Response to reviewers

Anonymous Reviewer n.2

This paper investigates the feasibility of CRNS-based SM monitoring in irrigated environments. The paper is informative with lots of simulations in different scenarios. Simulation of neutron count in different scenario was performed with Monte Carlo simulations and Ultra Rapid Adaptable Neutron-Only Simulation. However, obtained results were not validated using real case scenario of irrigated areas.

The author chose a square, not a circle, irrigated area. While the CRNS is tube-shaped and the footprint of the CRNS is circular, is there a reason for that specific shape? Also, do we expect an improved detection rate or minimal if he changed it to circular?

As Reviewer n.1 also points at the shape of the irrigated field, we provide here the same set of answers. We believe that a circular pivot irrigation field would have not been the best choice for this study. This because circular centre-pivot irrigated fields are very large and typically 400 m in radius (although 500 m are also common and larger exist). Small centre-pivot irrigated fields are not common. The large dimension of a centre-pivot irrigated field means that most of the neutrons detected by a CRNS placed in the middle of such large field (if not all detected neutrons) originate within the irrigated field. Thus, the irrigation that the CRNS would sense is comparable to a rain event, and we think this would not be as interesting as a smaller field of a few ha where the outside area plays an actual role.

Relatively small fields as those investigated in this study are most often rectangular and not circular. It is true that the rectangular shape can vary greatly and elongated rectangular shapes are common, but the inclusion of elongated shapes in this study would lead to a much more complex manuscript and would go beyond the scope of the manuscript. Since the manuscript is already long and complex in the current form, we believe that the reader would have strong difficulties in navigating through additional shapes of the irrigated area. Nonetheless, it could be expected that such elongated shapes would be more challenging for the CRNS compared to a squared shape. We agree with the reviewer that the selection of the shape is an important topic, and we will include additional considerations in section 4 "Limitations and outlook". We also think that future research, especially in real-case scenarios, should investigate these aspects and we will mention this in the revised manuscript.

Furthermore, we tested the simulation of a circular and rectangular (142x70 m) irrigated fields of 1 ha area and compare the results with those of a squared 1 ha irrigated field. The results are shown in Figure 1 *in a similar way as they are shown in Fig.8 of the manuscript. In general, differences between the squared, circular, and rectangular shaper are rather small, at least in this simulation setup. Compared to the squared shape, there might be sometimes a small tendency towards higher relative changes in detected neutrons for a circular shape and a tendency towards lower relative changes when a rectangular shape is used. However, results are too similar to draw meaningful conclusions. A clearer picture could possibly be obtained if these two additional scenarios are simulated for the entire soil moisture range of 0.05 to 0.50 cm^3 cm^{-3} and for the five investigated areas of the irrigated field. However, this would increase the number of simulations* *by +200%, which is not feasible due to time and computational constraints and goes beyond the scope of the manuscript. Thus, we decided not to add simulations of different field shapes to the manuscript.*

