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Supplement of

The effects of peat thickness and water table depth on CO_2 and N_2O emissions from agricultural peatlands – a process-based modelling approach

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S1. Supplementary Figures

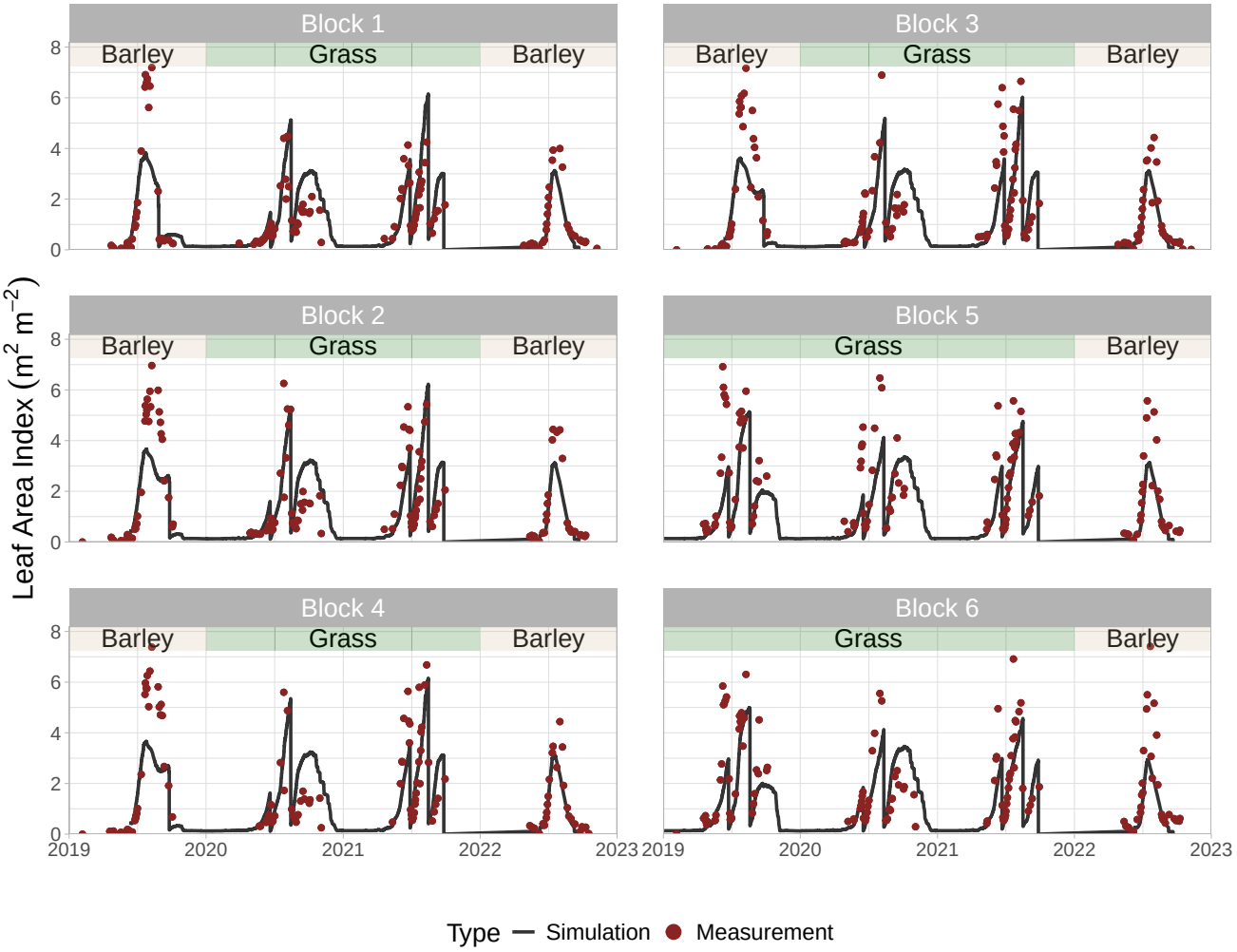

Figure S1. Leaf area index (LAI) in baseline scenarios.

