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CO_2 emissions of drained coastal peatlands in the Netherlands and potential emission reduction by water infiltration systems

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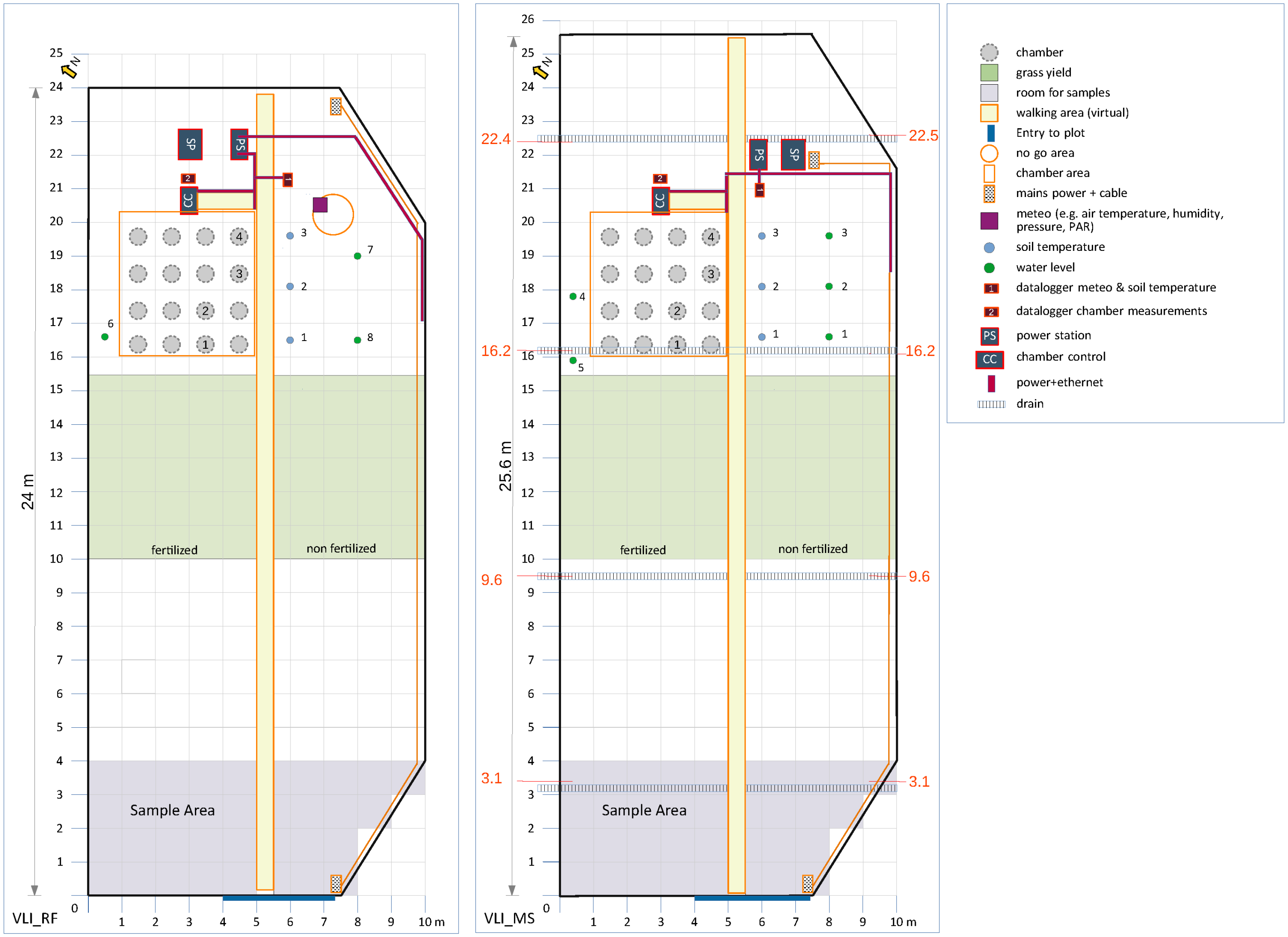
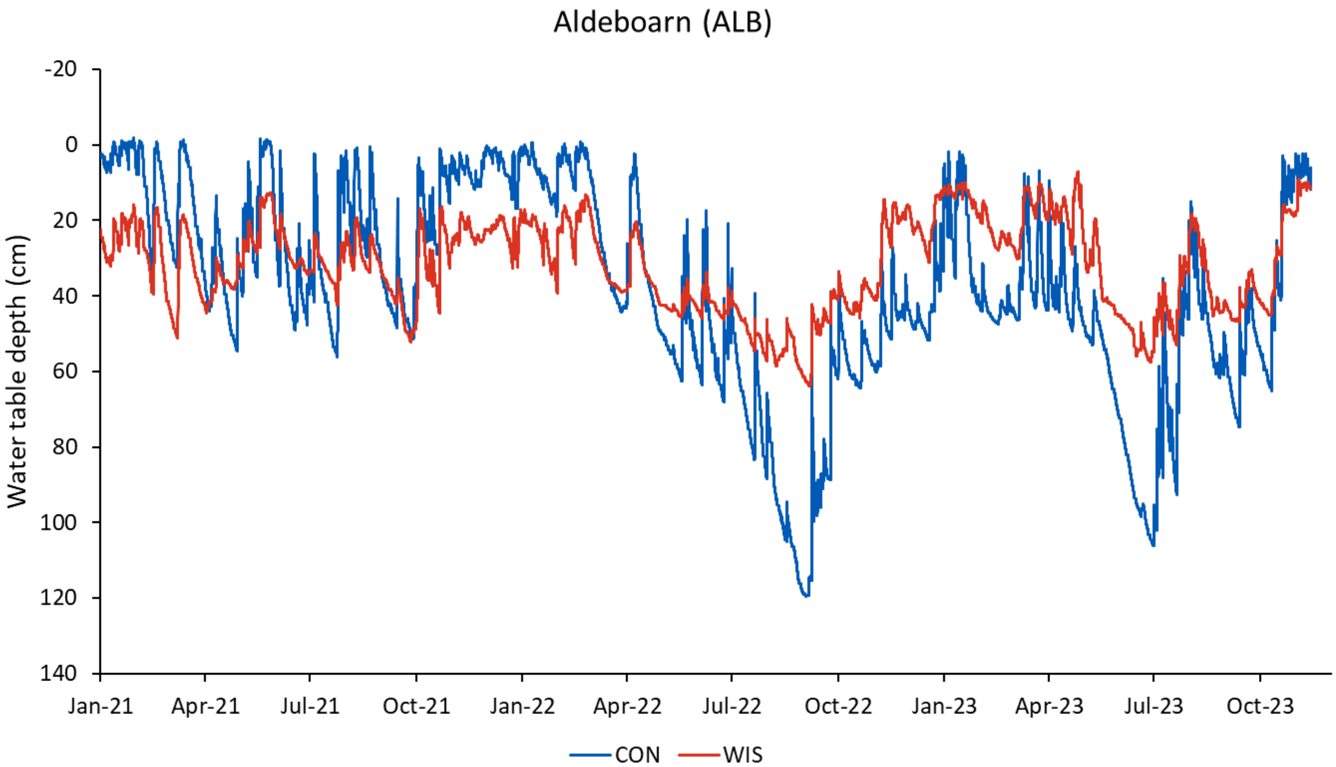
