Biogeosciences

Supplement of

Lawns and meadows in urban green space – a comparison from perspectives of greenhouse gases, drought resilience and plant functional types

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Table S1. Main soil characteristics of each intensive site and satellite plot (NA = non-available). The particle distribution was originally determined for Finnish classification and therefore, approximations were made for sand (0.06–2.0 mm), silt (0.002–0.06 mm) and clay (< 0.002 mm). Year = year of sample collections. CEC = Cation exchange capacity.

| Experiment	Location	Management	Year	Soil texture	Physical characteristics				Chemical characteristics			
					Soil density (kg m^{-3})	sand (%)	silt (%)	clay (%)	pH	CEC (cmol kg^{-1})	K (mg L^{-1})	P (mg L^{-1})
Intensive	KMP	lawn	2021	Sandy loam	873	72.2	25.6	2.2	6.3	NA	220	18.0
		meadow	2021	Sandy loam	3166	72.4	17.1	10.5	6.1	NA	120	3.8
	VKI	lawn	2020	Sandy loam	865	69.5	22.1	8.4	5.6	NA	97	12.0
		meadow	2021	Sandy loam	2265	59.1	31.8	9.1	6.5	NA	230	380.0
Satellite	JMT-3	lawn	2022	Silt loam	NA	5.2	68.9	26.0	5.3 (± 0.1)	20.3 (± 1.3)	220 (± 50)	4.6 (± 0.6)
		meadow	2022	Loamy sand	NA	73.7	23.5	2.8	6.5 (± 0.2)	15.8 (± 0.5)	84 (± 11)	1.9 (± 0.4)
	JMT-7	lawn	2022	Loamy sand	NA	82.7	14.9	2.4	6.5 (± 0.1)	16.5 (± 1.3)	150 (± 22)	26.5 (± 1.7)
		meadow	2022	Loamy sand	NA	81.4	16.0	2.6	6.5 (± 0.2)	14.8 (± 1.7)	155 (± 21)	23.3 (± 2.1)
	KO-4	lawn	2022	Sandy loam	NA	66.2	29.4	4.4	6.4 (± 0.3)	15.3 (± 1.5)	73 (± 4)	2.2 (± 0.3)
		meadow	2022	Sandy loam	NA	63.3	32.7	4.0	6.1 (± 0.4)	13.8 (± 1.3)	125 (± 17)	5.2 (± 3.4)
	PK-3	lawn	2022	Sandy loam	NA	68.8	27.6	3.6	6.2 (± 0.1)	14.5 (± 1.3)	92 (± 4)	2.2 (± 0.5)
		meadow	2022	Sandy loam	NA	68.4	27.1	4.5	6.1 (± 0.1)	15.0 (± 2.2)	99 (± 14)	2.8 (± 0.4)
	SK-1	lawn	2022	Sandy loam	NA	57.3	33.9	8.8	5.6 (± 0.1)	15.5 (± 1.3)	125 (± 17)	3.3 (± 0.7)
		meadow	2022	Sandy loam	NA	54.1	36.5	9.4	5.4 (± 0.0)	13.3 (± 1.3)	163 (± 28)	4.0 (± 0.5)
	SMT-12	lawn	2022	Loam	NA	47.7	42.7	9.7	5.8 (± 0.1)	11.3 (± 1.3)	155 (± 19)	5.6 (± 1.9)
		meadow	2022	Loam	NA	51.8	39.6	8.6	6.1 (± 0.2)	16.5 (± 0.6)	160 (± 29)	5.3 (± 1.5)

Table S2. Measurement campaign timeline.

Total number of TER measurements (total number of GPP measurements, number of quality-controlled GPP measurements) measured with the LI-COR device at the intensive sites. All TER measurements passed the quality control.

Total number of TER, CH_4 and N_2O measurements (−number of TER measurements removed in the quality control, if any) measured with the Gasmet device at the satellite sites. All CH_4 and N_2O measurements passed the quality control.

