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Simulating ecosystem carbon dioxide fluxes and their associated influencing factors for a restored peatland

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S1. Parameters values used in the reference model run

Table S1 List of model parameters used in the model run that differs from the model default for the BDB restored peatland, for details of the parameter, equations see Jansson and Karlberg (2011)

Symbol	Parameters	Value	Unite	References
p_{cmax}	Surface max cover, shrub-trees/sedges/moss	0.5/0.5/1	-	Nugent et al. (2018)
k_{rn}	Beer's extinction coefficient, shrub-trees/sedges/moss	0.5/0.5/1	-	Frolking et al. (2002)
p_{ck}	The sensitivity of reach max cover on LAI, shrub-trees/sedges/moss	1/2/4	-	Moore et al. (2002)
z_r	The lowest shrub rooting depth, shrub-trees/sedges/moss	0.5/0.35/0	m	Assumed
ε	Light use efficiency, shrub-trees/sedges/moss	1.15/1/0.65	g C MJ^{-1}	Kross et al. (2016)
θ_{Amin}	The minimum amount of air that is necessary to prevent a reduction of root water uptake, shrub-trees/sedges/moss	5/2/0	vol %	Silvola et al. (1996)
ψ_c	Critical pressure head for reduction of potential water uptake, shrub-trees/sedges/moss	100/60/40	cm water	
p_l	Coefficient determines how fast the reduction of potential water uptake when ψ_c is reached, shrub-trees/sedges/moss	1/0.5/4	day^{-1}	
p_{mn}	Threshold Air temperature when photosynthesis starts, shrub-trees/sedges/moss	5/5/0	^0C	Moore et al. (2006)
$p_{rl,sp}$	Specific leaf area, shrub-trees/sedges/moss	75/45/45	g C m^{-2}	Assumed
r_{alai}	LAI Scale factor for r_a of the shrub layer	100	m s^{-1}	
l_{c1}	Leaf allocation parameter, shrub-trees/sedges/moss	0.25/0.35/0.9	-	He et al. (2023)
r_{wc1}	Root allocation parameter, shrub-trees/sedges/moss	0.3/0.35/0.00	-	
l_{Lc}	Leaf litterfall rate, shrub-trees/sedges/moss	0.004/0.004/0.02	d^{-1}	Calculated based on literature pool turnover rates
l_{Rc}	Root litterfall rate, shrub-trees/sedges/moss	0.00175	d^{-1}	
l_{CRc}	Coarse root litterfall rate, shrub-trees/sedges/moss	0.0001	d^{-1}	
l_{Sc}	Stem litterfall rate, shrub-trees/sedges/moss	0.0005/0.0005/0.0001	d^{-1}	
z_o	The surface roughness length	0.001	m	Campbell et al. (2002)
ε_s	The emissivity of the ground	0.95	-	Kettridge and Baird (2008)
α_{dry}	Soil albedo when tension >10^4 cm H_2O	15	%	Kellner (2001)
α_{wet}	Soil albedo when tension <10 cm H_2O	5	%	
kB^{-1}	Difference between the natural logarithm of surface roughness length for momentum and heat	2.3	-	Humphreys et al. (2006)
ψ_g	The empirical correction factor compensates for the difference between the mean soil moisture potential in the top-soil layer and the soil moisture potential at the surface	2.1	-	Assumed

