

Reviewer 3

Comments and Suggestions for Authors

Review of manuscript sensors-3003165 Effect of biomass water dynamics in cosmic-ray neutron sensor observations: A long-term analysis of maize-soybean rotation in Nebraska by Morris et al.

Summary

The Authors present a study about biomass correction for improving soil water content estimation by means of cosmic ray neutron sensing techniques. The topic is relevant. The Authors present a very good data set and a scientifically sounded analysis. In general, the manuscript is well structured and written but some figures are a bit redundant. Discussion is reached. In suggesting possible improvements, I have listed below one major change in the presentation of the results that might improve the clarity of the manuscript and several but minor specific comments.

Thank you for review and recognition of this study's merit and relevance. We address your comments here in red italics, and changes to the manuscript are highlighted in yellow in the resubmitted file.

Major comments

I appreciated the decision to show one year and one location as example (Section 3.1) and then the overall results (section 3.2 and Figure 7). The year selected is however the 2020 where only TDR observations are available. The comparison to the gravimetric is shown later in section 3.3. I suggest the Authors showing first the results of the year where you have also the gravimetric samples and discussing the differences between using TDR and using the gravimetric. This would help understanding the results and would strengthen the use of TDR over all the years.

Figures 4, 5, and 6 were changed to have CSP1 2023 data presented, rather than 2020. These can be seen as the new figures 5, 6, and 7 (Lines = 319, 344, and 364 respectively) in the revised manuscript, or below.

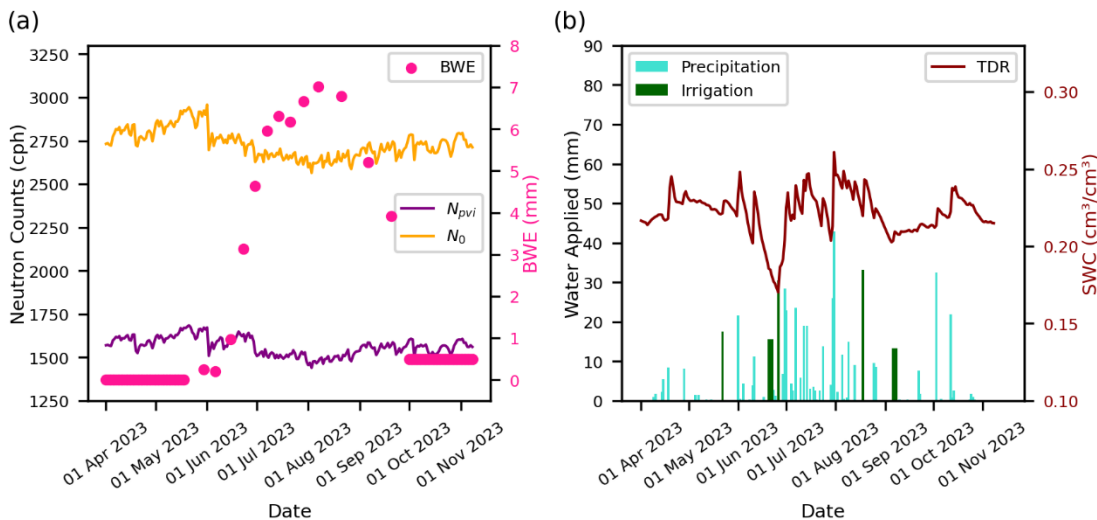


Figure 5. (a) Plot of N_{pvi} , N_0 , BWE time series. (b) A bar chart of the irrigation and precipitation (mm) at site CSP1 in 2023 and the corresponding SWC time series. The same plots for all other years and fields can be found in Supplementary Materials.

