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Supplement of

Tracking vegetation phenology of pristine northern boreal peatlands by combining digital photography with CO_2 flux and remote sensing data

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Supplement

Table S1: The monthly mean air temperatures and precipitations sums during the measurement years compared to the climate normal period 1981 – 2010. The data were obtained from the nearby weather observation stations of the Finnish Meteorological Institute.

Halssiaapa

Monthly mean air temperature (°C)

	1	2	3	4	5	6	7	8	9	10	11	12
2015	-14.1	-6.5	-2.3	0.9	6.3	10.2	12	13.5	9.5	0.6	-2.5	-8.9
2016	-18.1	-6.3	-4	1.1	9	12	16.8	12.2	8.5	1.7	-6.1	-9.1
2017	-10.2	-10.1	-5.6	-2.5	2.6	10.3	15.1	11.9	7.2	0.4	-5.5	-10.1
2018	-11.7	-14.9	-10.4	0.2	10.2	11	20.1	13.6	7.8	-0.4	-0.8	-8.5
2019	-16.8	-11.7	-7.2	1.7	5.4	12.5	13.5	12.3	7.3	-2.5	-8.5	-5.6
Mean 1981-2010	**-13.5**	**-12.7**	**-7.5**	**-1.3**	**5.3**	**11.6**	**14.5**	**11.7**	**6.2**	**0.1**	**-7.1**	**-11.7**

Monthly precipitation sum (mm)

	1	2	3	4	5	6	7	8	9	10	11	12
2015	49.5	17	48.2	10.4	101.6	71.1	89	53.8	72	37.8	71.8	40.7
2016	29.2	64.9	8.3	39.7	35.2	112.9	110.8	68.4	75.6	9.1	49	33.5
2017	24.1	14.9	26.6	28.2	9.3	36.5	83.5	57.6	27.1	41.5	54.6	39.5
2018	45.2	4.1	15.6	46.7	10.9	42.3	61.4	75.9	78.5	30.4	16.9	44.3
2019	28.3	36.5	66.6	6.4	53.2	71.3	28.2	27.4	35.9	66.7	38	68.9
Mean 1981-2010	**34.4**	**29.5**	**30.5**	**29.0**	**40.9**	**55.6**	**74.3**	**65.6**	**49.0**	**46.4**	**39.2**	**33.9**

Data from weather station: Sodankylä Tähtelä

Lompolojänkkä

Monthly mean air temperature (°C)

	1	2	3	4	5	6	7	8	9	10	11	12
2015	-14.7	-7.8	-3.2	0.5	5.1	9.7	11.9	13.1	8.9	-0.1	-3.3	-10.2
2016	-19.4	-9.2	-5.3	0.3	8.7	11	15.4	10.8	8.5	0.7	-7.8	-9.9
2017	-11.2	-11.1	-7.1	-2.8	2.5	10.3	13.6	11.1	7	-0.6	-7.3	-13.2
2018	-14.8	-15.7	-12.4	-0.6	9.1	9.8	19.1	12.5	7.2	-1.3	-2	-10.4
2019	-18.1	-13.5	-8.3	1.6	5.5	11.6	13.8	12.6	6.5	-3.7	-10.8	-7.2
Mean 1981-2010	**-14.2**	**-13.1**	**-7.9**	**-1.6**	**4.9**	**10.9**	**13.8**	**11.2**	**5.6**	**-0.9**	**-8.8**	**-12.5**

Monthly precipitation sum (mm)

	1	2	3	4	5	6	7	8	9	10	11	12
2015	42.2	22.9	32.4	28.2	85.7	69.9	57.7	59.1	56.8	22.5	40.9	37.3
2016	27.6	41.8	9.2	25.7	13.2	122.7	107.9	117.4	62	6.3	38.1	28
2017	32.8	18.6	20.5	19.2	20.6	29.1	94	97.6	22.7	36.3	47.3	30.5
2018	25.8	0.8	7.8	19.9	18.7	45	10.4	86.7	61	28.1	13.6	43
2019	17.3	25.3	27.6	7.9	66.5	71.7	24	39.3	71	29.6	29.2	57.3
Mean 1981-2010	**31.0**	**26.6**	**28.0**	**27.3**	**39.9**	**58.7**	**75.4**	**74.0**	**48.4**	**45.1**	**36.0**	**30.4**

Data from weather stations: Muonio and Alamuonio

Kaamanen

Monthly mean air temperature (°C)

	1	2	3	4	5	6	7	8	9	10	11	12
2015	-14.8	-6.8	-2.2	0.9	5.9	9.8	10.8	13.3	9.4	0.7	-2.5	-8
2016	-17	-7	-3.8	0.9	8.8	11	15.8	11.3	8.4	1.9	-5.2	-7.3
2017	-9.1	-10.1	-5.7	-2.6	2.3	8.7	14.6	11.3	7	0.9	-5.9	-11
2018	-12.9	-13.1	-11	-0.4	8.9	10.1	19.4	12.9	7.9	0.1	-0.6	-7.8
2019	-13.8	-12.2	-7.4	1.8	4.4	10.4	12.6	11.5	7.4	-2.6	-8.8	-5.8
Mean 1981-2010	**-12.8**	**-12.0**	**-7.4**	**-1.6**	**4.4**	**10.6**	**14.0**	**11.3**	**6.2**	**0.1**	**-7.1**	**-11.1**

Monthly precipitation sum (mm)

	1	2	3	4	5	6	7	8	9	10	11	12
2015	13.8	17.9	22.1	17.8	60.2	70.1	48.8	50.6	69	17.1	29.4	32.2
2016	31.4	48.6	10.3	25.9	34.7	104.1	80.6	146.3	68.6	10.9	44.1	47.9
2017	18.1	21.4	25	24.1	6	72.7	130	96.7	51.8	29.9	50.9	41.6
2018	35.9	4.8	17.6	32.3	34.6	52.4	44.8	134.7	84.8	27.5	32.8	31.8
2019	23.7	39.5	22.5	3.2	76.8	103.8	37.7	54.5	61.3	40.8	27.9	57
Mean 1981-2010	**24.5**	**23.0**	**23.4**	**27.9**	**38.4**	**50.3**	**71.5**	**67.6**	**45.7**	**40.3**	**29.5**	**24.1**

Data from weather stations: Inari Ivalo

Table S2. The significant differences in GCC between the sites (Halssiaapa (Hal), Lompolojänkkä (Lom) and Kaamanen (Kaa)) during the measurement years as a pairwise comparison (Dunn's test). The significance values were adjusted by the Holm correction for multiple tests. Z denotes the test statistic.

	2015		2016		2017		2018		2019	
	Z	p-value	Z	p-value	Z	p-value	Z	p-value	Z	p-value
Lom - Hal	-3.57	0.001	-5.90	<0.001	-4.95	<0.001	-6.92	<0.001	-4.20	<0.001
Lom - Kaa	-2.30	0.043	-5.11	<0.001	-1.79	0.074	-2.81	0.005	-1.49	0.137
Hal - Kaa	-1.25	0.212	-0.62	0.538	-3.21	0.003	-4.15	<0.001	-2.89	0.008

