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SCOTS PINE FORESTS IN THE NW ITALIAN ALPS. WHAT HAS CHANGED IN THE LAST 50 YEARS?

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Abstract

Pure Scots pine (*Pinus sylvestris* L.) stands occupy an area of more than 28,000 hectares in the western Italian Alps (Aosta Valley and Piedmont). The purpose of this study was to describe forest spatio-temporal dynamics over the last 50 years compared to the land-use change and to analyse the role of the Scots pine in two different ecoregions: intermediate and internal Alps.
In each site an area of about 4000 ha was selected and, following orthorectification and pre-processing, historical aerial photographs (1954, 2000) were analysed. Multiresolution segmentation and object-oriented classification methods were used in order to derive land use maps from the photos. Forest landscape structure has been analysed by means of landscape metrics and relations between topographic features, demographic density, land use changes were assessed.

Keywords: Land use changes, Object-oriented classification, Historical data, Pinus sylvestris L.,Western Italian Alps.

1. Introduction

Mountain landscapes in Europe are privileged areas for the study of interactions between ecological factors and anthropogenic land use practices (Stanners and Bourdeau 1995; Krauchi et al. 2000). Monitoring the causes, processes, and consequences of land-use change allows the assessment of current landscape functions, and provides an opportunity to ascertain the ecological processes linked to the newly arisen landscape patterns (Foster 1992; Burgi et al. 2004).
Since World War II the abandonment of rural areas has been leading to a strong polarization between accessible urbanized areas and underdeveloped rural land (Antrop 2004). A new landscape, predominantly covered by forest, is currently taking the place of the former pastures-meadows-forests mosaic. Abandoned farmland is undergoing a process of colonisation by tree and shrub species, while the reduction in management intensity facilitates the succession of stands composed of early-seral species (Piussi and Farrell 2000). The speed of forest expansion varies across multiple gradients of physiographic attributes, regional climate factors and land use history, i.e., time since the land was last cultivated or grazed (Bebi and Baur 2002; Poyatos et al. 2003).
Scots pine (*Pinus sylvestris* L.) is the second most widespread conifer species in the western Italian Alps, covering more than 28,000 ha. In the continental sectors it is both the early- and late-seral species, dry conditions strengthening its competitive ability (Ozenda 1985). In the

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external-intermediate sectors it is usually a pioneer species, favored by fires and heavy cuts (Gobet et al. 2003) or encroaching on abandoned areas (Naveh 1993). Because of its wide range, its strong early-seral character, i.e., reacting quickly to land-use change, and thanks to its strong dependence on humans for persistence, Scots pine can be assumed as an indicator species in order to investigate landscape dynamics associated with the abandonment of mountain areas.
The aim of this study is to assess landscape dynamics resulting from land-use change over the last 50 years in the Western Italian Alps. We analysed land abandonment patterns in two ecoregions (intermediate and internal Alps) characterized by different climate regimes and socio-economic histories. We are expecting to witness (a) an increasing dominance of forested areas and shrinkage of agricultural lands; (b) enhanced shape complexity of actual forest areas, as compared to more managed landscapes (Mladenoff et al. 1993). The role of local climate, topography and land use history was assessed to explain landscape patterns dynamics in the two sites; we expect forest expansion to be faster on lower elevations, where summer precipitation is high and snow-free season is long, where land abandonment was more pronounced and/or initial fragmentation was higher.

2. Methodology

2.1 Study area

The purpose of this study was to describe forest spatio-temporal dynamics over the last 50 years compared to the land-use change and to analyze the role of the Scots pine in two different ecoregions: intermediate Alps and internal Alps. Two sites in north west Italy were chosen: St. Denis (Aosta valley) is located in the medium part of Aosta Valley characterized by an internal (continental) climate (565 mm year-1 rainfall in Chatillon) and Toceno (Piedmont) characterized by an intermediate climate (1796 mm year-1 rainfall in Craveggia) typical of the northern lake district of Piedmont region. Those areas have undergone large changes in the number of inhabitants during the last 50 years, and even more changes in the proportion on agriculture-related workers. A slight decrease of residents has been observed (6% in St. Denis and 2% in Toceno), while a significant reduction of farmers has occurred (81% and 83% respectively) in both locations.

