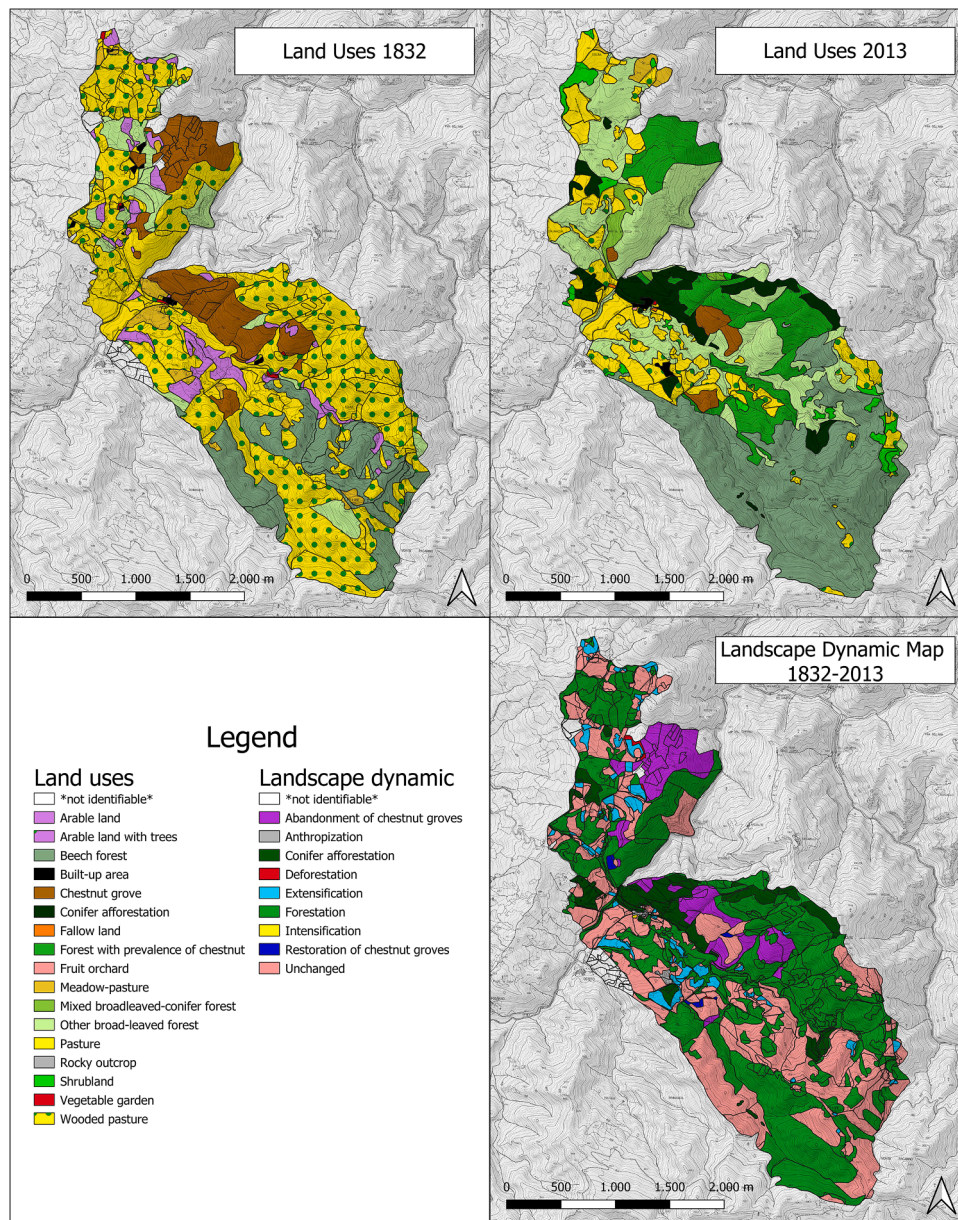
**Fig. 3.** Land use maps of 1832, 2013 and landscape dynamics map for the period 1832–2013.

completely disappeared following the decrease of population after the WWII; despite no precise data about the residents in Moscheta can be found, observing the population of the Firenzuola (the Municipality where Moscheta is located), it is possible to observe a rapid decrease of the number of people living in the municipality, concentrated in the years 1951–1970 (Fig. 4).

The analysis of the landscape dynamics (Table 1) shows that only the 34% of the total surface remained unchanged in the period 1832–2013, and that 45% (339 ha) was affected by forestation, at an average rate of 1.9 ha/year. The increase of forest surfaces is due to the abandonment of pastures and wooded pastures that have been colonized by forests through secondary succession; this phenomenon mainly interested wooded pastures, as 79% of their surface was classified in different types of forests in 2013. Overall, pastures and meadows decreased at an average rate of 1.7 ha/year. Forests surface also increased due to the direct human intervention, as 7% (50 ha) of the territory was affected by reforestation, mainly with Douglas fir (*Pseudotsuga menziesii*). Another important dynamic is the abandonment of chestnut groves (8% of the total surface, 60 ha), that mainly evolved into "forests with prevalence of

chestnut" (49% of the chestnut orchards of 1832). It is also worth noticing that 16% of the chestnut groves of 1832 (corresponding to 14 ha) was in 2013 classified as conifer reforestation, testifying the decline of chestnut cultivation during the 20th century that was no more considered economically interesting and was replaced by conifer plantation for timber production. Finally, the first results of the recent restoration initiatives are testified by the 1.96 ha of chestnut groves interested by restoration activities.

