Mean annual water table underestimates CO_2 emissions from rewetting peatlands

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Rodriguez Andres F., Pullens Johannes W.M. and Lærke Poul E.

Department of Agroecology, Aarhus University, Viborg

OBJECTIVE

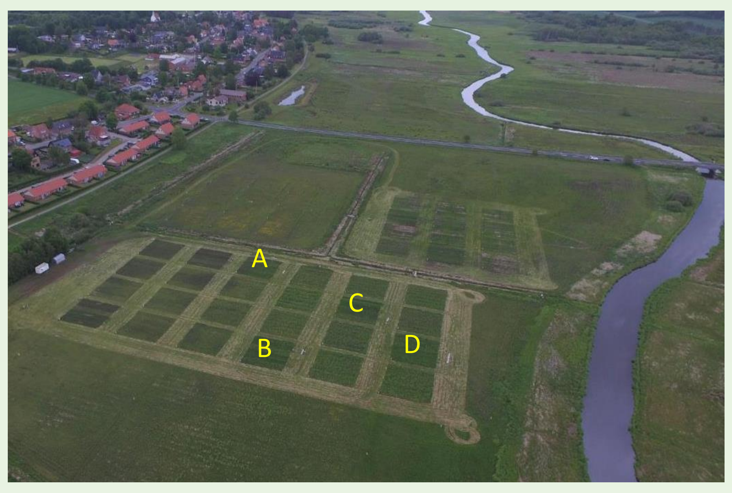
In this study, we use high temporal resolution water table data to estimate CO_2 emissions of a managed rewetting peatland. Additionally, we evaluate how pore water nutrients relate to these emissions.

BACKGROUND INFORMATION

- Peatland drainage is a significant agricultural greenhouse gases (GHG) source.
- Rewetting limits decomposition and reduces CO_2 emissions.
- There are uncertainties on the influence of nutrients and vegetation on GHG emissions from rewetted peatlands.
- Current GHG emission estimations are based on mean annual water table depth (Tiemeyer et al., 2020; Evans et al., 2021).

STUDY AREA

- Study was conducted between May 2021 and May 2022 in a fen peatland in central Denmark.
- Site was poorly drained and in transition to rewetting.
- Reed canary grass was sown in 2018 in the four studied plots.
- Three harvest treatments (zero cut, two cut, and five cut per year) in each plot.
- 200 kg N ha^{-1} y^{-1} applied equal in split doses to the two and five cut harvest treatments.



Study site, Nørrea valley, Vejrumbro

DATA COLLECTION

- Biweekly CO_2 measurements collected using a transparent manual chamber connected to an LGR-ICOS™ GLA131-GGA gas analyzer. Shroudings, including opaque condition, used to measure under four radiation levels.
- Nutrient concentrations: *NO_3, NH_4, total N (TN), total dissolved N (TDN), total P (TP), total dissolved P (TDP), total organic C (TOC), dissolved organic C (DOC), and Fe* measured in water samples collected biweekly from piezometers.

DATA PROCESSING

Hourly water table depth (WTD), soil temperature (Ts), photosynthetic active radiation (PAR), and ratio vegetation index (RVI) were used to model and obtain annual ecosystem respiration (Reco), and gross primary productivity (GPP).

$$Reco = t1 + (a * RVI) * e^{\left[b*\left(\frac{1}{T_{10}-T_0} - \frac{1}{T_S - T_0}\right)\right]} + [(WTD - WTD_{max}) * C]^2$$

$$GPP = \frac{GPP_{max} * PAR}{k + PAR} * \left(\frac{RVI}{RVI + \alpha}\right) * FT$$