2.2 Materials and methods

In each site an area of about 4000 ha was selected and, following orthorectification and pre-processing, historical aerial photographs (1954, 2000) were analysed (Ihse 1995, Al-Bakri et al. 2001, etcc.). The aerial photographs were mainly panchromatic, black and white and coloured, respectively at scales 1:55000 and 1:15000. The photos were orthorectified by using the digital photogrammetric software PCI Geomatica 9. The use of orthorectification was necessary to improve the spatial accuracy of the rectified photos (about 20 m RMS in the older photos) and because both sites contained steeply sloping land (Cameron et. al 1999).
An object-oriented image analysis, based on segments and not on single pixels, has been used in order to better relate image objects to real-world objects (Benz et al. 2004, Pillai et al. 2005). This type of analysis provide a more objective tool in the photointerpretation process. A fuzzy logic was used to derive 4 land use maps from the photos and to generate a semi-automatic classification. Therefore 2 land cover categories (forest and non forest) were identified.
After managing the vector spatial data in a GIS environment and converting them into raster (1 m pixel size) transition matrices were computed (Rhemtulla et al. 2002). Relations between topographic features (slope, aspect and elevation) and forest cover changes from the last 50 years were assessed.

A spatial pattern analysis focused on the landscape structure changes and its influence on the ecological processes was developed by calculate several landscape metrics (Ihse 1995, McGarigal and Marks 1995).

3. Results

The two study areas showed a comparable increase in forest cover (about +30%). However, landscape composition at the beginning of the 50-year period was quite different: the proportion of forest cover class in 1954 was 0.35 in St. Denis and 0.53 in Toceno.
In St. Denis, land use change caused an increase in number of patches per unit area and accordingly a decrease in their mean size (table 1). The trend towards fragmentation is not showing up in Toceno (mean patch area: 1 ha, unchanged).
Aggregation indices (Contagion and ENN_MN) show opposite dynamics: in the first area the last 50 years resulted in a more dispersed pattern of landscape categories, while in Toceno a higher degree of clumping is evident (contagion –3.8% and +4.2% respectively). Mean shape complexity increased in both sites, as shown by both DCAD and SHAPE_MN indices (especially in St. Denis).
The elevation pattern of afforestation rates is markedly different between the two sites. In St. Denis we observed the least change from non-forest to forest land cover on two elevation ranges (400-500 and 1300-1500 m a.s.l.) and in the highest parts of the study area. In Toceno newly forested areas are more uniformly distributed among all the elevation classes (figure 1). Referring to slope, flat areas are not interested by significant afforestation processes in neither site (figure 2 and 3). In St. Denis no change in non-forested areas was observed on steep terrain (more than 40°) while the strongest change was associated to medium slope classes (20° to 40°). The highly prevailing southern aspects did not allow us to detect any clear pattern as an effect of this morphological attribute.

4. Discussions

Land use change process trend and its intensity seemed not to be strictly influenced by the different social and economic situation observed in the two study sites. However a big difference in landscape pattern was observed due to a different land cover condition in 1954 (more forests in Toceno) and due to a different economic propensity of the two sites (Toceno is a more marginal land than St. Denis).
The afforestation process in St. Denis was inhibited by several social and economic factors and by local and regional incentives that encouraged a constant human presence on the land. In Toceno the positive weight of climate and rich soil conditions have intensified the invasive process of the early-seral species (e.g. Scots pine).
This increase in forest cover lead up to a more irregular landscape pattern in St. Denis and a more aggregated and regular pattern in Toceno, according to the *patch density* and *mean patch size* metrics. In the latter, the more homogeneous situation was probably due to a uniform abandonment of the whole area, while in St. Denis the maintenance of several pastures and croplands leads to process that caused a complex landscape mosaic.
Furthermore the human presence is mainly localized on more favorable morphological positions and consequently in the same places are concentrated the agriculture relate land use classes.
This general hypothesis is confirmed in St. Denis while in Toceno no morphological variables influences on cover changes were found.
A multidisciplinary and multiscale approach allowed us to deeply analyse the landscape structure and to better understand the role of Scots pine on the land abandonment dynamics.

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Table 1: Landscape metrics computed for St. Denis (SD) and Toceno (TC) at two period examinated.

METRICS		Units	SD 1954	SD 2000	TC 1954	TC 2000
TA	Total Area	ha	3401.7	3401.7	3726.5	3726.5
PD	Patch density	n/100 ha	111.8	145.8	97.8	101.1
LPI	Largest Patch Index	%	57.6	37.8	39.4	57.1
LSI	Landscape Shape Index	-	62.0	83.0	61.5	56.3
AREA_MN	Area Mean	ha	0.9	0.7	1.0	1.0
SHAPE_MN	Shape Index Distribution Mean	-	2.0	2.4	2.0	2.3
PAFRAC	Perimeter-Area Fractal Dimension	-	1.6	1.4	1.5	1.5
DCAD	Disjunct Core Area density	n/100 ha	21.8	27.6	20.4	23.6
CAI_MN	Core Area Index Distribution Mean	%	0.07	0.05	0.16	0.14
ENN_MN	Euclidean Nearest Neighbor Distance Distribution Mean	m	10.1	8.3	10.4	11.7
CONTAG	Contagion	%	66.0	62.8	64.1	68.3
AI	Aggregation Index	%	97.9	97.2	98.0	98.2