Total number of TER measurements measured with the Vaisala device at the satellite sites. All measurements passed the quality control.
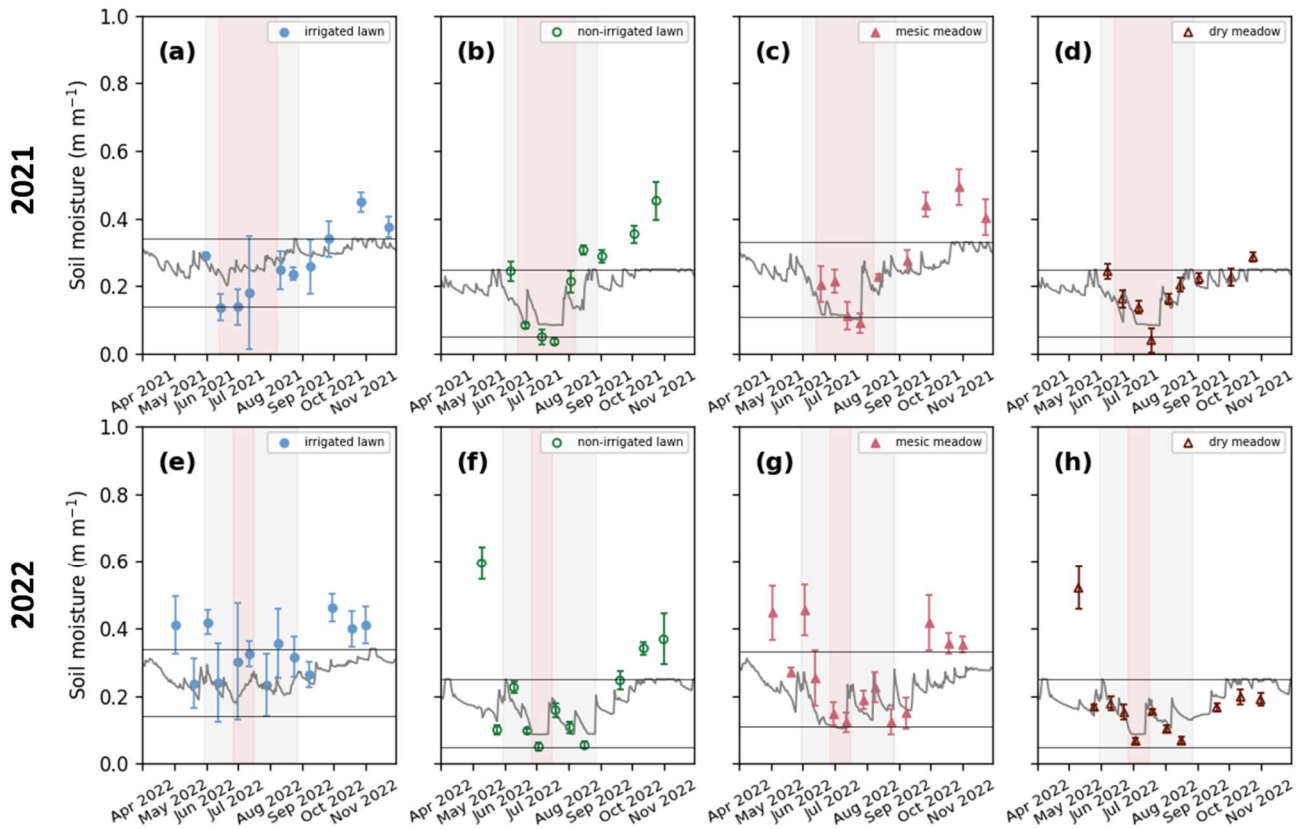
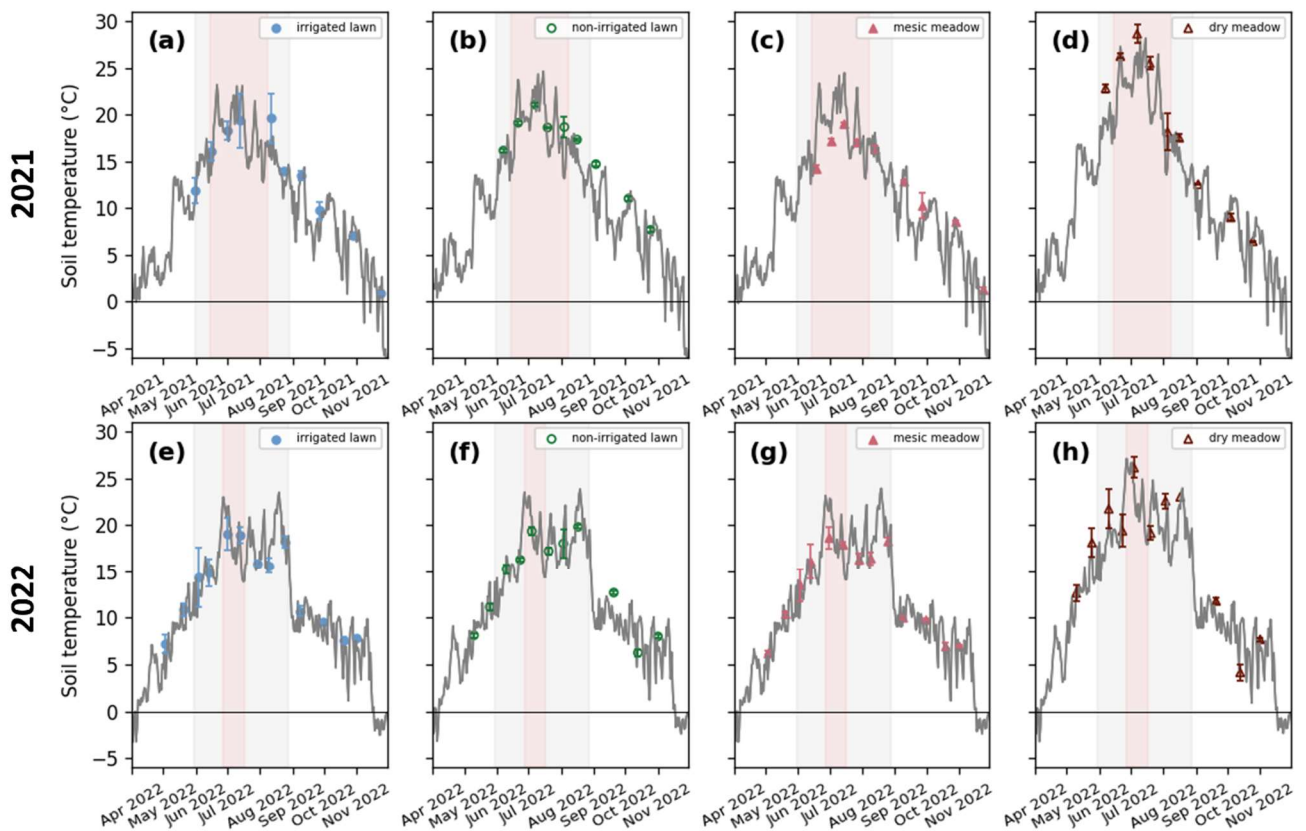| | | Intensive sites | | | | Satellite sites | | | | | | | | | | | |
| | | KMP | | VKI | | JMT3 | | JMT7 | | KO4 | | PK3 | | SK1 | | SMT12 | |
Year	Week	lawn	meadow	lawn	meadow	lawn	meadow	lawn	meadow	lawn	meadow	lawn	meadow	lawn	meadow	lawn	meadow
2020	29					4	4	4	4	4	4	4	4	4	4	4	4
	34					4	4	4	4	4	4 (−2)	4	4 (−1)	4	4	4	4
	41					4	4	4	4	4	4	4	4	4	4	4	4
	Total					12	12	12	12	12	12 (−2)	12	12 (−1)	12	12	12	12
2021	20					4	4	4	4	4	4	4	4	4	4	4	4
	23	3 (3, 3)	3 (3, 3)														
	24			4 (4, 4)	4 (4, 3)					4	4	4	4				
	25	4 (4, 4)	4 (4, 4)			4	4	4	4					4	4	4	4
	26			4 (4, 3)	4 (4, 2)												
	27	4 (4, 4)	3 (3.3)														
	28			4 (4, 4)	4 (4, 2)	4	4	4	4	4	4	4	4	4	4	4	4
	29	4 (4, 2)	4 (4, 4)														
	30			4 (4, 4)	4 (4, 4)												
	31		4 (4, 3)														
	32			4 (4, 2)	4 (4, 4)												
	33	4 (2, 2)	3 (1, 2)			4	4	4	4	4	4	4	4	4	4	4	4
	34			4 (4, 4)	3 (2, 2)												
	35	2 (1, 1)															
	36			4 (0, 0)	4 (0, 0)												
	37	4 (0, 0)	4 (0, 0)														
	38					4	4	4	4 (−1)	4	4	4	4	4	4	4 (−2)	4
	40	4 (3, 2)	3 (3, 3)														
	41			4 (0, 0)	4 (0, 0)												
	44	4 (4, 4)	4 (0, 0)	4 (0, 0)	4 (0, 0)												
	48	4 (0, 0)	4 (0, 0)														
	Total	37 (27, 14)	36 (24, 17)	36 (24, 20)	35 (22, 17)	20	20	20	20 (−1)	20	20	20	20	20	20	20 (−2)	20
2022	19	4 (0, 0)	4 (1, 1)														
