Abstract No: A-417

DOES HYDROLOGICAL RESTORATION AFFECT GREENHOUSE GASES EMISSION AND PLANT DYNAMICS IN *SPHAGNUM* PEATLANDS?

F. Laggoun-Défarge[1*], S. Gogo[1], L. Bernard-Jannin[1], C.Guimbaud[2], R. Zoccatelli[3], J. Rousseau[4], S. Binet[1], B. D'Angelo[1], F. Leroy[1], N. Jozja[3], F. Le Moing[1] and C. Défarge[1,3]

[1]*ISTO, University of Orléans/CNRS/BRGM, France.*
[2]*LPC2E, University of Orléans/CNRS, France.*
[3]*CETRAHE, University of Orléans, France*
[4]*SNE, 41200 Romorantin-Lanthenay, France.*

**Corresponding author: Fatima.Laggoun-Defarge@univ-orleans.fr*

SUMMARY

The C-sink function of peatlands is mainly controlled by soil waterlogging and *Sphagnum* moss dominance. La Guette peatland (Sologne, France) was drained for decades by a road ditch resulting in vascular plant (*Molinia caerulea*) invasion. Hydrological restoration was undertaken in 2014 and vegetation experiments were set up. In both downstream and upstream stations, three treatments (n=4) were conducted: "control" with intact vegetation, "bare peat", and "*Sphagnum*" (bare peat seeded with *Sphagnum*). Our aim was to assess the effect of such actions on plant community diversity and CO_2/CH_4 fluxes. In each plot, gas fluxes and plant cover were measured. 18 months after the restoration work, "bare peat" and "*Sphagnum"* plots were quickly colonised by *Eriophorum angustifolium* (up to 90%), *Rynchospora alba* (up to 10%), *Trichophorum cespitosum* (up to 60%). In both stations, control plots functioned as C sinks with lower CH_4 emissions and higher ecosystem respiration compared to the other treatments. However, at peak biomass the latter treatments tended to act as sinks for CO_2 in 2015 than in 2014 suggesting that plant cover, higher in 2015 than in 2014, is a crucial determinant for CO_2 fluxes. Although vegetation colonisation is proceeding fast, two years do not appear to be sufficient to trigger a C sink function in restored peatlands.

Keywords: *CO_2 and CH_4 fluxes, Molinia caerulea, peat organic matter, plant removal experiments, water table.*

INTRODUCTION

Northern hemisphere peatlands are estimated to contain about 300-400 Pg C as peat, corresponding to about 30% of the world's soil C stock in an area accounting for only 3-5% of the land surface. This C-sink function is largely controlled by the low rate of organic matter (OM) decomposition due to hydrological conditions that favour soil waterlogging, combined with the dominance of vegetation that produces decay-resistant litter, i.e. *Sphagnum* mosses that hampers microbial decomposition (Holden, 2005), resulting in a net accumulation of OM as peat. In Western Europe, due to a high anthropogenic pressure, e.g. hydrological disturbances (i.e. drainage), peat cutting and nutrient amendment, many peatlands are invaded by vascular plants at the expense of *Sphagnum* mosses (Francez & Vasander, 1995; Berendse *et al.* 2001; Bubier *et al.* 2007). It has been shown that drainage or increased air temperature can have direct negative effects on *Sphagnum* productivity by increasing evapotranspiration (Gerdol 1995; Weltzin *et al*. 2001). In the same way, vascular plants can gain a competitive advantage due to improved soil oxygenation (Buttler *et al.,* 2015) that also favors also greenhouse gases (GHG) emission (mainly CO_2). Careful attention is thus needed to understand how a change in plant species cover due to altered hydrological conditions can affect belowground interactions that largely control GHG (CO_2, CH_4) emissions and C stocks in peatlands. Nowadays several ecological engineering actions are being undertaken to restore peatland functioning. Our study aimed to assess the effect of such actions undertaken in a disturbed peatland (La Guette, France) on plant community diversity and GHG (CO_2, CH_4) fluxes. Hydrology has been monitored since 2010 and several environmental variables (e.g. vegetation, GHG emission), from the hydrological restoration of the peatland, i.e. 2014.