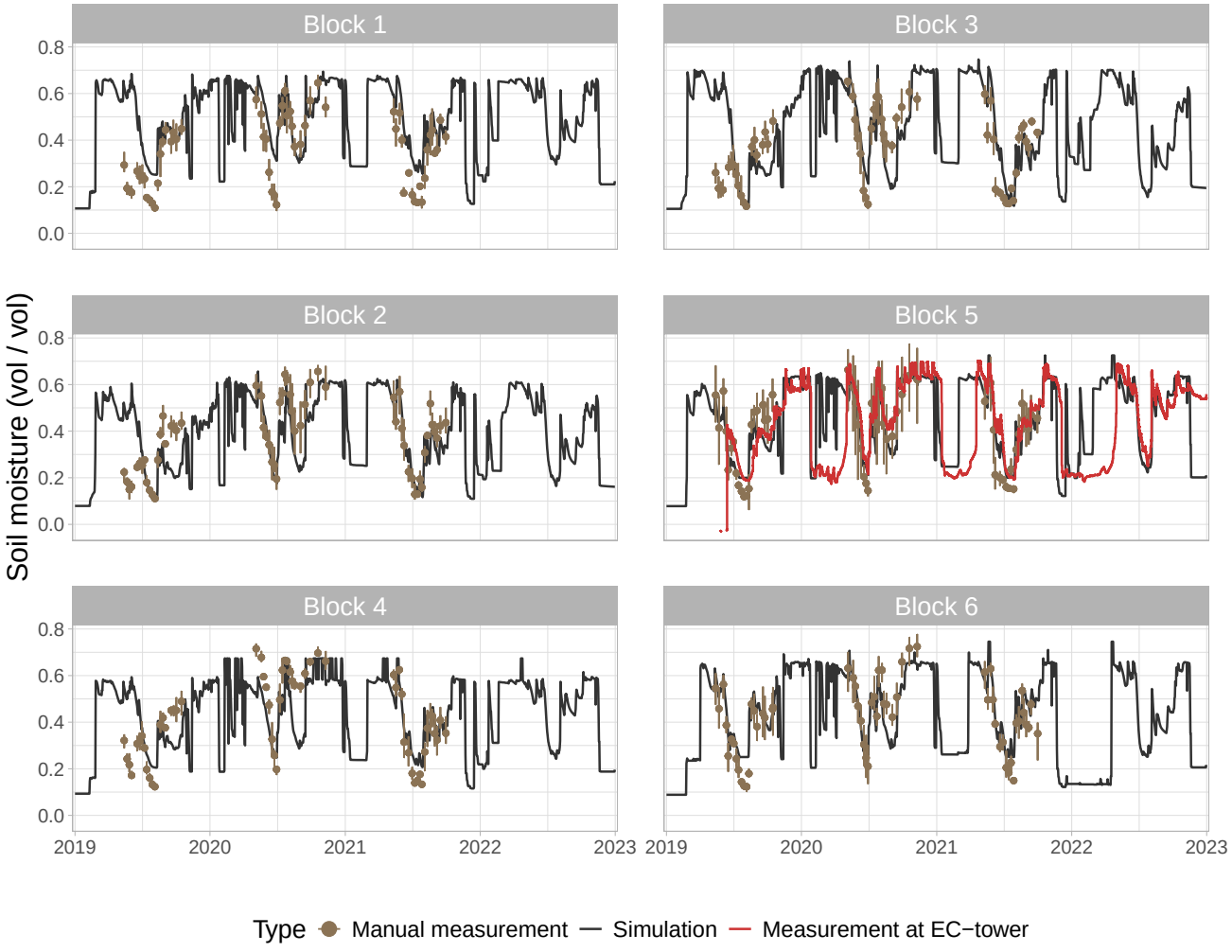

Figure S2. Soil moisture in baseline scenarios.

