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Measuring methods and integrated model to predict C-emissions and sequestration in natural peatland

REPORT

Measuring methods and integrated model to predict C-emissions and sequestration in natural peatland

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Introduction

The INTERREG NWE Care-Peat project aims on the reduction of carbon emissions and the increase of Carbon (C) storage in peatlands by testing innovative technologies and methods on pilot sites located in North-West Europe (Belgium, France, United Kingdom, Ireland and Netherlands). The main objective is to demonstrate and quantify Carbon dioxide (CO_2) emissions and C-storage by proposing restoration scenarios and solutions for the reduction of CO_2 emissions from peatlands, using advanced management tools developed from pilot sites.

The project focuses on the improvement of the interaction between hydrology and greenhouse gas emissions. For that, we developed a full methodology on two main objectives:

- to standardise the set-up of a field procedure to measure Greenhouse Gases (GHG) specifically CO_2 and Methane (CH_4) across all pilot sites;
- the implementation of (i) a numerical model to simulate carbon fluxes, especially ecosystem respiration (RECO), Gross Primary Production (GPP) and Net Ecosystem Exchange (NEE) at peatlands scale and (ii) a numerical tool dedicated to site managers and owners to estimate these fluxes.

Measurements of GHG fluxes

Usually, the success of restoration action in peatland is assessed by biodiversity surveys. This is a good technique to show how the provisioning service is recovered, but it provides less information on the C sink/source functioning of the ecosystem. As in the Care-Peat project, the aim is to promote practices that enhance C storing capacity of peatlands, one must be able to estimate whether or not the actions undertaken indeed stimulate the C sink capacity of the restored site. Furthermore, to disseminate to a large extent the need to take into account the C sink capacity in management practices among the managers community, it would be pertinent to produce a toolkit to assess the C sink restoration actions. To do so, GHGs fluxes should be measured using the same methodology and a model should be developed to produce a decision support tool (DST). In order to produce comparable data between sites and run a model applicable to all sites, a protocol should be written to obtain a coherent data set within the Care-Peat project.

1.1 What measurements and why

In theory, to know whether an ecosystem functions as a C sink or source, all the different fluxes of C have to be measured. Ecosystems can exchange C with the atmosphere (gaseous form) and with the hydrosphere (soluble or solid forms). These fluxes are:

1) Gross CO_2 input from photosynthesis or Gross Primary Production: **GPP**
2) CO_2 output from respiration (autotrophs and heterotrophs) or Ecosystem Respiration: **RECO**
3) CH_4 flux from the balance between methanogensis and methanotrophy or $\mathbf{FCH_4}$
4) Volatile organic compounds flux other than CH4 or $\mathbf{F_{VOC}}$
5) Carbon monoxide flux or $\mathbf{F_{CO}}$
6) Dissolved inorganic C flux or $\mathbf{F_{DIC}}$
7) Dissolved organic C flux or $\mathbf{F_{DOC}}$
8) Particulate organic C flux or $\mathbf{F_{POC}}$

The CO_2 balance is called net ecosystem exchange or NEE:

$$NEE = RECO - GPP \qquad \textit{eq 1}$$

NEE was proposed by scientists working on the atmosphere and they took the atmosphere as reference. This implies that when the ecosystem functions as a C sink, NEE is negative (GPP > RECO), and when the ecosystem function as a source, NEE is positive (RECO > GPP). The global C balance is called net ecosystem C balance or NECB (Chapin et al., 2006). This time the reference is the ecosystem. Furthermore, other than GPP all other C-fluxes in peatlands are exported and are thus noted negatively:

$$NECB = GPP - RECO - F_{CH4} - F_{VOC} - F_{CO} - F_{DIC} - F_{DOC} - F_{POC} \qquad \textit{eq 2}$$

All the terms of the NECB are not quantitatively equivalent. GPP and RECO are the two greatest fluxes, followed by FCH4, DIC, DOC and POC (in varying proportion depending on the site). F_{VOC} and F_{CO} are generally considered negligible.

The C fluxes need to be monitored at an adequate frequency and at “hot moments” (e.g. flooding events for DOC and POC) to grasp enough temporal variability to assess NECB. Monitoring the 6 most important fluxes requires the deployment of many instruments, needing important maintenance. Thus, a trade-off must be found between the resources available and the goals that can be achieved.
The Care-Peat project aims at showing good management practices leading to increase C sequestration. There are two main issues that should be considered: 1) what to compare and 2) what to measure?

1. Ideally, the C balance before should be compared to the one after restoration works. This implies that C fluxes are measured many years before the restoration works to grasp how each system behaves depending on climatic variations (dry vs wet years, hot vs cold years). This is not possible at the pilot sites because C fluxes are not currently measured in all sites, so the “before restoration” state of the system is not available.
2. Again, ideally, all the incoming and outgoing C fluxes should be measured to establish a full C balance. This is not possible at the pilot sites as all the required equipment and the task force required for such monitoring is currently not available.

These two issues can be resolved with these two propositions:

1. Instead of comparing C fluxes before and after restoration, C fluxes between an area of the site that will not be restored: CONTROL area, should be compared to an area of the site that will be restored: RESTORED area, if it is possible. In such a way, during the time frame of the Care-Peat project, it may be possible to assess the effect of restoration activities on C fluxes. As vegetation can vary within CONTROL and RESTORED areas (e.g. zones with Sphagnum and zones of bare peat within the RESTORED plot) a nested design can be applied across sub-areas within each area.
2. Instead of measuring all the C fluxes, NEE, RECO (both CO_2) and FCH_4 should be measured because: a) they are 3 of the most important fluxes in terms of quantity and b) they are all greenhouse gases (GHG). Thus, assessing the C balance of the GHG will give a good proxy of the total C budget and valuable information on the effect of restoration activities on climate change.

