How to assess cutover peatland regeneration with combined organic matter indicators ?

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Summary

When restored, cutover peatlands can favour biodiversity and carbon (C) sequestration. Within the EU program RECIPE, we aimed to identify combinations of site physico-chemical conditions, vegetation composition and below-ground microbiological characteristics that are beneficial to the long-term biodiversity and C sink function regeneration. To shed light on these characteristics, we assessed the bioindicator value of peat organic matter (OM) physico-chemistry from cutover peatlands at various stages of regeneration. Although OM continues to reflect disturbances in the catotelm deep peat, we show that along the chronosequence the regenerated peat tends to be biochemically and physically similar to the one from the non-exploited area of the same site. The combination of several indicators provides an efficient assessment of ecological conditions and makes valuable for the management of cutover peatlands.

Key index words: peatland, restoration, organic matter, bioindicator, management

Introduction

Peatlands are known to be important global sinks of carbon (Clymo, 1983). However, human activities endanger not only the sink capacity, but also the long term storage of carbon within the ecosystem. Perturbations are numerous ranging from local and direct (peat cutting), to global and indirect (climate change). This paper focuses on the local direct effect of peat cutting. The main question rising after such perturbation is how and under what conditions the peat accumulation process can be induced again (Chapman *et al.*, 2003). To provide management options that would preserve or enhance biodiversity for these abandoned peatlands, the European program RECIPE involved scientists from various domains of expertise working on peatlands located in Finland, France (2 sites), Switzerland and Scotland. In this paper, the results obtained from the study of Organic Matter (OM) quality in terms of peat biochemical and botanical composition are reported. Two approaches were used: 1) analyzes of peat profiles from different stages of regeneration illustrated by one of the studied peatlands: the Scottish site, and 2) experiments with a bioindicator as a response variable, in the four European sites. The aim of the first approach was to analyze peat OM evolution along the chronosequence. The aim of the second approach was to assess the effect of water table level and vegetation on peat chemistry (C/N) in each site.

Materials and methods

Study sites and sampling

For the first approach, the site was Middlemuir Moss in Scotland, an extensively exploited site from 1953 to 1998. One 0.5 m peat core was collected in four plots selected (Table 1) taking into account the age of abandonment and peat-forming key species, i.e. *Sphagnum* and *Eriophorum* species. For the second approach, 4 sites were studied: 1) the Finnish site Aitoneva where harvesting was abandoned in 1975; 2) the Russey site, a past (1968-1984) industrially extracted peat bog located in the French Jura mountains; 3) the Baupte in France (Normandy), a heavily industrially cutover peatland (1949-1995); and 4) the Scottish site, Middlemuir Moss. In each site, peat was placed *in situ* for 18 months in PVC tubes (n=3) and samples were analysed after removing the peat monoliths from the tube.

Table 1. Regeneration stages and dominant vegetation of the sampling areas at Middlemuir (Scotland).

Site	Time (y) since abandonment	Vegetation (code on fig)
A	< 5	Bare peat (Bare peat)
B	5 - 10	*Sphagnum fallax* > 95% (*S. fallax*)
C	5 - 10	*E. angustifolium* > 70%, *E. vaginatum* 5-10%, *S. fallax* 15-20% (*E. ang*)
D	> 50	*S. palustre* + *S. fallax* + *S. capillifolium* > 80%, *Molinia caerulea* (*S. spp* + herb.)

First approach – organic matter analysis of the peat profiles

Micromorphological identification and quantification of peat micro-remains were carried out using a photonic microscope under transmitted light (Comont *et al.*, 2006). Carbon (C) and Nitrogen (N) contents were determined by combustion of dried and crushed samples using a CNS-LECO 2000 analyzer. Neutral monosaccharides were released after H_2SO_4 hydrolysis and individual sugars were quantified by gas chromatography. The detailed procedure is given in Comont *et al.* (2006).

Micromorphology analysis and C/N were conducted on bulk peat samples to reveal the influence of source materials on the OM composition while monosaccharide analysis was conducted on a fine-grained fraction of the peat (< 200µm) to obtain information on OM degradation processes (Comont *et al.*, 2006).

