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Interactive comment on "Synchrotron microtomographic quantification of geometrical soil pore characteristics affected by compaction" *by* R. P. Udawatta et al.

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Interactive comment on "Synchrotron microtomographic quantification of geometrical soil pore characteristics affected by compaction" by R. P. Udawatta et al.

Anonymous Referee #2

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Overview:

Synchrotron-based X-ray tomography study enables detailed insights into the pore

space architecture at μm resolution. The authors used this technique to analyze the changes in pore space features during compaction. The main finding is that soil compaction leads to a significant reduction in macroporosity and that the reduction is pore size specific. More involved morphological features like coordination numbers and mean path lengths also exhibit characteristic differences. The analysis has no technical flaws. However, the findings are not supported by accompanying laboratory measurements so the implications for functional properties are not backed by data and the conclusions are a bit weak. The manuscript can be improved quite a bit (see my comments below). General comments:

1. The method description can be shortened considerably. Both the imaging & reconstruction (GSECARS and IDL) as well as the image processing methods (3DMA) have been published in detail elsewhere. It's sufficient to refer to them and state the impor- tant facts (energy, spatial resolution, filtering and segmentation method and network extraction). Thank you for the constructive suggestion. We have shortened the manuscript and included relevant literature with similar previous work by our group and others. However, another reviewer has suggested that paper was well-developed and provided sufficient information to understand the methods and therefore we did not condense the methods section excessively.

2. The main message gets lost in too many details. Too often you just repeat in the main text what has already been presented in Table 1 or the figures. As suggested we have removed the requested information in the results section and shortened the Results and Discussion sections.

3. The stated objective of your study (p4l25-27) is a bit vague. One could interpret it as if you used X-ray tomography in combination with 3DMA just because it was available to you and you want to demonstrate its capabilities now by detecting soil compaction at the pore scale. This may sound a bit unfair and I'm sure this is not true, but you need to put more effort into convincing the reader that from your findings one can learn something about the processes that act on the pore space during compaction. Thank

you for the comment. We have revised objectives as suggested.

4. Figures with 3D renderings or 2D sections of the pore space are required to get an idea about the expected differences. We have included two new figures in the revised manuscript as suggested.

5. The whole concept of coordination numbers and mean path length between adjacent nodes is well defined for rocks with distinct granular structure and clearly separable pore bodies and throats. For a soil with coherent structure and anisotropic macropores it might be somewhat ill-defined. I have to assume this, because you do not show images of the pore space. This may be the reason why you got unrealistically high coordination numbers, because it is not intuitive what a directly connected pore node is supposed to be in those cases (see comment below). It is therefore hard to judge for the reader how much the results for mean path lengths and coordination numbers depend on the parameters that you've set during network extraction. Thanks you for the comment. We have included a figure that shows differences between two densities. Since separation of solid and void is difficult using the raw images we agree that more sophisticated thresholding is required for these type analysis. However, we believe, indicator kriging method of the 3DMA Software is the best method to use. We believe that results from this study will help future research to be planned differently, since it shows the limits of the technique, and aid work for evaluation of these parameters to distinguish differences between in pore characteristics as influenced by soil management (tillage) practices.

6. In some occasions you refer to changes in functional properties due to soil compaction. However, you didn't measure those functional properties like water retention, air permeability penetration resistance etc. with accompanying laboratory measurements to support your findings. Therefore all implications are a bit speculative. The paper could be strengthened a lot, if you did this for the updated version of the draft (using the same sample preparation steps). Thank you for the good suggestion. We planned to conduct water retention and movement within those soils at those densities.

However, we did not complete those analysis for this paper and are being conducted for a separate study.

Specific comments:

p4l1: missing comma before connectivity Thanks, we have included a coma.

p5l5-7: What was the motivation to chose different size classes? Two different aggregate size classes were evaluated to quantify the changes in geometrical pore parameters as influenced by compaction and to evaluate whether CT methods have sufficient resolution at 9 micron scale to explain changes in geometrical pore properties.

p5l22-25: Irrelevant information. It's better to cite an appropriate reference for the GSECARS beamline here. Thanks for the suggestion we have edited this section as suggested.

p6l1-4: So you used a white beam setup with an energy range of 7-70keV and a spot size of 10-30μm. All other information is too complicated to understand for anyone who is not an expert in synchrotron X-ray tomography. We believed that sufficient information must be provided for the reader to understand the methods.

p6l10-13: irrelevant information Thanks for the suggestion we have deleted this section in the revised manuscript.

p6l24-25: unclear what the Riemann function does - better write: ... filtered back-projection with the IDL programming language (Rivers, 1998). We have revised this section in the revised manuscript.

p7l19-21: These statements are hard to understand for someone who hasn't used IK before. Two threshold have to be set a priori; one for dark voxels that definitively belong to pores and one for bright voxels that definitively belong to solid space. The remaining voxels are assigned by the IK algorithm according to neighborhood statistics. These two thresholds were set manually at the histogram peaks for pores and the aluminium wall. We have revised these sentences.

p8l3: ' ... pass so-called pore throats' We have revised these sentences.

p9l18-l25: This paragraph can be omitted (or should be placed somewhere else.) We have deleted this section as suggested.