1.2 GHG flux measurement methods

There are different techniques to measure GHG fluxes. The three most used techniques are: 1) eddy covariance, 2) gradient method, 3) chamber method.

The most common, cheap and easy to implement method is the closed chamber method, which consists in inserting a collar in the peat and then placing a chamber on the collars in a way that the system is airtight (no exchange of gas with the exterior). The gas within the chamber is analysed either by a sensor placed in the chamber or by a sensor outside the chamber equipped with a pump that first draws air from, and then puts back into the chamber. Many collars can be installed within a specific plot and the fluxes can be measured one after the other with the same chamber-sensor. Furthermore, automatic chambers are now available on the market that allow more frequent measurement than when the chambers are used manually. Thus, spatial variation can be easily assessed with a relatively low cost and easy maintenance.

In the Care-Peat project, we assessed the amount of CO_2 absorbed by the peatland. Furthermore, we studied additional plots that were composed of different vegetation, so a good spatial integration is required. As such the gradient method is not appropriate. The academic teams involved in the project are already equipped with chambers, either with sensors inserted in the chamber, or with an outside analyser and accompanying pump system. Therefore, the chamber method was found to provide the most pragmatic solution in measuring on-site carbon reductions during the Care-Peat project.

1.3 Experimental design

A trade-off should be found between 1) having many data on few vegetation types, which will allow a good modelling exercise, but a poor representation of the field variability, and 2) few data on many different vegetation types, which will give account of the vegetation variability, but with limited data to produce robust models for each vegetation type. The Care-Peat project will adopt a nested design, where fluxes can be measured in the two dominant representative vegetation types in each area (2 sub-areas within each area, Fig. 1).

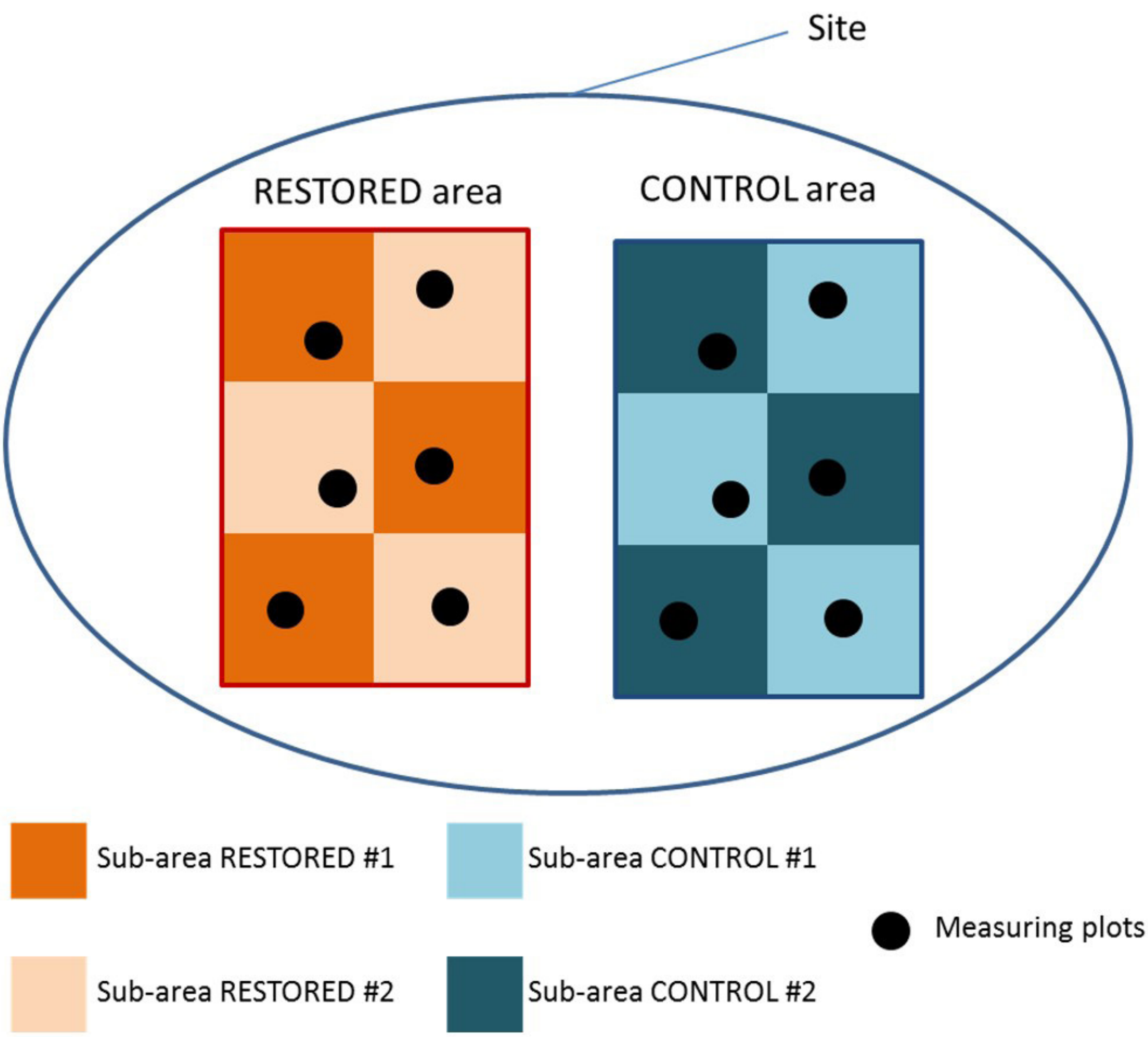


Figure 1. Schematic representation of the nested design adopted in the Care-Peat project.

1.4 GHG and ancillary variables

We monitored three fluxes variables including:

- Net Ecosystem Exchange or NEE;
- Ecosystem Respiration or RECO;
- CH_4 flux from the balance between methanogenesis and methanotrophy or F_{CH4}.

