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The pedological heritage of the Dolomites (Northern Italy): Features, distribution and evolution of the soils, with some implications for land management

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ABSTRACT

Since 1997, the Department of Environmental Sciences of Ca' Foscari University of Venice has undertaken numerous research projects aimed at deepening understanding of pedogenic processes in the Dolomites, and at highlighting the fundamental contribution that soil science can give to the conservation of natural resources and achieve sustainable management of mountain ecosystems. A total of several hundred profiles have been described, analyzed and mapped. This paper reports the results from the analysis of pedo-environmental characters of profiles developed from different parent materials, at altitudes between 1300 m and 2900 m and in different conditions of slope, exposure and vegetation cover. Soil forming factors, landforms and land surfaces have been interpreted to understand the soil-landscape in the mapped areas and to develop a qualitative model of soil geography into the Dolomites scenery. The application of land evaluation methods in some of the investigated territories that are subjected to intensive tourist fluxes revealed some criticisms. Collected results also highlighted the high environmental heterogeneity of soils of the Dolomites.

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1. Introduction

The Alpine environment has always attracted human attention, not only for its natural aspects, (rocks, glaciers, flora, fauna and streams), but also for esthetic reasons through its peerless sceneries of mountain landscapes, where soils contribute with their heterogeneity in morphology, colors and horizons. Soils of the Alpine environment occur extensively throughout the major mountain systems of the world, such as the Alps, the Andes, the Himalayas and the Rocky Mountains, and to a lesser degree in other mountainous areas, at elevation ranging between 1500 and 3000 m a.s.l. In Italy their greater extent is in the Alps (Previtali, 2002), but small areas of such soils occur also in the Apennines Chain (Baroni et al., 1990). In recent years, soils of the Dolomites region, in the eastern Italian Alps, have been studied by several scientists (Zilocchi, 2003; Sartori et al., 2005; Bini et al., 2008; Egli et al., 2008; Merkli et al., 2009), who outlined soil genesis and evolution under different lithological, geomorphologic and climatic conditions. Nevertheless, studies on the geographical distribution, pedological features and processes of soils in the alpine environment, as well as the development of interpretative schemes of the soil variability of the Alps, are far from being complete.

The Dolomites region, in Northern Italy (the name Dolomites comes from the Triassic calcareous rock discovered by the French geologist Dolomieau) is characterized by an enormous variability of soil landscapes, due to the quite young geological structure, to different lithological types and to morphological dynamics (Previtali, 2002; Merkli et al., 2009). Both geological and climatic conditions, as well as anthropogenic activities (e.g. skiing installation), contribute to landform processes: frequent landslides, rock falls and current erosion processes modify the landscape, and influence soil formation and evolution (Hall et al., 2002; Egli et al., 2003), besides posing serious threats to local people and to tourists.

The variety of the Dolomites landscape, deriving from the combination of different rocks, steep slopes and gentle footslopes, pasture and forest stands or dry and bare meadows (Sburlino et al., 1999), is known all over the world, and was recently (2009) recognized by the UNESCO as a World Human Heritage. The complexity of the geology adds difficulty to the study of the soil cover of the area, but at the same time it makes it extremely interesting, and allows a complete panorama of soils in this mountain and alpine environment.

In this work, most effort is concentrated on alpine and subalpine soils located in the center of the Dolomites Group, at elevations ranging between 1500 and 2400 m a.s.l. The main objective of the study is the characterization of the soils of the Dolomites mountains. In relation to this objective, it is possible: i) to investigate the role of the different soil forming factors and processes in the alpine environment, and ii) to develop a qualitative model of soil evolution and geography in the Dolomites landscape.

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Soils are fundamental components of ecosystems. The stability of mountain ecosystems depends primarily on soil conservation. Alpine soils are of particular concern because of their potential role in neutralizing acid deposition (Rochette et al., 1988; Briggs et al., 1989), in acting as a sink for atmospheric carbon dioxide (Garlato et al., 2009), and contributing to slope stability and protection from erosion (Harden, 2001; Bini et al., 2010), through the maintenance of traditional agricultural and forest activities.

A second objective of this study, therefore, is to assess the role and function of soil in controlling the geomorphologic fragility of the terrain, where an increasing number of tourists, changes in land use, and climate change are expected to intensify soil erosion (Bosco et al., 2009). This objective may be achieved by evaluating the actual soil erosion hazard, and the land suitability for different land uses (e.g. agriculture, forestry, pasture, and tourism), thus providing useful tools in soil protection strategies and sustainable land planning.

2. Study area

The Dolomites' range is located in the northeast region of the Italian Alps (Fig. 1, Table 1), where it covers approximately 140,000 ha, including eighteen peaks which rise to above 3000 m. Elevation ranges between 900 and 3400 m (Marmolada Glacier). Because of the landscape's exceptional beauty, the scientific relevance, and based on their outstanding universal value, the Dolomites have been added to UNESCO's World Heritage List in June 2009. Within the whole area designated by UNESCO, six reference sites located in the central part have been selected on the basis of their great geological and geomorphologic variability (Bosellini, 1996), with a close connection between rocks, landforms, vegetation cover and soil development.