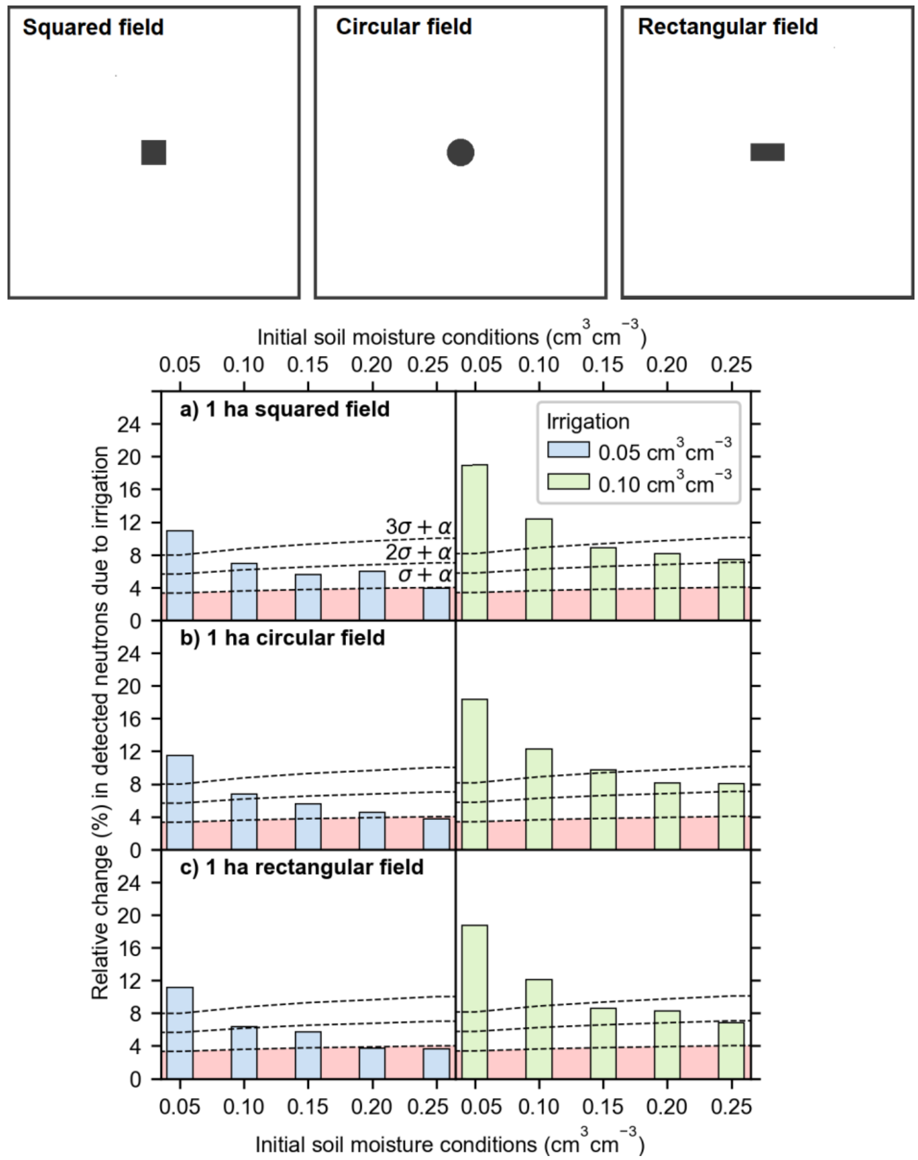

Figure 1: CRNS chance of detecting irrigation events of 0.05 and 0.10 cm3 cm-3 (blue and green bars respectively) in a) squared, b) circular, and c) rectangular irrigated field of 1 ha. The bars show the relative change in detected neutrons induced by the irrigation event while the dashed lines show the prescribed detection thresholds. The red area below the σ+α threshold indicates uncertain detection.

Belo few questions that could make the paper clearer for the reader:

We have carefully examined the comments provided by the reviewer and we offer here a point-by-point answer.

Line 14: the unit needs typo correction

The new version of the manuscript will offer a corrected version for this typo.

Introduction: Recent work on soil moisture mapping from SAR images is worth reporting in the introduction, primarily those that provide operational soil moisture mapping through the synergistic use of Sentinel-1 and Sentinel-2.

We agree with the reviewer that such studies on radar-derived SM products are of general interest and could fit the first paragraphs of the introduction. However, reviewer n.1 pointed at the length of the introduction, which will be shortened in the new version of the manuscript, and at the large number of general references on soil moisture. We would thus prefer not to add these further references to the manuscript at this point.

In line 143-144, you mentioned that variations in humidity, vegetation, and other environmental variables can affect the footprint but with less degree than the SM effect. However, in the simulation, these factors were fixed (line 167-170). Can you explain what the impact would be on the simulation results if you include the diurnal weather conditions?

We can expect that the diurnal changes in humidity and other environmental variables will affect the CRNS footprint and count rate as mentioned in the manuscript. Regarding the count rate, correction procedures exist for most of such variables and in real-world applications. For example, although atmospheric humidity could vary in an irrigated field, this is typically measured, and the count rate is corrected accordingly.

The effect on the footprint, on the other hand, cannot currently be corrected but only explored using neutron transport simulations. Based on this, we can expect a variation in the footprint due to atmospheric humidity changes as shown by Köhli et al. 2015. However, the investigation of a second humidity value would double the quantity of simulations and results. As multiple air humidity values would need to be simulated to obtain meaningful results, we believe that this would result in a too complex picture for the reader and, overall, in a confusing and unfocused manuscript. The same applies to other variables such as vegetation as this would go beyond the scope of the manuscript as the focus is on soil moisture. Nonetheless, we agree with the reviewer that such effects should be mentioned and possibly explored in future research, and we will add considerations on this matter to section "4 Limitations and outlook".

Line 187: why did you choose 9m radius specifically for all the simulations? Is there a method for choosing the right radius size for the tube?

The dimension of the virtual detector was set to 9 m as this is commonly done in such simulations with the URANOS model. In selecting the dimension, two aspects should be considered:

a) The smaller the virtual detector, the lower the chance of detecting a simulated neutron and thus the lower the statistical significance of the simulation. This can be counterbalanced by a higher number of simulated neutrons, which however can considerably extend the simulation time and computational needs.

b) A larger virtual detector has higher chance of detection and thus higher statistical significance of the simulations. But the more the dimension of the virtual detector is *stretched beyond that of the actual detector, the more secondary effects can influence the simulation results.*

In the end, a 9 m radius (generally below 5% of the footprint) is a good geometrical limit (and a good compromise between the above-mentioned aspects). This is valid for a typical analysis where there are no variations of the environmental topology in the immediate vicinities of the virtual detector. As these considerations are discussed in some of the literature that the manuscript refers to, we believe that there is no need at this point for additional information on such detail of the methods.

Looking at Table2 + Figure 3 and then Figure 6, Figure 7 and Fig 9. They are very well connected, I wonder why they did not come directly after each other so that it is easier for the reader to stay on track!

