Allegato 4a_2

Land use changes in the Gran Paradiso National Park

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Introduction

Mountain ungulates such as Alpine ibex *Capra ibex* and Alpine chamois *Rupicapra rupicapra* are habitat specialists adapted to the harsh conditions of the Alpine ecosystem, and are therefore particularly vulnerable to environmental changes. During the last decades mountain habitats have witnessed significant vegetation changes due to land abandonment by humans, changes in the management of domestic ungulates and climate change. Global warming has been particularly pronounced in mountain regions during the last century (Beniston 2003), leading to different consequences on vegetation, including an upward shift of the communities (Walther et al. 2005) and a slow migration of the tree limit in the Alps (Dullinger et al. 2004). This is particular important for herbivore species such as ungulates, for which changes in plant communities mean variations in quantity, quality and availability of food resources.

In spring and summer, both Alpine ibex (Grignolio et al. 2003) and chamois (Darmon et al. 2012) selected areas located at high altitudes, above the timberline, characterized by the presence of Alpine meadows (to accumulate as much fat as possible for the winter) and fallen rocks or stone ravines; in winter ibexes prefer rock-faces, where the risk of avalanches is low and where it is still possible to find snow-free patches, while chamois make higher use of wooded areas.

An assessment of the changes in vegetation and land use occurred during the last 25 years will be therefore useful to understand their role in the population trends of mountain ungulates, in order to give to the stakeholders an instrument to support the health and long-term persistence of these populations in face of future environmental changes.

Methods

Corine Land Cover

Corine Land Cover maps (CLC1990, 2000 and 2006, freely available from http://www.eea.europa.eu/data-and-maps) are the output of the Corine (Coordination of Information on the Environment) Programme of the European Commission, implemented in most of the EU countries, as well as in Central and Eastern European countries, in order to create an information system on the state of the European environment. The Corine Land Cover inventory is based on images acquired by earth observation satellites (Landsat-7, SPOT-4, and IRS P6) as the primary information source to derive land cover information (European Environment Agency 2007). Main technical parameters (scale - 1:100.000, minimum mapping unit - 25 hectares, and minimum width of linear elements - 100 metres), are the same for the three Corine land cover maps (Heymann et al. 1994). The standard CLC nomenclature includes 44 land cover classes, grouped in a three-level hierarchy. The five main (level-one) categories are: 1) artificial surfaces, 2) agricultural areas, 3) forests and semi-natural areas, 4) wetlands, and 5) water bodies (Heymann et al. 1994). Land cover changes from one map to the following, with an extension of at least 5 ha, have been mapped; changes should refer to real evolution processes and not to different interpretations of the same subject (Feranec et al. 2007).

For the purpose of this study, the three Corine maps (in vector format) were clipped on the Gran Paradiso National Park (hereafter GPNP) boundary and the area covered by each land cover class was calculated. Then, the overlap between the CLC1990 and CLC2000, and between the CLC2000 and CLC2006 was performed in order to detect the land use changes.

