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Abstract

Traditional landscape elements such as pasture patches enclosed in a forest matrix are progressively disappearing throughout the European Alps. We assessed the land mosaic shift of a protected area located in the western Italian Alps. In particular, the dynamics of pasture patches were studied at both landscape and stand level. Land-cover mapping through object-oriented analysis of historical aerial photographs was used to assess land-cover changes between 1954 and 2000. Spatial statistics were used to quantify landscape patterns, and field samplings within pasture patches were used to explore tree regeneration structure and composition. Our results showed a significant increase in the number of pasture patches caused by their fragmentation following forest expansion. The total surface area of pasture patches decreased by 43% and their core area decreased by 94%. The encroachment of trees on less accessible areas of the pasture patches caused a reduction of patch shape at landscape scale. The gap filling process started 40-50 years ago and began with an early invasion of light demanding species like sycamore maple (*Acer pseudoplatanus* L.) and common ash (*Fraxinus excelsior* L.), followed by European beech (*Fagus sylvatica* L.) and secondarily silver fir (*Abies alba* Mill.). Traditional land-use and population decline in the Pesio Valley led to a reduction in ecotone areas. A transition to a more homogeneous landscape is expected in the next decades. Given the cultural and productive nature of these mountain meadow-pasture communities, extensive livestock grazing systems could be used to manage their future conservation.

Key words

Landscape structure; secondary succession; historical ecology; Pesio Valley; traditional land-use

1. Introduction

European mountain regions are dominated by semi-natural ecosystems where natural and anthropogenic disturbance regimes coexist and have interacted for centuries (Naveh 1995). The structure of these landscapes is generally subject to consistent changes over time resulting in so-called mosaic shifts (Clark 1991; Turner and Meyer 1993). Land-use is considered the most important driving factor for landscape change in the Alps (Gehrig-Fasel et al. 2007) and must be taken into account when developing sustainable landscape management and conservation strategies (Chauchard et al. 2007).

A reduction in diversity (Grossmann and Mladenoff 2007; Sala et al. 2000) and habitat loss (Vitousek et al. 1997) are often associated with land-use and land-cover changes. Recent habitat loss in the Mediterranean basin has typically been caused by two main patterns of change (Falcucci et al. 2007): 1) an intensification of agriculture and increase of settlements leading to a reduction in forest cover on the plains and along the coastline, 2) land abandonment on mountainous and hilly areas reducing open areas through natural reforestation (MacDonald et al. 2000).

These changes are commonly due to the abandoning of traditionally managed forests, pastures, hay meadows and cultivated fields. Marginal land abandonment following rural depopulation and urbanization (Bätzing et al. 1996) has caused a steady decline of land-use practices in many mountainous Mediterranean regions (Papanastasis 1997). Extensive natural forest recovery through secondary succession has been observed in the Alps as a consequence of the abandonment of low-intensity farming (Dullinger et al. 2003; Motta et al. 2006; Chauchard et al. 2007; Sitzia et al. 2010).

Traditional practices, such as silvicultural intervention and grazing, have often created a complex mosaic of open areas, as well as sparse and dense forests. This traditional landscape mosaic can be mainly found in the subalpine (Garbarino et al. 2011) and montane belt (Sitzia and Trentanovi 2011). The forest patches can be considered as the most dynamic elements of these heterogeneous landscapes (Höchtl et al. 2005). In these situations, the surfaces of open areas tend to reduce due to trees encroaching on the abandoned land (Cousins et al. 2003; Dullinger et al. 2003). This secondary succession process is particularly evident in the montane belt of the outer Italian Alps (Motta and Garbarino 2003; Höchtl et al. 2005; Garbarino and Pividori 2006) where enclosed herbaceous patches, traditionally grazed during the summer, are important sources of plant diversity as well as food supplies for domestic and wild animals. The majority of these pasture patches are at risk of disappearing due to the abandonment of traditional practices (Grossi et al. 1995) and the subsequent secondary succession processes that are particularly fast and abrupt due to favorable climate and soil fertility. Changes in spatial patterns have been proven to consistently affect the species diversity of meadow patches enclosed by forests in the Eastern Italian Alps (Sitzia and Trentanovi 2011). In many previously managed forest ecosystems in the Italian Alps, the establishment of a protected area has resulted in abandonment and a subsequent process of "wilderness development" (Höchtl et al. 2005; Garbarino and Pividori 2006; Tattoni et al. 2011). Despite the importance of the secondary succession process in the Italian Alps, only a few studies have documented and quantified the effects of the decline of traditional land-use on landscape structure (Grossi et al. 1995; Tasser et al. 2007; Tattoni et al. 2010; Sitzia and Trentanovi 2011).

In this study, we assessed the land-cover changes in the upper Pesio Valley, where a traditional, long-term, homogeneous forest and pasture management has been strictly associated with the Carthusian religious order of monks. This protected area of southern Piedmont had a long tradition of forest and pasture management followed by a sudden abandonment. Thus, its current landscape pattern, dominated by pasture patches enclosed by forests, can be considered a legacy of the historical anthropogenic disturbance regime. The main objectives of the study were 1, to quantify the land-use changes and landscape structure dynamics in the upper Pesio Valley and 2, assess the effects of grazing decline on pasture patches at both landscape and stand level. A specific goal was to study species composition and the structure of secondary succession within the pasture patches. Management strategies for landscape diversity conservation were also discussed.

