Supplementary Information

Impact of drainage on soil CH_4 and N_2O fluxes in nutrient-rich hemiboreal peatland forests of Europe

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Contents:

12 pages; 1 supplementary, 3 figures and 10 tables.

Supplementary 1 Selection of soil water parameters for mixed-effect models on hourly fluxes.

In cases when the wells were dry, since the groundwater surface was below the depth of the wells, which occurred most frequently in DF sites during the dry period (Aug-Oct) of the year, while UF did not experience dry conditions. Hence, similar WTL values were assigned from the nearest on-site observation during the same-day campaign. Overall, the dataset (n = 3378 observations), WTL measurements were successfully obtained in 78% of cases. One drained site, LT-DB, exhibited consistently dry conditions throughout the monitoring period, with WTL undetectable in 82% of observations; hence, the maximum value of the well was assigned i.e., WTL below 150 cm. However, the assigned WTL values were treated consciously and not used in statistical analysis (see Method section).

Soil water parameters (SPC, pH and O_2) were not included in the models; 1) due to the limited number of measurement values available for soil water parameters, as the observation wells were dry in DF sites during the summer. 2) due to non-significant correlations between pH, O_2 and CH_4 fluxes, while N_2O fluxes showed slightly significant correlations with SPC, and O_2. While testing them in the models, neither of them appeared to be significant, and we would have lost 910 out of 3196 observations. Therefore, these observations were not used in the LME models predicting hourly CH_4 and N_2O fluxes.

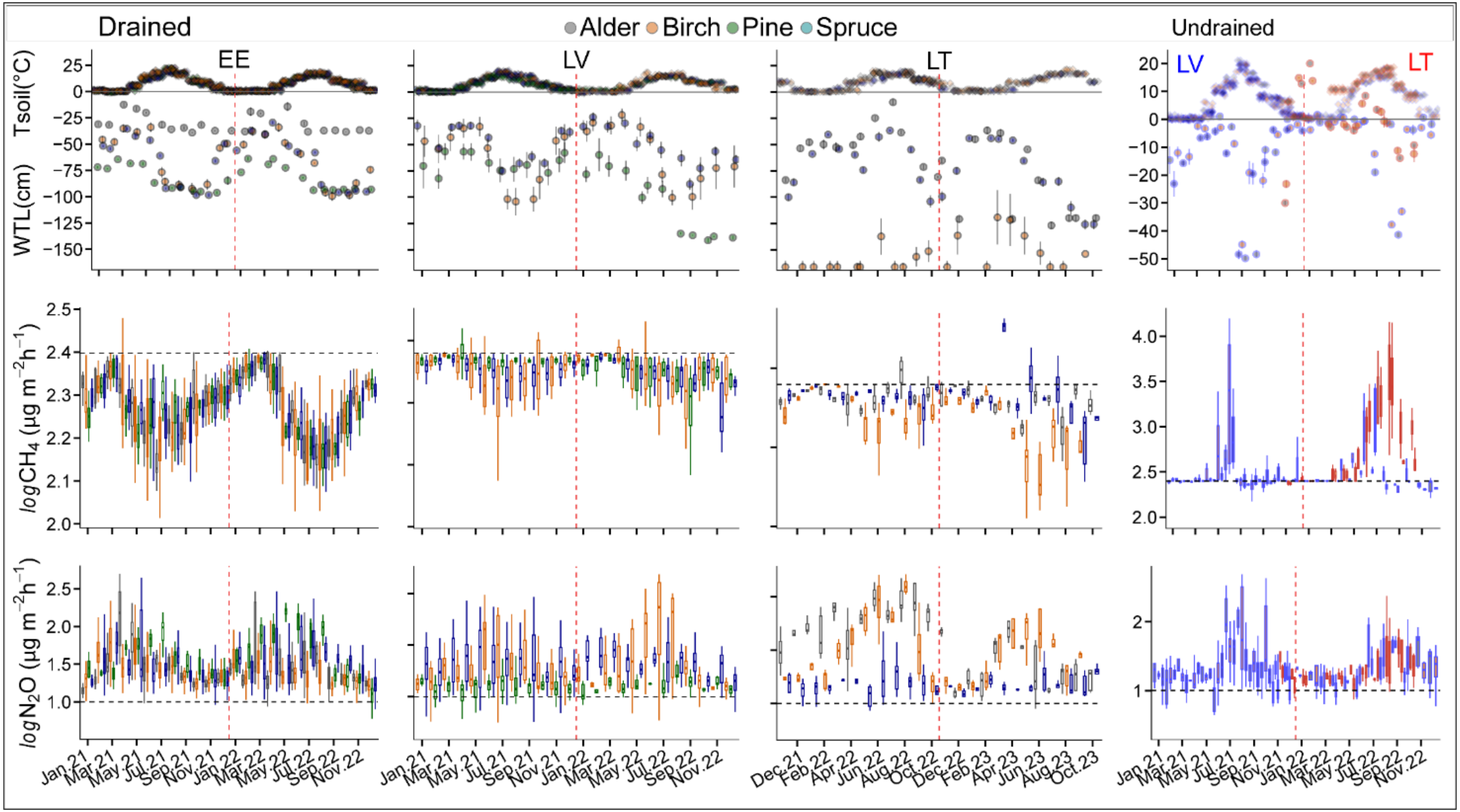

Fig. S1 Seasonal variation of soil environmental variables and average instantaneous flux of each sampling occasion during the measurement periods. Mean ± standard error soil temperature at 10 cm (Tsoil_10) and water table level (WTL), normalized CH_4 and N_2O fluxes (µg m^{-1} h^{-1}) showing median in the center, 25th and 75th percentile with top and bottom of the boxplots. Data were grouped by dominant tree stands represented by different colours: grey = alder, peach = birch, green = pine and blue =spruce.

