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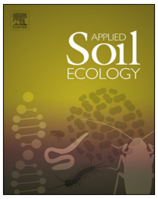

Plant cover and management practices as drivers of soil quality

S.C. Panico, V. Memoli, F. Esposito, G. Maisto, A. De Marco*

Dipartimento di Biologia, Università degli Studi di Napoli Federico II, Via Cinthia, 80126 Napoli, Italy

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ABSTRACT

Human activities intensively modify soil properties and quality according to land-use and management practices. In Mediterranean areas, pollution and fires may directly alter some soil abiotic properties as well as the steady-state condition of soil microbiota. The aim of this study was to evaluate if the chemical and biological characteristics of two kinds of soil, Arenosols and Andosols, of a natural reserve and an urban park respectively, were affected by the same or different plant covers (trees and grasses). At each site, five sub-samples of surface soils (0–10 cm) were collected under maquis (trees) and gap of grasses. The soils were analyzed for physico-chemical parameters (organic matter and water contents, pH, C, N, Cr, Cu, Ni and Pb concentrations) and biological parameters (microbial and fungal biomass, respiration, metabolic quotient and coefficient of endogenous mineralization). The soil quality was evaluated through an integrated index, calculated taken into account all the investigated parameters. The results highlighted that soils under trees inside the urban park, with the highest amount of organic matter, showed higher microbial biomass and activity as compared to soils under grasses. The high concentration of Cu and Pb in these latter soils inhibited the microbial biomass and activity that were not exclusively affected by litter quality. Soil quality would seem to be strongly affected by the pedogenetic derivation and the management practices more than plant covers.

1. Introduction

Human activities introduce pollutants, such as heavy metals, to soils through mining, smelting, industry, agriculture and burning fossil fuels, leading to alterations of several processes that could weaken the whole ecosystem (Pouyat et al., 2009), especially in urban and adjacent areas. Also some disturbances, such as fire, erosion, drought and salinization, have been identified as important threats to soil (Andrews and Carroll, 2001; Commission of the European Communities, 2002) because they may directly alter some soil chemical and physical properties as well as the steady-state condition of soil microbiota, important determinant of carbon turnover (De Marco et al., 2005).

The Mediterranean-type ecosystems, where a lot of areas have been affected by anthropic pressure for thousands of years, are, nowadays, one of the most significantly altered hotspots in the world (Falcucci et al., 2007). In fact, in these ecosystems, pollution and fires are widely recognized as the main drivers of human impact. In particular, fire is by far the most frequent and widespread cause of disturbance to vegetation, altering the structure of land cover and functioning of Mediterranean ecosystems (Dale et al., 2001). However, Mediterranean maquis is highly adapted to frequent fires, shrub fuels are known for their flammability and tendency to sustain high intensity fire (Malkisnon et al., 2011). In heavily degraded Mediterranean region, patches of high and low maquis with small clearings in the shrub cover dominated by herbaceous species occur (Ruth et al., 2009). This mosaic of vegetation contributes to the wide spatial variability of soil physical and chemical properties. Plant species, according to their morphologies, differently intercept air pollutants deriving by dry or wet deposition, affecting their soil accumulation (Maisto et al., 2004). Thus, in turns, determines consequences on soil biological diversity and processes (Trabaud, 2002) modifying soil fertility and quality (Caravaca et al., 2002). In fact, thus can cause changes in growth of the different components (fungi and bacteria) of soil microflora (Vásquez et al., 1993; Bååth et al., 1995; Díaz-Raviña et al., 2006) with consequences on efficiency in carbon assimilation and mineralization due to microbial community (Rutigliano et al., 2007). In addition, soil characteristics also depend on its proximity to lagoons and rivers that suffer both natural and man-induced pollution. In particular, the lagoons are often the recipient of domestic, agricultural and industrial discharges that eventually result in soil heavy metal accumulation (Arienzo et al., 2014).