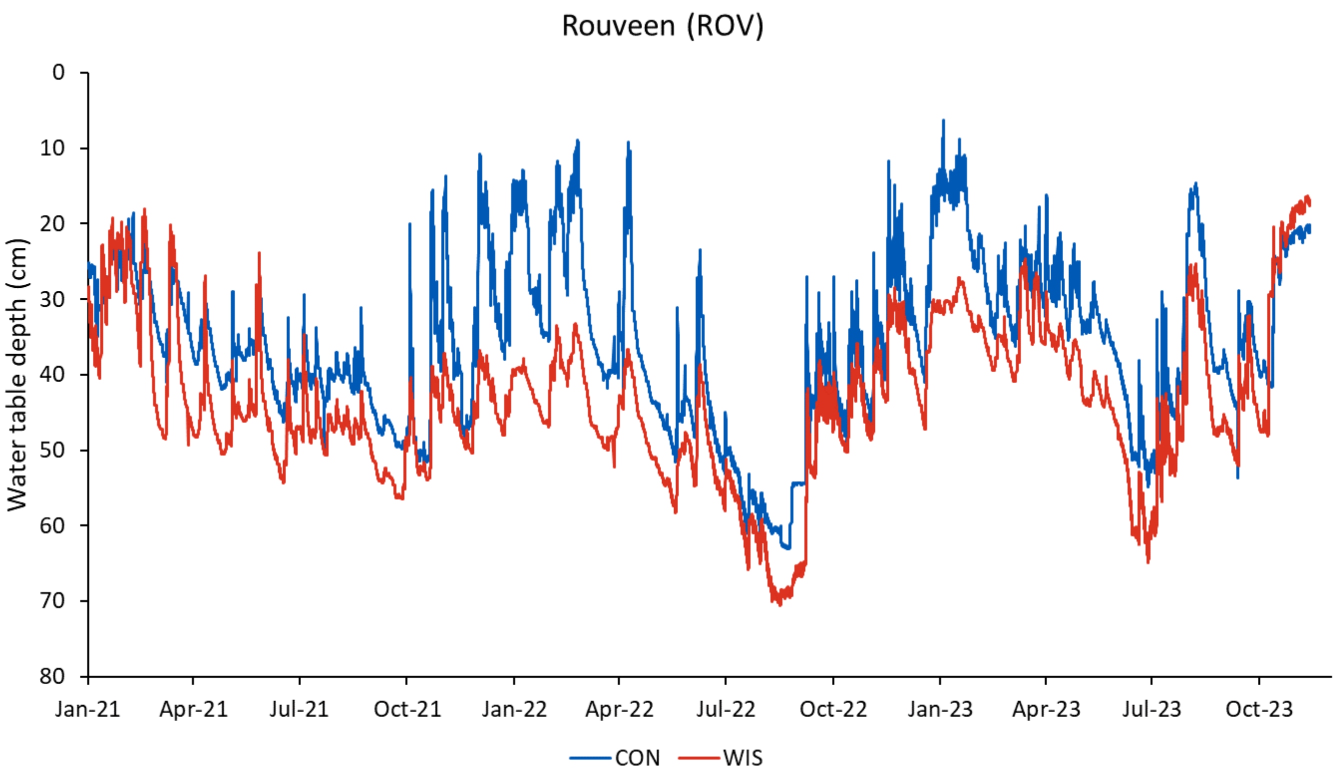
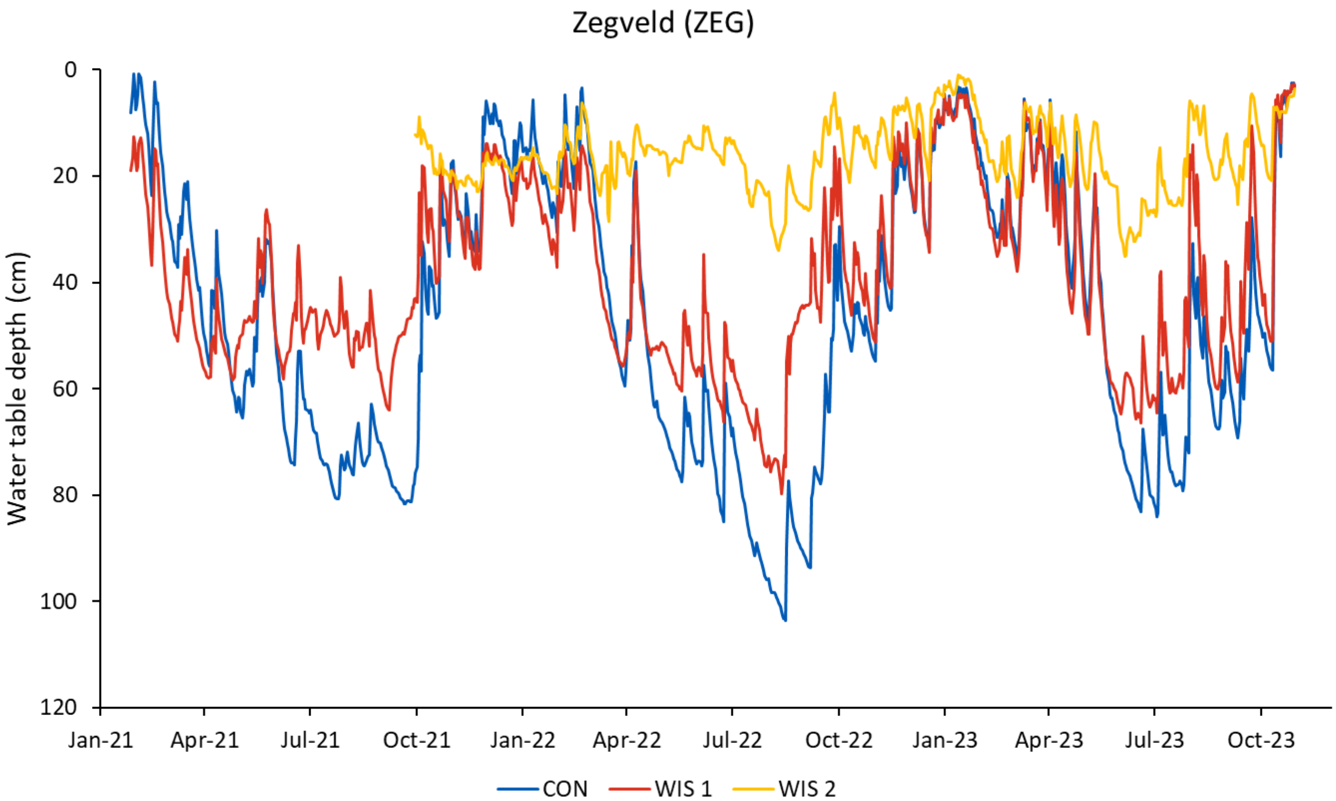
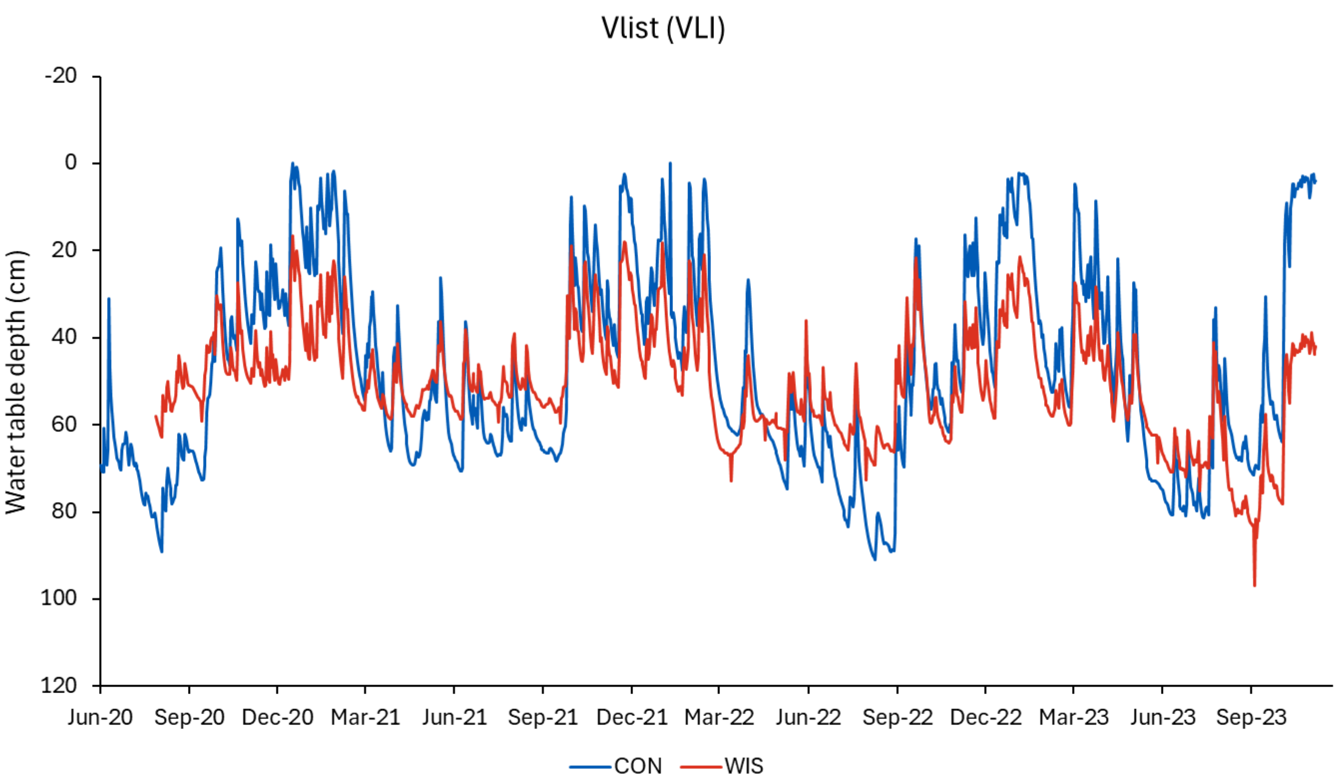