### 3.2. The forest landscape restoration project

Thanks to the efforts of the Regional Government of Tuscany and of the managing authority, from the 2010s, the area has been the subject of several initiatives with the aim of restoring the traditional historical landscape. The idea of a landscape restoration project was launched in 2007, with a study by Agnoletti (M. Agnoletti, 2007) on the feasibility of creating a Landscape Park and of restoring some portions of the traditional landscape. The FLR project mainly focused on the land uses that according to the previous analyses have been identified as priorities (in
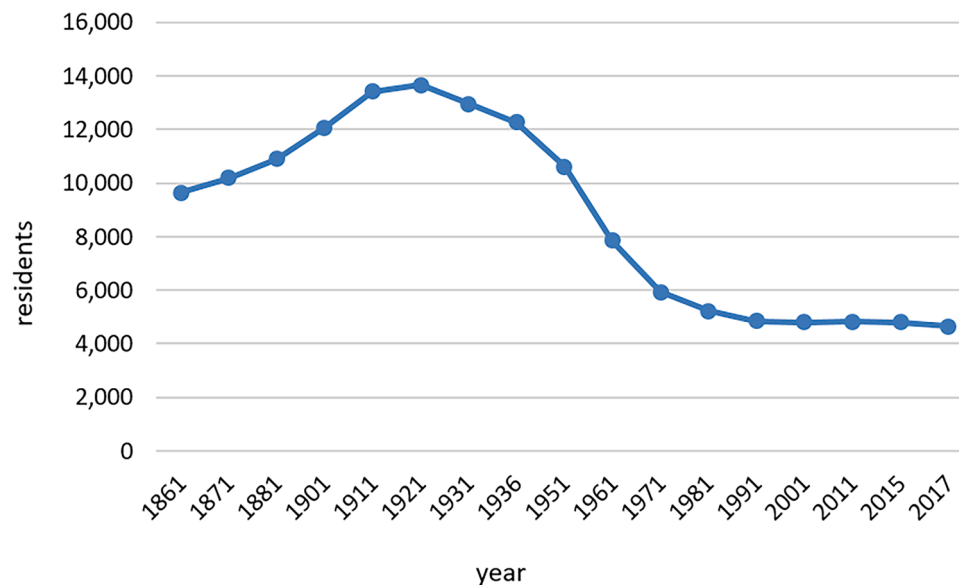
**Fig. 4.** Population of Firenzuola municipality for the period 1861–2017.

order of importance):

1. chestnut groves
2. wooded pastures and pastures
3. arable land

After the selection of the land uses to be recovered, an analyses of the different types of interventions have been carried out, considering the economic cost and the technical feasibility. Specifically, these analyses assessed the costs associated with skilled labour force, equipment utilization, and the implementation timelines of interventions, while considering their proximity to roads or trails, and potential future management strategies. The objective of these analyses was to identify those interventions that offered the greatest economic and technical feasibility for implementation.

1) Restoration of the chestnut groves. The recovery of chestnut groves depends greatly on the forest type that is present at the moment. The most convenient intervention is that of the simple recovery of the abandoned chestnut grove with the presence of monumental plants, as pruning and elimination of perishable or dead chestnut trees and of trees of other species are sufficient, together with the removal of the shrubs, and the progressive planting of new chestnut trees and their grafting with fruit varieties. Interventions that are not complex from a technical point of view, but take longer time to be completed, are related to aged chestnut coppices: in this case the gradual release of the best shoots from the stumps, allows the work to be set up and to reach the goal easily. Interventions to replace the conifer wood planted in the 1960s and 1970s and consequent restoration of the nineteenth-century chestnut groves are more complex from a technical point of view and also much more expensive from an economic point of view.
2) Restoration of pastures and wooded pastures. The restoration of pastures and wooded pastures represents a complex, but necessary phase of the FLR project, considering that these land uses underwent a significant reduction and that they deeply characterized the traditional landscape. In the best cases it would be sufficient to remove the shrubs to obtain pastures. Intermediate difficulty interventions are those for restoring wooded pastures actually occupied by a forest; in this case the coverage and

number of trees must be reduced, leaving those of larger dimensions (and therefore greater mechanical stability) and a certain number of younger ones. The most difficult cases are related to the restoration of pastures without trees, with the need to radically eliminate the tree component, especially if they are now occupied by conifer reforestation: in this case it is essential to guarantee the rapid restoration of a good herbaceous layer, which can be complicated by the colonization of shrubs, by the soil that has become unsuitable, or by an excessive slope that favors surface erosion.

3) Restoration of arable land. The intervention process for the restoration of arable land is particularly complicated, both from an economic and technical point of view. From a technical point of view, in fact, the abandonment of cultivation activities since long time and the replacement with other types of land use could have changed the soil characteristics making difficult to turn it back into productive agricultural soil. Furthermore, bringing back into cultivation land occupied by forests or pastures, although there are no particular restrictions given the national and regional laws, could be negatively perceived by visitors. Furthermore, these are expensive interventions that involve various phases: forest cutting, brush clearing, stump eradication, soil working, clearing, harrowing, plowing, etc.).