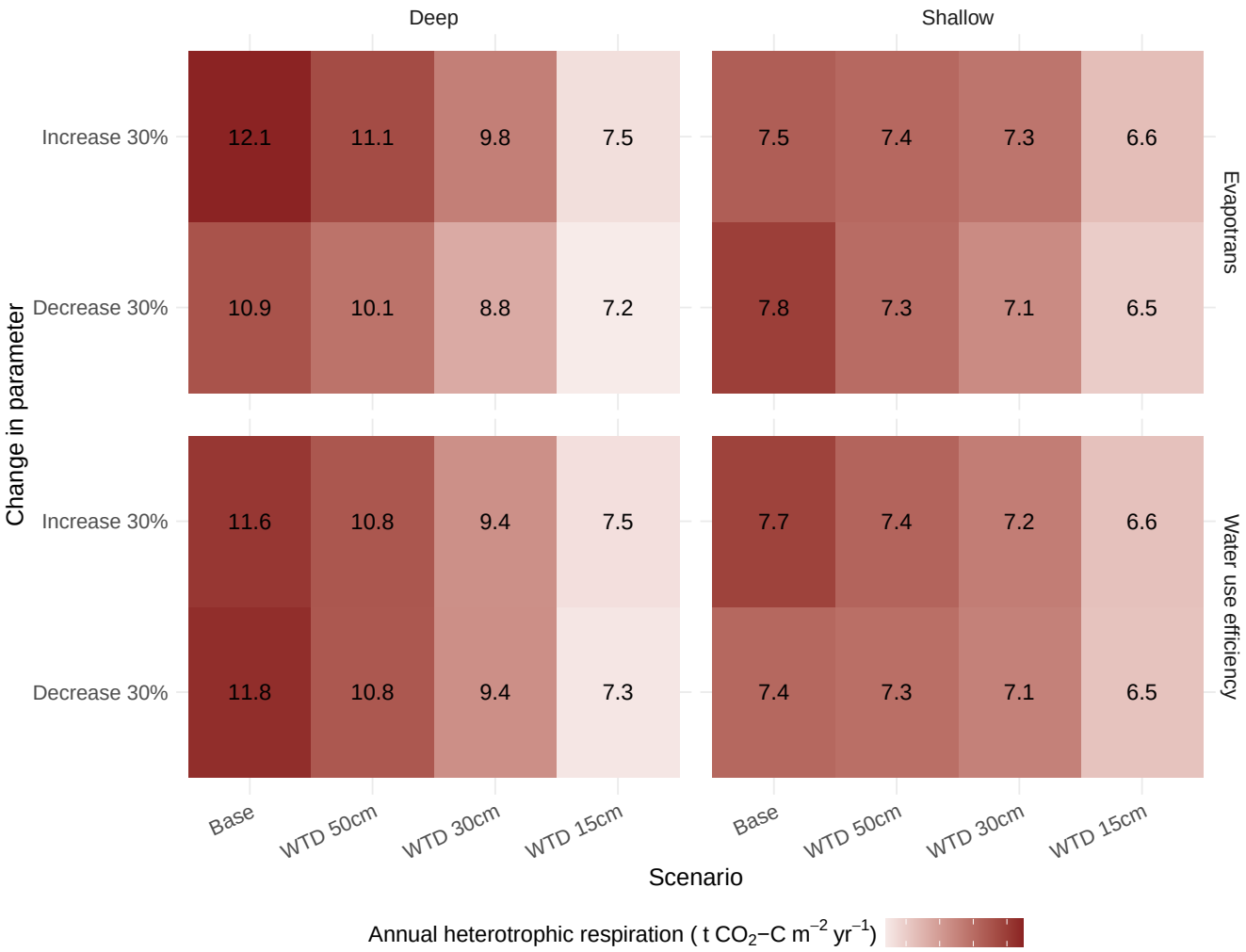

Figure S3. Average annual heterotrophic respiration in each water table depth (WTD) scenario for deep peat blocks (1,2,4) and shallow peat blocks (3,5,6) after changing potential evapotranspiration and water use efficiency parameters. In the baseline run the annual heterotrophic respiration was 11.8 t CO_2–C ha^{-1} yr^{-1} for deep peat blocks, 7.6 t CO_2–C ha^{-1} yr^{-1} and average of all blocks 9.7 t CO_2–C ha^{-1} yr^{-1}.