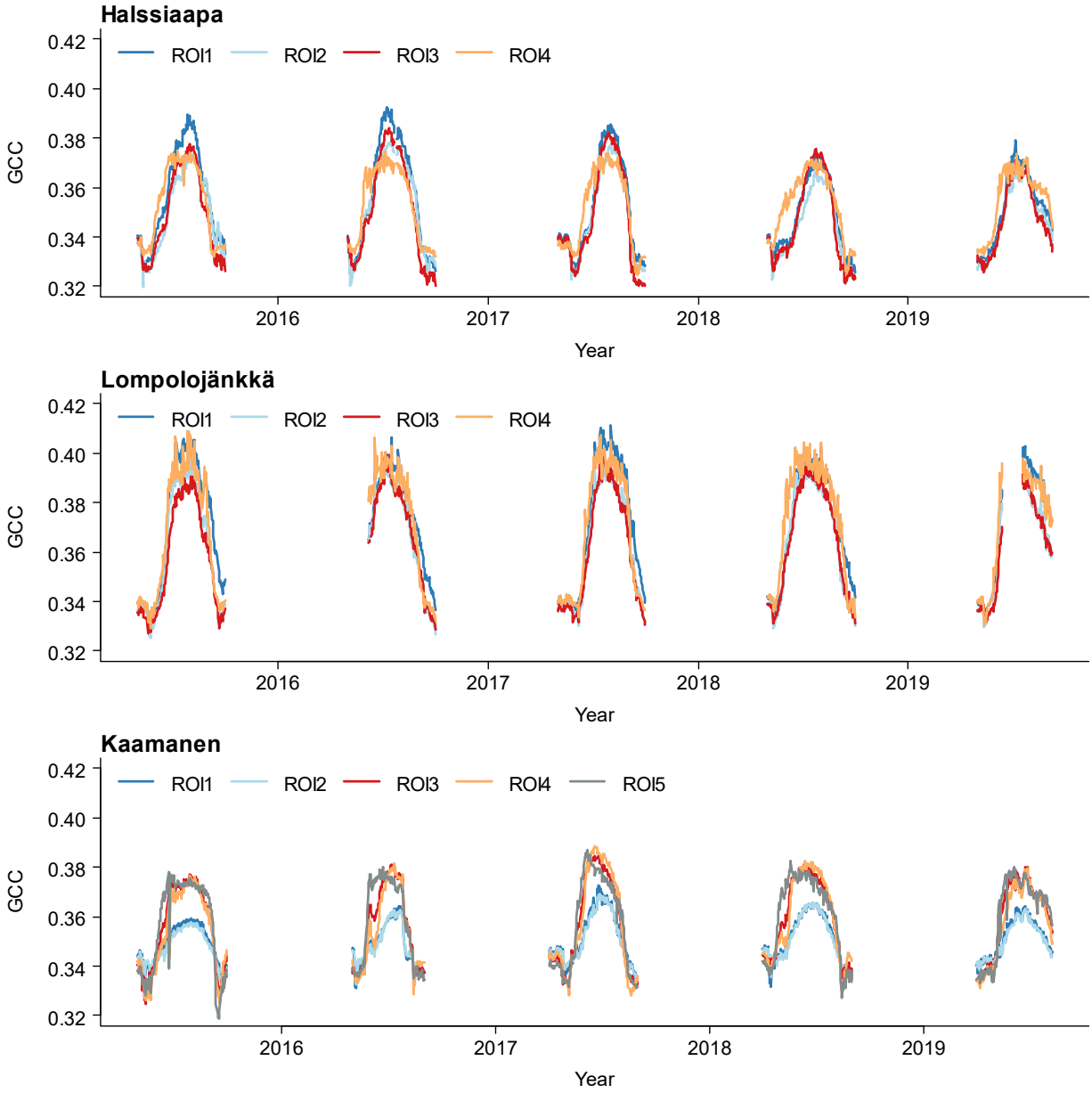

Figure S1: The GCC of the different Region of Interests (ROIs) of specific plant communities. The numbers 1-5 indicate the different plant communities detailed in Table 1.

Table S3: The significant differences between different plant communities as groupwise comparison (Kruskal-Wallis one-way analysis of variance on ranks). χ^2 denotes the chi-squared test statistic.

Halssiaapa			Lompolojänkkä			Kaamanen		
Year	χ^2	**p-value**	**Year**	χ^2	**p-value**	**Year**	χ^2	**p-value**
2015	19.42	<0.001	**2015**	43.47	<0.001	**2015**	37.68	<0.001
2016	7.94	0.047	**2016**	26.44	<0.001	**2016**	26.02	<0.001
2017	7.70	0.053	**2017**	33.21	<0.001	**2017**	8.12	0.087
2018	35.61	<0.001	**2018**	33.97	<0.001	**2018**	61.27	<0.001
2019	31.47	<0.001	**2019**	29.23	<0.001	**2019**	73.3	<0.001

Table S4: The significant differences between the different plant communities as a pairwise comparison (Dunn's test). The significance values were adjusted by the Holm correction for multiple tests. Z denotes the test statistic.

Halssiaapa

	2015		2016		2017		2018		2019	
	Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
ROI1 - ROI2	3.59	0.002	1.81	0.355	2.35	0.111	3.05	0.009	2.70	0.028
ROI1 - ROI3	3.56	0.002	2.76	0.034	2.31	0.105	1.56	0.236	2.41	0.047
ROI2 - ROI3	-0.03	0.975	0.96	0.676	-0.05	0.964	-1.49	0.136	-0.28	0.779
ROI1 - ROI4	1.11	0.532	1.32	0.561	1.01	0.630	-2.65	0.024	-2.19	0.058
ROI2 - ROI4	-2.47	0.053	-0.49	0.627	-1.35	0.710	-5.70	<0.001	-4.88	<0.001
ROI3 - ROI4	-2.44	0.044	-1.44	0.596	-1.30	0.577	-4.21	<0.001	-4.60	<0.001

Lompolojänkkä

	2015		2016		2017		2018		2019	
	Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
ROI1 - ROI2	4.20	<0.001	3.81	0.001	4.50	<0.001	3.76	<0.001	3.94	<0.001
ROI1 - ROI3	6.06	<0.001	3.83	0.001	4.82	<0.001	3.78	<0.001	4.05	<0.001
ROI2 - ROI3	1.86	0.126	0.02	0.984	0.32	0.750	0.01	0.989	0.11	0.915
ROI1 - ROI4	1.61	0.108	0.40	1.000	1.45	0.297	-0.67	1.000	0.37	1.000
ROI2 - ROI4	-2.59	0.028	-3.42	0.002	-3.06	0.007	-4.43	<0.001	-3.57	0.001
ROI3 - ROI4	-4.45	<0.001	-3.44	0.002	-3.37	0.003	-4.45	<0.001	-3.68	0.001

Kaamanen

	2015		2016		2017		2018		2019	
	Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
ROI1 - ROI2	0.89	0.742	-0.35	1.000	0.46	1.000	0.23	1.000	0.55	1.000
ROI1 - ROI3	-3.52	0.003	-3.69	0.002	-1.51	0.782	-4.86	<0.001	-5.36	<0.001
ROI2 - ROI3	-4.42	<0.001	-3.34	0.006	-1.98	0.433	-5.10	<0.001	-5.91	<0.001
ROI1 - ROI4	-2.42	0.078	-2.63	0.051	-1.77	0.534	-4.95	<0.001	-3.98	<0.001
ROI2 - ROI4	-3.31	0.006	-2.28	0.112	-2.24	0.254	-5.19	<0.001	-4.53	<0.001
ROI3 - ROI4	1.10	0.808	1.06	0.867	-0.26	1.000	-0.09	1.000	1.38	0.500
ROI1 - ROI5	-4.03	<0.001	-3.75	0.002	-1.42	0.784	-4.98	<0.001	-5.83	<0.001
ROI2 - ROI5	-4.93	<0.001	-3.40	0.005	-1.88	0.482	-5.22	<0.001	-6.38	<0.001
ROI3 - ROI5	-0.51	0.610	-0.06	0.952	0.10	0.923	-0.12	1.000	-0.47	0.638
ROI4 - ROI5	-1.61	0.425	-1.12	1.000	0.36	1.000	-0.03	0.975	-1.85	0.256

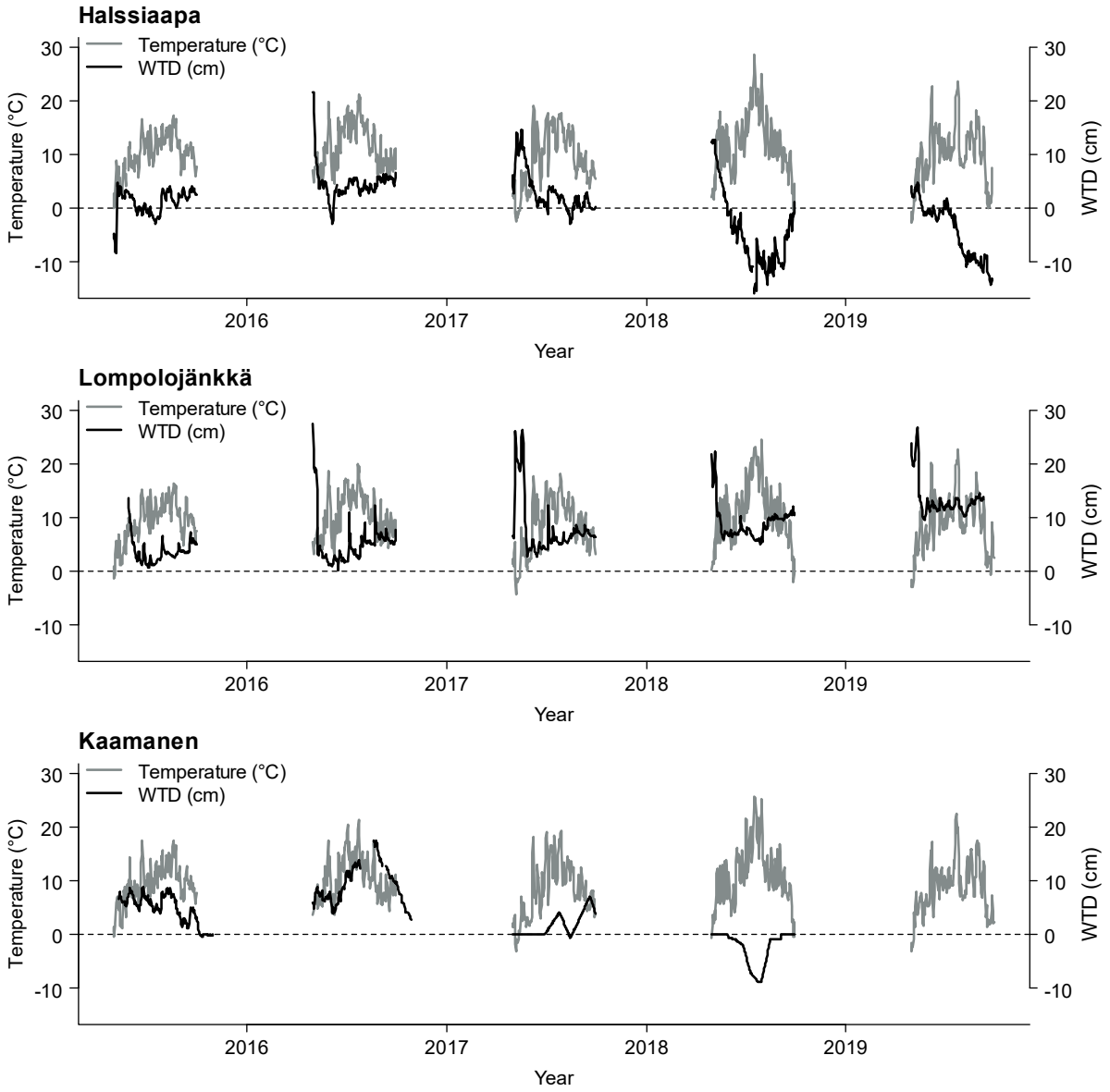

Figure S2: Daily mean temperatures (°C) and water table depths (WTD, cm) in 2015–2019 at the experimental sites. The WTD data from Kaamanen are missing in 2019.