Soil quality is often assigned to specific soil attributes (*i.e.*, pH, soil structure stability, organic matter content and nutrient supply), also if it is a complex functional concept and cannot be measured directly in the field or laboratory but can be indirectly inferred by soil indicators (Cherubin et al., 2016). Soil indicators are measurable properties and

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* Corresponding author at: Dipartimento di Biologia, Via Cinthia, 80126 Napoli, Italy.
E-mail address: ademarco@unina.it (A. De Marco).

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describe processes that have the greatest sensitivity to changes in soil functions and its ecosystem services (Andrews et al., 2004; Innangi et al., 2015; Zornoza et al., 2015; Memoli et al., 2018). To assess soil quality is essential to elaborate indices integrating the parameters that are affected by different types of disturbance and that vary in frequency and intensity in relation to human demography and management (Barbero and Quèzel, 1989).

The aim of this study was to evaluate if, in Mediterranean region, the chemical and biological characteristics of two kinds of soil, Arenosols and Andosols, found in a natural reserve and an urban park, respectively, were affected by the same or different plant covers (trees and grasses). The quality of the soils was estimated through an integrated index, taking into account all the investigated parameters. In this concern, the hypotheses were: soils under trees received a major input of litter as compared to those under grasses (H1); pollutant deposition was higher on soils under grasses (H2); microbial biomasses and activities were enhanced by more degradable litter (H3); soil quality of natural reserve was higher than that of urban park (H4). The findings of the research can provide information both at local and global scales, as they can be as useful tool in management plans and can increase the current dataset of soils of Mediterranean area.

2. Materials and methods

2.1. Study area and sampling

The research was carried out in the Mediterranean Region in the South of Italy characterized by dry summers and rainy autumns and winters (mean annual temperature: 18 °C; annual precipitation: 800 mm). In particular, it interested two sites: an urban park (UP) and a natural reserve (NR).

The urban park with an extension of approximately 10 ha, established in 1953 and abandoned until 1997, is located on a flat coastal area of Campi Flegrei, Naples near the Fusaro Lagoon (40°49′N, 14°03′E). The urban park plant cover is similar to that of the reserve including patches of high and low maquis with dominance of holm oak specimens and low shrubs and herbaceous species in the gaps. Soils of Phlegren volcanic region are *Molli-Vitric Andosols* with clay loam texture (di Gennaro, 2002 according to FAO classification, 1998). The Fusaro Lagoon is a saltwater lagoon of relevant hydrological interest. It has often been the object of attention for high levels of degradation and the general state of neglect that, over the years, have caused serious eutrophication phenomena (Carrada, 1973; Arienzo et al., 2014).

The natural reserve, established in 1977 and with an extension of approximately 268 ha, is located at Castel Volturno (40°57′N, 13°33′E) on a flat coastal area of Naples and is covered by a typical Mediterranean maquis, consisting of densely sclerophyllous shrubs and trees, including specimens of *Quercus ilex* L., *Myrtus communis* L., *Arbutus unedo* L., *Pistacea lentiscus* L., *Phillyrea latifolia* L. Locally, small clearings (gaps), representing the 20% of the maquis area, in the woody canopy were covered by grasses and bryophytes (De Marco et al., 2008). The natural reserve has often been interested by prescribed frequent fires that were used as useful tool in the management practices (D'Ascoli et al., 2005).

Soil at the nature reserve is a *Calcaric Arenosol* with sandy loam texture (di Gennaro, 2002 according to FAO classification, 1998).

At each site, five sub-sample of surface soils (0–10 cm) were collected under maquis (trees) and gap of grasses.