Finally, in order to decide the possible interventions, the future management has to be taken into consideration. Pastures and arable land needs to be regularly maintained in use, through grazing and agricultural activities, respectively. Otherwise processes of secondary succession will begin with a new expansion of the shrubs and trees and the failure of the works carried out. Considering that there was no possibility of having farmers dedicated to agricultural crops, the arable land restoration was not included in the project; however, the presence of livestock and especially of horses for tourist activities in the area, was perfectly compatible with the restoration and maintenance of pastures and wooded pastures.

Given the previous considerations, the FLR project of Moscheta focused on the restoration of abandoned chestnut groves with monumental plants (excluding those replaced by other types of forest or other land uses) and on the restoration of pastures and wooded pastures occupied by trees or shrubs. In addition to traditional land use restoration, other important interventions have been made to increase the touristic appeal of the area, including: regular management of the paths

**Table 1**
Cross tab for the period 1832–2013. The colors correspond to the ones of the dynamic map. .

| Land uses 1832 | Land uses 2013 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | rocky outcrop | built-up area | shrubland | chestnut | other broad-leaved forest | beech forest | forest | chestnut grove | fruit orchard | fallow land | vegetable garden | pasture | wooded pasture | meadow-pasture | conifer afforestation | Total |
| not identifiable | | | 0.92 | 0.80 | 2.51 | 1.25 | | | | | | 2.50 | 4.10 | | | **11.07** |
| built-up area | | 0.45 | | | 0.91 | | | | | | 0.10 | 0.66 | 0.31 | 0.01 | 0.02 | **2.47** |
| other broad-leaved forest | 0.09 | | 0.35 | 2.40 | 23.68 | 10.15 | 2.98 | 0.36 | | | | 2.89 | 4.40 | 0.68 | 0.53 | **48.52** |
| beech forest | | | 1.18 | 10.83 | 3.62 | 94.33 | | | | | | 0.09 | 1.92 | | 2.78 | **114.74** |
| chestnut grove | 0.02 | 0.01 | | 43.57 | 14.32 | 0.23 | 2.25 | 12.17 | | | | 1.14 | | | 14.33 | **88.03** |
| vegetable garden | | 0.06 | 0.03 | | 0.51 | | | | | | | 0.26 | 0.10 | | 0.17 | **1.12** |
| pasture | 0.06 | 0.12 | 3.48 | 4.81 | 22.43 | 2.77 | 2.67 | 1.24 | | 0.27 | | 16.15 | 12.77 | | 7.34 | **74.09** |
| wooded pasture | 0.16 | 0.90 | 13.28 | 38.09 | 102.12 | 122.04 | 1.37 | 0.05 | | 0.06 | | 26.29 | 24.82 | 4.57 | 18.17 | **351.91** |
| meadow-pasture | | 0.71 | 0.15 | 0.61 | 0.65 | 2.69 | | 0.21 | 0.11 | | | 7.06 | 1.38 | 0.26 | 3.87 | **17.69** |
| arable land | | | 0.23 | 1.26 | 5.75 | 1.66 | 0.83 | 0.11 | | | | 3.66 | 4.70 | 0.34 | 0.15 | **18.69** |
| arable land with trees | | 0.04 | 0.52 | 0.41 | 9.30 | 0.13 | 0.13 | | | | | 6.63 | 2.35 | 0.09 | 2.73 | **22.34** |
| **Total** | **0.32** | **2.28** | **20.13** | **102.76** | **185.80** | **235.25** | **10.24** | **14.14** | **0.11** | **0.34** | **0.10** | **67.33** | **56.83** | **5.95** | **50.09** | **751.66** |

with signage illustrating the ecological and historical characteristics of the local landscape, the realization of the Historical Landscape Museum in the ancient rooms of the abbey, the restorations of the traditional buildings for chestnut drying (Fig. 5).

The success of these initiatives led, in 2016, to the inscription of the area in the National list of historical Rural Landscape established by the Italian Ministry of Agriculture, Food Sovereignty and Forests (Agnoletti and Santoro, 2022), with the motivation of a landscape testifying the "ability of local populations to adapt the mountain environment to satisfy the conditions necessary for life, through the development of agricultural, forestry and pastoral practices that have left their mark on the natural environment", certifying the quality of the landscape and the effectiveness of the applied restoration project. The inscription in the Register has not been intended as the final goal by the local authorities, but as a recognition of the good quality of the ongoing applied strategies. In fact, after the inscription other interventions have been made and are planned for the future.

### 3.3. The landscape of 2023 and the evaluation of the forest landscape restoration project

The results of the spatial analyses (Fig. 6) show that the landscape of 2023 is still dominated by forests (81.5% of the territory, 612 ha), whose main type is represented by beech forests (30.8% of the total surface), followed by other broad-leaved forests (26.1%), forests with prevalence of chestnut (13.9%), and conifer reforestation (5.9%). Actually, chestnut groves occupy around 17 ha (2.3% of the entire surface). Meadows and pastures are found on a total of over 127 hectares (16.9%), mainly represented by wooded pastures (67.6 ha).

The analyses of the landscape dynamics for the period 2013–2023 (Table 2) highlights some interesting trends, as a consequence of the restoration initiatives carried out by the local authorities. The first one is related to the restoration of the chestnut groves, some of them still characterized by monumental trees, occurring on 4 ha. In addition to these 4 ha, it is necessary to consider that regular maintenance is carried out in the rest of the chestnut groves. The second one is the fact that the surface of pastures is almost unchanged in this period, and that about 6.5 ha of wooded pastures have been re-established (classified as deforestation) and are regularly grazed. In addition, the analysis of the dynamics shows that forestation is almost completely stopped (only 0.7 ha), testifying that the restoration of open spaces has been successful.