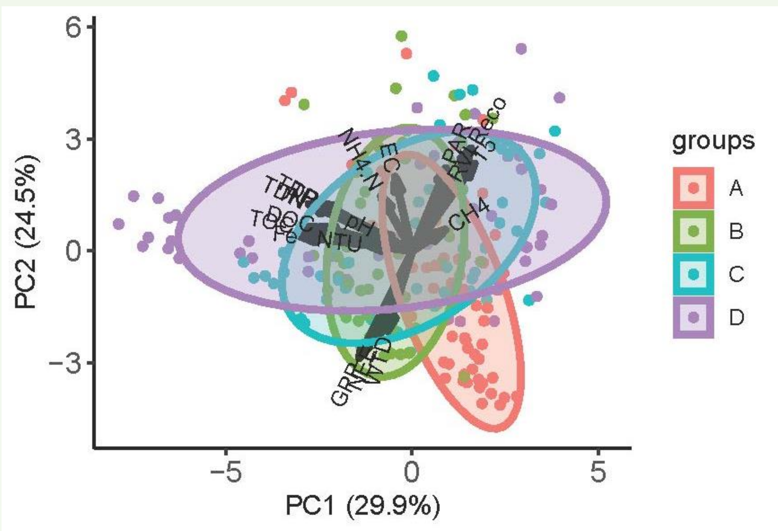
The net ecosystem exchange *(NEE)* was calculated as *= GPP + Reco*

The sensitivity of Reco to WTD and Ts data was tested by using mean annual data and comparing results to those of the hourly models.

RESULTS

Plot	Harv. treatment	Reco t CO_2-C ha^{-1} yr^{-1}	GPP t CO_2-C ha^{-1} yr^{-1}	NEE t CO_2-C ha^{-1} yr^{-1}	Yield t C ha^{-1} yr^{-1}	NECB t C ha^{-1} yr^{-1}
A	0	15.43	-14.19	1.24	NA	1.24
B		18.61	-13.02	5.59	NA	5.59
C		26.23	-16	10.23	NA	10.23
D		29.43	-18.88	10.55	NA	10.55
Average ± SE		22.43 ± 3.25	-15.52 ± 1.28	6.9 ± 2.2	NA	6.9 ± 2.2
A	2	14.9	-15.29	-0.39	1.92	1.53
B		23.57	-20.82	2.75	4.52	7.27
C		26.36	-22.04	4.32	4.63	8.95
D		23.7	-20.59	3.11	5.03	8.14
Average ± SE		22.13 ± 2.5	-19.69 ± 1.5	2.45 ± 1	4.03 ± 0.71	6.47 ± 1.68
A	5	20.6	-18.45	2.15	3.48	5.63
B		21	-20.17	0.83	3.88	4.71
C		23.66	-20.39	3.27	3.53	6.8
D		24.26	-21.88	2.38	4.5	6.88
Average ± SE		22.38 ± 0.92	-20.22 ± 0.7	2.16 ± 0.5	3.8 ± 0.23	6.0 ± 0.52

- GPP was different between harvest treatments. Biomass harvesting led to more photosynthesis.
- Marginally significant differences in Reco and net ecosystem C balance (NECB) between studied plot replicates.



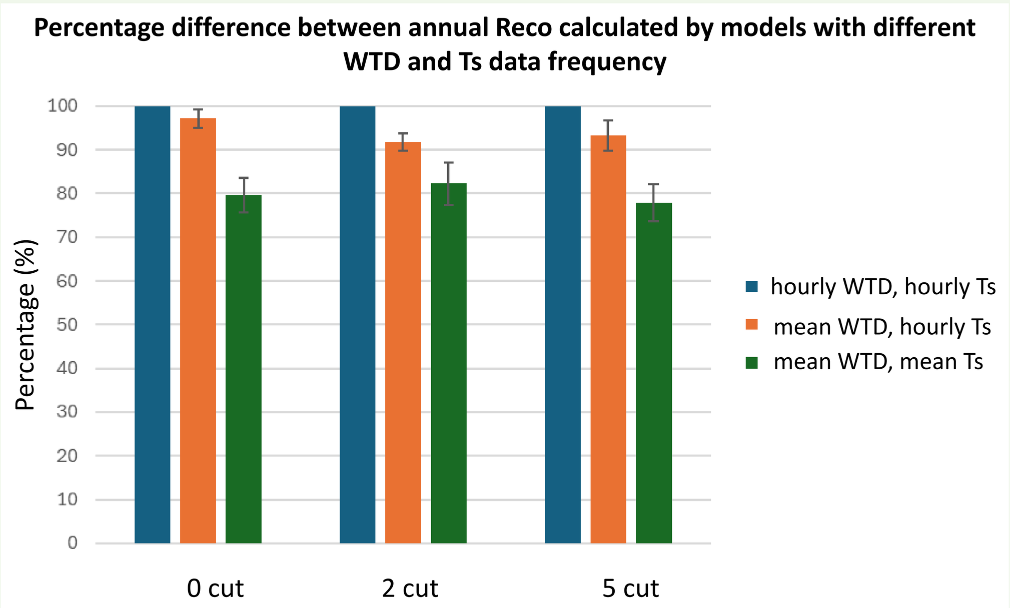
PCA plot showing variability on the data. PC1 shows the influence of nutrients, PC2 shows the influence of Reco and GPP the data.

