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Supplement of

Are C-loss rates from drained peatlands constant over time? The additive value of soil profile based and flux budget approach

J. Leifeld et al.

Correspondence to: J. Leifeld (jens.leifeld@agroscope.admin.ch)

Figure S1: Land use and ditches (in blue) in the "Havelländische Luch" near Paulinenaue from 1787 to 2010; rectangles: 7km x 6km = 42 km^2; sources: Schmettau Map (1787); Prussian Land Survey Maps (1840, 1882), Topographic Map of Deutsches Reich (1940); Modern Topographic Maps (1975, 2010); original map scales = 1:25,000 (except Schmettau Map); for details, please contact: sommer@zalf.de

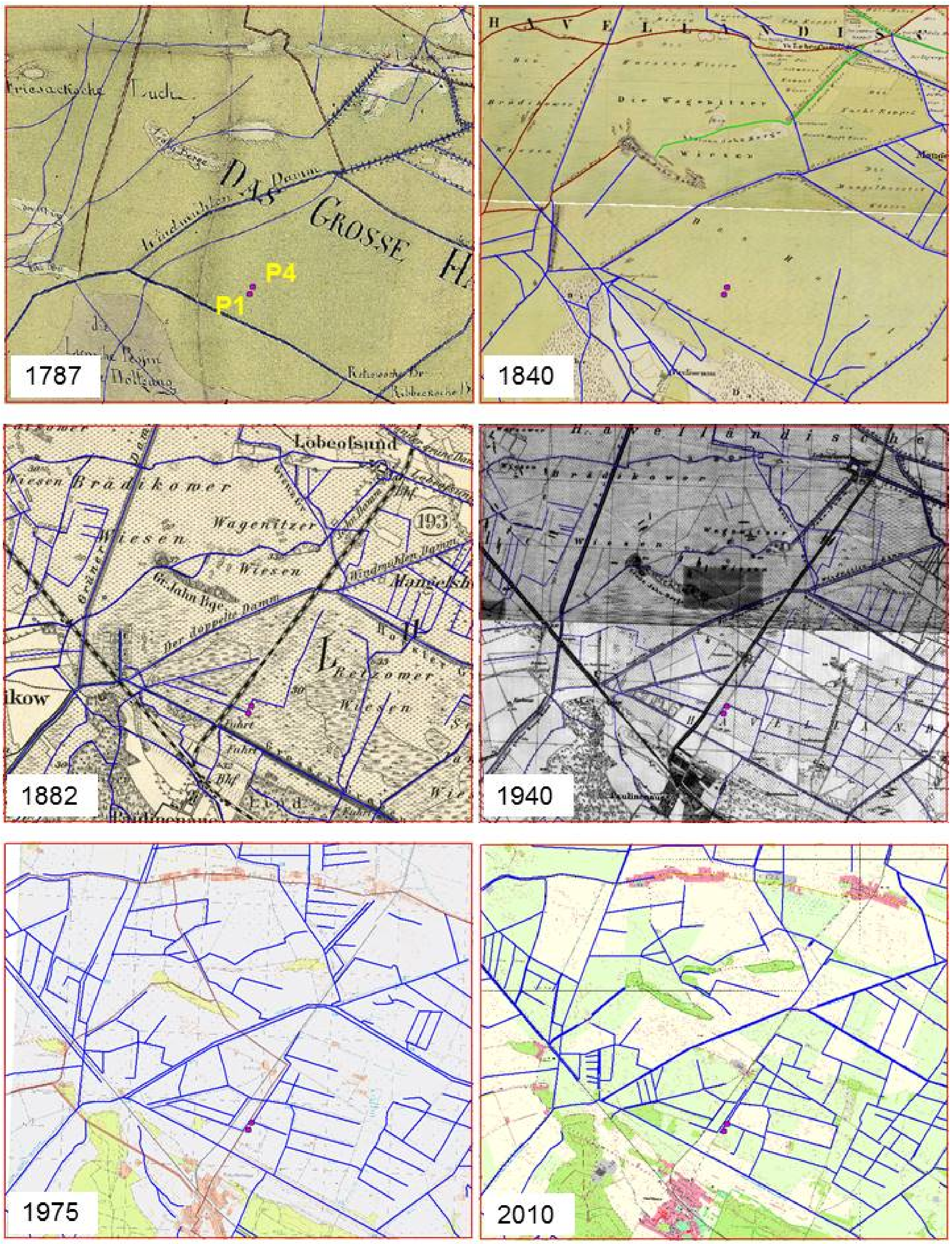


Table S1: Annual carbon balance, groundwater level, and precipitation for the 5y observation period; number in brackets = standard deviation