Second approach – experimental design

In each selected site (SC, FR, FB, FI), an experiment was designed to assess the effect of vegetation and water table on peat chemistry. The experimental setting consisted of digging a large hole with a rising slope. PVC tubes containing peat were placed at two different water table levels and 3 key-species (*S. fallax, E. vaginatum* and *E. angustifolium*) were placed in the tubes for 18 months. Tubes without plants served as controls. The C/N quotient was used as a response variable in a 2 ways ANOVA with water table level and vegetation as main effects, followed by a Tukey post-hoc test (Statsoft, 2001).

Results

First approach – OM bioindicators of the Scottish peat profiles

Micromorphology analysis showed that mucilage (a component derived partly from microbial syntheses) was dominant in the bare peat profile (Fig.1a), but not in the colonised plots. Well-preserved *Sphagnum*-derived tissues were recorded in the *S. fallax* area whereas amorphous OM and structureless tissues were recorded in the *E. angustifolium* area (Fig.1b,c). These two latter types of remains, especially the well preserved *Sphagnum*-derived tissues, are dominant at the peat surface in the advanced regeneration stage (Fig.1d).

Atomic C/N profiles were similar in bare peat and in the advanced regeneration stage treatment, noting a steeper decrease at 7.5 cm in the latter (Fig 2a,d). C/N ratio in the two early regeneration profiles was comparatively low at the surface (Fig. 2b,c).

Monosaccharide analysis showed the molecular signature of source materials: rhamnose (Rha) and galactose (Gal) from *S. fallax*, and arabinose and xylose from *E. angustifolium* (Fig. 3b,c) (Laggoun-Défarge *et al.*, in press). These monosaccharides contributed to the composition of the advanced regenerated peat (Fig. 3d). At depth of 7.5 cm and 25 cm, most of the monosaccharide concentrations in the early regeneration stage (*S. fallax* and *E. angustifolium* treatment) were lower than both bare peat and the advanced regeneration stage (Fig. 3).

Second approach – C/N as a bioindicator used in experimental design

In all the sites, the water table level and its interaction with vegetation had no effect on C/N quotient (all $F<1.8$, all $P>0.17$). Vegetation had an effect on the Scottish and Le Russey peat chemistry (Fig. 4, both $F>7.1$, both $P<0.002$): C/N in both *Eriophorum* plots was significantly lower than in the bare peat plot (Fig. 4a, b). C/N in the *S. fallax* plot was not significantly lower than the bare peat plot in the Russey site (Fig. 4a).

Discussion and conclusion

All bioindicators showed a dramatic impact of colonising vegetation on the structure and chemistry of newly formed peat. Cluster analysis on bulk C/N and total cellulosic sugar profiles (results not shown) showed that the advanced