NEE is measured with a transparent chamber to allow solar radiation to activate photosynthesis (Fig. 2a). In each plot, we measured NEE in saturated radiation condition for the day of measurement with no nets on it (Fig 2 a) and with nets of different meshes (coarse, intermediate and fine). RECO will be measured with an opaque chamber or by using a cover that is placed on the transparent chamber (Fig. 2 b). This will make data sets composed of 5 different fluxes. As F_{CH4} is measured at the same time as the CO_2 fluxes, five fluxes of CH_4 will be obtained.

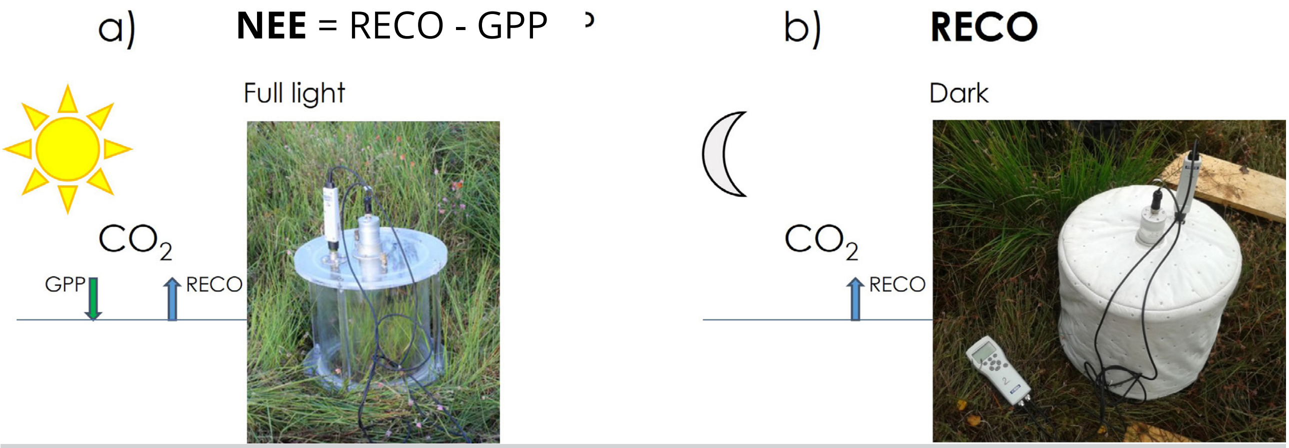


Fig. 2. Example of a transparent chamber to measure NEE (a) that can be covered to measure RECO (b).

The chamber is fitted on a collar that is inserted into the soil to assure airtightness of the system. Measurements can be done with equipment available on the market or self-made, with different geometry. In the Care-Peat project, a common type of chamber will not be recommended because each site may require different type of chamber depending on the height of the vegetation. To assess how the chamber type affects the measurement, we made at least one inter-comparison campaign during the course of the project.

The most important forcing variables are:

a) Air and soil temperatures => determine the rate of biological processes.
b) Light intensity => determine the amount of light available for photosynthesis.
c) Soil water content => determine 1) the amount of water available for biological processes, 2) the metabolic pathways as it affects the amount of available oxygen.
d) Photosynthetically active biomass => determine the maximum rate of photosynthesis,
Some variables (e.g. air temperature) are relatively easy to monitor and most national weather stations measure these variables. However, others (e.g. vegetation green biomass) are much more complicated to measure directly, and therefore proxies are typically used instead to give account of their effects.

In the Care-Peat project, it was advised that the following minimum data set of forcing variables was monitored:

- Air temperature (if possible in situ, but if not from the closest national weather station).
- Soil temperature (in situ, no alternatives) to be measured at approximately 10 cm depth. If possible one plot should have soil temperatures at a minimum of three depths (10, 20, 30 cm).
- Photosynthetic Photon Flux Density (PPFD) directly or calculated from total radiation (if possible in situ, but if not from the closest national weather station).
- Automatic piezometer (at least one per site) and one manual piezometer per measuring plot (associated to a collar) to measure water table depth as an integrated value for soil water content: the highest the level, the lower the oxygen availability (in situ, no alternatives).
- Vegetation index calculated from the plant species percentage cover => the highest the percentage, the highest the biomass, interpolation will be used to adjust the data to the same frequency as the other variables (in situ, no alternatives).

1.5 GHG measurement location and replication

Area. Each site had at least two areas: 1) **CONTROL** area not affected by the restoration activities that is to be tested, and 2) **RESTORED** area initially similar to the CONTROL area, which has been restored.

Sub-area. To take into account the variability of the vegetation, two sub-areas were chosen in each area. Typically, when Sphagnum will be added, a first sub-area was composed of Sphagnum, but sub-areas without Sphagnum (bare peat) may remain. In the CONTROL plot, the two main vegetation types chosen were site specific. Each sub-area was defined by the pilot manager.

Measurement plots. In every sub-area, we installed one collar in three replicate plots spread over the whole studied area. It is preferable that every year the collar location will be changed to avoid any bias caused by the collar.

Plot code. Each plot of the Care-Peat project had a code associated to GPS location details. The code was as follows (example for the La Guette pilot):

Country_Site_Year_Area name_Area number_sub-area number_plot number
FR_lgt_2020_C_1_1_1

The area number allows different study area code within each site. This is an example for the Little Wooden Moss:

UK_lwm_2020_C_1_1_1 (control area)

UK_lwm_2020_R_1_1_1 (Eriophorum + Sphagnum)

UK_lwm_2020_R_2_1_1 (Mixed grass + Sphagnum)

UK_lwm_2020_R_3_1_1 (Bog in a box)

The country code will be: BE, FR, IE, NL, UK. Each pilot manager will give a three letter code (lower case) for their pilot. Then, each flux was associated to a code. This is made to facilitate the data treatment and integration into a database.