### 3.4. Future interventions planned for the Moscheta landscape

As already stated, the FLR of Moscheta should not be considered as a finished project, but it is an ongoing project and other interventions are planned for the future.

1) Maintenance of monumental chestnut groves. Interventions of regular maintenance are planned for all the 17 ha of chestnut groves, including specific pruning interventions on individual trees for their consolidation, as well as the removal of shrubs and dead trees. Given the historical and landscape value of the monumental trees, the primary aim of the intervention is not to increase the production of chestnut, but to guarantee the best vegetative state of the chestnut trees, maintaining their monumental characteristics and therefore their landscape value.

2) Additional rehabilitation of other pastures and wooded pastures. Two other areas to be recovered as pastures and wooded pastures have been identified in the eastern part of the area, on the basis of the 1832 land use map, for a total surface of about 4 ha. These areas have been colonized by shrubs that will be cleared, while some pruning interventions on the existing trees are planned for removing the dead branches. Both of these areas are placed at high altitudes along a ridge and a path, therefore, they also can act as a viewpoint for visitors.

3) Pollarding of beech trees. A final type of intervention concerns the experimentation of pollarding interventions on selected beech trees. In Moscheta area there are still several beech trees that were once regularly pollarded, with the function of promoting complementarity with grazing activity, creating trees with peculiar shape and structure, with historical, cultural and landscape values. The cessation of this traditional practice is causing the disappearance of this heritage. It is therefore planned to start a trial on 10 selected beech trees, all located in the same area, along a road to facilitate cutting and logging operations. Different plants have already been selected in terms of diameter and position.

## 4. Discussion and conclusions

Moscheta landscape underwent the typical landscape and societal changes that affected the European mountain areas in the last 70 years, caused by strong depopulation and by the consequent cessation of the traditional forest and pasture management. The first part of the study identified the main trends of the abandonment phase (1832–2013), that can be summarized as follows:

- abandonment of pastures
- abandonment of chestnut cultivation
- abandonment of agricultural activities
- increase of forest surfaces

These trends are typical of most of the mountainous areas of southern Europe during the 20th century, and especially after the end of WWII, due to a rapid depopulation of marginal rural areas that caused the abandonment of the traditional livestock-based economy and of the other traditional agricultural activities (MacDonald et al., 2000; Plieninger et al., 2016; Quaranta et al., 2020; Bruno et al., 2021).

One of the main landscape changes occurred in Moscheta is the abandonment and decrease of chestnut groves, with multiple negative consequences. Considering that local chestnut groves were, and still are, characterized by monumental trees, the loss of about 60 ha of chestnut groves since 1832 means a serious loss from a landscape and cultural point of view. Results showed that this decrease was mainly a



**Fig. 5.** Restored chestnut groves with monumental trees (left), wooded pastures (middle), traditional buildings for chestnut drying (right).
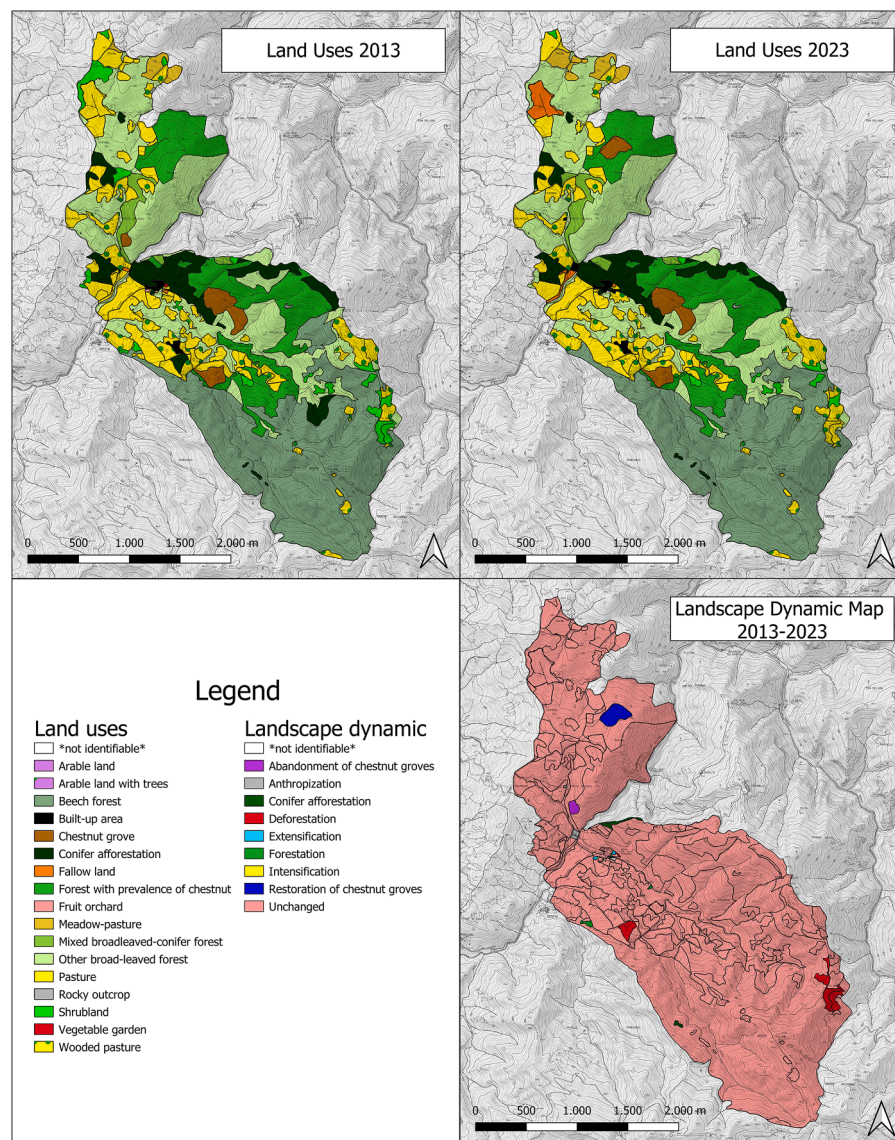
**Fig. 6.** Land use maps of 2013, 2023 and landscape dynamics map for the period 2013–2023.

