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Plant phenology and composition controls of carbon fluxes in a boreal peatland

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Vegetation drives the peatland carbon (C) cycle via the processes of photosynthesis, plant respiration and decomposition as well as by providing substrate for methane (CH4) and dissolved organic carbon production. However, due to the lack of comprehensive vegetation data, variations in the peatland C fluxes are commonly related to temperature and other more easily measured abiotic (i.e. weather and soil) variables. Due to the temporal co-linearity between plant development and abiotic variables, these relationships may describe the variations in C fluxes reasonably well, however, without representing the true mechanistic processes driving the peatland C cycle. As a consequence, current process-based models are poorly parameterized and unable to adequately predict the responses of the peatland C cycle to climate change, extreme events and anthropogenic impacts.

To fill this knowledge gap, we explored vegetation phenology and composition effects on the peatland C cycle at the Degerö peatland located in northern Sweden. We used a greenness index derived from digital repeat photography to quantitatively describe plant canopy development with high temporal (i.e. daily) and spatial (plot to ecosystem) resolution. In addition, eddy covariance and static chamber measurements of carbon dioxide (CO_2) and CH4 fluxes over an array of vegetation manipulation plots were conducted over multiple years.

Our results suggest that vascular plant phenology controls the onset and pattern of eddy covariance-derived gross primary production (GPP) during the spring period, while abiotic conditions modify GPP during the summer period when plant canopy cover is fully developed. Inter-annual variations in the spring onset and patterns of plant canopy development were best explained by differences in the preceding growing degree day sum. We also observed strong correlations of canopy greenness with the net ecosystem CO_2 exchange and ecosystem respiration. On average, vascular plant and moss production accounted for $\sim$60 and 40% of GPP, respectively. However, while the seasonal variation of vascular plant productivity was driven by plant phenology, water table level was the strongest control of moss productivity. Across vegetation manipulation plots, highest chamber-derived GPP and net CO_2 uptake occurred when both vascular and moss species were present. Furthermore, CH4 fluxes increased with the amount of sedge species leaf area; however, their seasonal flux patterns were more closely related to water table level than to plant phenology.

Overall these findings highlight the need for better understanding the separate controls of biotic and abiotic drivers of the peatland C fluxes to improve predictions of ecosystem processes and the peatland C sink strength in response to future climate change and management impacts.