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Supplement of

Carbon sequestration in different urban vegetation types in Southern Finland

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Table S1. Soil properties of the park site (*Tilia cordata*), urban forest (*Betula pendula*), irrigated lawn and non-irrigated lawn used in the model simulations. The percentages in the particle size distribution refer to large particles - sand - silt - clay. The soil properties were measured at the park and urban forest. Due to the close connection with the park, the soil properties at the lawns were assumed to be equal to the park.

	Park	Urban forest	Lawns
Soil type	Sandy loam	Sandy loam	Sandy loam
Bulk density (kg/l)	1.15	1.14	1.15
Particle size distribution	5% - 66% - 21% - 8%	3% - 71% - 15% - 11%	5% - 66% -21% - 8%
Carbon content (%)	3.7	3.9	3.7
Nitrogen content (%)	0.252	0.329	0.252
C:N ratio	14.8	11.9	14.8
pH	5.6	6.5	5.6
Wilting point	0.069	0.078	0.069
Field capacity	0.233	0.235	0.233

Table S2. Growing degree days with a base temperature of 5°C (GDD5, degree days), accumulated precipitation during summer (May–August, mm), accumulated short wave radiation during summer months ($\mathrm{kWm^{-2}}$), maximum temperature (Max T, °C), the number of days when precipitation is below 1.4 mm (Dry days) and the number of days when daily shortwave radiation is lower than average in Kumpula during 2006–2021.

Year	GDD5	Summer precipitation	Summer radiation	Max T	Dry days	Cloudy days
2006	1846	87	30.05	25	108	32
2007	1656	320	27.14	23	81	54
2008	1538	220	26.46	22	87	62
2009	1539	325	26.99	23	86	57
2010	1745	211	26.95	26	94	57
2011	1863	310	27.70	25	90	48
2012	1538	258	27.61	23	87	50
2013	1781	212	27.19	24	96	52
2014	1710	280	25.28	26	81	59
2015	1518	236	26.75	22	89	60
2016	1636	270	26.65	21	92	52
2017	1389	211	26.54	19	95	61
2018	1964	144	30.48	27	105	34
2019	1679	215	28.81	25	100	43
2020	1720	296	29.27	24	94	40
2021	1777	293	28.08	27	94	48
Ave	1681	243	27622	24	92	51
STD	151	65	1399	2	8	9

Table S3. Pearson's correlation coefficient (r), mean bias error (MBE) calculated as the difference between observation and the model, and Root Mean Square Error (RMSE) of leaf area index (LAI) in 2018–2021.

Habitat	Year	r JSBACH	r LPJG	r SUEWS	MBE JSBACH	MBE LPJG	MBE SUEWS	RMSE JSBACH	RMSE LPJG	RMSE SUEWS
	2018	0.9	0.88	0.85	0.03	0.47	0.11	0.46	0.73	0.54
	2019	0.91	0.9	0.87	0.16	0.64	0.38	0.44	0.8	0.57
Forest	2020	0.95	0.94	0.89	-0.08	0.24	-0.08	0.34	0.46	0.49
	2021	0.97	0.96	0.93	0.0	0.14	-0.05	0.24	0.31	0.36
	Average	0.93	0.92	0.89	0.03	0.37	0.09	0.37	0.58	0.49
	2018	0.8	0.88	0.86	0.01	0.8	0.48	0.58	0.99	0.67
	2019	0.91	0.9	0.87	0.15	0.82	0.69	0.44	1.0	0.83
Park	2020	0.91	0.93	0.88	-0.1	0.41	0.23	0.46	0.69	0.55
	2021	0.97	0.98	0.94	-0.12	0.39	0.16	0.3	0.55	0.4
	Average	0.89	0.92	0.89	-0.01	0.61	0.39	0.44	0.81	0.61
	2018	0.58	0.41	0.38	0.49	-0.05	0.92	0.67	0.63	1.22
	2019	0.93	0.85	0.88	0.37	0.0	0.84	0.48	0.33	0.95
Lawn	2020	0.83	0.83	0.72	0.18	-0.07	0.43	0.51	0.49	0.78
	2021	0.75	0.88	0.67	0.19	0.09	0.56	0.52	0.53	0.92
	Average	0.77	0.74	0.66	0.31	-0.01	0.69	0.54	0.49	0.97
	2018	0.84	0.64	0.86	0.4	0.31	0.73	0.55	0.66	0.85
	2019	0.83	0.78	0.83	0.48	0.49	0.94	0.67	0.72	1.06
Irrigated lawn	2020	0.83	0.84	0.84	0.24	0.11	0.46	0.55	0.51	0.69
	2021	0.93	0.91	0.92	-0.01	0.41	0.29	0.33	0.6	0.47
	Average	0.86	0.79	0.86	0.27	0.33	0.6	0.53	0.62	0.77

Table S4. Summertime net ecosystem exchange of CO_2 (NEE), Pearson's correlation coefficients (r) between observed and simulated NEE by different models over the target area including diverse urban vegetation (Fig. 1a) during the summer seasons (May–September) together with the coverage of Eddy covariance data during the same months. Ave represents average and STD standard deviation during the years.

