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Landscape and climate impacts on Holocene lake carbon accumulation along a boreal-subarctic catchment

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Inland waters play a role in local and global carbon (C) cycling by storing C in sediments, emitting carbon dioxide (CO_2) and methane (CH4) to the atmosphere, and by transferring and processing of C discharged downstream. Essentially, part of terrestrial C is displaced to the aquatic systems through lateral transfer and thus physical and biological properties of both, catchment and lake, shape lake C fluxes and modulate the effects of external forcing such as climate, nutrient and acid depositions. Lake sediments offer long-term records to probe the influence of rapidly changing landscapes, and the relative roles of climate, vegetation and lake characteristics, on aquatic C sequestration. Here we focus on quantitative and qualitative changes in sediment organic C accumulation in four lakes along a catchment at the boreal-subarctic ecotone in Finland. We reflect past C accumulation against present-day C flux dynamics and catchment characteristics. The four study lakes have had the same climatic forcing over the Holocene, but different positions, morphology, and vegetation development in their respective close catchments. High-resolution C accumulation rates were calculated for the past ca. 9500 years for each core. Elemental and isotopic concentrations of C and nitrogen (N), and C:N ratios were used to infer relative changes in terrestrial and aquatic C inputs. Visible-near-infrared spectroscopy (VNIRS) was applied to reconstruct lake water total organic carbon (TOC) and chlorophyll a (Chl a) concentrations. In their current state, the four lakes were placed along clear and parallel upstream-to-downstream gradients in sub-catchment peatland abundance (0–30%) and CO_2 flux (from a slight uptake to 27 mmol m-2d-1). Spatial pattern of CH4 effluxes varied from 1 to 1.7 mmol m-2d-1. Long-term apparent C accumulation rate ranged from 3 to 13 g m-2yr-1 along the elevational, peatland abundance and CO_2 efflux gradients indicating peatlands as significant sources of organic carbon. Rapid fluctuations in C accumulation took place over the Holocene with differing between-lake patterns. Carbon quality changes followed overall Holocene climate development, but again with significant between-lake differences in the magnitude and direction of change. We suggest that the major shifts in C accumulation and source were associated with water level fluctuations, peatland development and aquatic macrophyte abundance. Despite their location in the same catchment, the four basins faced a unique combination of changes in these factors over the Holocene, and thus presented highly individualistic responses to large-scale climate forcing. We propose that multi-lake data are essential when interpreting landscape modulation of external forcing. Together with increasing the number and geographical coverage of high-resolution datasets, multi-lake data will be pivotal when defining critical ecosystem thresholds.