Restoration of Terminated Peat Cuttings by Rewetting

A project on the *Restoration of Terminated Peat Cuttings by Rewetting*, extending over more than 20 years, was carried out in Sweden between 1997 and 2018. The original aim of the project was to investigate the effects of rewetting on soil, hydrology, water chemical conditions and vegetation, and the development of these conditions over time.

After some years, the effects of greenhouse gas fluxes and carbon balances attracted increasing interest, and studies into the effects on greenhouse gas fluxes of common ecotopes/microsites started about 10 years after rewetting. Financial contributions to the project were made by the Swedish Energy Agency and the Swedish Peat Research Foundation, while the Swedish University of Agricultural Sciences hosted it.

The peat company Neova AB provided field preparations. Three peat-extraction areas, Porla, Toftmossen and Västkärr, located in central south Sweden, were studied. After rewetting, the sites were turned into shallow wetlands, forming a nutrient gradient from the poor Porla site, over the intermediate Toftmossen site to the fairly rich Västkärr site (Fig. 1). The Toftmossen site was mainly used in the greenhouse gas (GHG) studies.

Starting conditions

By finishing peat extraction, a bare peat surface existed. Such cut-over areas should be put in after-use. There are a number of alternatives for finished extracted peatlands and in Sweden the common use is often either forest or wetland. A wetland case can start as a shallow bird lake, which in time will become terrestrialized towards mire conditions. In this project, investigations initially focused on lake/wetland conditions. Vegetation development over time will alter the initial physical and chemical conditions.

Soil material - peat

Remaining soil peat, once extraction was finished, formed prerequisites for wetland substrates and peat surface structures. In the Västkärr area, a levelled, fen peat surface, with a thickness of 0.2 to 0.4 m above postglacial clay, formed a stable lake bottom. Discharging groundwater through the clay provided nutrients to the lake water.

At the Porla site, there was a till mineral soil underlying the *Carex* and *Sphagnum* peat. The till had a broken topography furnishing both thin and thick peat cover, ranging from almost zero up to two meters of peat. In the case of thick peat layers, the top c. 0.7 m was *Sphagnum* peat with fen peat below. After rewetting, the top *Sphagnum* peat became swollen and partly floating (Lundin *et al.*, 2016). This formed floating peat rafts with low buoyancy, further increasing the risk of peat transportation to downslope surface stream water. This risk was low, however, in the Porla lake, which was blocked by dams, but in other cases, more open flow paths of surface water could conduct such floating peat.

The chemical composition of peat at both the Västkärr and Porla sites, turning into a bottom substrate, did not change considerably after

