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Modelling dissolved organic carbon dynamics in a rehabilitated *Sphagnum*-dominated peatland

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INTRODUCTION

Sphagnum-dominated peatlands represent a major stock of the global soil carbon (C) pool (Gorham, 1991). Dissolved organic carbon (DOC) exports through runoff and leaching could reduce their potential C storage function (Billett et al., 2004) and impact downstream water quality (Ritson et al., 2014). DOC dynamics in peatlands is strongly controlled by site hydrology, especially by water table depth (WTD), and disturbances such as drainage can lead to increased DOC export (Strack et al., 2008). In addition, hydrological restoration (e.g. rewetting) can be undertaken to restore peatland functioning with a potential impact on DOC dynamic and export.

While changes in DOC net production resulting from WTD drawdown can be assessed through field studies, the contribution of DOC production and consumption are more difficult to evaluate (Strack et al., 2008). In this case, process-based biogeochemical models simulating DOC dynamics combined with hydrological models adapted to peatlands specific settings are relevant tools to study factors controlling DOC production and consumption in such environments.

In this study a module simulating DOC production and consumption was added to an existing WTD dependent hydrological model. The model was applied to two sites of a peatland, one of them having experienced rewetting. The objective is to identify factors controlling DOC dynamics and to assess the impact of rewetting on DOC export in a *Sphagnum*-dominated peatland.

MATERIAL AND METHODS

The La Guette peatland (150m a.s.l., 47°19N, 2°16'E, 20 ha), 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 site can be separated into an upstream and a downstream sub-basin (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, hydrological restoration was undertaken in the downstream sub-basin to raise the

water table level and to promote the soil rewetting. Water table level and DOC concentrations in pore-water were monitored in each sub-basin since 2014.

A biogeochemical module was added in a conceptual water table dependent hydrological model that has already been successfully applied in the study area (Binet et al., 2013). The newly added module is based on functions describing DOC production and consumption for each reservoir of the hydrological model: the runoff reservoir (S_m) and the percolation reservoir (S_e).

In the added module, DOC is produced from SOC pool, and is function of temperature and WTD as described in equation 1.

$$DOC_{prod} = k_{prod} \cdot SOC \cdot 2^{T/10} \cdot (Se/Se_{max})^2 \quad (1)$$

DOC_{prod} is the DOC production rate (mg day^{-1}), k_{prod} is the production constant (day^{-1}), SOC is the soil organic carbon amount (mg), T is the temperature ($^{\circ}\text{C}$) and Se is the water depth in the percolation reservoir (mm).

DOC consumption is based on DOC concentrations and temperature as described in equation 2.

$$DOC_{cons} = k_{cons} \cdot [DOC] \cdot V \cdot 2^{T/10} \quad (2)$$

DOC_{cons} is the DOC consumption rate (mg day^{-1}), k_{cons} is the consumption constant (day^{-1}), $[DOC]$ is the DOC concentration in pore water (mg L^{-1}) and V is the volume of water in the considered reservoir (L)

The hydrological and biogeochemical model parameters (k_{prod} and k_{cons}) were calibrated for each sub-basin for the simulated period (01/08/2014 to 01/05/2016).

RESULTS AND DISCUSSION

DOC concentrations simulated for each location are shown in figure 1 and calibrated parameters of the biogeochemical module in the table 1. Overall, the DOC concentrations for each sub-basin are well represented with a RMSE (root-mean-square error) of 1.9 and 0.4 mg L^{-1} for downstream and upstream sub-basins, respectively. First of all, it is important to notice that DOC dynamics is different for each location. In upstream sub-basin, DOC concentrations decrease in the late summer while they increase in downstream sub-basin at the same period. The model was able to represent these differences in DOC dynamics between each location. One factor that can explain these differences is the hydrological conditions. In the downstream sub-basin, the drainage of the surface reservoir (S_m) is slower and the WTD remains closer to the surface than in upstream sub-basin during summer. As DOC production is related to the WTD while DOC consumption is not, the DOC production to consumption ratio is larger in the downstream than in the upstream sub-basin. This can explain why DOC concentrations are rising in the downstream sub-basin while they are decreasing in the upstream sub-basin. In addition, k_{cons} calibrated values were the greatest in the upstream sub-basin for each reservoir (table 1). This enhanced the differences in DOC dynamics

between both sub-basins by accelerating DOC consumption in the upstream sub-basin. It could be related to differences in organic matter quality and/or bacterial communities between the two locations.