M_T	The snow melting coefficients for air temperature	2	kg C m^{-2} d^{-1}	Gustafsson et al. (2001)
M_R	The snow melting coefficients for radiation	2×10^{-7}	kg J^{-1}	
θ_{sat}	Total porosity *	98.8 - 90	vol %	Measured
$n_{tortuosity}$	Tortuosity	1	-	Default
θ_m	Macroporosity *	30-10	vol %	Liu and Lennartz (2019)
k_{minus}	The minimum hydraulic conductivity	1×10^{-5}	mm d^{-1}	Alvenäs and Jansson (1997)
k_{sat}	Total saturated hydraulic conductivity*	100000 - 600	mm d^{-1}	McCarter and Price (2015) and Gauthier et al. (2022)
θ_r	Residual water content*	10-30	vol %	Schwärzel et al. (2002); Menberu et al. (2021) and McCarter and Price (2013)
θ_{wilt}	Wilting point *	10-30	vol %	
a_{scale}	The sorption scaling coefficient to calculate macropore flow	0.05	-	Assumed
a_{surf}	The first-order coefficient for surface runoff	0.05	-	Assumed
d_{space}	The distance between drainage ditches	500	m	Measured
z_{ditch}	Drainage ditch depth	0.7	m	
p_{max}	The maximum surface water pool cover	0.3	-	Assumed
$f_{wcovtot}$	The maximum amount of water on the soil surface pool	50	mm	Mustamo et al. (2016)
k_l	First-order decomposition coefficient for labile C	0.25	yr^{-1}	Frolking et al. (2010)
k_{ref}	First-order decomposition coefficient for refractory C	0.004	yr^{-1}	
C_{tot}	Total soil C at 1.5 m profile	101800	g C m^{-2}	Calculated from measured bulk density and C concentration
$C_{tot,\ layer}$	Total soil C for each simulated layer*	625-56000	g C m^{-2}	
Q_{10}	Q_{10} value for decomposition	3	-	Lafleur et al. (2005)
$p_{\theta Low}$	Lower range for moisture response	50	vol %	Or et al. (2007)
$p_{\theta Upp}$	Upper range for moisture response	30	vol %	
$p_{\theta p}$	Shape coefficient for the response function	1	-	
$p_{\theta satact}$	Anaerobic activity	0.1	-	Scanlon and Moore (2000)
h_1	Thermal conductivity coefficient for peat soil	0.01	W m^{-1} C^{-1}	Lai, (2022)
h_2	Thermal conductivity coefficient for peat soil	0.0075	W m^{-1} C^{-1}	
c_f	The coefficient for frozen surface conduction damping function	0.2	C^{-1}	Assumed

* Note different values were used for the simulated 9 soil layers, the range from top to bottom layer was given.

S2. Time series of surface energy fluxes and soil temperature profiles, used for model evaluation and validation, and additional simulation results for future climate change impact

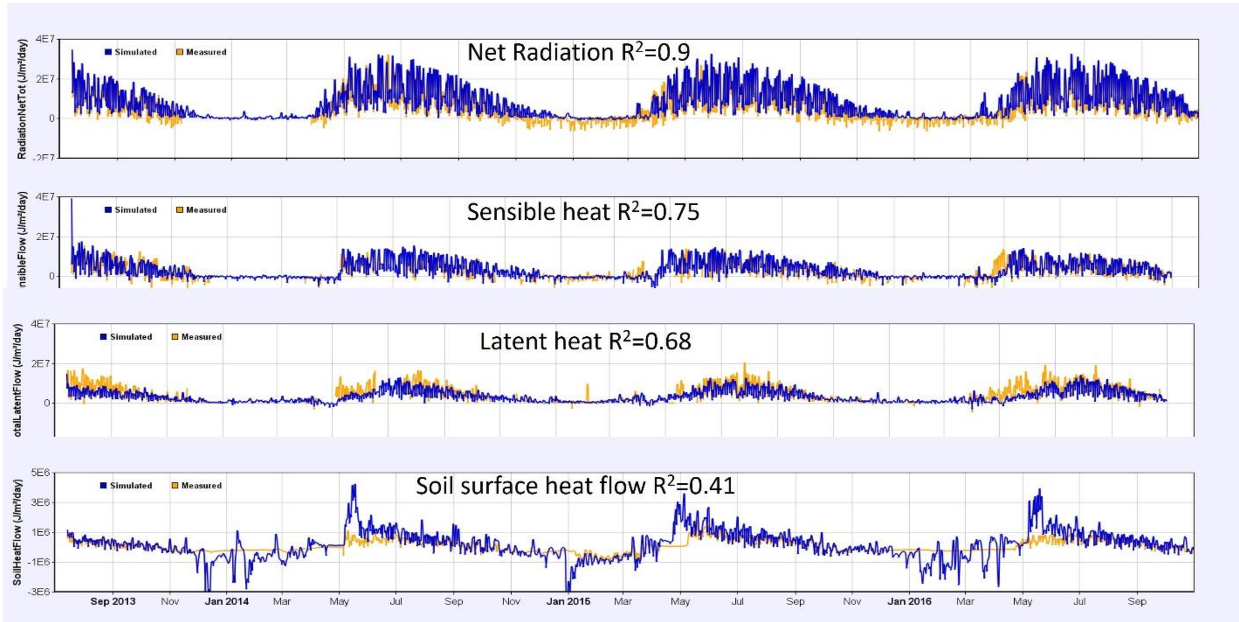

Fig. S1 Measured (orange) and simulated (blue) daily total net radiation, sensible heat, latent heat and soil surface heat flux.