	JSBACH		LPJ-GUESS		SUEWS		coverage (%)
	NEE	r	NEE	r	NEE	r	
2006	-202.28	0.78	-129.26	0.72	-326.30	0.71	16.99
2007	-196.22	0.39	-100.93	0.38	-239.24	0.02	15.69
2008	-210.01	0.76	-100.80	0.69	-295.20	0.54	22.88
2009	-244.15	0.83	-121.34	0.67	-325.23	0.81	30.07
2010	-151.81	0.81	-83.69	0.70	-148.97	0.79	18.95
2011	-169.58	0.79	-94.67	0.85	-246.09	0.81	25.49
2012	-241.95	0.79	-97.52	0.77	-303.34	0.79	31.37
2013	-192.81	0.73	-113.26	0.74	-224.98	0.73	11.11
2014	-179.48	0.75	-76.76	0.81	-213.81	0.68	24.18
2015	-257.66	0.67	-147.32	0.72	-346.72	0.73	32.68
2016	-207.54	0.57	-100.04	0.36	-265.74	0.59	37.25
2017	-203.83	0.76	-104.42	0.65	-214.05	0.68	19.61
2018	-151.50	0.64	-89.78	0.57	-189.81	0.53	26.14
2019	-205.67	0.76	-109.28	0.74	-330.54	0.75	11.76
2020	-228.79	0.69	-119.18	0.76	-245.48	0.60	24.84
2021	-162.25	0.72	-85.16	0.61	-191.92	0.47	22.88
Ave	-200.35	0.71	-104.59	0.67	-256.71	0.64	23.24
STD	32.23	0.11	18.31	0.14	59.06	0.20	7.40
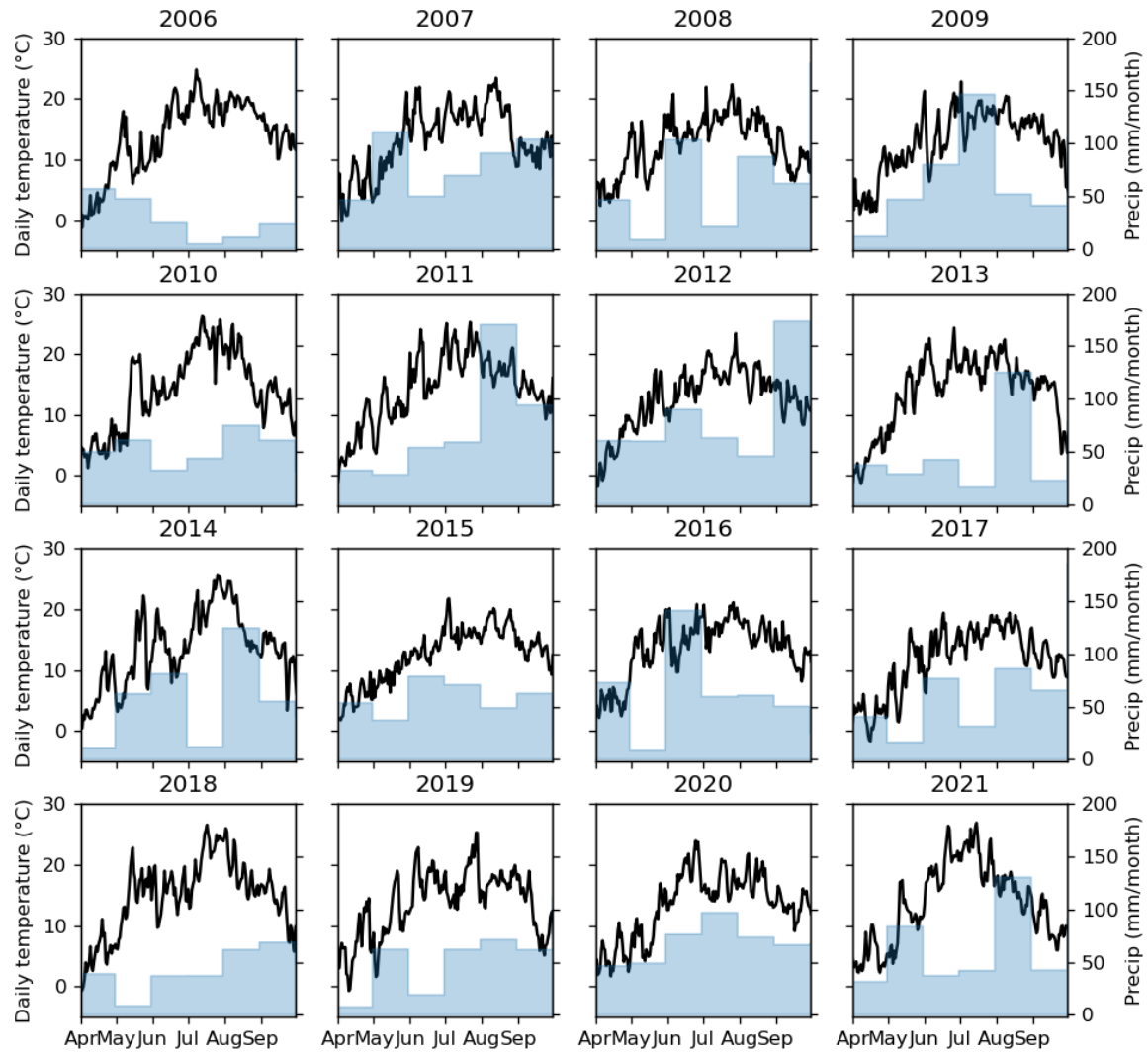
Figure S1. Observed daily temperature (line) and monthly precipitation sum (blue bar) during the growing season in Kumpula in 2006–2021.