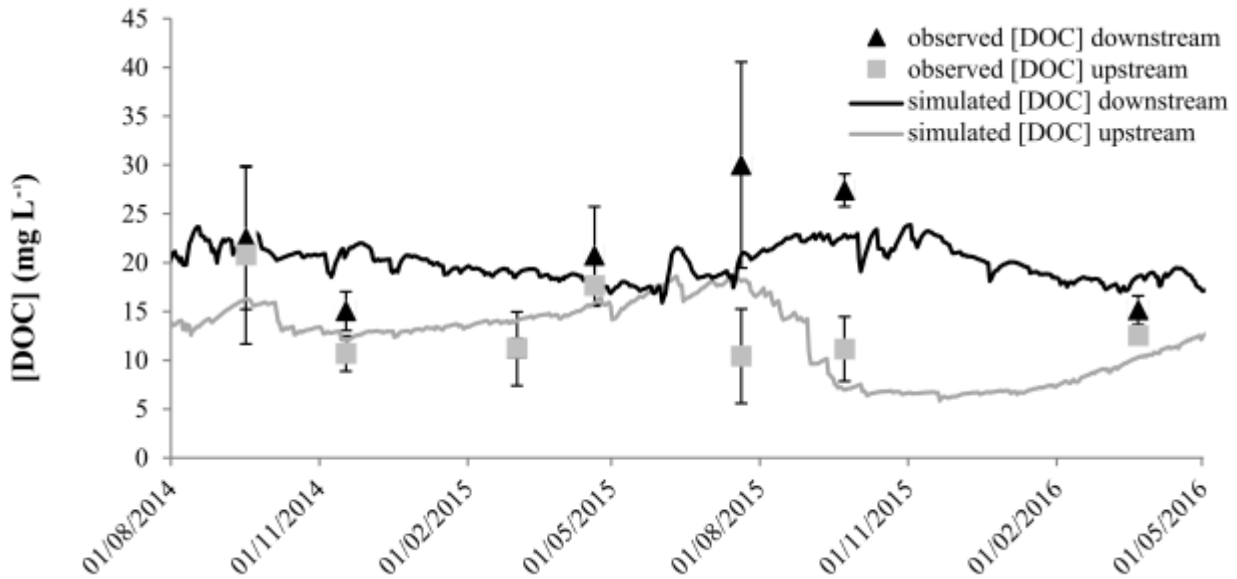


Figure 1: Measured and simulated DOC concentration in upstream (grey) and downstream (black) sub-basins. Error bars represent the standard deviation of measurements (n=4).

Table 1: Calibrated coefficient of the DOC module for each reservoir (Se and Sm) and each sub-basin. The RMSE of the calibrated models are also indicated. See the text for explanations.

Sub-basin	k_{cons}^{Se}	k_{prod}^{Se}	k_{cons}^{Sm}	k_{prod}^{Sm}	RMSE (mg L ⁻¹)
Upstream	5.4 ^{E-3}	1.1 ^{E-7}	0.5	1.0 ^{E-7}	0.4
Downstream	9.4 ^{E-3}	2.3 ^{E-9}	1.2 ^{E-2}	3.5 ^{E-6}	1.9

The results allow drawing a first assessment of DOC production, consumption and exports in the peatland. The results presented in the table 2 indicated that DOC production is more important than DOC consumption over the simulated period for both locations. In agreement with the highest DOC production due to high water level, and with the lowest DOC consumption due to small decay rates, DOC exports are the largest in the downstream sub-basin. There is a difference of one order of magnitude between DOC exports in both sub-basins, meaning that hydrological conditions identified as one of the main controlling factor in DOC dynamics can play an important role when considering large scale C balance in peatlands.

CONCLUSION

The implementation of a DOC module in a hydrological model adapted to peatlands led to correctly reproduce DOC concentrations chronicle in two contrasted locations of a small French peatland

(rewetted vs unaffected). The results identified the hydrological conditions as a major factor controlling DOC dynamics and exports in the area. In addition, secondary factors related with DOC consumption rates and possibly linked to organic matter quality and bacterial communities have been identified. The results indicate that the rewetting of a previously drained peatland can lead to an increase of one order of magnitude of DOC exports. In order to consolidate these findings, the model should now be applied to peatlands with a wide range of climatic conditions and anthropic pressures. This should be facilitated by the low input requirements of the model (i.e. piezometric levels and pore water DOC concentrations).

Table 2: Amount of DOC produced (DOC prod), consumed (DOC cons) and exported out of the system (DOC export) over the simulated period

Sub-basin	DOC prod (g m ⁻² yr ⁻¹)	DOC cons (g m ⁻² yr ⁻¹)	DOC export (g m ⁻² yr ⁻¹)
Upstream	27	25	2
Downstream	32	10	22

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Utilized text editor - Word for Windows, preferable size – RTF, type – Times new roman, 12 pt. 1,5 intervals, fields – 2 cm, paragraphs are divided by open line. Text must be no formatted, without the indentions. Figures and tables should be sent in the electronic form, in the sizes BMP, PCX, TIFF or JPG in high resolution (=>600 DPI). Lines in the figures must be not less than 0,25 pts, permission - 600 dpi. The volume of the theses of reports must not exceed 4 pages, including tables, figures and bibliography.

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