1.6 GHG measurement conditions: flux and field campaign

For the estimation of one flux, concentration of GHG within the chamber should be done at the minimum frequency of one measurement every five seconds. The time length of the chamber measurement to calculate a flux should be as short as possible, and ideally between one and two minutes, to prevent overheating within the chamber itself. A minute is also often required to stabilize the entire system, so the total length of the overall measurement should be between two to three minutes. Measurements should be done with cover (RECO), without cover (NEE in light saturated condition) and with the three different nets (NEE with varying light intensity). The measurements should also be conducted when light is not limiting (e.g. > 1000 µmol of photon m^{-2} s^{-1}) to enable the assessment of the maximum GPP. The measurement should be carried out at constant PPFD (± 10%), and the chamber needs to be ventilated between each measurement.

At the minimum, it is expected that one set of fluxes (with different radiation intensity, see the following section) should be measured in each replicate plot during a single campaign. A minimum of twelve campaigns per year is required to catch the whole range of air temperature and water table depth. These twelve campaigns can be spread over the year or can be combined to limit the number of field trips (e.g. six field trips combining two campaigns at each time, or four field trips combining three campaigns). More campaigns can be undertaken during the growing season when the largest range of all the forcing variables is expected.

Thus, for a single person with one chamber and one sensor measuring both CO_2 and CH_4, a minimum total of 24 CO_2 light response curves, and CH_4 fluxes in each vegetation type (sub-areas), were measured over the two years of the Care-Peat project.

In each pilot data-set, the time-zone will have to be explicitly mentioned to avoid any errors based on timestamp.

Model for the estimation of GHG fluxes

One of the objectives of the INTERREG Care-Peat project was to improve the understanding of the interaction between hydrology and GHG emissions and to simulate carbon fluxes at the peatland and atmosphere interface, especially ecosystem respiration (RECO), Gross Primary Production (GPP) and Net Ecosystem Exchange (NEE) at peatland scale. This goal however, remains a challenge because of the specificities of each site. Indeed, peatlands are complex ecosystems where water, solute and gas fluxes can vary strongly during a year. In consequence, RECO, GPP and NEE are vulnerable to change in hydrological and weather conditions and vegetation developing at the surface.

Several previous experiments reported that NEE fluxes change drastically according to water table depth. Regressions based on experimental data have been performed to quantify this change but these values are associated with a large uncertainty (Evans et al. 2021). This could be induced because RECO and GPP are not explicitly described and simulated as well as the effects of change in hydrological conditions on these two parameters.

To overcome this limitation, a numerical model explicitly predicting gaseous C-fluxes resulting from RECO and GPP has been developed, calibrated and validated against data acquired on several pilot sites of the project. The following paragraphs present the main steps of both the model and the Decision Support Tool and the associated user's guide.

2.1 The ecosystem respiration

2.1.1 The conceptual model

The ecosystem respiration (RECO) is assumed to be mainly driven by heterotrophic aerobic respiration driven by microbial activity. This reaction could be written in a generic form as follow:

$$SOM + O_2 \approx CO_2 + H_2O \qquad \textit{eq. 3}$$

This reaction, where SOM stands for the organic matter, is mainly kinetically constrained, allowing the use of mathematical formalism which does not account for thermodynamic parameters. Hence, a linear mass balance equation is used to describe aerobic respiration driven by microbial activity. This biochemical reaction occurs mainly in the unsaturated zone, and in a lesser extent in the saturated zone. Accordingly, CO_2 fluxes are assumed to be generated only in the unsaturated zone when it exists as encountered under dry conditions. For flooded conditions, a more complex conceptual framework has been developed taking account in situ gas production induced by aerobic respiration, leading to bubble formation and/or collapse (André et al., 2023). Therefore, the model simulates respiration along a peatland profile represented as a porous media, partially or fully water saturated.

This porous media is divided in Representative Elementary Volume (REV, see Fig. 3), allowing to average system properties over a macroscopic length. The REV contains the three main phases that could be encountered in such system: water, air and solid phases. The proportion of each phase can change at each timestep. The water, solid and gas phases are assumed well-mixed and therefore without concentration gradients inside a REV, thus resulting in uniform reaction rates within the control volume.

Flow velocity in water or gas phases is proportional to the pressure gradient. Water flow is assumed to be not impacted by gas flow. Flow and transport processes as well as biogeochemical reactions are assumed to be uniformly distributed in the control volume.