Table 1: Total volume is hard to interpret. You should use porosities instead. There seems to be a footnote for Aggregate* compaction, but I couldn't find it. What are the units in the ANOVA lines? Sizes and volumes or probabilities We have provided the sample size (5 mm long and 5mm diameter) and bulk density values in the methods section. Porosity can be estimated from those values. We also have provided CT resolved pore volume in Table 1 to estimate CT resolved porosity.

p10l1: Geometrically Thanks for the suggestion. It was corrected.

p11l6-7: That's only the case, if the largest pore has connection to the surface. This comment is true. However, our samples were uniformly packed and on seals were present that would prevent connections to the surface.

p11l7-8: Do you present the results of the Assouline model somewhere in you paper and compare them to measures values? Otherwise this statement is a bit speculative and should be changed accordingly. Thanks for the suggestion. We have revised this section.

Figure 1: The differences between the sub-figures are hard to see. Also, why did you use selected replicates and not the the average pore size distribution of all three replicates. I suggest to plot treatment averages with for different line styles in one figure on a reduced x-range up to 400μm. Treatment averages were provided in the table (1). Sample average was also included in each figure. We attempted to develop all replicates in a figure for each treatment, it was too crowded. Then we developed a figure using average values. It did not represent samples as those frequencies were not the same for all samples.

Figure 2: Same problem like Fig. 1. Why did you pick specific replicates and not

treatment averages? All replicates seem to have virtually identical size distributions, which is in contrast to what you state in the text. Treatment averages were provided in the table (1). Sample average was also included in each figure. We attempted to develop all replicates in a figure for treatment it was too crowded. Then we developed a figure using average values. It did not represent samples as those frequencies were not same for all samples.

p11l27-p8l3: 'Masked' might be the wrong word here. Compaction is just less severe in a sand as compared to a silt loam with macropores. We have edited this sentence in the revised manuscript.

p12l3-11: Your statements in this paragraph are not justified by your results, because you did not conduct a REV analysis. To do so you need to start with a small sub-volume, increase it in steps and look how porosity or any other property changes with sample volume. Only if the value stabilizes before you've reached the total sample size, is an REV truly reached. Also, your samples are very different from those in Wildenschild et al. Please do a correct REV analysis or omit this paragraph altogether. We have deleted this paragraph as suggested.

p12l14: omit 'i.e. a good pore network.' Thanks, revised as suggested.

p12l15: How can a pore node be directly connected to so many neighbouring nodes? Do up to 40 pores meet in one singular bond of the network? Even more than ten is hard to imagine. So what does the algorithm consider to be directly connected? The explanation in on page 9, l8-9 is not helpful. The resolution was 9 micrometers and there are smaller pores that were detected by the method. The measurement is likely an artifact of the method. Moreover the probability for these points is so small to be insignificant. Only large pore coordination number $\leq$ 20 was used to determine characteristics coordination numbers.

Fig 3: Same problem like figures before: Why not treatment averages and plotting all in one figure with different symbols? Otherwise the impact of different treatments is difficult to evaluate. Treatment averages were provided in the table (1). Sample average was also included in each figure. We attempted to develop all replicates in a figure for treatment it was too crowded. Then we developed a figure using average values. It did not represent samples as those frequencies were not same for all samples.

p12l16-18: Leave out this sentence. It's just trivial that the probability has to decrease with increasing CN. We have deleted this sentence in the revised manuscript.

p12l24-29: That information is explained in too much detail and dilutes the main message, which is that different initial aggregate sizes had no significant effect on CN (or Co). Table 1 provides statistical differences and mean values for each treatment. We have revised this section.

p13l14: 'imply' is a to strong word here, because CN is a local property whereas air continuity is a global percolation property. They don't necessarily need to be correlated. Independent laboratory measurements with the same aggregate packing would be helpful. Thanks for the suggestion. This is beyond the scope of the paper and we will not be able to conduct this additional work

p13l29-p14l1: This information is irrelevant. We have deleted this sentence in the revised manuscript.

p14l11-23: The whole discussion would be easier to follow if you showed 2D section or 3D renderings of the pore space architecture for different treatments. After reading the draft the greater path lengths for smaller aggregates don't make much sense too me and the presented explanation is not convincing. Thanks for the suggestion. We have included 2 figures as suggested.

p15l16-17: Be more specific. How do they agree with your results? Values like 1.20-1.21 are quite different from 1.46-1.74. We have revised this statement.

p16l14-15: 'These results provide a picture ...' - To put it in a bit exaggerated terms, this study merely collected all results that 3DMA is able to compute and presented

them in every detail. However, a general picture of what happens in the pore space during compaction is not given. It is somwhat obvious that macroporosity decreases and that big pores are more likely to be closed during compaction. Any further insights into pore-scale processes during compaction are not really obvious from the text, or at least not well discussed. They might be somewhere, but it's just too many results and unrelated discussions which distract from that important message. You could shorten the result section and provide this discussion as the separate section in between the results and the conclusions.

We have included a section that address the above comment. This section summarizes the effects of mechanical compaction on CN, path length, and tourtuocity.

Please also note the supplement to this comment:
http://www.soil-discuss.net/2/C460/2015/soild-2-C460-2015-supplement.pdf

Interactive comment on SOIL Discuss., 2, 825, 2015.

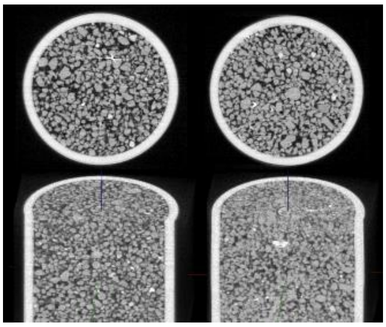

Figure 1.

Fig. 1.