consequence of depopulation, but in some cases it has been an intentional choice, as more than 14 ha of 1832 chestnut groves have been affected by direct conifer plantations in the 1960s, in view of a hypothetical (and never realised) growth of the local timber market. Thanks to the FLR carried out by local authorities, nowadays Moscheta has raised interest among visitors, that can practice different activities, from hiking to horse riding. Particularly interesting, is the possibility for visitors to collect chestnuts in the monumental chestnut groves, in exchange for a reduced payment to the managing body, testifying the relation of monumental chestnuts with rural tourism. In fact, monumental trees can be an important resource for rural tourism (Cannizzaro and Corinto, 2014), and monumental chestnut trees represent an important heritage for the mountainous heritage landscapes of southern Europe becoming relevant landmarks and cultural icons (Gaspar Bernárdez Villegas et al., 2021). Chestnuts have in fact represented a crucial food source in mountainous areas, where cereals were difficult to cultivate, providing chestnuts for flour, but also firewood, leaves and timber, being a real multipurpose tree with a strong cultural role (Patrício et al., 2014; Gullino et al., 2009). Chestnut groves, beside the landscape and cultural role, are also important for biodiversity conservation. Due to their density, vertical and horizontal structures, regularly managed chestnut groves, in fact, represent a peculiar habitat, very

different to the one related to seminatural forests with prevalence of chestnut trees. According to Gondard (Gondard et al., 2006) plant species diversity is higher in chestnut groves than in chestnut coppices. Other authors also suggested the importance of mature chestnut groves for beetle communities (Parisi et al., 2020) or for epiphytic lichens (Pezzi et al., 2020). Finally, according to Morelli et al. (Morelli et al., 2019) the restoration of ancient chestnut grove can be important for different endangered bird species.

The reduction of pastures and wooded pastures have significant negative consequences on biodiversity too (Sartorello et al., 2020; Bazzi et al., 2015; Watt et al., 2007), also considering that the reduction of open spaces is one of the main land use changes at EU level in the last decades and that, at the same time, these habitats are among the priority ones due to their importance for different taxa (Loran et al., 2017; Rodríguez-Rojo et al., 2022; Plieninger et al., 2015). Therefore, the restoration of wooded pastures carried out in Moscheta is another key activity, with positive impact for both landscape and biodiversity.

FLR initiatives and nowadays more and more important to re-establish not only degraded or abandoned agroecosystems, but also the ecosystem services related to a particular land use of management practice. According to Stanturf et al. (Stanturf et al., 2014), the interventions carried out in Moscheta are better defined as rehabilitation,

**Table 2**
Cross tab for the period 2013–2023. The colors correspond to the ones of the dynamic map.

| Land uses 2013 | Land uses 2023 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | rocky outcrop | built-up area | shrubland | of chestnut | forest | beech forest | conifer forest | chestnut grove | fallow land | pasture | wooded pasture | meadow-pasture | conifer afforestation | Total |
| rocky outcrop | 0.32 | | | | | | | | | | | | | **0.32** |
| built-up area | | 2.28 | | | | | | | | | | | | **2.28** |
| shrubland | | | 6.26 | | 7.49 | 0.79 | 0.90 | | | | 4.68 | | | **20.12** |
| forest with prevalence of chestnut | | | | 97.98 | | | 0.69 | 4.08 | | | | | 0.01 | **102.76** |
| other broad-leaved forest | | 0.02 | | 6.23 | 178.60 | | 0.16 | | | | 0.05 | | 0.74 | **185.80** |
| beech forest | | | | | 9.12 | 225.83 | | | | | | | 0.29 | **235.24** |
| mixed broadleaved-conifer forest | | | | 0.01 | 0.01 | | 9.85 | | | | | | 0.39 | **10.24** |
| chestnut grove | | | | | 1.07 | | | 13.07 | | | | | | **14.14** |
| fruit orchard | | | | | | | | | | | 0.11 | | | **0.11** |
| fallow land | | 0.33 | | | | | | | | | | | | **0.33** |
| vegetable garden | | | | | | | | | 0.10 | | | | | **0.10** |
| pasture | | 0.05 | | | 0.10 | | | | 8.55 | 48.21 | 5.11 | 5.30 | | **67.32** |
| wooded pasture | | 0.44 | | | 0.13 | 0.44 | | | | | 55.81 | | | **56.82** |
| meadow-pasture | | | | | | | | | | 0.54 | | 5.41 | | **5.95** |
| conifer afforestation | | 0.04 | | 0.62 | | 4.41 | 0.53 | | | 0.07 | 1.81 | | 42.63 | **50.11** |
| **Total** | **0.32** | **3.16** | **6.26** | **104.83** | **196.51** | **231.47** | **12.13** | **17.15** | **8.65** | **48.82** | **67.57** | **10.71** | **44.06** | **751.64** |