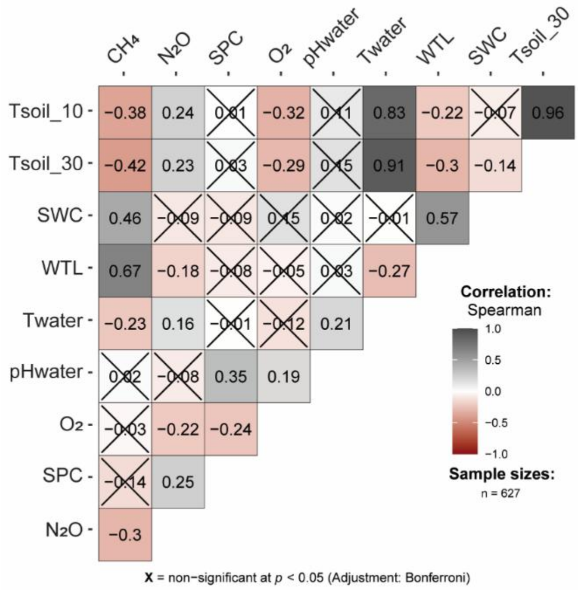

Fig. S2 Relationships between the hourly soil CH_4 and N_2O fluxes and soil parameters; WTL, soil water-table level; SWC soil water content; Tsoil_10, Tsoil_30, soil temperature at depths of 10 and 30 cm. Soil-water characteristics include O_2 %, oxygen content; SPC, specific conductance, pH and TW, water temperature in drained and undrained sites. The values indicate spearmen rank correlation coefficients, and crosses denote non-significant relationships between the variables.

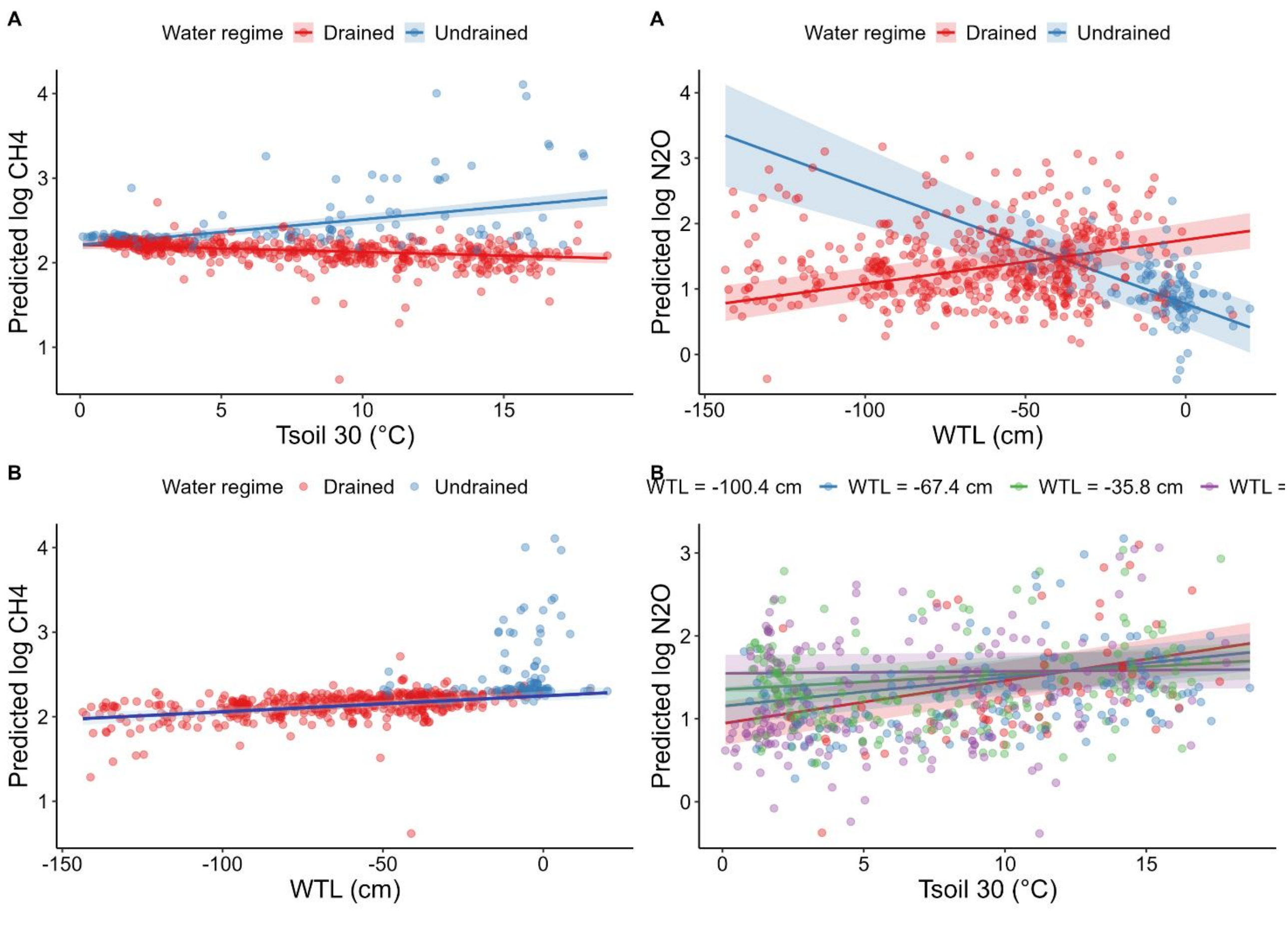

Fig. S3 Prediction effects from the LME models explaining normalized CH_4 and N_2O fluxes. Panel (A) and (B) indicate the selected model outcome according to drainage regime, dominated tree species and the interaction between Tsoil and WTL on CH_4 and N_2O fluxes, respectively. The error bars and shaded area of regression lines represent 95% confidence intervals. The zero scale on the y-axis is equivalent to 2.4 for CH_4 and 1.1 for N_2O fluxes.