	20			4 (4, 3)	4 (4, 1)	4	4	4	4	4	4 (−2)	4	4 (−1)	4	4	4	4 (−1)
	21	4 (4, 4)	4 (4, 2)														
	22			4 (4, 4)	4 (4, 4)												
	23	2 (1, 1)	4 (2, 2)														
	24			4 (4, 4)	4 (4, 4)	4	4	4	4	4	4	4	4	4	4	4	4
	25	4 (4, 4)	4 (3, 3)														
	26			4 (4, 4)	4 (3, 3)												
	27	4 (3, 3)	4 (4, 4)														
	28			4 (4, 4)	4 (4, 4)	4 (−1)	4 (−1)	4	4 (−2)	4	4	4	4 (−1)	4 (−1)	4 (−1)	4	4 (−1)
	29	4 (0, 0)	4 (0, 0)														
	30			4 (4, 4)	4 (4, 4)												
	31	4 (3, 3)	3 (1, 1)														
	32			4 (4, 3)	4 (4, 4)												
	33	5 (4, 4)	4 (2, 2)			4	4	4	4	4	4	4	4	4	4	4	4
	34			4 (4, 4)	4 (1, 1)												
	35	4 (0, 0)	4 (4, 1)														
	37	4 (3, 3)	4 (0, 0)														
	38					4	4	4 (−1)	4 (−1)					4	4 (−3)	4	4
	39			4 (4, 0)	4 (4, 0)					4	4	4	4				
	40	4 (0, 0)	4 (0, 0)														
	42			4 (0, 0)	4 (0, 0)												
	43	4 (2, 1)	4 (1, 1)														
	45	4 (0, 0)	4 (0, 0)	4 (0, 0)	4 (0, 0)												
	Total	51 (24, 15)	51 (22, 16)	44 (36, 30)	44 (32, 25)	20 (−1)	20 (−1)	20 (−1)	20 (−3)	20	20 (−2)	20	20 (−2)	20 (−1)	20 (−4)	20	20 (−2)
Total over 3 years		88 (51, 29)	87 (46, 33)	80 (60, 50)	79 (54, 42)	52 (−1)	52 (−1)	52 (−1)	52 (−4)	52	52 (−4)	52	52 (−3)	52 (−1)	52 (−4)	52 (−2)	52 (−2)
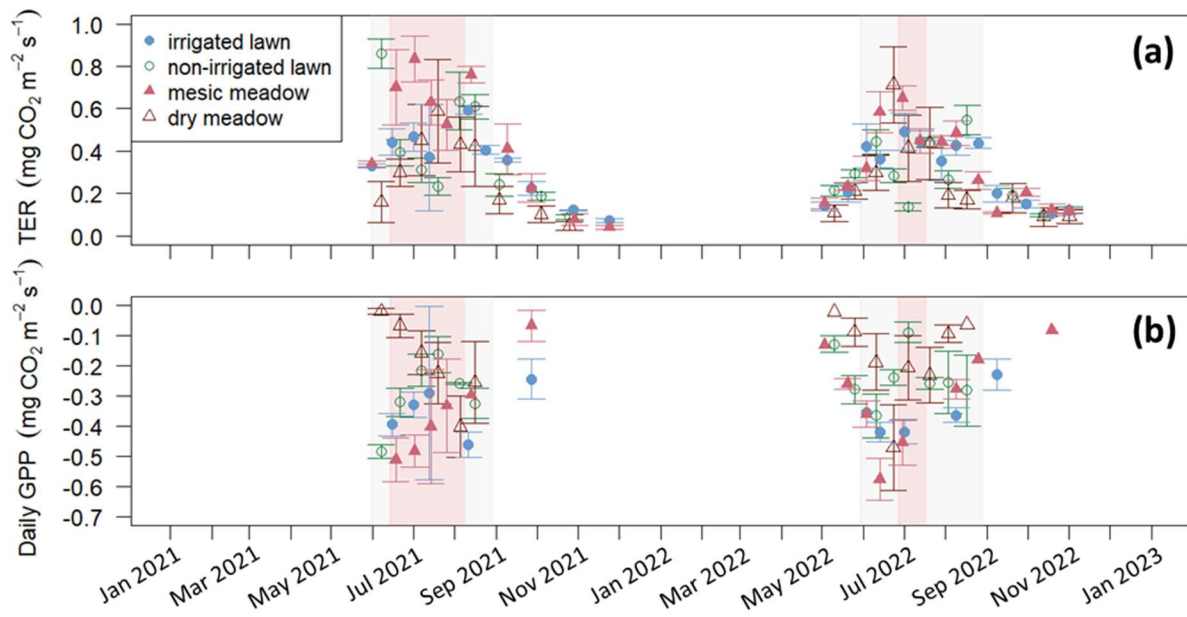
Figure S1. Dynamics of the measured TER (a) and calculated daily GPP (b), where the irrigated lawn is KMP lawn, the non−irrigated lawn is VKI lawn, the mesic meadow is KMP meadow, and the dry meadow is VKI meadow. Red rectangles indicate the drought periods according to the SPEI and light grey rectangles represent the summer season.