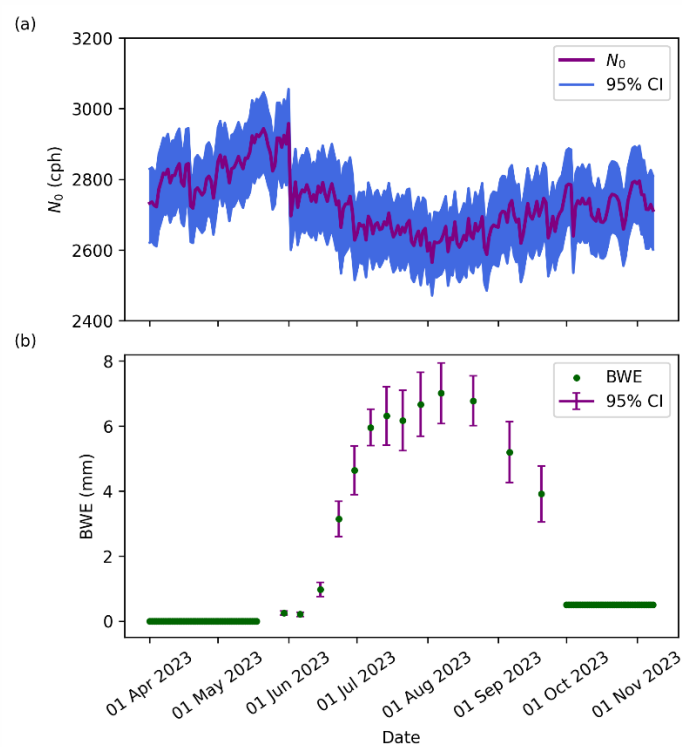


Figure 6. (a) Time series of N_0 using TDR in Equation 4. Error bars represent the 95% confidence interval. For N_0 , the uncertainty from the TDR was propagated through Equation 4. (b) The corresponding BWE for CSP1 in 2023. The uncertainty for BWE was calculated from the six replicate plots across the field on each sample date. The BWE uncertainties were calculated using standard errors.

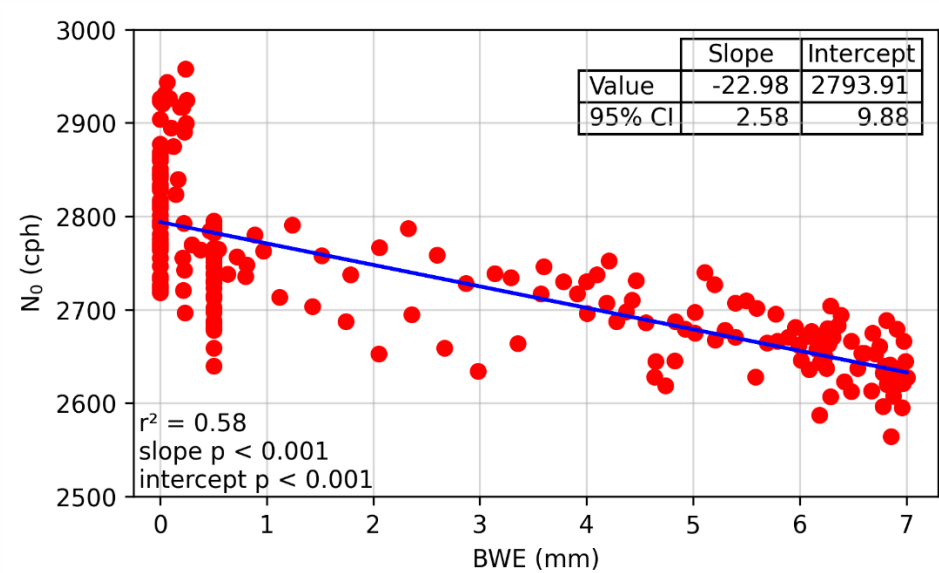


Figure 7. Scatterplot of N_0 vs. BWE for CSP1 for 2023. This plot presents the slope and intercept values with their corresponding 95% confidence interval, p-values, and the coefficient of determination for the relationship. Residual values are likely caused by noise in TDR measurements and their spatial averaging with a small number of sensors.

We have also added a paragraph segment to address and emphasize the key differences in TDR and gravimetric data: “The key differences between using TDR data and gravimetric data are the accuracy and uncertainty. Gravimetric data is considered the most accurate SWC measurement method, but it is difficult to collect, which is why this study only has 8 or 9 gravimetric SWC measurements per field. TDR data was collected hourly and then averaged to daily values, meaning one data observation per day. Over the course of the growing season this is 228 observations. The gravimetric data is considered a more accurate SWC estimate, but the values have more uncertainty due to the small number of observations compared to TDR data.” (Lines 387 – 385)

Specific comments (L – line number)

L63. 3rd instead of 2nd?