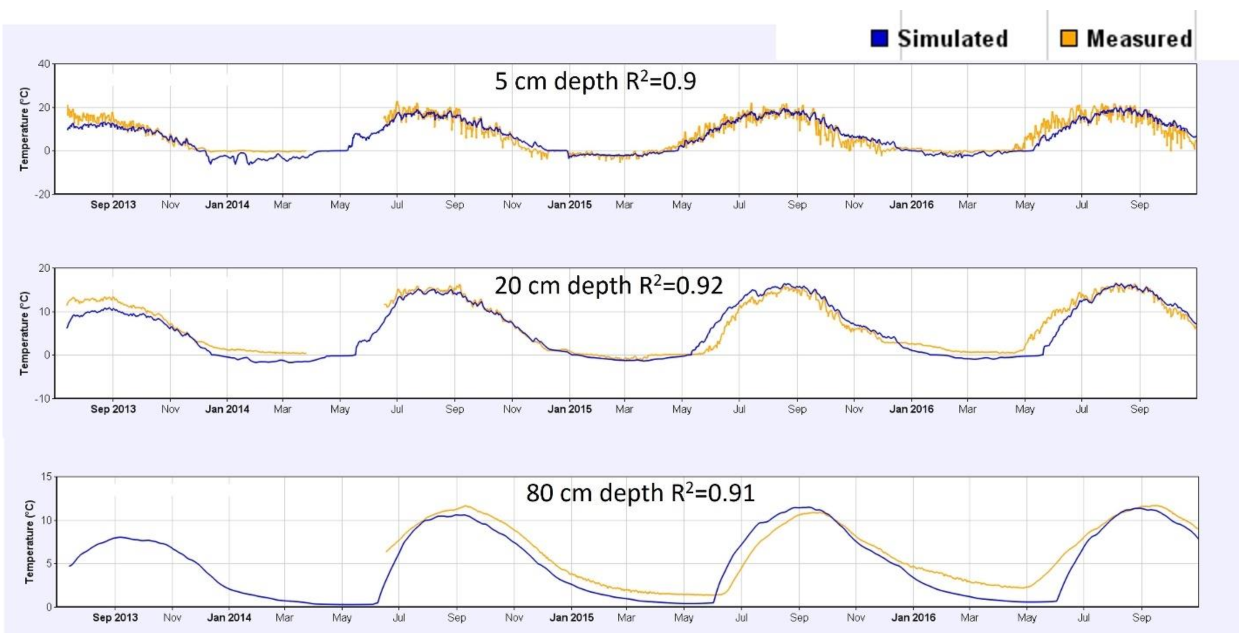

Fig. S2. Measured (orange) and simulated (blue) 30-minute soil temperature profiles

