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Redox dynamics and electron flow budgets in a minerotrophic fen soil – effects of a drying and rewetting cycle

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Covering only ∼3 % of the earth's surface but storing ∼24 % of the world's soil carbon, peatlands play an important role in the global carbon cycle. The significant emission of greenhouse gases makes them an important factor in the discussion about climate change. Future climate scenarios for temperate regions also predict higher temperatures and an increasing frequency of extreme weather events – causing more frequent drying/rewetting cycles. Yet, the feedback mechanisms in peatlands are not well known.

To evaluate the effect of drying and rewetting, three cores (60 cm diam., 60 cm depth) from a northern temperate fen were incubated in a climate chamber (15˚ C; 12h/12h day/night cycle) for 9 months. The plants of one core had been removed, but were kept on the other two cores (grasses and sedges, few mosses). The water table of all cores was adjusted and held at 10 cm below surface for 70 days (artificial precipitation). Subsequently, two cores were dried out (with and without vegetation) by stopping precipitation. The third core (with vegetation) was kept at high water table as a control. Within 50 days, the water table dropped ∼45 cm. Thereafter, we rewetted (>30 mm d-1) till the water table was back up at 10 cm within 2 days.

Drying and rewetting had a substantial effect on internal C-turnover and electron acceptor pools. Production of in CO_2/CO_3^{2-} followed closely the water table rise and drop (concentrations of 2-5 mmol L^{-1} below, 1-2 mmol L^{-1} above the water table), whereas methanogenesis lagged behind. The electron acceptor pool (NO_3^-, Fe(III), SO_4^{2-}) was renewed in the upper profile during drying out, but there was still some methane detectable in the main root zone under vegetation, indicating anoxic microenvironments. After the rapid rewetting, electron acceptors were consumed sequentially. In the upper layers sulfate was present ($>$100 μmol L^{-1}) for about 50-70 days before methane concentrations reestablished ($>$ 390 μmol L^{-1}). The long lasting sulfate pool contrasted high measured sulfate reduction rates (50 - $>>$250 nmol cm^{-3} d^{-1}, radiotracer studies at 20 ˚C). This suggests a renewal of the electron acceptor pool by a not yet known mechanism as also the total estimated electron acceptor pools could not account for net CO_2 production.

The CO_2 release through respiration remained fairly constant during the drying/rewetting cycle (200-300 mmol m^{-2} d^{-1}), while the type of vegetation had a substantial effect on photosynthesis (250 – 600 mmol CO_2 m^{-2} d^{-1}) and CH_4 release (0 - 40 mmol m^{-2} d^{-1}).

This study demonstrates the impact of a changing climate on carbon turnover in peatland ecosystems. A permanently high water table allowed little renewal of electron acceptors and promoted methanogenesis, a recycling of electron acceptors during drying and rewetting impeded methanogenesis but accelerated internal turnover.