The Effects of Correction Factors on Cosmic-Ray Neutron Rover Calibration across Multiple Locations

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Soil Moisture Calibration

Four field campaigns were conducted around the MOISST site (June 25 & July 15, 2014) and the field of the USDA Grazing Research Lab in El Reno, OK (June 20 & July 21, 2014). Three target field were chosen in El Reno, and four in Marena. The field-average soil moisture were estimated by taking 16 measurements (0 – 12 cm soil layer) at 4 radial directions and 4 radial distances (20 m, 60 m, 140 m, and 300 m). To calibrate the soil moisture probe (HydroSense II, Campbell Scientific), four volumetric soil samples were taken per field per day.

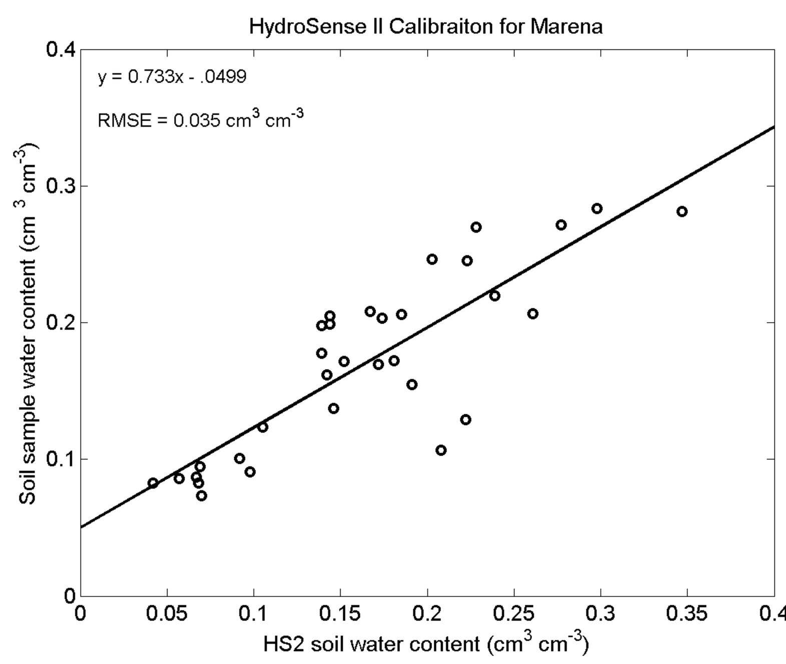

Figure 1. Volumetric soil sample water content (0-10 cm) vs. HydroSense II soil water content for four fields at Marena.

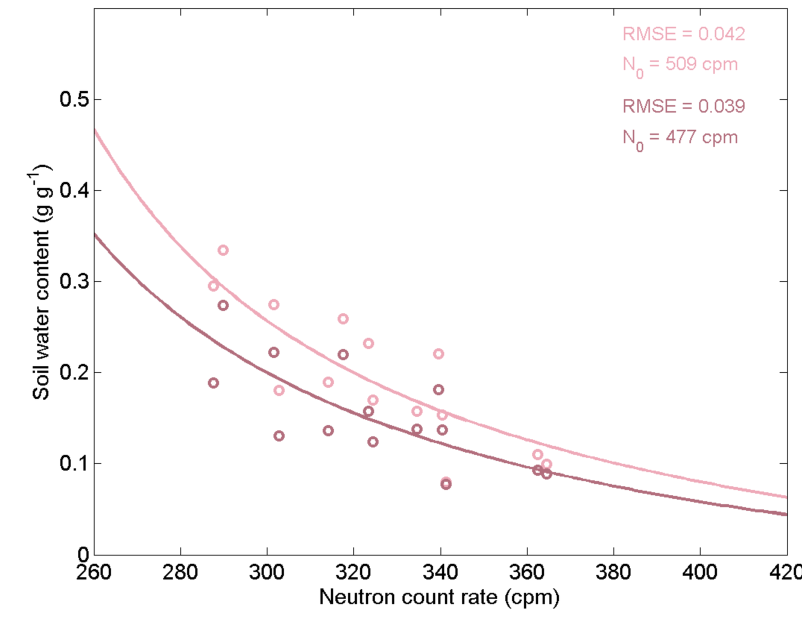

Figure 2. Effect of calibration for portable soil moisture sensors on shape-defining function. The pink circles and curve represent the raw data and their fitted shape-defining function. The purple ones represent the calibrated soil moisture probe readings.