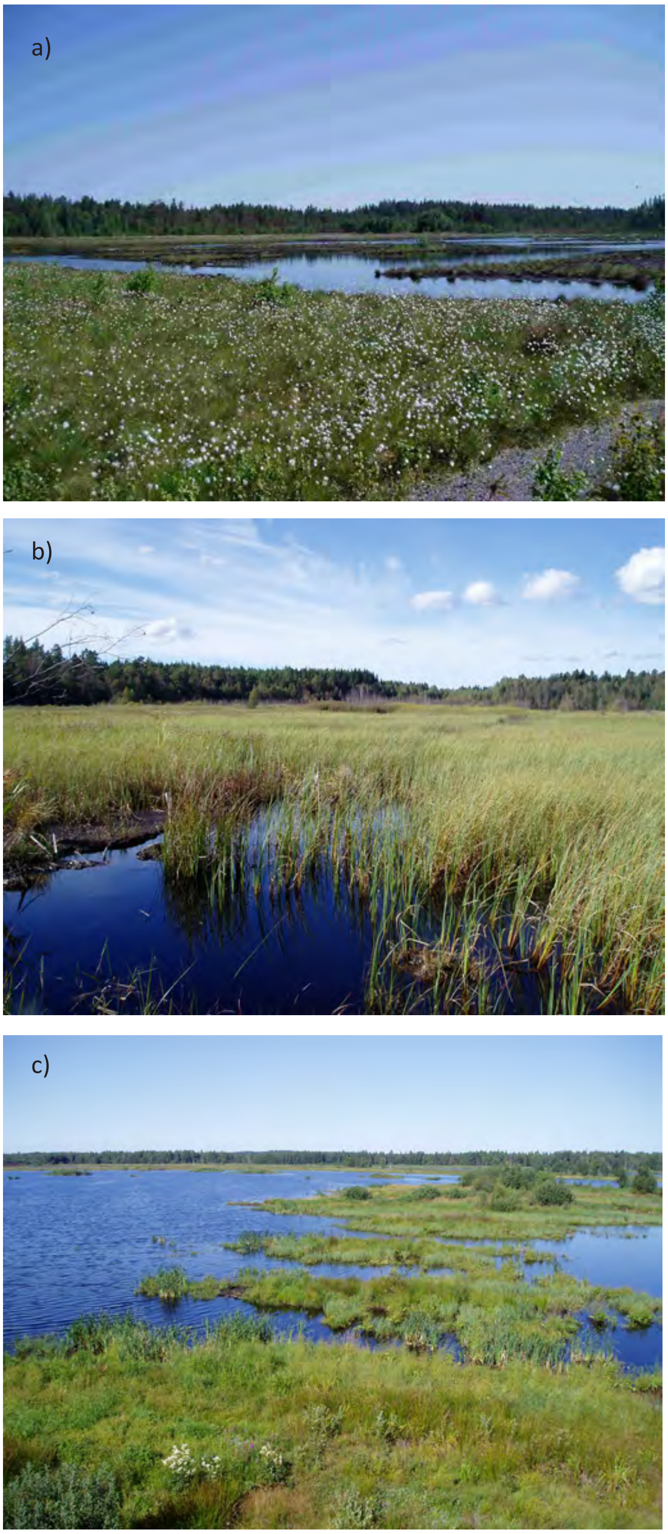


Figure 1. The three wetlands, Porla (a), Toftmossen (b) and Västkärr (c), after a 7-10 years of rewetting. Photos: Lars Lundin

rewetting. Carbon and phosphorus content, as well as pH, were fairly stable. Nitrogen content increased somewhat with a higher share of ammonium. C/N became somewhat lower at the Porla site (Lundin *et al*., 2016).

Hydrology

Obviously, hydrology changed from drained conditions in the extraction phase to shallow, open lake conditions with water depths of about one meter on average. Runoff decreased after rewetting, and both low and high discharges lessened. There were also longer periods with no water flow and cessation of discharge (Lundin *et al*., 2016). This could have deteriorating effects on the living environment in downstream water courses.

Water chemistry

Water chemical conditions differed between the three wetlands with poor conditions in Porla lake (whose pH level was just above 5, while Toftmossen water showed a pH around 6 and Västkärr, being richest, had a pH of 6 to 7). Also, nutrients such as base cations, phosphorus and inorganic nitrogen compounds, showed similar pH patterns.

After rewetting, the pH level at Porla lake was almost unaltered, whereas the Västkärr pH decreased at first, but after a number of years

Table 1. Average chemical composition before and years after rewetting at the Porla and Västkärr sites.

	Västkärr lake		Porla lake	
	Before	After 13-15 years	Before	After 12-14 years
Variable				
pH	6.1	6.7	5.4	5.0
NO_3-N, mg/L	0.63	0.18	0.09	0.06
NH_4-N, mg/L	0.64	0.36	0.64	0.17
Org-N, mg/L	1.31	1.70	0.86	0.84
Total-N, mg/L	2.58	2.24	1.58	1.07
PO_4-P, µg/L	31	16	3	4
Total-P, µg/L	34	76	16	20

increased, reaching values higher than before rewetting. Most ions and elements showed lower concentrations after rewetting at both the Porla and Västkärr sites. In contrast to this, phosphorus concentrations increased (Table 1). Element transportation out of the wetlands mostly decreased (Lundin *et al*., 2016).

Dissolved oxygen content was often at an acceptable level, probably due to the rather shallow water depths being mixed by wind. However, during stagnation periods in late winter and late summer, dissolved oxygen was depleted and short periods of anoxic conditions occurred (Lundin *et al*., 2016) with effects on bottom fauna life.