Table S3. Model parameters used in JSBACH.

Parameters	irrigated lawn	non-irrigated lawn	mesic meadow	dry meadow
		Sites		
root depth	0.12	0.12	0.20	0.18
field capacity	0.14	0.05	0.11	0.05
wilting point	0.34	0.25	0.33	0.21
max LAI	2.2	1.6	4.1	1.1
fcrit	0.9	0.9	0.8	0.9
fwilt	0.33	0.2	0.28	0.28

Figure S2. Annual dynamics of soil moisture at the four intensive sites. Grey continuous lines represent JSBACH simulations and triangles and dots represent the mean of manual measurements with standard deviation bars. (a, e) 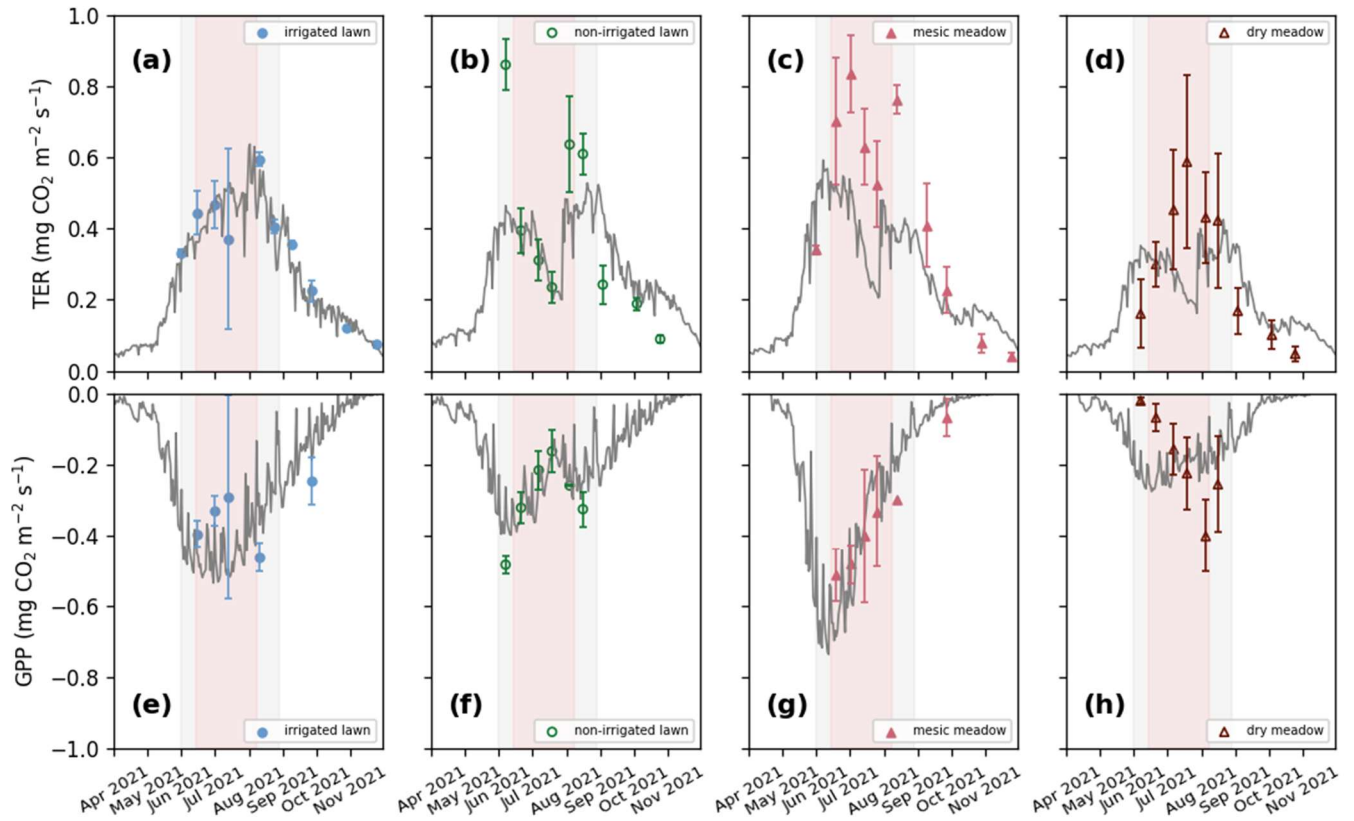Irrigated lawn = KMP lawn; (b, f) non−irrigated lawn = VKI lawn; (c, g) mesic meadow = KMP meadow; (d, h) dry meadow = VKI meadow. Red rectangles indicate the drought periods according to the SPEI and light grey rectangles represent the summer season.