Physiognomic vegetation maps

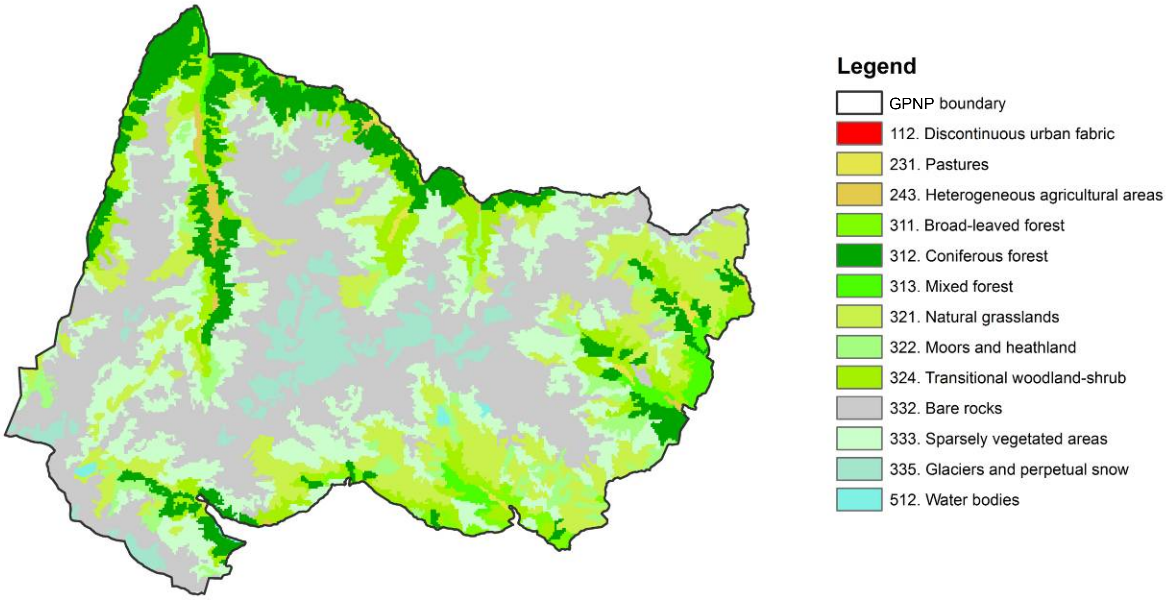
Three physiognomic vegetation maps (1988, 2001 and 2009) were recently drawn for sample areas of Piedmont and Val d'Aosta regions, including the GPNP (Martinasso 2012). These maps were obtained by interpreting three Landsat images (Landsat TM for 1988, Landsat ETM+ for 2011 and 2009), using 9 physiognomic classes: 1) rocky areas, 2) grasslands, 3) shrublands, 4) sparse coniferous forests, 5) dense coniferous forests, 6) broad-leaved forests, 7) snowfields, 8) glaciers, 9) lakes. Each pixel (30 x 30 m) has been assigned one of the physiognomic classes using the supervised classification method according to the maximum likelihood criterion; the classification was then validated through already classified Landsat images, Digital Terrain Models (DTMs) of Piedmont and Val d'Aosta, aerial photographs of the Italian National Geoportal and field validation (Martinasso 2012). Also in this case, the three vegetation maps (in raster format) were clipped on the GPNP boundary, and the area covered by each physiognomic class was calculated. Then the couples of images 1988-2001 and 2001-2009 were superimposed in order to find the pixels that changed in a different class during the periods considered.

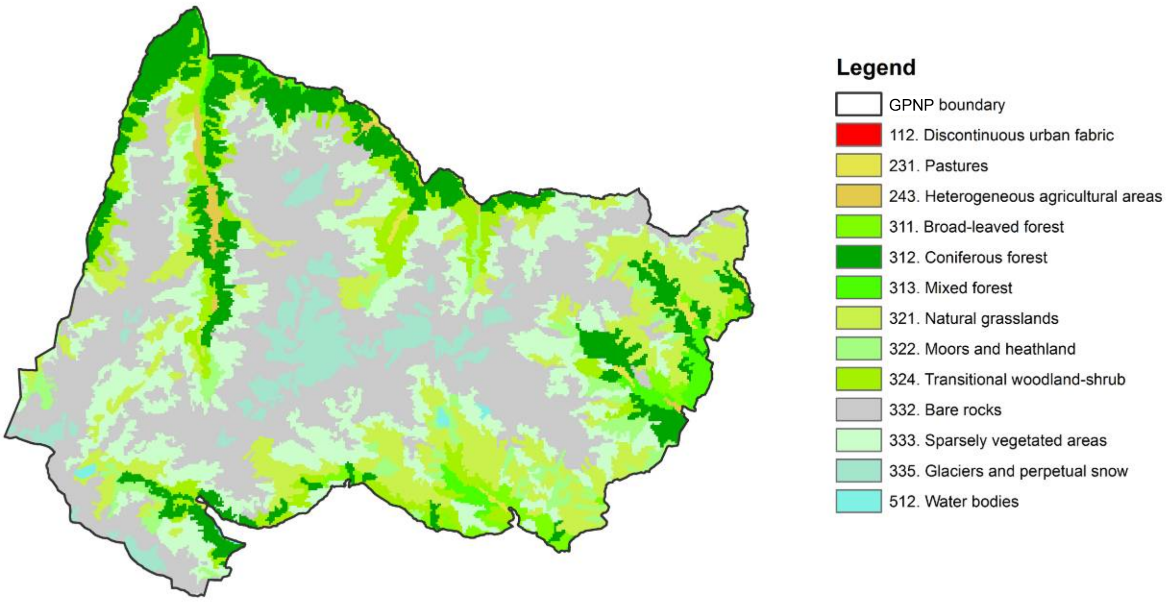
The analysis of maps was performed using the ArcGIS 9.3 software by Esri, with the Spatial Analyst Tools and Hawth's Analysis Tools (Beyer 2004) extensions.