2. Materials and methods

2.1. Study area

The upper Pesio Valley study site (44°13' N; 7°40' E) is a 4150 ha watershed (Fig. 1) located within the "Parco Naturale del Marguareis" Regional Park in the municipality of Chiusa Pesio (southern Piedmont, Italy). Average rainfall at Certosa di Pesio (860 m a.s.l.) is 1457 mm year–1, with two peaks in May and November. The bedrock is porphyry and the elevation range is from 780 to 2651 m a.s.l. The watershed is covered by forests typical of the montane belt where silver fir (*Abies alba* Mill.) and European beech (*Fagus sylvatica* L.) occupy 31 and 29% respectively (IPLA 1999). Other important components (17%) of the landscape are the recent secondary forest dominated by common ash (*Fraxinus excelsior* L.) and sycamore maple (*Acer pseudoplatanus* L.) and ravine habitats dominated by sycamore maple and little leaf linden (*Tilia cordata* Mill.).

2.2. Land-use history

The forest and land-use history of the Pesio Valley is strongly influenced by the arrival of the Carthusian monks in 1173. The monks cultivated and favored chestnut (*Castanea sativa* L.) at low

elevations, mainly for the nuts, beech for firewood at mid elevations and silver fir for round timber at higher elevations. This model of silvicultural management was used by the Carthusians at all their monasteries throughout the Alps and Apennines. Until recently, the forests in this valley were intensively managed with three main peak periods of exploitation: 1) between 1760-1854 when the “Savoia” Glass and Crystal factory in Chiusa di Pesio was active, 2) in the early 1900s, just before the 1st World War and, 3) during and following the 2nd World War (Motta and Garbarino 2003). Forest logging became strictly controlled at the end of the 1970s (Piedmont Regional Law No. 84, December 28th, 1978) when the Regional Park was established (Motta and Garbarino 2003). Livestock grazing had been common in these areas since the bronze and copper ages (De Beaulieu 1977). These activities contributed to creating and maintaining large pasture patches (so-called “gias”) enclosed by forest, which effectively lowered the natural treeline.
The average small size of pastures in the area become a limitation for their economic sustainability, and they were gradually abandoned. The main aim of the Natural Park (IUCN category IV) was the preservation of the pure silver fir forest (Prel and Buscaié) and currently, after its natural return, the protection of wolf (*canis lupus*) habitat.
The whole study area falls within Chiusa di Pesio municipality borders, so we considered that the demographic trend of this town, obtained from statistical records (ISTAT 2000), represents the population dynamics of the study site (Fig. 2). Both population and cultivated land areas significantly declined between 1950 and 1990, but there was a turnaround in the last decade of the studied period (1990-2000).

2.3. Landscape analysis
Aerial photographs for the years 1954 and 2000 were used to study the upper Pesio Valley watershed (Table 1). Historical aerial photographs were scanned and orthorectified at 1-m resolution using PCI Geomatica 10.2 (PCI-Geomatics 2010). Automated object-oriented segmentation (scale parameter = 10; 0.5 ha mapping resolution) with eCognition 4.0 (Definiens 2004) was used to delineate polygons that were manually classified into six land-cover classes (‘Dense forests’: >80% crown cover, ‘Sparse forests’: 30-80% crown cover, ‘Meadows’: open grasslands, ‘Pasture patches’: grasslands enclosed by a forest matrix , ‘Rocks’: bare soil, water bodies and rocks, ‘Urban’: streets and buildings). In order to compare land-covers over time, total area must be constant so a seventh land-cover class (‘No data’) was added to both land-cover maps in order to remove shaded areas. The two resulting raster maps were then enhanced in a GIS environment in order to reduce the effect of different input image quality and achieve a minimum mapping unit (MMU) of 0.5 ha. An on screen accuracy assessment using the aerial photos as reference data (Congalton 1991) was performed on each map resulting in a K statistic ranging from 0.87 (92% overall accuracy) for the 1954 period to 0.82 (87% overall accuracy) for the 2000 period.
A change detection analysis was performed first on the whole area, then on two subsamples based on an elevation cutoff of 1500 m a.s.l. This allowed us to disentangle the dynamics of the lower area dominated by forests and enclosed pastures from those of the treeline where open pastures dominated. The elevation cutoff used is particularly appropriate for this environment because it overlaps with the upper altitudinal range of European beech species distribution.
Landscape structure was measured using the spatial analysis program *Fragstats 3.3* (McGarigal and Marks 1995) on land-cover raster-based (1-m resolution) maps for each date, using an 8-cell neighborhood rule. We selected representative metrics (Li and Wu 2004, Cushman et al. 2008) for landscape complexity (e.g. patch density, edge density, and landscape shape index), fragmentation (e.g. core area metrics), aggregation (e.g. division and contagion), and landscape composition and diversity (e.g. Simpson’s index). We expected a general simplification of the landscape due to increased

aggregation of forest patches caused by land abandonment. A further selection on landscape metrics was performed excluding those that were highly correlated ($r > 0.8$) (Tischendorf 2001). Landscape structure was analyzed at landscape level (10 metrics) and at the class level by computing 7 metrics for the 6 land-cover classes for the two time periods.