MATERIALS AND METHODS

The La Guette peatland (150m a.s.l., 47°19N, 2°16'E, 20 ha, Figure 1), located in the Sologne forest (Neuvy-sur-Barangeon, France) is a transitional fen composed of moss patches (*Sphagnum cuspidatum* and *S. rubellum*) and of *Calluna vulgaris* and *Erica tetralix*. The mean annual precipitation and temperature is 883 mm and

11°C respectively. Two sub-hydrological systems (upstream and downstream sub-watersheds) characterise the site (Binet *et al*, 2013). The peatland has been invaded by *Molinia caerulea* and *Betula spp* for 30 years with an acceleration of the invasion in the recent decades (Gogo *et al.,* 2011). This was partly caused by a road ditch at the outlet that accelerated the peatland drainage. In February 2014, we undertook hydrological restoration in the downstream sub-watershed to raise the water table level and to promote the soil rewetting. This consisted in building thresholds composed of eight trenches dug in the peat soil and filled with sand and bentonite. In addition, manipulative experiments were initiated in two experimental stations: 1) within the downstream sub-watershed impacted by the restoration work and 2) within the upstream one supposedly non-affected by the restoration work. In each station three treatments were applied, each in four replicates: A) control (intact plots), B) bare peat (vegetation and first 5 cm of peat removed), and C) *Sphagnum* treatment (bare peat with *Sphagnum capitula* spread to accelerate C accumulating vegetation recolonisation). In each station (12 plots of 2m x 2m each), we measured CO_2 and CH_4 fluxes about once a month at the peak biomass using a closed static chamber (diameter of 30.5 cm, height of 30 cm), with a GMP343 Vaisala probe for CO_2 fluxes and with SPIRIT, a portable infrared laser absorption spectrometer for CH_4 fluxes (see D'Angelo *et al.,* 2016 and Gogo *et al.,* 2011 for CO_2 and CH_4 measurements respectively). Plant species abundance was measured with a 50-50 cm gridded frame placed above a permanently marked subplot. Water table level was monitored since 2010.

RESULTS AND DISCUSSION

Effect of the restoration on the peatland hydrology

The water table depth was monitored since 2010 in two piezometers: WO and DO located in the downstream and the upstream sub-watershed respectively.

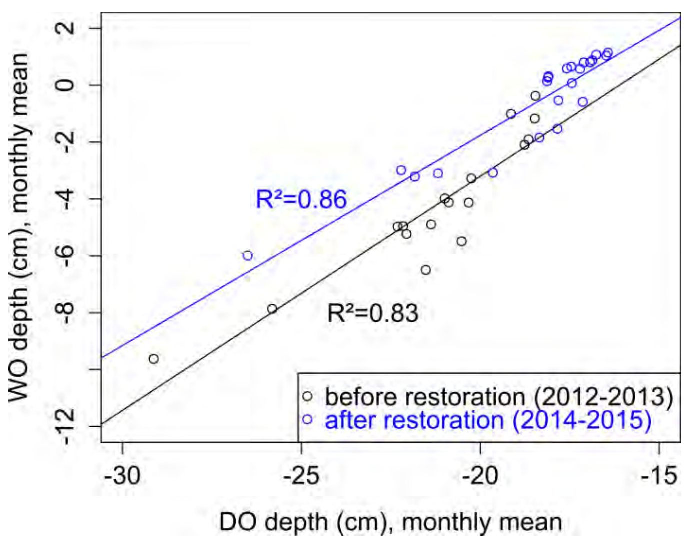

Figure 1: Relationship between the monthly water table depth in WO and DO piezometers before and after the hydrological restoration

To assess the specific role of the restoration, we analysed the relationship between monthly water table depth in WO and DO for two periods: the two years preceding the restoration (2012-2013) and the two following years (2014-2015) (Figure 1). The results indicated a strong linear correlation between water table depths in the two piezometers. This correlation was different for the two periods analysed: for the same water table depth in DO, the water table depth in WO was higher for the period after the restoration. This could indicate that restoration work led to an increase in the water table depth in the downstream sub-watershed since the water table depth in the upstream sub-watershed remained unchanged. However, a longer dataset chronicle is needed to confirm this tendency.

Influence of treatments on gas fluxes

On the whole, when the results of the 2 stations are pooled, differences in net ecosystem exchange (NEE), ecosystem respiration (ER) and CH_4 fluxes were observed between treatments (Figure 2). During the growing season (May to September), ER was found to be higher in the control plots, where the water table depth was lower (8 cm below the surface in average) than in the other two treatments (1 cm above the surface in average). In the same period, a negative NEE was recorded in these plots which thus acted as a sink for CO_2. The bare peat and the *Sphagnum* plots exhibited low CO_2 fluxes in 2014 and did not have a marked positive or negative CO_2 balance, in contrast to 2015 where they tended to act as a sink for CO_2 at peak biomass. This suggests that plant colonisation, higher in 2015 than in 2014, is a crucial determinant for CO_2 fluxes. In the same plots, higher CH_4 fluxes were measured during the growing season compared to the controls (Figure 2), probably in relation with the high water table depth recorded during the two years (data not shown).