Results

Corine Land Cover

According to the Corine land cover classification, in 1990 36.17% of the GPNP area was covered by bare rocks and 19.16% by sparsely vegetated areas (Fig. 1 and 2).


Legend
GPNP boundary
112. Discontinuous urban fabric
231. Pastures
243. Heterogeneous agricultural areas
311. Broad-leaved forest
312. Coniferous forest
313. Mixed forest
321. Natural grasslands
322. Moors and heathland
324. Transitional woodland-shrub
332. Bare rocks
333. Sparsely vegetated areas
335. Glaciers and perpetual snow
512. Water bodies


Legend
GPNP boundary
112. Discontinuous urban fabric
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312. Coniferous forest
313. Mixed forest
321. Natural grasslands
322. Moors and heathland
324. Transitional woodland-shrub
332. Bare rocks
333. Sparsely vegetated areas
335. Glaciers and perpetual snow
512. Water bodies

and

Another 13.81% was covered by natural grasslands (a land use class that corresponds mainly to Alpine meadows), and the classes moors/heatland and transitional woodland-shrub represented altogether 11.82% of the Park. Coniferous forests were far more widespread than broad-leaved forests (covering 9.58 and 0.87%, respectively), while the agricultural areas and pastures covered only 1.18% of the protected area. Glaciers and snowfields covered 5.45% of the Park, and other classes (water bodies and urbanized areas) were negligible (Fig.1 and 2).