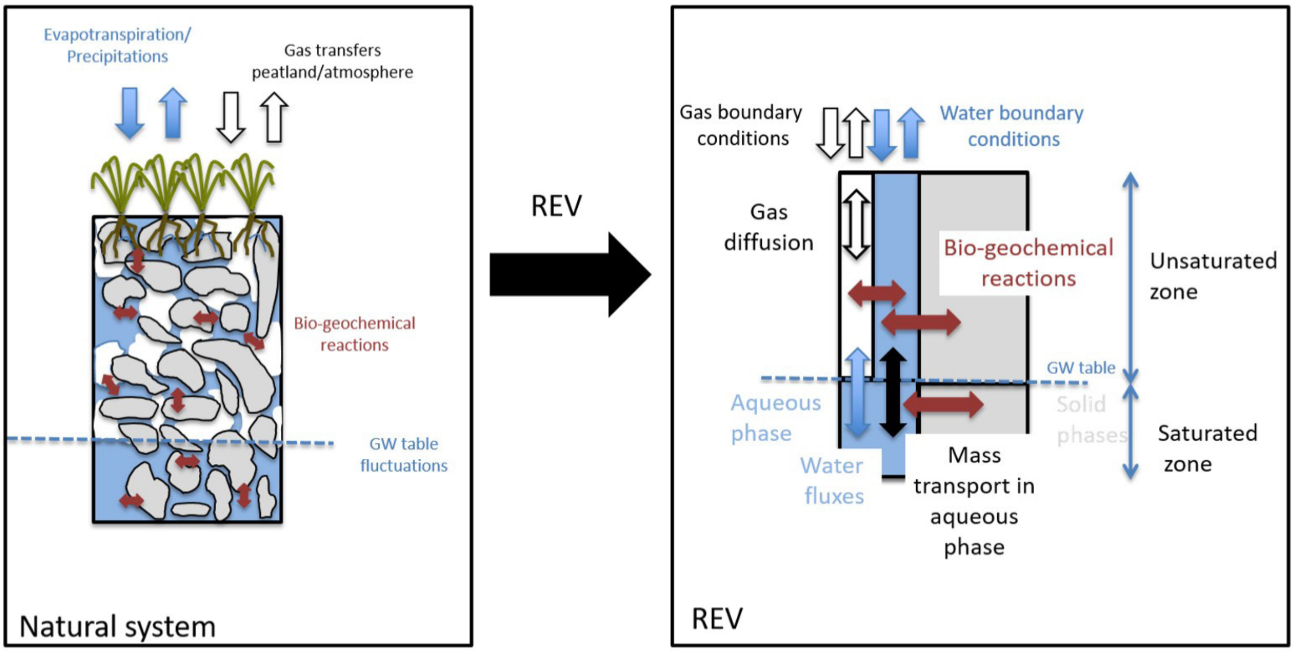


Figure 3. Sketch illustrating the continuum representation used in macroscopic reactive transport model.

2.1.2 The software

The reactive transport model (RTM) was built using the HPx code coupling the HYDRUS-1D software (Simunek et al., 2016; Jacques et al., 2018) with PHREEQC software (Parkhurst and Appelo, 2013). It solves the coupled reactive-transport equations using a sequential non-iterative approach. HYDRUS-1D acts as the solver for the hydrological and transport processes, including variable-saturated water flow, solute transport, diffusion in the gas phase and heat transport, whereas PHREEQC is the solver for the thermodynamic and kinetic (bio)-geochemical reactions.

The model mimics a 100 cm depth soil profile by simulating a variably saturated 1D column. Upper and lower boundary conditions concerning water, solute and gas fluxes have been fixed. Daily potential water fluxes, calculated as the difference between rainfall and potential evaporation, were used as upper boundary conditions for flow processes. Concerning water flow, a transient boundary condition is applied to the bottom of the column corresponding to daily changes of water table level. A Cauchy-type boundary condition is applied at the top boundary for gas and solute fluxes under dry conditions when an unsaturated zone exists. Under flooded conditions, gas fluxes at the top of the column are calculated by assuming that all the existing CO_2 bubbles pop up at the surface at the end of the timestep (André et al., 2023). A closed boundary condition is assumed for gas and solute fluxes (Neumann-type conditions) at the bottom of the column (no solute and gas output fluxes are expected).

2.1.3 The model calibration

The model was calibrated and validated to simulate CO_2 fluxes induced by aerobic respiration at peatland surface as well as soil water content at different depths (Devau et al., 2021). For that, a site with available long-time series data is required. The La Guette site (France) offered this opportunity. From September 2017 to November 2020, these variables have been measured at high frequency (daily measurements minimum). More precisely, greenhouse gas emissions have been investigated using an eddy-covariance station that was installed in early September 2017. Fluxes were measured every 15 minutes and were used to calculate net ecosystem exchange (NEE). Fluxes measured at night conditions were used to estimate RECO. Soil water content and soil temperature at -2, -5, -10, -20 and -40 cm depths were also monitored. In addition, additional variables required to define upper and lower boundary conditions related to water flow dynamic have been measured on the La Guette site. Meteorological data used to calculate upper boundary conditions (rainfall, net solar radiation, atmospheric pressure, wind direction and speed, air temperature and humidity) were automatically monitored thanks to two automatic stations installed on the site since November 2010. Lower boundary condition is fixed based on Water table level monitoring done below the position of the weather stations.

2.1.4 The surrogate model

The first attempts to use RTM model to simulate flow and CO_2 fluxes issued from RECO demonstrate that the more parameters are available, the better the model estimates. Unfortunately, limited numbers of measurements are commonly available for most of the sites. Therefore, a surrogate model dependent on less parameters was built to simulate ecosystem respiration (André et al., 2022). This model is simpler to use than the RTM model and is usable in different environments. To keep the model as simple as possible and since water table depth is a classical parameter recorded in numerous sites, this parameter was assumed as the only parameter affecting CO_2 fluxes issued from aerobic respiration.

To develop this surrogate model, the RTM is used to simulate annual CO_2 fluxes at fixed water table depth ranging from -10 cm depth (flooded conditions) to 60 cm depth (dry conditions). For each simulation, soil water content increases gradually from surface to water table. For example, when the water table is deeper, water content is lower at the surface. Hence, the gradient of soil water is broader in the simulations where water table depth is fixed at 60 cm depth. Based on these simulated values, annual CO_2 fluxes expressed in square metres are calculated. These simulated values were used to elaborate a surrogate model corresponding to a two-degree polynomial model predicting annual CO_2 fluxes according to water table depth (Fig. 4).

$$RECO\ (kgCO_2.m^{-2}.y^{-1}) = 1.7\ 10^{-3}\ z^2 + 3.26\ 10^{-2}\ z + 0.234 \qquad \text{Eq. 4}$$

where z is the effective water table depth (in cm).

