Data Article

Experimental data showing the effect of wetting on soil structure transformations: 3D images

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A B S T R A C T
Structure of the pore network of the soil controls many processes in the soil. Soil moistening have a profound impact on soil structure, which may affect a soil functions. This dataset presents the non-destructive three-dimensional (3D) visualization of the same soil sample under two different saturation conditions: air-dried and saturated beyond the field capacity [1]. The data were obtained by X-ray computed tomography and stored as three-dimensional 8-bit grayscale arrays. Two reconstructed images of the same sample were produced for future research. This dataset provides a valuable and unique insight for the qualitative and quantitative analysis.

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Specifications Table

| Subject | Geophysics |
|---------|------------|
| Specific subject area | Non-destructive Measurements in Soil |
| Type of data | Image |
| How the data were acquired | The data were obtained by X-ray computed tomography using Bruker SkyScan 1172 microtomograph. |
| Data format | Raw: reconstructed 3D data; .tiff |
| Description of data collection | X-ray computed tomography (X-CT) was carried out under two different saturation conditions: air-dried and saturated near the boundary field capacity. After the first air-dry tomography scanning, the sample was moistened by supplying excess water through the base standing on several filter papers. |
| Data source location | Russia, Vladimir Region, Suzdalsky district, Russian valley northwest of Vladimir, 56.417416, 40.426769 |
| Data accessibility | Dmitriy, Ivonin (2022). “Experimental data showing the effect of wetting on soil structure transformations: 3D images”, Mendeley Data, V1, doi: 10.17632/2wr9jpf3k.1 |
| Related research article | Ivonin, D.; Kalnin, T.; Grachev, E.; Shein, E. Quantitative Analysis of Pore Space Structure in Dry and Wet Soil by Integral Geometry Methods. Geosciences 2020, 10, 365. https://doi.org/10.3390/geosciences10090365 |

Value of the Data

- Three-dimensional images of soil sample at two different saturation conditions enable researchers to study the effect of wetting on soil structure transformations.
- Many significant morphological properties of soils, such as pore shape and size distribution, specific surface area and curvature, pore connectivity, tortuosity, can be quantified using this dataset.
- This dataset can be used as a scene for modeling filtration and other processes to obtain hydraulic conductivity and water retention curve.
- The presented dataset makes it possible to assess the structure-property relationship and to establish a minimum representative volume (REV) in structured soils.

1. Data Description

This dataset contains reconstructed 3D images of the same sample in a dry condition and in a moisture-saturated condition. The dataset is available at the open repository Mendeley Data. The region of interest scans are stored in 8-bit 3D TIF files: «dry-13-column.tif» and «wet-13-column.tif» for air-dried and near-saturated conditions, respectively. «rec.log» is the log file from the Bruker SkyScan 1172 microtomograph. Images have a dimension of 500 × 500 × 1000 voxels with 31.68 μm resolution. The voxel size of the 3D images is 31.68 μm in each dimension. Fig. 1 shows cross-sections from tomographic image corresponding to the same regions within the samples. 3D visualization of the void space of the sample in a dry and in a capillary-saturated conditions is presented in Fig. 2.
Fig. 1. Two-dimensional slices of tomographic images in a dry condition (left column) and in a capillary-saturated condition (right column).
2. Experimental Design, Materials and Methods

A soil pit is excavated with a shovel to select the monolithic sample, a level ground with a size of at least 10 × 10 cm is chipped at the chosen depth. The ground is cut off with a knife along the perimeter by 5 cm in depth to form a “soil pocket” in the form of a truncated cone. The cut-off part of the syringe is gradually put on this “soil pocket”. Simultaneously, the soil truncated cone is vertically trimmed along the course of the syringe every 5–10 mm to avoid trashing the monolithic sample or damaging it with roots.

Our research consists of two parts: the tomographic imaging of the soil samples was carried out in an air-dry state and after capillary saturation to the field capacity. Water saturation of sample included moisturizing the air-dry sample which had been imaged with excess moisture through a substrate of several layers of filter paper for 7 days with constant pouring of water until a waterlined appeared on the surface of the paper substrate. Then it was free-drained on a sandy substrate to a constant weight in the absence of evaporation and then imaged for 2–3 h. Before the tomographic imaging, the sample was sealed with a plastic film in order to
avoid water evaporation and the structure deformation due to shrink processes caused by the evaporation while imaging.

X-CT measurements were performed using SkyScan 1172 (Belgium) with different energy settings for dry (100 kV, 100 μA, Al+Cu filter) and wet (70 kV, 129 μA, Al filter) samples. The Hamamatsu 100/250 X-ray source with 10 W output and a SHT 11-megapixel detector panel was used. Images were acquired at a pixel size of 7.92 μm with a camera binning of 2 × 2. Exposure time was 1200 ms, and scans were performed in 180°-mode with angular step of 0.40°. The total acquisition time was approximately 53 min per sample. More detailed information about the image acquisition workflow is given in the log file.

Projection images were reconstructed into cross-sections with the Feldkamp algorithm [2] using SkyScan’s NRecon v.1.6.10.4 software (Bruker, Kontich, Belgium). For the reconstruction parameters, smoothing was fixed at 3; ring artifact correction was set at 14%. For each soil sample, we obtained a stack of 2000 × 2000 × 4000 images with a resolution of 7.92 μm. The reconstructed images were stored as 16-bit TIFF images. The total reconstruction time was approximately 35 min per stack. To satisfy memory limitation, the final images were reduced to 8-bit pixel depth and downsampled four times by averaging to an image size of 500 × 500 × 1000 pixels. The voxel size of the 3D images is 31.68 μm.

The tomographic work was carried out with the involvement of the equipment from the Center for the Collective Use of Scientific Equipment “Functions and properties of soils and soil cover” of V.V. Dokuchaev Soil Science Institute.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT Author Statement

Dmitriy Ivonin: Methodology, Writing – original draft, Software, Visualization; Timofey Kalnin: Conceptualization, Methodology, Data curation, Writing – review & editing, Validation, Investigation; Alexandr Dembovetskiy: Writing – review & editing, Investigation; Eugene Grachev: Methodology, Investigation, Conceptualization; Evgeny Shein: Conceptualization, Methodology.

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References

[1] D. Ivonin, T. Kalnin, E. Grachev, E. Shein, Quantitative Analysis of Pore Space Structure in Dry and Wet Soil by Integral Geometry Methods. Geosciences (Basel) 10 (2020) 365, doi:10.3390/geosciences10090365.
[2] L.A. Feldkamp, L.C. Davis, J.W. Kress, Practical cone-beam algorithm, J. Opt. Soc. Am. A, JOSAA. 1 (1984) 612–619, doi:10.1364/JOSAA.1.000612.