One of the advantages of the cosmic-ray neutron soil moisture rover is that it can be used in conducting large-area soil moisture field campaigns. However, the calibration for Cosmic-ray Soil Moisture Observing System (COSMOS) suggests that the rover has to be calibrated locally, which is usually inconvenient in practice. This research ***aims*** to examine the applicability of the shape-defining function in large-area rover survey by fitting calibration data collected from multiple locations.

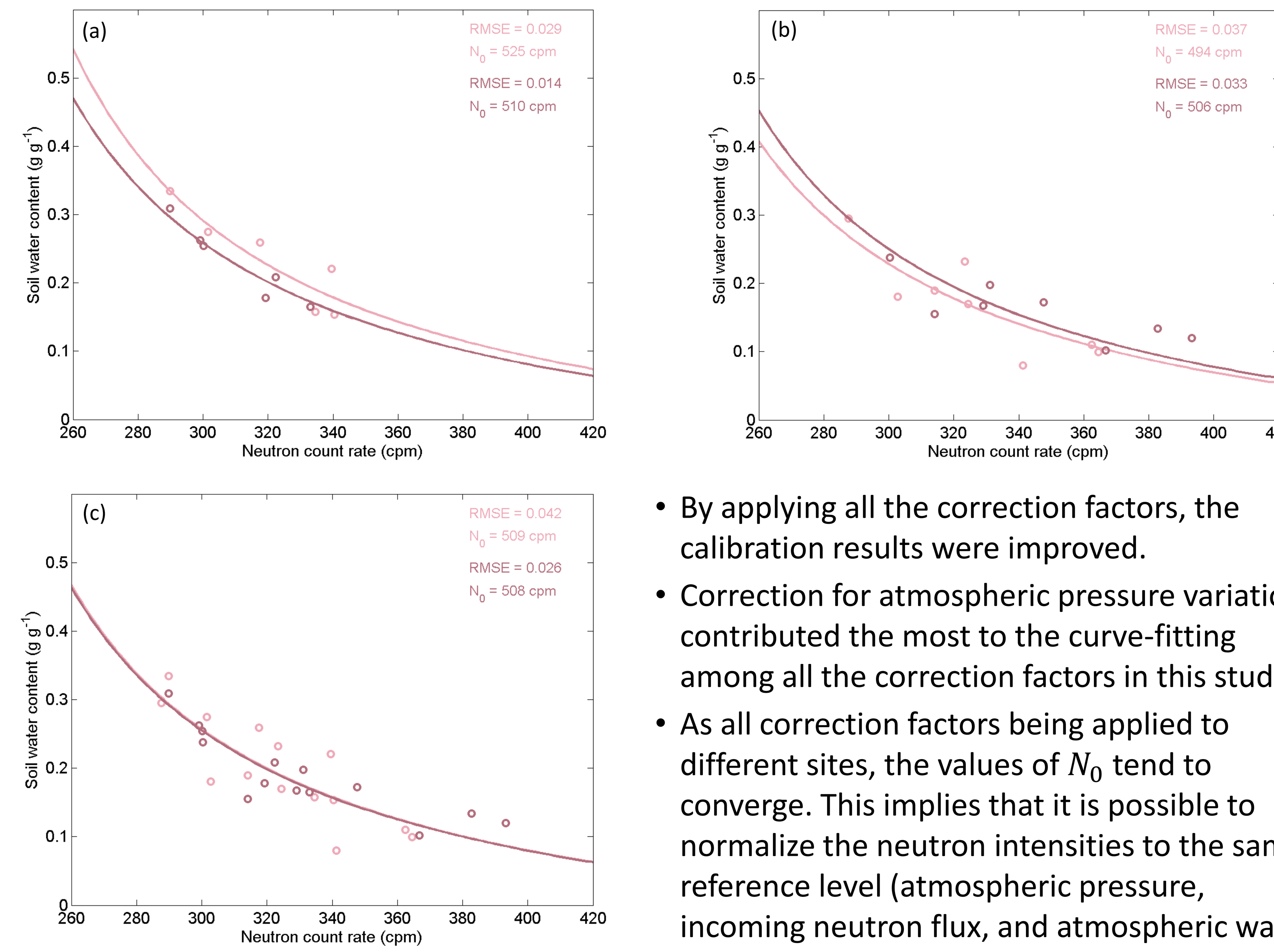

Figure 9. The pink circles and curve show the raw data and their fitted shape-defining function. The purple ones represent the data with all corrections. (a) The effect of all correction factors applied to the shape-defining function with data at El Reno (b) The effect of all correction factors applied to the shape-defining function with data at Marena (c) The effect of all correction factors applied to the shape-defining function with data from two sites combined.

- By applying all the correction factors, the calibration results were improved.
- Correction for atmospheric pressure variation contributed the most to the curve-fitting among all the correction factors in this study.