Table S1 Site type classification of drained peatland forests based on soil characteristics, and ground vegetation.

Site type	Oxalis	Alnus fen / Birch fen	Myrtillus	Dryopteris
Estonia (Lõhmus, 1981, 2004; Paal, 1997)	Jänesekapsa-kõdusoo *Oxalis* drained swamp	Lodu or madalsoo *Alnus* fen / Birch fen	Mustika-kõdusoo (*Myrtillus* drained swamp)	Sõnajala (Dryopteris)
Latvia (Bušs, 1981)	Oxalidosa turf. mel.	Dryopterioso-caricosa	Myrtillosa turf. Mel.	Dryopteriosa
Lithuania (Petrokas and Manton, 2023)	Oxalido	Fluviale	Myrtillo	Urtico
Characteristics	Well-decomposed, highly productive drained lowland peat soils	High productive, mobile mineral-rich groundwater, and well decomposed peat soils	Developed on drained (usually transitional mire) moderaterly decomposed peat soils	Peat soil in floodplains and river valleys, subjected to nutrient-rich riverine floods and subsurface water.
Forest stands	Picea abies, Pinus sylvestris, Populus tremula or their mixture	Alnus glutinosa, Alnus incana, Betula pendula, Populus tremula	Pinus sylvestris, Betula spp, Abies alba	Betula pendula, Alnus glutinosa, Alnus incana, Picea abies,
Undergrowth	Frangula alnus, Sorbus aucuparia and Prunus padus	Prunus padus, Padus avium, Sorbus aucuparia, Frangula alnus, Salix and Ribes species.	Frangula alnus, Viburnum opulus, Juniperus communis and Salix species.	Padus avium, Ribes spp., Frangula alnus, Lonicera xylosteum, Viburnum opulus Salix, Lonicera and Ribes species.
Ground vegetation	Oxalis, Vaccinium, Urtica, and Carex species.	Molinia, Calamagrostis. Ranunculus, Lysimachia, Lycopus and Carex species.	Vaccinium, Eriophorum, Ledum palustre Phragmites, and Carex species.	Athyrium, Dryopteris, Filipendula, Urtica, and Carex species.
Moss layer	Sphagnum. Polytrichum, Pleurozium, Dicranum, Aulacomnium.	Calliergon, Drepanocladus, Fissidens, Climacium, Plagiomnium, Calliergonella.	Sphagnum, Polytrichum, Pleurozium, Dicranum.	Rhytidiadelphus, Eurhynchium, Climacium, Calliergonella, Plagiomnium., Rhodobryum and Sphagnum spp.
Soil pH at rhizosphere	Moderately acidic to neutral	Slightly acidic	Acidic	Slightly acidic

Table S2 Long-term and mean annual air temperature and precipitation sum for the two-year study periods. Climate variables are calculated from Jan 2021 to Dec 2022 for Estonia and Latvia, and from Nov 2021 to Oct 2023 for Lithuania.

Country	Estonia	Latvia	Lithuania
Annual temperature, °C (1991-2020)	6.3	6.8	7.4
2021	6.4	7.0	8.0
2022	6.9	7.3	8.9
Annual precipitation, mm year $^{-1}$ (1991-2020)	673	686	695
2021	597	676	717
2022	472	685	612

Table S3 Description of the study sites and their locations, dominant tree stands and site type (E Lõhmus 1981), Myrtillus – M, Oxalis – O and Alnus – A for descriptions, see Table 1. The site code indicates the dominant tree stands (A – alder, B – birch, P – pine, S – spruce), drainage status (D – drained, U – undrained) and country (EE= Estonia, LT=Lithuania, LV=Latvia). Annual average temperature (Tsoil_10 and Tsoil_30 °C) of soil layers 10 and 30 cm, and Tsoil_10 of summer, soil moisture (SWC, m^3 m −3). ***Average*** *± SE, median and summer water level depths (WTL, cm), and chemical characteristics of groundwater (pH, SPC and O_2) of each site during the measurement period and the number of sampling events.*