2.2. Soil physico-chemical analyses

The soil samples were sieved (< 2 mm) and divided in aliquots to measure: water content (WC), pH, organic matter (OM) content, and C, N, Cr, Cu, Ni and Pb concentrations. Soil water content was assayed drying 5 g of each soil sample at 105 °C until to reach a constant weight. According to USDA-NRCS (2017), pH was measured on soil: distilled water (1:2.5 = v:v) suspension by potentiometric method. In order to calculate OM content, the organic carbon (C_{org}) was determined by gas-chromatography (Thermo Finnigan, CNS Analyzer) on soil samples previously treated with HCl (10%) to exclude carbonates. Successively, the OM content was obtained multiplying the C_{org} for 1.724 (Pribyl, 2010). Total C and N concentrations were evaluated on oven-dried (105 °C, until constant weight) and grounded (Fritsch Analysette Spartan 3 Pulverisette 0) soil samples by gas-chromatography (Thermo Finnigan, CNS Analyzer). Successively, C/N ratios were calculated. Total concentrations of Cr, Cu, Ni and Pb were measured, via graphite furnace, by atomic absorption spectrometry (SpectrAA 20 – Varian) on oven-dried (105 °C until constant weight) and grounded (Fritsch Analysette Spartan 3 Pulverisette 0) soil samples dissolved by an acid mixture (HF 50% and HNO_3 65% at 1:2 = v: v) in a micro-wave oven (Milestone mls 1200 – Microwave Laboratory Systems).

Table 1
pH and water content – Mean values (± s.e.) of pH and water content (WC, expressed as % d.w.) in soils collected at the urban park and the natural reserve under different vegetation covers (maquis and gap of grasses). In bold the maximum and minimum values are reported. Different letters indicate the statistically significant differences (one way ANOVA, $P < 0.05$).

Site typology	Vegetation cover	pH	WC
Urban Park	Maquis	7.22 ± 0.04^{A}	$\mathbf{60.34 \pm 1.73^{A}}$
	Gap	$\mathbf{6.67 \pm 0.04^{B}}$	38.44 ± 0.75^{B}
Natural Reserve	Maquis	7.51 ± 0.03^{A}	16.19 ± 0.22^{A}
	Gap	$\mathbf{7.47 \pm 0.02^{A}}$	$\mathbf{15.11 \pm 0.23^{A}}$

All the described analyses were performed in triplicates.

2.3. Soil biological analyses

Microbial and fungal biomass as well as microbial respiration were measured on fresh soils stored at 4 °C until time of measurements (within a week after sampling). Microbial biomass carbon (C_{mic}) was evaluated by the method of substrate-induced respiration (SIR) according to Degens et al. (2001), while microbial potential respiration (Resp) according to Froment (1972). The CO_2 evolution from the samples at 55% of water holding capacity was measured by NaOH absorption followed by two-phase titration with HCl (Froment, 1972), after incubation at 25 °C in tight containers for 5 and 10 days, respectively, to evaluate C_{mic} and Resp. Total fungal biomass (FB) was assayed by membrane filter technique (Sundman and Sivela, 1978), after staining with aniline blue, determining hypha length by intersection method (Olson, 1950) with an optical microscope (Optika, B-252). In order to make comparable the soil samples collected at different sites, all data were expressed per unit of soil dry weight. The results obtained by the biological analyses were used to calculate two indices: the metabolic quotient (qCO_2), *i.e.* the degree of microbial biomass activity, and the coefficient of endogenous mineralization (CEM), *i.e.* the rate of organic carbon mineralization (Anderson and Domsch, 1993). The qCO_2 was calculated as ratio between Resp and C_{mic}, whereas the CEM was calculated as ratio between Resp and C_{org}.

2.4. Soil quality index (SQI)

In order to evaluate the soil quality, an integrated index was calculated taken into account all the investigated parameters that were ranked by linear scoring technique according to Liebig et al. (2001). The scores, ranging from 0 to 1, were assigned applying the *more is better* or *less is better* functions. The *more is better* function was applied to WC, OM, C and N contents, C_{mic}, FB, Resp and CEM; whereas, the *less is better* function was applied to qCO_2 and metal concentrations (Marzaioli et al., 2010). The maximum score for pH was attributed to 7 (Liebig et al., 2001). The SQI was calculated by summing the parameter scores and dividing for the number of parameters according to Andrews et al.,