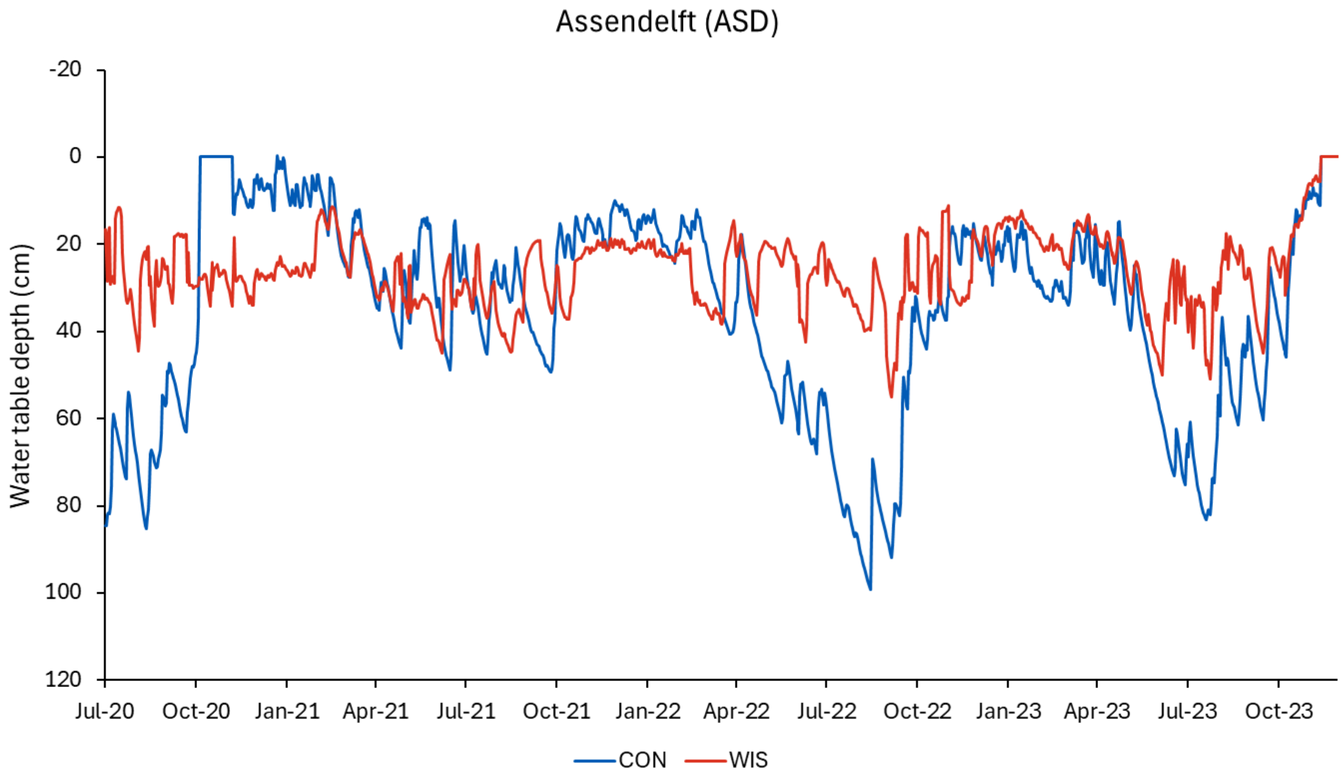
Figure S1. Example of a technical drawing of the measurement plots for a location (VLI) with both a water infiltration system and control plot.