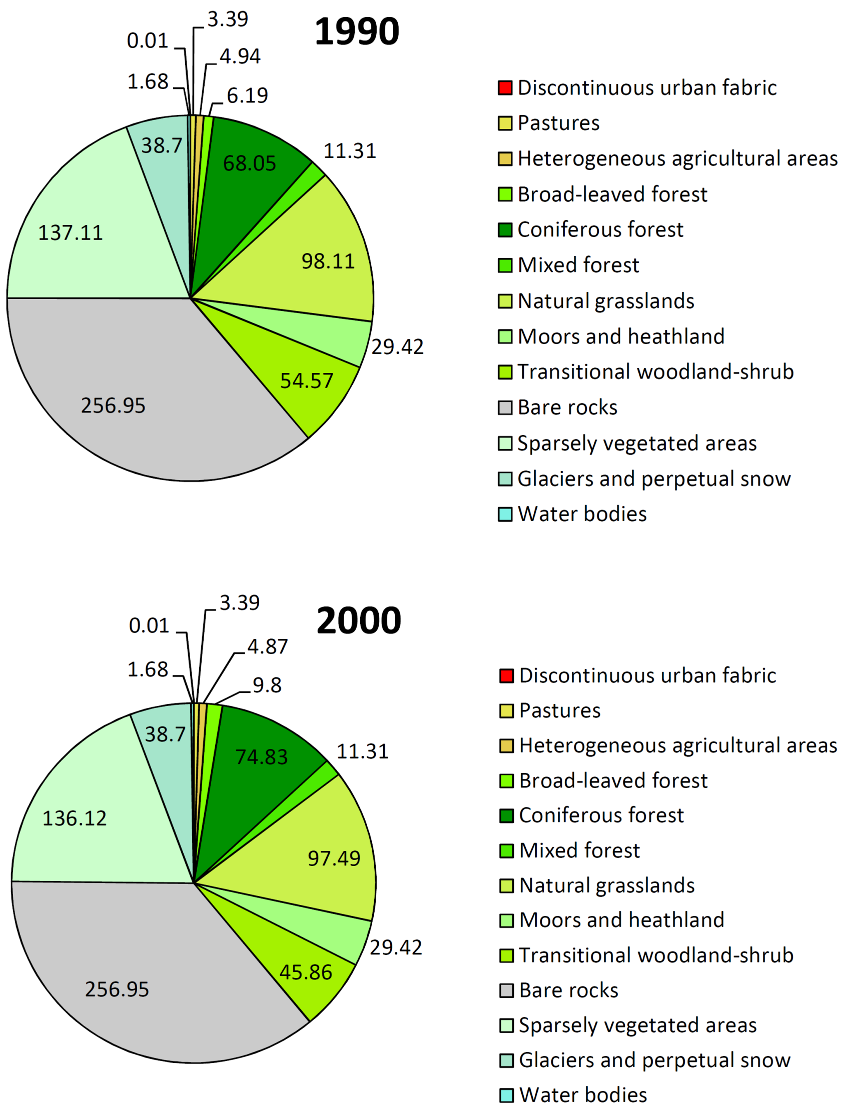

Fig. 2. Areas (in km^2) of each land use class in the Corine land cover (CLC) maps of the Gran Paradiso National Park in 1990 (upper panel) and 2000 (lower panel). CLC map of 2006 is identical to CLC 2000 within the Park boundaries.

1990-2000

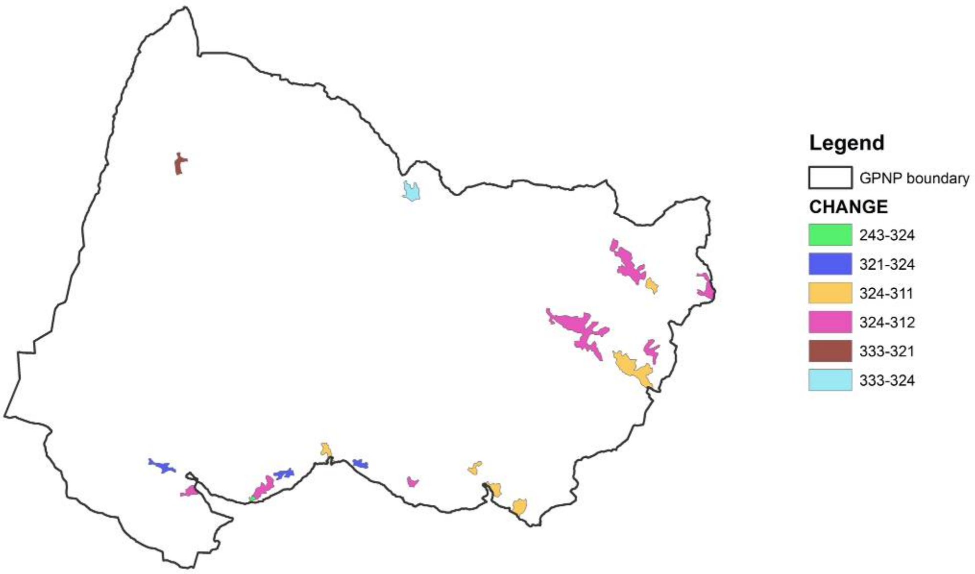

Fig. 3. Patches of land use change between 1990 and 2000 in the Gran Paradiso National Park according to Corine land cover classification.

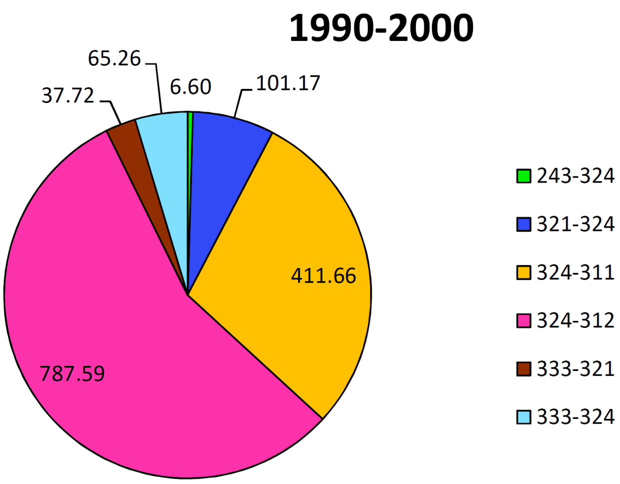

Fig. 4. Areas (in ha) of each type of land use change between 1990 and 2000 in the Gran Paradiso National Park according to Corine land cover classification.