- As all correction factors being applied to different sites, the values of N_0 tend to converge. This implies that it is possible to normalize the neutron intensities to the same reference level (atmospheric pressure, incoming neutron flux, and atmospheric water vapor) and to convert them to soil moisture with one calibration function.
- Estimating lattice water and SOC at unsampled locations is key to the application of shape-defining function in large-area rover measurements.

Correction for Lattice Water and Soil Organic Carbon

Due to the mechanisms of the cosmic-ray neutron probes, other source of hydrogen in soil need to be considered.

Eight soil samples were collected and mixed from each field. Soil lattice water w_{lat} (the amount of water released between 105°C and 1000 °C) and soil organic carbon were analyzed in the Activation Laboratories, Ontario, Canada.

Figure 3. Soil samples from Cross Timbers at Marena were being mixed.

Soil organic matter were converted into an equivalent amount of water w_{SOC}, according to the method proposed by Hawdon et al. (2014).

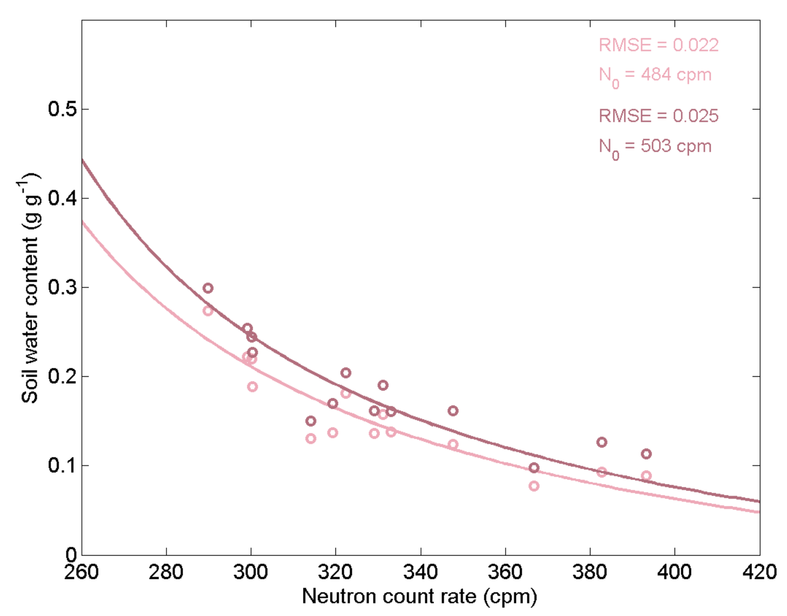

Figure 4. Effect of lattice water on cosmic-ray rover calibration. The pink circles and curve represent the regression without the lattice water corrections. The purple ones represent the data included the lattice water as an additional source of hydrogen.