as they are aimed at restoring desired species composition and structure of a degraded/abandoned agroecosystem. The rehabilitation of the traditional landscape of Moscheta has been successful thanks to the combined work of local stakeholders and to an accurate planning of the different interventions, calibrated on the availability of local economic and professional resource, as well as on the technical feasibility. In fact, as highlighted by Höhl et al. (2020), the major obstacles to FLR consist in a lack of local stakeholder involvement and in environmental and technical barriers. In addition, the Moscheta rehabilitation project has also allowed to preserve traditional ecological practices related to the management of historical chestnut groves and of wooded pastures, increasing the touristic attractiveness of the area.

This study represents the first assessment of the FLR carried out in Moscheta, that could be integrated with studies focusing on landscape perception carried out among visitors, in order to evaluate the perception of the different landscape features and lands uses, to better plan future rehabilitation interventions. The importance of the study case of Moscheta is not limited to the local setting, as the trends occurring to the area in terms of land use changes and in terms of abandonment of regular forest and pasture management, have deeply affected many rural areas in Europe. Therefore, the activities carried out by the local managing authorities together with the Regional Government, exemplifies that FLR is possible and could have a big impact on related ecosystem services and on the touristic attractiveness of the area. The success of this approach, testified by the inclusion of the area in the National Register of Historical Rural Landscapes, could favor the replicability in similar cultural forest landscapes in European mountainous area, to preserve and enhance cultural landscapes and related ecosystem services and traditional ecological knowledge.

**CRediT authorship contribution statement**

**Beatrice Fiore:** Writing – review & editing, Writing – original draft, Software, Methodology, Conceptualization. **Francesco Piras:** Conceptualization, Methodology, Software, Writing – original draft, Writing – review & editing. **Antonio Santoro:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Data availability**

Data will be made available on request.

# References

Abellán, F.C., García Martínez, C., 2021. Landscape and tourism as tools for local development in mid-mountain rural areas in the southeast of Spain (Castilla-La Mancha). Land. (Basel) 10 (2), 221. https://doi.org/10.3390/land10020221.

Agnoletti, M., 2007a. The degradation of traditional landscape in a mountain area of Tuscany during the 19th and 20th centuries: implications for biodiversity and sustainable management. For. Ecol. Manage. 249 (1–2), 5–17. https://doi.org/10.1016/j.foreco.2007.05.032.

Agnoletti, M., 2007b. Il Parco Del Paesaggio Rurale Appenninico Di Moscheta. Pacini, Pisa, Italy.

Agnoletti, M., Santoro, A., 2022. The Italian national register of historical rural landscapes. Cultural Heritage—Possibilities for Land-Centered Societal Development 15–34. https://doi.org/10.1007/978-3-030-58092-6_2.

Agnoletti, M., Marinai, V., Paoletti, S., 2006. The project for the rural landscape park in Moscheta (Tuscany, Italy). The Conservation of Cultural landscapes. CABI, pp. 73–93. Wallingford, UK.

Agnoletti, M., Piras, F., Venturi, M., Santoro, A., 2022. Cultural values and forest dynamics: the Italian forests in the last 150 years. For. Ecol. Manage. 503, 119655 https://doi.org/10.1016/j.foreco.2021.119655.

Agnoletti, M., Emanueli, F., Corrieri, F., Venturi, M., Santoro, A., 2019. Monitoring Traditional Rural Landscapes. The Case of Italy. Sustainability. 11, 6107. https://doi.org/10.3390/su11216107.

... & Ameztegui, A., Morán-Ordónez, A., Márquez, A., Blázquez-Casado, Á., Pla, M., Villero, D., Coll, L., 2021. Forest expansion in mountain protected areas: trends and consequences for the landscape. Landsc. Urban. Plan. 216, 104240 https://doi.org/10.1016/j.landurbplan.2021.104240.

Amodio, T., 2022. Territories at risk of abandonment in Italy and hypothesis of repopulation. Belgeo. Revue belge de géographie (4). https://doi.org/10.4000/belgeo.57229.

Anselmetto, N., Weisberg, P.J., Garbarino, M., 2024. Global change in the European Alps: a century of post-abandonment natural reforestation at the landscape scale. Landsc. Urban. Plan. 243, 104973 https://doi.org/10.1016/j.landurbplan.2023.104973.

Bazzi, G., Foglini, C., Brambilla, M., Saino, N., Rubolini, D., 2015. Habitat management effects on Prealpine grassland bird communities. Italian Journal of Zoology 82 (2), 251–261. https://doi.org/10.1080/11250003.2014.983566.

Bebi, P.S.E.P., Seidl, R., Motta, R., Fuhr, M., Firm, D., Krumm, F., Kulakowski, D., 2017. Changes of forest cover and disturbance regimes in the mountain forests of the Alps. For. Ecol. Manage. 388, 43–56. https://doi.org/10.1016/j.foreco.2016.10.028.