Year	C-balance (g C m^{-2} a^{-1})		Groundwater Level (m)		Precipitation (mm)
Site	**P1**	**P4**	**P1**	**P4**	
2007-2008	513 (35)	98 (51)	-0.11 (0.19)	-0.05 (0.19)	1011
2008-2009	770 (36)	877 (66)	-0.42 (0.18)	-0.38 (0.16)	454
2009-2010	545 (24)	856 (37)	-0.41 (0.27)	-0.36 (0.23)	512
2010-2011	1010 (56)	1946 (50)	-0.26 (0.24)	-0.24 (0.23)	564
2011-2012	717 (29)	753 (63)	-0.22 (0.24)	-0.20 (0.22)	658
5y-mean	711	906	-0.28	-0.23	640
5y-sd	200	664	0.23	0.21	221

Figure S2: Influence of SOM stocks (surficial soils, 1966) on SOM changes [Δ SOM] over time, with Δ SOM = SOM stocks of surficial soils (1966) minus adjacent buried soils under dams, ie “Luchdämme” (1718-24) and railway dam Paulinenaue-Neuruppin (1882); negative values = SOM losses, positive values = SOM gains for period 1882-1966 (railway dam) or 1720-1966 (“Luchdämme”); data source: Gerhart Mundel: Studies on the genesis of the “Havelländisches Luch” and its changes related to amelioration in due consideration of peat mineralization (in German). PhD thesis, German Academy of Agricultural Sciences, Berlin, 1969.

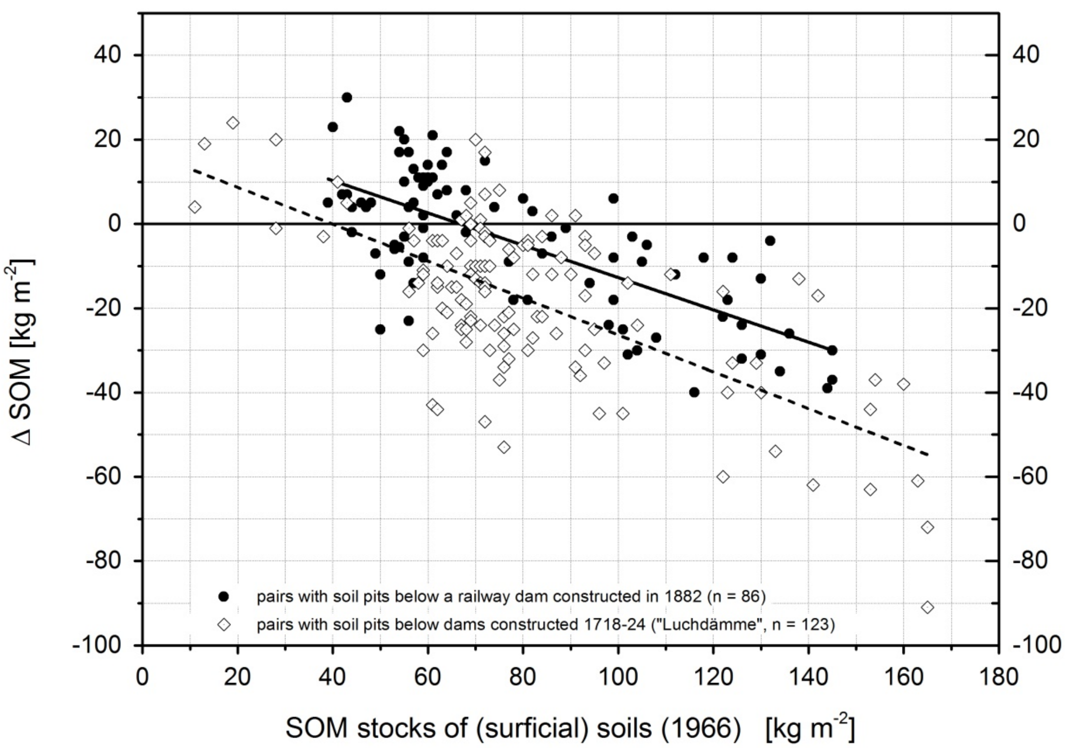
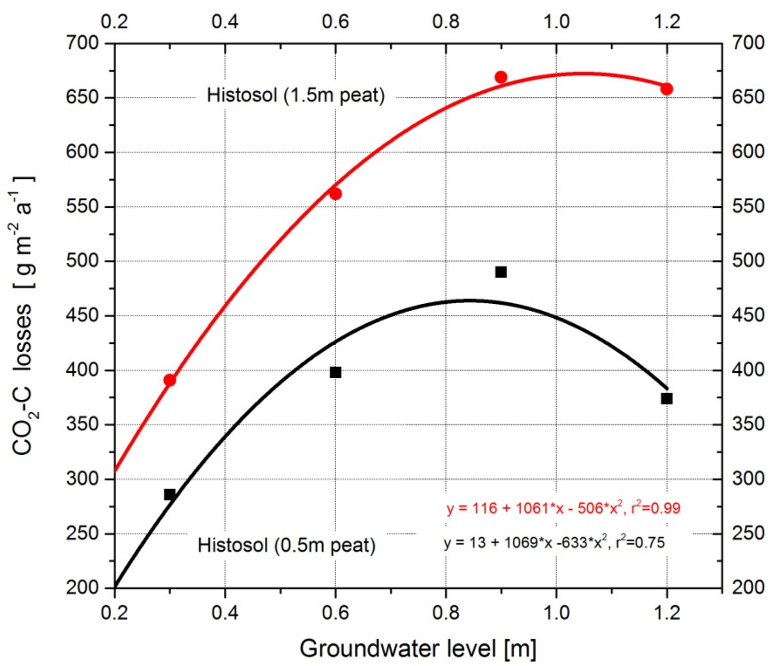