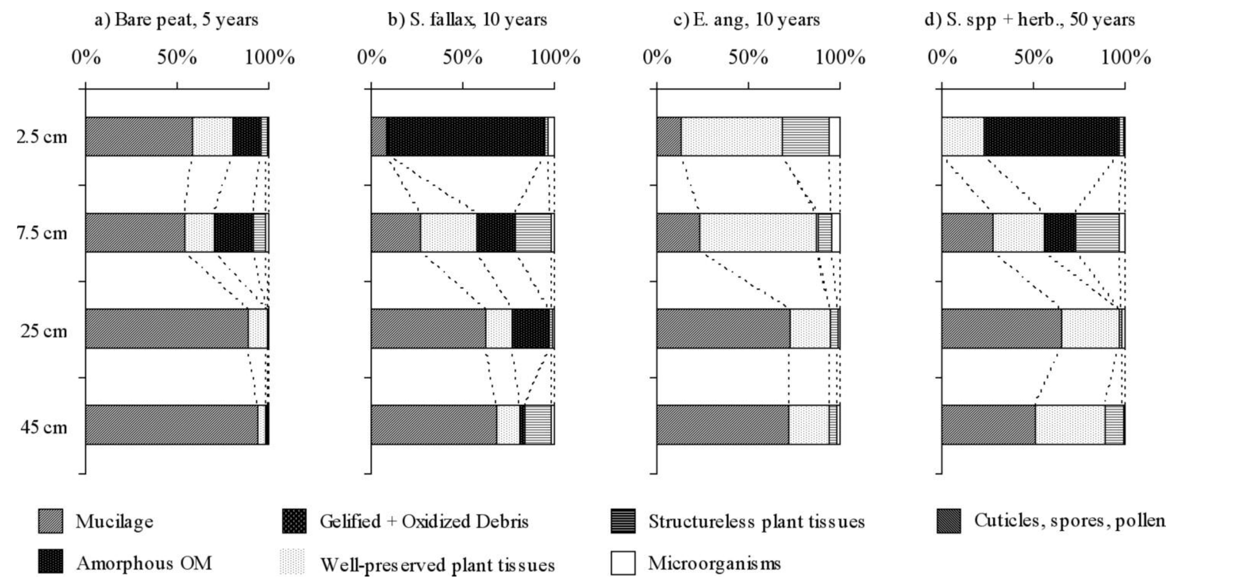

Figure 1. Mean depth evolution of relative percentages of organic remains of bulk peat in recent and advanced regeneration stages of Middlemuir peatland (Scotland)

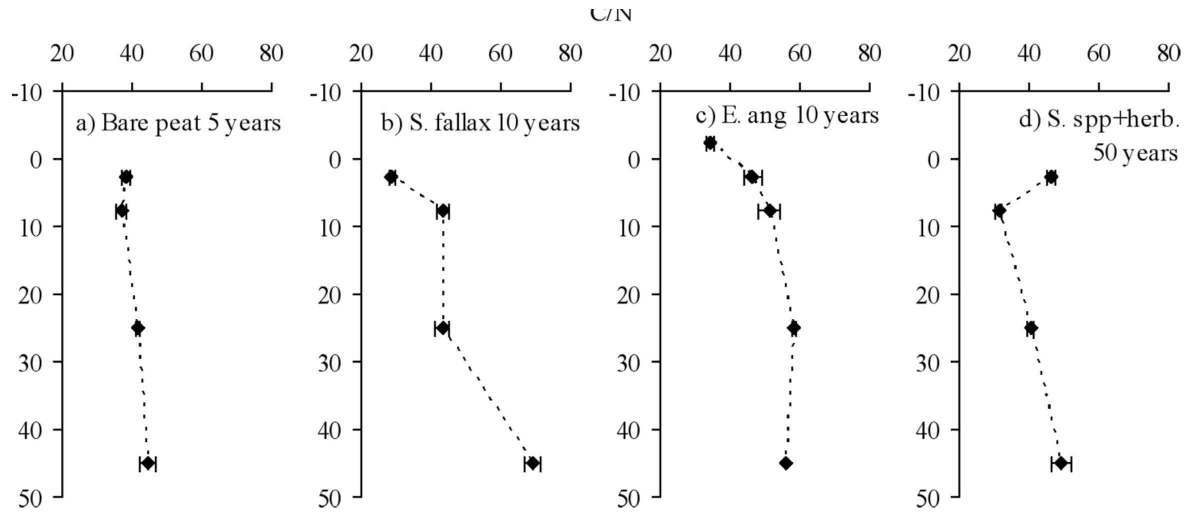

Figure 2. Mean depth profiles of atomic C/N quotient of the peat fine-grained (<200 μm) fraction in the regeneration stages of Middlemuir peatland (Scotland).