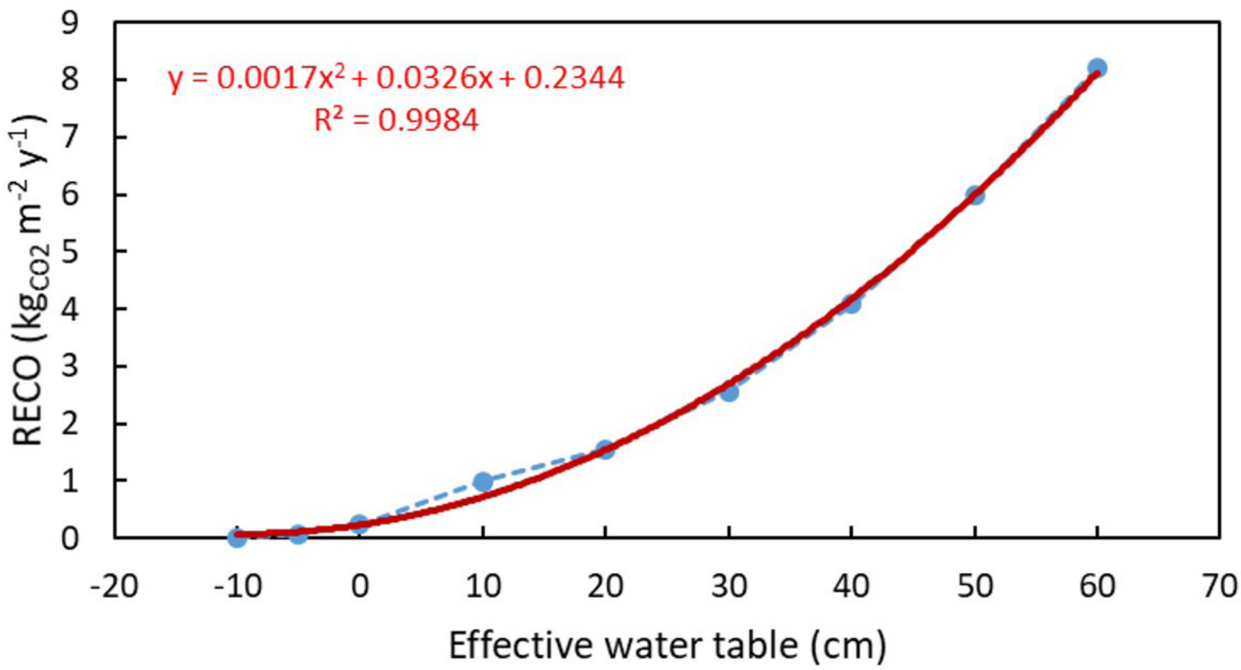


Figure 4. Annual simulated values of RECO. Law applicable widely using only data of effective water table

2.2 The Gross Primary Production

The estimation of the Gross Primary Productivity (GPP) is based on the hypothesis that GPP only depends on the irradiance (PPFD = Photosynthetic Photon Flux Density) and air temperature.

According to many authors (Leroy et al., 2019), a rectangular hyperbola saturation curve is often used to link GPP to PPFD:

$$GPP = \frac{PPFD \times GPP_{max}}{PPFD+k} .T\_scale \qquad \text{eq. 5}$$

where GPP_{max} is the maximum GPP (μmol.m^{-2}.s^{-1}), PPFD, the photosynthetic photon flux density (μmol.m^{-2}.s^{-1}) and k is the half saturation value (μmol.m^{-2}.s^{-1}).

T_scale is an adimensional temperature factor proposed by Raich et al. (1991) and Kandel et al. (2013). These authors proposed the following relationship:

$$T\_scale = \frac{(T-T_{min}).(T-T_{max})}{(T-T_{min}).(T-T_{max})-(T-T_{opt})^2} \qquad \text{eq. 6}$$

where T_{min}, T_{opt} and T_{max} represent the minimum, optimum and maximum air temperature for photosynthesis and were set at 0, 20 and 40°C, respectively. It is to note that these three values are chosen for all the sites investigated in this study.

Table 1 summarizes the values of the parameters usable to calculate the GPP for the different sites of the project.

Table 1 – List of parameters used to calculate the GPP for the different sites of the project.

Vegetation	**GPP_{max} (μmol/m²/s)**	**k (μmol/m²/s)**
Dominated Molinia	-2.60	200
Bare Peat	-	-
Dominated Cotton Grass	-22.50	150
Grazed pasture*	-	-
Dominated sphagnum	-1.50	340
Juncus Effesus	-4.55	86.8
Dominated Calluna vulgaris	-5.00	420.0

** Linear law: GPP (in μmol.m-².s⁻¹) = - 0.0115 PPFD – 0.6512 (André et al., 2022)*

2.3 The Net ecosystem Exchange

The Net Ecosystem Exchange (NEE) is calculated from the values of RECO and GPP according to equation 1.

The micrometeorological sign convention is used, whereby negative NEE fluxes indicate removal from the atmosphere and positive NEE fluxes indicate addition to the atmosphere.

2.4 The Care-Peat Decision Support Tool

The main purpose of the Care-Peat Decision Support Tool (DST) is to provide a tool to site managers/ owners to optimize the management/restoration of their sites. For that, the tool needs to predict the actual GHG fluxes (i.e. if peatland behaves as a source/sink of carbon) but also to simulate these same fluxes in case of different restoration scenarios. This is why the developed tool should be based on the estimation of GHG emissions due both to ecosystem respiration and vegetation uptake according to equations presented in the model.

The tool is an EXCEL file in which two methods of calculations are possible.

1st option: "Mean_Calculations" sheet

The user only knows global values corresponding either to point measurement or mean values based on several measurements (e.g. time series measured on one or several plots or field campaigns performed on several plots) of the investigated field:

- mean water table depth (in metres from surface)
- mean temperature (in °C)
- mean PPFD (Photosynthetic Photon Flux Density in $\mu mol.m^{-2}.s^{-1}$)

The user fills in the white boxes of the file with the three input data (Fig. 5). They then select the type of vegetation present on the studied site among seven different vegetation types.