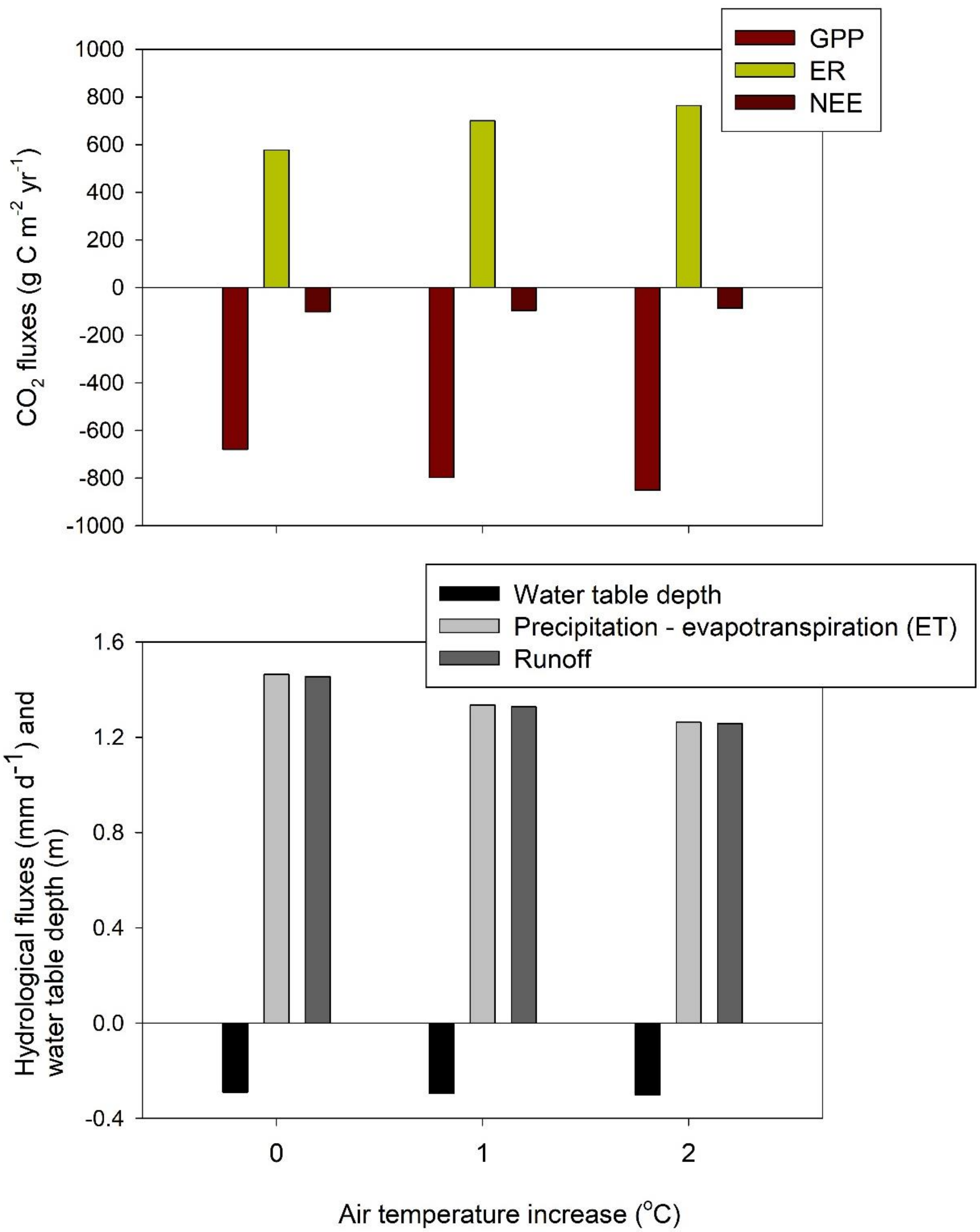

Fig S3. Simulated mean annual CO_2 fluxes and hydrological fluxes (precipitation - evapotranspiration, and runoff) and water table depth under future year around temperature increase; scenario 0 is the reference run. Equilibrium model runs use BDB 2013-2016 setup and Rivière-du-Loup 1994-2021 climate data.