2.4. Pasture patches analysis

Pasture patches were studied separately because of their cultural value and importance as traditional land-use. Thus, the class 'Pasture patches' was extracted from the land-cover maps of the two periods (Fig. 3) and their characteristics were analyzed in a GIS environment.
Data on the percentage cover of tree regeneration divided by species, shrubs, herbaceous plants and bare soil were visually estimated in the field on 44 pasture patches. These openings were georeferenced with a Trimble GEOXM GPS and their topographic features such as elevation, aspect and slope were derived from a DEM. Two gaps representing two extremes in the gap filling process were selected from the 44 pasture patches and their tree regeneration structure and composition was measured. Gap 1 was completely closed by tree encroachment and gap 2 was still an open area at the time of our field survey. In both gaps, two intersecting transects (20 m wide and between 60 and 90 m long) were established following a North-South and East-West direction. All trees, saplings and seedlings were mapped and their diameter (at 50 cm and 130 cm height), height, and canopy size (4 radii) were measured. An increment core from all trees with a diameter > 1 cm was collected at 50 cm from the tree base, in order to estimate their establishment year. In the laboratory, all the cores were fixed to wooden supports and prepared with a razor to obtain an optimal surface resolution. For cores that did not intersect the pith, its position and the number of missing rings were estimated by means of a pith locator (Duncan 1989). When the number of missing rings could not be estimated, the core was discarded.

3. Results

The total area of forest cover increased in upper Pesio valley study site at the expense of almost all the other land-cover classes (Table 2). 'Sparse forests' and 'Pasture patches' had the strongest reductions (-45.9% and -42.9%, respectively). The 'Meadows' class also decreased (-9.9%), but conversely there was a strong increment (+180%, +9 ha) of human infrastructure in the studied period. The cover of 'Sparse forests' was reduced almost exclusively below 1500 m a.s.l. (Table 3), where the reductions of 'Meadows' and 'Pasture patches' were also stronger. However, the change detection analysis showed that a consistent (78.2%) proportion of the studied landscape remained unchanged.

3.2 Landscape composition

A general increase in landscape heterogeneity from 1954 to 2000 was observed. In fact, several complexity indices (Patch density, Edge density and Landscape Shape Index) increased (Table 4). An increase in aggregation was suggested by the reduction of ENN and Division indices and increase of the Contagion index.
The metrics at class level for the 1954-2000 period (Table 5) showed an increased simplification of polygons classified as 'Dense forests' due to an oversimplification of the shape (LSI) and an increase in core area (TCA and CPLAND). Conversely, the shape complexity of 'Sparse forests' and 'Pasture patches' increased as a consequence of fragmentation of the patches. This was particularly evident for 'Pasture patches' that showed a consistent (-94%) reduction in the Total Core Area.

3.3 Pasture patches dynamics

A total of 83 (1954) and 119 (2000) pasture patches were located by remote detection from aerial photographs of the upper Pesio Valley. The average size of these patches was 1.67 ha and 0.52 ha, and the total patch area was 122 ha and 62 ha, in 1954 and 2000, respectively. Pasture patches total surface area declined by 43% and was severely fragmented during the studied period. Their patch density and shape complexity increased by 75% and 11%, respectively. 75% of the smaller (< 0.5 ha) pasture patches in 1954 had been completely closed by forest, and had disappeared in 2000.

Sycamore maple and common ash were the species dominating the secondary succession within the pasture patches (Fig. 4). Other species such as beech, white birch (*Betula pendula* L.), hazel (*Corylus avellana* L.), wild cherry (*Prunus avium* L.) and goat willow (*Salix caprea* L.) were locally abundant. Pian di Ortet pasture patch was completely invaded by pioneer species such as ash and maple, but some regeneration of beech was also present at the time of the field survey. The closure of the patch started about 40 years ago (Fig. 5). The other surveyed patch (San Michele) was only partially covered by maple that, together with goat willow, began to invade the open area about 40-50 years ago. Beech started to regenerate under their canopy 25 years ago, invading from the original open borders around the patch.

4. Discussion

4.1. Landscape changes

Forest expansion at the expense of open areas was the main land-cover change observed in upper Pesio Valley and was strongly favored by the decline in population and traditional land-use. The two most important landscape change processes were canopy closure ('Sparse forests'-to-'Dense forests' transition) and the expansion of woodlands on old pastures (Meadows-to-Forests and Pasture patches-to-Forest transitions). The observed natural reforestation has a similar pattern to that of other European mountain areas (MacDonald et al. 2000). An increase in human settlements was observed within the study area due to the construction of the village of Ardua in the period 1965-1970. This village was built on one of the largest low elevation meadow-pastures in the area. As on many other sites in the Alps and northern Italy, a concurrent increase in forests and settlements reduced the structural heterogeneity of this landscape. The landscape below 1500 m a.s.l. emerged as the most dynamic one, largely due to the higher density of open areas and fast tree encroachment processes. Because of high site fertility, a strong decline was observed in 'Sparse forests', 'Meadows' and 'Pasture patches'.