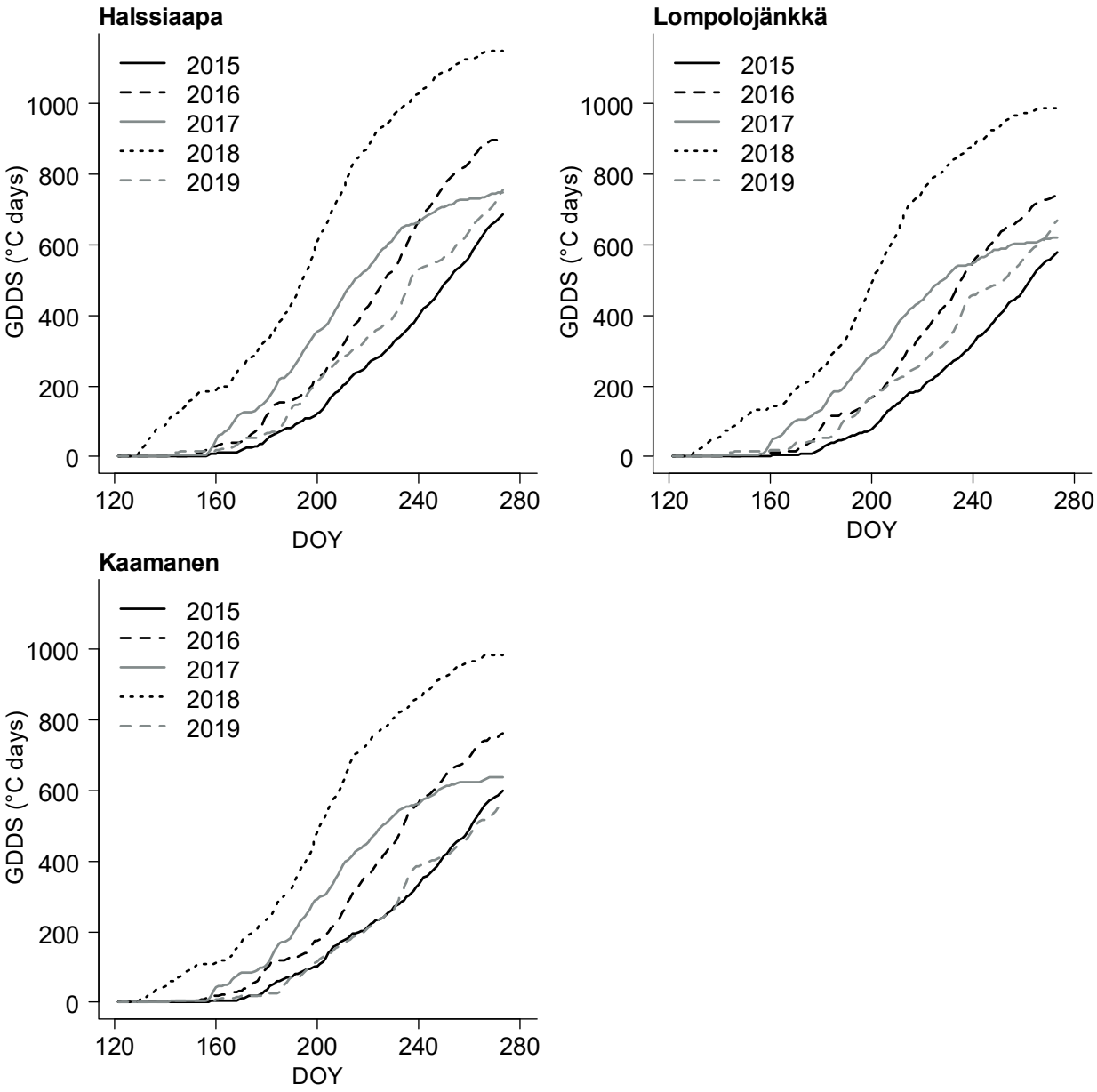

Figure S3: The growing degree day sums (GDDS) in 2015 – 2019 at the experimental sites.

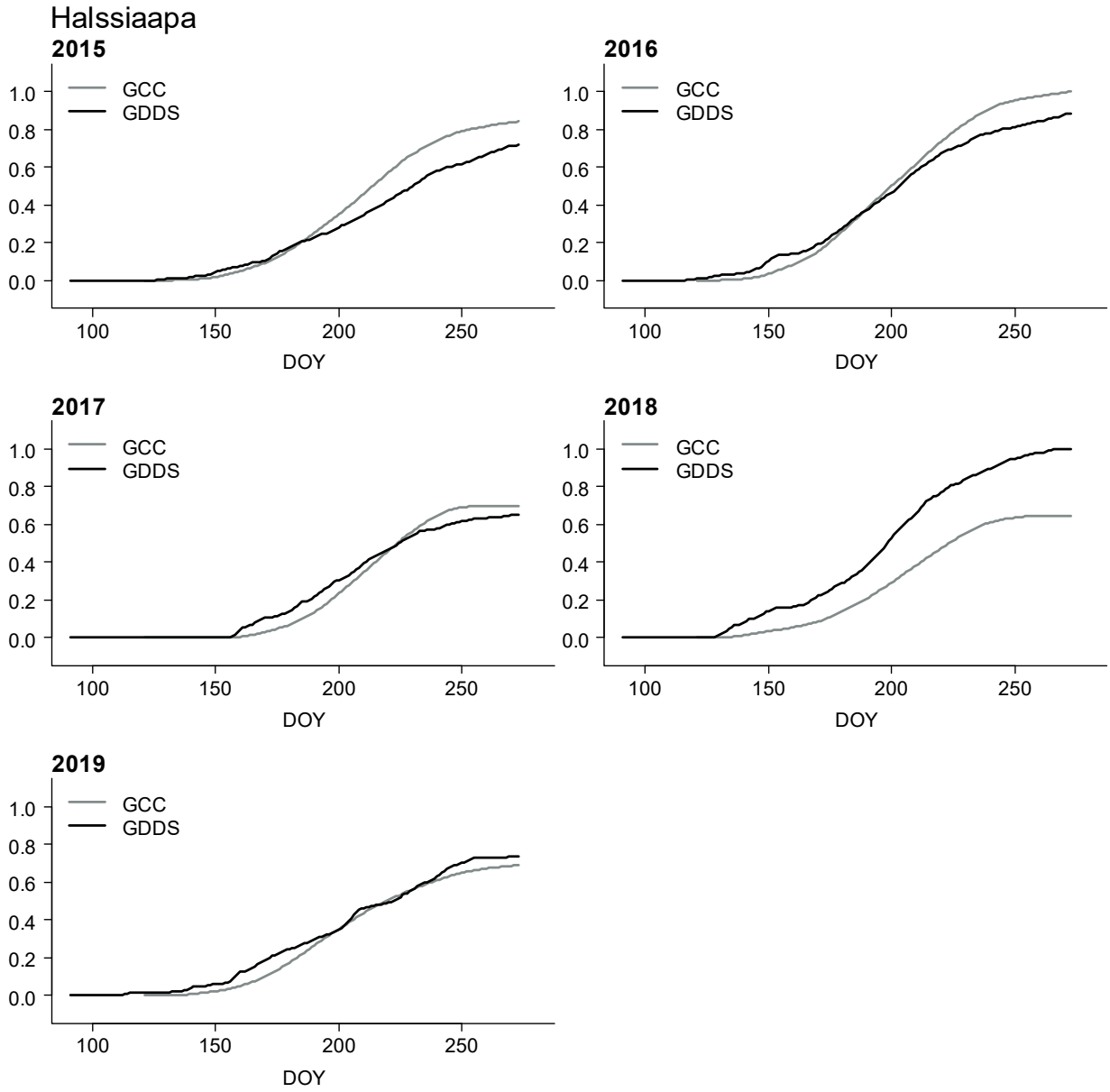

Figure S4: The normalized cumulative GCC and growing degree days (GDDS) in 2015 – 2019 at the experimental sites.

