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Mechanistic Understanding of Soil Hierarchical Structure

Anna Yudina (1,2) and Konstantin Romanenko (1,2)

(1) Dokuchaev Soil Science Institute, Departments of Soil Physics and Hydrology, Moscow, Russia (yudina_av@esoil.ru), (2) Lomonosov Moscow State University, Department of Soil Physics and Reclamation, Moscow, Russia

Structure is the most complex soil property having dualistic nature. The structure determines the most soil processes and reflect their consequences on soils formation. Each structure level is characterized by specific interactions, processes, and functions that can be used as criteria for their separation. Mechanistic understanding of hierarchical structure organization enables to include it into dynamic soil models. The goal of this study is to describe the mechanisms of microstructure organization and dynamics for 10 main zonal soil types - from Podzols (tundra) to Ferrasols (tropics). X-ray microtomography of macroaggregates has allowed to separate functional zones of microstructures by its bulk density. These zones save their spatial positions after wetting/drying cycles, while connectivity density of pore network increases in water saturation and decreases at drought. In Chernozems for example, large (>425 μm) zones with high bulk density are mainly localized on the outer shell of the aggregates, whereas intermediate size (210-425 μm) zones of medium bulk density regularly fill the internal shell. The smallest (<210 μm) zones with the lowest bulk density form the film under surface pore channels inside of the aggregates. Laser diffraction analyses combined with chemical, ultrasonic and hydraulic stresses on soil samples allowed to distinguish three types of microstructures and their relationships with physico-chemical properties. Soil organic carbon (SOC) was closely linearly correlated (R^2=0.83) to the differences between elementary particle size distribution (obtained after pretreatment by ultrasonic energy equal of 450 J·ml-1; Yudina et al., 2018) and microaggregate size distribution (obtained after intense stirring (2500 min-1) of water suspension after 10 minutes). SOC however, is not unique binding agent for the formation of such elementary soil particles. Particles in Ferralsols are strongly bound by organic matter. In contrast, the elementary soil particles in Retisols, Phaeozems and Vertisols are not really bound by SOC and presented by particulated organic matter because of their complete oxidation (mineralization). Microaggregate content (sum of differences between microaggregate size distribution and elementary particle size distribution) in Retisols has a positive relationship (R^2=0.60) with content of crystalline Fe oxides and negative (R^2=0.68) with amorphous Fe oxides. Microaggregation in Chernozems increases from AB to B horizon and are highest under specific ratio of SOC and carbonate content (SOC:Ccarb=1:2). The types of microstructures, their sizes and localization were described with specifics to soil formation processes. Combination of this hierarchical structure organization with data, obtained by X-ray microtomography, will allow to develop a 3D-model of soil structure organization.

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