The Pesio landscape spatial pattern showed an overall increase in heterogeneity due to the fragmentation of open areas and the expansion of new forest patches. Our spatial analysis at class level showed that the aggregation of 'Dense Forests' increased due to the consistent secondary succession processes, while other classes such as 'Meadows', 'Sparse forests', and 'Pasture patches' became more fragmented and their core areas reduced. Of particular interest is the increasing number of patches of all classes due to the establishment of new 'Dense forests' patches on open areas and the coexisting fragmentation of all the other classes. The increase of landscape fragmentation observed in our study area is in agreement with many studies on landscape changes and reforestation (Sitzia et al. 2010). However, recent research in the Italian Apennines demonstrated that reforestation could be accompanied by simplification and homogenization of the traditional mosaic with no intermediate fragmentation process (Bracchetti et al. 2012).

4.2. Enclosed pasture patches

Pasture patches enclosed by a forest matrix were common elements of the historical landscape in the upper Pesio Valley. The decline of traditional practices and mainly of seasonal pasturing led to a reduction in the overall surface area of pasture patches while increasing their number. This dynamic can be explained by the expansion of new forests that caused the complete closure of smaller patches and the fragmentation of bigger ones. Patch shape reduction was observed at landscape scale, over the time range analyzed due to the encroachment of trees in less accessible areas of the pasture patches (Sitzia and Trentanovi 2011). In some cases the clear-cut borders that existed between pasture patches and surrounding forest were smoothed, creating wider ecotones composed mainly of different species from the matrix. Similar dynamics have also been observed in other Italian (Höchtl et al. 2005; Sitzia and Trentanovi 2011) and European sites (Grossi et al. 1995). The majority of pasture patches or other clearings have disappeared, reducing forest edges and the ecotone areas influencing animal and plant diversity (Ihse and Lindahl 2000; Lütolf et al. 2009; Niedrist et al. 2009). Spatial attributes often determined by land-use legacies are important constraints for plant species diversity, especially where site conditions and management are not influential (Borcard et al. 1992; Svenning and Skov 2005; Sitzia and Trentanovi 2011).

The secondary succession within enclosed pasture patches was dominated by light demanding species such as common ash and sycamore maple. These tree species are widely recognized as being the typical gap fillers of large canopy openings in the montane belt of the Mediterranean basin (Guidi and Piussi 1993; Alberti et al. 2009). Ash was commonly planted near shepherd's huts (Bargioni et al. 1996), as the leaves were used to feed cattle (pollarding) when grass was scarce (e.g. late snowfall). These adult trees are now important seed sources for recolonisation. Other early seral species such as white birch, hazel, wild cherry and goat willow also invaded the pasture patches, but were less common. In our study, we analyzed the regeneration structure and composition of only two pasture patches in order to give a descriptive example of the secondary succession process in the upper Pesio Valley. While we cannot generalize what we observed at local scale for the whole area, our plots can be used as ground controls for the dynamics suggested by the remote sensing analyses. In particular, it was possible to estimate an approximate starting date for gap closure (40-50 years ago), and to confirm that beech seedlings normally establish only after a preparation period of dominance by light demanding species. However, through the field data collection we observed a high variability of the structure and composition of the secondary succession. This variability is strongly affected by the time-since-abandonment and by topographic-edaphic constraints (Chauchard et al. 2007; Gimmi et al. 2008; Tasser and Tappeiner 2002). The most common situation observed in Pesio Valley is that of an early invasion of ash and maple followed a few decades later by beech and secondarily silver fir. This time lag could also depend on frequency of masting years (Piovesan and Adams 2001) and seed dispersal mode (Gimmi et al. 2010). The observed secondary succession on pasture patches was quite fast because of improved soil fertility due to past livestock grazing (Koerner et al. 1999), the availability of seed sources adjacent to the gaps and also to the low competition by other species due to the phytotoxic effect of ash litter (Marigo et al. 2000).

4.3 Management directions

This study highlights how important the legacy of landscape history is (Burgi et al. 2013; Garbarino et al. 2013) for the management of semi-natural grasslands in the Alps. Land-use/land-cover change studies are very important for protected areas (Rocchini et al. 2006) in that they support management activities such as Park zoning, abandoned areas restoration, and wildlife planning (Pedrini and Sergio 2001; Sergio et al. 2005). Landscape change monitoring studies (Tattoni et al. 2011) promote participative planning approaches that are particularly important for cultural landscapes that need to be actively managed to maintain their ecosystem services. Our results on the decline and fragmentation of pasture patches and open areas are generally in agreement with similar studies (Sitzia and Trentanovi 2011; Tattoni et al. 2011) and highlight the need to extend this type of analysis to other Alpine sites.