Figure S3. Annual dynamics of soil temperature at the four intensive sites. Grey continuous lines represent JSBACH simulations and triangles and dots represent the mean of manual measurements with standard deviation bars. (a, e) Irrigated lawn = KMP lawn; (b, f)

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non−irrigated lawn = VKI lawn; (c, g) mesic meadow = KMP meadow; (d, h) dry meadow = VKI meadow. Red rectangles indicate the drought periods according to the SPEI and light grey rectangles represent the summer season.
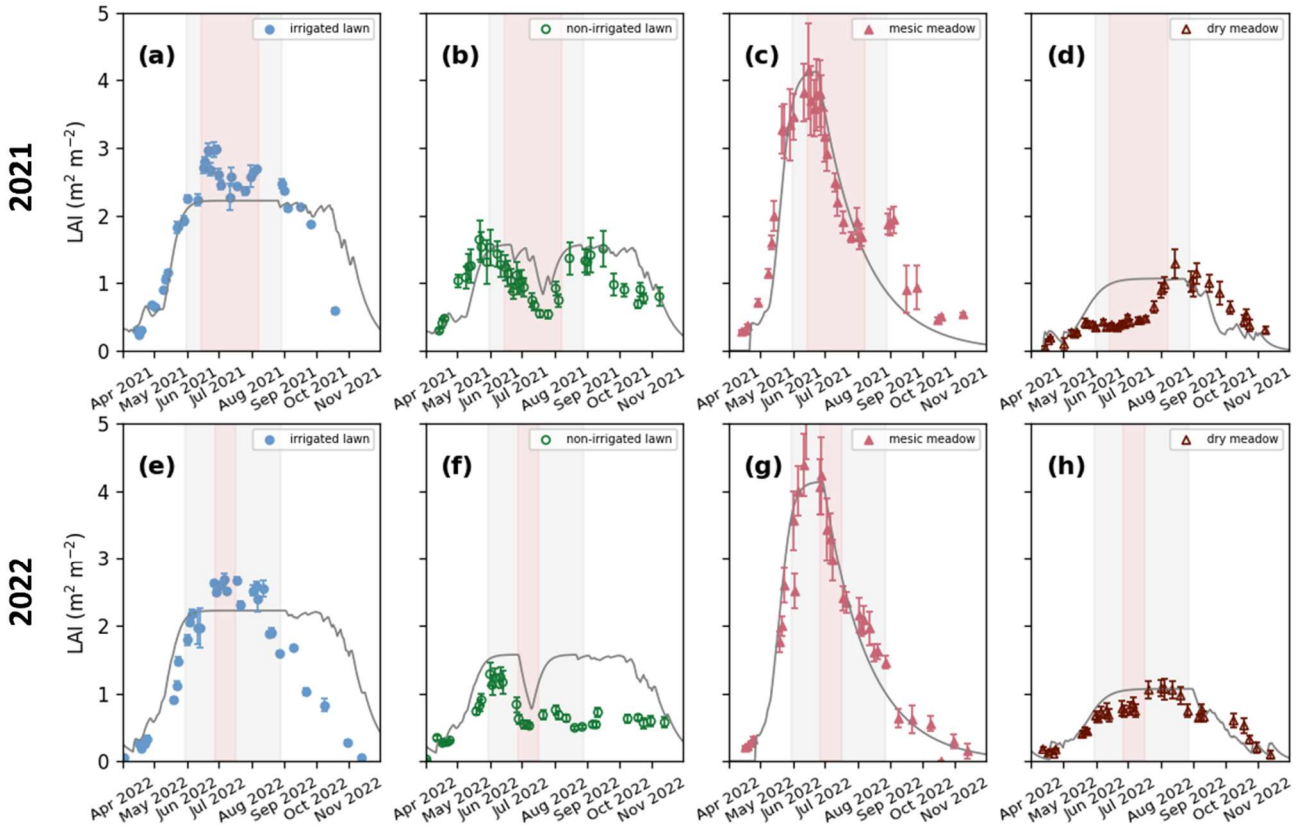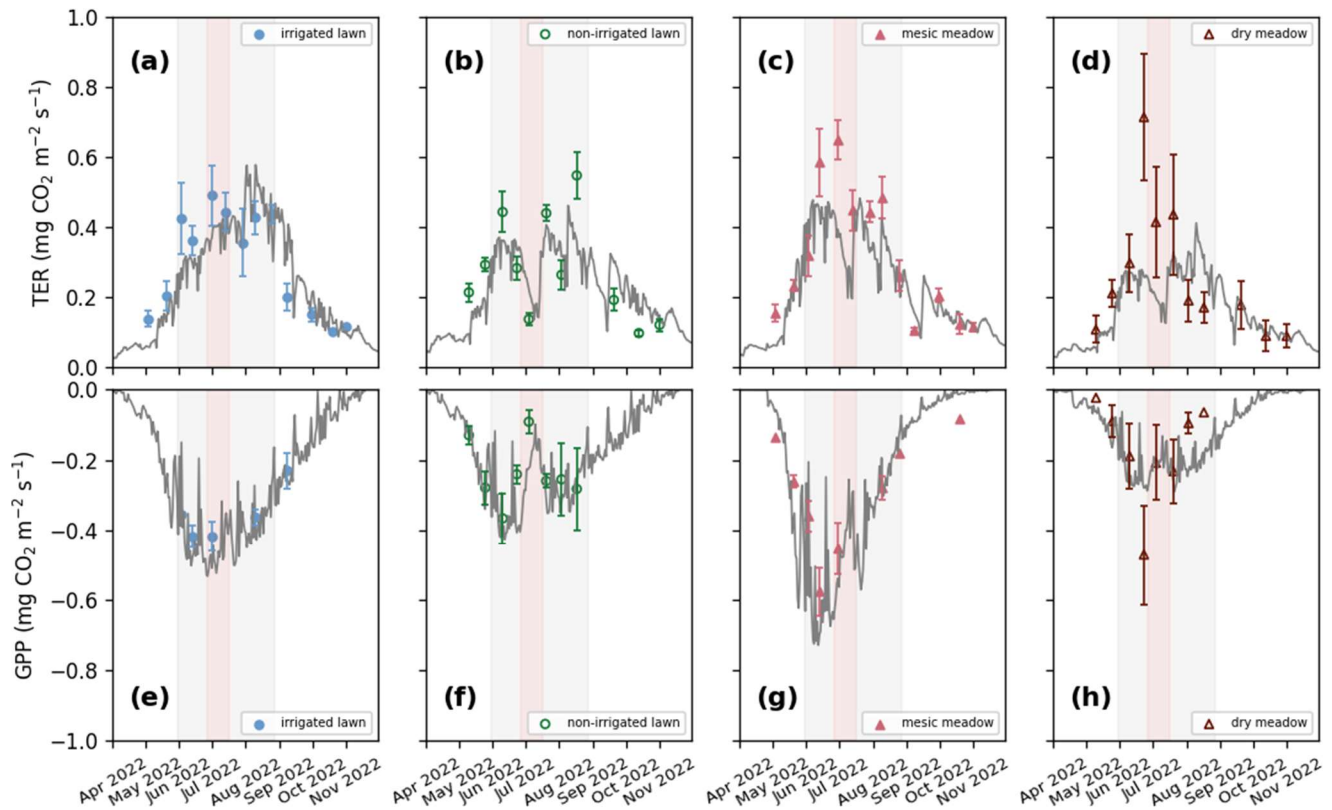