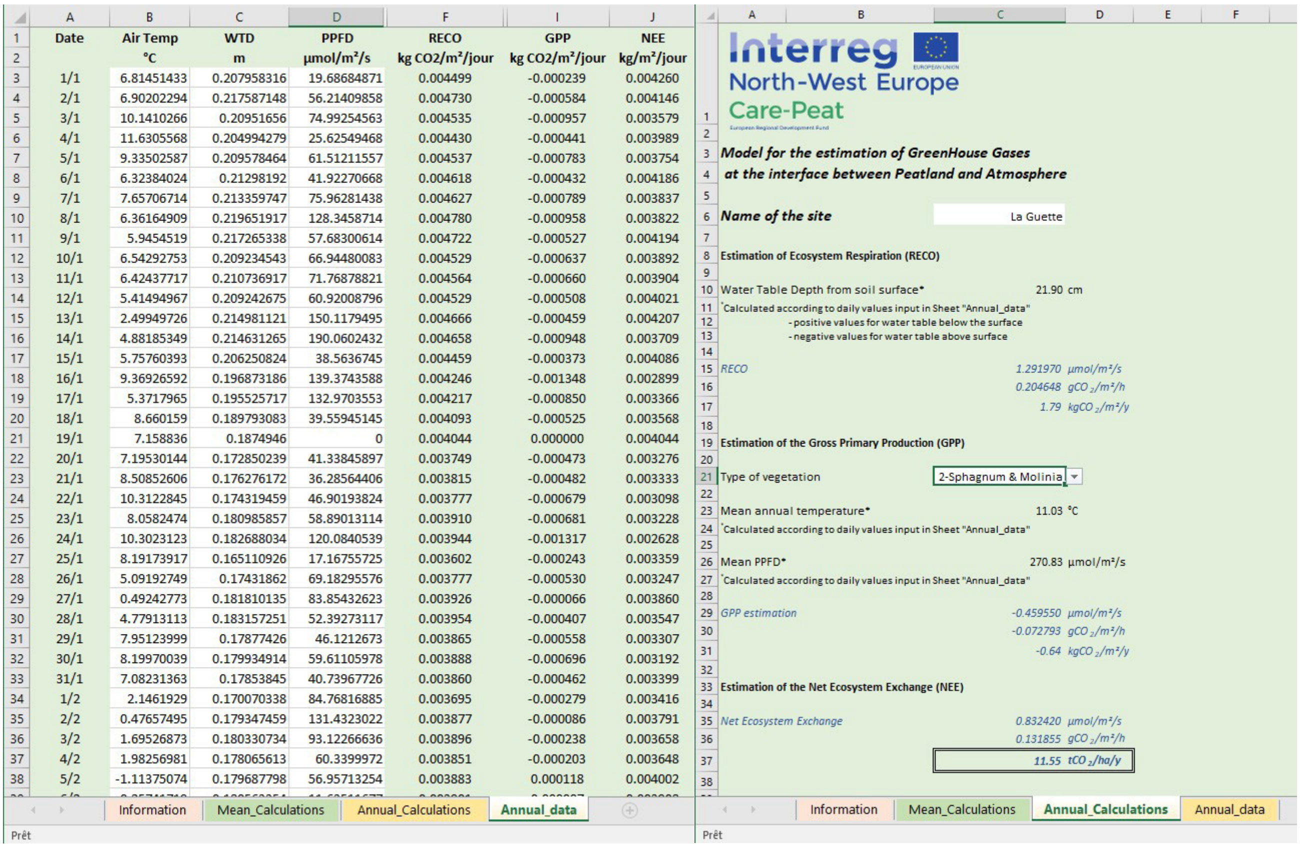
The DST then calculates the GHG fluxes including respiration fluxes, Gross Primary Production and Net Ecosystem Exchange according to different units.

Figure 5. Screenshot of the "Mean_Calculations" sheet. The white boxes have to be filled in by the user. This sheet contains the results of RECO, GPP and NEE fluxes.

2nd option: "Annual_Calculations" sheet

The user measures every day relevant information collected from captors installed in the field. Three parameters are needed for the calculations: the mean daily water table (m), the mean daily temperature (°C) and the mean daily PPFD (µmol.m^{-2}.s^{-1}) for each day of a year (Fig. 6). The user can prepare the data in a separate file and then copy and paste the relative values into the sheet "Annual_data": here only the white columns require values. The green columns are then automatically calculated.

Then, in the "Annual_Calculations" sheet, the user only needs to select the vegetation type in the drop-down list. The DST then calculates the GHG fluxes in relation with respiration, Gross Primary Production and Net Ecosystem Exchange according to different units.