We suggest that management attention should focus on two concurrent goals: maintaining landscape diversity by limiting secondary succession within open areas and enhancing the structure of the surrounding forest matrix by adopting close-to-nature forestry. The first goal could be achieved by adopting extensive livestock systems, which are economically marginal and less advanced than intensive systems, but can contribute to landscape maintenance (Marini et al. 2011; Sturaro et al. 2009) through the conservation of enclosed pasture patches and fragmented mountain meadow-pasture communities. The second could be attained through transformation of the structurally regular forest matrix (beech coppices and pure mono-layered silver fir stands), that are the heritage of past land-use, into mixed and uneven-aged forests (Motta and Garbarino 2003). Preserving both cultural heritage and diversity of the environment is an important goal for previously intensively managed ecosystems such as those in the montane belt of the outer Alps.

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Table captions

Table 1. Main characteristics of the aerial photographs used in the land-cover change analysis at upper Pesio Valley study site.

Table 2. Transition matrix showing land-cover changes (ha) from 1954 to 2000. Values are expressed in hectares and in percentage (in parentheses) relative to the total area of the class in 1954.

Table 3. Change detection summary statistics (ha) for upper Pesio Valley divided by two altitudinal bands (< 1500 m a.s.l. and > 1500 m a.s.l.). Overall percentage rate of changes for the studied landscape are indicated in the third column.

Table 4. Metrics at landscape-level (McGarigal and Marks 1995) computed for the upper Pesio Valley at two periods (2 land-cover maps).

Table 5. Metrics at class-level (CA = Class Area, PD = Patch Density, ED = Edge Density, LSI = Landscape Shape Index, TCA = Total Core Area, CPLAND = Core Area Percent of Landscape, ENN_MN = Euclidean Nearest Neighbor Mean) computed for the upper Pesio Valley at two periods (2 land-cover maps).

Tables

Table1

Year	1954	2000
Flight	G.A.I.	TerraItaly 98/99
Reference	IGMI 1954	MATTM 2011
Date	October 1954	April 1998 - November 1999
Mean nominal scale	1:65000	1:40000
Film	Panchromatic B/W	Panchromatic Color
Focal length (mm)	153.16	153.31
Mean height (m)	10000	6000
Mean resolution (m)	1	1

Table 2

Land cover in 1954	Land cover in 2000						
	Dense Forest	Sparse Forest	Meadows	Rocks	Urban	Pasture Patch	Total area (ha)
Dense Forest	1898.68 (95%)	37.01 (2%)	37.77 (2%)	8.75 (<1%)	0.32 (<1%)	11.10 (1%)	1993.63 (48%)
Sparse Forest	173.43 (71%)	45.43 (19%)	16.55 (7%)	6.90 (3%)	0.18 (<1%)	1.62 (1%)	244.11 (6%)
Meadow	113.07 (9%)	41.15 (3%)	1028.84 (80%)	98.80 (8%)	0.07 (<1%)	4.95 (<1%)	1286.88 (31%)
Rock	13.69 (3%)	6.73 (1%)	76.93 (15%)	432.03 (82%)	0.00 (<1%)	0.06 (<1%)	529.44 (13%)
Urban	0.43 (9%)	0.00 (<1%)	0.03 (1%)	0.00 (<1%)	4.02 (86%)	0.18 (4%)	4.66 (<1%)
Pasture Patch	45.90 (50%)	2.09 (2%)	0.01 (<1%)	0.46 (1%)	9.16 (10%)	33.82 (37%)	91.45 (2%)
Total area (ha)	2245.20 (54%)	132.41 (3%)	1160.12 (28%)	546.95 (13%)	13.75 (<1%)	51.73 (1%)	4150.16 (100%)

Table 3

	Bands elevation				Overall rate of change (%)
	≤ 1500 m a.s.l.		> 1500 m a.s.l.		
Period	1954	2000	1954	2000	1954 – 2000
Dense Forests	1520.2	1707.6	473.4	537.7	+12.6
Sparse Forests	131.2	19.0	111.0	113.4	-45.9
Meadows	148.5	67.1	1223.1	1144.8	-9.9
Rocks	8.5	5.8	529.9	541.2	+3.4
Urban	4.7	13.7	0.0	0.1	+180.0
Pasture patches	109.5	46.9	12.3	14.8	-42.9
Pasture patches area mean	1.63	0.59	0.77	0.38	-

Table 4

Metrics (abbreviation)	Component measured	Units	1954	2000
Patch density (PD)	Density	n/100ha	7.20	17.73
Edge Density (ED)	Edge	m/ha	107.88	114.50
Landscape Shape Index (LSI)	Edge	-	17.38	18.43
Shape Index Mean (SHAPE_MN)	Shape	-	2.22	1.85
Total Core Area (TCA)	Core Area	ha	2270.30	2292.00
Disjunct Core Area Density (DCAD)	Core Area	n/100ha	4.29	4.68
Euclidean Nearest Neighbor Mean (ENN_MN)	Proximity	m	115.73	85.90
Contagion Index (CONTAG)	Contagion	%	67.34	69.78
Division Index (DIVISION)	Contagion	%	75.63	71.43
Simpson's Diversity Index (SIDI)	Diversity	-	0.69	0.64