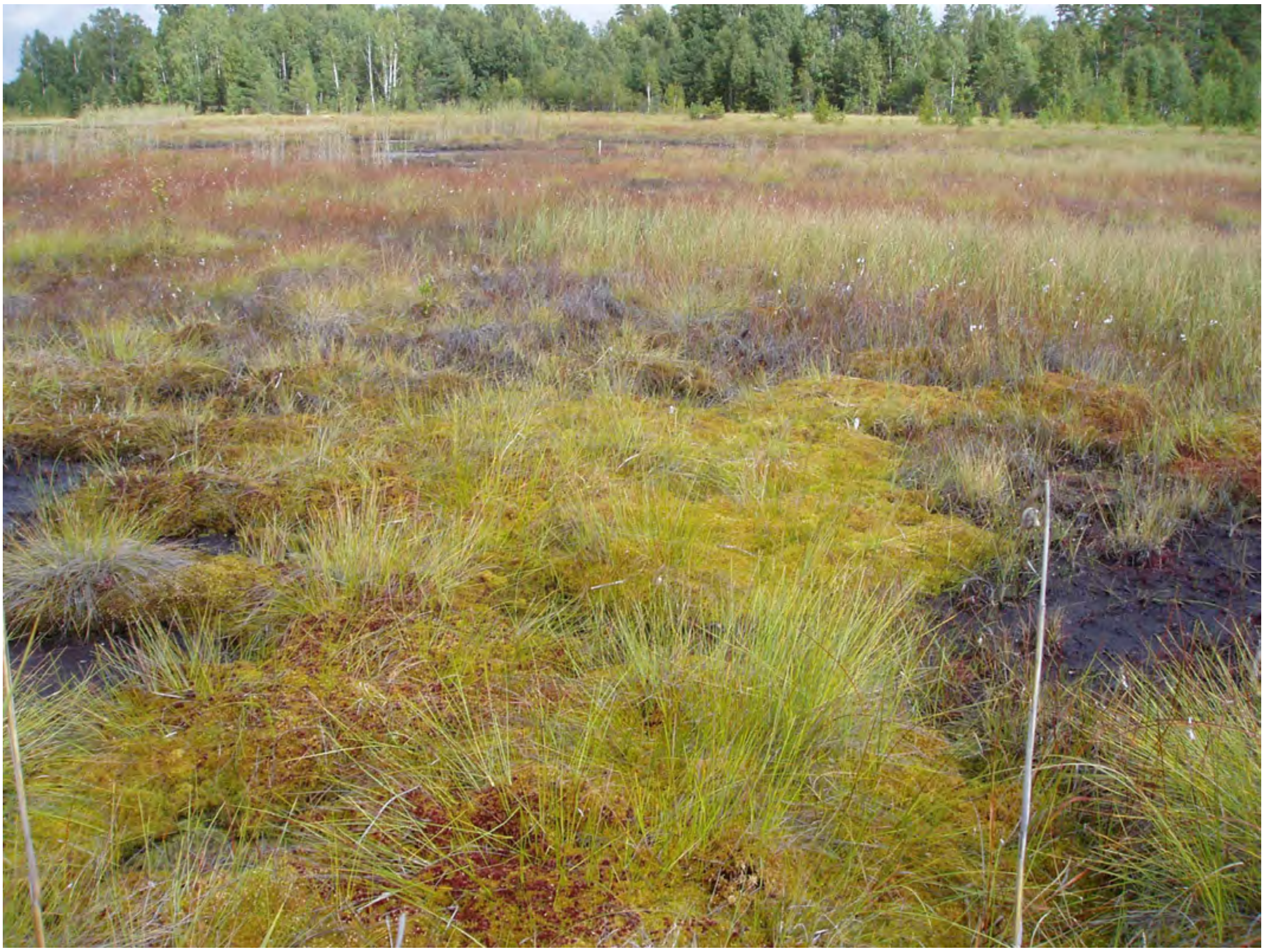
Vegetation development

On termination of peat extraction, there were mainly bare peat surfaces in the cut-over areas, with few plants connecting to the remaining ditches. However, colonization started quite rapidly at the Västkärr site after 2-3 years, with vegetation dominated by grasses such as *Glyceria fluitans*, *Phalaris arundinacea* and *Poa trivialis*. Other species were *Equisetum spp*. and *Potamogeton spp*.

