Soil structure recovery after compaction – roles and dynamics of different structure forming processes

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Introduction

Structure is a fundamental feature of soils. It determines the size and quality of the living space for soil organisms and plant roots, and governs soil functioning as an ecosystem compartment and soil usability for agricultural production. Soil compaction by farming traffic modifies soil structure and adversely affects soil functioning. The regeneration of compacted structure is not solely possible by mechanical loosing with help of tillage measures – supporting physico-chemical and biological processes are necessary to improve soil structure at small scales and to improve structural stability. Although these processes are qualitatively known more or less, their contribution to structure improvement as well as possibilities to direct and enhance their activity by soil management is quantitatively not well understood. Thus there is a lack of information regarding soil structure recovery rates and regaining of various functions in the course of structure recovery.

To address this gap, we designed a long-term field experiment for systematically evaluating and monitoring post-compaction evolution of soil structure and associated functions – termed the soil structure observatory (SSO).

Material and method

The SSO was established in 2014 on a loamy soil in Zürich (Switzerland) to provide information on functional recovery of compacted soil by different post-compaction soil management. The intention is to direct the activity of the recovery processes by applying combinations of different cropping and tillage practices (natural recovery of bare and vegetated soil, anthropogenically assisted recovery by arable crop rotation with and without...
soil tillage). Observations were based on (i) continuous measuring of soil state variables and (ii) periodic sampling campaigns to quantify soil properties and soil organism populations (microorganisms, earthworms) as well as crop yields.

Results and discussion

We present results of initial compaction and recovery within the first two years following compaction, focusing on soil physical functions.

Following compaction, infiltration rates were reduced by three orders of magnitude whereas porosity decreased by 15 and 3% at 0.1 and 0.6 m depths, respectively. Transport properties were influenced more significantly than bulk properties such as porosity. For example, the relative gas diffusion coefficient at -100 hPa decreased from 0.024 to 0.006 for a 15% decrease in porosity at 0.1 m depth. After compaction, mechanical penetration resistance nearly doubled within the 0-0.3 m layer (from 1.0 to 2.0 MPa).

Infiltration rates recovered within one year, with higher rates in vegetated relative to bare soil compacted plots. Recovery rates in deeper soil horizons were slower, with small increases in porosity and transport properties, dominated by the appearance of individual macropores (as seen in X-ray CT images). No clear differences in soil properties and their recovery were found among management and cropping systems, except for tillage treatments. The total porosity of the tilled topsoil (0.1 m depth) was fully recovered, but not fluid transport functions, indicating that tillage is not simply the inverse process of compaction. Nevertheless, soil fragmentation caused by tillage seems to accelerate soil structure recovery.

In contrast to the small extent of recovery of soil physical functions, crop yields recovered more rapidly, although they did not fully recover yet.

Conclusion

We conclude that after a considerable compaction event soil functions recover at different rates, and that the overall recovery rates decrease with soil depth. Soil structure recovery by physico-chemical and biological processes is initiated in local pockets, e.g. through macropores created by roots and earthworms or cracks caused by soil shrinkage or tillage.