Figure S4. Annual dynamics of leaf area index (LAI) at the four intensive sites. Grey continuous lines represent JSBACH simulations and triangles and dots represent the mean of manual measurements with standard deviation bars. (a, e) Irrigated lawn = KMP lawn; (b, f) non−irrigated lawn = VKI lawn; (c, g) mesic meadow = KMP meadow; (d, h) dry meadow = VKI meadow. Red rectangles indicate the drought periods according to the SPEI and light grey rectangles represent the summer season.
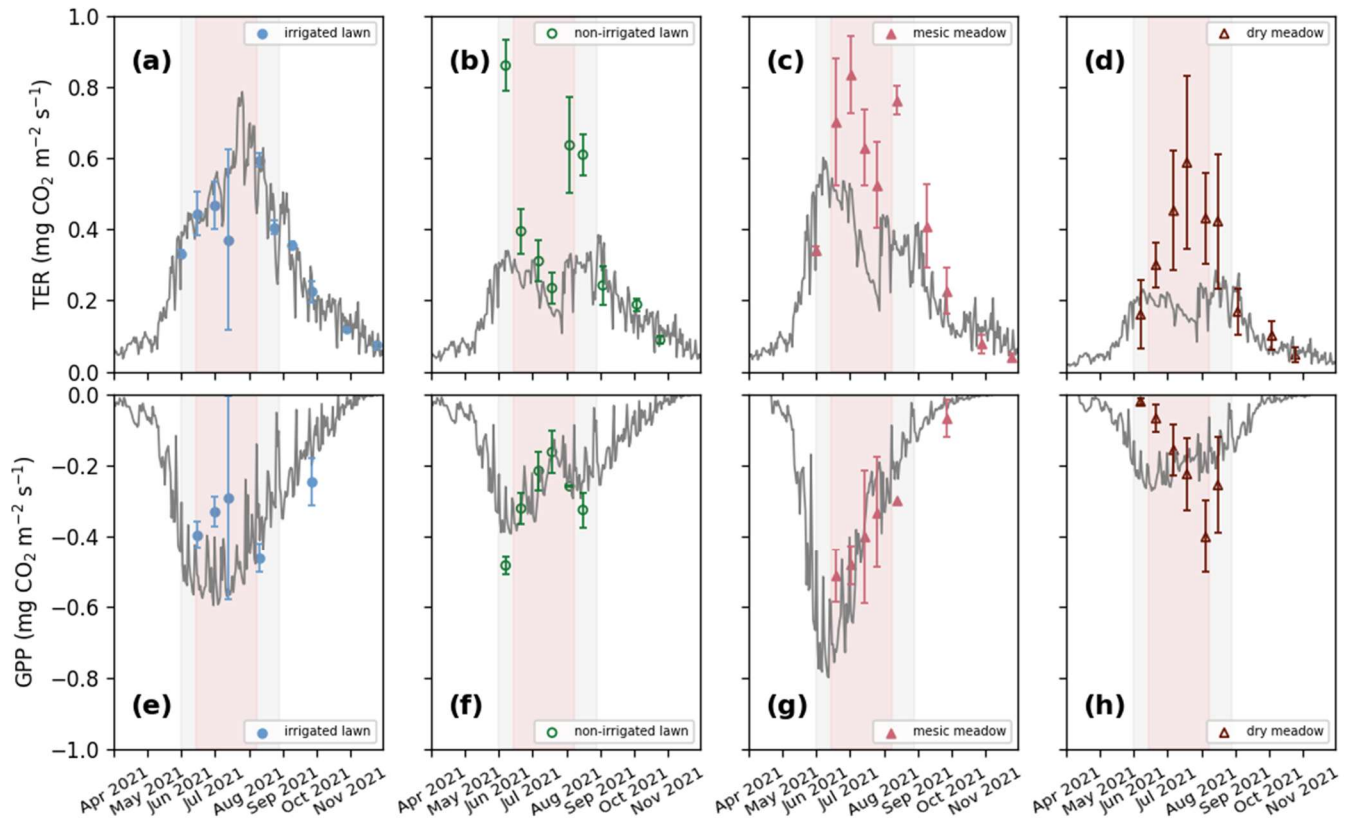
Figure S5. Seasonal dynamics of mean total ecosystem respiration (TER, abcd) and daily photosynthesis (GPP, efgh) in the four intensive sites in 2021. Grey continuous lines represent JSBACH simulations and triangles and dots represent the mean of manual measurements with standard deviation bars. (a, e) Irrigated lawn = KMP lawn; (b, f) non−irrigated lawn = VKI lawn; (c, g) mesic meadow = KMP meadow; (d, h) dry meadow = VKI meadow. Red rectangles indicate the drought periods according to the SPEI and light grey rectangles represent the summer season.