Bruno, D., Sorando, R., Álvarez-Farizo, B., Castellano, C., Céspedes, V., Gallardo, B., Comín, F.A., 2021. Depopulation impacts on ecosystem services in Mediterranean rural areas. Ecosyst. Serv. 52, 101369 https://doi.org/10.1016/j.ecoser.2021.101369.

Cannizzaro, S., Corinto, G.L., 2014. The role of monumental trees in defining local identity and in tourism: a case study in the Marches Region. Geoprogress Journal 1 (1), 29–48.

César, R.G., Belei, L., Badari, C.G., Viani, R.A., Gutierrez, V., Chazdon, R.L., Morsello, C., 2020. Forest and landscape restoration: a review emphasizing principles, concepts, and practices. Land, 10 (1), 28. https://doi.org/10.3390/land10010028.

Faccioni, G., Sturaro, E., Ramanzin, M., Bernués, A., 2019. Socio-economic valuation of abandonment and intensification of Alpine agroecosystems and associated ecosystem services. Land. use policy. 81, 453–462. https://doi.org/10.1016/j.landusepol.2018.10.044.

Foggin, M., Emslie-Smith, M., Hergarten, C., 2018. Food systems and agrobiodiversity in the mountains of central Asia. Mt. Res. Dev. 38 (2), 175–179. https://doi.org/10.1659/MRD-JOURNAL-D-18-0048.

Gaspar Bernárdez Villegas, J., Rigueiro Rodríguez, A., Silva de la Iglesia, I., 2021. Monumental Sweet Chestnuts (Castanea sativa Mill.) in Galicia's Cultural Landscape (NW Spain). Landscapes 22 (2), 147–172. https://doi.org/10.1080/14662035.2021.2035095.

Gondard, H., Romane, F., Regina, I.S., Leonardi, S., 2006. Forest management and plant species diversity in chestnut stands of three Mediterranean areas. Forest Diversity and Management 69–82. https://doi.org/10.1007/978-1-4020-5208-8_5.

Grêt-Regamey, A., Brunner, S.H., Kienast, F., 2012. Mountain ecosystem services: who cares?. In: Mt. Res. Dev, 32 https://doi.org/10.1659/MRD-JOURNAL-D-10-00115.S1.

Gullino, P., Larcher, F., Devecchi, M., 2009. The importance of the chestnut cultivation and its evolution in the piedmont landscape (North-West Italy). In: In: I European Congress on Chestnut-Castanea, pp. 37–42. https://doi.org/10.17660/ActaHortic.2010.866.1.

Höhl, M., Ahimbisibwe, V., Stanturf, J.A., Elsasser, P., Kleine, M., Bolte, A., 2020. Forest landscape restoration—What generates failure and success? Forests. 11 (9), 938. https://doi.org/10.3390/f11090938.

Koohafkan, P., Altieri, M.A., 2011. Globally Important Agricultural Heritage Systems. A Legacy For the Future. Food and Agriculture Organization of the United Nations, Rome, Italy.

Körner, C., 2000. The alpine life zone under global change. Gayana Botanica 57 (1). https://doi.org/10.4067/S0717-66432000000100001.

Lake, F.K., Parrotta, J., Giardina, C.P., Davidson-Hunt, I., Uprety, Y., Mansourian, S., Parrotta, J., 2018. Integration of Traditional and Western knowledge in forest landscape restoration. Forest Landscape restoration: Integrated approaches to Support Effective Implementation. Routhledge, London, UK, pp. 198–226.

Loran, C., Munteanu, C., Verburg, P.H., Schmatz, D.R., Bürgi, M., Zimmermann, N.E., 2017. Long-term change in drivers of forest cover expansion: an analysis for Switzerland (1850-2000). Reg. Environ. Change 17, 2223–2235. https://doi.org/10.1007/s10113-017-1148-y.

... & MacDonald, D., Crabtree, J.R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gibon, A., 2000. Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. J. Environ. Manage. 59 (1), 47–69. https://doi.org/10.1006/jema.1999.0335.

Mansourian, S., 2021. From landscape ecology to forest landscape restoration. Landsc. Ecol. 36, 2443–2452. https://doi.org/10.1007/s10980-020-01175-6.

... & Mansourian, S., Parrotta, J., Balaji, P., Bellwood-Howard, I., Bhasme, S., Bixler, R.P., Yang, A., 2020. Putting the pieces together: integration for forest landscape restoration implementation. Land. Degrad. Dev. 31 (4), 419–429. https://doi.org/10.1002/ldr.3448.

Marchant Santiago, C., Olivares, F., Caviedes, J., Santana, F., Monterrubio-Solís, C., Ibarra, J.T., 2023. Agrobiodiversity in mountain territories: family farming and the challenges of social-environmental changes. Montology Palimpsest: A Primer of Mountain Geographies. Springer International Publishing, Cham, pp. 313–331. https://doi.org/10.1007/978-3-031-13298-8_18.

Mele, E., Egberts, L., 2023. Exploring travel blogs on tourism and landscape heritage: representations of the Swiss Alps. Journal of Heritage Tourism 18 (6), 785–806. https://doi.org/10.1080/1743873X.2023.2237617.