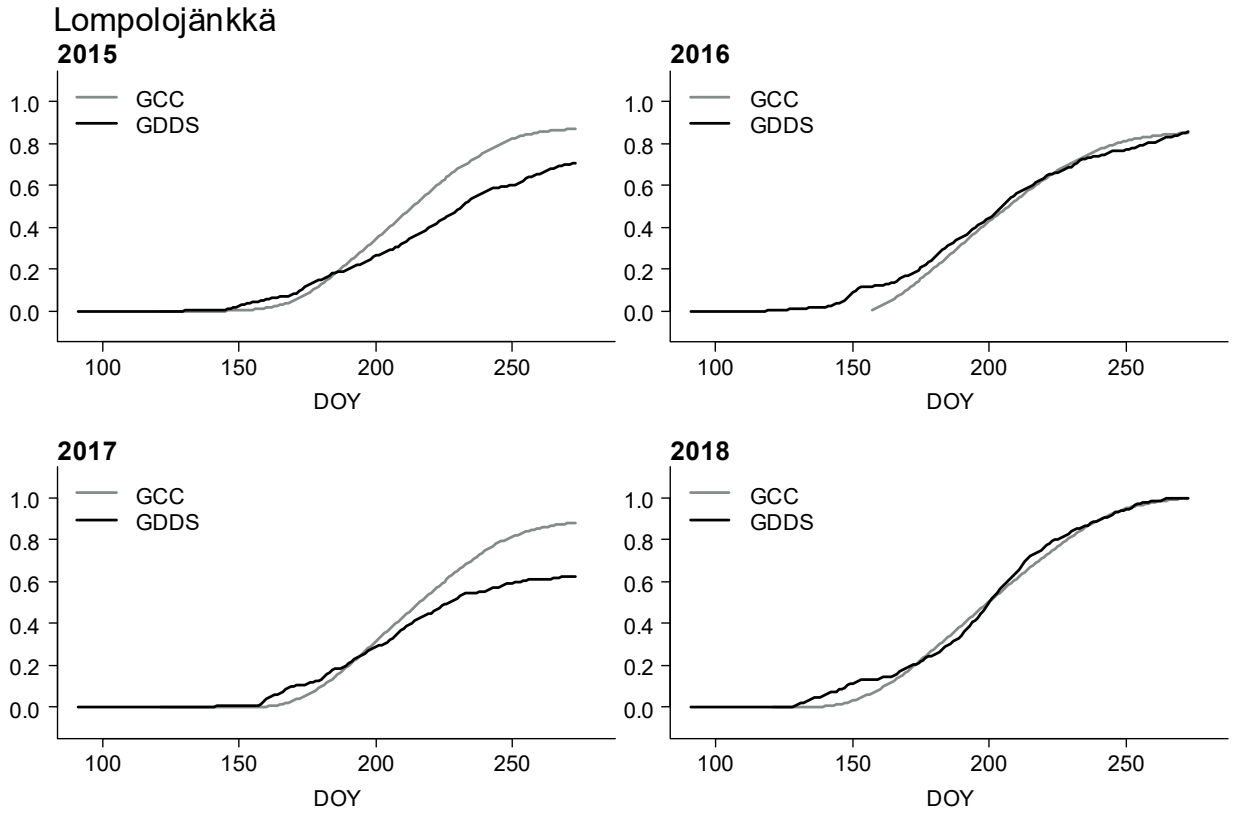

Figure S5: The normalized cumulative GCC and growing degree days (GDDS) in 2015 – 2019 at the experimental sites. The data from 2019 is missing.

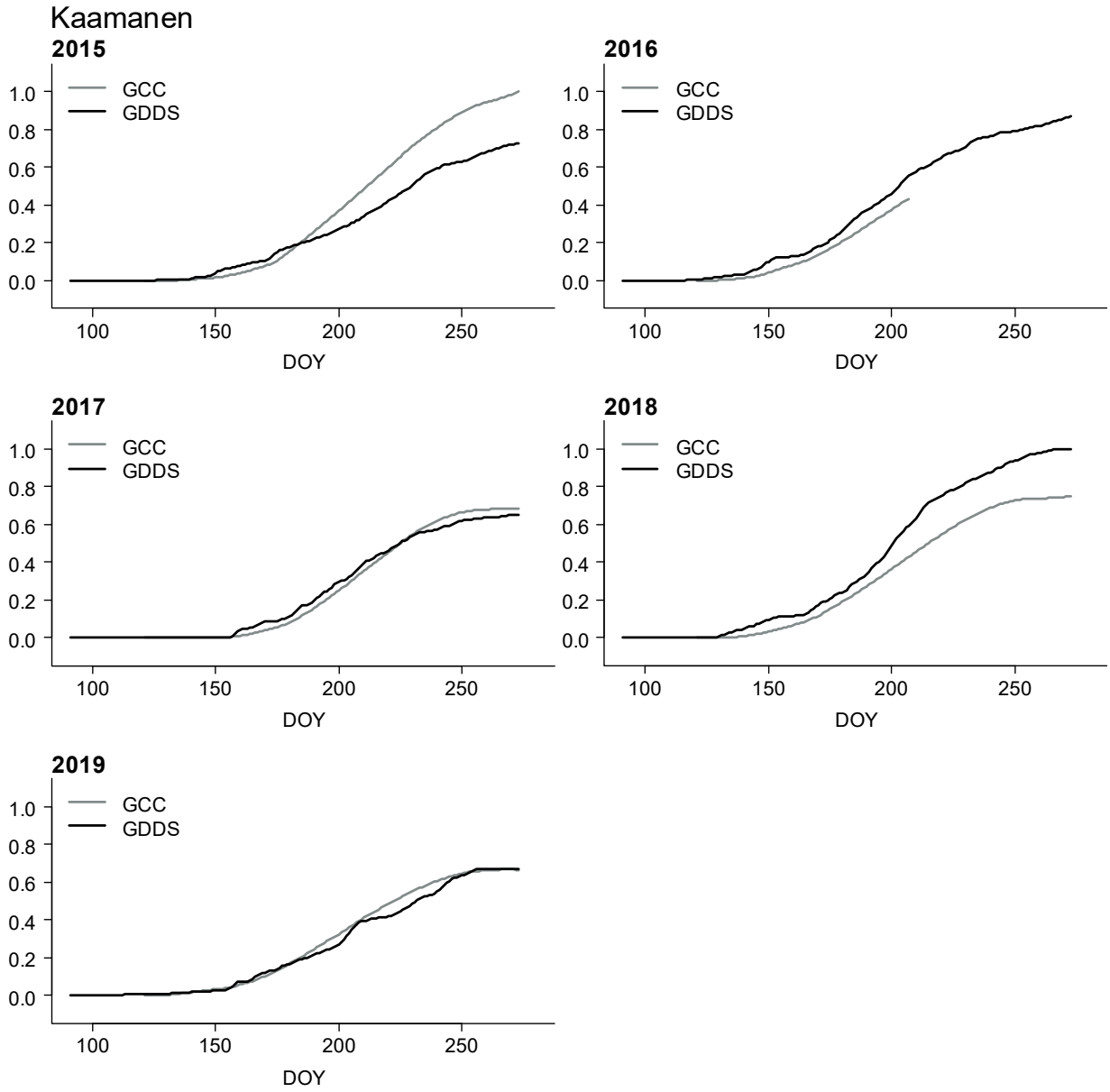

Figure S6: The normalized cumulative GCC and growing degree days (GDDS) in 2015 – 2019 at the experimental sites.

Table S5. The significant differences of mean three-day difference in GCC divided to temperature classes (<5 °C, 5–10 °C, >10 °C) between the sites as groupwise comparison (Kruskal-Wallis one-way analysis of variance on ranks). χ^2 denotes the chi-squared test statistic.

Temperature class < 5 °C		
Month	χ^2	**p-value**
May	2.23	0.328
June	0.86	0.652
July	-	-
August	-	-
September	1.32	0.518

Temperature class 5-10 °C		
Month	χ^2	**p-value**
May	3.40	0.182
June	29.1	<0.001
July	5.60	0.061
August	21.32	<0.001
September	16.57	<0.001

Temperature class > 10 °C		
Month	χ^2	**p-value**
May	8.66	0.013
June	26.61	<0.001
July	9.25	0.010
August	9.96	0.007
September	13.65	0.001

Table S6. The significant differences of mean three-day difference in GCC divided to temperature classes (5–10 °C, >10 °C) between the sites (Halssiaapa (Hal), Lompolojänkkä (Lom) and Kaamanen (Kaa)) as a pairwise comparison (Dunn's test). The significance values were adjusted by the Holm correction for multiple tests. Z denotes the test statistic. Temperature class < 5 °C is missing from the analysis since the groupwise comparison showed no significant differences.

