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Understanding N2O and CH4 flux dynamics from soil to tree level in a grey alder forest under experimental flooding conditions

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Forest soils under elevated soil water content are considered to be a substantial natural source of nitrous oxide (N_2O) and methane (CH_4), important greenhouse gases (GHGs). Wetland trees may also contribute to the forest GHGs exchange by release of both gases into the atmosphere. Extreme climate events, for instance, long lasting heavy rain or drought, alter soil conditions. In particular, soil water content influences GHG relevant biochemical processes within the soil. Thus, understanding the ecosystem adaptation strategies to environmental modifications and their dynamics is the key to predict ecosystem responses to global change.

We conducted an intensive overland flow experiment in a grey alder forest. The aim was to better understand biochemical process and flux dynamics in the soil-tree-atmosphere continuum related to ecosystem N_2O and CH_4 turn-over and emissions.

The study site is located at a 40-years old grey alder (*Alnus incana*) stand in Estonia, consisting of two experimental plots: a flooded plot (FP; 40×40 m), where in summer 2017 during two weeks 55-70 m^3 of water per day was applied using an irrigation pipe system, and a control plot (CP; 20×20 m). The study period was divided into three periods: pre-flooding (8 July–7 August), flooding (8–21 August) and post-flooding (22 August–7 November).

The exchange of N_2O and CH_4 was determined at eight adjacent soil-tree-pairs at the FP. The stem fluxes in profiles (0, 80 and 170 cm stem height) were measured within 24 campaigns using closed static chambers and gas chromatography, whereas the soil fluxes were quantified automatically using the dynamic chamber system (Picarro 2508). Additionally, piezometers, automatic groundwater level wells, soil temperature and moisture sensors were installed to determine the coherent soil conditions. The composite topsoil samples were taken during five campaigns for physico-chemical analysis in the lab. Analogous equipment was established at three soil-tree-pairs in CP.

The trend for fluxes from stem and soil surface have shown similar pattern during pre-flooding, flooding and post-flooding periods. At flooding period, both were net sources of N_2O and CH_4. In contrast to N_2O, a delay in the increase of CH_4 fluxes from both stems and soil in response to flooding was observed. Comparing stem and soil fluxes at an ecosystem scale, stem N_2O flux was lower than from soil whilst stem CH_4 emissions during the post-flooding period turned to be significantly higher than from soil. Stem fluxes of N_2O and CH_4 significantly decreased within the first 80 cm of stem height.

Furthermore, our results demonstrate a substantial relation between N_2O flux from stem surface, soil moisture, and nitrogen (ammonia, nitrate) availability in the adjacent soil. N_2O emitted from the tree stems seems to predominantly originate from the soil. CH_4 fluxes from stem were coherent with soil water content and, thus, seem to be affiliated to soil CH_4 turnover processes in the soil.

Concluded, stem fluxes, especially during extreme events such as long-lasting overflow, are essential elements in forest nitrogen and carbon cycles and must be included in relevant models.