Between 1990 and 2000 some changes occurred in the natural vegetated areas (Fig. 3 and 4). In particular, 14.43% of the transitional woodland-shrub present in 1990 turned into coniferous forest (7 patches), while another 7.54% turned into broad-leaved forest (7 patches). On the other hand, 1.03% of natural grasslands (3 patches) and 0.48% of sparsely vegetated areas (1 patch) turned into transitional woodland-shrub in 2000, while 0.28% of sparsely vegetated areas turned into natural grasslands (1 patch). Other changes can be considered negligible. Altogheter these land use changes represent 1.98% of the GPNP area (Fig. 3 and 4). No changes were recorded between the CLC1990 and CLC2000 within the GPNP boundaries.

Physiognomic vegetation map

According to the classification of the physiognomic vegetation map, in 1988 39.85% of the Park area was covered by bare rocks, 24.18% by grasslands and 4.49% by shrublands (Fig. 5). Sparse and dense coniferous forests were the more widespread woods (covering 5.44% and 7.73%, respectively), while broad-leaved forests covered only 1.50% of the protected area. Glaciers, snowfields and water bodies (3.48%, 13.12% and 0.21%, respectively) covered the rest of the GPNP area (Fig. 5). Changes in the vegetated areas detected with this method were more complex (Fig. 6). Considering only the changes that involved a total area over 3 km^2 (and ignoring changes between glaciers and snowfields, and vice versa), we can observe between 1988 and 2001 20.12 km^2 of grasslands turning into bare rocks, while the reverse was observed for 19.27 km^2; 7.70 km^2 of sparse coniferous forests might have turned into grasslands (5.70 km^2 the reverse), 6.44 $km^2$of shrublands into grasslands (3.11 km^2 the reverse), 6.06 km^2 of sparse coniferous forests into shrublands (4.31 km^2 the reverse), 5.10 km^2 of dense coniferous forests into bare rocks (4.65 km^2 the reverse), 4.94 km^2 of dense coniferous forests into sparse coniferous forests (3.92 km^2 the reverse), 4.88 km^2 of shrublands into bare rocks (2.41 km^2 the reverse), and 3.79 km^2 of dense coniferous forests into shrublands (2.91 km^2 the reverse).

