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Using reconstructions of the global peat C balance over the Holocene to constrain the timing and magnitude of anthropogenic land use emissions

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Major circumpolar peatlands of the northern hemisphere have established over the last 14 kyr, with the majority of peat C sequestered during the Holocene. Today, this C storage amounts to 500-600 GtC. In spite of this substantial impact on the C cycle, independent records of the total terrestrial C balance suggest a small long-term trend over the last 6 kyr. The advent of agriculture, associated land use change, and resulting cumulative CO_2 emissions of 50-350 GtC have occurred during a period of continued C sequestration in peatlands. Relatively small variations in the total terrestrial C balance have thus been interpreted to indicate a coincidental timing and a similar magnitude of these compensating fluxes and to lend support for upper-end estimates of preindustrial land use emissions.

Here, we test this hypothesis by combining observation-based reconstructions of the terrestrial C balance (ΔC) and peat storage (ΔC_{peat}) with new results from process-based global land C cycle models that hindcast peat C dynamics and CO_2 emissions from anthropogenic land use change (ΔC_{LUC}) following a set of contrasting land use reconstructions. Recent data compilations of peat C accumulation histories allow us to provide an improved temporal resolution of observation-based ΔC_{peat}. We assess the terrestrial C budget $\Delta C = \Delta C_{peat} + \delta$ for different periods in the Holocene and in the last millennium and confront ΔC_{LUC} with the budget residual δ.

We find that the combination of ΔC_{peat} and ΔC and their temporal variations provide additional constraints on ΔC_{LUC} estimates that have thus far not been taken into account. Between 11-7 kyr BP, ΔC_{peat} alone accounts for the majority of ΔC, incompatible with upper-end ΔC_{LUC} estimates. Between 7-5 kyr BP and 5-2 kyr BP, the budget reveals a substantial land C source, but all model-based estimates of ΔC_{LUC} fall short of explaining the magnitude of δ. ΔC reveals a relatively stable overall C balance during the last millennium before 1750, but substantial C loss from land thereafter. The combination of ΔC_{peat} and ΔC estimates thus support land use reconstructions with negligible ΔC_{LUC} before 7 kyr BP and a substantial fraction of ΔC_{LUC} occurring after Industrialisation.