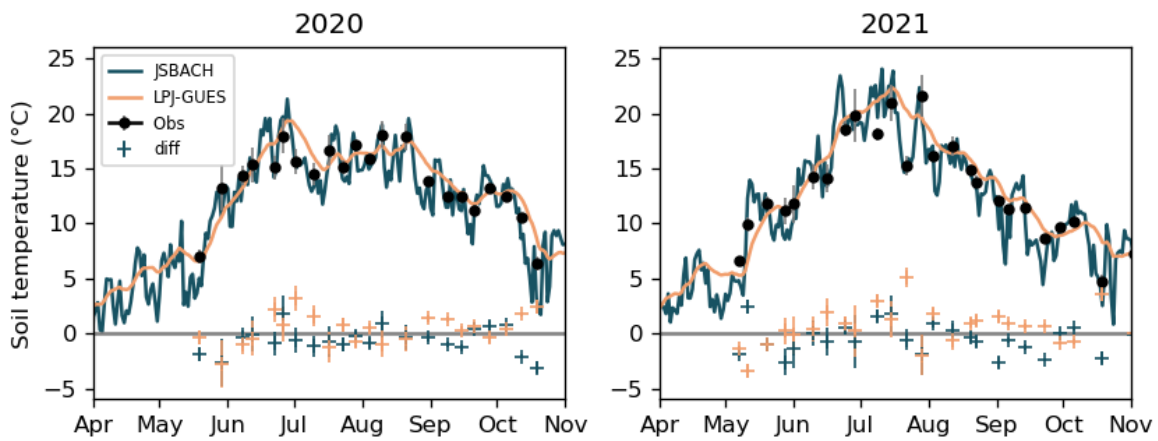
Figure S2. Observed (dots) and simulated (lines) soil temperature and their residuals (crosses) at the park site from April to October 2020 and 2021. The simulated temperature represents the 5–15 cm for JSBACH and 0–50 cm for LPJ-GUESS. The observations are from 10 cm and averaged over 8 collars. The error bars of the observations represent the standard deviation of the collars. The crosses are residuals between observations and models for JSBACH (blue) and LPJ-GUESS (orange).
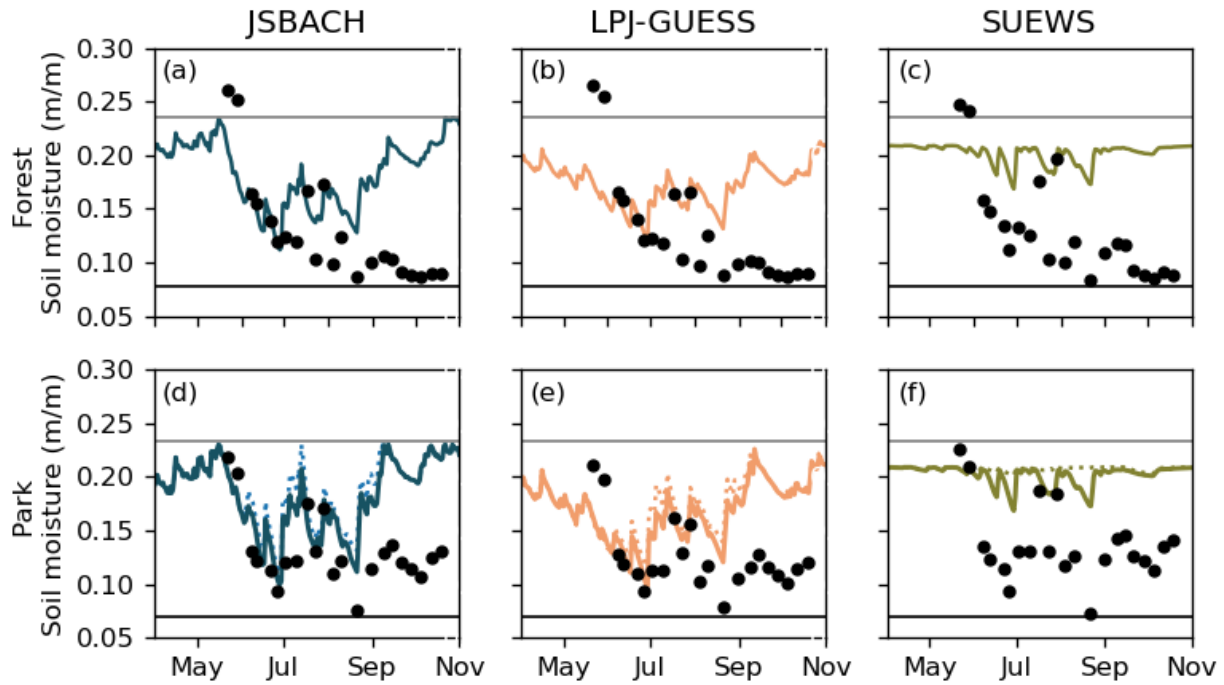
Figure S3. Daily mean soil moisture of the root-zone estimated by the different models (lines) and observed (dots) in the urban birch forest (upper panels) and the park site with trees (lower panels) from May to October 2020. Solid lines are from non-irrigated simulations and dotted lines from irrigated ones. The horizontal, black lines represent the used wilting points and the grey lines the field capacities.
