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► **To cite this version:**

Pierrick Priault, Caroline Plain, Daniel Epron. Impact of climate warming on the carbon sink capacity of peatlands ecosystems.. Joint European Stable Isotope Users group Meeting, Aug 2008, Presqu'île de Giens, France. hal-02979128

HAL Id: hal-02979128

<https://hal.science/hal-02979128v1>

Submitted on 27 Oct 2020

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Impact of climate warming on the carbon sink capacity of peatlands ecosystems.

INTRODUCTION

Up to now, disagreement exists concerning climate change effects on **global soil carbon stocks**, depending notably on the **temperature sensitivity** of the ecosystems. Davidson and Janssens (2006)¹ pointed out wetlands, peatlands and permafrost soils as "obvious environments in which current constraints on decomposition are likely to change as a result of climatic disruption, thus potentially exposing large stocks of carbon to less constrained decomposition during the next few decades." Sphagnum-dominated peatlands have the greatest peat accumulation potential due to low rates of plant residue decomposition². The **PEATWARM project³** supported by the French ANR aims to evaluate the impact of a moderate temperature rise on the pool of peat organic matter and hence the long-term carbon sequestration potential of peatland ecosystems using the standard International Tundra EXperiment protocol in a natural and undisturbed ombrotrophic french bog (see map).



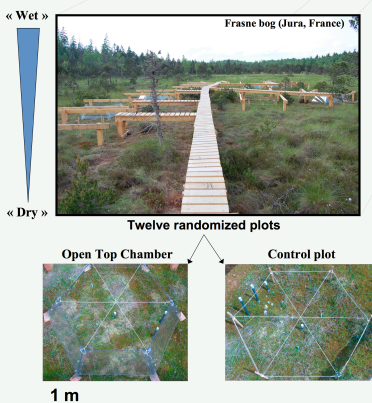
In this context we characterize **gas exchange and isotopic discrimination of respiratory fluxes** in relation to **temperature** on plant and peat samples placed under controlled conditions in an incubator coupled with a tunable diode laser spectrometer (TDLS). The **substrate moisture** effect on those parameters will be also investigated by taking into account the soil humidity gradient of our field site along the Frasné bog: two sets of plots were selected and characterized as "Wet" and "Dry" sites, as described in the table below:

		Moisture condition	
		Dry	Wet
Temperature	OTC	• • •	• • •
	Control	• • •	• • •

Twelve randomized plots gathering three replicates of each temperature and moisture conditions.

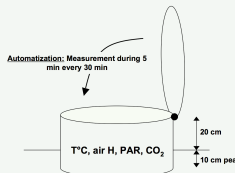
EXPERIMENTAL DESIGN

I.1 Field experiments



CO₂ samplings and measurements

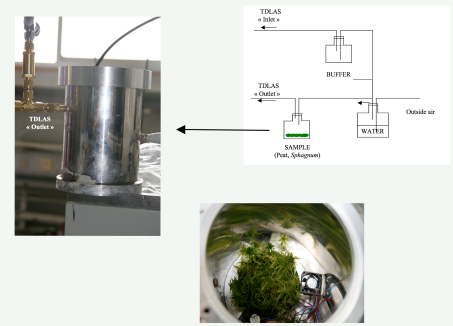
- Permanent CO₂ sample transparent plots will be established on *Sphagnum* surfaces and inserted 10 cm into the peat. These chambers are coupled with an infrared gas analyser functioning in a closed mode to continuously measure overall CO₂ fluxes:



- Peat and *Sphagnum* samples collection and Keeling plots measurements will be performed **monthly** from 2009 during March-November period and analysed in the lab using incubator coupled with a **tunable diode laser spectrometer** enabling high-time-resolved measurements of CO₂ fluxes and signatures.

I.2 Controlled conditions experiments.

Respiratory fluxes and isotopic signatures from peat and *Sphagnum* samples were analysed in controlled conditions at Nancy 1 University in relation to temperature and water status of the site of collection («Wet» vs. «Dry»). The experimental device is described below:



Sphagnum placed in a stainless-steel incubator controlling both temperature and air humidity.

PRELIMINARY RESULTS

II.1 Peat cores analyses

$\delta^{13}C_{OM}$	Resp		$\delta^{13}C_{res}$	
	10 °C	25 °C	10 °C	25 °C
-27.4 ± 0.1	0.5 ± 0.1	1.9 ± 0.1	-26.4 ± 0.4	-27.3 ± 0.3
-27.3 ± 0.1	0.4 ± 0.1	1.4 ± 0.1	-24.7 ± 0.5	-27.2 ± 0.2
-27.1 ± 0.1	0.3 ± 0.1	1.6 ± 0.1	-26.1 ± 0.6	-26.8 ± 0.2
-26.8 ± 0.1	0.5 ± 0.1	2.3 ± 0.1	-25.5 ± 0.6	-26.8 ± 0.2
Not determined				
-26.4 ± 0.1	0.8 ± 0.1	2.0 ± 0.1	-26.5 ± 0.4	-27.6 ± 0.2