Table 5

Land-cover Classes	Year	Metrics (Units)						
		CA (ha)	PD (n/100ha)	ED (m/ha)	LSI (n)	TCA (ha)	CPLAND (%)	ENN_MN (m)
Dense Forests	1954	1993.59	1.06	60.97	14.17	1288.63	31.05	82.88
	2000	2245.23	3.76	57.13	12.51	1609.50	38.78	48.80
Sparse Forests	1954	244.13	2.63	29.50	19.59	35.49	0.86	94.63
	2000	132.42	4.12	23.61	21.28	6.40	0.15	80.68
Meadows	1954	1286.89	1.13	59.15	17.11	675.61	16.28	83.81
	2000	1160.11	3.25	67.26	20.49	491.67	11.85	53.67
Gaps	1954	91.45	1.35	13.56	14.71	6.75	0.16	156.89
	2000	51.73	2.36	11.30	16.3	0.42	0.01	112.83

Figure Captions

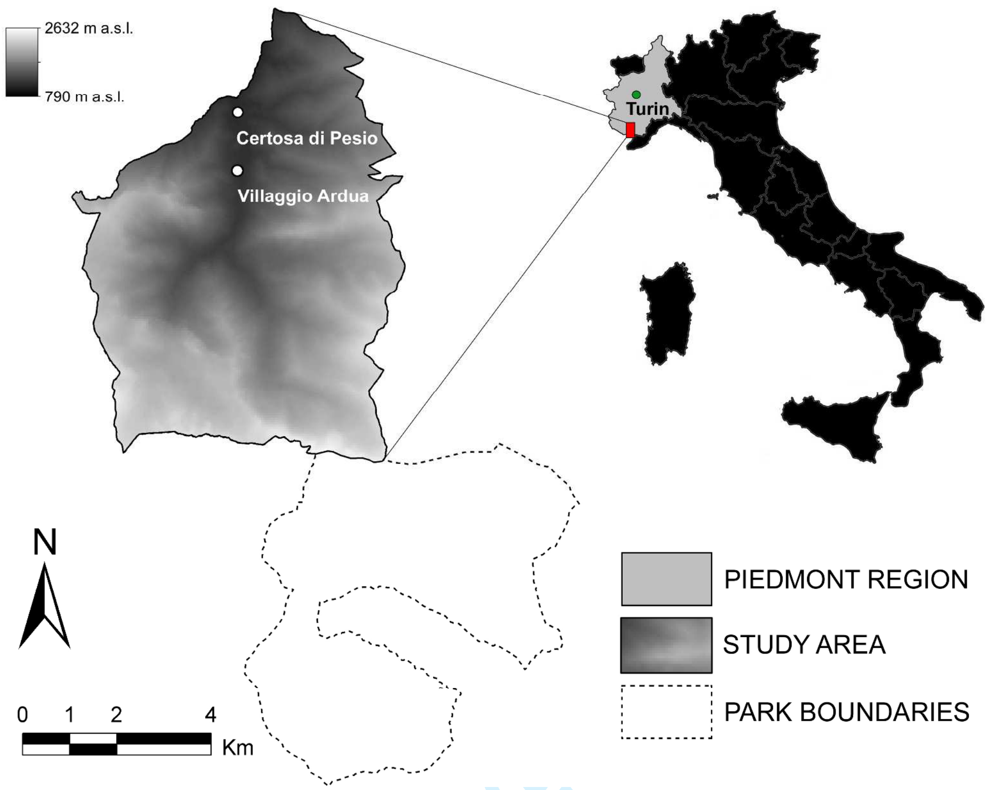
Figure 1. Location of the upper Pesio Valley in the “Parco Naturale del Marguareis” Regional Park. The locations of Ardua village and Certosa di Pesio monastery are also indicated.

Figure 2. Number of residents in the Chiusa di Pesio municipality (black curve). The cultivated surface areas (grey curve) are plotted on the secondary y-axis (data from ISTAT 2000).

Figure 3. Pasture patches (black polygons) maps of the upper Pesio Valley (grey border) derived by photointerpretation of aerial photographs in 1954 (a) and 2000 (b). The topography of the area is showed as a hillshade background layer.

Figure 4. Regeneration composition of 44 surveyed pasture patches in the upper Pesio Valley, calculated as total frequencies of each tree species (*Abies alba*: AbAl; *Fraxinus excelsior*: FrEx; *Fagus sylvatica*: FaSy; *Acer pseudoplatanus*: AcPs; *Salix caprea*: SaCa; *Corilus avellana*: CoAv; *Betula pendula*: BePe; *Prunus avium*: PrAv).