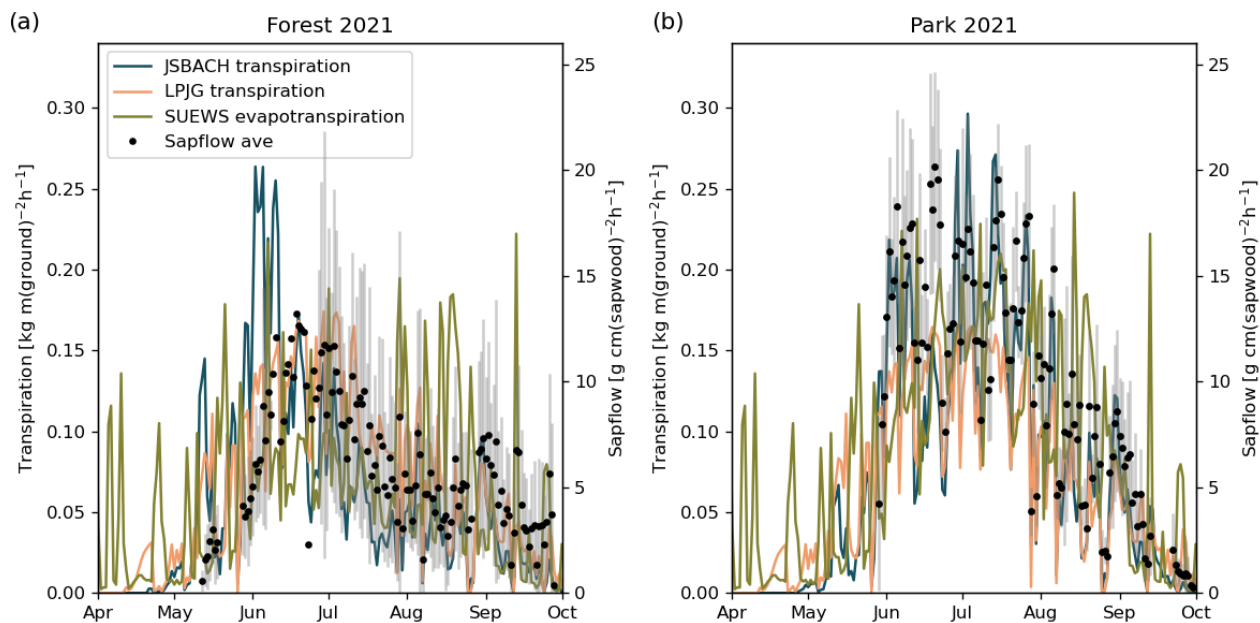
Figure S4. Observed daily sap flow measurements (black dots) and modelled transpiration (color lines) by JSBACH and LPJ-GUESS, and modelled evapotranspiration by SUEWS in the forest site (a) and in the park (b) in 2021. The observations are averages over three trees and the error bars of the observations represent the standard deviation of the 3 trees.
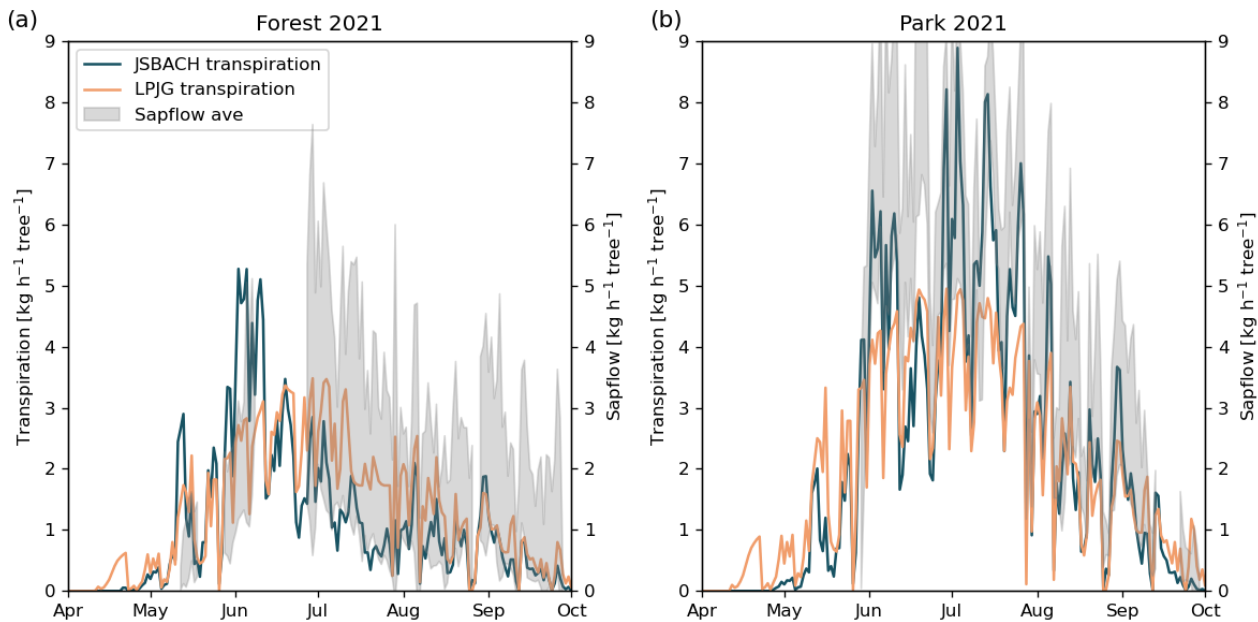
Figure S5. Minimum and maximum hourly sap flow (shaded areas) and simulated transpiration (lines) per tree ($kg\,h^{-1}$) estimated from the sap flow rates and JSBACH and LPJ-GUESS simulations for the forest site (a) and for the park trees (b) in 2021. The shaded area represents the standard deviation in the individual sap flow measurement rates. Model estimates of whole-tree transpiration were obtained by dividing the transpiration per square metre by the estimated tree density.