Temperature class 5-10 °C

	May		June		July		August		September	
	Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
Lom - Hal			-5.05	<0.001			-1.64	0.102	1.40	0.161
Lom - Kaa			-4.13	<0.001			3.02	0.005	4.03	<0.001
Hal - Kaa			-0.99	0.320			-4.48	<0.001	-2.61	0.018

Temperature class > 10 °C

	May		June		July		August		September	
	Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
Lom - Hal	-2.15	0.062	-1.93	0.054	2.69	0.022	0.03	0.976	3.67	<0.001
Lom - Kaa	-2.90	1.10E-02	-5.04	<0.001	0.14	0.891	2.72	0.013	2.21	0.054
Hal - Kaa	1.29	0.198	3.70	<0.001	2.54	0.022	-2.820	0.014	1.23	0.218

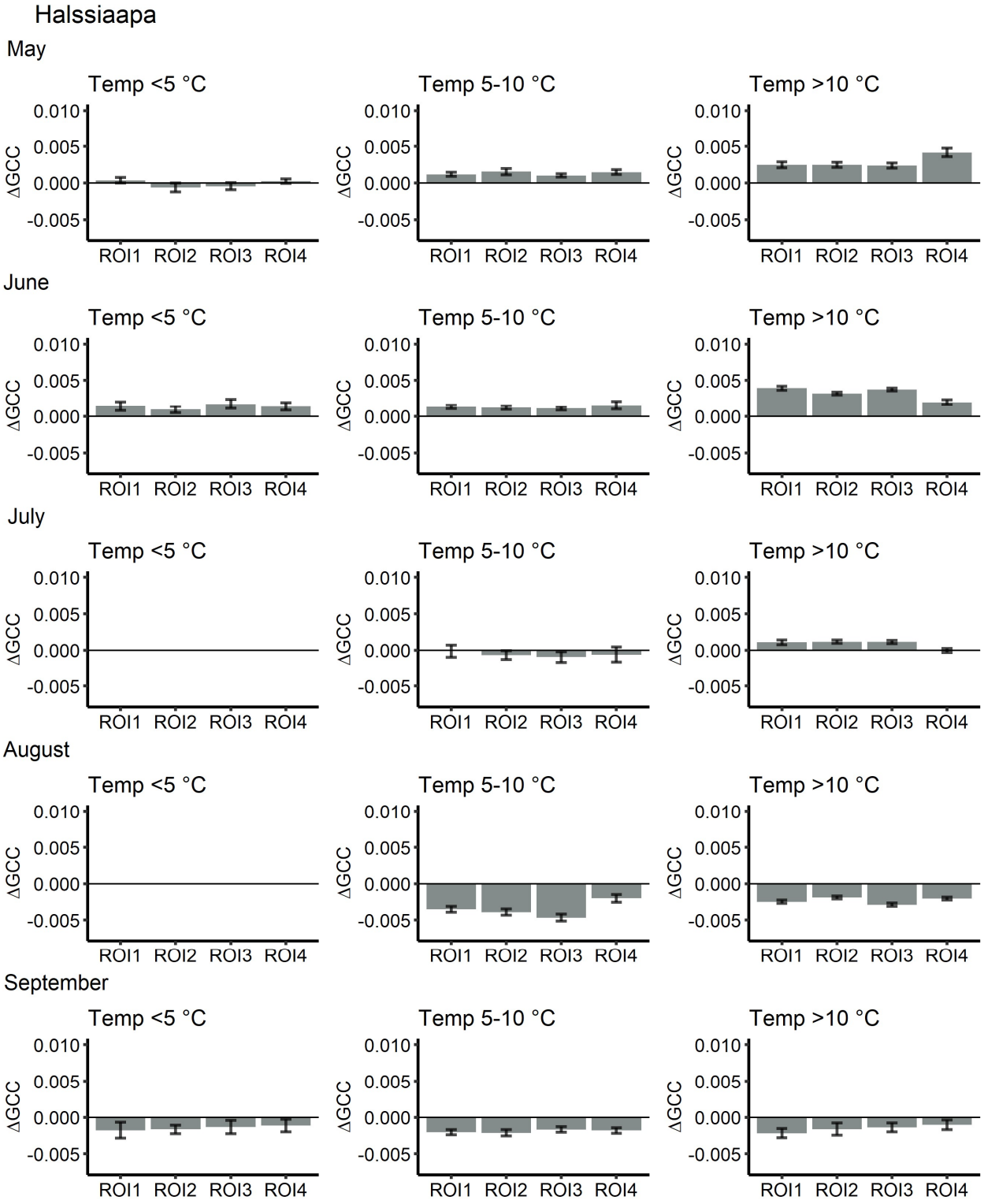

Figure S7: Mean three-day difference in GCC divided to temperature classes (<5 °C, 5-10 °C, >10 °C) at Halssiaapa from May to September. No temperature data in the <5 °C class in July and August. The error bars denote the standard error.

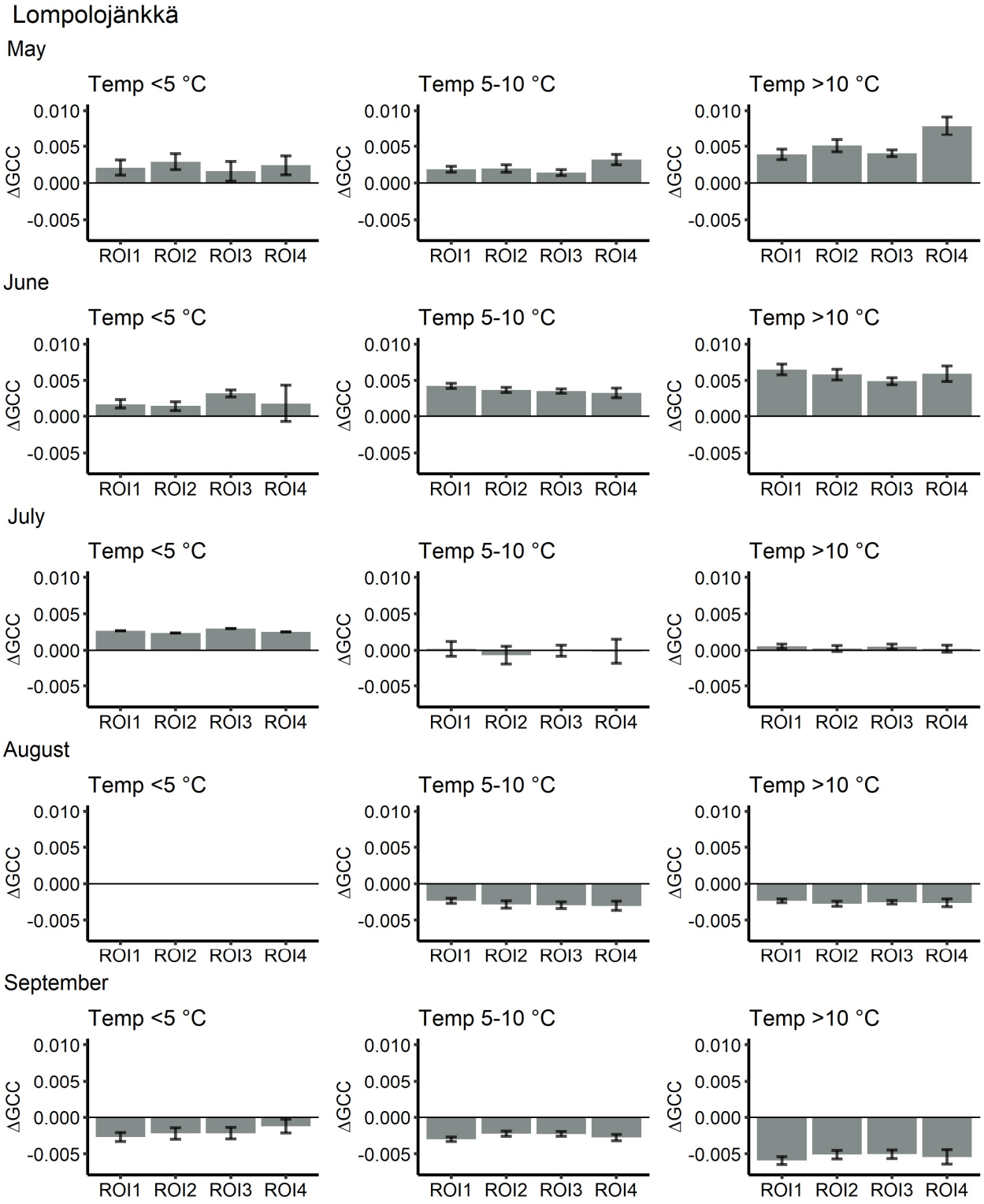

Figure S8: Mean three-day difference in GCC divided to temperature classes (<5 °C, 5-10 °C, >10 °C) at Lompolojänkkä from May to September. No temperature data in the <5 °C class in August. The error bars denote the standard error.