Regime	Site type	Site code	Latitude	Longitude	Sampling period and no. of events	Soil				Water					
						Mean Tsoil_10 (°C)	Summer Tsoil_10 (°C)	Mean Tsoil_30 (°C)	SWC (m^3 m^{-3})	Mean WTL (cm)	Median WTL (cm)	Summer WTL (cm)	pH	SPC (µScm $^{-1}$)	O_2 (%)
Drained	Myrtillus	EE_P	58°25'42"N	26°22'25"E	01/21-12/22 (48)	7.1±1	13.0	7.4±0.8	0.34±0.02	−82.3±1.8	−86.8	−88	5.2	107.0	37.3
	Myrtillus	LV_P1	57°16'8"N	25°59'33"E	01/21-12/21 (12)	5.8±1.6	10.4	6.3±1.2	0.24±0.03	−31.8±2.7	−32.8	−36	4.2	75.7	27.9
	Myrtillus	LV_P2	57°16'11"N	25°59'33"E	01/21-12/21 (12)	5.9±1.5	10.1	6.4±1.2	0.31±0.03	−51.6±3.9	−47.3	−49	5.1	77.9	11.8
	Myrtillus	LT_S	54°47'39"N	24°4'51"E	11/21-10/23 (30)	8.7±1.2	12.9	8.9±0.9	0.25±0.02	−70.2±4.9	−63.8	−77	5.7	130.2	43.5
	Oxalis	EE_B1	58°26'16"N	26°21'21"E	01/21-12/22 (48)	7.2±1	12.9	7.5±0.7	0.31±0.02	−70.3±4.7	−54.0	−91	6.5	397.8	44.9
	Oxalis	EE_B2	58°20'52"N	26°28'34"E	01/21-12/22 (48)	8±1	14.0	8.4±0.8	0.39±0.02	−57.3±2.2	−54.5	−65	6.5	324.1	59.2
	Oxalis	LT_B	54°47'24"N	24°4'49"E	11/21-10/23 (28)	9.4±1.3	14.4	9.3±1	0.29±0.02	−143±2.2	−150.0	−155	NA	NA	NA
	Oxalis	LV_B1	57°19'20"N	26°3'51"E	01/21-12/22 (24)	7.5±1.3	12.8	7.3±1	0.72±0.04	−27.1±5.6	−12.9	−46	6.9	195.7	41.4
	Oxalis	LV_B2	56°41'38"N	25°41'16"E	01/21-12/22 (24)	7.3±1.3	12.2	7.5±1.1	0.42±0.04	−93.6±6.9	−88.2	−107	5.4	156.9	41.6
	Oxalis	LV_P3	56°47'4"N	23°51'45"E	01/21-12/22 (24)	7.4±1.1	11.7	7.5±0.7	0.27±0.02	−112±5.2	−118.4	−120	6.4	207.5	37.0
	Oxalis	EE_S	58°26'19"N	26°21'14"E	01/21-12/22 (24)	7.1±0.9	12.5	7.4±0.7	0.30±0.02	−66.2±3.5	−58.2	−78	6.6	458.5	36.7
	Oxalis	LV_S1	56°59'59"N	24°39'32"E	01/21-12/22 (24)	6.8±1.2	11.7	7.1±0.9	0.33±0.02	−80.2±3.7	−81.8	−92	6.5	290.1	35.1
	Oxalis	LV_S2	56°23'34"N	25°39'13"E	01/21-12/22 (24)	7.3±1.3	12.4	7.5±1	0.43±0.04	−31.4±3.3	−28.4	−39	6.4	157.1	39.8
	Oxalis	LV_S3	56°23'42"N	25°39'5"E	01/21-12/22 (24)	7.6±1.3	13.0	7.6±1	0.36±0.04	−41.9±3.7	−36.3	−52	6.3	214.8	13.2
	Oxalis	LV_S4	57°20'14"N	26°1'35"E	01/21-12/21 (12)	6.6±1.6	11.2	6.8±1.3	0.61±0.04	−31.4±5.5	−27.9	−40	6.2	127.2	7.7
	Oxalis	LV_S5	57°20'50"N	25°55'32"E	01/21-12/21 (12)	6.1±1.7	11.0	6.3±1.4	0.33±0.04	−53.3±7.2	−48.9	−68	6.3	92.6	45.0
	Alnus	EE_A	58°25'1"N	26°29'4"E	01/21-12/22 (48)	7.4±0.9	12.5	7.6±0.7	0.42±0.02	−29.4±1.8	−35.7	−33	6.6	429.6	7.6
	Alnus	LT_A	54°47'35"N	24°4'28"E	11/21-10/23 (30)	9.1±1.2	14.1	9.2±1	0.36±0.03	−65.6±6.1	−54.1	−71	6.3	726.1	45.1
Undrained	Dryopteris	LT_UA	54°32'28"N	23°36'41"E	11/21-10/22 (12)	10.8±1.7	15.3	10.4±1.5	0.96±0.01	−1.7±3.8	−2.8	−1	6.7	436.9	29.0
	Dryopteris	LV_UA	56°34'26"N	24°49'46"E	01/21-12/22 (24)	7.6±1.3	12.8	7.5±1	0.85±0.03	−8.4±3.2	−1.2	−16	6.5	145.1	31.9
	Dryopteris	LT_UB	54°32'38"N	23°33'57"E	11/21-10/22 (12)	10.7±1.7	15.4	10.4±1.5	0.97±0.01	−1.5±3.2	−1.8	−1	6.5	392.1	38.2
	Dryopteris	LV_UB1	57°17'26"N	25°59'55"E	01/21-12/22 (24)	6.9±1.2	12.1	6.9±1.1	0.74±0.05	−9.8±2.8	−3.7	−17	6.0	106.5	37.3
	Dryopteris	LV_UB2	57°16'45"N	25°51'13"E	01/21-12/21 (12)	6±1.9	11.2	5.9±1.5	0.59±0.07	−11.9±3.6	−7.0	−16	6.6	151.4	27.9
	Dryopteris	LV_US1	57°16'44"N	25°51'16"E	01/21-12/21 (12)	6.2±1.9	11.3	6.1±1.5	0.55±0.08	−11.8±4.4	−5.0	−13	6.7	151.3	11.8
	Dryopteris	LV_US2	57°18'42"N	25°56'10"E	01/21-12/21 (12)	6.4±1.8	11.9	6.4±1.6	0.55±0.06	−15.3±3.6	−10.1	−22	7.1	215.6	43.5

Table S4 Site level chemical contents (Mean ± SD) of soil layers at 0-20 cm depths. Abbreviations details for study sites Table S3, and chemical parameters listes in Table S5