This line was changed as follows: “This includes first- and second-order scale correction factors for time-varying air pressure (1st), high-energy neutron intensity (1st), and atmospheric water vapor (2nd), as summarized in Zreda et al. [Error! Reference source not found.] and continually improved by the community [Error! Reference source not found.]” (Lines 73 – 76)

This was changed to reflect that air pressure and high-neutron intensity have the most significant influence on neutron counts, while atmospheric water vapor has less of an influence. In this case, the third-order correction would be the biomass correction proposed in this manuscript.

L160 Any comments on the plant residues? They were left in place for soil cover. If too dry to affect BWE and fb factor, they might affect soil carbon?

The plant residues may have an influence on the soil carbon, however, it is likely not a major influence. In 2014 the soil organic carbon ($\theta_{SOC_{eq}}$) in CSP3 measured to be 0.006 g g^{-1} , while in 2023 the value in CSP3 was 0.0097 g g^{-1} . This change may reflect the impact of plant residues in the soil, but this was not directly analyzed.

A paragraph was also added to address the impact of plant residues and potential influences on soil carbon:

“At the end of each season, the crop grown that year is harvested. The soil surface is not cleaned, so a small litter layer of plant matter remains on the surface. In the years that maize was grown, there is approximately 50 cm tall stover left over on the ground surface. This stover is very dry, and it was estimated that this stover contains 0.5 mm or less BWE. In the years when soybeans are grown, the plants are harvested very close to the ground, so most of the previous years' stover is removed as well. Any litter that remains is likely blown away or desiccates over the winter season. Some litter may remain and become incorporated into the soil as soil organic carbon ($\theta_{SOC_{eq}}$), which may account for the slight increase in $\theta_{SOC_{eq}}$ in CSP3 between 2014 and 2023 (Table 2).” (Lines 275 – 283)

L183. CRNS is sensitive to the upper soil layers but TDR have been installed at 10 cm and down. Any comments? A discussion when comparing TDR and gravimetric could be reported not only in the discussion section but also when results are presented.

CRNS is most sensitive to the upper soil layers. The TDR sensors were installed as the Long-Term Agricultural Research network and Ameriflux projects, and they were not for direct use in this study. This lack of an upper TDR sensor is proposed as a source of error in this study.

The following sentence was added to the manuscript address the lack of a shallow TDR sensor: “The TDR sensors were installed as part of the Long-Term Agricultural Research network and Ameriflux projects, but they were not for direct use in this study. For this reason, the TDR sensors were installed at depths to meet the goal of those projects, which do not necessarily align with the goals of this study.” (Lines 192 – 195)

The following paragraph (shown above as well) was added to address the need for comparing TDR and gravimetric values:

““The key differences between using TDR data and gravimetric data are the accuracy and uncertainty. Gravimetric data is considered the most accurate SWC measurement method, but it is difficult to collect, which is why this study only has 8 or 9 gravimetric SWC measurements per field. TDR data was collected hourly and then averaged to daily values, meaning one data observation per day. Over the course of the growing season this is 228 observations. The gravimetric data is considered a more accurate SWC estimate, but the values have more uncertainty due to the small number of observations compared to TDR data.” (Lines 387 – 385)

L196. I have seen some effort of the Authors in comparing the weight functions. Is still debated if one or other is better? Please elaborate a bit on that on the manuscript to help the readers to understand the motivation behind.

It is still debated which weighting method is best. Figures 8, 10, and 11 best show that in each field, a different weighting method performs best in the fit of the linear relationship. The method by Schron et al. (2017) is considered the best weighting method currently, but these results do not strongly support one method over another.

A sentence was added to the manuscript to address this: “Recently, the Schron et al. [11] weighting method has been proposed as the most accurate weighting method, accounting for both radial distance and depth for neutron influence. This study used the 10, 25 cm weighting to directly compare to TDR measurements and arithmetic average weighting to compare to a prior study in this same field [22]” (Lines 215 – 219)

L220. I would add a short description about how LW and SOC were determined or add a reference where it is described. Since you work with long-term experimental sites, any idea about the changes of these values in time? Also in relation to the plant residues?