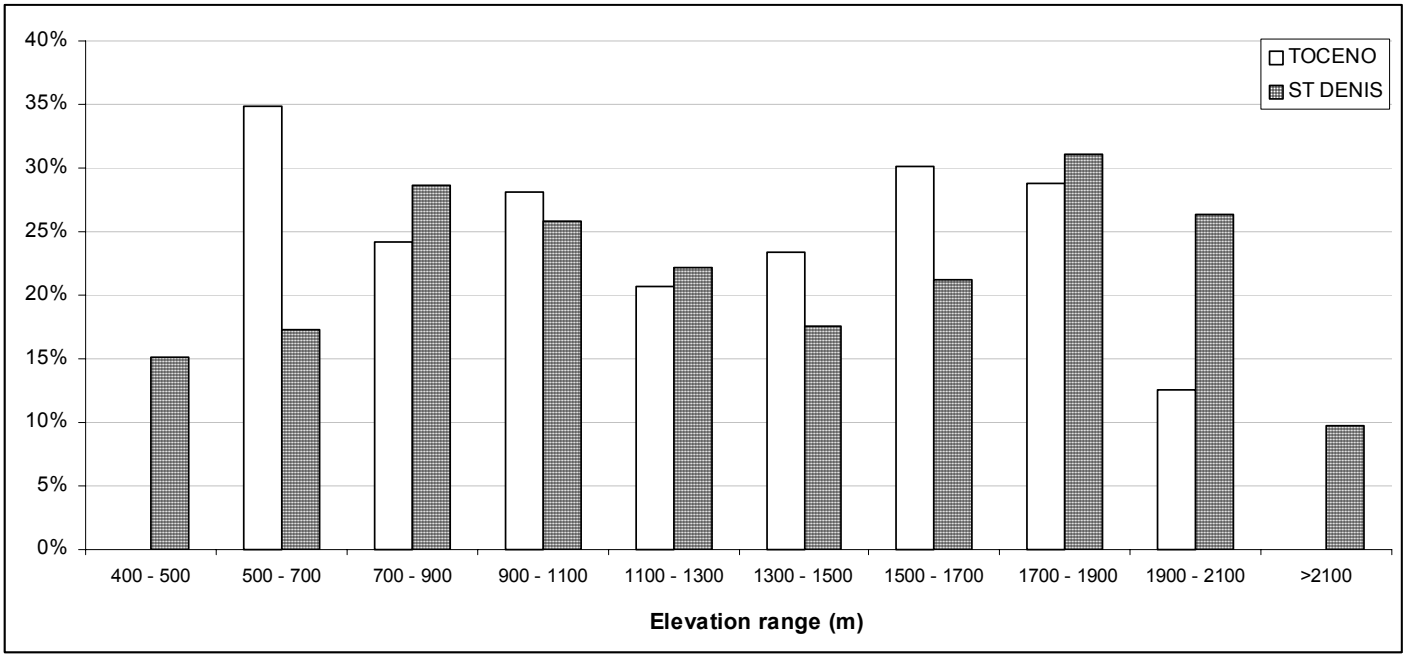

Figure 1: Percentage of afforested areas in the two sites according to different elevation classes.