Date	Air Temp °C	WTD m	PPFD µmol/m²/s	RECO kg CO2/m²/jour	GPP kg CO2/m²/jour	NEE kg/m²/jour
1/1	6.81451433	0.207958316	19.68684871	0.004499	-0.000239	0.004260
2/1	6.90202294	0.217587148	56.21409858	0.004730	-0.000584	0.004146
3/1	10.1410266	0.20951656	74.99254563	0.004535	-0.000957	0.003579
4/1	11.6305568	0.204994279	25.62549468	0.004430	-0.000441	0.003989
5/1	9.33502587	0.209578464	61.51211557	0.004537	-0.000783	0.003754
6/1	6.32384024	0.21298192	41.92270668	0.004618	-0.000432	0.004186
7/1	7.65706714	0.213359747	75.96281438	0.004627	-0.000789	0.003837
8/1	6.36164909	0.219651917	128.3458714	0.004780	-0.000958	0.003822
9/1	5.9454519	0.217265338	57.68300614	0.004722	-0.000527	0.004194
10/1	6.54292753	0.209234543	66.94480083	0.004529	-0.000637	0.003892
11/1	6.42437717	0.210736917	71.76878821	0.004564	-0.000660	0.003904
12/1	5.41494967	0.209242675	60.92008796	0.004529	-0.000508	0.004021
13/1	2.49949726	0.214981121	150.1179495	0.004666	-0.000459	0.004207
14/1	4.88185349	0.214631265	190.0602432	0.004658	-0.000948	0.003709
15/1	5.75760393	0.206250824	38.5636745	0.004459	-0.000373	0.004086
16/1	9.36926592	0.196873186	139.3743588	0.004246	-0.001348	0.002899
17/1	5.3717965	0.195525717	132.9703553	0.004217	-0.000850	0.003366
18/1	8.660159	0.189793083	39.55945145	0.004093	-0.000525	0.003568
19/1	7.158836	0.1874946	0	0.004044	0.000000	0.004044
20/1	7.19530144	0.172850239	41.33845897	0.003749	-0.000473	0.003276
21/1	8.50852606	0.176276172	36.28564406	0.003815	-0.000482	0.003333
22/1	10.3122845	0.174319459	46.90193824	0.003777	-0.000679	0.003098
23/1	8.0582474	0.180985857	58.89013114	0.003910	-0.000681	0.003228
24/1	10.3023123	0.182688034	120.0840539	0.003944	-0.001317	0.002628
25/1	8.19173917	0.165110926	17.16755725	0.003602	-0.000243	0.003359
26/1	5.09192749	0.17431862	69.18295576	0.003777	-0.000530	0.003247
27/1	0.49242773	0.181810135	83.85432623	0.003926	-0.000066	0.003860
28/1	4.77913113	0.183157251	52.39273117	0.003954	-0.000407	0.003547
29/1	7.95123999	0.17877426	46.1212673	0.003865	-0.000558	0.003307
30/1	8.19970039	0.179934914	59.61105978	0.003888	-0.000696	0.003192
31/1	7.08231363	0.17853845	40.73967726	0.003860	-0.000462	0.003399
1/2	2.1461929	0.170070338	84.76816885	0.003695	-0.000279	0.003416
2/2	0.47657495	0.179347459	131.4323022	0.003877	-0.000086	0.003791
3/2	1.69526873	0.180330734	93.12266636	0.003896	-0.000238	0.003658
4/2	1.98256981	0.178065613	60.3399972	0.003851	-0.000203	0.003648
5/2	-1.11375074	0.179687798	56.95713254	0.003883	0.000118	0.004002

Figure 6. Screen shot of the “Annual_data” sheet where daily air temperature, water table depth and solar radiations are input (left) and the “Annual_Calculation” sheet where the type of vegetation is selected (right). This last sheet contains the results of RECO, GPP and NEE fluxes.

References

André L., Aitova E., Keightley A., Mazeron J., Devau N., Gogo S. (2022) – Application of the GHG model to pilot sites of Care-Peat project. Deliverable D.WP T1 3.3. Final report. BRGM/RP-72049-FR, 23 p.

André L., Gogo S., Devau N. (2023) – Final version of the integrated numerical model for Carbon-fluxes. Deliverable D.WP T1 3.4. Final report. BRGM/RP-72493-FR, 23 p.

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. J. Hydrol. 499, 132-139.

Devau N., Gogo S., André L. (2021) - Development, calibration and validation of a numerical model for C-fluxes. Deliverable T1 3.2. Report BRGM/RP-71118-FR, 25 p.

Evans, C.D., Peacock, M., Baird, A.J., Artz, R.R.E., Burden, A., Callaghan, N., Chapman, P.J., Cooper, H.M., Coyle, M., Craig, E., Cumming, A., Dixon, S., Gauci, V., Grayson, R.P., Heldter, C., Heppel, C.M., Holden, J., Jones, D.L., Kaduk, J., Levy, P., Matthews, R., McNamara, N.P., Misselbrook, T., Oakley, S., Page, S.E., Rayment, M., Ridley, L. M., Stanley, K.M., Williamson, J.L., Worrall, F., Morrison R. (2021) Overriding water table control on managed peatland greenhouse gas emissions. Nature 543, 548-568.

Jacques, D., Šimůnek, J., Mallants, D., van Genuchten, M.Th. (2018) The HPx software for multicomponent reactive transport during variably-saturated flow: Recent developments and applications. J. Hydrol. Hydromech., 66, 2018, 2, 211–226. https://doi.org/10.1515/johh-2017-0049

Kandel, T.P., Elsgaard, L. and Lærke, P.E. (2013). Measurement and modelling of CO_2 flux from a drained fen peatland cultivated with reed canary grass and spring barley, Gcb Bioenergy, 5(5), 548-561, https://doi.org/10.1111/gcbb.12020

Leroy, F., Gogo, S., Guimbaud, C., Bernard-Jannin, L., Yin, X., Belot, G., Shuguang, W., and Laggoun-Défarge, F. (2019). CO_2 and CH_4 budgets and global warming potential modifications in Sphagnum-dominated peat mesocosms invaded by Molinia caerulea. Biogeosciences, 16, 4085–4095, https://doi.org/10.5194/bg-16-4085-2019

Parkhurst, D.L., Appelo, C.A.J. (2013) Description of Input and Examples for PHREEQC Version 3 – A computer program for speciation, batch-reaction, one dimensional transport and inverse geochemical calculations, chapter 43 of section A. Groundwater Book 6, Modeling Techniques

Raich, J.W., Rastetter, E.B., Melillo, J.M., Kicklighter, D.W., Steudler, P.A., Peterson, B.J., Grace, A.L., Moore III, B., Vorosmarty, C.J. (1991). Potential net primary productivity in South America: application of a global model. Ecological Applications, 1, 399–429. https://doi.org/10.2307/1941899

Šimůnek, J., van Genuchten, M. Th., Šejna, M. (2016). Recent Developments and Applications of the HYDRUS Computer Software Packages. Vadose Zone J., doi:10.2136/vzj2016.04.0033

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