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Filling the gap between punctual and satellite soil moisture measurements through proximal gamma-ray spectroscopy

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Filling the gap between punctual ($\sim$cm^2) and catchment ($\sim$10 ha) soil moisture measurements is an urgent open issue that recently boosted the development of nuclear based monitoring techniques hinging on the detection of cosmic-ray neutrons and gamma-rays. Indeed, despite the increasing number of satellite missions and the growing availability of open access satellite images repositories, calibration ground-truth measurements are required for a comprehensive interpretation of hyperspectral data.

The fate of the sparse and sporadic punctual measurements performed with electromagnetic and gravimetric methods is to be overcome by innovative technologies for a non-invasive, contactless and continuous monitoring of soil moisture at field scale. In this scenario, proximal gamma-ray spectroscopy is identified as a promising tool for a full exploitation of high quality satellite data, with the perspective of realizing tangible applications in the field of sustainable agriculture, threatened by relentless effects due to climate changes. The terrestrial gamma signal measured with a spectrometer installed at a few meters above the ground is inversely correlated with soil water content and is basically insensitive to variations in cosmic radiation and soil chemical composition.

With a dedicated experiment carried out in a tomato agricultural test field, we hourly collected gamma-ray spectra over a period of 7 months covering the entire crop growing season. We obtained reliable non-stop estimates of top soil ($\sim$ 30 cm) moisture levels with a $\sim$2$\cdot$10^3 m^2 footprint by calibrating and correcting with a Monte Carlo based approach the gamma signal due to the naturally occurring potassium radioisotope (^{40}K) detected during the entire crop season.

Proximal gamma-ray spectroscopy with permanent stations is one of the best space-time trade-off methods which can provide accurate time series of soil moisture, concurrently minimizing time costs and manpower thanks to the employment of real-time and remotely controlled sensors. This proof of concept experiment demonstrates that networks of proximal gamma-ray spectroscopy stations can potentially fulfill the spatiotemporal requirements for the calibration of satellite observations, as well as provide a support decision tool for a rational use of water resources.