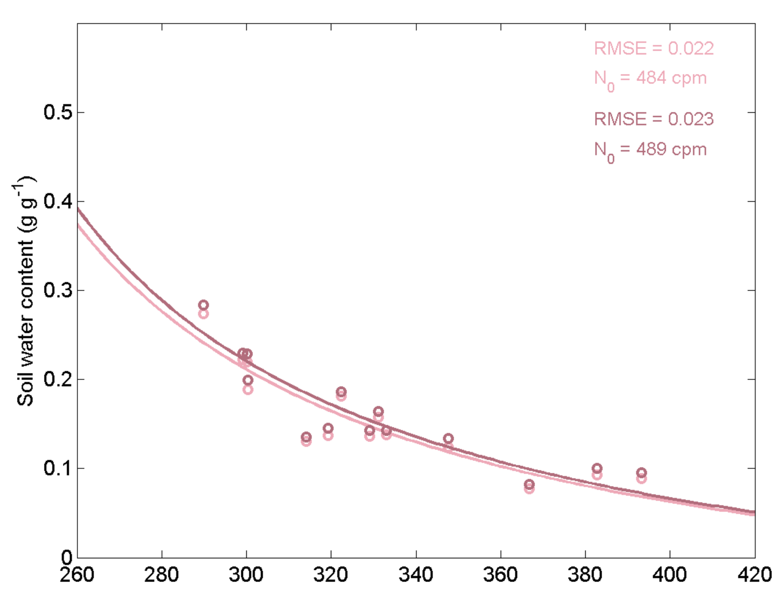

Figure 5. Effect of soil organic carbon on cosmic-ray rover calibration. The pink circles and curve represent the regression without the soil organic carbon corrections. The purple ones represent the data included the soil organic carbon as an additional source of hydrogen.

Application of Calibration Results and Correction factors

Shape-defining function (Desilets et al., 2010):

$$\theta = \frac{0.0808}{\frac{N}{N_0} - 0.372} - 0.115$$

$$\theta = \theta_g + w_{lat} + w_{SOC}$$

$$N = N_{raw}\frac{f_p f_{wv}}{f_i}$$

Correction for Atmospheric Pressure Variation

The neutron intensities were corrected to a reference pressure P_{ref}, which is the average atmospheric pressure at El Reno on June 20 in this study.

$$f_p = \exp[\beta(P - P_{ref})]$$

In the equation above, β is the atmospheric attenuation coefficient and P is the atmospheric pressure (Desilets and Zreda, 2003).

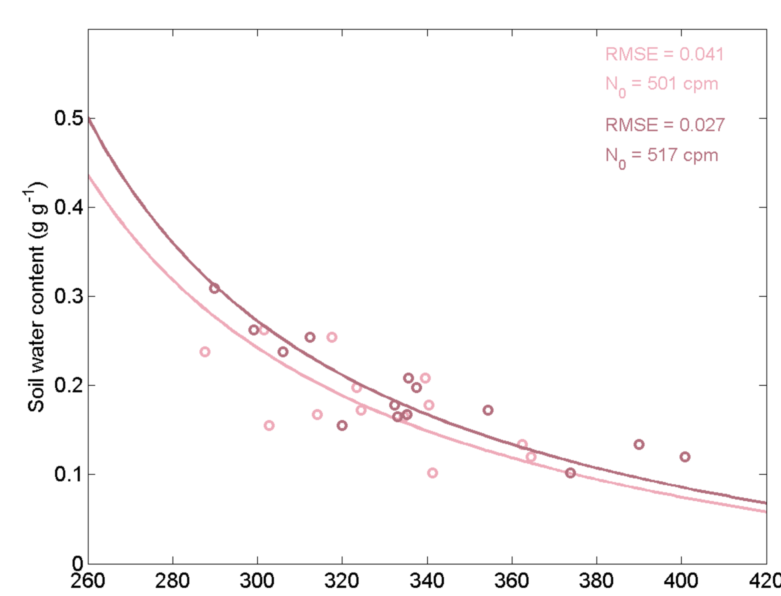

Figure 6. Effect of atmospheric pressure variation on cosmic-ray rover calibration. The pink circles and curve show the raw data and their fitted shape-defining function. The purple ones represent the data with atmospheric pressure corrections.

Correction for Incoming Neutron Flux Intensity

The variation of neutron flux intensity also has an effect on the measured neutron intensity. The neutron monitor data at Dourbes, which has the most similar cut-off rigidity and altitude with the study sites, were used in the calculation for neutron flux intensity correction factor f_i.

$$f_i = \frac{I_m}{I_{ref}}$$

In the equation above, I_m and I_{ref} are the selected neutron monitor counting rate and the reference counting rate respectively.