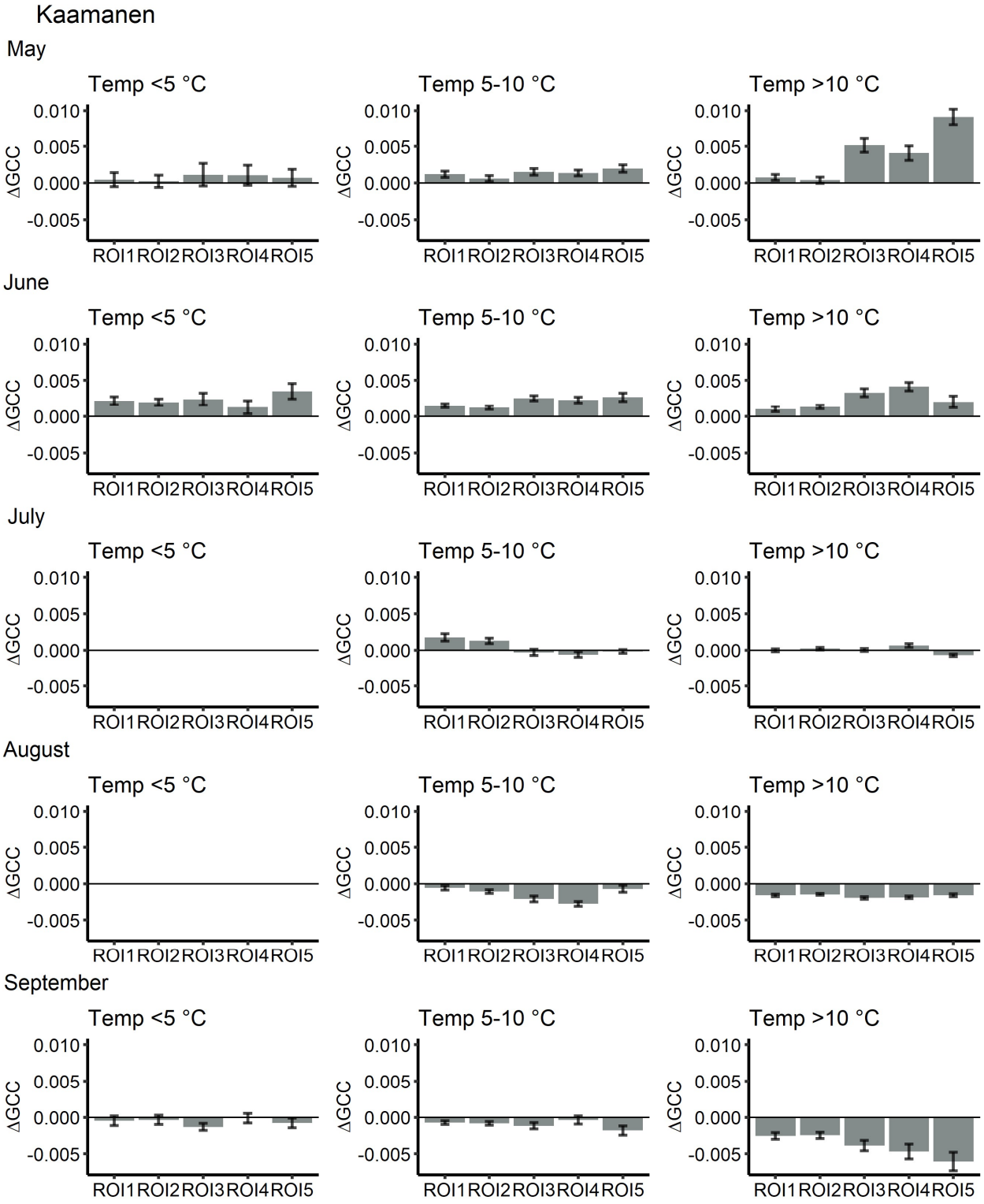

Figure S9: Mean three-day difference in GCC divided to temperature classes (<5 °C, 5-10 °C, >10 °C) at Kaamanen from May to September. No temperature data in the <5 °C class in July and August. The error bars denote the standard error.

Table S7: The significant differences in GPP_{max} between the sites during the measurement years as groupwise comparison (Kruskal-Wallis one-way analysis of variance on ranks). For interpretation, asterisk denotes significant ($p < 0.05$) difference among all sites. χ^2 denotes the chi-squared test statistic.

Year	χ^2	p-value
2015	9.56	0.008
2016	12.79	0.002
2017	4.24	0.120
2018	7.72	0.021
2019	27.18	<0.001

Table S8: The significant differences in GPP_{max} between the sites (Halssiaapa (Hal), Lompolojänkkä (Lom) and Kaamanen (Kaa)) during the measurement years as a pairwise comparison (Dunn's test). The significance values were adjusted by the Holm correction for multiple tests. For interpretation, asterisk denotes significant ($p < 0.05$) difference between two sites. Z denotes the test statistic.

	2015		2016		2017		2018		2019	
	Z	p-value	Z	p-value	Z	p-value	Z	p-value	Z	p-value
Lom - Hal	-1.92	0.109	0.84	0.403	0.22	0.827	-0.82	0.396	-0.58	0.559
Lom - Kaa	-3.08	0.006	-2.33	0.039	-1.65	0.200	-2.75	0.018	-4.88	<0.001
Hal - Kaa	1.21	0.225	3.51	0.001	1.89	0.177	1.42	0.311	4.25	<0.001

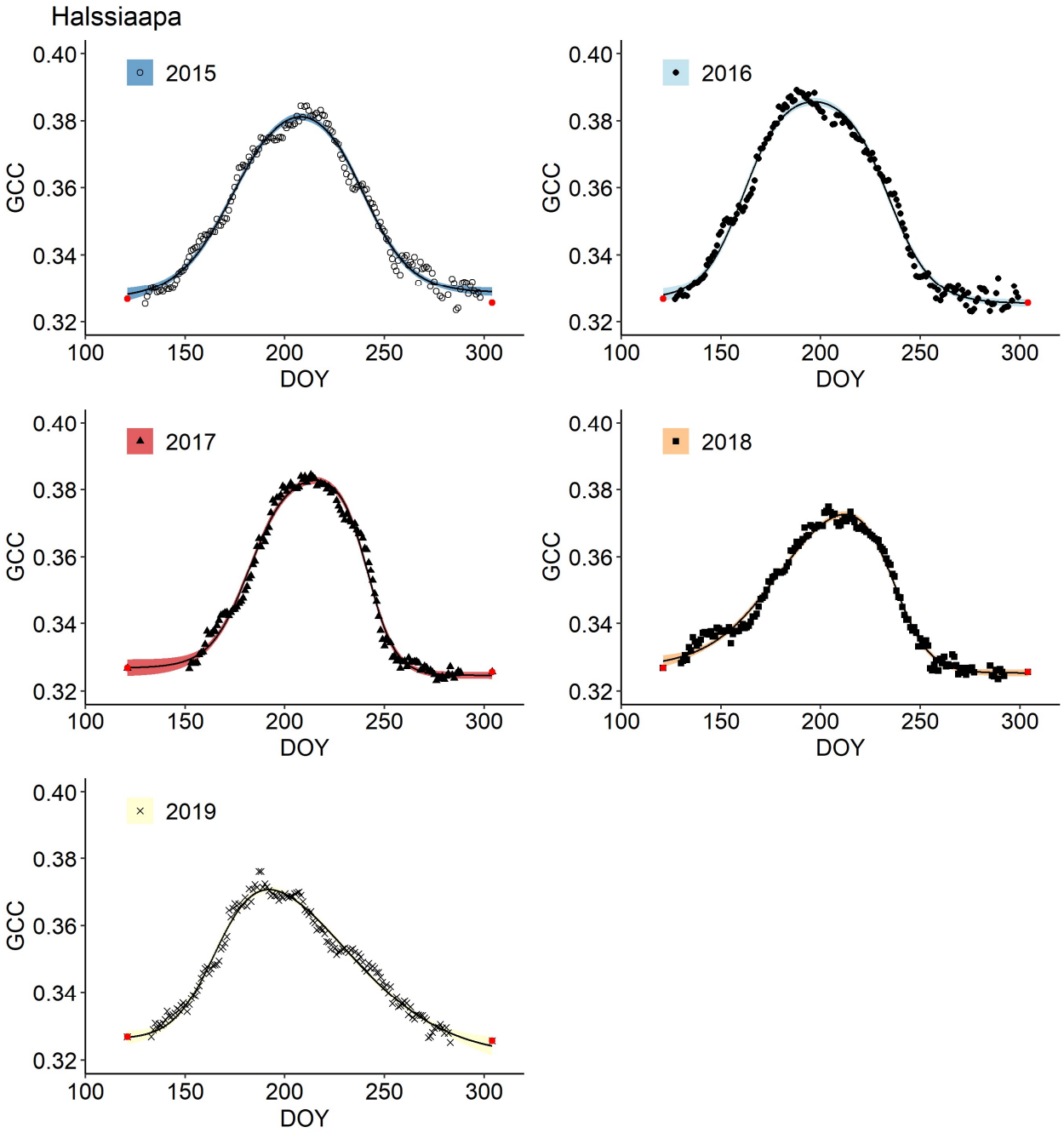

Figure S10: The GCC values and fitted function with the 95 % confidence intervals in 2015 – 2019 at Halssiaapa. The red dots indicate the fixed start and end points in the fitting.