Figure S3: Lysimeter experiments on the influence of groundwater level on CO_2 losses from two Histosols under grassland; mean annual CO_2 losses during 1968-1970 (3y); data source: G. Mundel. Studies on peat mineralization in fens (in German). Arch.Acker-u.Pflanzenbau u. Bodenkd. 10, 669-679, 1976.



Supplement to Material and Methods

1.1 Gas flux measurements

Biweekly measurements of CH_4 emissions were conducted by a static closed (Non-Flow-Through Non-Steady-State (NFT-NSS)) chamber system (Livingston and Hutchinson 1995), whereas measurements of CO_2-exchange were compiled all three to four weeks, using a dynamic closed (Flow-Through Non-Steady-State (FT-NSS)) chamber system (Drösler 2005).

The dynamic system consists of a portable infrared gas analyzer (LI 820 gas analyzer [LI-COR Biosciences, Lincoln, Nebraska, USA]) and manually operated, cubic opaque and transparent PVC chambers with a light transmission of 76%. The chambers sized 0.56 m^2 at the base and had a total volume of 0.296 m^3. To avoid biased air stratification, the chambers were equipped with two adjustable fans, assure efficient headspace mixing during measurements. Transparent and non-transparent extensions (0.296 m^2) as well as external fans were used to enlarge the chamber volume appropriate to plant height and minimize plant irritation (Li et.al. 2008). Airtight closure was ensured by rubber foam cartridge seals at the bottom of the chambers. Identical sized opaque PVC chambers, equipped with four vents for taking gas samples were used for CH_4 measurements. Within the deployment time of 60 minutes, four samples are drawn at 20 minutes intervals by the placement of vacuumed glass vials on the vents. Taken gas samples were analyzed for CO_2-, CH_4- and N_2O-concentrations using a gas chromatograph, equipped with flame ionization detector (FID) and electron capture detector (ECD) (Shimadzu 14A). To estimate R_{eco}- (opaque) and NEE-fluxes (transparent), chambers were deployed on the three repetitive plots of the measurement site, marked by cubic PVC collars. The CO_2-concentration in ppm inside the chambers was determined at 5 second intervals during separated, five minute measurements. To cover a broad variance of air and soil temperatures (opaque chambers) and photosynthetic active radiation (PAR) (transparent chambers), continuously measurements were conducted over the course of one to two bright days, starting before sunrise. In order to relate the CO2 fluxes to prevailing environmental conditions, the photosynthetic photon flux density, the air temperature inside and outside the chamber, soil temperatures in 2, 5 and 10 cm depth (respectively water temperature), as well as the water level was currently recorded during measurements (Alm et. al. 2007). Measurement campaigns were realized once a month in growing season and fall, to once all six weeks during wintertime (Li et.al. 2008).

1.1.1 FLUX calculation

Gas fluxes were calculated under consideration of chamber volume, basal area, air temperature and air pressure according to the ideal gas law using linear regression. CH_4 fluxes were computed, using the R package FLUX. The evolution of the CO_2 concentration in the chamber headspace over time was, however, analyzed by a variable moving window approach and certain flux calculation algorithm (Hoffmann et. al 2014). Thereby ,5% of data points were discarded at both ends of a measurement, to avoid noise in the data, due to turbulences and pressure disturbances, as well as ascending saturation and canopy microclimate effects caused by initial chamber deployment (Kutzbach et. al. 2007, Langensiepen et.al. 2012).

1.1.2 Parameter estimation

R_{eco}-model parameters were compiled for each CO_2-flux-set by using the temperature dependent Arrhenius-type R_{eco}-flux model of Lloyd and Taylor (1994).

$$R_{eco} = R_{ref} * e^{E_0\left(\frac{1}{T_{ref}-T_0}-\frac{1}{T-T_0}\right)}$$

With R_{eco} the measured ecosystem respiration rate [µmol^{-1} m^{-2} s^{-1}], R_{ref} the respiration at reference temperature (T_{ref}) [283.15 K], T0 the temperature constant for the beginning of biological processes [227.13 k] and T as the mean temperature over the turn of the flux measurement in 2 cm, 5 cm and 10 cm soil depth or air temperature in 20 cm height, respectively.

