Quick response to the reviewer comments on the paper titled "Integral quantification of seasonal soil moisture changes in farmland by cosmic-ray neutrons" by Rivera Villarreyes, Baroni, and Oswald.

We highly appreciate the constructive comments of the reviewer and respond briefly to the major points.

(i) The paper is not always written in a clear and understandable way; especially the methodology section has to be more comprehensive (see comments below). [by Reviewer #1 (H. Bogena), and similar reviewer #3 (H. Flühler)].

We will improve the final quality in revised manuscript based on the various suggestions provided by all three reviewers, and our own, additional efforts.

(ii) There are several issues concerning the calibration methodology, e.g. calibration data, validation of the calibration parameters (see comments below). [by Reviewer #1 (H. Bogena), and also reviewer #2 and #3 (H. Flühler)]

In this manuscript, we suggest a procedure to ease the practical application of the method without the need of modeling neutron scattering or locations with a deep soil monitoring network, based on intensive but practical monitoring activities.
Some specific points are

- Calibration procedure – There is only one calibration, resulting in a single set of calibration parameters. In difference to standard calibration procedures for other types of devices, we decided to use not all data from the first measurement period, but only three selected short-periods within. These periods are chosen to cover a range of medium moist conditions, with (presumed) reasonably similar moisture in the penetration depth of the CRS and the close-to-surface soil measurements. The CRS-derived soil moisture outside these three short-periods is not adjusted by calibration of the parameters and thus could be counted to testing the method.

- Validation – For the whole winter period the single, original calibration parameters were used. Outside the periods with snow cover, which has its own specific influence, this could be taken as validation, on top of the intermediate periods from the summer campaign (see above).

- Penetration depth and calibration – We are very aware of the fact that local soil moisture measurements in different depths will improve the calibration and testing of the CRS-method and a better assessment of the actual penetration depth, depending on soil moisture itself. Notwithstanding, we have assessed the method and applied it based on common and practicable FDR measurements representing the topsoil surface only, in its own right.

- Calibration function – The mathematical form of the calibration function Is based on the results from Desilets et al. (2010) and is a fit to values resulting from a statistical simulation of neutron transport at the soil-atmosphere interface, fully based on

physical principles. Thus it is more than an empirical function, allowing also evaluating values (somewhat) outside the range of measured soil moisture values used for calibration. It also can be transformed mathematically, if a different counting rate N0, e.g. a lower one, shall be used for normalizing the count rates, resulting in a different value of two of the three calibration parameters. This dependence is also a reason why calibration parameter values differ from the ones reported by Desilets et al. (2010).

(iii) Some of the statements have to revised, e.g. concerning the measurement footprint and the transferability of the calibration (see comments below). [by Reviewer #1 (H. Bogena), and similar reviewer #3 (H. Flühler)]

We will rework the conclusions on footprint, transferability and soil effects based on the reviewers' comments to achieve more carefully phrased statements.

(iv) Some physical explanations are missing, e.g. effects of snow on neutrons count rate, effects of freezing on MR2 readings (see comments below). [by Reviewer #1 (H. Bogena), and similar #3 (H. Flühler)]

We will include a better explanation concerning to these points. On one hand we will in more detail discuss existing work on snow influence (e.g. by Kodama et al.) on measured neutrons. Also, we will estimate snow water mass equivalent instead of referring to snow height only. On the other hand, we will state clearly, that for freezing conditions the MR2 readings are not representing total soil moisture, but give a lower limit to it, because frozen water has a reduced dielectric constant. In this sense they are not working the way we need it to be useful as soil moisture measurements or even testing the CRS. However, in the revised manuscript we will describe that more adequately.

I would suggest to split the Summary and Conclusions section into a Discussion and a short Conclusion chapter.). [by Reviewer #1 (H. Bogena)]

The other reviewers did not have a similar suggestion. We will be happy to change the sections if the editor will favor this.

<u>Specific comments</u>

For this quick response we have selected the key points and these are discussed below:

P13 L7 But the measurement depth of the CRS at medium wet conditions is more than 0.1 m (see above).

The phrasing of out sentence was misleading. The CRS penetration depth, as far as we know about it, is indeed larger than 0.1 m; we just wanted to argue that for drier

conditions the overlap between the depth of origin of detected neutrons would be worse than if we take medium moist to moist conditions.

P16 L11 Did you combined the measurements of both CRS to reduce variability?

And **P16 L11-13 Did you use the complete measurement period?**

No, we just used the second moderated counter for comparison with the first, showing a good correlation (r^2 = 0.81 for one hour integration and r^2 = 0.97 for six hours integration). Also, the second counter had some more gaps in the data record due technical issues we had decided, for simplicity of the analysis, not to include them in the further interpretation. The gain in signal-to-noise would be about √2, thus not immense.

P16 L21-23 Suppose you want to use the CRS for long-term monitoring of soil moisture. In case the soil moisture would decrease to a value below this minimum soil moisture value, calibration function would not be valid anymore. Therefore, the calibration is only valid for soil moisture higher than the minimum soil moisture value of the calibration period.

Please see response to general comment (ii), last point.