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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Coupling X-ray microtomography and macroscopic soil measurements: a method to enhance near saturation functions?" *by* E. Beckers et al.

Anonymous Referee #1

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General recommendation:

The paper describes how X-ray microtomography data can be used as auxiliary information to improve the estimation of hydraulic properties near saturation. The approach is promising as it is generally accepted that near-saturated hydraulic measurements are afflicted with the highest uncertainty. The paper is well written and fulfills style criteria almost completely. However, the paper cannot be published in its present state. The authors claim that the results are preliminary and the focus is rather on methodological aspects. Yet, for a method paper the authors failed to provide enough information on how they processed their image data. I reckon that their findings strongly depend on

image segmentation , as well as image enhancement and postprocessing, given that a Luvisol usually exhibits a lot of porosity close to image resolution (34 μm). The authors should at least run a sensitivity analysis to demonstrate the effect.

Specific comments:

1. The paper should definitely include some vertical image slices or three-dimensional image cuts for each horizon. In this way, the readers could easily form their own opinion about differences between treatments and the suitability of the chosen structural parameters

2. The references for the propsed image processing tool chain are not appropriate. Plougonven (2009) is a dissertation in French and Beckers et al. (2012) is an abstract for a conference. My suggestion would be to use this paper as an occasion to properly introduce your methodology.

3. You've cited Baveye et al. [1] which is a good source to highlight the user-dependency of image processing results. The recent draft missed the chance to convince the reader that image processing results might in fact be not too user-dependent. I assume, that the histograms of your image are barely bimodal due to severe partial volume effects, i.e. silt loams usually exhibit a lot of porosity in the size range close to image resolution (34 μm) and therefore have a high volume proportion of voxels in the gray value range between pores and solid. In this case, simple thresholding will lead to a fair amount of misclassification errors and should be replaced by a locally-adaptive method, e.g. hysteresis segmentation, indicator Kriging, Bayesian Markov randomfield segmentation [2-5]. Also, Otsu's method is known to be biased if the volume proportion and variance of the two classes are imbalanced which is very likely for soil images like that [6]. There are three things that you should do:

a. Create a new figure with some representative histograms. Maybe I'm wrong and the histograms are clearly bimodal.

b. Replace simple thresholding by a locally-adaptive method. I'm sure Avizo provides a couple of solutions.

c. Do a sensitivity analysis, i.e. plot porosity, specific surface and connectivity as a function of threshold for a suitable threshold range. I reckon, porosity won't change all that much, but specific area and connectivity definitely will.

4. The structural parameters listed in the postprocessing section (p 4809, l 1-14) are poorly explained. For instance, how is the inertia tensor defined? Are surfaces directly obtained on the voxel image or on isosurfaces? Consider drawing a sketch of a simple pore geometry for which each measure is highlighted in some way.

5. The conclusions have to be shaped up a little. What makes the paper stand out against previous papers that combined image analysis with hydraulic properties? How can additional information beyond macroporosity, like specific surface area or specific connectivity really be used to improve model predictions? What are the limitations of this approach?

Technical comments:

P 4801, l 8-9: Be more specific about the additional clues.

P 4801, l 18-22: A plenty of studies about the impact of tillage on soil structure have been published after 2008. I would like to see some more recent references [7-9].

P 4803, l 22: Replace 'enhance' with 'improve'.

P 4803, l 6: I'm not familiar with the term Richards' apparatus. Maybe consider rephrasing.

P 4804, l 13-20: How did you collect the samples? Silt loam samples are prone to sampling artifacts like soil compaction or cracks close to the sample container. A figure with some vertical slices or 3D cuts provide a good lead how severely your samples are affected by these problems.

P 4806, l17-19: Taking only one sample out of eight makes the values quite arbitrary. Consider taking at least the highest three replicates out of eight.

P 4811, l 18-24: Which algorithm did you apply for fitting (e.q Levenberg-Marquardt)?

p 4813, l 8-10: You've mentioned that you measured Ksat in two directions. To which of them do you refer here?

P 4813, l 12-23: Why don't use the permeameter measurements to condition your model and fit both h(θ) and K(h) simultaneously?

P 4813, l 20: Rephrase 'greater improvement'.

P 4814, l 21-24: Be more specific about 'present an enhancement'. How does the separation of pores improve hydraulic functions? Pore size distributions, surface area measurements or connectivity metrics can also be obtained for the entire pore space, without the requirement to label each pore cluster individually. What would be the advantage to do so?

P 4815, l 7: Why should mean object position in small samples (5x3cm) be important at all with respect to effective horizon properties? This creates the impression, that you just used any parameter that was available in Avizo without thinking it over whether they make any sense.

P 4815, l 8-9: Replace 'the inverse than for' with 'the reverse order as compared to'.

P 4815, l 10-11: Specific surface is not a topological, but a metric property, i.e. either [L2] or [L2/ L3] if expressed as a density.

P 4815, l 13-15: How could this refinement be achieved?

P 4815, l 17: Maybe I missed it, but where did you present results for the dispersion coefficient? Is it in the PCA figures or hydraulic functions? The entire paragraph seems to be barely supported by any figure or table.

P 4816, l 4: Replace 'but scarcely are' with 'but occur scarcely'.

P 4816, l9-13: Again, the size of a pore is a local property, but the pore size distribution in one (or many) sample(s) is a global property, just like the retention function is a global property. The term 'local' is misleading, because you are interested in a representative pore size distribution of the horizon.

P 4816, l 24-25: The most determining parameters (specific surface and specific connectivity) presumably experience the highest influence from image processing, i.e. noise removal, image segmentation, etc. This is why a sensitivity analysis would be a benefit for this study.

P 4824: Font size is too small.

P 4825: Font size too small.

P 4826-4827: It is not obvious from the captions how Figs. 4-5 are different from each other.

References:

1. Baveye, P.C., et al., Observer-dependent variability of the thresholding step in the quantitative analysis of soil images and X-ray microtomography data. Geoderma, 2010. 157(1-2): p. 51-63.

2. Schlüter, S., U. Weller, and H.-J. Vogel, Segmentation of X-ray microtomography images of soil using gradient masks. Computers & Geosciences, 2010. 36(10): p. 1246-51.

3. Houston, A.N., et al., Adaptive-window indicator kriging: A thresholding method for computed tomography images of porous media. Computers & Geosciences, 2013. 54(0): p. 239-248.

4. Wang, W., et al., Comparison of image segmentation methods in simulated 2D and 3D microtomographic images of soil aggregates. Geoderma, 2011. 162(3-4): p.

231-241.

5. Kulkarni, R., et al., Three-dimensional multiphase segmentation of X-Ray CT data of porous materials using a Bayesian Markov random field framework. Vadose Zone Journal, 2012. 11(1).

6. Kurita, T., N. Otsu, and N. Abdelmalek, Maximum likelihood thresholding based on population mixture models. Pattern Recognition, 1992. 25(10): p. 1231-1240.

7. Schlüter, S., U. Weller, and H.-J. Vogel, Soil-structure development including seasonal dynamics in a long-term fertilization experiment. Journal of Plant Nutrition and Soil Science, 2011. 174(3): p. 395-403.

8. Eden, M., et al., Linking soil physical parameters along a density gradient in a loess-soil long-term experiment. Soil Science, 2012. 177(1): p. 1-11.

9. Holthusen, D., et al., Physical properties of a Luvisol for different long-term fertilization treatments: I. Mesoscale capacity and intensity parameters. Journal of Plant Nutrition and Soil Science, 2012. 175(1): p. 4-13.

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