S2. Supplementary Tables

Table S1. Parameter values changed for the simulation runs and their differences to the default parameter values in the model. Parameters were selected to correct undesired model behavior and to enhance dynamics seen in the empirical observations. The modifications to decomposition rates (METRX_KR_DC_HUM) were necessary to achieve representative emission levels, while modifications to GDD (required growing degree days for plant development) and senescence (maximum percentage of biomass being subject senescence due to age, drought or frost) parameters were crucial to replicate plants' seasonal dynamics in northern latitudes. Other parameters governed daily runoff from surface water (FRUNOFF), change in potential evapotranspiration (WCDNDC_INCREASE_POT_EVAPOTRANS), albedo (ALB), relative available soil water content at which drought affects photosynthesis activity (H2OREF_A), or stomata are fully closed (H2OREF_GS), maximum instantaneous water use efficiency (WUECMAX), biomass fraction of fruit at maturity (FRACTION_FRUIT), decline of specific leaf area with crop age (SLADECLINE) and specific leaf area in the shade (SLAMAX).

Type	Name	Value	Default
SITE	FRUNOFF (time step dependent)	8	6
	METRX_KR_DC_HUM2	1.4e-3	1.2e-3
	METRX_KR_DC_HUM3	1.0e-3	2.5e-5
	WCDNDC_INCREASE_POT_EVAPOTRANS	1.7	1.0
PERG	ALB	0.16	0.12
	H2OREF_A	1e-6	0.65
	H2OREF_GS	1e-6	0.33
	SENESCENCE_AGE	7e-4	1e-2
	SENESCENCE_DROUGHT	5e-5	1e-2
	SENESCENCE_FROST	0.9	1e-2
	WUECMAX	14	5.3
SBAR	GDD_FLOWERING	650	910
	GDD_GRAIN_FILLING	780	930
	GDD_MATURITY	1350	1660
	FRACTION_FRUIT	0.66	0.5
	SLADECLINE	0.65	0
	SLAMAX	20	27
	SENESCENCE_AGE	7.4e-2	0
	SENESCENCE_DROUGHT	6.5e-2	0
	SENESCENCE_FROST	2.1e-2	0

Table S2. Simulated autotrophic (Ra), heterotrophic (Rh) and total respiration (TER) together with gross primary production (GPP) at the different blocks during 2019-2022. Carbon related values are t CO_2–C ha^{-1} yr^{-1} and unit of N2O is kg N_2O–N ha^{-1} yr^{-1}.

Block	Year	Ra	Rh	TER	GPP	N2O
1	2019	4.26	11.41	15.68	8.99	15.33
1	2020	6.76	11.32	18.08	12.90	27.56
1	2021	7.31	10.88	18.18	14.16	22.29
1	2022	3.68	11.60	15.28	7.97	20.05
2	2019	4.80	12.64	17.44	9.90	31.68
2	2020	7.01	13.05	20.06	13.34	51.72
2	2021	7.47	12.08	19.55	14.49	30.60
2	2022	3.68	13.81	17.50	7.99	27.70
3	2019	4.44	6.45	10.89	9.17	11.10
3	2020	6.79	7.33	14.12	12.97	14.67
3	2021	7.21	6.39	13.60	14.04	12.68
3	2022	3.62	8.35	11.97	7.81	12.41
4	2019	4.82	11.96	16.78	9.88	19.34
4	2020	7.05	10.82	17.88	13.42	26.68
4	2021	7.39	11.47	18.85	14.34	20.96
4	2022	3.67	10.93	14.60	7.96	14.71
5	2019	6.22	7.41	13.63	11.81	8.49
5	2020	7.29	7.66	14.95	13.65	10.00
5	2021	6.75	7.22	13.97	12.97	6.39
5	2022	3.67	8.67	12.34	7.95	11.87
6	2019	6.08	8.04	14.11	11.55	13.73
6	2020	7.24	8.13	15.37	13.59	21.51
6	2021	6.54	7.64	14.18	12.60	11.66
6	2022	2.96	8.33	11.29	6.15	6.85