We agree with the reviewer that such alternative order of the results can offer a nice storyline and a clearer reding. In the new version of the manuscript, we will reorganize the results sections. We will first discuss the footprint dimensions (current Fig.4 and Fig.5) and then the other aspects (Tab. 2, Fig.3, Fig.6, Fig.7, Fig.8, and Fig.9). We will then adapt the consistency of other sections such as abstract, introduction, and conclusions. This will not alter the overall results or the message of the manuscript but will offer a better reading experience.

Lines 374 – 376: "As shown in Figure 8, an irrigation event that leads to a 0.05 cm3cm-3 increase in SM can be detected with CRNS (relative change in detected neutrons higher than $3\sigma + \alpha$) when the initial SM of the simulation domain is 0.05 cm3cm-3." It looks like there is an overlap in this figure: the green bars represents the 0.05 cm3cm-3 initial SM and the blue bar for the 0.10 cm3 cm-3 . Indeed, the relative change is lower when the increase of soil moisture is higher. Is that correct?

We thank the reviewer for the comment as we now understand that the readability of Fig.8 should be improved. In Fig.8, the blue bars on the left plots refer to a 0.05 cm^3 cm^{-3} irrigation event and the green bars at a 0.10 cm^3 cm^{-3} event. The initial soil moisture is indicated on the X-axis at the bottom of the figure. Thus, the relative change is higher when the increase in soil moisture due to irrigation is 0.10 cm^3 cm^{-3} (green bars, left side). The relative change is generally lower when the initial soil moisture is higher.

To improve the readability of the figure, we will include titles with the irrigation amount on top of the X-axis and we will improve the legend. The new figure will clearly refer to irrigation-related soil moisture changes (see following Figure 2*). We believe that this new version will be a meaningful improvement, and we thank the reviewer for his comment. Please note that further modifications to Fig.8 were made according to the comments of Reviewer n.1 and due to the current use of multiple simulation results for the homogeneous initial soil moisture conditions.*

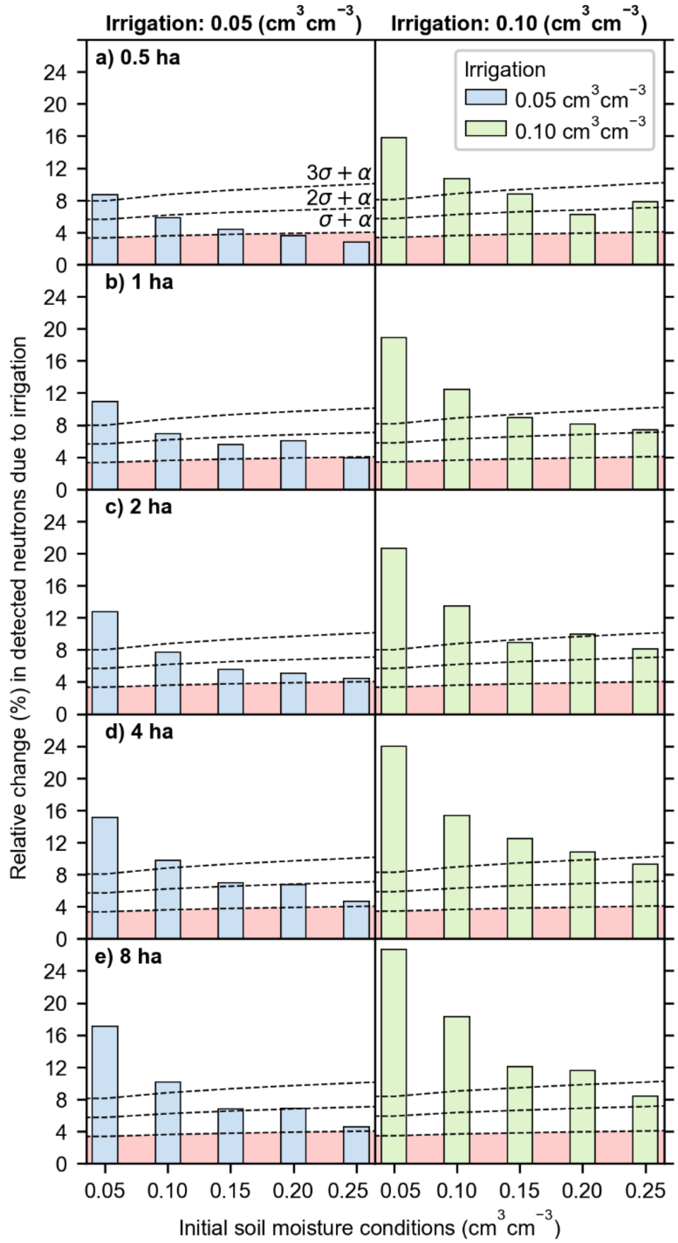

Figure 2: alternative figure that substitutes Fig.8 in the new version of the manuscript.