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A long-term soil structure observatory for post-compaction soil structure evolution: design and initial soil structure recovery observations

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Soil compaction due to agricultural vehicular traffic alters the geometrical arrangement of soil constituents, thereby modifying mechanical properties and pore spaces that affect a range of soil hydro-ecological functions. The ecological and economic costs of soil compaction are dependent on the immediate impact on soil functions during the compaction event, and a function of the recovery time. In contrast to a wealth of soil compaction information, mechanisms and rates of soil structure recovery remain largely unknown.
A long-term (>10-yr) soil structure observatory (SSO) was established in 2014 on a loamy soil in Zurich, Switzerland, to quantify rates and mechanisms of structure recovery of compacted arable soil under different post-compaction management treatments. We implemented three initial compaction treatments (using a two-axle agricultural vehicle with 8 Mg wheel load): compaction of the entire plot area (i.e. track-by-track), compaction in wheel tracks, and no compaction. After compaction, we implemented four post-compaction soil management systems: bare soil (BS), permanent grass (PG), crop rotation without mechanical loosening (NT), and crop rotation under conventional tillage (CT). BS and PG provide insights into uninterrupted natural processes of soil structure regeneration under reduced (BS) and normal biological activity (PG). The two cropping systems (NT and CT) enable insights into soil structure recovery under common agricultural practices with minimal (NT) and conventional mechanical soil disturbance (CT).
Observations include periodic sampling and measurements of soil physical properties, earthworm abundance, crop measures, electrical resistivity and ground penetrating radar imaging, and continuous monitoring of state variables – soil moisture, temperature, CO_2 and O_2 concentrations, redox potential and oxygen diffusion rates – for which a network of sensors was installed at various depths (0-1 m).
Initial compaction increased soil bulk density to about half a metre, decreased gas and water transport functions (air permeability, gas diffusivity, saturated hydraulic conductivity), and increased mechanical impedance. Water infiltration at the soil surface was initially reduced by three orders of magnitude, but significantly recovered within a year. However, within the soil profile, recovery of transport properties is much smaller. Air permeability tended to recover more than gas diffusivity, suggesting that initial post-compaction recovery is initiated by new macropores (e.g. biopores). Tillage recovered topsoil bulk density but not topsoil transport functions. Compaction changed grass species composition in PG, and significantly reduced grass biomass in PG and crop yields in NT and CT.