Table S3. Simulated NEE, N2O and NECB values for shallow and deep peat blocks.

Peat depth	Scenario	Year	NEE (t CO_2–C ha^{-1})	N2O (kg N_2O–N ha^{-1})	NECB (t CO_2–C ha^{-1})
Shallow	Baseline	2019	2.04	11.10	4.88
Shallow	Baseline	2020	1.41	15.39	4.15
Shallow	Baseline	2021	0.71	10.24	4.42
Shallow	Baseline	2022	4.56	10.38	5.89
Shallow	WTD 50 cm	2019	1.19	10.89	4.23
Shallow	WTD 50 cm	2020	0.83	12.14	3.64
Shallow	WTD 50 cm	2021	-0.15	7.01	3.67
Shallow	WTD 50 cm	2022	5.04	6.97	6.28
Shallow	WTD 30 cm	2019	0.94	10.16	4.11
Shallow	WTD 30 cm	2020	0.32	10.70	3.18
Shallow	WTD 30 cm	2021	-0.58	4.23	3.28
Shallow	WTD 30 cm	2022	4.86	6.49	6.11
Shallow	WTD 15 cm	2019	0.23	9.76	3.57
Shallow	WTD 15 cm	2020	-0.30	6.73	2.61
Shallow	WTD 15 cm	2021	-0.73	2.88	3.18
Shallow	WTD 15 cm	2022	2.99	4.24	4.47
Deep	Baseline	2019	7.04	22.12	9.31
Deep	Baseline	2020	5.45	35.32	8.29
Deep	Baseline	2021	4.53	24.62	8.60
Deep	Baseline	2022	7.82	20.82	9.28
Deep	WTD 50 cm	2019	5.85	22.29	8.50
Deep	WTD 50 cm	2020	3.03	26.05	5.91
Deep	WTD 50 cm	2021	3.25	18.56	7.34
Deep	WTD 50 cm	2022	7.95	18.99	9.42
Deep	WTD 30 cm	2019	4.66	23.78	7.58
Deep	WTD 30 cm	2020	1.36	19.44	4.32
Deep	WTD 30 cm	2021	1.12	10.87	5.26
Deep	WTD 30 cm	2022	6.27	13.69	7.74
Deep	WTD 15 cm	2019	1.71	19.97	4.76
Deep	WTD 15 cm	2020	-0.04	9.04	3.00
Deep	WTD 15 cm	2021	-0.70	4.12	3.46
Deep	WTD 15 cm	2022	3.85	8.76	5.32

Table S4. Annual NEE and N2O from EC measurements. NECB calculated by the sum of NEE and carbon from harvest as no manure was applied in years 2020–2022.