Aldeboarn (ALB)
-20
0
20
40
60
80
100
120
140
Water table depth (cm)
Jan-21
Apr-21
Jul-21
Oct-21
Jan-22
Apr-22
Jul-22
Oct-22
Jan-23
Apr-23
Jul-23
Oct-23
CON
WIS


Rouveen (ROV)
0
10
20
30
40
50
60
70
80
Water table depth (cm)
Jan-21
Apr-21
Jul-21
Oct-21
Jan-22
Apr-22
Jul-22
Oct-22
Jan-23
Apr-23
Jul-23
Oct-23
CON
WIS


Zegveld (ZEG)
Water table depth (cm)
0
20
40
60
80
100
120
Jan-21
Apr-21
Jul-21
Oct-21
Jan-22
Apr-22
Jul-22
Oct-22
Jan-23
Apr-23
Jul-23
Oct-23
CON
WIS 1
WIS 2


Vlist (VLI)
Water table depth (cm)
-20
0
20
40
60
80
100
120
Jun-20
Sep-20
Dec-20
Mar-21
Jun-21
Sep-21
Dec-21
Mar-22
Jun-22
Sep-22
Dec-22
Mar-23
Jun-23
Sep-23
CON
WIS



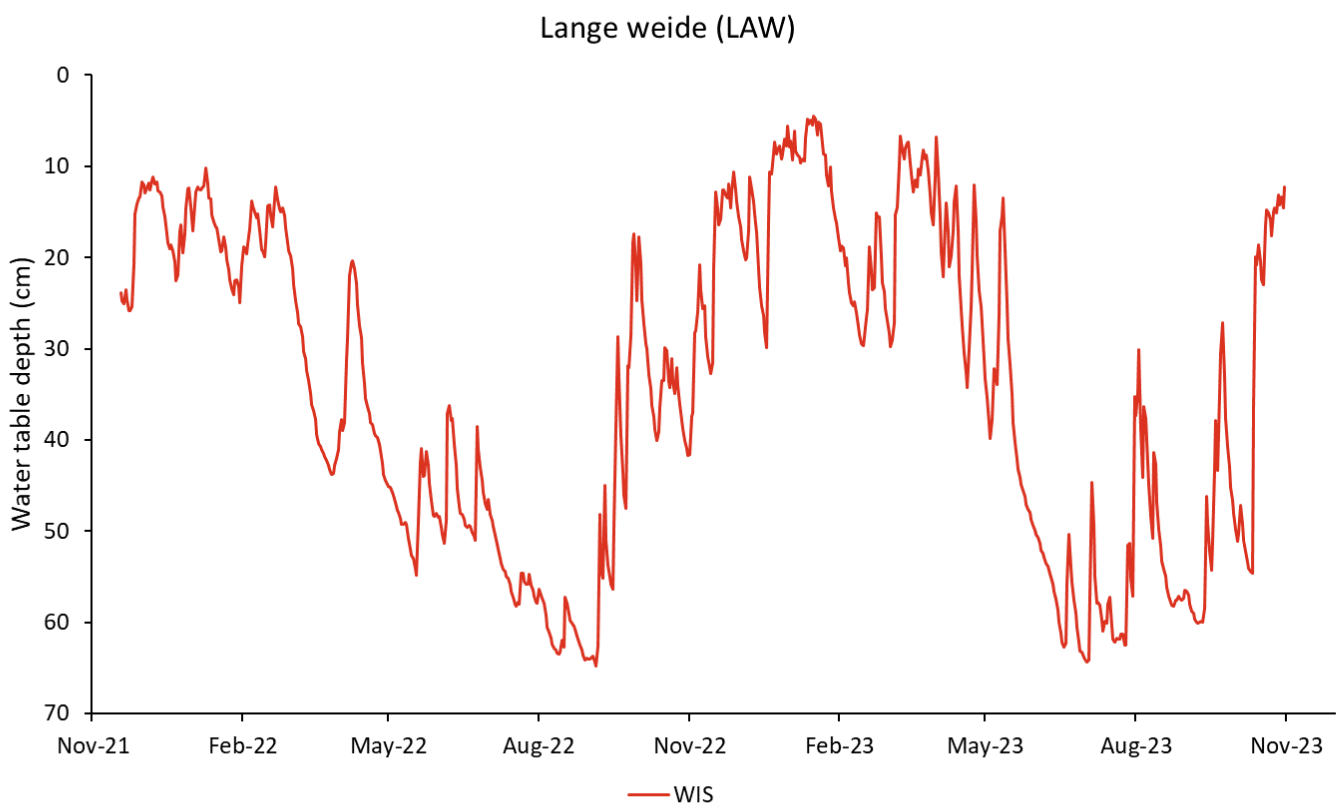


Figure S2. Timeseries graphs showing hourly values of the average water table depth for the control (CON) and water infiltration system (WIS) plot for each of the studied locations.

Table S1. Estimated carbon budgets, their standard deviation (SD) and average annual (WTD_a) and summer (WTD_s) water table depths. Net ecosystem carbon balance (NECB), net ecosystem exchange (NEE), gross primary production (GPP), ecosystem respiration (R_{eco}), and harvest are presented in t CO_2-C ha^{-1} yr^{-1}. Annual (Cexp_a) and summer (Cexp_s) exposed carbon is presented in kg m^{-2} yr^{-1}.