Figure S6. Seasonal dynamics of mean total ecosystem respiration (TER, abcd) and daily photosynthesis (GPP, efgh) in the four intensive sites in 2021 when the soil carbon pools were adjusted to meet the observed TER values. Grey continuous lines represent JSBACH simulations and triangles and dots represent the mean of manual measurements with standard deviation bars. (a, e) Irrigated lawn = KMP lawn; (b, f) non−irrigated lawn = VKI lawn; (c, g) mesic meadow = KMP meadow; (d, h) dry meadow = VKI meadow. Red rectangles indicate the drought periods according to the SPEI and light grey rectangles represent the summer season.

Figure S7. Seasonal dynamics of mean total ecosystem respiration (TER, abcd) and daily photosynthesis (GPP, efgh) in the four intensive sites in 2022 when the soil carbon pools were adjusted to meet the observed TER values. Grey continuous lines represent JSBACH simulations and triangles and dots represent the mean of manual measurements with standard deviation bars. (a, e) Irrigated lawn = KMP lawn; (b, f) non−irrigated lawn = VKI lawn; (c, g) mesic meadow = KMP meadow; (d, h) dry meadow = VKI meadow. Red rectangles indicate the drought periods according to the SPEI and light grey rectangles represent the summer season.

Table S4. Annual net ecosystem exchange (NEE) calculated with JSBACH for the year 2021 and 2022 with adjusted soil carbon content.

| Year	Sites	Characteristics	Annual NEE (g CO_2 m^{-2} yr^{-1})	NEE for Apr-Oct (g CO_2 m^{-2} yr^{-1})
2021	**KMP lawn**	Irrigated lawn	328	−209
	VKI lawn	Non−irrigated lawn	2663	1722
	KMP meadow	Mesic meadow	1476	703
	VKI meadow	Dry meadow	2140	1499
2022	**KMP lawn**	Irrigated lawn	−195	−801
	VKI lawn	Non−irrigated lawn	1496	519
	KMP meadow	Mesic meadow	571	−283
	VKI meadow	Dry meadow	1205	566

Table S5. R^2 calculated for soil moisture, soil temperature and LAI in the standard simulation where the soil carbon was stabilized based on the standing vegetation in 2021 and 2022.