Year	NEE (t CO_2–C ha^{-1})	N2O (kg N_2O–N ha^{-1})	NECB (t CO_2–C ha^{-1})
2020	1.06	4.74	4.29
2021	1.79	6.09	5.51
2022	5.12	13.0	6.91

Table S5. Soil-related parameters used in the simulations: bulk density (bd; kg dm^{-3}), pH, organic carbon content (corg; g g^{-1}), nitrogen content (norg; g g^{-1}), α and n as used in the van Genuchten functions for water retention curves, saturated hydraulic conductivity (sks; cm min^{-1}), porosity (m^3 m^{-3}), silt content (g g^{-1}), and minimum water filled pore space (m^3 m^{-3}). The layer split indicates how many sublayers each initialised layer contains with similar attributes. The initialisation of C and N pools is based on extrapolating the C and N contents measured in Yli-Halla et al. (2022, supplement) to the beginning of the spin-up simulation. The extrapolated carbon and nitrogen amounts are distributed into the topmost soil layers to account the depletion during spin-up years. The hydrological parameters were iteratively determined relying on literature values and the model response compared to the observed values on the site.

Block	Stratum	Stratum(mm)	Layers(num)	bd	pH	corg	norg	alpha	n	sks	porosity	silt	wfpsmin
1	1	200	10	0.475	5.8	0.258	0.014	0.785	1.4	0.004			0.23
1	2	300	10	0.21	5.8	0.594	0.030	0.975	1.3	0.004	0.7		0.21
1	3	100	2	0.15	5.8	0.715	0.037	3	1.4	0.004	0.7		0.3
1	4	100	2	1.64	4.9	0.01	0.0007	4.5	1.35	0.004	0.48	0.7	0.25
1	5	300	5	1.35	4.4	0.007	0.0004				0.41	0.7	
1	6	1000	10	1.32	4.9	0.01	0.0008					0.7	
2	1	200	10	0.49	5.6	0.344	0.021	0.795	1.4	0.004			
2	2	200	10	0.22	5.6	0.607	0.033	0.925	1.3	0.004			
2	3	100	4	0.81	5.2	0.083	0.0049	6	1.5	0.004			
2	4	100	2	1.63	4.9	0.006	0.0006	6	1.5	0.004	0.39	0.7	
2	5	400	4	1.63	4.9	0.01	0.0005			0.004		0.7	
2	6	200	2	1.65	4.9	0.025	0.0012					0.7	
2	7	800	4	1.32	4.9	0.008	0.0005					0.7	
3	1	200	10	0.36	5.8	0.258	0.015	0.795	1.4	0.004			
3	2	100	10	0.89	5.8	0.088	0.0050	0.925	1.3	0.004			
3	3	300	10	1.63	4.9	0.005	0.0002	6	1.5	0.004	0.38	0.7	
3	4	400	10	1.41	4.4	0.003	0.0002			0.002	0.5	0.7	
3	5	600	10	1.27	4.4	0.008	0.0007					0.7	
3	6	400	10	1.32	4.9	0.013	0.0008					0.7	
4	1	300	15	0.62	5.6	0.268	0.016	0.795	1.4	0.0045			0.2
4	2	200	10	0.23	5.6	0.522	0.028	0.825	1.3	0.004			0.2
4	3	100	4	1.63	5.2	0.002	0.0004	6	1.5	0.004	0.4		0.3
4	4	400	10	1.41	4.9	0.007	0.0003			0.005			0.3
4	5	600	10	1.27	4.9	0.012	0.0006						0.3
4	6	400	5	1.32	4.9	0.007	0.0006						0.3
5	1	100	5	0.61	6.1	0.301	0.017	0.75	1.4	0.0045		0.7	0.16
5	2	100	5	0.21	6.1	0.471	0.029	0.95	1.3	0.0045		0.7	
5	3	100	4	1.62	5.6	0.0062	0.0006	6	1.4	0.004			
5	4	100	4	1.33	5.4	0.0024	0.0002	6	1.5	0.00054	0.45	0.7	
5	5	400	10	1.33	4.9	0.0024	0.0002			0.00045		0.7	
5	6	200	4	1.33	4.4	0.0024	0.0002			0.00045		0.7	
5	7	800	8	1.48	4.4	0.0054	0.0004					0.7	
5	8	200	2	1.32	4.4	0.0063	0.0004					0.7	
6	1	100	5	0.696	6	0.219	0.011	0.8	1.35	0.0025	0.72		0.2
6	2	100	4	0.644	6	0.223	0.011	0.975	1.20	0.0025			0.2
6	3	100	2	1.65	6	0.01	0.0009	6	1.46	0.004	0.45	0.6	0.3
6	4	700	7	1.33	5	0.003	0.0002	2	1.35	0.0005	0.4	0.7	0.2
6	5	900	3	1.48	4	0.004	0.0001	2	1.35	0.002	0.4	0.7	0.2
6	6	100	1	1.32	5	0.005	0.0003	2	1.35	0.002		0.7	0.2