Loc	Treat-ment	Year	NECB	NECB SD	CO_2 flux data availability (%)	NEE	GPP	R_{eco}	Harvest	Start date of NECB	End date of NECB	WTD_a (cm)	WTD_s (cm)	Cexp_a	Cexp_s
ALB	CON	2021	1.3[x]	2.5[y]	76.8	-3.2[z]			4.9	2021-01-01	2022-01-01	21	31	11.1	16.6
ALB	CON	2022	1.6[x]	0.6	89.3	-2.4	21.9	19.5	4.6	2022-01-01	2023-01-01	44	66	25.5	42.0
ALB	CON	2023	-1.7[x]	0.5	84.0	-6.4	28.5	22.2	5.6	2022-11-14	2023-11-14	47	59	27.6	36.3
ALB	WIS	2021	3.0[x]	0.6[y]	37.2	-1.4[z]			4.9	2021-01-01	2022-01-01	30	32	18.2	19.5
ALB	WIS	2022	0.1[x]	0.5	81.0	-3.7	19.8	16.1	4.5	2021-11-14	2022-11-14	37	45	22.5	28.7
ALB	WIS	2023	-0.5[x]	0.5	93.4	-5.1	24.9	19.7	5.7	2022-11-14	2023-11-14	29	37	17.4	22.5
ASD	CON	2020	4.7	1.1	93.3	-4.1	24.3	20.2	8.8	2020-04-01	2021-04-01	34	65	26.7	53.2
ASD	CON	2021	4.4	0.7	91.4	-4.4	23.0	18.6	8.7	2021-01-01	2022-01-01	25	32	20.4	24.9
ASD	CON	2022	0.9	0.6	90.5	-5.0	19.3	14.3	5.9	2022-01-01	2023-01-01	44	68	36.3	55.3
ASD	CON	2023	5.6	0.6	87.1	-0.9	21.3	20.4	6.5	2022-10-15	2023-10-14	38	55	30.3	45.9
ASD	WIS	2020	1.1	0.9	90.0	-5.5	22.4	16.9	6.6	2020-04-01	2021-04-01	25	26	24.9	25.7
ASD	WIS	2021	2.6	0.9	88.8	-4.5	21.0	16.5	7.1	2021-01-01	2022-01-01	27	32	26.5	30.4
ASD	WIS	2022	1.2	0.8	93.9	-4.7	20.5	15.7	5.9	2022-01-01	2023-01-01	27	30	26.5	28.9
ASD	WIS	2023	0.5	0.6	85.3	-5.5	21.6	16.1	6.0	2022-10-15	2023-10-15	25	31	24.9	30.0
LAW	WIS	2022	5.1	0.6	89.0	-0.3	20.7	20.4	5.4	2022-02-01	2023-02-01	35	48	22.3	30.5
LAW	WIS	2023	4.3	0.5	92.0	0.0	25.0	25.0	4.3	2022-11-01	2023-11-01	32	45	20.8	28.4
ROV	CON	2021	4.9	2.6[y]	64.6	-0.7[z]			5.5	2021-01-01	2022-01-01	37	41	20.4	22.6
ROV	CON	2022	1.0	0.3	90.9	-4.5	20.6	16.0	5.5	2021-12-27	2022-12-27	37	47	20.6	25.8
ROV	CON	2023	2.8	0.6	85.9	-5.1	22.7	17.6	7.9	2022-12-27	2023-12-27	27	32	14.1	17.1
ROV	WIS	2021	5.3	2.4[y]	67.2	-1.0[z]			6.4	2021-01-01	2022-01-01	44	47	29.3	31.2
ROV	WIS	2022	3.3	0.3	90.3	-2.2	18.0	15.8	5.5	2021-12-27	2022-12-27	48	53	31.6	34.6
ROV	WIS	2023	3.5	0.5	91.3	-3.6	24.8	21.1	7.1	2022-12-27	2023-12-27	42	46	27.9	30.4
VLI	CON	2020	6.6	1.3	76.4	-2.1	25.1	23.0	8.7	2020-04-01	2021-04-01	44	69	39.1	57.2
VLI	CON	2021	5.7	0.7	94.5	-3.1	23.5	20.4	8.8	2021-01-01	2022-01-01	43	58	38.5	49.7
VLI	CON	2022	7.6	0.6	84.9	0.1	21.1	21.2	7.5	2022-01-01	2023-01-01	51	67	44.5	55.7
VLI	CON	2023	6.3	0.4	92.3	-0.6	21.0	20.4	6.9	2022-10-15	2023-10-15	46	64	40.5	54.1
VLI	WIS	2020	3.8	0.7	78.3	-3.5	22.5	19.0	7.3	2020-04-01	2021-04-01	44	53	37.2	44.6

VLI	WIS	2021	2.9	0.6	93.0	-4.2	21.4	17.2	7.1	2021-01-01	2022-01-01	47	52	39.7	43.7
VLI	WIS	2022	6.6	0.6	87.7	-0.5	19.6	19.0	7.1	2022-01-01	2023-01-01	51	57	43.1	48.0
VLI	WIS	2023	2.8	0.5	90.3	-4.1	22.9	18.8	6.8	2022-10-15	2023-10-01	53	60	44.9	50.2
ZEG	CON	2021	8.3	0.7	61.2	-0.5	19.5	19.1	8.8	2021-01-01	2022-01-01	45	64	47.5	63.5
ZEG	CON	2022	4.6	0.8	66.8	-2.2	26.0	23.8	6.9	2021-11-01	2022-11-01	51	73	52.7	73.3
ZEG	CON	2023	4.0	0.8	88.1	-1.7	23.9	22.3	5.6	2022-11-01	2023-11-01	37	55	38.2	56.5
ZEG	WIS1	2021	5.0	0.9	80.0	-3.9	19.7	15.8	9.0	2021-01-01	2022-01-01	40	49	36.9	42.3
ZEG	WIS1	2022	2.2	0.7	75.2	-5.0	24.2	19.2	7.2	2022-01-01	2023-01-01	41	53	37.4	44.8
ZEG	WIS1	2023	2.6	0.5	85.9	-2.5	27.1	24.6	5.2	2022-11-01	2023-11-01	33	46	31.1	40.3
ZEG	WIS2	2022	2.0	0.4	66.1	-1.7	23.1	21.4	3.7	2022-02-01	2023-02-01	15	18	15.4	18.1
ZEG	WIS2	2023	1.5	0.5	82.4	-2.6	25.2	22.6	4.1	2022-11-01	2023-11-01	15	19	15.4	19.0