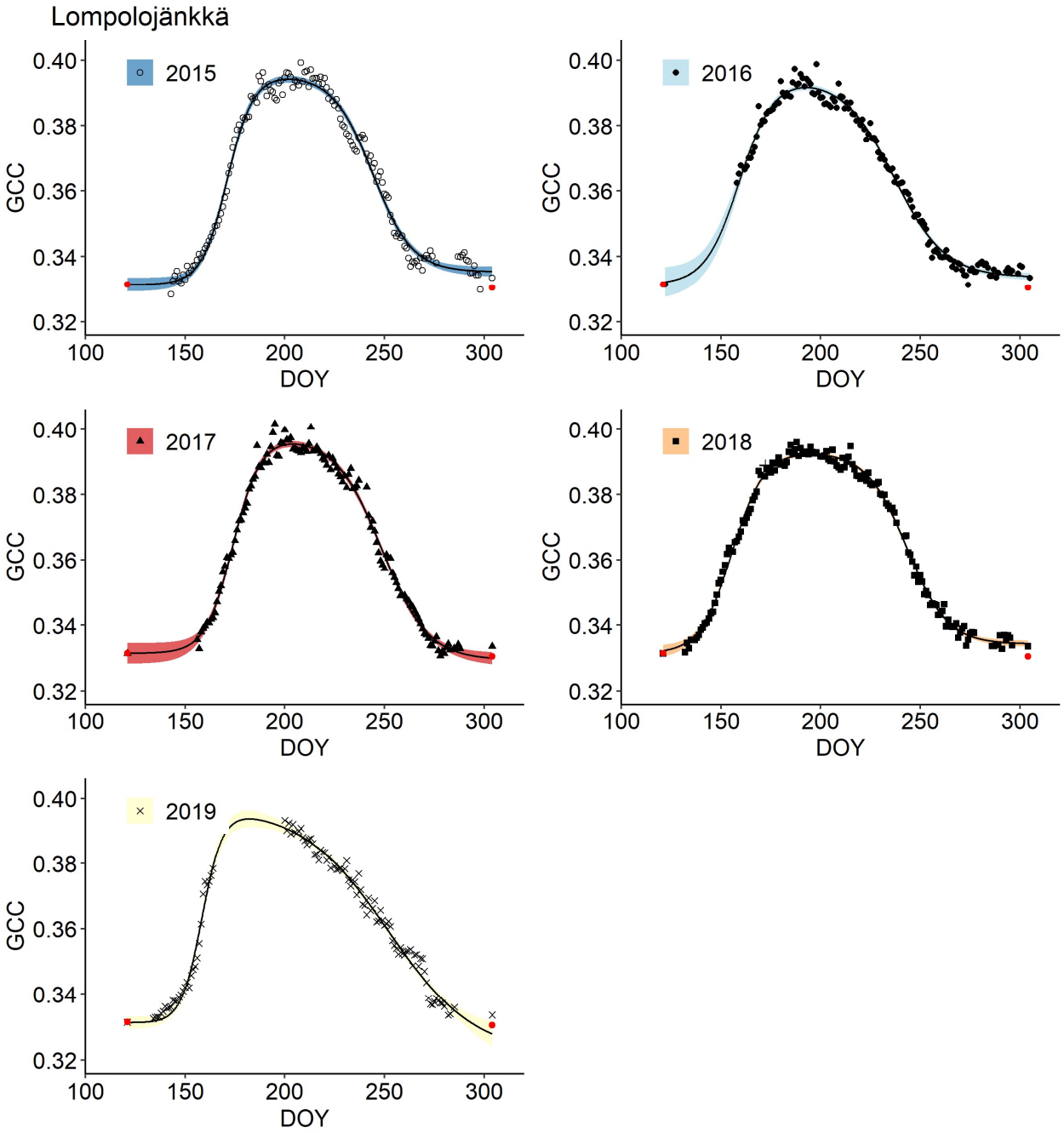

Figure S11: The GCC values and fitted function with the 95 % confidence intervals in 2015 – 2019 at Lomoplojänkkä. The red dots indicate the fixed start and end points in the fitting.

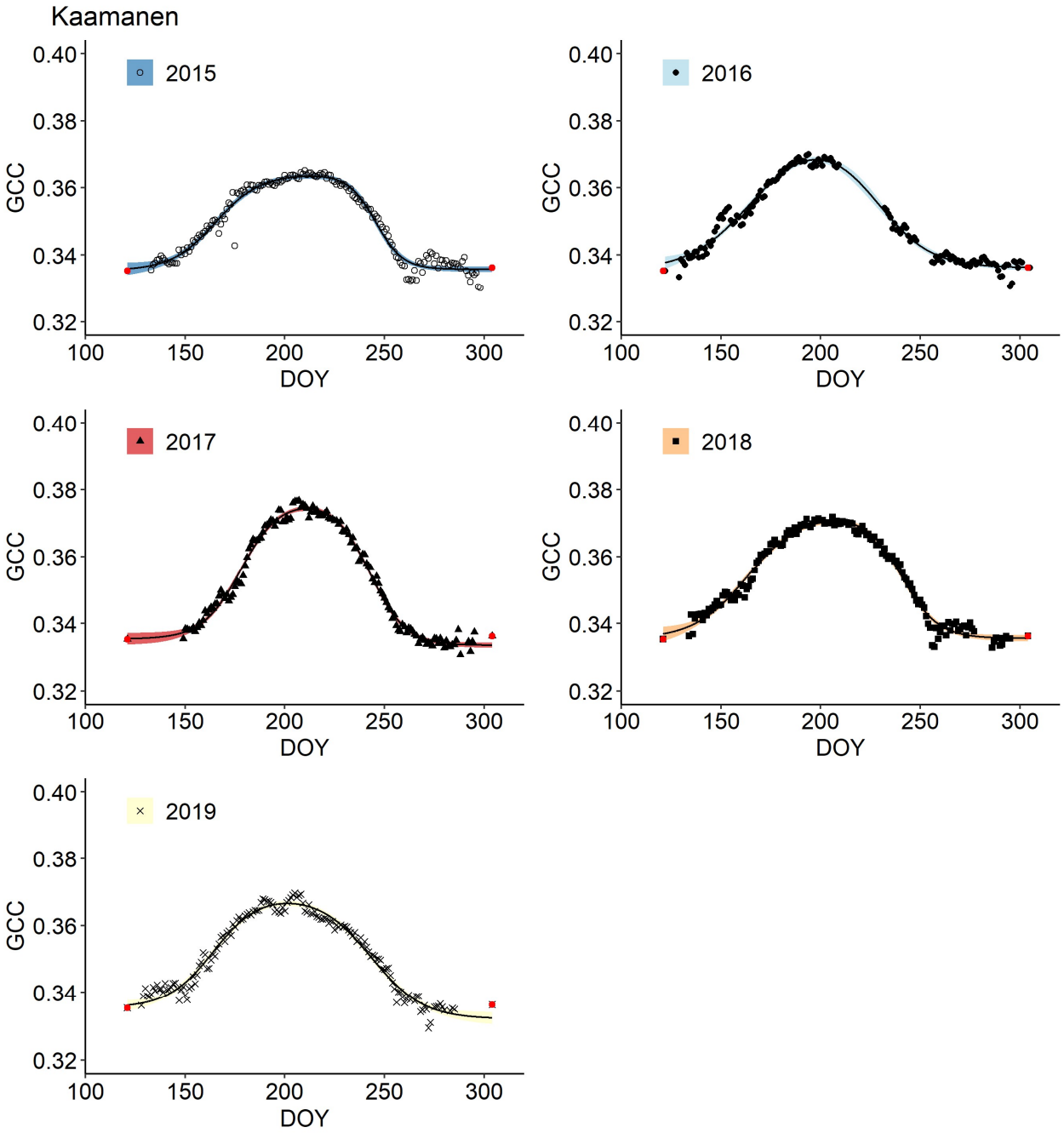

Figure S12: The GCC values and fitted function with the 95 % confidence intervals in 2015 – 2019 at Kaamanen. The red dots indicate the fixed start and end points in the fitting.

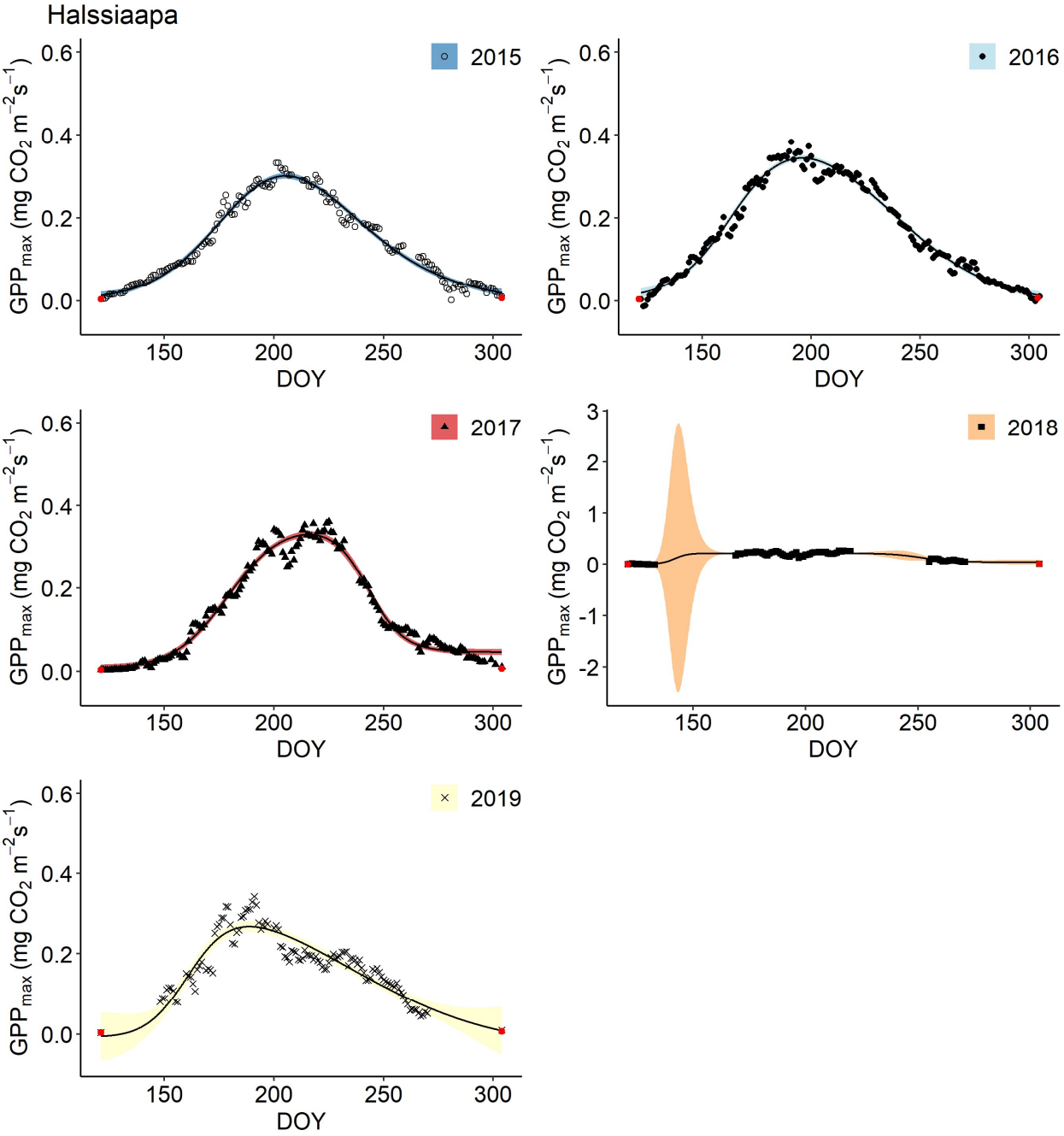

Figure S13: The GPP_{max} values and fitted function with the 95 % confidence intervals in 2015 – 2019 at Halssiaapa. Note the different scale in 2018. The red dots indicate the fixed start and end points in the fitting.