The selected areas, moreover, also represent some of the most naturalistically and economically important areas of the Dolomites, among which Cortina is known as the Dolomites' pearl, one of the most famous tourism places in the world.

Table 1
Extensions and elevation ranges of studied sites.

Site name	Province	Extent (km^2)	Elevation range (m a.s.l.)
Paneveggio-Pale S. Martino Regional Park	Trento	197	1200–2400
Fassa valley	Trento	200	1175–2810
Valfredda valley	Belluno	5	1800–2400
Gares valley	Belluno	36.5	890–3192
Cortina d'Ampezzo territory	Belluno	255	1224–3244
Visdende valley	Belluno	70	1250–2700

2.1. Geology and geomorphology

The geology and lithology strongly influence the geomorphology of the studied areas, through karst processes (where the mountain ranges consist predominantly of limestone and dolomite) and differential erosion processes, enhanced by the high variability of rocky outcrops, due to both erosional and tectonic processes (Neri and Gianolla, 2007). Yet, the main parent materials outcropping in the six areas can be divided into four main lithological domains (Sartori et al., 2005; Neri and Gianolla, 2007):

* areas of calcareous rocks highly resistant to erosion;
* areas of siliceous metamorphic and volcanic and sandstones which can vary from resistant to moderately resistant to erosion;
* areas of outcrops of marls, conglomerates and sandstones which can vary from moderately to poorly resistant to erosion;
* areas of recent (Plio–Pleistocene and Holocene) deposits; glacial, alluvial and colluvial materials, which are composed exclusively of calcareous or siliceous lithotypes, or of a mixture of them, with different degrees of heterogeneity (Corsini et al., 2001).

Some of the study areas (e.g. Cortina) also show important examples of different types of ancient and active landslides (collapse, overturning, sliding), which have a primary role in the morphological

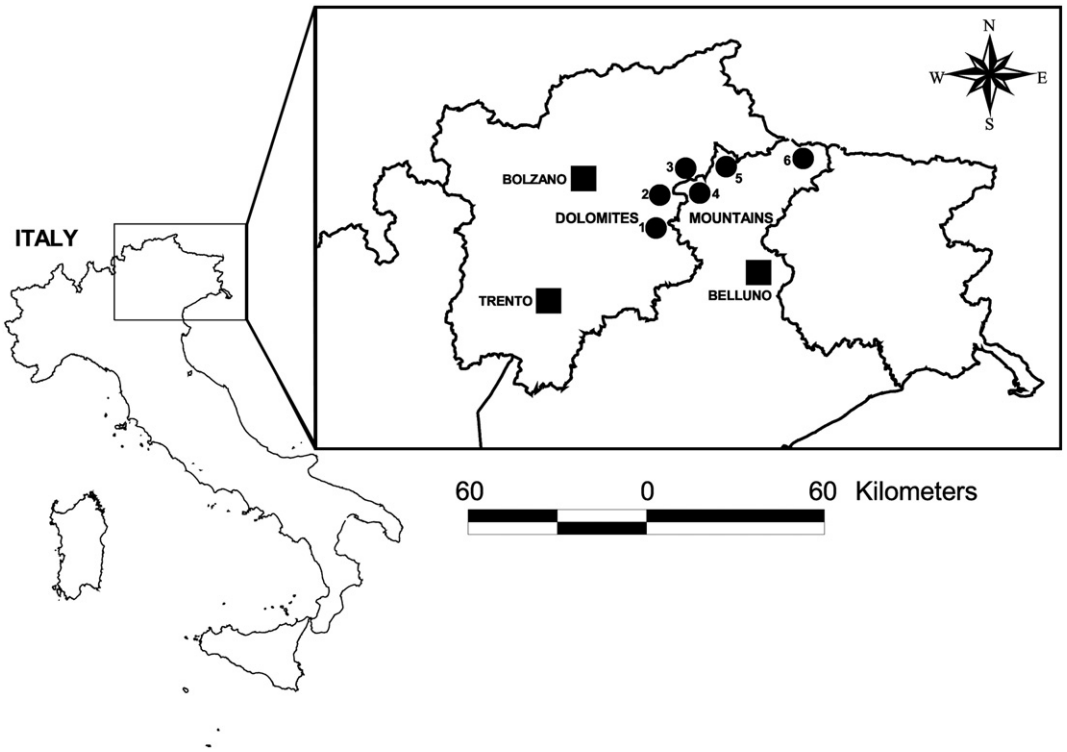

Fig. 1. Research area and selected sites in Trento and Belluno provinces (NE Italy): (1) Paneveggio-Pale S. Martino Regional Park, (2) Fassa valley, (3) Valfredda valley, (4) Gares valley, (5) Cortina d'Ampezzo territory, and (6) Visdende valley.

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