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Soil quality in a Mediterranean area of Southern Italy as related to different land use types

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ABSTRACT

The impact of different land use types on soil quality was evaluated by measuring several soil properties that are sensitive to stress or disturbance and by using two synthetic approaches, i.e. a numerical quality index and multivariate analysis. A Minimum Data Set of soil indicators was selected including physical (texture, bulk density and water holding capacity), chemical (pH, cation exchange capacity, electrical conductivity, organic carbon, total and mineral nitrogen, available K, Ca, Mg, P contents and total Cd, Cr, Cu, Pb and Zn contents) and biological (microbial biomass, fungal mycelium, soil potential respiration and potentially mineralizable nitrogen) parameters. These parameters were assayed on soil samples collected with seasonal frequency (except for physical parameters, determined only in autumn) in an area of Southern Italy under different land use types (i.e. permanent crops, grazing lands, shrublands, coniferous and mixed forests). Moreover, for most of the land use types, a further distinction on the basis of topographic position (hill, middle-hill and plain) was carried out. Annual means of the data (except for texture) were used to calculate a soil quality index (SQI) and elaborated by multivariate analyses (Cluster Analysis and Principal Component Analysis, PCA) in order to distinguish among different soil quality classes. Data indicated a clear difference in soil quality among the studied areas: low soil quality ($SQI < 0.55$) in almost all permanent crops; intermediate soil quality ($0.55 < SQI < 0.70$) in shrublands, grazing lands, coniferous forest and middle-hill olive grove (the only crop with an herb layer on the soil surface); high soil quality ($SQI > 0.70$) in mixed forests. Results suggested that the permanent crop management had generally a strong negative impact on soil quality, while the moderate grazing activity and the crop management that leaves an herb cover on the soil had a lower negative impact. Nevertheless, the abandonment of cultivated lands, with consequent development of shrublands, produced an improvement of soil quality suggesting a good recovery capacity in the studied soil.

1. Introduction

Soil is an important component of terrestrial ecosystems because it preserves nutrient reserves, supports many biological processes (such as activities linked to nutrient cycles) and filters, keeps and transforms pollutants reducing their toxic effect. To preserve this resource and its functions, it is necessary first of all to know the conditions and the processes occurring in it, for example, through the determination of soil quality. The last has been described by Karlen et al. (1997) and the committee for Soil Science Society of America as "the capacity of soil to function to sustain plant and animal productivities, to maintain or enhance water and air quality and to support human health and habitation".

Soil quality may be affected by land use type and agricultural management practices because these may cause alterations in soil physical and chemical properties and in soil biotic community (Caravaca et al., 2002) determining, in turn, a reduction in land productivity (Islam and Weil, 2000; Sánchez-Marañón et al., 2002). It has been reported that soil land use (arable versus pasture) influenced biological soil quality more than soil type (Fromm et al., 1993).

Soil quality is a combination of soil physical, chemical and biological properties that are able to readily change in response to variations in soil conditions (Brejda et al., 2000). According to many authors (Doran and Parkin, 1994; Karlen et al., 1997; Liebig et al., 2001) these properties are grouped into a Minimum Data Set (MDS), i.e. a collection of selected indicators able to measure soil state and function from plot to regional scale (Karlen et al., 1997). A wide amount of indicators of different nature makes interpretation of results difficult, so it is essential to elaborate numerical indices that represent synthetic tools able to integrate information about soil quality functions deriving from single parameters. A lot of different methods have been suggested to calculate indices from indicators collected into a Minimum Data Set (Karlen et al., 1997;

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Liebig et al., 2001; Wienhold et al., 2004; Zornoza et al., 2008). Generally, the definition of a soil quality index starts by choosing a Minimum Data Set; as different indicators are expressed by different numerical scales, scoring functions were used to normalize data (linear and nonlinear scoring). The integration of adimensional indicators (obtained by normalization) into quality indices is possible through many procedures based on additive, multiplicative or weighed mean techniques (Andrews et al., 2002).

The aim of this study was to estimate the impact on soil quality of different land use types in an area of Southern Italy by determining a lot of parameters and by using two synthetic approaches, i.e. a numerical quality index (elaborated according to Andrews et al., 2003) and multivariate analyses (Cluster Analysis and Principal Component Analysis). For this purpose, soils from permanent crops (citrus and peach orchards, olive groves and vineyard), grazing lands, shrublands, coniferous and mixed forests were seasonally sampled and physical, chemical and biological parameters were determined. The Minimum Data Set of parameters was chosen according to Doran and Parkin (1994), also adding other parameters (cation exchange capacity, available contents of Ca and Mg, total contents of Cd, Cr, Cu, Pb, Zn, fungal mycelium) in order to better characterize studied soils and to consider the impact of human activities on the study area (i.e. agricultural and industrial activities, vehicle traffic). On the basis of results of soil quality index and multivariate analyses, different soil quality classes were identified.