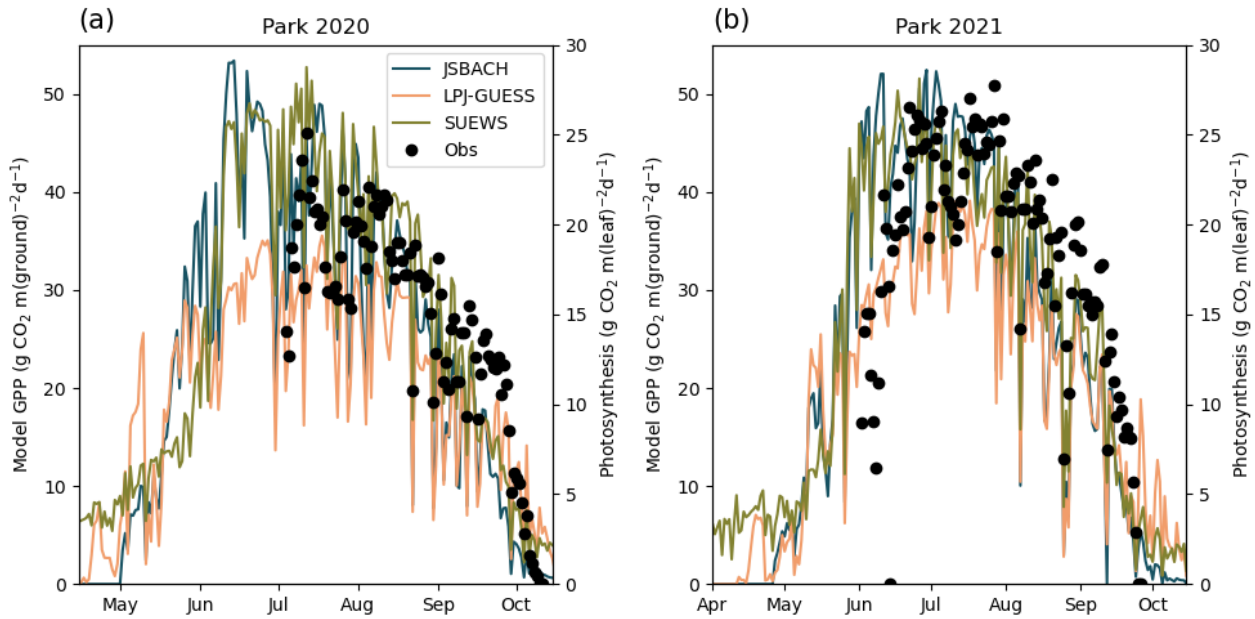
Figure S6. Daily photosynthesis (GPP) per leaf area derived from the automatic shoot measurements at the park site and model simulations (lines) pf photosynthesis (GPP) per ground area in the years 2020 (a) and 2021 (b).
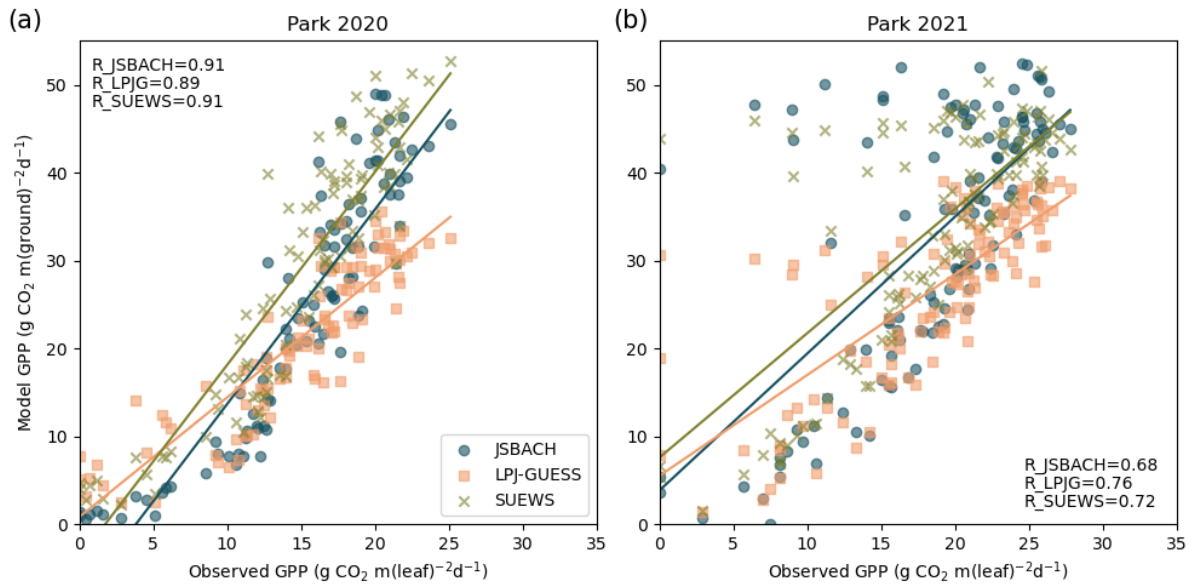

Figure S7. Correlation between the GPP derived from the observations and modelled in the park in the year 2020 (a) and year 2021 (b). The same data are shown in the time plot in Fig. S6. Note that the estimates derived from the observations and models simulations have different units.