The lowest Akaike Information Criterion (AIC) was chosen to compute GPP-fluxes by model and subtract R_{eco} of NEE measurements. In case Lloyd and Taylor equation was not applicable to the data-set, the average of measured non-transparent CO_2-fluxes was used.

PAR dependent GPP-flux models for each CO_2-flux-set were calculated according to the rectangular, hyperbolic light response equation of Michaels and Menten (1913).

$$GPP = \frac{GP_{max} * \alpha * PAR}{\alpha * PAR + GP_{max}}$$

With GPP the calculated gross primary productivity [µmol^{-1} m^{-2} s^{-1}], GP_{max} the maximum rate of carbon fixation at infinite PAR [CO_2-C mg m^{-2} h^{-1}], α the light use efficiency [CO_2-C mg m^{-2} h^{-1}] and PAR the photon flux density of the photosynthetic active radiation [µmol^{-1} m^{-2} s^{-1}].

Due to chamber induced light transmission loss, PAR was corrected by -14% before applying to eq. (2).

GPP-parameters with lowest AIC were used for modeling process. In case the parameter estimation for eq. (2) was not possible or insignificant a nonrectangular hyperbolic light-response function was used (Glimanow et. al. 2013). This usually resulted in significant estimates of parameters.

$$GPP = \alpha * \mathrm{PAR} + \mathrm{GP}_{\max} - \sqrt{(\alpha * \mathrm{PAR} + \mathrm{GP}_{\max})^2 - 4 * \alpha * \mathrm{PAR} * \mathrm{GP}_{\max} * \theta}$$

With θ the convexity coefficient of the light-response equation (dimensionless).

However, if no negative correlation between data-sets and PAR was found, an average parameters approach was used. Under the general assumption of declining GPP-fluxes between 0 and 100 $\mu mol^{-1}\ m^{-2}\ s^{-1}$ the parameters α and GP_{max} were set on -0.01 and the average of measured GPP-fluxes, respectively.

1.1.3 Modelling approach

Annual CH_4 emissions were calculated by simple linear interpolation between campaigns. To model R_{eco}, GPP and NEE, the records of prevailing environmental conditions and determined parameters of R_{eco} and GPP were used. Before applying these parameters on the environmental controls temperature and PAR, measured air and soil temperatures were corrected. Paired difference tests were performed to obtain spatial heterogeneity within the temperature values. Subsequently, site related climate data was generated by correlating records of the climate station with temperature values obtained during the gas exchange measurement. To gain the final NEE-model, Parameter estimates of R_{eco} and GPP were applied to recalculated best-fit temperatures and PAR, respectively. Thereby computed fluxes of R_{eco} and GPP were blended between campaigns, using a weighted average. To avoid influence of the previous and following campaign parameters on flux estimates of the day of measurement, determined parameters were maintained stable between the first and last measurement of a campaign. Finally NEE was calculated as the sum of R_{eco} and GPP.

1.1.4 Error prediction

Besides the error of calculated fluxes and measured temperatures and PAR, mayor uncertainty arises from site specific temperature models as well as parameter estimation for R_{eco} and GPP. Furthermore, temporal interpolation of modeled fluxes between measurement campaigns is of crucial importance. Moreover, significant uncertainty may also occur due to irreducible random variability (Moriasi et al. 2007). To include mentioned sources of error, uncertainty quantification of modeled R_{eco}, GPP and NEE fluxes was performed by a comprehensive error prediction as following:

(i) In order to address the occasionally small samples size of below n=30, bootstrap confidence intervals were used to calculate the error of measured CO_2-fluxes

(ii) Consecutively, confidence intervals for estimated parameter sets of R_{eco}, GPP and the temperature model were determined (alpha=0.01). In case parameter estimation failed the standard deviation was used to compute the confidence interval of the given average flux or temperature value

(iii) Afterwards, 1000 different temperature models were created, by randomly sampling each temperature value within the calculated confidence range. Similarly, parameter sets for R_{eco} and GPP were 1000 times randomly sampled as well, using case resampling

(iv) Maintained parameter sets and temperature models were subsequently used to compute R_{eco} and GPP models between two campaigns

(v) Accordingly, resulted campaign interspace specific sums of R_{eco} and GPP-fluxes were bootstrapped and the 0.01 and 0.99 quantile was calculated

(vi) Finally, the total uncertainty for modeled NEE and given probability was estimated, following the law of error propagation

The same algorithm was applied to estimate the model error of interpolated CH_4 emissions, by using the campaign specific average CH_4 fluxes and linear interpolation between campaign values.

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