Site code	Peat depth	BD (kg m $^{-3}$)	Corg (g kg $^{-1}$)	C/N	Ctot (g kg $^{-1}$)	N_{Tot} (g kg $^{-1}$)	Ca (g kg $^{-1}$)	pH	Mg (g kg $^{-1}$)	P (g kg $^{-1}$)	K (g kg $^{-1}$)	Ash %
EE_P	93	143 ± 52	471 ± 3	24 ± 1.4	528 ± 6	19.6 ± 1.2	12.7 ± 2.5	3.4 ± 0.1	770 ± 80	555 ± 82	332 ± 124	5.8 ± 0.6
LV_P1	165	147 ± 42	480 ± 8	31.8 ± 4.6	539 ± 15	15.4 ± 1.9	1.4 ± 0.5	2.4 ± 0.1	445 ± 194	517 ± 125	333 ± 186	4 ± 1.6
LV_P2	138	433 ± 539	339 ± 221	28.5 ± 5.5	384 ± 248	11 ± 6.7	1.1 ± 1	2.6 ± 0.4	362 ± 275	332 ± 181	523 ± 249	32.1 ± 44.2
LT_S	120	206 ± 22	446 ± 38	25.3 ± 6.1	538 ± 52	18.4 ± 3.2	3.5 ± 0.8	2.7 ± 0.2	530 ± 107	448 ± 195	346 ± 220	10.7 ± 7.5
EE_B1	76	232 ± 21	418 ± 2	14.5 ± 0.5	488 ± 6	28.6 ± 1	43.6 ± 1.9	5.5 ± 0.2	908 ± 39	695 ± 185	245 ± 108	16.4 ± 0.4
EE_B2	95	211 ± 14	432 ± 7	14.5 ± 0.8	502 ± 11	29.6 ± 1.5	43.6 ± 4.7	5.2 ± 0.4	2363 ± 542	863 ± 167	138 ± 56	13.6 ± 1.5
LT_B	150	201 ± 22	426 ± 31	20.6 ± 4.3	494 ± 42	21.2 ± 3.1	13.5 ± 12.8	3.4 ± 0.8	846 ± 402	512 ± 183	641 ± 371	14.7 ± 6.2
LV_B1	90	236 ± 47	377 ± 44	13.3 ± 1.2	420 ± 64	28 ± 4.2	13.5 ± 1.2	5.8 ± 0.2	1878 ± 212	2545 ± 769	640 ± 112	24.7 ± 8.8
LV_B2	56	219 ± 20	458 ± 5	17.2 ± 1.7	526 ± 6	26.8 ± 2.4	13.7 ± 1.7	3.7 ± 0.2	1533 ± 486	735 ± 114	477 ± 130	8.4 ± 0.9
LV_P3	28	487 ± 425	235 ± 154	16 ± 2.9	274 ± 183	15.4 ± 11.8	3.4 ± 1.8	3.5 ± 0.3	305 ± 179	798 ± 608	545 ± 59	52.7 ± 30.6
EE_S	87	212 ± 19	421 ± 1	14.2 ± 0.4	478 ± 5	29.6 ± 0.8	40.9 ± 2.5	5.4 ± 0.2	1050 ± 68	812 ± 173	312 ± 122	15.8 ± 0.4
LV_S1	50	245 ± 22	438 ± 15	15.5 ± 1.4	526 ± 24	28.1 ± 1.3	16.9 ± 9.2	4.1 ± 0.7	688 ± 321	1395 ± 330	385 ± 107	12.5 ± 3.1
LV_S2	86	184 ± 6	430 ± 11	16.5 ± 2.7	511 ± 22	26.2 ± 3.4	24.5 ± 1.7	5.3 ± 0.1	2637 ± 300	885 ± 292	280 ± 111	14.1 ± 2.2
LV_S3	95	212 ± 32	414 ± 45	17.5 ± 2.7	481 ± 66	24 ± 3.6	18.5 ± 6.6	4.8 ± 0.7	2118 ± 553	880 ± 224	445 ± 263	17.1 ± 9.1
LV_S4	68	161 ± 11	453 ± 11	14 ± 1.3	531 ± 21	32.3 ± 2.7	17.2 ± 4.8	4.2 ± 0.6	737 ± 204	983 ± 339	525 ± 277	9.4 ± 2.3
LV_S5	212	156 ± 21	462 ± 7	23.2 ± 2.8	524 ± 41	20.1 ± 2.1	9.7 ± 4.1	3.4 ± 0.3	1205 ± 424	522 ± 113	385 ± 330	7.7 ± 1.4
EE_A	35	464 ± 173	151 ± 69	10.7 ± 0.5	177 ± 76	14 ± 6.1	18.7 ± 6.6	5.6 ± 0.2	1795 ± 373	962 ± 285	580 ± 92	69.8 ± 13.8
LT_A	120	357 ± 107	312 ± 68	14.2 ± 1.4	356 ± 75	21.7 ± 4.5	25.2 ± 6	4.7 ± 0.8	2189 ± 176	1224 ± 270	1671 ± 310	37.4 ± 13.4
LT_UA	130	204 ± 27	380 ± 7	13 ± 0	432 ± 17	29.4 ± 0.7	34.9 ± 3.3	5.6 ± 0.2	3117 ± 254	1183 ± 85	2045 ± 598	24 ± 1.4
LV_UA	100	168 ± 34	334 ± 87	11.3 ± 1.8	406 ± 77	29.7 ± 5.7	23.2 ± 5.6	5.4 ± 0.1	2362 ± 432	4505 ± 3393	685 ± 431	33.3 ± 17.5
LT_UB	140	216 ± 20	372 ± 28	12.5 ± 0.8	426 ± 42	29.5 ± 0.9	33.1 ± 3.1	5.6 ± 0.2	3413 ± 732	1228 ± 260	2273 ± 784	25.6 ± 5.6
LV_UB1	230	140 ± 46	432 ± 15	20.3 ± 1.5	436 ± 18	21.3 ± 1.7	16.4 ± 4.6	5.1 ± 0.1	1755 ± 385	925 ± 375	615 ± 319	13.5 ± 2.7
LV_UB2	134	154 ± 20	425 ± 11	16.5 ± 1.4	478 ± 21	26 ± 1.9	33.7 ± 2.1	5.3 ± 0.1	2482 ± 273	1327 ± 421	1128 ± 362	15 ± 2.2
LV_US1	205	195 ± 33	399 ± 18	18.5 ± 4.2	449 ± 33	22.2 ± 3	30 ± 3	5.3 ± 0.1	2905 ± 249	1377 ± 283	1763 ± 430	20.2 ± 3.6
LV_US2	221	140 ± 16	425 ± 14	14 ± 1.1	479 ± 17	30.6 ± 2.3	21.2 ± 3.2	4.8 ± 0.1	1233 ± 186	2350 ± 543	540 ± 61	14.9 ± 2.8

