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Soil air CO_2 concentration as an integrative parameter of soil structure

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The assessment of soil structure is an important but difficult issue and normally takes place in the laboratory. Typical parameters are soil bulk density, porosity, water or air conductivity or gas diffusivity. All methods are time-consuming. The integrative parameter soil air CO_2 concentration ($[CO_2]$) can be used to assess soil structure in situ and in a short time. Several studies highlighted that independent of soil respiration, $[CO_2]$ in the soil air increases with decreasing soil aeration. Therefore, $[CO_2]$ is a useful indicator of soil aeration.
Embedded in the German research project RÜWOLA, which focus on soil protection at forest sites, we investigated soil compaction and recovery of soil structure after harvesting. Therefore, we measured soil air CO_2 concentrations continuously and in single measurements and compared the results with the measurements of bulk density, porosity and gas diffusivity.
Two test areas were investigated: At test area 1 with high natural regeneration potential (clay content approx. 25 % and soil-pH between 5 and 7), solid-state CO_2-sensors using NDIR technology were installed in the wheel track of different aged skidding tracks in 5 and 10 cm soil depths. At area 2 (acidic silty loam, soil-pH between 3.5 and 4), CO_2-sensors and water-tension sensors (WatermarkR) were installed in 6 cm soil depth.
The results show a low variance of $[CO_2]$ in the undisturbed soil with a long term mean from May to June 2014 between 0.2 and 0.5 % $[CO_2]$ in both areas. In the wheel tracks $[CO_2]$ was consistently higher. The long term mean $[CO_2]$ in the 8-year-old-wheel track in test area 1 is 5 times higher than in the reference soil and shows a high variation (mean=2.0 %). The 18-year-old wheel track shows a long-term mean of 1.2 % $[CO_2]$. Furthermore, there were strong fluctuations of $[CO_2]$ in the wheel tracks corresponding to precipitation and humidity. Similar results were yielded with single measurements during the vegetation period using a portable soil CO_2-measuring apparatus based on NDIR technology.
Ex situ determination of gas diffusivity indicate comparable results: There are significant differences in gas diffusivity between the wheel track of the 8-year-old skidding track and the reference soil, but no significant differences between the 18-year-old wheel track and the reference soil. Considering the parameter bulk density, no coherent results are delivered.
Apparently, soil CO_2 concentration is a suitable indicator of soil aeration deficiency and consequently soil compaction and structure regeneration. In further studies, soil compaction and regeneration of acidic silty soils and loamy sandy soils will be investigated using both CO_2 logger and established soil physical parameters to validate this method.