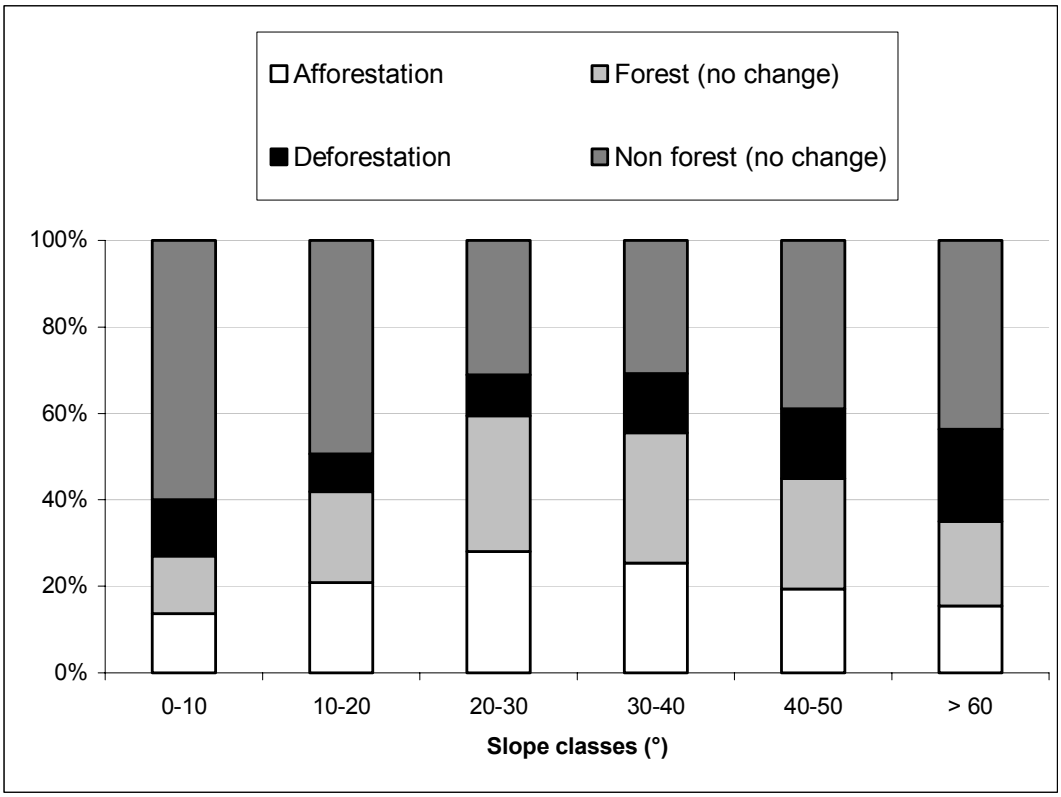

Figure 2: Land use changes in St. Denis. Percent area partitioned by slope.

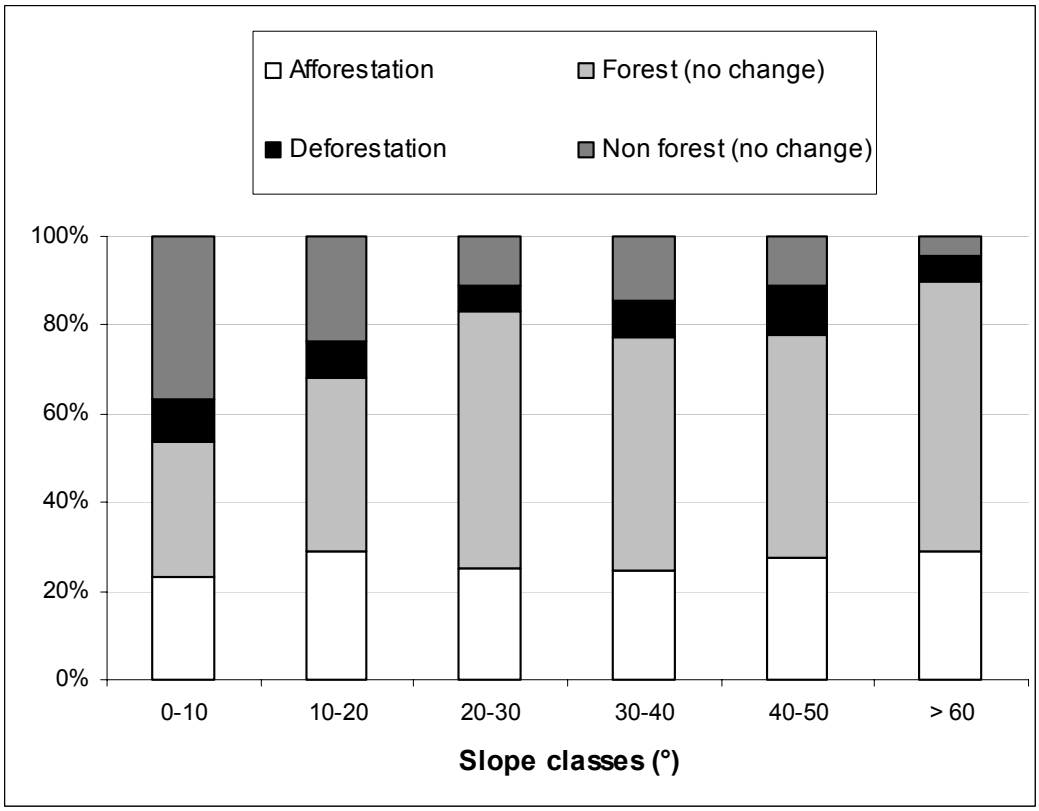

Figure 3: Land use changes in Toceno. Percent area partitioned by slope.