Persistence and intensity of soil water repellency from soils with andic properties from the Campania region (Southwest, Italy) under different forest types

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Introduction

Soil water repellency (SWR) is a property of many soils that is getting more and more interesting for the scientific community, because of its consequences on soil erosion risk, runoff or infiltration rates and even plant ecology. The presence of hydrophobic organic acids released by roots and plant tissues, fungal activity, organic matter mineralization rates, or wildfires are considered the main causes of SWR. Some of the consequences of SWR are reduced soil infiltration rates, enhanced runoff flow and soil erosion. Significance of these phenomena is increased upon the severity and spatial variability of SWR. SWR is often associated to vegetation types, although it cannot be assumed that certain species always induce water repellency under natural conditions. Because of relicts, wastes and aromatic oils in their tissues, evergreen trees as eucalyptus and conifers are usually associated with soil hydrophobicity, although it has been found also in a variety of soils, climates and vegetation types. But the relationship between water repellent soils and plant species is not always one-to-one. Soil properties as texture, aggregate, acidity, microbe and other are also implied in the development of hydrophobicity. Regarding organic matter, several authors have reported inconsistent results after studying the relationship between soil organic matter content and SWR. A possible explanation for this is that quality of organic matter is more important than content. Consequently, it is necessary to investigate the role that organic matter content and properties play in the development of hydrophobicity in different soil and vegetation types.

The objective of this research is to study the relationship between SWR and organic matter properties in andic soils from the Campania region (SW Italy) under different vegetation types.

Methods

EXPERIMENTAL DESIGN

Soil samples were collected in Andosols under different natural or anthropized forest types (Pinus sp., Fagus sp., Castanea sp. and Acacia sp.) in the Italian Campania region: Monte Veszi (Ischia, Naples); Castello (Castelvetrano, Avola); Lago Laceno (Bagnoli, Avellino); Valmonte Santa Croce (Roscamonfina, Castellammare di Stabia). Figure 1 shows the location of sampling areas. Persistence and intensity of SWR is studied and compared to other soil properties related with SWR occurrence: soil acidity and salinity, texture, organic content, humic and fulvic acids and soil lipid content. SWR was also studied in soil samples after soil lipids were extracted.

ANALYTICAL METHODS

Soil water repellency. Persistence and intensity of surface soil samples with a porosity of 45% (0.5 μm) was measured using the WDP test and the percentage of ethanol (PE) test, respectively. SWR was carried out with water at different intensities for 20 s, and then increased by 0.5 ml of ethanol in each intensity. The PE test was carried out by increasing the percentage of ethanol (0, 10, 20, 30, 40, 50 and 100%) in water (0, 1, 2 and 3 ml of ethanol). The PE water was applied onto the soil surface and the soil was scored in 1, 2, 3 or 4 (no repellent), 5 (very repellent), 6 (completely repellent) or 7 (non-repellent). SWR was considered to be soil repellent if it resisted the PE test for at least 30 s.

Soil acidity and salinity. Soil pH and electrical conductivity of soil extracts were assessed in 1:2.5 soil:water ratio. Soil texture analysis was measured with the pipet method. Clay fraction was calculated as the difference between 100% and the sum of sand and clay fractions.

Organic C and humic acids. Soil samples were treated with an aqueous solution (100 mL) of NaOH (0.1 N) and NaNO3. The resulting solution was adjusted to 65 °C during 48 h. Total extractable C (TTC) was determined in an aliquot (10 mL) by oxidation with C2O2H2 (50 mL, 100 °C) and titration with Fer. Humic (HA) and fulvic acids (FA) were determined in an aliquot (25 mL). The solution was acidified and the precipitate (HA) was separated by centrifugation from the supernatant (FA) and other organic fractions. The supernatant was extracted and passed through a polyethylene/ethylene column in order to separate FA from the other material, FA being retained by the sorbent. FA from the precipitate was reabsorbed. FA and HA content was determined by titration after oxidation with C2O2H2.

