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A process-based model of soil structure to assess the impact of biological agents, climate and reduced tillage

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Soil structure can be defined as the spatial arrangement of voids and solids in soil. It is a dynamic soil property due to agents' activity such as (i) mechanical action of soil tillage (ii) earthworms through their burrowing activity and faeces production and (iii) climate impact due to rain or temperature. Soil structure is often studied because of its impacts on soil functional properties, e.g. water percolation, soil water conductivity. In a context of farming practices shift towards non-ploughing techniques, it is needed to evaluate impacts on soil structure and consequently on its functional properties.

Existing models have adopted two strategies to simulate soil structure: (i) to use of measured parameters to adjust a theoretical model or (ii) to build a soil structure by simulating processes that are its base. The first strategy does not deal with the difficulty to access soil structure by itself because input measured parameters are needed. The second one starts from either a virgin structure or a structure coming from strategy (i). This starting structure is then altered according to one structuring agent. At present, there is a need for such dynamic models of soil structure. They must be explicit (3D) and common for a large set of structuring agents too. They must also deal with several issues: e.g. to memorize the many voids and solids building up the soil structure or the need to be fast enough to simulate soil structure dynamics for a month, a year, etc. A first proposal, based on the strong assumption that soil is fractal, was made by Marilleau et al. (2008).

In our model three structuring agents were chosen: tillage, earthworm's activity and solid particles settlement due to climate. It first focuses on the building of a computerized soil structure which is a common base to simulate the agents. It aims at being as generic as possible by using an object-oriented structure. The concept of voxel is used to split the soil into elementary units and each of these voxels displays a state chosen within a pre-established list (e.g. fresh organic matter, voids). Voxels are grouped into piece. This grouping allows reducing memory consumption by using an encoding algorithm which takes part of the recurring structure of the soil at small scales. As seen previously, models of category (ii) sometimes start from an existing soil structure. In the model the initial structure is defined using simple parameters such as porosity and fresh organic matter content. By doing so, one is able to account for example for a dense plow-pan. The model is coded in both Python and C++ and has been coupled with a simulator of earthworm activity yet. This simulator accounts for faeces and burrows production of two ecological categories (anecics and endogeics). Thanks to images recently acquired with X-ray tomography, a simulator of tillage effect and settlement is been added.

To conclude, we will mainly present the approach used to build the computerize model of soil structure. Several results of simulation will be also shown.