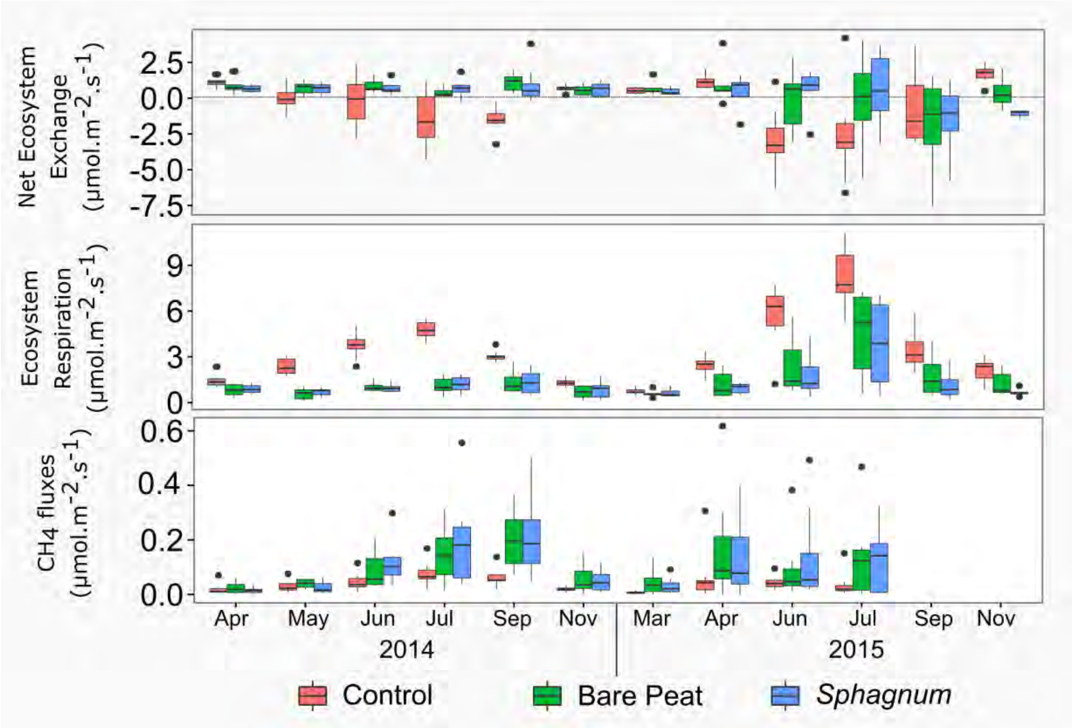

Figure 2: Net ecosystem exchange, ecosystem respiration and CH4 fluxes for the three treatments (control, bare peat and Sphagnum) in upstream and downstream stations (the two stations were pooled: n=8)

Influence of treatments on plant species cover

A plant removal experiment was performed to renew the vegetation and increase the moisture of surface peat. 18 months after the restoration work, ‒bare peat” and ‒*Sphagnum”* plots were quickly colonised by *Eriophorum angustifolium* (up to ca. 90%), *Trichophorum cespitosum* (up to ca. 60%) and *Rynchospora alba* (up to ca. 10%) (Figure 3). Considering all the vascular plants, it appeared that in bare plots, the abundance of *E. angustifolium* and *T. cespitosum* was higher during the growing season of 2015 as compared to 2014. Similarly, vascular plant cover became more heterogeneous in *Sphagnum* plots during the 2015 growing season compared to 2014. It is worth noting that in these plots, *Sphagnum* moss abundance increased at the beginning of the first growing season (May and June 2014) and remained roughly constant thereafter. Overall, this seemed to be related to the degree of wetness of microhabitats (Price & Whitehead 2004). The plant species cover in the control plots was almost constant in 2014 and 2015 and was dominated by *M. caerulea* and *E. tetralix* at peak biomass.