Table S5 Soil characteristics in the drained (n=18) and undrained (n=7) sites with different dominant tree stands. Soil physical parameters, WTL - water level depth; SWC - soil water content; Tsoil - temperature at depths 10 and 30 cm, and soil-water parameters, SPC - specific conductivity; pH; O_2 - oxygen content are reported as means (± SE) over the entire measurement period. Soil chemical variables are means (± SE) for soil layers at 0-20 cm depths, expressing BD, bulk density; Corg, soil organic carbon; Ctot and Ntot, total carbon and nitrogen; Ca, calcium; Mg, magnesium; K, potassium; P, phosphorous; SPC, specific conductance; O_2, dissolved oxygen concentration.

Variable	Drained				Undrained		
	Alder	Birch	Pine	Spruce	Alder	Birch	Spruce
Soil physical properties							
WTL (cm)	-42 ± 1.3^{A}	-77 ± 1.5^{B}	-80 ± 1.3^{C}	-58 ± 0.9^{D}	-6.2 ± 1.2^{a}	-8.3 ± 0.8^{b}	-13.6 ± 1.2^{c}
SWC ($m^3\ m^{-3}$)	0.40 ± 0.01^{A}	0.39 ± 0.01^{A}	0.30 ± 0.01^{B}	0.34 ± 0.01^{C}	0.88 ± 0.01^{a}	0.74 ± 0.02^{b}	0.55 ± 0.02^{c}
Tsoil 10 cm	8.0 ± 0.3^{A}	7.8 ± 0.2^{AB}	6.9 ± 0.3^{C}	7.3 ± 0.2^{BC}	8.7 ± 0.4^{a}	7.6 ± 0.4^{b}	6.3 ± 0.5^{b}
Tsoil 30 cm	8.1 ± 0.2^{A}	8.0 ± 0.2^{AB}	7.2 ± 0.2^{C}	7.5 ± 0.2^{BC}	8.5 ± 0.3^{a}	7.5 ± 0.3^{b}	6.3 ± 0.4^{b}
Soil water properties							
Twater (°C)	7.7 ± 0.3^{A}	7.2 ± 0.1^{A}	6.5 ± 0.1^{B}	7.5 ± 0.1^{A}	9.3 ± 0.3^{a}	7.8 ± 0.3^{b}	6.5 ± 0.4^{c}
SPC (μScm^{-1})	583 ± 18.8^{A}	318 ± 6.1^{B}	120 ± 3.6^{C}	258 ± 5.5^{D}	229 ± 11.8^{a}	183 ± 8.9^{b}	183 ± 6.2^{a}
pHwater	6.43 ± 0.04^{A}	6.37 ± 0.03^{A}	5.25 ± 0.06^{B}	6.33 ± 0.03^{A}	6.57 ± 0.05^{a}	6.27 ± 0.05^{b}	6.7 ± 0.06^{a}
O_2 (%)	24.9 ± 1.5^{A}	35.9 ± 1.0^{B}	42.0 ± 1.3^{C}	34.5 ± 0.8^{B}	33.9 ± 2.1^{a}	32.4 ± 1.7^{a}	35.1 ± 2.1^{a}
Soil chemical properties							
BD ($kg\ m^{-3}$)	393 ± 32^{A}	217 ± 5^{B}	302 ± 74^{AB}	198 ± 5^{B}	186 ± 10^{a}	170 ± 11^{a}	168 ± 11^{a}
C_{tot} ($g\ kg^{-1}$)	296 ± 27^{A}	487 ± 8^{B}	431 ± 37^{B}	516 ± 6^{B}	419 ± 16^{a}	446 ± 8^{a}	464 ± 9^{a}
C_{org} ($g\ kg^{-1}$)	259 ± 24^{A}	423 ± 6^{B}	381 ± 33^{B}	439 ± 4^{B}	357 ± 18^{a}	409 ± 8^{b}	412 ± 6^{b}
N_{tot} ($g\ kg^{-1}$)	19.1 ± 1.4^{A}	25.9 ± 0.7^{B}	15.3 ± 1.5^{A}	24.6 ± 0.8^{B}	29.6 ± 1.1^{a}	25.6 ± 0.9^{b}	26.4 ± 1.5^{ab}
C/N ratio	13.1 ± 0.5^{A}	16.8 ± 0.7^{B}	25.1 ± 1.4^{C}	18.9 ± 0.8^{B}	12.2 ± 0.4^{a}	16.4 ± 0.8^{b}	16.2 ± 1.1^{b}
$pH_{KCl\ soil}$	5 ± 0.2^{A}	4.5 ± 0.2^{AB}	3 ± 0.1^{C}	4.1 ± 0.2^{B}	5.5 ± 0.1^{a}	5.3 ± 0.1^{b}	5.1 ± 0.1^{b}
Ca ($g\ kg^{-1}$)	23 ± 1.6^{A}	23.6 ± 2.7^{A}	4.7 ± 1^{B}	16.8 ± 1.8^{A}	29 ± 2.2^{a}	27.8 ± 2.1^{a}	25.6 ± 1.6^{a}
Mg ($mg\ kg^{-1}$)	2058 ± 74^{A}	1396 ± 116^{B}	470 ± 53^{C}	1187 ± 114^{B}	2739 ± 150^{a}	2550 ± 199^{a}	2069 ± 259^{a}
K ($mg\ kg^{-1}$)	1307 ± 138^{A}	464 ± 51^{B}	433 ± 39^{B}	378 ± 32^{B}	1365 ± 250^{a}	1339 ± 205^{a}	1152 ± 203^{a}
P ($mg\ kg^{-1}$)	1137 ± 70^{A}	977 ± 132^{B}	550 ± 71^{C}	796 ± 55^{B}	2844 ± 829^{a}	1160 ± 90^{b}	1863 ± 189^{a}
Ash (%)	48.2 ± 4.8^{A}	15.4 ± 1.1^{B}	23.7 ± 6.6^{B}	12.2 ± 0.8^{B}	28.7 ± 3.7^{a}	18 ± 1.6^{b}	17.5 ± 1.2^{b}