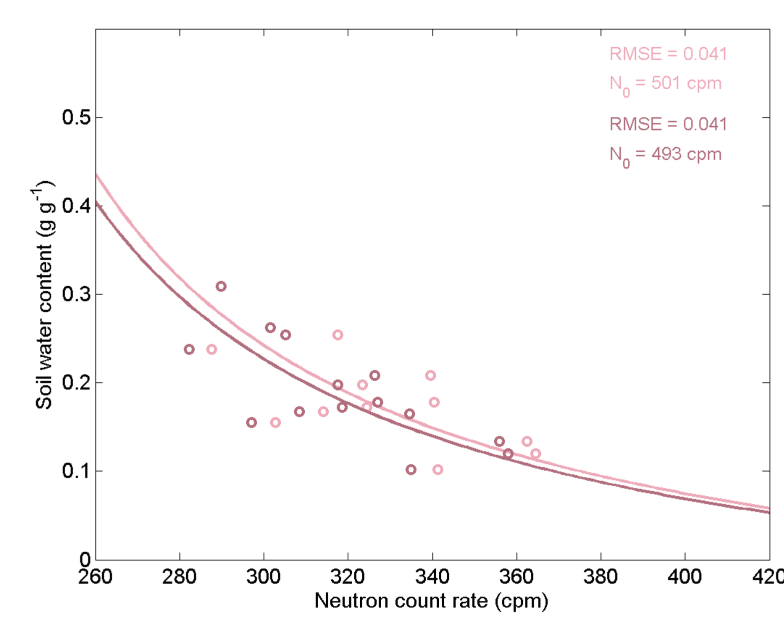

Figure 7. Effect of neutron influx intensity on cosmic-ray rover calibration. The pink circles and curve show the raw data and their fitted shape-defining function. The purple ones represent the data with incoming neutron flux corrections.

Correction for Atmospheric Water Vapor Variation

The correction factor for atmospheric water vapor variation f_{wv} is calculated from the equation below (Roselom et al., 2013), in which ρ_{v0} is the selected absolute humidity, and ρ_{v0}^{ref} is the reference absolute humidity.

$$f_{wv} = 1 + 0.0054(\rho_{v0} - \rho_{v0}^{ref})$$

Absolute humidity were calculated using the air temperature and relative humidity data from Oklahoma Mesonet stations nearby.

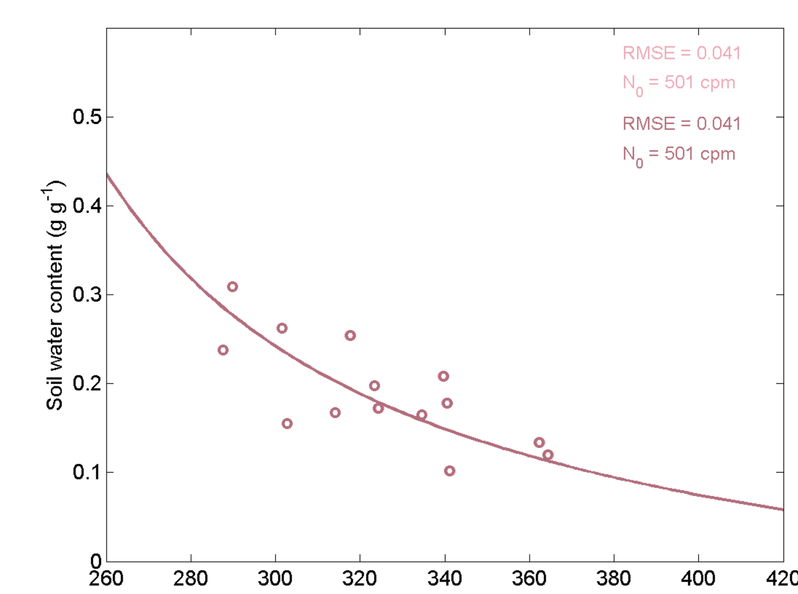

Figure 8. Effect of atmospheric water vapor variation on cosmic-ray rover calibration. The purple circles and curve show the data with atmospheric water vapor corrections. The data without the corrections are drawn with pink color, which highly overlap with the corrected ones.

References

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