Open water and bare peat made up 20-30% of the coverage and higher in the case of high water levels. In later stages, after almost 20 years of lake conditions, the number of species decreased and the vegetation was dominated by *Carex spp.*, *Phragmites australis*, *Typha latifolia* and *Phalaris arundinacea* (Kozlov *et al*., 2016).

Especially evident, was the emerging reed *Phragmites australis*, growing out into open water with a bulrush (T*ypha spp.*) board in many places. Onshore, deciduous trees such as sallow (*Salix spp.*), birch (*Betula spp.*) and alder (*Alnus spp.)* hampered the open water view and had to be cut to keep the range of sight free.

Figure 2. Rewetted peatland where cotton grass (*Eriophorum spp*.) as a pioneer plant is paving the way for *Sphagnum spp*. Photo: Lars Lundin



Vegetation colonization was slower in the Porla area compared with the Västkärr site. Large parts of the soil surface were dominated by bare peat and open water. In a few locations close to old ditches, *Polytrichum spp*. and *Phragmites australis* were found. However, with time, *Eriophorum vaginatum* and *Eriophorum angustifolium* in particular started to colonize, and (after 5-7 years had a coverage of around 20% and almost 30%, respectively. Occurrence of *E. vaginatum* was higher than for *E. angustifolium*.

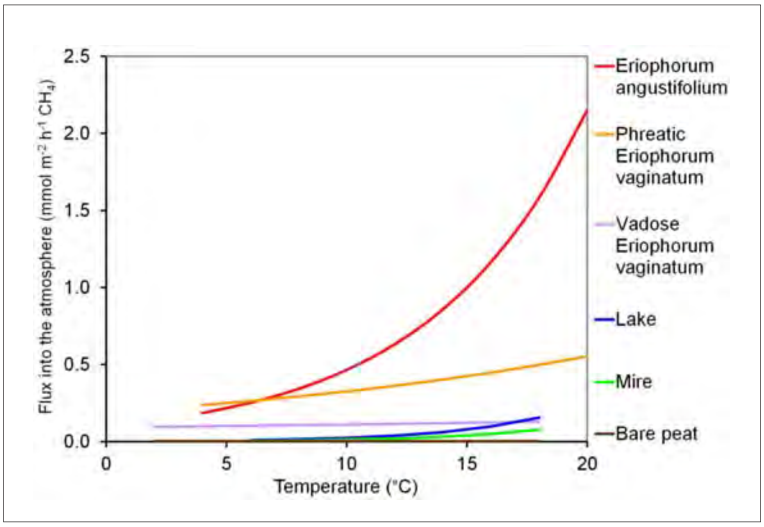


Figure 3. Ecotope CH_4 fluxes (mmol m^{-2} h^{-1}) related to soil or water temperature (°C). Fluxes are estimated with a linear mixed-effects model based on measured temperature ranges.

After about seven years, *Sphagnum spp*. started to appear commonly, increasing in a number of places and expanding to cover 20-30% of the studied plots after another 7-10 years. Total plant cover increased from ca. 40% in year seven after rewetting to almost 80% after another ten years, with bare peat and open water making up the rest. *Drosera spp*. occurred frequently in up to 10% of the studied plots (Kozlov *et al.*, 2016).

It could be concluded that *Sphagnum spp*. establishment was largely connected to the occurrence of cotton grass (*E. vaginatum*) (Fig. 2). In the Toftmossen area, the occurrence and coverage of *Sphagnum spp.* was also increasing over the years studied.

Greenhouse gas fluxes

For all sites, CO_2 net emissions were generally low or negative (CO_2 uptake) from ecotopes with wetland/peatland vegetation (*Sphagnum spp.*, *Eriophorum spp.* in water, *Carex spp*. and other grasses) or from open water bodies. The drained bare peat and bare peat with *Eriophorum vaginatum* tussocks showed the highest ecosystem CO_2 net emissions due to oxidative peat consumption and strong root respiration.