2. Materials and methods

2.1. Study area and experimental design

The study was carried out in an area of Southern Italy (Maddaloni, Campania Region) comprised between 40 and 420 m above sea level with a total extension of 33.33 km^2. The area is affected by a widespread agricultural activity, a strong urbanization, an intense and uncontrolled activity of extraction of calcareous and tuff materials for building use and a cement industry. The study area is characterized by a Mediterranean climate with warm and dry summers and mild and rainy winters. The annual mean temperature is 17.1 °C with the minimum temperatures recorded between November and March and the maximum temperatures between June and September; the annual rainfall (around 1050 mm) is distributed mainly between October and March, with a summer dryness period lasting from June to September, when the maximum temperature is associated with the minimum rainfall values (Blasi et al., 1999). The soil of the study area is classified as Molli-Vitric Andosols (di Gennaro, 2002).

Sampling sites were chosen using information obtained from the integration of different cartographic instruments, such as topographic map of the area (1:5000 scale; Zappariello Company, 1999), digital orthophoto plane (1:10000 scale; Compagnia Generale Riprese Aeree of Parma, 1999) and land use map (1:5000 scale) referred to Maddaloni area. According to CORINE Land Cover legend, different types of land use have been chosen (Table 1): (1) forests, in particular one coniferous plantation and two mixed forests of coniferous and broad-leaved trees, developed on the Maddaloni castle garden, abandoned for at least 100 years; (2) permanent crops, i.e. citrus and peach orchards, olive groves and vineyard, generally managed with tillage until 20–30 cm (except for hill and middle-hill olive groves and middle-hill citrus orchard), mineral (N, P and K) fertilization (except for hill olive grove), application of herbicide (except for hill and middle-hill olive groves) and pesticide (except for hill olive grove); (3) grazing lands by sheep and (4) shrublands developed on an olive grove abandoned for about 40 years. Total surface of areas covered by each land use type was calculated (Table 1) by a GIS (Geomedia 5.2) using functions of analysed geometry. Moreover, for most of land use types, it has been possible to make a further distinction on the basis of topographic position: hill, middle-hill and plain (Table 1). Within each plant cover type a sampling site has been chosen for each available topographic position (Table 1). Seasonal and annual crops, near to the selected study sites, were not included in this study because of continuous changes in cultivation and the shortage of information on management history and practices.

2.2. Soil sampling and pre-treatment

In each sampling site (Table 1) soil was collected in three different plots (20 m × 20 m large) in order to have three field replicates for each plant cover type and topographic position, at 0–10 cm depth (the only soil layer present in the hill plots). In each plot, seven soil cores (diameter: 7 cm) were sampled and mixed together in order to obtain a homogeneous sample. Moreover, to obtain, for each chemical and biological parameter, values representative of the whole year, soil sampling was performed four times with seasonal frequency: during spring (in favourable conditions of moisture and temperature), in late summer (after a long warm and dry period), in late autumn (at the end of a very rainy period) and in late winter (at the end of a cold period).

Table 1
Land use, CORINE Land Cover level, topographic position, label and size of studied sites (each corresponding to one type of plant cover for each topographic position). The whole surface area of each plant cover type for each topographic position, within Maddaloni area, is reported in the last column.

Land use	CORINE Land Cover level	Topographic position	Label	Size (ha)	Whole surface of each land use type (ha)
Coniferous forest	3.1.2	Hill (h)	CF_h	2	36
Mixed forests	3.1.3	Hill (h)	MF_h	4	14
		Middle-hill (mh)	MF_{mh}	1	1
Shrublands	3.2	Hill (h)	S_h	5	63
		Middle-hill (mh)	S_{mh}	2	36
Citrus orchards	2.2.2	Middle-hill (mh)	CO_{mh}	1	216
		Plain (p)	CO_p	5	652
Vineyard	2.2.1	Plain (p)	V_p	2	189
Peach orchard	2.2.2	Plain (p)	PO_p	3	11
Olive groves	2.2.3	Hill (h)	OG_h	3	191
		Middle-hill (mh)	OG_{mh}	2	17
		Plain (p)	OG_p	1	25
Grazing lands	3.2.1	Hill (h)	GL_h	5	49
		Middle-hill (mh)	GL_{mh}	2	41