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A carbon budget of Norway: integration of terrestrial and aquatic C fluxes

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The land sink for atmospheric CO_2 in northern landscapes is significant but its size and future strength is debated. Aquatic export of C, often disregarded in terrestrial C sinks estimates, can be significant. Here, we quantify C stocks and sinks in main land cover categories in Norway for 1990-2008, and evaluate the relative importance of terrestrial uptake and aquatic losses of C in the four major discharge areas of Norway.

Forest inventory data, a soil model, a soil C database, literature data, and river monitoring data are used to quantify C stocks and fluxes and their uncertainty. The mean annual C uptake in terrestrial ecosystems Norway was 6.1 $\pm$ 0.3 Tg C yr-1 (19 g C m-2 yr-1) balancing 40% of mean annual C emissions from mainland Norway. Total organic C (TOC) inputs from rivers to coastal areas were 1.1 $\pm$ 0.1 Tg C yr-1 (3.3 g C m-2 yr-1), of which half may be buried permanently in coastal sediments representing an additional C sink. Subartic Norway (25% of Norway) contributed <5% to the terrestrial C sink and almost 10% to the riverine C export in Norway. In-lake and in-stream processes resulted in losses of terrestrially fixed DOC as CO_2, indicating that headwater TOC export could be between 5 to 7 g C m-2 yr-1.

Forests accumulated most C (5.9$\pm$ 0.4 Tg C yr-1 or 51 g C m-2 yr-1). The present forest sink is primarily a legacy from earlier intense forestry which led to low standing stocks at the start of the 20th century. Compared with forest soils (9 g C m-2 yr-1), C sequestration in peatlands (32 g C m-2 yr-1) was very effective. The largest losses of organic C were from cultivated organic soils (-0.42 $\pm$ 0.17 Tg C yr-1; -35 g C m-2 yr-1). All flux estimates are independent and based on highly varying data availability and methods. Cross-validation would add to the credibility of these numbers and their uncertainty.

Riverine TOC fluxes and C uptake in biomass were of similar size in subarctic Norway. In boreal, oceanic Norway riverine TOC fluxes were 30% of biomass C uptake. It is unclear whether these riverine C exports (originating in forest soils and peatlands) represent an additional loss for which terrestrial C uptake must be corrected. This is because of the soil model, which conceptualizes the soil C sink as a product of temperature and litter flow. This concept does not include a role for precipitation in soil C accumulation – either by vertical displacement of DOC from topsoil to subsoil or by including lateral losses of C from soils to rivers. Climate predictions indicate more precipitation and higher precipitation intensity, suggesting larger transport from soils to rivers to coastal areas with uncertain implications for the terrestrial C sink. To improve northern landscape C balances a catchment perspective would be valuable, integrating across ecosystems and connecting vertical and lateral C fluxes.