Methane (CH_4), however, mainly showed low emissions from bare peat, mire and lake water, whereas the highest CH_4 emissions were found for wet Eriophorum spp. ecotopes (Fig. 3), for *Carex spp.* and other grasses.

Regarding N_2O emissions, these were mainly negligible from the three sites and also from the different ecotopes.

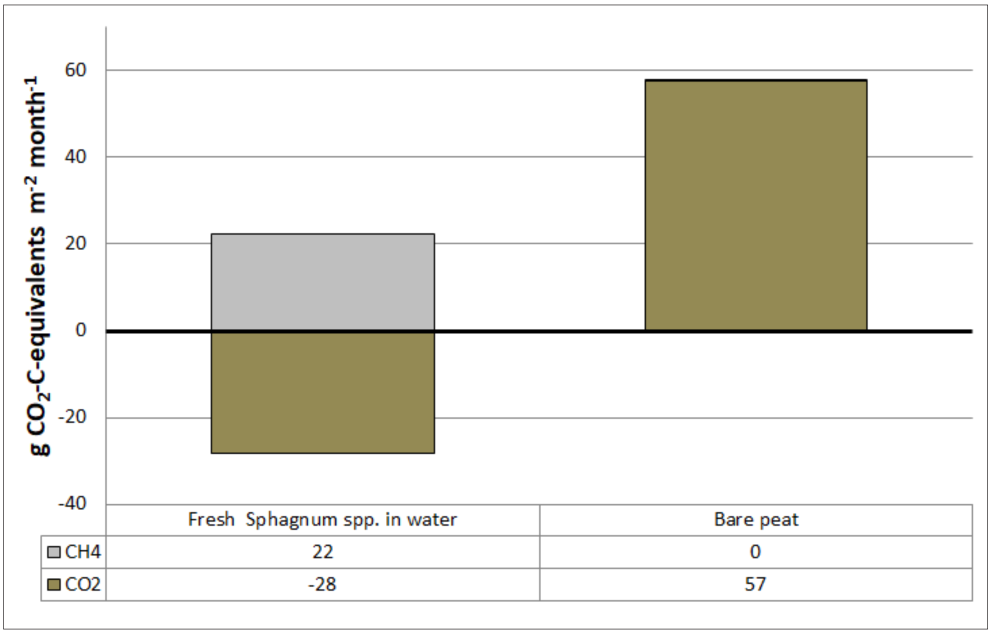


Figure 4. Net emissions (measured with automated transparent chambers) of CO_2 and CH_4 (g-CO_2-C equiv. m^{-2} and month) from the Sphagnum sites, in comparison to bare peat sites from the rewetted peatland at Porla during the vegetation seasons 2016 and 2017. A minus sign indicates uptake.

Depending on temperature, soil moisture, height of the water table and light, ecotopes with peatland vegetation (e.g., *Sphagnum spp.*) can be sinks or sources of greenhouse gases, whereas bare peat sites are carbon sources (Fig. 4).

CH_4 fluxes to the atmosphere from vascular plants directly after rewetting can be considerable. However, if the shallow lakes develop into bogs or poor fens with *Sphagnum spp*. as the main vegetation form, a greenhouse gas balance close to zero can be obtained, since the relatively small emissions of CH_4 from *Sphagnum spp*. lawns can be balanced by CO_2 uptake.

Conclusion

To sum up, it could be stated that rewetting of terminated, peat cut-over areas is beneficial for landscape diversity and biodiversity. The main effects on hydrology were lower discharges, of special concern in low discharge situations. Most concentrations of chemical compounds became lower but total phosphorus increased.

The significance of this from a GHG perspective could be more complex and needs further investigation to determine the consequences. Over time, carbon is sequestered in the newly formed peat, which would have significance for GHG balance reclamation of the mire landscape.

As long as large areas of bare peat exist, ecosystem respiration may govern the GHG fluxes from rewetted peatlands. Creating a carbon source by drainage is a fast process, but creating a C sink by rewetting may take decades.

Related literature

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