Figure 5. Regeneration structure expressed by age (a, c) and diameter distribution (b, d) of Pian di Ortet (a, b) and San Michele (c, d) pasture patches. Tree species (*Larix decidua*: LaDe; *Abies alba*: AbAl; *Fraxinus excelsior*: FrEx; *Fagus sylvatica*: FaSy; *Crataegus monogina*: CrMo; *Acer pseudoplatanus*: AcPs; *Salix caprea*: SaCa; *Corilus avellana*: CoAv; *Betula pendula*: BePe; Others: rare species) are indicated with different colors.



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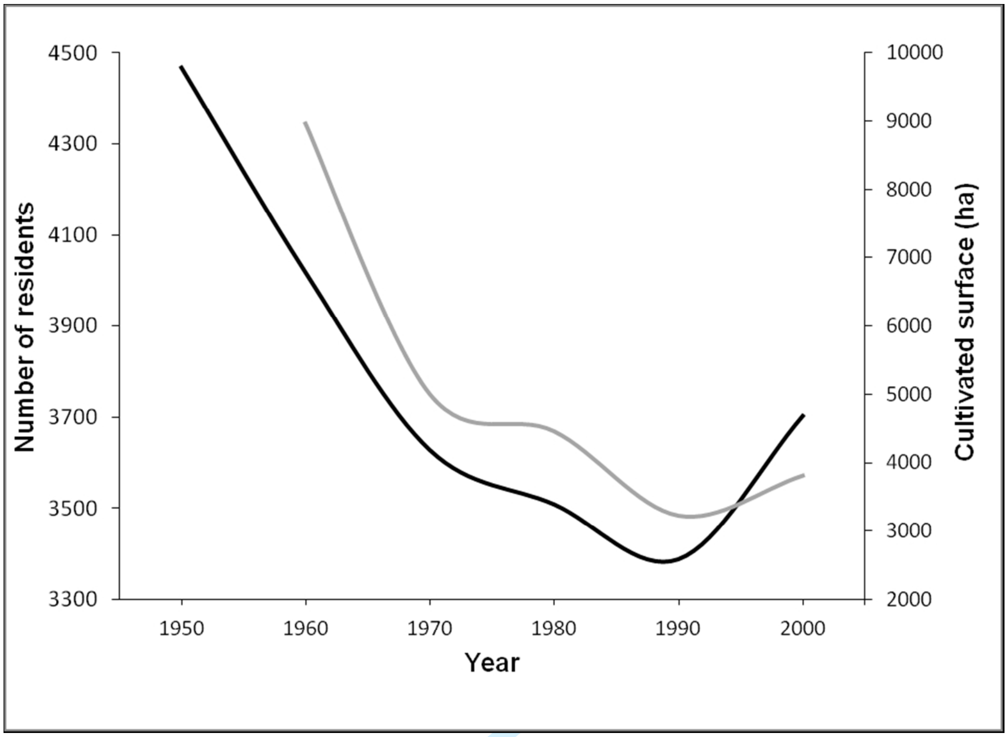

Number of residents of the Chiusa di Pesio municipality (black curve). The cultivated surface (grey curve) are plotted on the secondary y-axis (data from ISTAT 2000).
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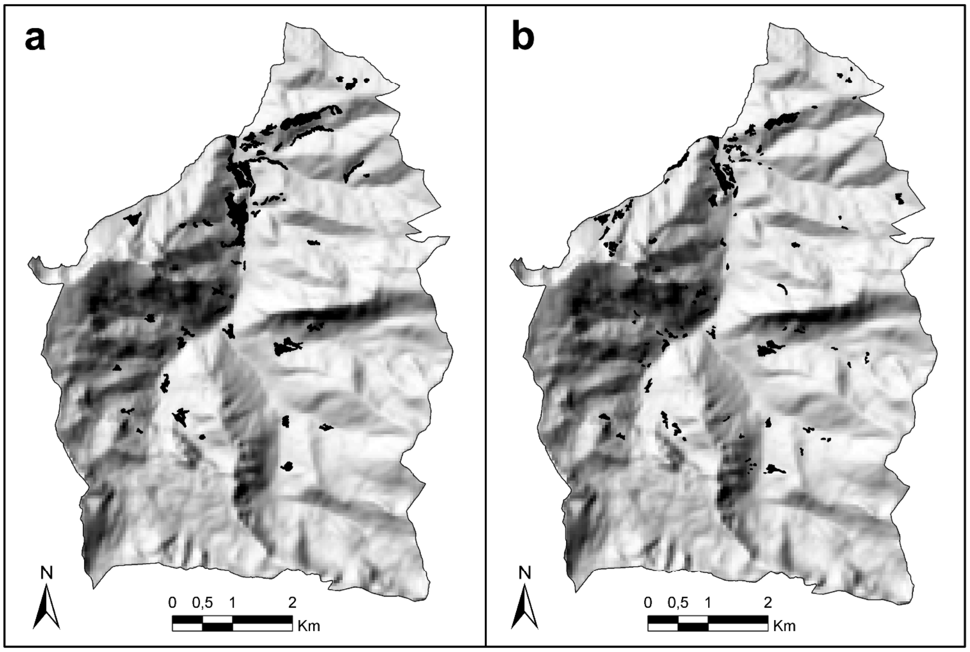

