Low Cost Neutron and Muon Detectors for Soil Moisture Monitoring

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Water scarcity is a significant challenge for the world's population. With the likelihood of extreme droughts increasing each year, technologies to promote sustainable irrigation and improve resilience to water shortage are needed. Continuous monitoring of soil moisture in arid regions is a major problem as existing techniques can have high associated costs per hectare. Whilst in ground sensors can provide relatively low cost soil moisture measurements at a single point, extrapolating their readings to a large site requires good knowledge of how variations in local soil composition can modify sensitivity. Satellite data has been shown to provide a competitive cost/hectare when mapping large sites, however the resolution is typically at the kilometre scale [1], and continuous measurements at high temporal resolution, like those needed to support smart irrigation plans, can be prohibitively expensive.

Cosmic Ray Neutron Sensing (CRNS) of soil moisture is a technique already well established in the hydrological community [2]. Helium-3 based CRNS probes placed above an area of interest can detect cosmic ray neutrons backscattered from the surrounding soil 130-240m away [3]. By monitoring the variation in the total neutrons observed over time (and correcting for the incoming cosmic ray rate) it is possible to estimate the proportion of neutrons moderated by hydrogen in the soil. In turn this can be used to infer the average volumetric soil moisture content for the entire site. With such a large detector footprint, the technique offers a way to bridging the difference in length scales between point probes and satellite data, however the high cost of Helium-3 tubes is currently a barrier for adoption of this technique outside of the hydrological community.

At the University of Durham and Sheffield we are developing new boron-nitride based cosmic ray detectors as alternatives to expensive Helium-3 detectors. Taking advantage of developments in scintillator composites driven by the nuclear industry, and low power instrumentation capable of single photon counting, these low-cost detectors will be specifically optimised for use on smallholder farms. In this poster I will present the first of these new systems before discussing the use of low cost muon sensors to automatically correct for temporal variations in the incoming cosmic ray intensity.

[1] Cui, C., Xu, J., Zeng, J., Chen, K. S., Bai, X., Lu, H., ... & Zhao, T. (2018). Soil moisture mapping from satellites: An intercomparison of SMAP, SMOS, FY3B, AMSR2, and ESA CCI over two dense network regions at different spatial scales. Remote Sensing, 10(1), 33.

[2] Franz, T. E., Zreda, M., Rosolem, R., & Ferre, T. P. A. (2012). Field validation of a cosmic−ray neutron sensor using a distributed sensor network. Vadose Zone Journal, 11(4), vzj2012-0046.

[3] Köhli, M., Schrön, M., Zreda, M., Schmidt, U., Dietrich, P., & Zacharias, S. (2015). Footprint characteristics revised for field−scale soil moisture monitoring with cosmic−ray neutrons. Water Resources Research, 51(7), 5772-5790.