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Forest ecosystem response to sudden flooding in the middle of growing season: The FluxGAF experiment

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Understanding the capacity of ecosystems to adapt to environmental modifications is the key to predict ecosystem responses to global change. FluxGAF campaign ("Biogeochemical Fluxes in a Grey Alder Forest") was a large-scale forest manipulation experiment to gain insight into how forest ecosystems during active growth period can respond to flash floods that are predicted to become more frequent in future climates. The study was in a 40-yrs old hemiboreal Filipendula-type grey alder (Alnus incana) stand on former agricultural land (Umbric Planosol) in Estonia. Two experimental plots were established in 2017: a flooded plot (FP; 40×40 m) where water was pumped using an irrigation pipe system (2 weeks, each day 55–70 m3), 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). During flooding, 875 m3 of water was provided to 1600 m2 forest area, corresponding to 547 mm precipitation.

From 25 m eddy tower following fluxes were measured: CO_2 & H_2O (Licor Li-7200), CH4 & N2O (Aerodyne QCL-Tildas), VOCs (PTR-TOF-MS). In FP, 8 microsites were equipped with CO_2, CH4, N2O chambers (automatic soil chambers (Picarro 2508), tree stem chambers (TSC; 0.1, 0.8 and 1.8 m from ground)), piezometers, automatic groundwater level wells, soil temperature and moisture sensors (0-10 cm). Four analogous microsites were established in CP. From TSCs, during 28 campaigns CO_2 flux was measured by EGM-5 analyser; CH4 and N2O gas samples (0, 60, 120 and 180 min) were analysed in lab by Shimadzu GC2400. In each microsite, during 7 campaigns (three in flooding period), composite soil samples from 0 10 and 30 40 cm were taken for physico-chemical, N2 flux and transcriptomic analysis in labs. During 8 campaigns, groundwater parameters were analysed. In 8 microsites (four in FP), root C exudation cuvettes around fine roots were installed. In 8 sessions, in situ leaf photosynthesis activity of different plants was measured using portable Walz GFS-3000.

The forest sequesters C, whereas NEE of CO_2 decreased during flooding; it was associated with reduced leaf-level photosynthesis in the over- and understory species. Among VOCs, methanol and isoprene showed increasing flux. Eddy fluxes of CH4 and N2O showed diurnal pattern with lower values in night-time but no increase during flooding. Soil CO_2 emission decreased and CH4 fluxes increased when flooded. It was coherent with water table in wells and soil moisture values. However, the clearest flooding effect was found in N cycles: during flooding cycle, in FP soil N2O flux significantly increased whereas chambers in CP did not show any trends. Simultaneously, NO_3 concentration in soil of FP lowered and NH4 concentration elevated in flooding, compared to CP. In FP, CH4 and N2O fluxes from TSCs of lowest positions increased during flooding. As a direct stress response to flooding, in FP trees grew aerial roots. After flooding, tree root C exudate rate was higher than in CP. Results of this experiment provide an important opportunity to include such climatic extremes into global models.