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Chernozem aggregate waterstability loss investigation in a long-term bare fallow experiment

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The research is focused on mechanisms of aggregate waterstability controlled by soil organic matter (SOM). The objects of the research are two contrast variants of typical chernozem – under native grassland and under a 60-year bare fallow experimental plot (100 m^2) on the territory of Central Chernozem Biosphere Reserve, Russia. Seasonal plowing and deficiency of fresh plant residues (due to weeding out) resulted in a rapid mineralization of SOM. The C_{org} content in the 0-20 cm topsoil under native grassland is 6-4.5 %. For the last two decades C_{org} content under bare fallow has stabilized on the 2.6% level and is therefore assumed to represent stable SOM pool. However excellent aggregate waterstability of chernozem is completely lost under bare fallow. Therefore the aim of our study is to reveal the role of different SOM pools spatial and functional organization in aggregate waterstability formation.

Bulk soil samples were collected from 2 m grassland profile and 1.5 m bare fallow profile with 10 cm interval and simultaneous measurements of soil field density and moisture. Following samples were analysed: bulk samples, dry and wet-sieving aggregates, undisturbed and pulverized aggregates, granule-densimetric fractions obtained by sedimentation of bulk samples (clay <2, fine silt 2-5 and coarse silt >5 mkm) with following densimetric fractionation in bromoform (light ρ <2.0, medium ρ (2.0-2.4) and heavy fraction ρ >2.4 g/cm^3), and above mentioned samples after removal of SOM by hydrogen peroxide. Isolation of aggregates and granule-densimetric fractionation were carried out for bulk soils at 0-20, 40-50 and 80-90 cm depth.

We use elemental analysis (C, H, N), size exclusion and hydrophobic interaction chromatography of humic substances (HS), laser diffraction particle size analysis, specific surface area (SSA) measurements by nitrogen adsorption and micromorphological examination of thin sections.

Detailed characteristics obtained for aggregates and granule-densimetric fractions from a typical chernozem soil under native grassland and under 60-year bare fallow show that overall decrease in C_{org} under bare fallow is about 50% due to loss of light fractions, 30% due to loss in clay fraction and 15% due to loss in coarse silt medium fraction. Light fraction has predominant particle sizes of D_{10}-D_{90}=(2-20) mkm in fine silt and (7-70 mkm) in coarse silt. Light fraction particles are mostly hydrophobic in nature and may function as high contact seals between soil particles, enhancing hydrophobic interactions within aggregate in the presence of water, and preventing its rapid entrance into the aggregate. Reduction of light fractions fivefold and the increase in SSA (opening of clogged pores) due to overall loss in C_{org} content allow more rapid water move into the aggregate. Moreover, stable residual of light fraction under bare fallow becomes extremely water-repellent which should make the aggregate system unstable upon water percolation.

We observe mineralization and washing out of low-molecular hydrophilic HS from bare fallow soil components. Hydrophilic HS may function as bonding mediators between mineral particles and high-molecular hydrophobic HS. Therefore we propose that disruption of aggregate waterstability results from SOM hydrophilic-hydrophobic disbalance. Molecular parameters of HS hydrophobic and hydrophilic components are substantially different. The enhancement in hydrophobic interaction ability of HS components is accompanied by increase in molecular weight and C_{org} content, and decrease in nitrogen content.

Waterstable aggregates are shown to contain HS with stronger hydrophobic properties than that of dry-sieving ones and it results in a more pronounced reduction of SSA upon waterstable aggregation.

The experimental results give evidence and characteristics of at least four SOM pools in a typical chernozem soil: degradable sorbed SOM (accounts for 0.9% of C_{org} content), which probably includes dissolvable SOM, degradable particulate organic matter (POM) (1.1%), stable sorbed SOM (2%) and stable POM (0.5%).

In analytical aspect of the research possibility to describe soil components as a whole through parameters of soil particles and SOM characteristics can be realized:

a) profile distribution of the average C_{org} content over soil layer mass is closely fitted by the sum (exp1+exp2+C), indicating particular OM pools;

b) C_{org} content ($\sim$2%) of stable to long-term degradation sorbed SOM is set in the power parameter of experimental curve SSA (C_{org}) for chernozem under grassland.

c) fractal dimension discontinuities correspond to classification boundaries of colloidal, clay, silt and sand particles (0.5; 2; 20 mkm);

d) qualitative change of hydrophobic properties is described by one parameter presumably related to structure of high molecular HS.