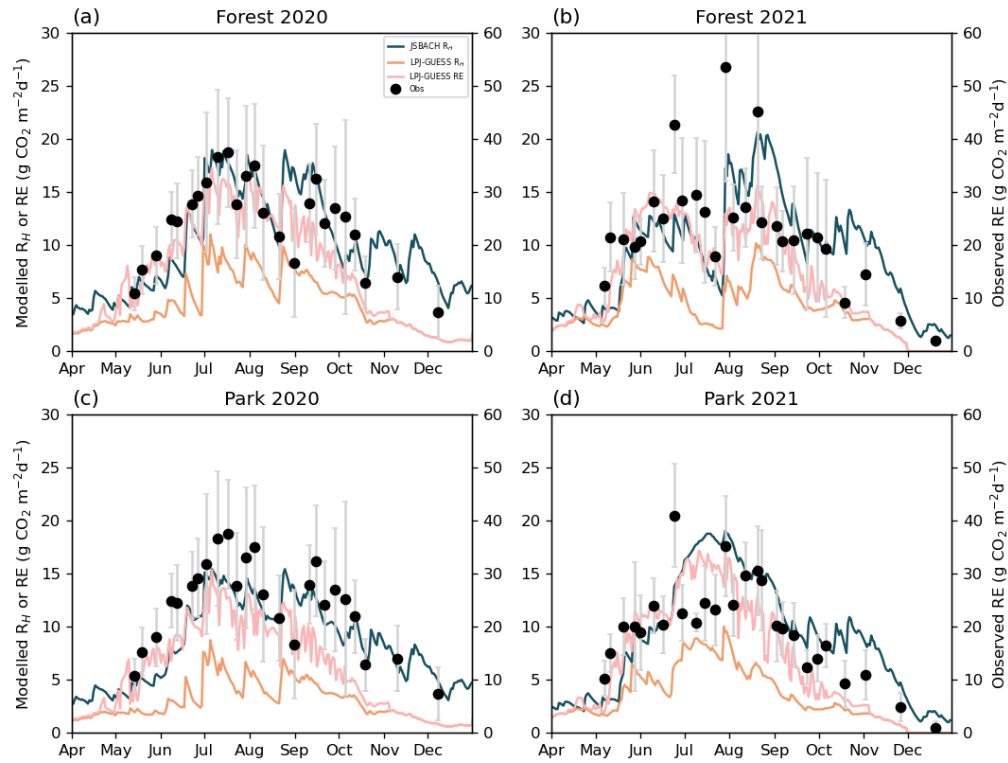
Figure S8. Timeseries of manual observation of soil respiration (dots), modelled heterotrophic respiration (R_H, blue and orange lines) and modelled soil respiration from LPJ-GUESS (RE, pink line) in the forest (panels (a) and (b)) and under the park trees (panels (c) and (d)) in 2020 (a and c) and 2021 (b and d). The observed fluxes and simulations by models are from the non-irrigated forest and irrigated linden trees. Observations are averages of 8 collars and error bars are their standard deviations. Note that model results and observations are depicted on different scales in the figure.
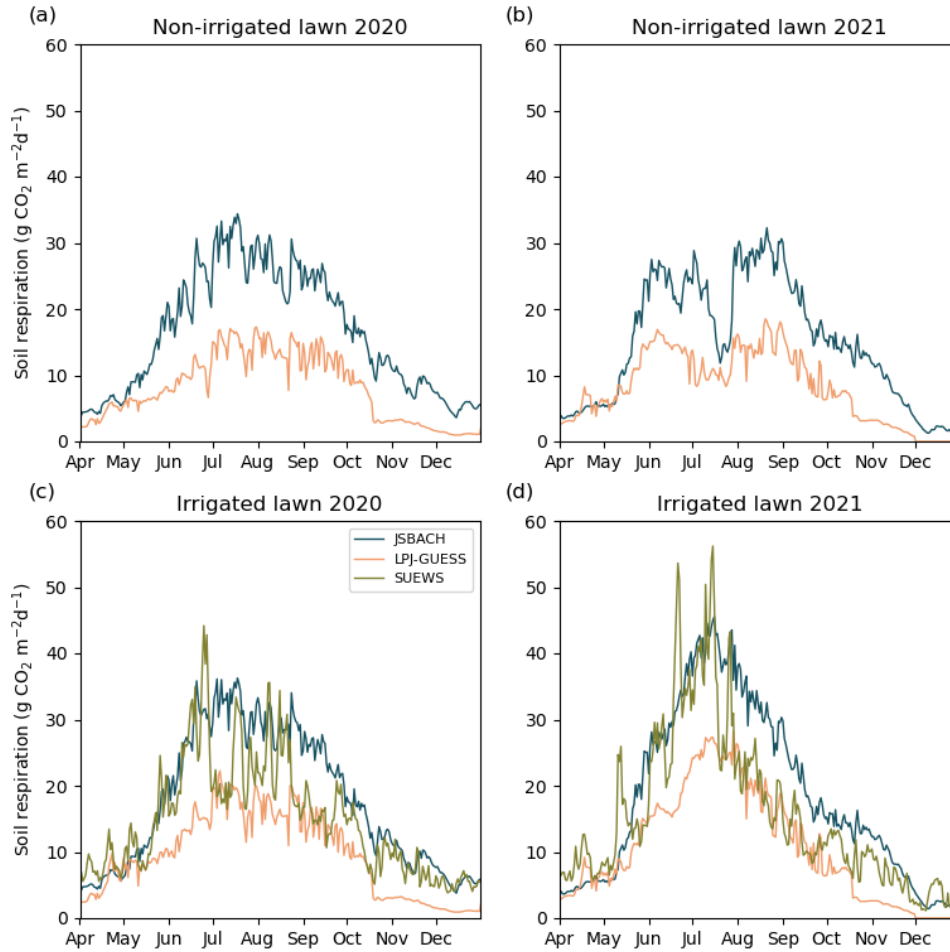
Figure S9. Simulated soil respiration on lawns in 2020 (left) and 2021 (right). JSBACH and LPJ-GUESS values are from non-irrigated lawn simulations in the above panels and the below ones from the irrigated simulations.

