Soils as a target of anthropogeographic landscape changes in alpine areas (Dolomites, northern Italy)

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Abstract
The paper deals with the study of soils as a target of human-induced landscape changes in a typical alpine area, in the Dolomites region (Italy). A general soil survey allowed identification of different landform units in terraced soil systems. Forty representative soil profiles developed from limestone and under different vegetation cover (meadows, pasture, forest and agricultural land) were opened and sampled for routine analyses. Selected soil properties, both physical (soil structure, porosity, texture, root penetration depth, skeleton, water retention) and bio-chemical (pH, nutrient status, carbonate content, solute translocation, organic matter content and transformation, soil fauna activity) allowed assessment of the consistent effects of land use change on soils and soilscapes. Different evolutionary stages were recorded in the changing terraced landscape:

- little degradation under permanent meadow (older than 50 years);
- moderate degradation under forest (30 - 50 years);
- high degradation under abandoned forest (<50 years).

Dynamic soil properties, and the processes involved, proved greatly useful to understand transformation mechanisms and to assess possible consequences of land abandonment on soils and the whole environment.

Key Words
Terraced landforms, anthropogenic soils, land use, dynamic properties.

Introduction
The European Landscape Convention, subscribed by 27 States of the European Union (E. U. 2000), defines the landscape as a portion of land whose characteristics derive from natural and/or human factors, and which plays important general functions. The soil is defined, in turn, as part of the landscape, resulting from the synergism of different environmental factors, as expressed by the well known equation (Jenny 1941):
S= f(cl,o,r,p,t).
The increasing influence of human activities on the landscape and the transformation of the traditional socio-economy towards new development models has determined consistent effects on soils, particularly in mountainous areas. The progressive marginalisation of such areas as a consequence of land abandonment, in the whole alpine arc, has noticeable effects on soils and soilscapes, namely:

1. at ecological and environmental level:
   - Progressive re-naturalisation of open spaces;
   - Biodiversity reduction;
   - Slope instability;
   - Hydrogeological hazard;
   - Potential forest fire increase;

2. at economic level:
   - loss of economic capacity;
   - tourism negative impact;
   - loss of attraction capacity and appeal
   - difficult accessibility;

3. at social and cultural level:
   - know-how and *savoir-faire* losses;
   - cultural landscape disappearance;
   - natural resources banalisation;
   - wellness perception for both residents and tourists.

Consequently, the conservation of the soil resource is considered a fundamental item for human society, as it is stated in the Alps Convention (1991), "with the objective of protecting and restoring natural environment and landscape, in such a way to guarantee the ecosystem efficiency, flora and fauna conservation, unicity, diversity and beautifulness of nature and landscape". Indeed, soils present different aspects that qualify them as cultural heritage, assuming different values for each case:

- historical valency (paleosols and soils at archaeological site);
- scientific valency (soils that exemplify natural and/or anthropic processes);
- ecological valency (soils as parts of fragile ecosystems);
- aesthetic valency (soils that contribute to the amenities of the landscape);
- social-economic valency (touristic exploitation of marginal areas).

Therefore, soil study is a major concern in conservation of natural and cultural landscape, and is fundamental in land planning.
The objectives of this paper are:

- to identify different soil types of a changing alpine landscape;
- to highlight relationships among soil properties, land use changes and new landforms;
- to suggest new perspectives in the management of alpine terraced landscapes.

Materials and methods

The study area is located in the southern part of the Dolomites region, and covers a narrow belt about 50 Km in length; parent material is limestone; altitude varies between 400 and 1200 m a.s.l., with steep slopes, mostly terraced; the vegetation cover is a mosaic of meadows, pasture, mixed hardwood, or agricultural land. Presently, many terraced systems are abandoned and have lost their original function of protecting soil and land from degradation. Within the frame of the European project "Terraced Landscapes of the Alpine Arc" (ALPTER project 2006-2008), terraced landforms with different land use were identified by comparison of different sets of aerial photographs (1954-2006). Afterwards, 40 soil profiles were opened and sampled at different sites in artificially build terraces. Dynamic soil properties that may change in short time (Richter *et al.* 2007; Bellamy *et al.* 2005), both physical (e.g. soil structure, soil porosity, texture, root penetration capacity, etc.), and chemical (nutrient status, salinity, acidity, solute translocation, etc.) or biological (organic matter transformation, biological activity, etc.) were selected for each profile, following the DPSIR model, in order to understand how natural or man-induced environmental modifications (driving forces and pressures) may influence directly (impacts) the soil resource (state), in terms of soil responses to anthropic activities.

Results

Land use changes in the terraced landforms of Dolomites consist of a relevant decrease in total agricultural land (-40% in the last 50 years);

- permanent meadows and pasture present a significant decrease (3000 hectares, up to 15%) in the same period;
- forests have increased by 25% (28000 hectares) in the same period; however, most of the forested territory is not man-assisted during the expansion process, and this may determine significant relapses in ecosystem conservation;
- soil properties which change in a short time, as a consequence of changing land use, erosion processes, agricultural practices, etc. are: root penetration depth, skeleton percentage, water retention capacity, organic matter content and type, biological activity, fauna abundance and typology.

Three developing stages occur in terraced soils:

- little degraded soils under permanent meadow (>50 years old): deep umbric horizon, active pedofauna (mostly earthworms), strong crumb structure, good nutrient status. No structural landform degradation, no ecological degradation (INCEPTISOLS);
- moderately degraded soils under forest (<50 years old): reduced soil depth, shallow umbric horizon, slowed biological activity; reduced forest floor. No structural landform degradation, moderate ecological degradation, loss of biodiversity (INCEPTISOLS);
- strongly degraded soils under forest (<50 years old): shallow depth, abundant skeleton, little water retention, reduced biological activity, inconsistent forest floor, strong erosion phenomena. Structural and ecological degradation (ENTISOLS).

Conclusions

In the last two centuries, new agro-forestry systems, increased industrial activities, and the dichotomy between soil knowledge and land use, have determined intensive soil exploitation, determinating soil loss by erosion, chemical contamination, acidification, low fertility, or inhibiting its ecological functions (biomass production, biological filter, genetic reserve, habitat for flora and fauna). The reduced soil capability for agriculture and food production are evidence of the human contribution to the Global Soil Change, as suggested by Arnold et al. (1990), Richter (2007) and Zalaseiwich (2008). Although soils of artificial terraces occupy large areas all over the world, and have undergone to profound transformation with aggradation and degradation processes (e.g. cumulization, haploidization, pedoturbation, entisolization), only in recent years there has emerged the opportunity to revise their taxonomic allocation in a new category within the traditional soil classification systems (e.g. Soil Taxonomy, WRB), and one of the major types of ANTHROPOGENIC soils distributed on our planet (Dudal 2004; Icomanth 2007). Man becomes leading actor of land transformation, and plays an important part in the changing world, as well summarized by the Nobel Prize winner Paul Crutzen (2002) in defining the ANTHROPOCENE as the man-induced new geological era of this millennium. Differences among Anthropogenic and natural soils, therefore, should be evidenced, in view of a correct management of terraced areas. The study of the already recorded soil dynamic properties, and the processes involved, moreover, may be of great utility to understand possible consequences of land abandonment on soils and the whole environment. Although the effects of global soil change are presently little quantified, to understand how and at which intensity soils modified by man react, in tune, with the environment, is of capital importance to predict and quantify the anthropic effects in a short time and to realize effective management of rapidly changing ecosystems.

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