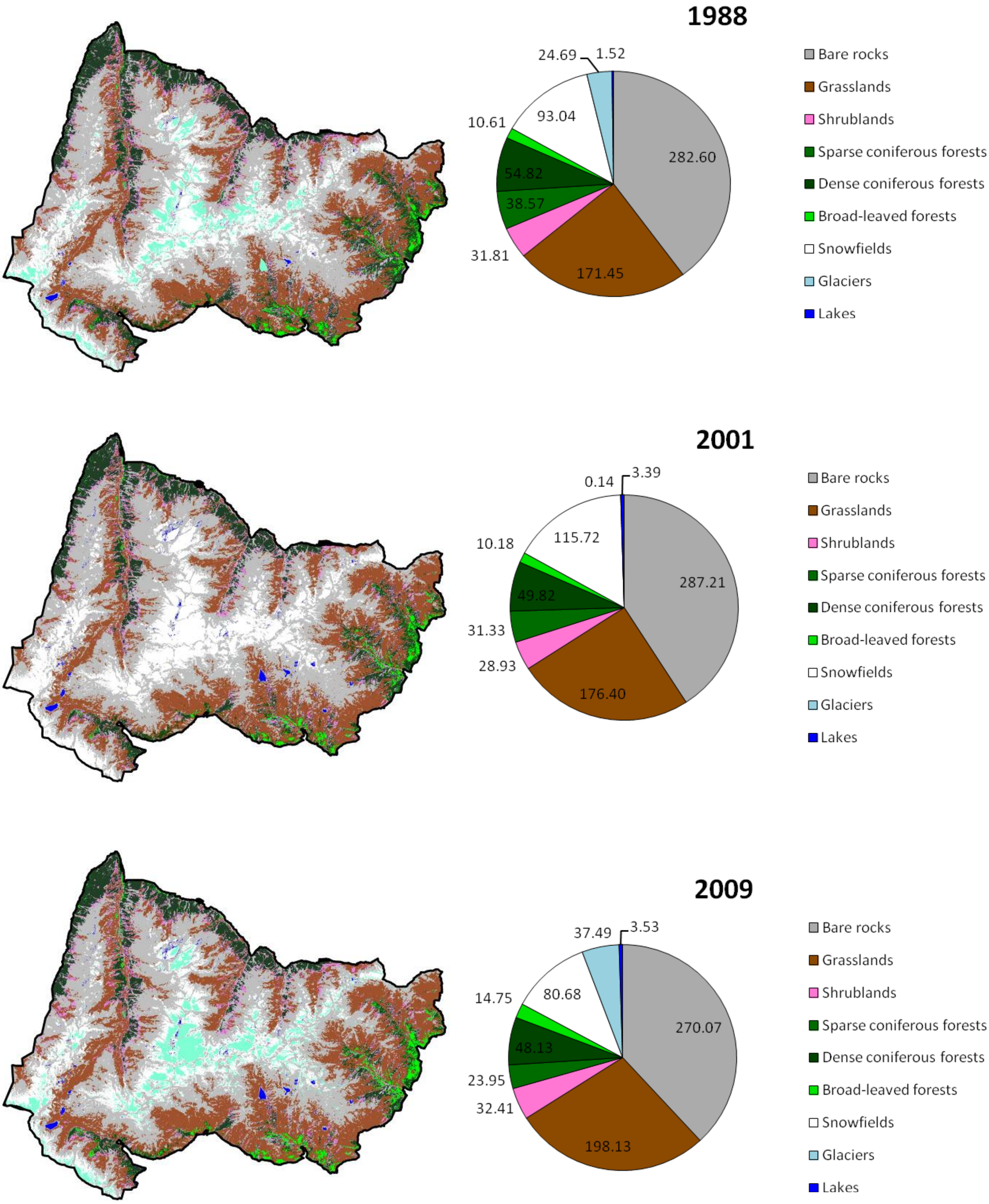

Fig. 5. Physiognomic vegetation maps of the GPNP in 1988, 2001 and 2009, obtained through the supervised classification of three Landsat images.