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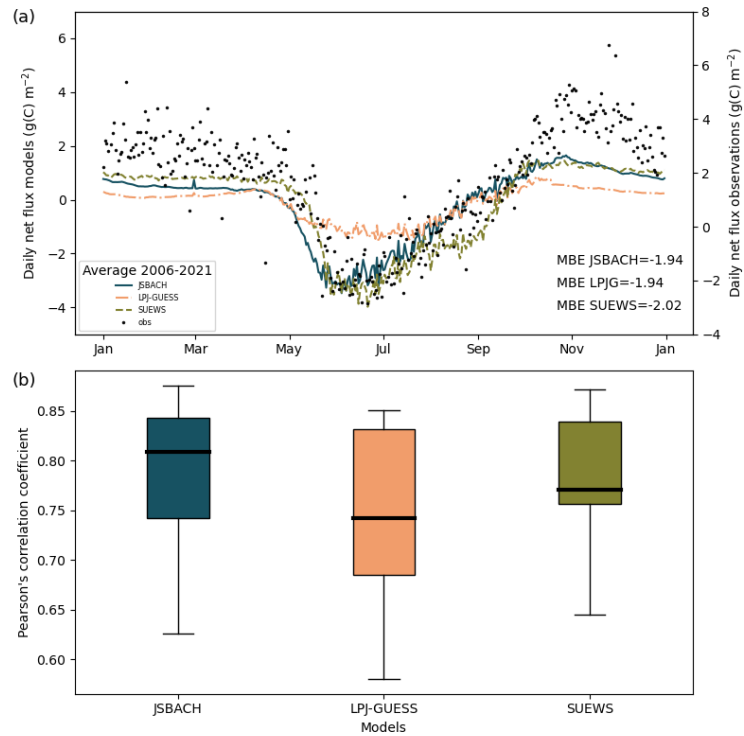
Figure S10. a) Measured (dots) and modelled (lines) daily mean net ecosystem exchange of CO_2 (NEE) on the target area (Fig. 1) as an average over the years from 2006 to 2021. b) Pearson's correlation coefficients between observations and models over the years 2006 to 2021. Mean bias errors are in the panel (a).
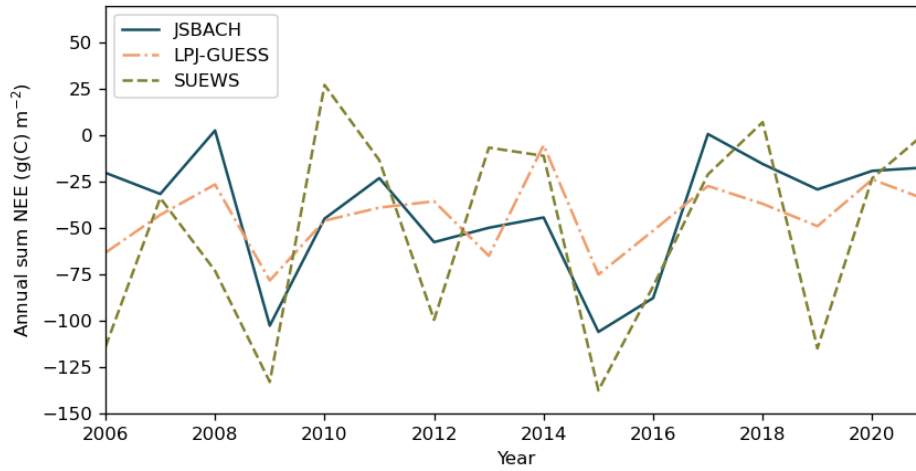
Figure S11. Annual net ecosystem exchange of CO_2 (NEE) simulated with the different models over the target area (Fig. 1a) during 2006–2021.
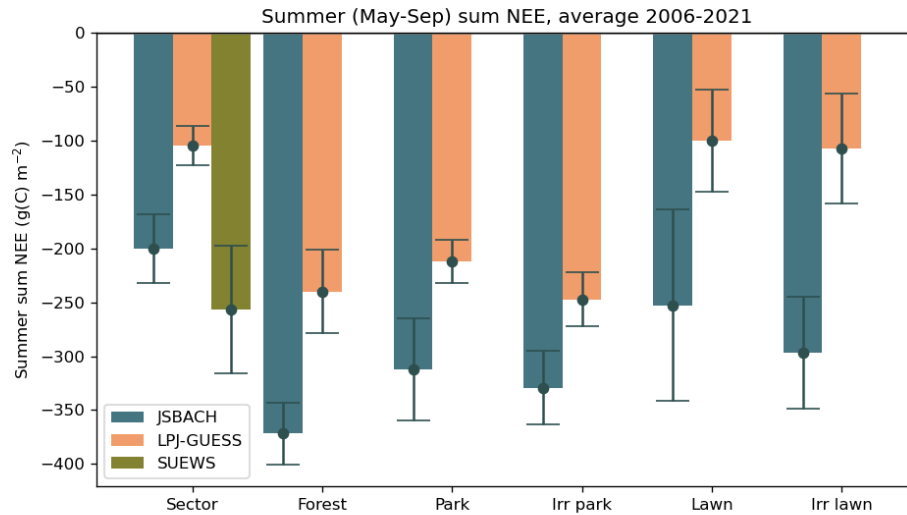

Figure S12. Net ecosystem exchange of CO_2 (NEE) during summer months (May-Sep) for the target area (Sector, Fig. 1a) and the different vegetation types studied as an average over the years 2006–2021. Error bars indicate the standard deviation between the years.
