Impact of Biomass Water Equivalent on Cosmic-Ray Neutron Sensor Estimates

Samir K. Al-Mashharawi¹, Marcel M. El Hajj¹, Matthew F. McCabe¹, and Susan C. Steele-Dunne²

¹Hydrology, Agriculture and Land Observation (HALO) Laboratory, Division of Biological and Environmental Sciences and Engineering, King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia
²Department of Geoscience and Remote Sensing, Delft University of Technology, Delft, the Netherlands.

Biomass water equivalent represents the cumulative vegetation water content and biological hydrogen contained within plant tissue and can provide valuable insights into ecosystem-scale water dynamics. Several studies conducted in crop and forest fields have reported that variation in biomass water equivalent can decrease the accuracy of soil moisture estimates when using the Cosmic-Ray Neutron Sensor (CRNS): a novel approach for real-time soil moisture monitoring. Indeed, with an increasing biomass water equivalent, more neutrons at epithermal and thermal energy levels are held by the hydrogen atoms in the vegetation, leading to an overestimation of soil moisture. In this study, we explore the impact of such variations in biomass water equivalent on the estimated soil moisture from CRNS sensors installed in two distinct orchard plantations. The first plantation is an olive orchard located in northern Saudi Arabia (desert climate), while the second is a cherry orchard located in southeastern France (Mediterranean climate). Utilizing a site-specific calibration value (N₀), soil moisture was derived from neutron counts, and compared to reference in-situ soil moisture. The estimated and reference soil moisture difference was analyzed as a function of biomass water equivalent variations. As biomass water equivalent measurements were not possible to obtain at equivalent CRNS acquisition rates, the vapor pressure deficit (VPD), a meteorological variable, in plants, it is used to describe the difference in water vapor pressure between the inside of a leaf and the surrounding air, was used as a proxy. An optimization procedure was performed to update N₀ (N₀,opt) in such a way that the difference between estimated and reference soil moisture is minimized. Variations in N₀,opt are subsequently correlated with VPD to confirm the link between neutron count variations and seasonal changes in biomass water equivalent. Results showed that without considering the effects of biomass water equivalent on neutron counts, the estimated soil moisture overestimates the reference soil moisture when the VPD is low (no stress conditions) and matches the reference soil moisture when the VPD is high (water stress conditions). Moreover, the results showed that the change in N₀ (1 - N₀,opt / N₀) correlated well with VPD (R² = 0.7). An improved understanding of the potential effects of biomass water equivalent on CRNS signals is required for understanding water dynamics in trees and providing insights for optimizing irrigation.