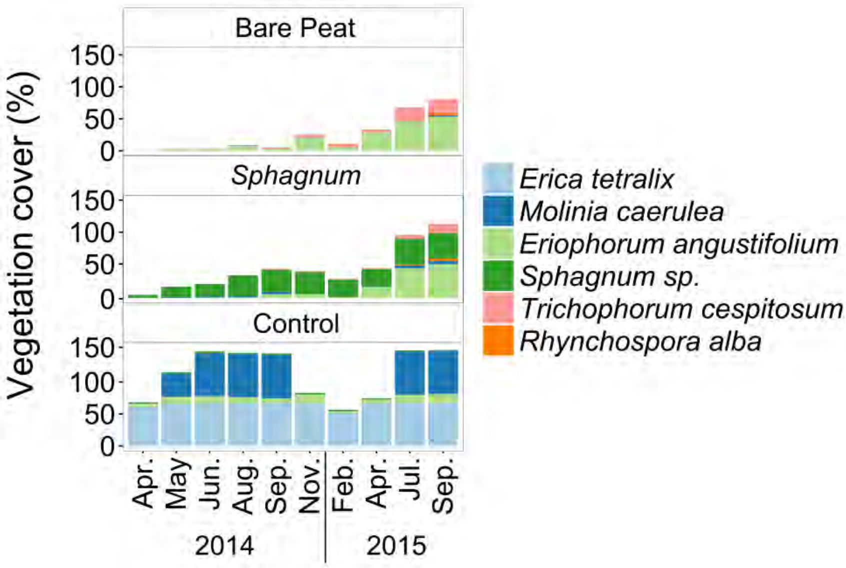

Figure 3: Vegetation cover (%) in the three treatment plots (bare peat, *Sphagnum* and control, mean of replicates)

CONCLUSION

The hydrological restoration carried out in La Guette peatland had an impact on the water table dynamics in the downstream sub-watershed. The treatments have been shown to affect CO_2 and CH_4 emissions and vegetation cover. Although a longer period of monitoring is needed to better assess the impact of hydrological restoration on gas emission, the first hints of the positive effect of the restoration work were detected, namely decreased water table fluctuations and the return of typical acidic fen vegetation.

ACKNOWLEDGEMENTS

This work was funded as part of the CARBIODIV project, Labex VOLTAIRE (ANR-10-LABX-100-01) and the French Peatland Observatory (SNO Tourbieres).

REFERENCES

1. Berendse, F., Van Breemen, N., Rydin, Hå., Buttler, A., Heijmans, M., Hoosbeek, M.R., Lee, J.A., Mitchell, E., Saarinen, T. & Vasander, H. (2001) Raised atmospheric CO_2 levels and increased N deposition cause shifts in plant species composition and production in Sphagnum bogs. *Global Change Biology*, 7, 591–598.
2. Binet, S., Gogo, S. & Laggoun-Défarge, F. (2013) A water-table dependent reservoir model to investigate the effect of drought and vascular plant invasion on peatland hydrology. *Journal of Hydrology*, 499, 132–139.
3. Bubier, J.L., Moore, T.R. & Bledzki, L.A. (2007) Effects of nutrient addition on vegetation and carbon cycling in an ombrotrophic bog. *Global Change Biology*, 13, 1168–1186.
4. Buttler, A., Robroek, B.J.M., Laggoun-Défarge, F., Jassey, V.E.J., Pochelon, C., Bernard, G., Delarue, F., Gogo, S., Mariotte, P., Mitchell, E.A.D. & Bragazza, L. (2015) Experimental warming interacts with soil moisture to discriminate plant responses in an ombrotrophic peatland. *Journal of Vegetation Science*, 26, 964–974.
5. D'Angelo, B., Gogo, S., Laggoun-Défarge, F., Le Moing, F., Jégou, F., Guimbaud, C. (2016). Soil Temperature Synchronisation improves representation of diel variability of Ecosystem Respiration in *Sphagnum* Peatlands. *Agricultural and Forestry Meteorology*, 223, 95-102.
6. Francez, A.-J. & Vasander, H. (1995) Peat accumulation and peat decomposition after human disturbance in French and Finnish mires. *Acta oecologica*, 16, 599–608.
7. Gerdol, R. (1995) The growth dynamics of Sphagnum based on field measurements in a temperate bog and on laboratory cultures. *Journal of Ecology*, 83, 431–437.
8. Gogo, S., Guimbaud, C., Laggoun-Défarge, F., Catoire, V., Robert, C. (2011) In situ quantification of CH_4 bubbling events from a peat soil using a new infrared laser spectrometer, Note. *Journal of Soils and Sediments*, 11, 4, 545-551.
9. Gogo, S., Laggoun-Défarge, F., Delarue, F. & Lottier, N. (2011) Invasion of a *Sphagnum*-peatland by Betula spp and Molinia caerulea impacts organic matter biochemistry. Implications for carbon and nutrient cycling. *Biogeochemistry*, 106, 53–69.
10. Holden, J. (2005) Peatland hydrology and carbon release: why small-scale process matters. *Philosophical Transactions of the Royal Society A*, 363, 2891–2913.
11. Price, J.S. & Whitehead, G.S. (2004) The influence of past and present hydrological conditions on *Sphagnum* recolonization and succession in a block-cut bog, Quebec. *Hydrological Processes*, 18, 315 – 328.
12. Weltzin, J.F., Harth, C., Bridgham, S.D., Pastor, J. & Vonderharr, M. (2001) Production and microtopography of bog bryophytes: response to warming and water-table manipulations. *Oecologia*, 128, 557–565.