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A long-term soil structure observatory for post-compaction soil structure and function recovery rates

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Soil compaction by farming traffic modifies soil structure and adversely impacts soil functioning and associated ecosystem services. The direct and indirect ecological and economic costs of compaction are borne by the severity of loss of soil functions and the recovery time to pre-compaction state. Quantitative assessment of compaction damage is hampered by lack of information regarding soil structure recovery rates and regaining of various functions. 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). The SSO was established in 2014 on a loamy soil near Zürich (Switzerland) to provide replicated information on functional recovery of compacted soil under different post-compaction soil management and cropping systems (natural recovery of bare and vegetated soil, and arable cropping with and without soil tillage). Observations were based on continuous monitoring of soil state variables periodic sampling campaigns of soil properties and biological measures. We present results of initial compaction and recovery within the first two years following compaction focusing on soil physical functions. Infiltration rates were reduced by three orders of magnitude due to compaction while porosity decreased by 15, 9 and 3% at 0.1, 0.3 and 0.6 m depth. Transport properties were influenced more significantly than changes in 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. The penetration resistance nearly doubled within the 0-0.3 m layer (from 1.0 to 2.0 MPa). Infiltration rates were recovered within one year with higher rates in vegetated relative to bare soil treatments. Recovery rates within the soil body were slower with small increase in porosity and fluid transport properties, dominated by appearance of individual macropores (as seen in X-ray CT images). These changes did not significantly influence metrics measured at the soil core scale. No clear differences in soil properties and their recovery were found among management and cropping systems, except for tillage treatments. The total porosity at 0.1 m depth was fully recovered under tillage 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. Despite small signs of recovery of soil physical functions, crop yields recovered quickly, but are not fully recovered yet. We conclude that different functions recover at different rates, and that the overall recovery rates decrease with soil depth. Soil structure recovery following compaction is initiated in local pockets, e.g. through macropores created by roots and earthworms or cracks caused by soil shrinkage.