Thank you for addressing this lack of information. A description of how these values were determined was added to the manuscript: “ θ_{LW} and $\theta_{SOC_{eq}}$ were determined by gathering a ~100 gm aggregate soil sample from each location (~5 gm each) for each field at depths of 0-10 cm, 10-20 cm, and 20-30 cm. The samples from each field were air-dried and sent to Activation Laboratories Ltd. in Canada, where infrared spectroscopy (IR absorption) was utilized to determine $\theta_{SOC_{eq}}$ and θ_{LW} was determined by thermal decomposition in a resistance furnace followed by IR absorption. Given the proximity of the fields and similar results, the average value of the three fields was used in the data processing. The detection limits in determining θ_{LW} and $\theta_{SOC_{eq}}$ were 0.5% and 0.1% by mass, respectively. One item of note is the increase in $\theta_{SOC_{eq}}$ between 2014 and 2023.” (Lines 241 – 249)

The following sentences were also added to address changes in these values over time and the potential influence of plant residues: “A possible explanation for this is crop litter, which will be further discussed. Another factor that may influence this is a change in sampling methodology between 2014 and 2023. In

2014, total carbon and CO₂ were measured, and the organic carbon was calculated using stoichiometry. In 2023, organic carbon was measured as well.” (Lines 249 – 253)

L229. Adding the IMZ area and the plant sampling location at Figure 2 would help the reading.

Thank you for this helpful suggestion. The location of all IMZs have been added to Figure 3 (formerly Figure 2) in gray. (Lines 162 – 168)



Figure 3. Locations of CRNS and profiles of in-situ soil water content (SWC) time domain reflectometry (TDR) sensors in this study for sites CSP1, CSP2, and CSP3. TDR sensor depths are 10, 25, 50, and 100 cm for all sites and 175 cm for CSP3 only. Field sites CSP1 and CSP2 have three profiles, and CSP3 has four. TDR sensors are denoted with location markers and their associated IMZ number, while the CRNS sensors are denoted with thumbtacks. Gray markers show the IMZs where only vegetation samples are collected and no TDR sensors are present.

A brief description of the biomass sampling methodology around these IMZs was also added: “These IMZs are 10m x 10m areas surrounding the markers in Figure 3. Only 3 or 4 of the 6 IMZs have associated TDR sensors with them, which are shown in Figure 3.” (Lines 260 – 261)

L279. I do not really see a similar general patterns? Why should that be? Please elaborate on that.

This plot shows N_0 and N_{pvi} . By similar general patterns, it was intended to mean that peaks occur at the same timings for both plots. N_0 is more exaggerated than N_{pvi} , but the timing of peaks is similar.

The sentence with this statement was reworded to more clearly iterate the meaning: “The plot illustrates that N_{pvi} and N_0 follow similar general patterns, as peaks have nearly the same timing and shape, only the amplitude varies, with more subdued peaks for N_{pvi} values. The amplitude variations exist because the N_0 values account for the pore water content, lattice water content, soil organic carbon, and fixed parameters, while N_{pvi} does not. This similarity in shape is anticipated, as N_0 is calculated by the modified Desilets equation (Equation 2) using N_{pvi} as an input value.” (Lines 323 – 329)

Figure 4b shows a remarkable drop in TDR observations in April. Can this be explained or rather a sensor malfunction? This dynamic also affects the N_0 in figure 4a but might be considered an error. I suggest a quality check of the TDR data before looking at N_0 and BWE relation. CRNS SWC could also be added and discussed in Figure 4b. Please also clarify if this TDR time series is the average of all the sensors (location and depth) within the field.

With the figures changed prior in this review, the drop in TDR observations in April is not as severe. In the CSP1 2020 figure, this severe drop in TDR observations was likely due to dry winter and spring seasons in combination with warm spring conditions. Irrigation in CSP1 in 2020 was performed in April.

The only other year this occurred was in 2021. Irrigation occurring this early indicates extremely dry conditions, which affirms the severe drop in TDR observations. A more likely source of this drop is sensor error. In early 2020 routine maintenance could not be performed on TDR sensors due to the onset of COVID restrictions, so sensor error is likely. These sensors were able to be serviced around the time of the TDR rebound.