Lipids. Soil lipids were extracted in a dichloromethane-methanol solution. The extract was evaporated in a water bath using a rotary evaporator (Buchi) to remove solvents. Lipid fractions were transferred into pre-weighed vials and oven-dried (30 °C). Lipid contents were determined gravimetrically.

Results and discussion

Table 1 shows the characteristics of studied soil profiles. Soil texture was mostly sandy, with sand content between 420 and 836 g/kg. All soils were acidic, with pH ranging between 4.44 and 6.95. Highest Tec content was observed in soils under Castanea and Acacia (Ischia) and Fagus (Lago Laceno), with TEC ranging between 44.3 and 63.1 in the Ah horizon.

Persistence of SWR (expressed as log(WDP)) is shown in Figure 2. Most soil horizons showed subcritical SWR, with droplets infiltrating in a short time (WDP < 5 s), and two soil profiles showed strong to extreme SWR (Roscamonfina under Pina and Lago Laceno under Fagus) in Ah horizons. Soil horizons under Castanea and Acacia were wettable or showed subcritical water repellency (WDP > 2 or > 4 s) and PE class 1. Soils under pine plantations in the Lago Laceno area showed subcritical WR just in the Ah horizon. In contrast, soils under Fagus (Lago Laceno area) and Roscamonfina (Roscamonfina area) showed strong WR in the upper horizons. In the first case, WR was strong in the Ah horizon (WDP 380 s, EP class 6) and subcritical (WDP 1.2 s) in E, Bw and C horizons. In the second case, WR was observed over the soil profile (the Ah (WDP 473 s, EP class 5), E (108 s, 4), Bw (204 s, 5) and Bw (4 s, 1), with C horizon showing strong repellency. Although SWR is expected to increase with TEC content and decrease in depth, strong to extreme WDPs were observed in surface or immediately subsurface horizons with TEC content above 30 g/kg, humic acid content above 10 g/kg and lipid content above 10 g/kg.

Table 2 shows the R-Pearson rank correlations between WDP, PE classes and different soil properties. WDP and PE class were moderately correlated (r 0.685). WDP was significantly correlated to pH (r = 0.295) and TEC (r = 0.361), but no significant correlations were found between WDP and humic or fulvic acids, lipids or other variables, as expected. In contrast, intensity of SWR (PE) was significantly correlated to TEC (r 0.514), humic acids (r 0.500), fulvic acids (r 0.515), lipids (r 0.425) and N-Kjeldahl (r 0.414). Both variables, WDP and PE, measure different aspects of SWR. As a consequence, in the study area, soil acidity and organic carbon are responsible of delayed infiltration of water. On the other hand, the intensity of SWR is controlled by organic matter chemical properties and composition.

Table 1: Characterization of soil profiles. WDP: persistence of SWR (PE); intensity of SWR: WDP; persistence of SWR: in lipid-free soil samples; EC: electric conductivity; TEC: total extractable carbon; HA: humic acid content; FA: fulvic acid content.

After lipids from soil samples were extracted, persistence of SWR was assessed again (WDP2). SWR decreased in soil samples with most of droplets infiltrating instantaneously (WDP 0 s).

Surprisingly, some samples showed similar or increased SWR. In the Ah horizon from Lago Laceno under Fagus, for example, WDP increased from 380 s (strong water repellency) to 3600 s (extreme water repellency). This was a non-expected response, although it may be attributed to conformational changes in organic substances coating soil mineral particles during the process of lipid extraction.

Another possible explanation is that the effect of hydrophobic/humic acids was masked by lipids in these soils, as WDP2 from water-repellent soil samples was lower (r 0.380) after lipid extraction showed significant and strong correlation with lipid acid content.

However, further research is needed to confirm or reject these hypotheses.

Table 2: A Pearson rank correlations between persistence of SWR (WDP), intensity of SWR (PE), and persistence of SWR in water-extracted soil samples after lipid extraction (WDP2). Significant correlations (p<0.05) are not displayed.