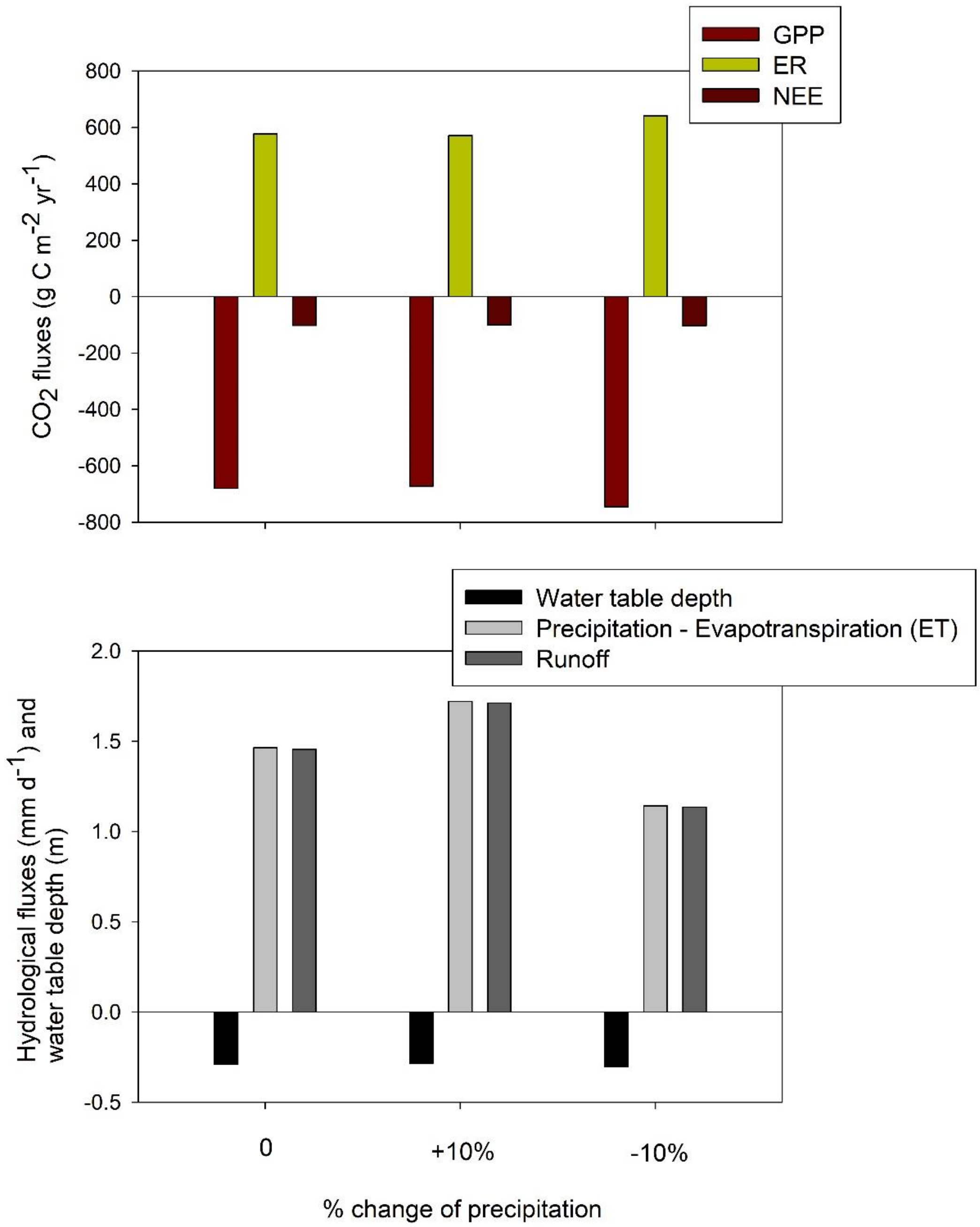

Fig S4. Simulated mean annual CO_2 fluxes and hydrological fluxes (precipitation - evapotranspiration, and runoff) and water table depth under future year around precipitation increase or decrease by 10%; scenario 0 is the reference run. Equilibrium model runs use BDB 2013-2016 setup and Rivière-du-Loup 1994-2021 climate data.

References

Alvenäs, G., and Jansson, P.E.: Model for evaporation, moisture and temperature of bare soil: calibration and sensitivity analysis, Agricultural and Forest Meteorology, 88, 47-56, 1997.

Campbell, D.R., Lavoie, C., and Rochefort, L.: Wind erosion and surface stability in abandoned milled peatlands, Canadian Journal of Soil Science, 82, 85-95, 2002.

Frolking, S., Roulet, N.T., Moore, T.R., Lafleur, P.M., Bubier, J.L., and Crill, P.M.: Modeling seasonal to annual carbon balance of Mer Bleue Bog, Ontario, Canada, Global Biogeochemical Cycles, 16, 4-1-4-21, 2002.

Frolking, S., Roulet, N.T., Tuittila, E., Bubier, J.L., Quillet, A., Talbot, J., and Richard, P.J.H.: A new model of Holocene peatland net primary production, decomposition, water balance, and peat accumulation, Earth System Dynamics, 1, 1-21, 2010.

Gauthier, T.-L.J., Elliott, J.B., McCarter, C.P.R., and Price, J.S.: Field-scale compression of Sphagnum moss to improve water retention in a restored bog, Journal of Hydrology, 612, 128160, 2022.

Gustafsson, D., Stähli, M., and Jansson, P.-E.: The surface energy balance of a snow cover: comparing measurements to two different simulation models, Theoretical and Applied Climatology, 70, 81-96, 2001.