The new figure does have a shift in TDR values present, and this is addressed as follows: “There is a shift in June, which is likely due to sensor error, which was then repaired.” (Line 342 – 353)

Add line was added to the figure caption to clarify that this is the average of all TDR sensors in the field, after the 10, 25 cm weighting was applied: “The TDR values were weighted with the 10 cm sensor having 75% contribution and the 25 cm sensor having 25% contribution. The averaged values of all TDR sensors in the field was used to plot the line.” (Lines 322 – 324)

Figure 5. Am I wrong or these plots show the same as figure 4a but with bands? I think the figures are redundant and I suggest to rather keep only one, e.g., to show in figure 4b the time series as in figure 5.

These figures do show similar items. However, the main purpose of Figure 5 (now Figure 6 in the revised manuscript) was to show the error ranges on the N_0 and BWE measurements. With the error ranges included in Figure 5a (formerly 4a), the figure becomes unclear and difficult to understand. Another benefit of Figure 6 is that it highlights the timing of N_0 and BWE with one another.

In Figure 5 I see that after harvesting BWE remains higher than zero, but I did not find information about it in the manuscript. Please clarify.

This information was not addressed in the manuscript. An explanation for this has been added: “After harvest, BWE remains higher than zero to account for the plant debris, like corn stover, on the surface. Most of this debris degrades over the winter and is completely removed with soybean harvests the following year.”

L356 – 361. Hard to read and follow this text. Better to summarize the message rather than writing all the years

Agreed, this was confusing to read and difficult to follow. It was determined that the information conveyed was rather clear in the figure itself (error bars overlapping in Figure 9 in the revised manuscript), so the figure was referenced, rather than explicitly listing every year. This was changed as follows:

Lines 415 to 417: “Within all three fields, the confidence intervals overlap between several years, indicating they fall within one another’s error ranges (please see Figure 9 to view confidence intervals).”

Lines 430 to 433: “The confidence intervals overlap for many years presented (Figure 9).”

L380. Does the seasonal precipitation can really explain the intercept variation? Why? Please elaborate on that.

Thank you for pointing this out. We have removed this sentence. Upon further reflection, there is not enough evidence to back up this claim and this could be an interesting direction for further research.

L381. At CSP3, there seems to be a systematic shift to higher intercept values from 2016 to 2023. Could you explain that? Anything about the time changes of organic carbon? See comment above.

We agree that there does appear to be a systemic shift to higher intercept values; however, we do not have a physical explanation of why this happens. The soil organic carbon does change slightly, but as mentioned in a prior comment, most of this is removed every other year when soybeans are harvested. It is unlikely that a small change in the organic carbon would have this sudden and significant of a change on the intercept. In short, we do not know why this happens, but it should be investigated.

This was addressed as such in the revised manuscript: "To the author's knowledge, there is no clear physical explanation for this shift. One potential source of this change is an increase in soil organic carbon; however, as previously mentioned, most of this is removed every two years. While this is within the range of the overall average, this area deserves additional investigation." (Lines 436 – 440)

We also note that while there is a shift, it is not extreme, as it falls within the 5% error range of the overall average TDR value for this field. A black dashed line was added to Figure 9 (formerly Figure 8) to show where the global averages of each slope and intercept occur (Lines 401 – 405).