[x]Including fertilisation of organic manure of 0.32 and 0.53 t CO_2-C ha^{-1} yr^{-1} for ALB CON and WIS 2021, respectively, and 0.71 and 0.98 t CO_2-C ha^{-1} yr^{-1} for both ALB plots in 2022 and 2023, respectively. The SD of organic mature application was 50% of the estimate.

[y]NECB SD was roughly estimated and is highly uncertain due to large data gaps in CO_2 fluxes.

[z]NEE was gapfilled using Random Forest instead of the Lloyd-Taylor approach. This also resulted in NEE not being partitioned into GPP and Reco. We used the same input variables as used in the Lloyd-Taylor approach. A regression forest was trained with the flags n_subfeatures = -1 (number of features to consider at random per split, in this case an infinite number); n_trees = 250 (number of trees to train); partial_sampling = 0.7 (fraction of samples to train each tree on); max_depth = -1 (maximum depth of the decision trees, grown to maximum extent, in our case no maximum depth); min_samples_leaf = 5 (the minimum number of samples each leaf needs to have at minimum); min_samples_split = 2 (the minimum number of samples in needed for a split) using the MLJ.jl and DecisionTree.jl packages in the Julia 1.8.3 environment. The choices made in were informed by iterative experimentation using latin hypercube sampling in the Julia 1.8.3 environment.

Table S2. Model fits for the empirical relation between annual water table depth (WTD_a; m) and net ecosystem carbon balance (NECB; t CO_2-C ha^{-1} yr^{-1}). Model slopes and intercepts are given with their 95% confidence interval (CI).

Type	Model equation	Slope	95%CI slope*	Intercept	95%CI intercept*	R-function {package}
Linear regression	lm(NECB ~ WTD_a)	8.45	1.43–15.47	0.05	-2.64–2.73	*lm {stats}*
Robust linear regression	rlm(NECB ~ WTD_a)	9.20	2.60–15.80	-0.15	-2.68–2.37	*rlm {MASS}*
Deming regression**	deming(NECB ~ WTD_a, xstd = WTD_SD, ystd = NECB_SD***	14.35	-44.13–72.84	-2.31	-22.58–17.96	*deming {deming}*
Linear Mixed Effects Model	lmer(NECB ~ WTD_a + (1|Location)	4.81	-1.84–11.50	1.37	-1.40–4.14	*lmer (lmerTest)*

* To calculate CIs in R, we used the function confint.lm (package 'stats') for the simple linear regression. For robust linear regression, we also used the function confint.lm after obtaining the model's residual degrees of freedom using the summary.rlm function of the 'MASS' package. For Deming regression, CIs were given by printing the fitted model object. For the linear mixed effects model, we used the function confint.merMod (package 'lme4') to calculate CIs via parametric bootstrapping (100,000 bootstrap replicates).

** Estimated with standard deviation (SD) estimates for WTD_a per site-year, based on groundwater well replicates (*n*=3). When well replicates were not present, average control site SD estimates were used. Estimates of the NECB SD were obtained as described in the main text.

*** WTD_SD and NECB_SD are the estimated standard deviations of the annual water table depth (WTD_a) and net ecosystem carbon balance (NECB), respectively.

Table S3. Overview of fitted empirical relations to estimate net ecosystem carbon balance (NECB; t C ha^{-1} yr^{-1}) based on mean annual water table depths (WTD_a) that are plotted in Figure 9 of the main text. Please note that the fit of Koch et al. (2023) is identical to the fit of Tiemeyer et al. (2020) and thus not separately included here.

Study	Function with parameters
Current study	$\mathrm{NECB} = 8.45\ \mathrm{WTD_a} + 0.05$
Couwenberg et al. (2011)	$\mathrm{NECB} = 20.54\ \mathrm{WTD_a} - 1.29$
Fritz et al. (2017)	$\mathrm{NECB} = 12.27\ \mathrm{WTD_a} - 0.02$
Tiemeyer et al. (2020)	$\mathrm{NECB} = -0.93 + 11.00\ e^{-7.52\ e^{12.97\ \mathrm{WTD_a}}}$
Evans et al. (2021)	$\mathrm{NECB} = 9.27\ \mathrm{WTD_a} - 1.69$

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