He, H., Moore, T., Humphreys, E.R., Lafleur, P.M., and Roulet, N.T.: Water level variation at a beaver pond significantly impacts net CO_2 uptake of a continental bog, Hydrology and Earth System Sciences, 27, 213-227, 2023.

Humphreys, E.R., Lafleur, P.M., Flanagan, L.B., Hedstrom, N., Syed, K.H., Glenn, A.J., and Granger, R.: Summer carbon dioxide and water vapor fluxes across a range of northern peatlands, Journal of Geophysical Research: Biogeosciences, 111, G4, 2006.

Jansson, P.-E., and Karlberg, L.: User manual of Coupled heat and mass transfer model for soil-plant-atmosphere systems, Royal institute of technology, Department of land and water resources, Stockholm, 2011.

Kellner, E.: Surface energy fluxes and control of evapotranspiration from a Swedish sphagnum mire, Agricultural and Forest Meteorology, 110, 101-123, 2001.

Kettridge, N., and Baird, A.: Modelling soil temperatures in northern peatlands, European Journal of Soil Science, 59, 327-338, 2008.

Kross, A., Seaquist, J.W., and Roulet, N.T.: Light use efficiency of peatlands: Variability and suitability for modeling ecosystem production, Remote Sensing of Environment, 183, 239-249, 2016.

Lafleur, P.M., Moore, T.R., Roulet, N.T., and Frolking, S.: Ecosystem Respiration in a Cool Temperate Bog Depends on Peat Temperature But Not Water Table, Ecosystems, 8, 619-629, 2005.

Liu, H., and Lennartz, B.: Hydraulic properties of peat soils along a bulk density gradient-A meta study, Hydrological processes, 33, 101-114, 2019.

McCarter, C.P.R., and Price, J.S.: The hydrology of the Bois-des-Bel bog peatland restoration: 10 years post-restoration, Ecological Engineering, 55, 73-81, 2013.

McCarter, C.P.R., and Price, J.S.: The hydrology of the Bois-des-Bel peatland restoration: hydrophysical properties limiting connectivity between regenerated Sphagnum and remnant vacuum harvested peat deposit, Ecohydrology, 8, 173-187, 2015.

Menberu, M.W., Marttila, H., Ronkanen, A.K., Haghighi, A.T., and Kløve, B.: Hydraulic and Physical Properties of Managed and Intact Peatlands: Application of the Van Genuchten‐Mualem Models to Peat Soils, Water Resources Research, 57, 7, e2020WR028624, 2021.

Moore, T., Bubier, J., Frolking, S., Lafleur, P.M., and Roulet, N.T.: Plant biomass and production and CO_2 exchange in an ombrotrophic bog, Journal of Ecology, 90, 25-36, 2002.

Moore, T.R., Lafleur, P.M., Poon, D.M.I., Heumann, B.W., Seaquist, J.W., and Roulet, N.T.: Spring photosynthesis in a cool temperate bog, Global Change Biology, 12, 2323-2335, 2006.

Mustamo, P., Hyvärinen, M., Ronkanen, A.K., Kløve, B., and Moffat, A.J.: Physical properties of peat soils under different land use options, Soil Use and Management, 32, 400-410, 2016.

Nugent, K.A., Strachan, I.B., Strack, M., Roulet, N.T., and Rochefort, L.: Multi-year net ecosystem carbon balance of a restored peatland reveals a return to carbon sink, Glob Chang Biol, 24, 5751-5768, 2018.

Or, D., Smets, B.F., Wraith, J.M., Dechesne, A., and Friedman, S.P.: Physical constraints affecting bacterial habitats and activity in unsaturated porous media – a review, Advances in Water Resources, 30, 1505-1527, 2007.

Scanlon, D., and Moore, T.: Carbon dioxide production from peatland soil profiles: the influence of temperature, oxic/anoxic conditions and substrate, Soil Science, 165, 153-160, 2000.

Schwärzel, K., Renger, M., Sauerbrey, R., and Wessolek, G.: Soil physical characteristics of peat soils. Journal of Plant Nutrition and Soil Science, 165, 479-486, 2002.

Silvola, J., Alm, J., Ahlholm, U., Hykänen, H., and Martikainen, P.J.: CO_2 fluxes from peat in boreal mires under varying temperature and moisture conditions, Journal of Ecology, 84, 219-228, 1996.