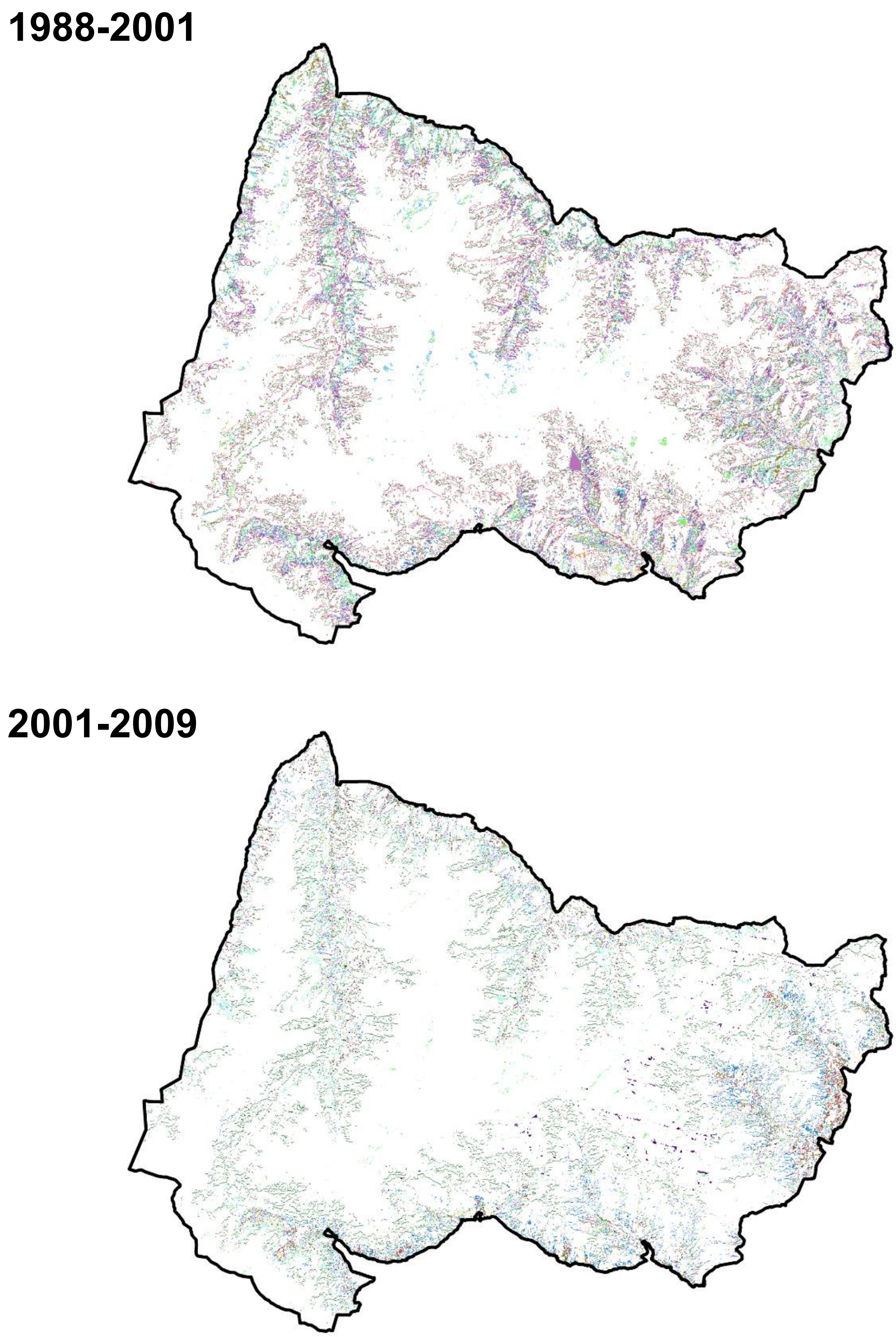

Fig. 6. Changes in the vegetated areas between 1988 and 2001 (upper panel) and between 2001 and 2009 (lower panel) in the Gran Paradiso National Park according to the physiognomic vegetation maps. Each coloured pixel indicates a change between two physiognomic classes. Changes between snowfields and glaciers (and vice versa) have been ignored.

Between 2001 and 2009 19.28 km^2 of bare rocks might have turned into grasslands (0.27 km^2 the reverse), 7.38 km^2 of sparse coniferous forests into grasslands (0.91 the reverse), 5.66 km^2 of grasslands into shrublands (0.45 km^2 the reverse), 4.37 km^2 of dense coniferous forests into bare rocks (2.48 km^2 the reverse), 4.30 km^2 of dense coniferous forests into sparse coniferous forests (3.59 km^2 the reverse), and 3.69 km^2 of sparse coniferous forests into broad-leaved forests (1.11 km^2 the reverse).

Discussion

Corine land cover maps highlighted a closure of the wood between 1990 and 2000, as well as an upward shift of the natural grassland limit. These effects can be due both to changes in human land use (land abandonment) and to climate change. However, only a specific and annual study on sample areas can disentangle the role of the two factors.

Between 2000 and 2006 no changes in land use have been detected within the GPNP boundaries by the Corine project. It is possible that the time span (6 years instead of 10) was too short to detect changes in the vegetated patches, or that the extension of the changed patches was too small (smaller than 5 ha, not detected by Corine land cover). Another possibility is that the drivers that led to changes in the previous period (human land use or climate change) slowed their pace in the second period.

This is particular important for mountain ungulates, as both the closure of the wood and an upward shift of the communities mean a reduction of favourite habitats during spring and summer, when it is particular important for these large herbivores to accumulate fat for the winter. Further monitoring of this changes are therefore necessary for the conservation of Alpine ibex and chamois.

As regards the physiognomic vegetation maps, changes detected between 1988 and 2001 and between 2001 and 2009 are numerous and often senseless, in particular during the first period. It is possible that the supervised classification failed to classify correctly a part of the pixels, or that the high resolution (30 m) used led to a non-perfect overlay of the maps. Therefore, this method is likely not suitable for a study of land use changes in the medium term.

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