Table S6. Statistics for soil moisture and leaf area index (LAI). Simulated soil moisture was compared with manual chamber measurements (2019–2021), and simulated LAI with satellite observations (2019–2022).

Block	Soil moisture		Leaf area index
	NSE (Nash Sutcliffe Effciency)	R^2	R^2
1	–0.24	0.43	0.61
2	0.30	0.39	0.64
3	0.06	0.36	0.66
4	0.40	0.40	0.63
5	0.75	0.75	0.64
6	0.66	0.69	0.57

Table S7. Monthly and yearly total precipitation and air temperature mean from January 2019 to December 2022 in comparison to the long term average of 1991-2020 (Jokinen et al. 2021).

Time	Total precipitation (mm)					Air temperature mean (°C)				
period	2019	2020	2021	2022	1991-2020	2019	2020	2021	2022	1991-2020
January	22	45	32	15	36	-12.1	-1.9	-10,0	-7.6	-8.0
February	37	69	35	56	30	-6.0	-4.1	-12.7	-7.2	-8.2
March	44	23	31	13	28	-3.7	-1.9	-3.9	-2.7	-4.0
April	3	14	53	24	24	4.2	0.1	1.8	0.3	1.9
May	60	31	57	32	42	7.6	6.0	7.5	8.1	8.0
June	55	37	45	58	53	14.3	16.4	15.6	14.8	13.3
July	2	165	32	40	77	14.6	14.3	17.7	16.0	16.2
August	104	30	127	121	70	13.7	13.6	12.8	14.9	14.0
September	44	95	45	27	53	8.9	9.7	7.3	7.7	9.0
October	59	92	87	69	54	2.0	4.9	5.2	4.7	3.0
November	56	87	22	18	47	-3.0	1.5	-2.8	-1.7	-1.6
December	35	44	14	42	42	-2.0	-1.8	-9.7	-6.1	-5.2
Year	519	732	580	514	555	3.2	4.7	2.4	3.4	3.2

Table S8. Management event from 2019 and 2020.

