# Measuring soil moisture with cosmic rays

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WHEN it comes to water in cotton production, every drop counts. Water has become a valuable commodity, as the weather becomes more unpredictable and demand across the primary industries increases. Despite being world leaders in water use efficiency, the Australian cotton industry is still under pressure to adapt and improve.

It is estimated that 20 per cent of water is lost across a cotton farm, due to field seepage and evaporation. In part, this can be attributed to the limitations in how soil moisture (SM) is measured and estimated at a field scale. Technologies such as capacitance probes have become the standard on cotton farms to measure SM, and consequently, very small volumes of soil are used to infer the moisture of entire paddocks, or farms.

In recent years there has been interest in the applications of cosmic ray neutron sensors (CRNS) as a tool to measure soil moisture across a larger footprint. Primary cosmic rays, often in the form of protons, are a natural occurrence from outer space. Upon reaching Earth's atmosphere, they collide with atoms in the air, becoming fast neutrons, and losing energy with each interaction until they reach a state of thermal equilibrium and become thermalised neutrons. Collisions with hydrogen atoms in particular, reduce the energy of these fast neutrons, and hydrogen occurs most commonly at the Earth's surface in the form of water. CRNS measures the flux of fast neutrons – the more hydrogen (or water), the fewer fast neutrons present.

CRNS are ground-based, remote-sensing, and can measure a radius of up to 300 metres, as well as a depth of 10 to 90 cm depending on the soil moisture content, with saturated profiles only capable of shallower measurements. The measurements are passive, non-invasive, and mostly insensitive to variations in soil characteristics such as texture, surface roughness and bulk density. Without the need for physical contact with soil, the sensors have the potential be moved around a field or farm to collect spatial data or left at a fixed point for temporal measurements.


**The author with the CosmOz Rover at the study site.**

**FIGURE 1: Change in NDVI during study, with CosmOz range marked**


(Source: Irrisat)

While this technology has seen success in measuring SM in natural vegetation and dryland agricultural systems, it has not been trialled with irrigated systems. A preliminary study in the use of this novel technology in irrigated cotton was conducted by the University of Sydney, using the CosmOz Rover, a CRNS developed by CSIRO, and supported by the CRDC in the 2018–19 cotton season. The study consisted of two fields at Narrabri, one in fallow, the other irrigated cotton. Gravimetric moisture content was collected at 12 sites and three depths across both fields over a four week period to calibrate an existing CRNS soil moisture model. There was a strong correlation (-0.65) between the fast neutron count from the CosmOz rover and the soil moisture in the irrigated field, but the model could not be accurately calibrated.

As existing models have been designed for native vegetation systems and dryland cropping, future studies involving more intensive cropping systems should include biomass as a factor, which has been typically neglected as it is fairly consistent in native systems and dryland cropping. Over the course of the study there was a rapid increase in cotton biomass, which results in an increase in water content, organic compounds, and ultimately hydrogen atoms at ground level. Another potential factor which could benefit from future investigation, is the effect of segmented irrigation to the CosmOz readings. Due to the size of the study field, it was irrigated in sections. As the CosmOz returns a single weighted value, where areas closer to the sensor play a larger role in the measurements, this would have impacted the fast neutron count.

While CRNS is currently a costly, novel technology for measuring soil moisture content which still requires refinement, particularly in an intensive cropping system such as cotton, its ability to measure such large areas is unparalleled in conventional technology. Accurate paddock scale SM measurements would provide growers with both knowledge and confidence in their irrigation practices, improving both scheduling and amount of irrigation water applied, paving the path for growers to produce more crop for their drop.