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SOIL GAMMA-RAY SPECTROSCOPY FOR PRECISION AGRICULTURE WITH HPGE DETECTORS: A FULL METHOD FOR RADIONUCLIDES SPECIFIC ACTIVITY ESTIMATION FOR IN-SITU MEASUREMENTS THROUGH MONTE CARLO SIMULATIONS

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Efficient soil exploitation in agriculture has always been a crucial issue. Nowadays, valid results in precision agriculture cannot be pursued without a multi-source analysis of soil properties, which must be carried forward by different and complementary techniques. Indeed, spectroscopy (VNIR-SWIR, gamma), remote-sensing, proximal electromagnetic and geo-chemical analysis are all essential for complete soil characterization. Pignoletto collaboration [1], coordinated by INFN of Milano Bicocca, aims to provide the best tools and guide-lines for precision agriculture, by integrating these parallel efforts and developing methods for the rapid characterization of agricultural terrains through remote and proximal devices (drones and rovers). Soil gamma-ray spectroscopy is particularly suitable since it provides bulk information about radionuclides concentration in the ground, which can be correlated to the presence of soil constituents (like organic matter, clay, silt) [2][3][4]. Measurements are performed with HPGe detectors, since their overall performance in efficiency and resolution allows to take precise measurements on soil samples in laboratory (CANBERRA BEGe detector) and quick acquisitions in the field (portable HPGe ORTEC-DETECTIVE-X). The main goal is to achieve precise in-situ estimations of radionuclide specific activity (Bq/kg) comparable with those achieved in laboratory. In fact, acquiring data on an extended field source makes the estimation of radionuclide concentration trickier, but at the same time it permits faster coverage of large areas and non-invasive soil analysis. Since a portable detector on the ground has a specific field of view, which may be influenced by many factors like soil composition, density and shape, Monte Carlo simulations are essential in order to estimate detector efficiency in different set-ups. MC code Arby, based on Geant4, is employed to estimate detectors efficiency and to take into account how soil source parameters affect the acquisition. Portable HPGe is employed in three main set-ups: lying on the ground, placed on a tripod or suspended few meters above the ground (as it will be implemented on drones). Simulations allow to estimate, in each case, HPGe efficiency and field of view for different emitted gamma energies. Coefficients can be extracted which allow to convert gammas count rate in concentration measurements (Bq/kg). Finally, simulations also suggest the optimal grid which the detector must follow in order to grant complete and rapid soil analysis, depending on detector height, soil density and terrain constituents variability.

[1] <https://pignoletto.mib.infn.it>

[2] Elejalde C., et al. Correlations between soil parameters and radionuclide contents in samples from Biscay (Spain). *Water, Air, and Soil Pollution*, 1996

[3] Claudia Dierke, Ulrike Werban, Relationships between gamma-ray data and soil properties an agricultural test site. *Geoderma*, 2013

[4] Reinhardt, N. and Herrmann, Gamma-ray spectrometry as versatile tool in soil science: A critical review. *J. Plant Nutr. Soil Science*, 2019

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