Year	Sites	Characteristics	R^2 for soil moisture	R^2 for soil temperature	R^2 for LAI
2021	**KMP lawn**	Irrigated lawn	0.868	0.910	0.857
	VKI lawn	Non−irrigated lawn	0.866	0.654	0.260
	KMP meadow	Mesic meadow	0.885	0.927	0.920
	VKI meadow	Dry meadow	0.776	0.896	0.161
2022	**KMP lawn**	Irrigated lawn	0.549	0.961	0.709
	VKI lawn	Non−irrigated lawn	0.425	0.885	0.509
	KMP meadow	Mesic meadow	0.653	0.957	0.920
	VKI meadow	Dry meadow	0.068	0.880	0.826
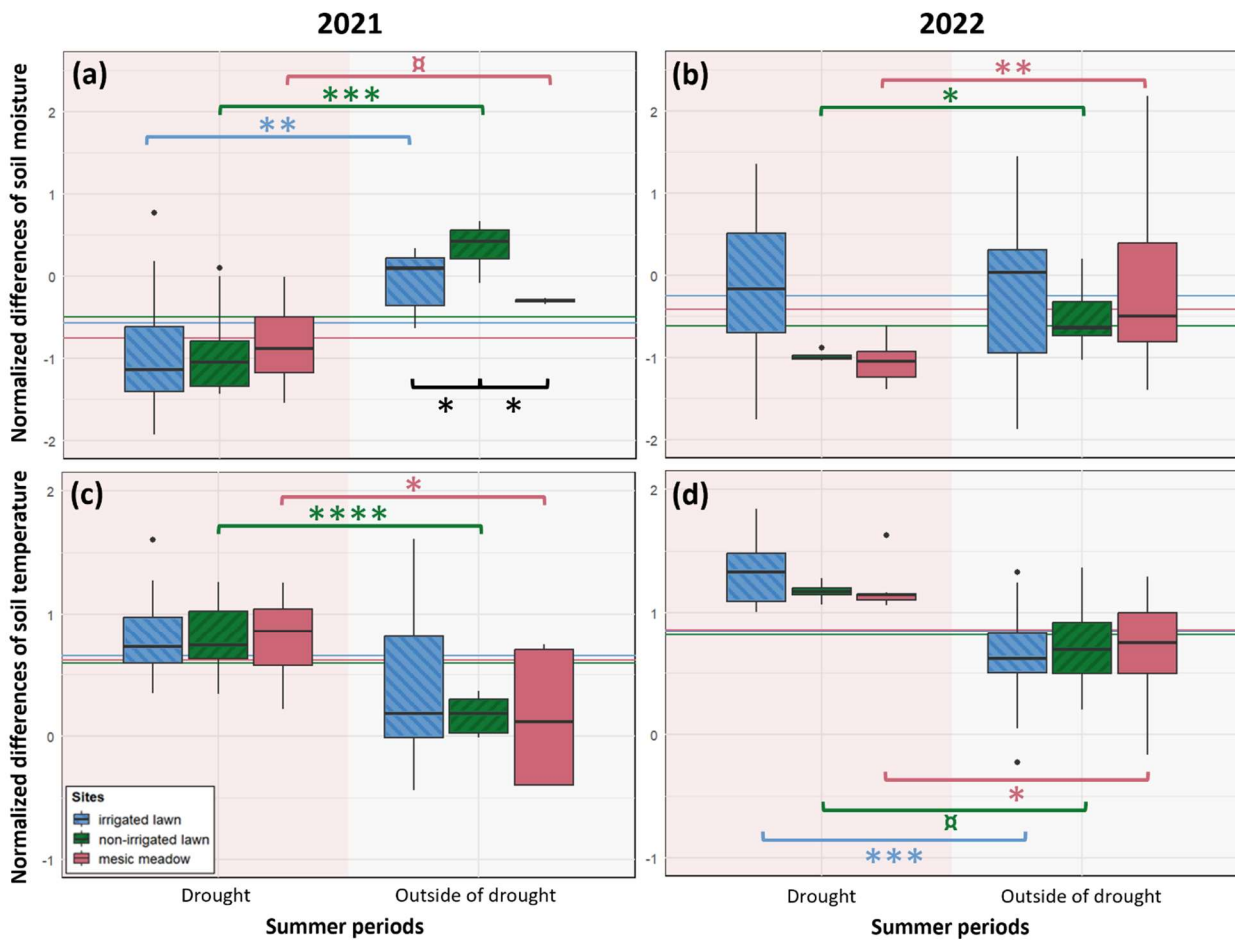
Figure S8. The resistance indices of lawns and meadows to drought events in 2021 and 2022, where the irrigated lawn is KMP lawn, the non−irrigated lawn is VKI lawn, the mesic meadow is KMP meadow, and the dry meadow is VKI meadow. The values are normalized differences between the measured values during the drought and outside it between June to August in 2021 (first column) and in 2022 (second column), calculated for the soil moisture at 5 cm depth ((a) and (b)) and the soil temperature at 10 cm depth ((c) and (d)). Horizontal lines represent the summer average of each site. Droughts were defined in Fig. 2 (June 14th–August 8th, 2021 and June 27th–July 17th, 2022). (¤ for p−value ≤ 0.10; * for p−value ≤ 0.05; ** for p−value ≤ 0.01; *** for p−value ≤ 0.001; and **** for a p−value ≤ 0.0001).
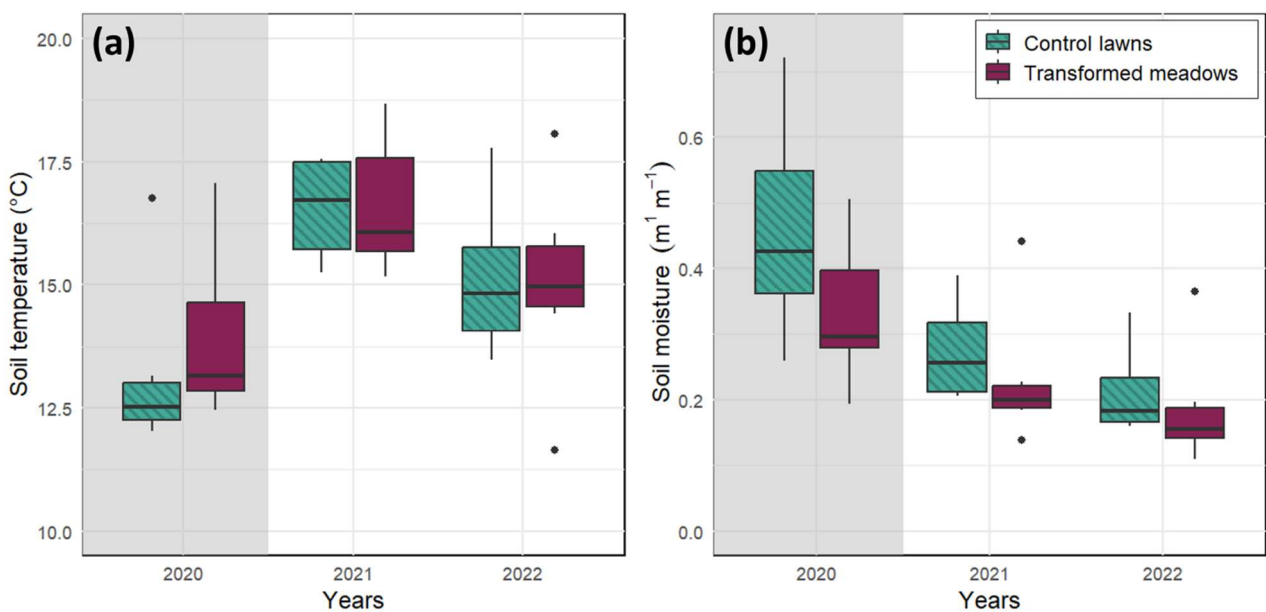
Figure S9. (a) soil temperature at 10 cm depth, and (b) soil moisture at 5 cm depth measured on the satellite sites before and after transformation, which happened at the end of 2020 only on the transformed lawns (¤ for p−value ≤ 0.10; and * for p−value ≤ 0.05).

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Table S6. Correlation values between cover proportions of the plant functional types. The plant functional types are legumes (*Fabaceae*), grasses (*Poaceae*), forbs (other families of flowering vascular plants, which do not belong to one of the listed categories), trees, sedges (*Carex*), horsetails (*Equisetum*), and mosses (*Bryophyta*).

	Grasses	Legumes	Forbs	Trees	Sedges	Horsetails	Mosses
Grasses	1.00						
Legumes	−0.42	1.00					
Forbs	−0.55	0.21	1.00				
Trees	−0.24	−0.28	0.11	1.00			
Sedges	−0.14	0.08	0.36	−0.15	1.00		
Horsetails	0.08	0.01	0.11	−0.21	0.73	1.00	
Mosses	0.03	−0.31	−0.31	0.33	−0.07	−0.10	1.00