- Nutrients positively correlated to each other suggesting common drivers.
- Reco and Ts negatively correlated to GPP and WTD.
- Data clustering with plots A and D having the largest differences.
- Higher nutrient concentrations generally found in plots C and D (plots with highest CO_2 emissions), while lowest nutrient concentrations were found in plot A.
- Including nutrients to linear mixed models improved Reco models.

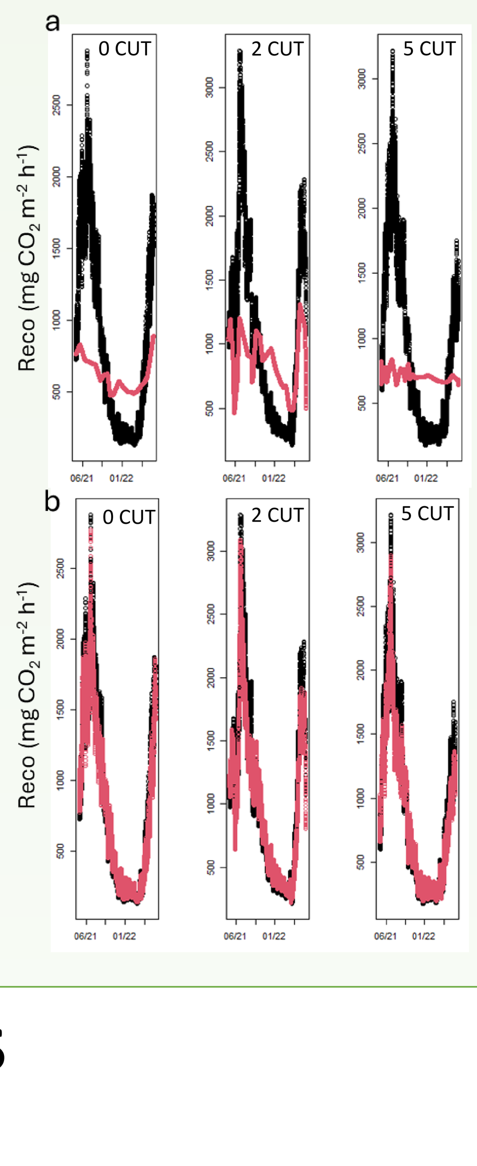
Table showing the effect of adding nutrients to linear mixed models of Reco, GPP, and NEE.

Parameter	Reco effect	GPP effect
TOC	Sig	N
DOC	Sig	N
TN	Sig	N
TDN	Sig	N
NH_4	N	N
TP	Sig*	N
TDP	Sig*	N
Fe	Sig*	N
pH	Sig*	Sig*
Turbidity	N	N
EC	N	Sig*

Sig* indicates an improvement of linear model which varied between harvest treatments, N indicates no effect of improving linear model.



- Using mean WTD and mean Ts, while keeping hourly RVI leads to an underestimation of annual Reco that ranged between 11 and 29%.
- Using mean WTD and hourly Ts and RVI leads to an Reco underestimation of 6% on average.



Comparison of Reco modelled by hourly WTD and Ts (black line) to Reco modelled with mean annual WTD (red line, top), and Reco modelled with mean annual WTD and hourly Ts (red line, bottom). Example for plot B.

CONCLUSIONS

- Biomass harvesting did not increase GHG emissions during early rewetting.
- The use of high frequency WTD data can capture CO_2 dynamics throughout the year.
- Data on pore water nutrient concentrations can lead to an understanding of peatland heterogeneity and could potentially improve Reco estimations.