A MULTIDISCIPLINARY AND MULTISCALE APPROACH TO DEFINE THE SUBSOIL CHARACTERISTICS OF A SANDY SOIL TEST SITE

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An accurate estimation of the Soil Water Content (q) is nowadays required in many fields and applications: assessments of landslide susceptibility, slope stability analysis, civil engineering, in the recharge of aquifers, in the remediation of contaminated lands and other hydrogeological applications.

The estimation of the Volumetric Water Content (q_v), which is related to gravimetric water content (q_g) by the water unit weight (g_w) and soil dry unit weight (g_d), is evaluated by different techniques both in the laboratory and in the field (Di Matteo *et al*., 2009; Evett *et al*., 2008; Dobriyal *et al*., 2012, Ercoli *et al*., 2018a; Ercoli *et al*., 2018b).

Among the field sensors, dielectric soil-moisture probes are commonly used in unsaturated soil conditions (Reid *et al*., 20008). These probes include Time Domain Reflectometers (TDR), Frequency domain reflectometers (FDR) and Capacitance Probes (CP). Among the CP probes, the PR2/6 (Delta-T Devices, Cambridge, UK) allows to measure θ_v at different depths by measuring the relative dielectric constant (ε_r) of the damp soil. The PR2/6 probe emits a signal of 100 MHz using six pairs of stainless-steel rings (0.10, 0.20, 0.30, 0.40, 0.60 and 1.00 m depth), which transmits an electromagnetic field within the soil across a distance of about 0.10 m surrounding the probe. The change in the circuit output (in volts—V) is related to the square root of soil permittivity ($\sqrt{\varepsilon_r}$) by a sixth-order polynomial fit (Delta-T Devices Ltd., 2016), from which the q values can be estimated (Qi *et al*., 2010; Di Matteo *et al*., 2017).

Here we present a multidisciplinary and multiscale approach to analyze the subsurface geological structures and the water content pattern in unsaturated zones. A sandy soil site was used as a test area to study the characteristics of the subsurface, using different geophysical and geotechnical techniques together with a capacitance probe.

The study area is localized on the left bank of the Tiber River alluvional plane (43.12561N 12.43460E EPSG:4326), where a sand unit was deposited after the erosion of a flyschoid units (Marnosa Arenacea Fm), widely outcropping within the region.

In the site, we integrate the data obtained with:

- A capacitance probe (PR2/6 probe, Delta-T Devices, Cambridge, UK).
- Reflection and Refraction seismics:
  The seismic acquisition was performed using 24-bit DoReMi modular seismographs.

This instrument has been set with a sampling frequency of 3000 Hz. The energization was carried out using an 8 kg hammer on an aluminum plate, using a starter geophone as a trigger, and 48 geophones (40 Hz) spaced 1 m as receivers.

- Ground Penetrating Radar:
  The Georadar used is a Zond-12e GPR Advanced, with antennae 500, 300 and 100 MHz, a time windows of 100 ns, a sample number/trace of 1024 and a scan rate of 40.
- Electrical tomography:
  The geo-electric survey was carried out using a MAE georesistivimeter, model X612EM +, which allows multi-electrode measurements, optimizing acquisition times.
- Thermal property investigations (thermal conductivity):
  We used the 1.2 m MAE thermal probe, model A5000T.

The aim is to highlight the limits and explore the possibilities of each one of these investigations, particularly in their integrated use, to efficiently characterize the subsurface from the lithological point of view and its relationship with the natural water content of the sandy soils.

This work represents a reference work-flow model for future studies in similar areas, and data and results here presented could provide solid constraints for engineering and hydrogeological applications.

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