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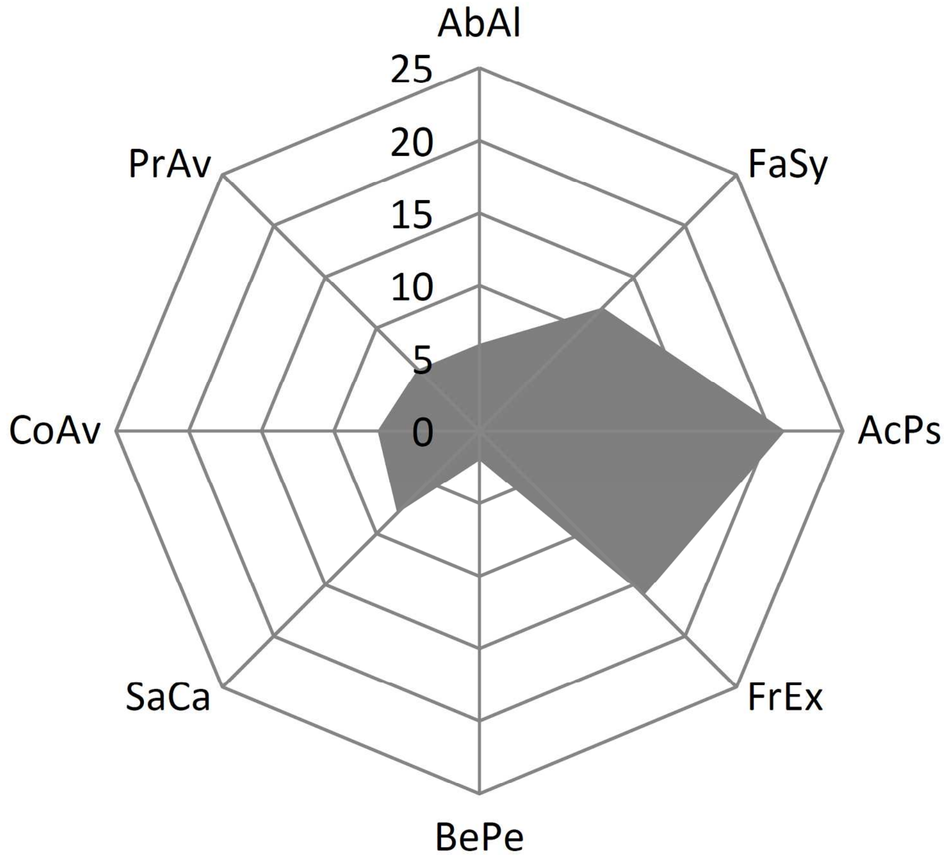

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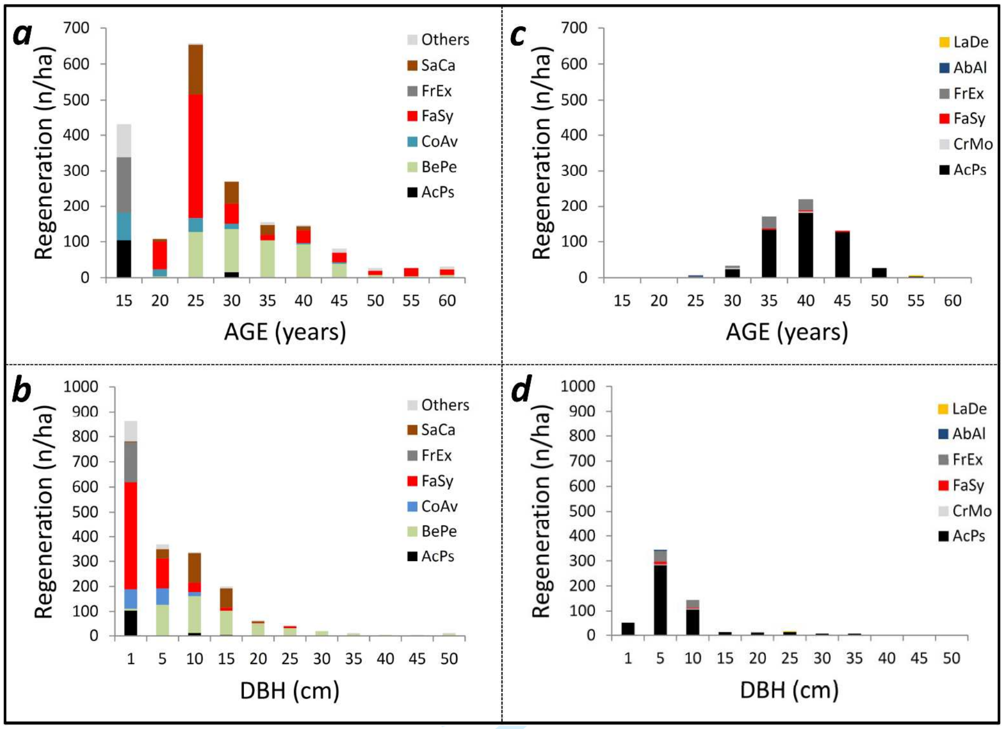

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