Fertilization induced changes in soil stability at the microscale revealed by rheometry

Dissertation zur Erlangung des Doktorgrades der Agrar- und Ernährungswissenschaftlichen Fakultät der Christian-Albrechts-Universität zu Kiel, vorgelegt von M. Sc. Dörthe Holthusen aus Westerstede

published in the Schriftenreihe des Instituts für Pflanzenernährung und Bodenkunde, Vol. 89

Summary

The present work deals with the impact of fertilization on soil stability as it can be determined with the help of rheometry. The sensitivity of rheometry to detect differences in microstructural stability was proved in previous works but still there is a lack of knowledge with regard to the influencing factors, especially salts that occur in soils. Special attention was paid to potassium (K) as several studies revealed a positive impact of K fertilization on water use efficiency of plants. Besides the fact that K decreases the transpiration rate of plants, another explanation is the improvement of soil structure in the wake of K amendment as it might enhance microstructural stability and therewith increase plant available water. Thus, the general research objective was the impact of K, but also of organic versus mineral fertilization on microstructural stability by means of an amplitude sweep test to eventually allow for a comparison of fertilization impacts at different time and spatial scales.

The first attempt was to test how K influences the shearing resistance of a saturated sample at a short-term range. Samples from glacier till were saturated with KCl solutions of varying concentrations for three different time periods. It could be shown that the rheological parameters shear stress τ at the end of the linear viscoelastic range, maximum shear stress τ_{max} and storage modulus G' and loss modulus G'', respectively, at the yield point were increased due to increasing K concentrations in the soil. Raising the time of exposure to the salt solution enhanced this effect, thus indicating that age-hardening is promoted by KCl. Additionally, the impact of drying was found to be related to shear strength as with decreasing matric potential the soil samples had higher values of rheological parameters, i. e. a higher strength.

To supplement the investigations of the impact of K with regard to the long-term range, the second attempt dealt with the observation of microstructural properties of samples from several long-term fertilization trials. Those plots were mainly designed to reveal the impact of different K fertilization rates on plant growth and yield but are also adequate for the investigation of soil properties. Hence, the shear resistance of soil samples was determined at several matric potential levels and afterwards related to the physico-chemical properties of the soil. Both the consideration of the impact of single or combined parameters revealed that soil physical parameters are not determined by a single factor but

depend on a multiplicity of parameters that, in turn, interact with each other. With regard to K, both stabilizing and destabilizing effects were found, mostly related to soil texture: While soils with rather coarse texture were stabilized by K, soils with an average clay content revealed a destabilizing impact of K fertilization. Furthermore, the soil with the highest clay content was obviously unaffected. Generally, the observed differences were amplified by drainage to -3 and -6 kPa matric potential.

In the last part of this work, several plots of a long-term experiment at the Dikop farm near Bonn, Germany, were investigated for their physical properties at meso- and microscale. To determine the impact of organic versus mineral fertilization, undisturbed samples from plots with mineral and organic as well as combined fertilization were examined. Organic and mineral fertilization increased porosity of the soil similarly, but plots with organic amendment had a much better pore functionality that was also more persistent during mechanical stresses. The microstructural stability was significantly decreased by mineral fertilization but not enhanced by organic fertilization. Obviously, the microstructural stability was different than the stability measured at the mesoscale with one exception: Cyclic compressiblity c_n had a strong correlation with maximum shear resistance τ_{max}. Thus these two parameters may allow for the upscaling of rheological parameters to the mesoscale. After remoulding the samples, the previous organic fertilization led to increasing stability, either as single treatment or in combination with mineral fertilization, whereas mineral fertilization alone had destabilizing impact. K fertilization seemed to decrease shear resistance at the microscale but the actual K content of the soil was positively related to soil stability. Manifold interactions with organic fertilization treatments and matric potential of remoulded samples underline the need for further research. However, it can be assumed, that organic fertilization preserved the former structure partly.

In a nutshell, the impact of K on microstructural stability is rather ambiguous and always requires the additional consideration of the investigated soil itself as well as the time and spatial scale. Furthermore, the results present a first approach for the upscaling of rheological parameters to the mesoscale.