*Letters indicate pairwise significant differences

Table S6 Hourly mean ± standard error, season-specific mean ($\mu g\ m^{-2}\ h^{-1}$) and cumulative annual ($kg\ ha^{-1}\ y^{-1}$) CH_4 and N_2O fluxes at the drained and undrained study sites. Year I and II present measurement years; n represents the number of sampling days, Nov-Apr = Non-growing and May-Oct=Growing. (see Table S2 for study sites) .

Site code	Year	n	Mean CH_4	Non−growing, Growing	Ann−ual	n	Mean N_2O	Non−growing, Growing	Ann−ual
EE_P	I	143	−59.8 ± 2	−51.1, −68.5	−4.9	144	27.3 ± 2.1	15.8, 38.9	2.4
	II	144	−62.6 ± 2.9	−33.2, −92	−5.4	142	52.5 ± 4.3	32.1, 72.8	4.5
LV_P1	I	53	−17.6 ± 1.9	−16.1, −19.2	−1.5	60	0.1 ± 0.7	0, 0.2	0.0
LV_P2	I	56	−19.5 ± 4.5	−6.5, −32.5	−1.4	60	−0.3 ± 0.8	−0.2, −0.3	0.0
LT_S	I	76	−39.9 ± 3.9	−25.4, −49.9	−2.8	85	15.5 ± 3.2	9.1, 20.1	1.2
	II	60	−25.3 ± 14.3	6.4, −53	−2.3	64	8.9 ± 1.7	5.4, 11.8	0.7
EE_B1	I	142	−76.4 ± 2.4	−55.6, −96.6	−6.3	144	21.6 ± 2.4	25.9, 17.4	1.9
	II	141	−70.5 ± 3.4	−35.6, −103.9	−6.0	139	12 ± 1.2	12.9, 11.2	1.1
EE_B2	I	141	−46.9 ± 2.6	−31.6, −62.1	−3.9	144	17.4 ± 2	16.4, 18.5	1.5
	II	141	−44.5 ± 2.5	−23.2, −65.5	−3.7	142	11.7 ± 1.9	19, 4.4	0.9
LT_B	I	74	−70.9 ± 5.2	−35.6, −97.8	−5.1	78	429 ± 72.5	71.4, 706	31.0
	II	58	−104 ± 7.6	−65.7, −142.3	−8.3	60	97.6 ± 18.4	64.7, 130	7.8
LV_B1	I	56	−12.2 ± 6.1	−9, −15.9	−0.8	59	8.8 ± 3.6	2.7, 15.2	0.7
	II	56	−19.1 ± 7.8	−6.8, −31.4	−1.5	57	11 ± 5	1.8, 21.3	0.9
LV_B2	I	60	−101 ± 6.6	−65.6, −136.9	−8.2	58	113 ± 23.2	28.9, 192	9.6
	II	53	−103 ± 7.5	−68.8, −129.4	−7.1	53	303 ± 71.1	35.3, 509	23.1
LV_P3	I	60	−65.3 ± 5.6	−58.6, −71.9	−5.2	59	4.1 ± 1.4	0.1, 7.8	0.3
	II	57	−70.1 ± 6.6	−59.4, −82	−5.6	57	2.8 ± 1.2	0.5, 5	0.3
EE_S	I	143	−57.6 ± 2.2	−45.1, −70.3	−4.8	143	25.5 ± 4.5	22, 28.9	2.2
	II	139	−60.9 ± 2.8	−35, −84.9	−5.0	143	30.3 ± 3.6	25.2, 35.3	2.7
LV_S1	I	59	−82.5 ± 6.7	−66.2, −98.3	−6.6	59	14.7 ± 2.4	8.6, 20.6	1.2
	II	54	−87.3 ± 7.1	−69.4, −104	−6.9	58	46.1 ± 5.7	48.6, 43.7	3.8
LV_S2	I	59	−67 ± 4.9	−50, −83.5	−5.4	57	140 ± 22.6	85.4, 197	13.0
	II	57	−70.9 ± 8	−69.9, −71.9	−5.3	58	70.7 ± 17	75.8, 65.5	5.6
LV_S3	I	60	−60 ± 3.1	−45.6, −74.4	−4.9	60	73.4 ± 7.7	62.1, 84.8	6.1
	II	58	−66.5 ± 5.4	−70, −62.9	−5.1	56	33.1 ± 4.3	38.6, 26.7	2.5
LV_S4	I	55	−8.7 ± 6.2	−14, −3.7	−0.8	57	112 ± 20.9	123.1, 100	9.8
LV_S5	I	60	−69.4 ± 4.8	−46.2, −92.6	−5.7	59	2.1 ± 1	2.3, 1.8	0.2
EE_A	I	139	−61.5 ± 2.7	−41.2, −80.3	−5.1	144	30.4 ± 5.9	36.8, 23.9	2.9
	II	144	−54.4 ± 3	−30.1, −78.8	−4.6	142	20.2 ± 3.5	21.3, 19.1	1.8
LT_A	I	75	−34.8 ± 5.2	−42.7, −28.9	−2.9	77	583 ± 60.8	264.4, 835	42.7
	II	63	−47.2 ± 5	−37.1, −57	−4.3	68	84.9 ± 15.2	83.1, 86.6	5.6
LT_UA	I	55	1008 ± 343	143.1, 2047	120.0	60	15.2 ± 4.5	8.2, 22.2	1.0
LV_UA	I	57	13.2 ± 8.5	−0.9, 28.9	1.3	60	23.2 ± 7.4	4, 42.5	2.0
	II	56	16.1 ± 7.1	−6.4, 40.2	1.6	59	10.6 ± 2.8	8.6, 12.6	0.9
LT_UB	I	53	922 ± 325	42.9, 2069	93.3	60	7.2 ± 2.3	1.6, 12.8	0.5
LV_UB1	I	58	924 ± 410	19.1, 1830	79.3	59	61.8 ± 15.9	5.2, 116.5	5.5
	II	54	201 ± 79.4	13.5, 403	16.4	54	9.9 ± 2.8	2, 17.9	0.8
LV_UB2	I	53	46.1 ± 25.4	7.4, 89.5	3.6	59	4.5 ± 1.9	1.8, 7.3	0.4
LV_US1	I	58	275 ± 106	108, 431	20.8	58	5.9 ± 2.2	0.3, 11.8	0.6
LV_US2	I	57	78.2 ± 43.8	6.5, 147	7.7	59	7.4 ± 2.3	1.2, 13.4	0.7

