EGU21-7582
https://doi.org/10.5194/egusphere-egu21-7582
EGU General Assembly 2021

High-resolution near-surface soil moisture through the combination of Sentinel-1 and Cosmic-Ray Neutron Probe in a Mediterranean agroforestry

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The precise estimation and mapping of the near-surface soil moisture (~5cm, SM_{5cm}) is key to supporting sustainable water management plans in Mediterranean agroforestry environments. In the past few years, time series of Synthetic Aperture Radar (SAR) data retrieved from Sentinel-1 (S1) enable the estimation of SM_{5cm} at relatively high spatial and temporal resolutions. The present study focuses on developing a reliable and flexible framework to map SM_{5cm} in a small-scale agroforestry experimental site (~30 ha) in southern Italy over the period from November 2018 to March 2019. Initially, different SAR-based polarimetric parameters from S1 (in total 62 parameters) and hydrologically meaningful topographic attributes from a 5-m Digital Elevation Model (DEM) were derived. These SAR and DEM-based parameters, and two supporting point-scale estimates of SM_{5cm} were used to parametrize a Random Forest (RF) model. The inverse modeling module of the Hydrus-1D model enabled to simulate two supporting estimates of SM_{5cm} by using i) sparse soil moisture data at the soil depths of 15 cm and 30 cm acquired over 20 locations comprised in a SoilNet wireless sensor network (SoilNet-based approach), and ii) field-scale soil moisture monitored by a Cosmic-Ray Neutron Probe (CRNP-based approach). In the CRNP-based approach, the field-scale SM_{5cm} was further downscaled to obtain point-scale supporting SM_{5cm} data over the same 20 positions by using the physical-empirical Equilibrium Moisture from Topography (EMT) model. Our results show that the CRNP-based approach can provide reasonable SM_{5cm} retrievals with RMSE values ranging from 0.034 to 0.050 $cm^3\ cm^{-3}$ similar to the ones based on the SoilNet approach ranging from 0.029 to 0.054 $cm^3\ cm^{-3}$. This study highlights the effectiveness of integrating S1 SAR-based measurements, topographic attributes, and CRNP data for mapping SM_{5cm} at the small agroforestry scale with the advantage of being non-invasive and easy to maintain.