Morelli, F., Python, A., Pezzatti, G.B., Moretti, M., 2019. Bird response to woody pastoral management of ancient chestnut orchards: a case study from the southern Alps. For. Ecol. Manage. 453, 117560 https://doi.org/10.1016/j.foreco.2019.117560.

... & Nadal-Romero, E., Juez, C., Khorchani, M., Peña-Angulo, D., Lana-Renault, N., Regüés, D., García-Ruiz, J.M., 2021. Impacts of land abandonment on flood mitigation in Mediterranean mountain areas. Nature-Based Solutions for Flood Mitigation: Environmental and Socio-Economic Aspects 189–214. https://doi.org/10.1007/698_2021_772.

Parisi, F., Lombardi, F., Marziliano, P.A., Russo, D., De Cristofaro, A., Marchetti, M., Tognetti, R., 2020. Diversity of saproxylic beetle communities in chestnut agroforestry systems. iForest-Biogeosciences and Forestry 13 (5), 456. https://doi.org/10.3832/ifor3478-013.

Parrotta, J., Yeo-Chang, Y., Camacho, L.D., 2016. Traditional knowledge for sustainable forest management and provision of ecosystem services. Int. J. Biodivers. Sci. Ecosyst. Serv. Manage 12 (1–2), 1–4. https://doi.org/10.1080/21513732.2016.1169580.

Patrício, M.S., Galante, M., Bihun, Y., 2014. The bread tree: a primer on the culture of sweet chestnut (Castanea sativa Mill.) in Portugal. The Journal of The American Chestnut Foundation 28 (5), 23–27.

Pezzi, G., Gambini, S., Buldrini, F., Ferretti, F., Muzzi, E., Maresi, G., Nascimbene, J., 2020. Contrasting patterns of tree features, lichen, and plant diversity in managed and abandoned old-growth chestnut orchards of the northern Apennines (Italy). For. Ecol. Manage. 470, 118207 https://doi.org/10.1016/j.foreco.2020.118207.

Piras, F., Fiore, B., Santoro, A., 2022. Small Cultural Forests: landscape Role and Ecosystem Services in a Japanese Cultural Landscape. Land. (Basel) 11, 1494. https://doi.org/10.3390/land11091494.

... & Plieninger, T., Hartel, T., Martín-López, B., Beaufoy, G., Bergmeier, E., Kirby, K., Van Uytvanck, J., 2015. Wood-pastures of Europe: geographic coverage, social–ecological values, conservation management, and policy implications. Biol. Conserv. 190, 70–79. https://doi.org/10.1016/j.biocon.2015.05.014.

... & Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., Verburg, P. H., 2016. The driving forces of landscape change in Europe: a systematic review of the evidence. Land. use policy. 57, 204–214. https://doi.org/10.1016/j.landusepol.2016.04.040.

Quaranta, G., Salvia, R., Salvati, L., Paola, V.D., Coluzzi, R., Imbrenda, V., Simoniello, T., 2020. Long-term impacts of grazing management on land degradation in a rural community of Southern Italy: depopulation matters. Land. Degrad. Dev. 31 (16), 2379–2394. https://doi.org/10.1002/ldr.3583.

Rodríguez-Rojo, M.P., Roig, S., López-Carrasco, C., Redondo García, M.M., Sánchez-Mata, D., 2022. Which factors favour biodiversity in Iberian Dehesas? Sustainability. 14 (4), 2345. https://doi.org/10.3390/su14042345.

Santoro, A., Venturi, M., Bertani, R., Agnoletti, M., 2020. A review of the role of forests and agroforestry systems in the FAO Globally Important Agricultural Heritage Systems (GIAHS) programme. Forests. 11 (8), 860. https://doi.org/10.3390/f11080860.

Sartorello, Y., Pastorino, A., Bogliani, G., Ghidotti, S., Viterbi, R., Cerrato, C., 2020. The impact of pastoral activities on animal biodiversity in Europe: a systematic review and meta-analysis. J. Nat. Conserv. 56, 125863 https://doi.org/10.1016/j.jnc.2020.125863.

Sgroi, F., 2020. Forest resources and sustainable tourism, a combination for the resilience of the landscape and development of mountain areas. Science of the Total environment 736, 139539. https://doi.org/10.1016/j.scitotenv.2020.139539.

Sil, Â., Fernandes, P.M., Rodrigues, A.P., Alonso, J.M., Honrado, J.P., Perera, A., Azevedo, J.C., 2019. Farmland abandonment decreases the fire regulation capacity and the fire protection ecosystem service in mountain landscapes. Ecosyst. Serv. 36, 100908 https://doi.org/10.1016/j.ecoser.2019.100908.

Stanturf, J.A., Palik, B.J., Dumroese, R.K., 2014. Contemporary forest restoration: a review emphasizing function. For. Ecol. Manage. 331, 292–323. https://doi.org/10.1016/j.foreco.2014.07.029.

Venturi, M., Piras, F., Corrieri, F., Fiore, B., Santoro, A., Agnoletti, M., 2021. Assessment of Tuscany landscape structure according to the regional landscape plan partition. Sustainability. 13 (10), 5424. https://doi.org/10.3390/su13105424.

Watt, A.D., Bradshaw, R.H.W., Young, J., Alard, D., Bolger, T., Chamberlain, D., Vanbergen, A., 2007. Trends in biodiversity in Europe and the impact of land use change. In: Biodiversity under Threat. Issues in Environmental Science and Technology, 25, pp. 135–160.