Block	Date	Crop	Event	Additional information
5, 6	2019-05-13	G	Fertilization	N80-P8-K48 kg/ha
2	2019-06-02	B	Slurry	N57-P6-K51 kg/ha
1	2019-06-06	B	Harrowing	
1	2019-06-07	B	Sowing + Fertilization	Sowing density: 200kg/ha Fert.: N57-P5.6-K33.6 kg/ha
3	2019-06-08	B	Slurry	N57-P6-K51 kg/ha
2-4	2019-06-10	B	Harrowing	
2, 4	2019-06-10	B	Sowing + Fertilization	Sowing density: 200kg/ha Fert. block 2: N27-P0-K1 kg/ha Fert. block 4: N57-P5.6-K33.6 kg/ha
3	2019-06-11	B	Sowing + Fertilization	Sowing density: 200kg/ha Fert. block 2: N27-P0-K1 kg/ha
1-4	2019-06-13	B	Rolling	
5, 6	2019-06-24	G	Harvest	Block 5: 6871.2 kg DW/ha Block 6: 5486.1 kg DW/ha
5, 6	2019-07-05	G	Fertilization	N51.48-P0-K53 kg/ha
5, 6	2019-08-20	G	Harvest	Block 5: 4250.1 kg DW/ha Field block 6: 4131.9 kg DW/ha
1	2019-08-26	B	Harvest	8647.1 kg DW/ha
4	2019-09-24	G	Harvest	4442.5 kg DW/ha
2, 3	2019-09-25	B	Harvest	Block 2: 2449 kg DW/ha Block 3: 3005.3 kg DW/ha
6	2019-10-15	G	Slurry	N57-P6-K51 kg/ha
1-6	2020-05-29	G	Fertilization	N80-P8-K48 kg/ha
5, 6	2020-06-17	G	Mowing + Harvest	Block 5: 3934.3 kg DW/ha Block 6: 4200.1 kg DW/ha
1-4	2020-06-20	G	Mowing	
1-4	2020-06-24	G	Harvest	Block 1: 1548.0 kg DW/ha Block 2: 250.6 kg DW/ha Block 3: 1778.4 kg DW/ha Block 4: 1267.6 kg DW/ha
1-6	2020-06-30	G	Fertilization	N66-P0-K36 kg/ha
5, 6	2020-08-11	G	Mowing	
5, 6	2020-08-12	G	Harvest	Block 5: 3473.7 kg DW/ha Block 6: 3420.9 kg DW/ha
1-4	2020-08-14	G	Mowing	
1-4	2020-08-21	G	Harvest	Block 1: 4178.3 kg DW/ha Block 2: 6673.4 kg DW/ha Block 3: 5180.7 kg DW/ha Block 4: 5458.5 kg DW/ha

Table S9. Management event from 2021 and 2022.

Block	Date	Crop	Event	Additional information
1-6	2021-05-26	G	Fertilization	N70-P7-K42 kg/ha
5, 6	2021-06-22	G	Mowing + Harvest	Block 5: 5055.7 kg DW/ha Block 6: 4613.1 kg DW/ha
1-4	2021-06-28	G	Mowing	
1-4	2021-07-02	G	Baling	Block 1: 6240.8 kg DW/ha Block 2: 5885.8 kg DW/ha Block 3: 6455.0 kg DW/ha Block 4: 5422.2 kg DW/ha
1-6	2021-07-07	G	Fertilization 2	N66-P0-K36 kg/ha
1-4	2021-08-16	G	Mowing 2	
5, 6	2021-08-17	G	Mowing + Harvest	Block 5: 3966 kg DW/ha Block 6: 3616.8 kg DW/ha
1-4	2021-08-17	G	Harvest	Block 1: 5264.3 kg DW/ha Block 2: 3935.6 kg DW/ha Block 3: 5280.6 kg DW/ha Block 4: 4039.1 kg DW/ha
5, 6	2021-09-26	G	Herbicide	Glyphosate
1-4	2021-09-27	G	Herbicide	Glyphosate
1-6	2021-11-15	G	Ditch work	Ended on 2021-11-15
6	2022-06-01	B	Ploughing	
5	2022-06-02	B	Ploughing	
3, 4	2022-06-04	B	Ploughing	
1, 2	2022-06-05	B	Ploughing	
1-4	2022-06-09	B	Sowing + Fertilization	Sowing density: 200kg/ha Fert.: N60 - P6 - K36 kg/ha
5, 6	2022-06-10	B	Sowing + Fertilization	Sowing density: 200kg/ha Fert.: N60 - P6 - K36 kg/ha
3-6	2022-07-05	B	Herbicide	Tribenuron-methyl
1, 2	2022-07-06	B	Herbicide	Tribenuron-methyl
All	2022-09-09	B	Harvest	Block 1: 5275.3 kg DW/ha Block 2: 4349.6 kg DW/ha Block 3: 5038.0 kg DW/ha Block 4: 4986.1 kg DW/ha Block 5: 4177.5 kg DW/ha Block 6: 4140.6 kg DW/ha
All	2022-09-21	B	Herbicide	Glyphosate
5, 6	2022-10-11	B	Ploughing	Ended on 2022-10-11
1-4	2022-10-12	B	Ploughing	Ended on 2022-10-14