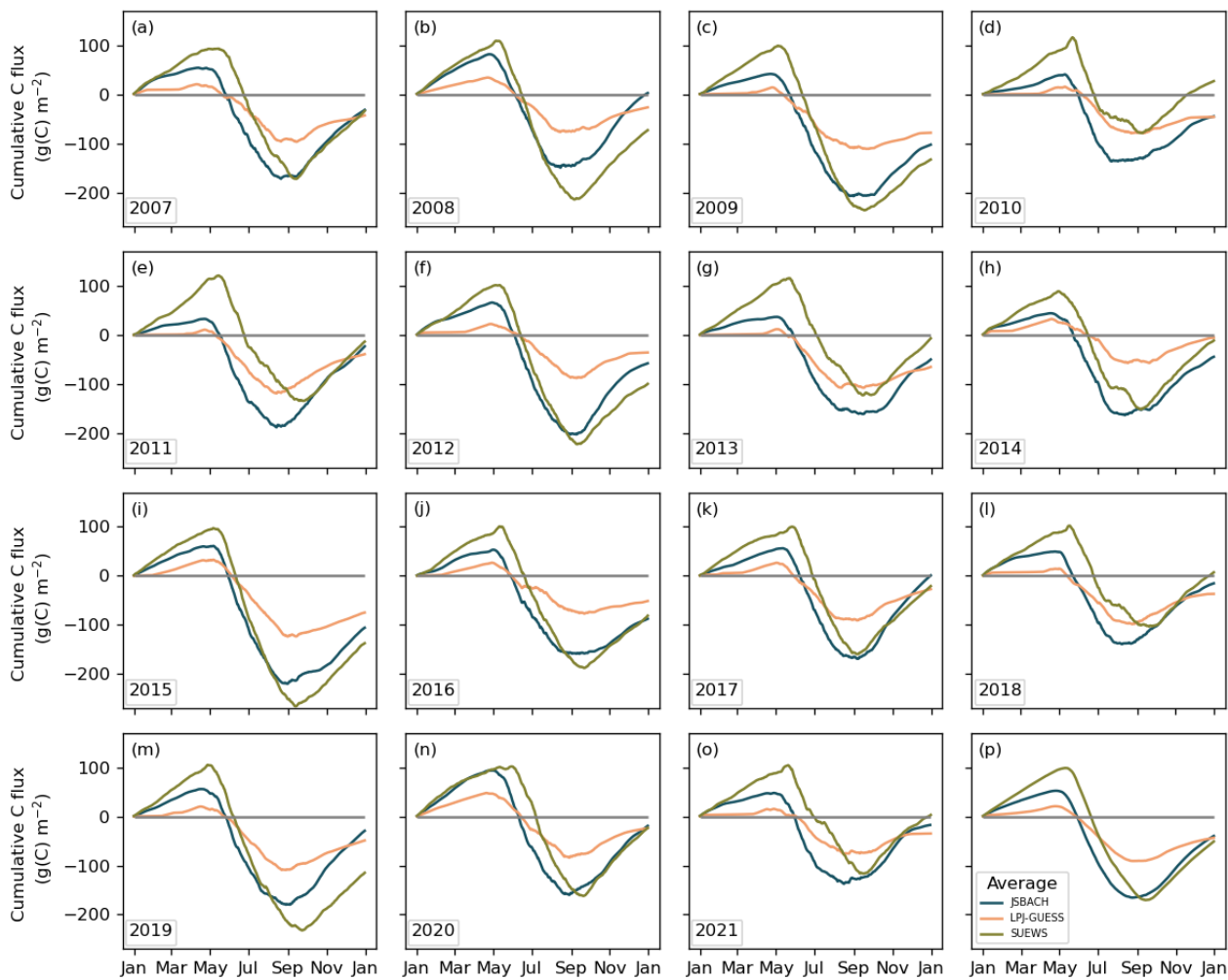
Figure S13. Cumulative net ecosystem exchange of CO_2 (NEE) by JSBACH, LPJ-GUESS and SUEWS in the different study years and as an average in the sector (Fig. 1).
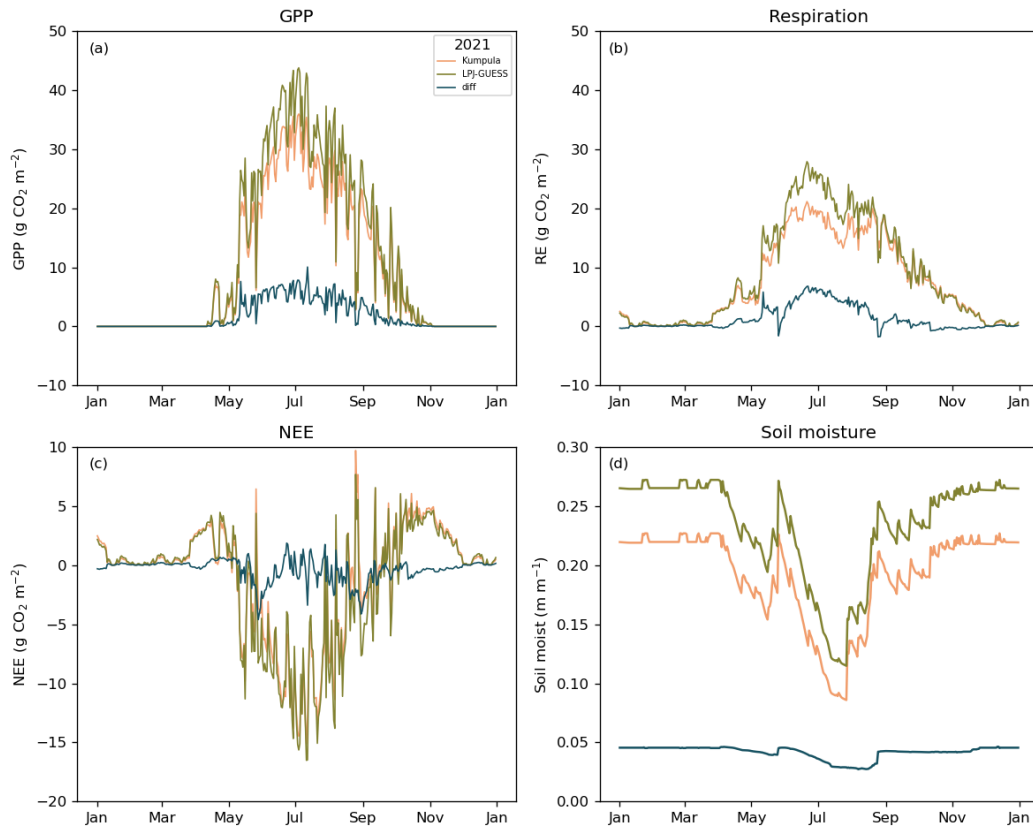
Figure S14. Urban forest GPP, respiration, NEE and soil moisture from LPJ-GUESS for year 2021 using the soil parameters from LPJ-GUESS soilmap (green line) and observed values (orange line). The blue line is difference between them.