Table S7 Detailed estimates of the individual mixed model effect on normalized CH_4 and N_2O hourly mean fluxes, fixed effects were soil temperature, water table level depth, and drainage regime (DF, UF). Random effects were sites, measurement years, and sampling events.

	log10 CH_4			**log10 N_2O**		
Predictors	Estimates	CI	R^2	Estimates	CI	R^2
(Intercept)	2.24 ***	2.15 – 2.33	-	1.24 ***	1.02 – 1.46	-
Tsoil	-0.005 ***	-0.01 – -0.01	0.007	0.02 ***	0.02 – 0.03	0.03
WTL	0.003 ***	0.00 – 0.00	0.30	0.001 ***	0.00 – 0.01	0.005
Drainage	0.39 ***	-0.06 – 0.03	0.29	-0.45 ***	-0.82 – -0.09	0.07
Random Effects						
σ^2		0.02		0.10		
$\tau_{00\ Sitecode}$		0.01		0.19		
$\tau_{00\ annual\ year}$		0.00		0.01		
$\tau_{00\ Day\ index}$		0.01		0.06		
$N_{Sitecode}$		25		25		
$N_{Annual\ year}$		2		2		
$N_{Day\ index}$		228		228		
$N_{Observations}$		609		609		

*Estimates of significance are shown as; *** $p<0.001$ and CI= 95% confidence interval*

Table S8. Soil annual mean (± SE) and median CH_4 and N_2O emissions (kg ha^{-1} y^{-1}) across sites with different dominant tree species on drained and undrained soils.

Drainage	Drained				Undrained		
Stands	Alder	Birch	Pine	Spruce	Alder	Birch	Spruce
n	4	10	6	12	3	4	2
CH_4	−4.2 ± 0.5 (−4.42)	−5.1 ± 0.8 (−5.54)	−3.9 ± 0.8 (−5.04)	−4.6 ± 0.5 (−5.05)	40.9 ± 39 (1.57)	48.1 ± 22.4 (47.83)	14.2 ± 6.5 (14.24)
N_2O	13.3 ± 9.8 (4.24)	7.9 ± 3.4 (1.69)	1.2 ± 0.7 (0.29)	4.1 ± 1.1 (2.60)	1.3 ± 0.4 (1.03)	1.8 ± 1.2 (0.63)	0.6 ± 0.02 (0.65)

Table S9 Results of linear mixed-effect models explaining normailzed annual emissions of CH_4 and N_2O as response variables. Fixed effects were drainage regime (drained, undrained), tree stands *(alder, birch, spruce, pine), soil temperature 30 cm (Tsoil, °C;), soil water-table level (WTL, cm),* soil water specific conductivity (SPC, *$\mu S\ cm^{-1}$*), stand age, peat depth *and soil chemical properties of 0-20 cm depth (*pH*, organic C, potassium (K), magnesium (Mg)).* Predictor varaibles are arranged by higher marginal R^2 values and s*ignificant ($p<0.05$) and near-significant effects ($p<0.1$) were retained.*

Annual CH_4					Annual N_2O				
Predictor	Estimate	Std. Error	p-value	R^2	Predictor	Estimate	Std. Error	p-value	R^2
WTL	0.004	0.001	<0.001	48.0	Site_type	-0.551	0.211	0.02	27.0
Site_type	0.208	0.094	0.04	43.8	Drainage × Stands	-0.514	0.279	0.08	26.3
Drainage × Stands	0.236	0.126	0.08	41.6	Drainage	-0.305	0.126	0.02	15.6
Drainage	0.273	0.054	<0.001	39.7	Stand age	-0.003	0.002	0.07	10.1
K	0.000	0.000	<0.001	24.0	Peat depth	-0.002	0.001	0.10	7.9
Peat depth	0.002	0.001	0.01	18.3	SPC	0.001	0.000	0.07	6.5
Mg	0.000	0.000	0.01	15.6	WTL	-0.002	0.001	0.10	5.7
pHsoil	0.065	0.026	0.02	13.1	Tsoil	0.036	0.015	0.02	4.6
O_2	-0.004	0.002	0.00	11.1	C_{Org}	0.001	0.000	0.10	1.9

Table S10. Estimates of the model fit on the annual CH_4 and N_2O fluxes of all sites DF and UF measured per year.

Model	n	Equation	Beta	Beta1	Resid./ R^2	p-value
log (CH_4+10)	40	Y=log(a*exp(b*WTL))	1.53 ± 0.1	0.008 ± 0.001	0.26	<0.001
log (N_2O+1)	40	Y=log(a*dnorm(CN, mean, sd) mean=18.5 ± 0.8, sd = 4.8 ± 1.0	9.69 ± 1.6	-	0.37	<0.001

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