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To cite this version:

Sébastien Gogo, Fatima Laggoun-Défarge, Laure Comont, Christian Défarge, Jean-Robert Disnar, et al.. How to assess cutover Peatland regeneration with combined organic matter indicators ?. Proceedings of the 13th International Peat Congress, Jun 2008, Tullamore, Ireland. pp.394-397. insu-00325479

HAL Id: insu-00325479

https://hal-insu.archives-ouvertes.fr/insu-00325479

Submitted on 29 Sep 2008

In: *After Wise Use – The Future of Peatlands*, C. Farrell & J. Feehan Eds, Proceedings of the 13th International Peat Congress, Ireland, Tullamore, 8-13 June 2008, IPS (Finland), 2008, pp. 394-397.

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 unreveal 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.

Keywords: 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 raised 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 is a past (1968-1984) industrially extracted peat bog located in the French Jura mountains; 3) the Baupte in France (Normandy) is a heavily industrially cut-over 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 analyzed after removing the peat monoliths from the tube.

(**insert Table 1**)

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 colonized 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).

(**insert Fig. 1**)

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).

(**insert Fig. 2**)

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).

(**insert 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).

(**insert Fig. 4**)

DISCUSSION/CONCLUSION

All bioindicators showed a dramatic impact of colonizing 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 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 *S. spp* tissues (Laggoun-Défarge et al., in press). In the early regeneration stages, chemical and structural OM changes induced by colonizing 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. Francez (personal communication) showed that in deep peat carbon mineralization both in aerobiosis and anaerobiosis conditions is maximum 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.

ACKNOWLEDGEMENTS

This paper is a contribution of the RECIPE project (reconciling the commercial exploitation of peat with biodiversity in peatland ecosystems) supported by the EU Commission (no. EVK2-CT-2002-00154).

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TABLES AND FIGURES CAPTIONS

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

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

Fig. 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).

Fig. 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)

Fig. 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)

TABLE

Table 1.

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.)

FIGURES

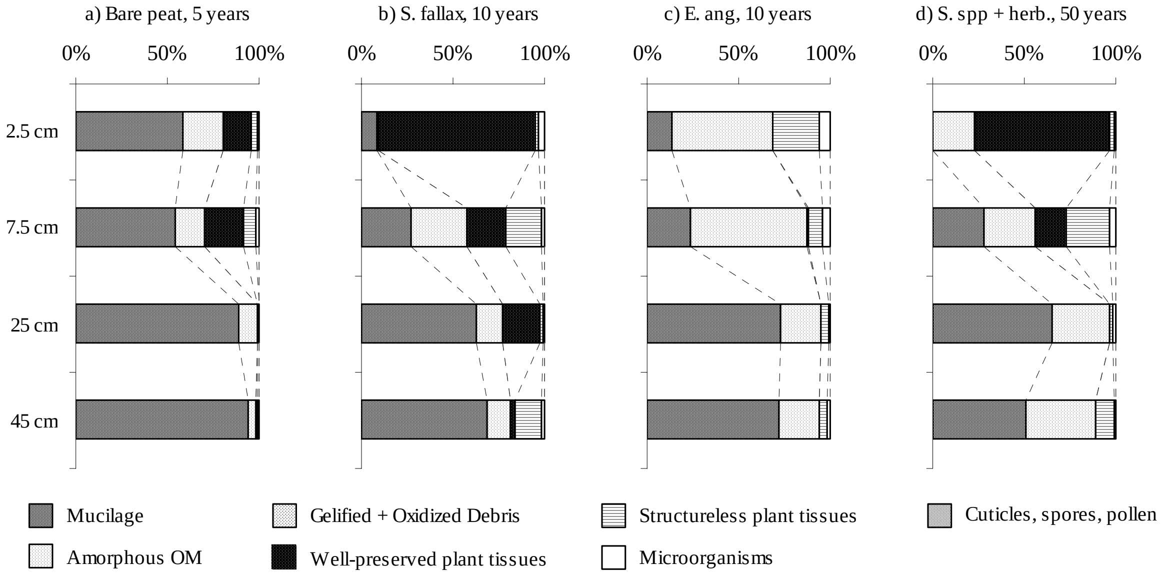

Figure 1.

