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Long-term effects of conventional and conservation tillage on soil structure and hydraulic properties

Steffen Schlüter (1), Caroline Großmann (1), Julius Diel (1), Annette Deubel (2), and Jan Rücknagel (3)

(1) Department of Soil System Sciences, Helmholtz-Centre for Environmental Research – UFZ, Halle, Germany (steffen.schlueter@ufz.de), (2) Department of Agriculture, Ecotrophology and Landscaping, Anhalt University of Applied Sciences, Bernburg, Germany, (3) Department of Agronomy and Organic Farming, Institute for Agricultural and Nutritional Sciences, Martin Luther University Halle-Wittenberg, Halle, Germany

There is a long-lasting debate about the effects of tillage practices on soil structure and structure-mediated ecosystem properties like hydraulic conductivity and crop productivity. This is investigated in a long-term field experiment on tillage practices at the Westerfeld trial in Bernburg, Germany (25 years of different management).Here we combine soil structure information obtained with X-ray microtomography with conventional properties like bulk density, air capacity and saturated conductivity, as well as integrative, ecological properties like earthworm abundance and crop yield. This study goes beyond previous studies in that the soil microstructure is investigated in two different depths, within (13-23cm) and underneath (28-38cm) the plow horizon. Furthermore the microstructure is investigated at two different resolutions (60μm and 20μm) by employing a nested sampling design.

The plowed horizon in the conventional tillage plots differs from the undisturbed soil underneath the cultivator reach (13-23cm) in the reduced tillage plot by lower bulk density, higher air capacity, higher saturated hydraulic conductivity, higher macroporosity and pore connectivity. 25 years of reduced tillage caused a trend towards higher saturated conductivity at a depth of 28-38cm as compared to the plow pan in the conventional tillage plot, despite insignificant changes in macropre density and macropore connectivity. Image-based macroporosity and laboratory-based air capacity showed good agreement. The combination of pore size distribution and pore connectivity revealed characteristic differences between both management practices and soil depths.

Overall, the combination of hydraulic measurements and X-ray CT imaging of soil microstructure provides a comprehensive view on soil structure modification by tillage practices. The change from conventional to reduced tillage lead to a compaction of soil that has not be compensated by higher bioturbation as reported for other sites due to unfavorable conditions for anecic earthworms (frequent dry periods with severely impaired penetrability of the loess substrate) as well as the absence of very deep rooting, perennial crops in crop rotation.