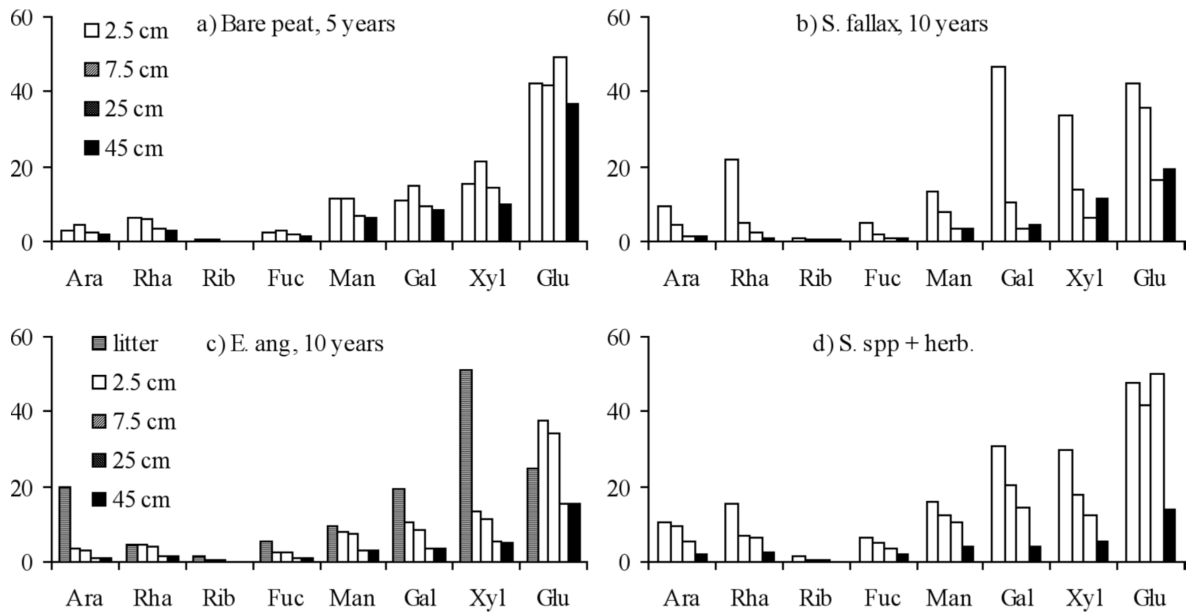

Figure 3. Profiles of monosaccharide (arabinose, rhamnose, ribose, fucose, mannose, galactose, xylose and glucose) concentrations (mg g^{-1} dw) of the peat fine-grained (<200 μm) fraction in the regeneration stages of Middlemuir peatland (Scotland)

regeneration stage profile is more similar to bare peat than any other early regeneration stage. The two peat-forming plants investigated here differed by their decomposability: *Sphagnum*-derived tissues were preserved, whereas *Eriophorum* litter was quickly decomposed to structureless tissues and amorphous OM. Observations by cryo-scanning electron microscopy of the peat from a similar chronosequence in one of the studied sites (Le Russey) were in accordance with this result (Comont *et al.*, 2006). With time, plant-derived OM becomes more heterogeneous with a notably better preservation of *Sphagnum* spp. tissues (Laggoun-Défarge *et al.*, in press). In the early regeneration stages, chemical and structural OM changes induced by colonising plants seem to be accompanied by an increased rate of mineralization: at depth, monosaccharide concentrations were lower in the early regeneration stage than in both bare peat and the advanced regenerated profile. A.-J. Francez (Université de Rennes 1, pers. comm.) showed that in deep peat carbon mineralization both in aerobiosis and anaerobiosis conditions is maximal after 10 to 20 years of regeneration.

The second experiment, involving vegetation and water table manipulation, provides some clues about what is occurring in early regeneration stages. In Scotland and Le Russey, there is a decrease in C/N quotient in vascular plants plots (probably due to rhizospheric processes) that might improve decay conditions. The vegetation effects seem to be related to the degree of site exploitation. Significant effects were observed in the Scottish site and in Le Russey, where peat cutting was either manual or extensive. Inversely no effects were observed in Finland and Baupte, where peat cutting was intensive.

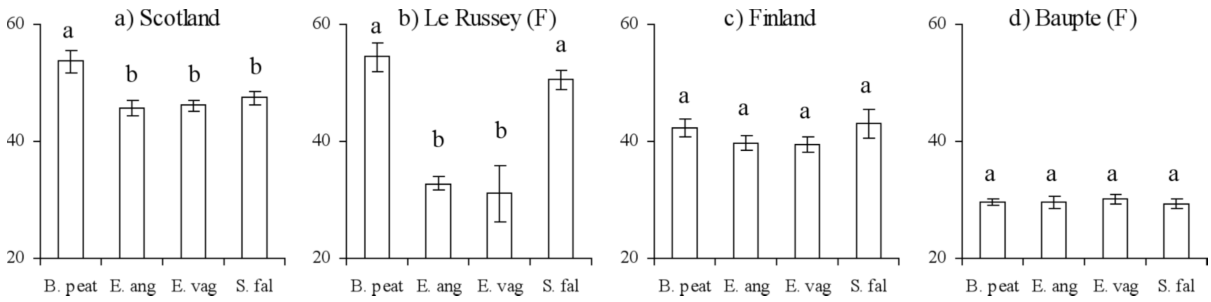

Figure 4. Effect of vegetation (bare peat, *E. angustifolium*, *E. vaginatum*, *S. fallax*) on C/N quotient in experimental design in each country (± 1 standard error, n=3) (significant differences, $P < 0.05$, are shown by different letters)

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