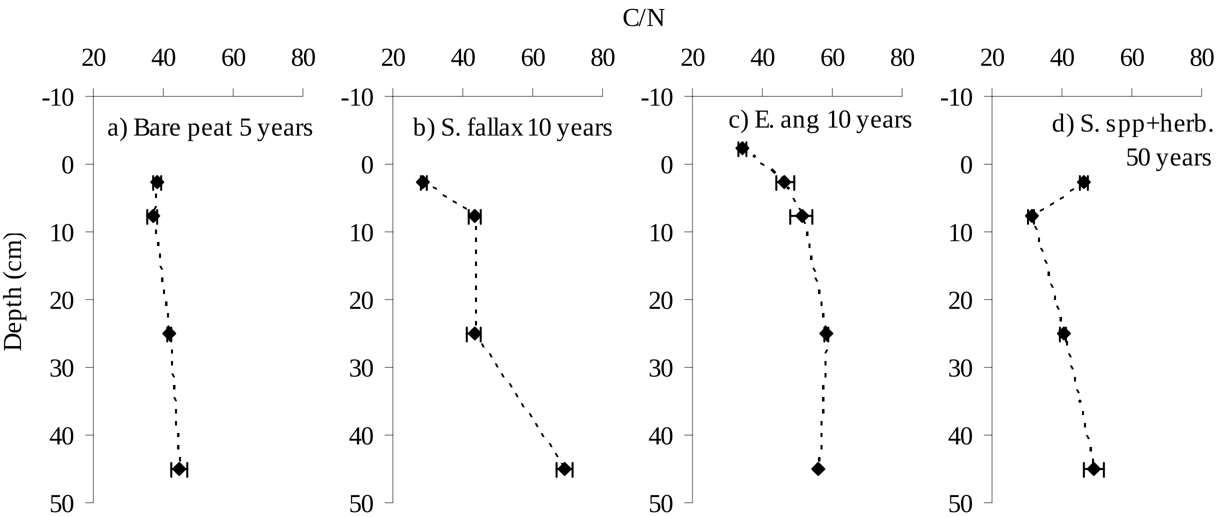

Figure 2.

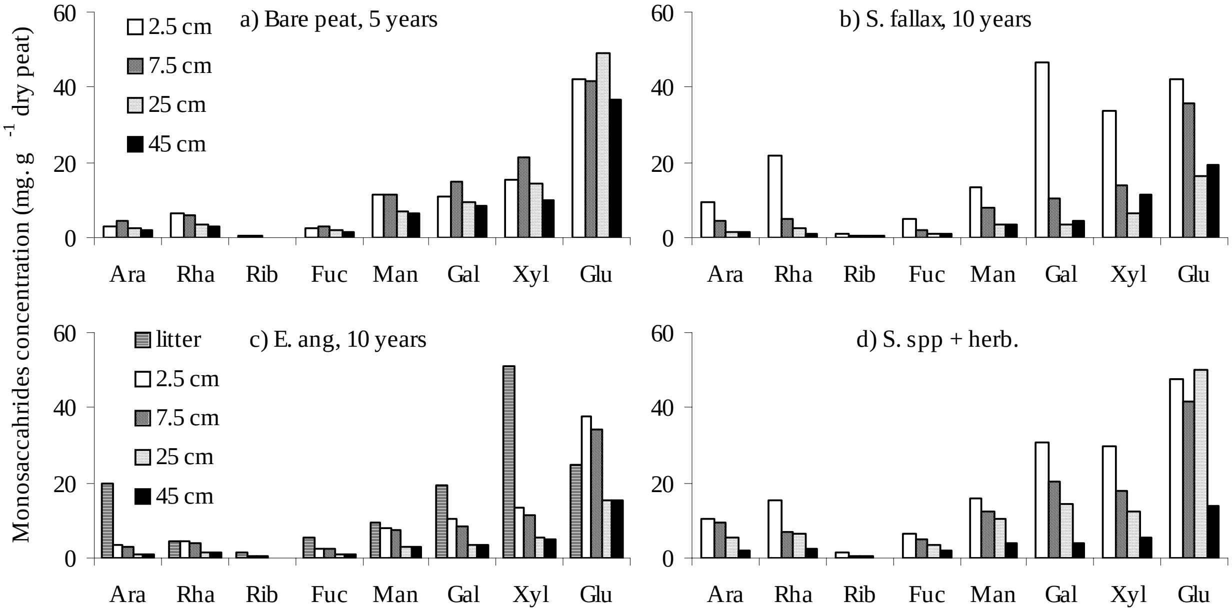

Figure 3.

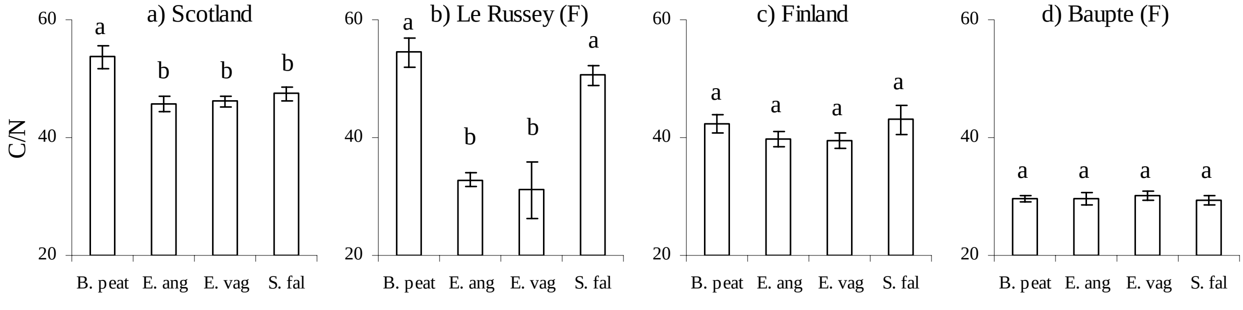

Figure 4.