Water content

90 - 95 %

Structure

Dark peat
Mineralization at an advanced stage from the first 15 cm



$\delta^{13}C_{OM}$	Resp		$\delta^{13}C_{res}$	
	25 °C	10 °C	25 °C	10 °C
-27.1 ± 0.1	1.5 ± 0.1	0.3 ± 0.1	-28.2 ± 0.2	-26.2 ± 0.5
-27.0 ± 0.1	1.7 ± 0.1	0.4 ± 0.1	-28.5 ± 0.1	-26.6 ± 0.6
-27.1 ± 0.1	0.9 ± 0.1	0.2 ± 0.1	-27.3 ± 0.2	-24.8 ± 0.4
-27.2 ± 0.1	1.1 ± 0.1	0.2 ± 0.1	-28.7 ± 0.4	-26.3 ± 0.3
Not determined				
-27.4 ± 0.1	0.9 ± 0.1	0.2 ± 0.1	-28.8 ± 0.4	-28.1 ± 0.2

Water content

90 - 92 %

Structure

Blond fibrous peat, with fairly intact *Sphagnum* mosses in the first 20 cm.
Early stage of mineralization for the deepest layers

Respired CO₂ and Organic Matter carbon isotopic signatures (respectively $\delta^{13}C_{res}$ and $\delta^{13}C_{OM}$) are expressed in ‰ and respiration rates (Resp) in $\mu\text{moles CO}_2 \text{ m}^{-2} \text{ s}^{-1}$. Results are presented \pm Std Error.

II.2 Gas exchange and isotopic discrimination in *Sphagnum*

Sphagnum samples were collected independently from peat in the dry area and placed in the incubator for analysis as shown by the picture below.



$\delta^{13}C_{res}$	Resp		$\delta^{13}C_{OM}$	
	25 °C	10 °C		25 °C
-30.8 ± 0.1	-31.3 ± 0.3	2.9 ± 0.1	0.9 ± 0.1	-27.0 ± 0.1

① A decrease in respiration rates with depth occurs in peat collected in «Wet» area for both 25 and 10°C while they are almost stable and even slightly increase for peat from drier place.

② Respired CO₂ from «Dry» sites peat samples is consistently ¹³C-enriched from 0.5 to 1.5‰ comparing to «Wet» site samples at 25°C. This difference was not encountered when considering the respective organic matter isotopic signatures.

③ A temperature decrease tends to induce a $\delta^{13}C_{res}$ enrichment in peat samples while no marked changes were observed for *Sphagnum*.

④ The carbon isotopic signature of total organic matter is similar between *Sphagnum* and peat samples up to 15 cm in «Wet» condition but only to 7.5-10 cm for the drier condition. Indeed, $\delta^{13}C_{OM}$ remains constant from 0 to 15 cm depth in «Wet» site peat samples while ¹³C content tends to increase in deeper layers of peat from drier sites.

HYPOTHESIS AND FUTURE PROSPECTS

Involvement of microbial activity for OM decomposition.

A decreased peat water content may increase the peat gaseous O₂ concentration and thus its availability for microbe respiration.

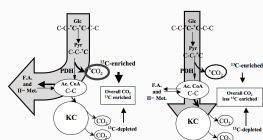
Changes in the substrates used for respiration and/or in their respective isotopic signatures.

Involvement of discriminating steps during photosynthesis in *Sphagnum*

Sugars could be preferentially respired at low temperature and ¹³C-depleted molecules such as lipids at high temperature.

Changes in the relative contribution of respiratory pathways.

e.g. regarding metabolic demand, which is low for instance at low temperature favouring in this case the left situation of the graph below, that is the release of ¹³C-enriched CO₂.



Major expected fluxes of respiratory substrates (grey arrows) explaining $\delta^{13}C$ of dark respired CO₂ depending on the respiratory energy demand. Glc: glucose; Pyr: pyruvate; PDH: pyruvate dehydrogenase; Ac: CoA; acyl-CoA; KC: Krebs cycle; F.A.: fatty acids and li-Met: secondary metabolites. Based on Priault et al.⁴

To be continued ...

⇒ Further experiments are needed to validate these preliminary results

⇒ These respired CO₂ $\delta^{13}C$ values will be further compared to that of potential substrates (litter, organic matter, microbial carbon, starch, soluble sugars and amino acids from vegetation...) to assess the origin of the ecosystem respired CO₂ and give indication on potential respiratory discriminating steps.

⇒ These data will be involved in the preparation of a peatland-based carbon biogeochemical model including the response to temperature and moisture disturbances of the different above-ground compartments.

REFERENCES

- Davidson E.A. and Janssens I.A. (2006) Temperature sensitivity of soil carbon decomposition and feedbacks to climate changes. *Nature* 440, 165-173.
- Thormann et al. (1999) Aboveground peat and carbon accumulation potentials along a bog-fen-marsh wetland gradient in southern boreal Alberta, Canada. *Wetlands* 19, 305-317.
- PEATWARM: this european project examines to what extent climatic warming can modify the functioning of peatlands in temperate regions and thus to deteriorate their carbon sink function investigating the effects on (1) vegetation, (2) the balance of above- and belowground C fluxes (especially by the isotopic signature of respired CO₂), (3) microbial diversity and activity in *Sphagnum* mosses and peat, and (4) the dynamics of labile and recalcitrant OM of the peat substrate. Main coordinator: Fatima Lagouan-Defarge (ISTO - Orléans, France).
- Priault et al. Pronounced differences in diurnal variation of carbon isotope composition of leaf respired CO₂ among functional groups. *New Phytologist* in revision.