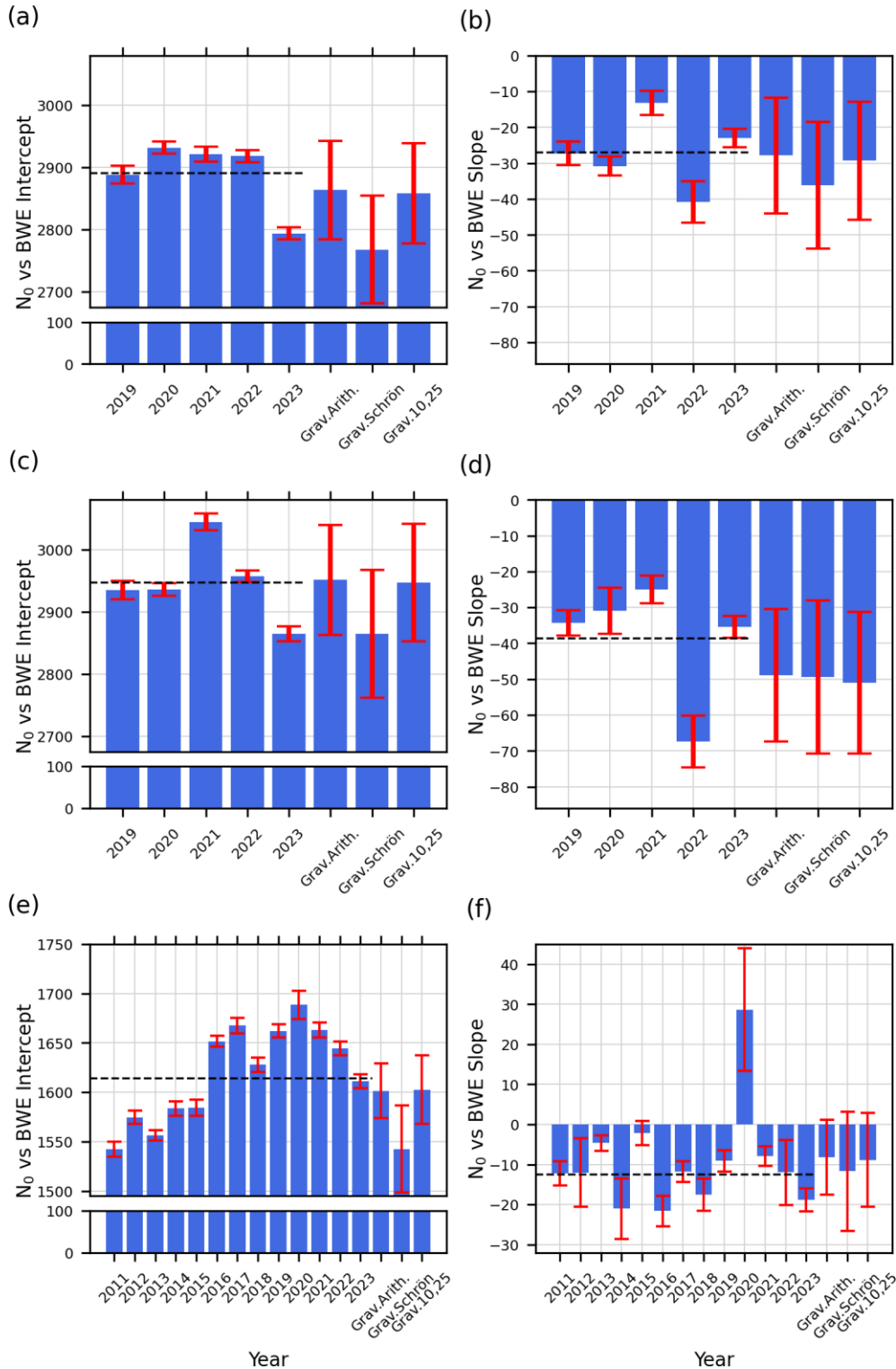


Figure 9. Yearly plot of N_0 vs. BWE slopes and intercepts for (a) & (b) CSP1, (c) & (d) CSP2 and (e) & (f) CSP3. (a), (c), and (e) are intercepts, (b), (d), and (f) are slopes. Please note the broken axis on the intercept plots. Error bars show the 95% confidence intervals. The black dashed lines denote the overall average of TDR slopes and intercepts within each site.

This was also addressed in writing in the manuscript: “All within-field intercept values are within 200 counts, which is within 5% error range of the average TDR value.” (Line 433 – 435) and “Within all three fields, the confidence intervals overlap between several years, indicating they fall within one another’s error ranges (please see Figure 9 to view confidence intervals). Most TDR slope values within each field are within 10% error of the average slope value for CSP1 and CSP2. This same consistency likely is not seen in CSP3 due to more variability in measurements.” (Line 417 – 421)

L436. Instead of “gravimetric data set” is SWC data set.

Thank you for catching this. We changed this to SWC data set.