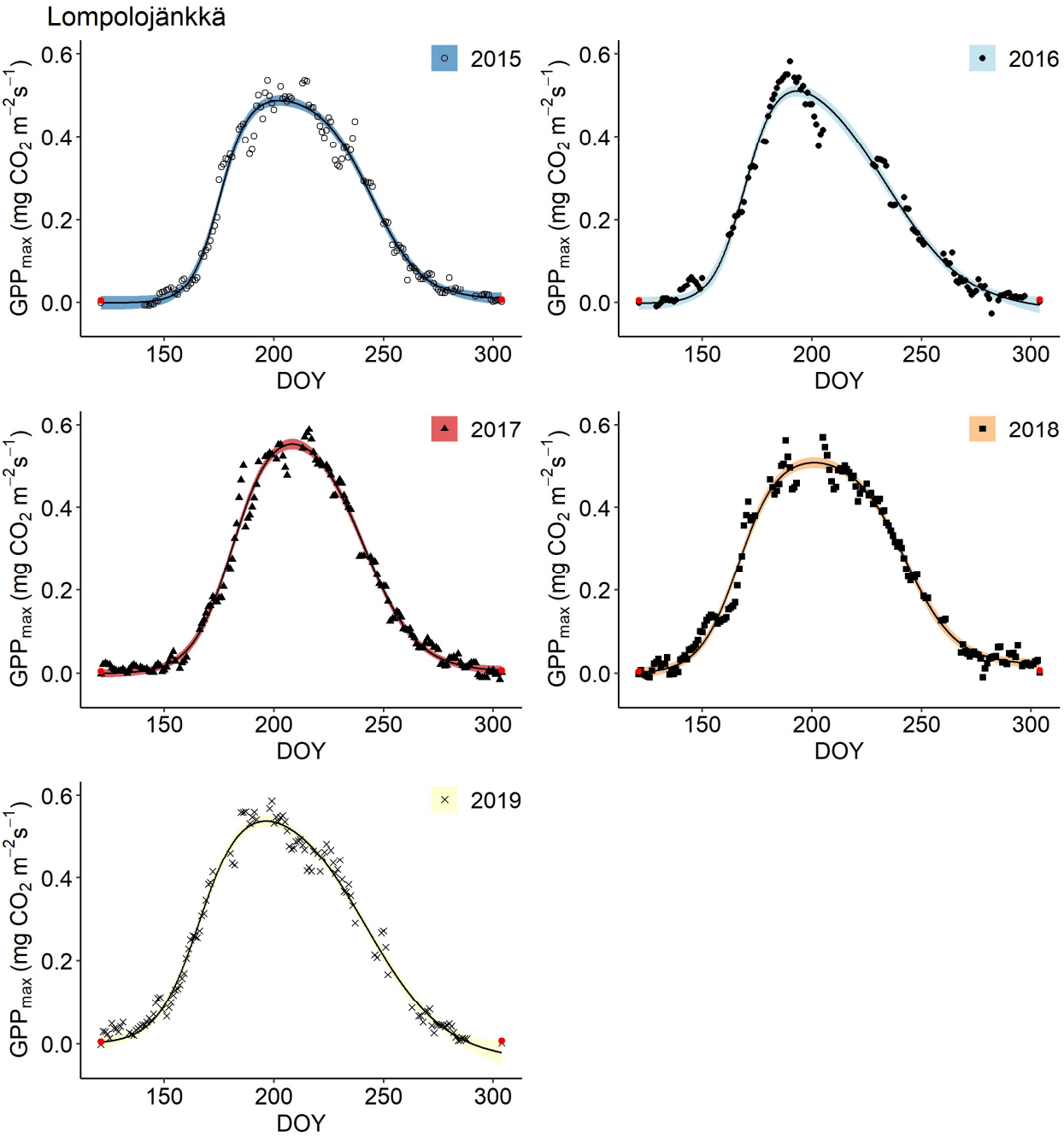

Figure S14: The GPP_{max} values and fitted function with the 95 % confidence intervals in 2015 – 2019 at Lompolojänkkä. The red dots indicate the fixed start and end points in the fitting.

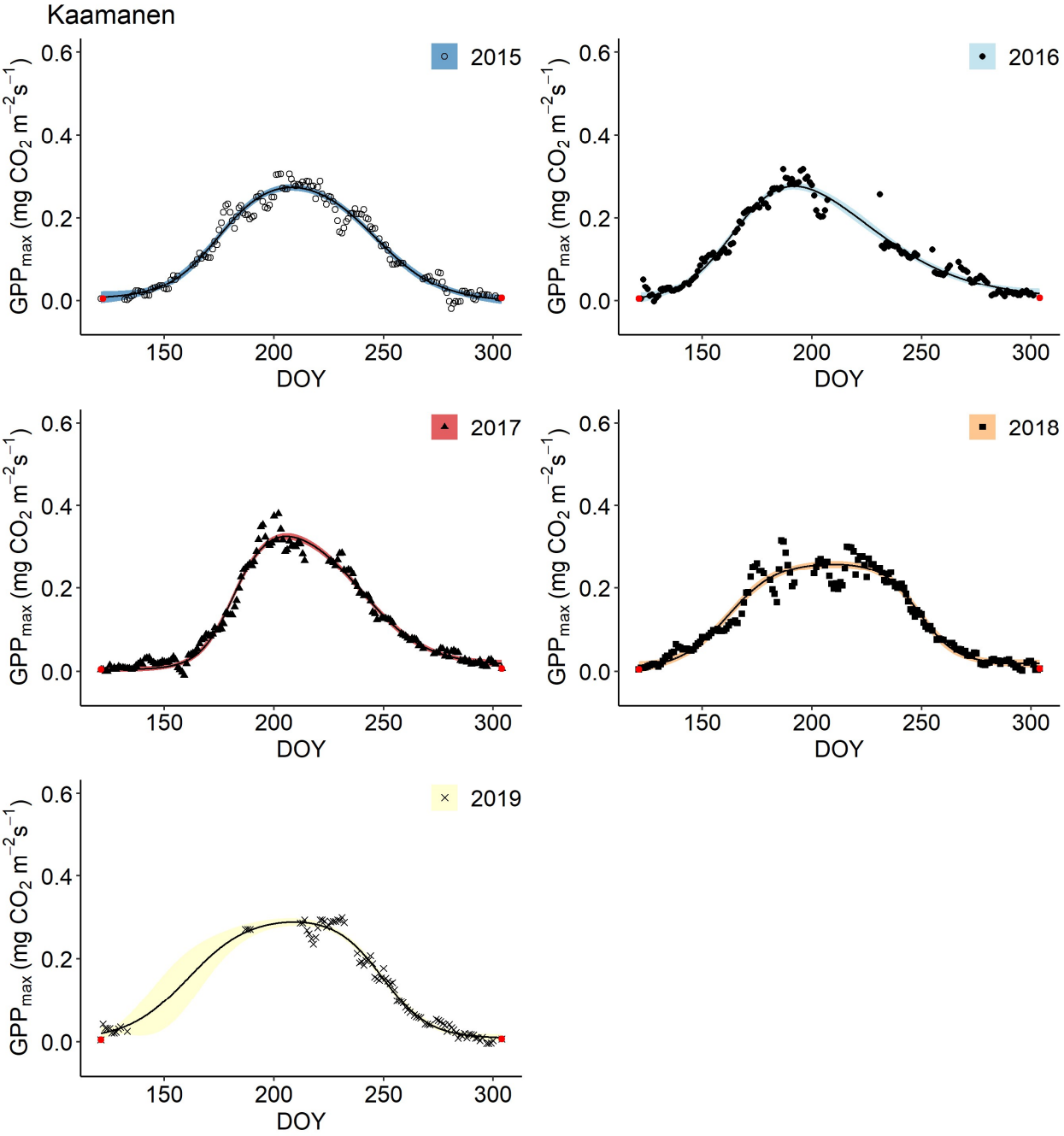

Figure S15: The GPP_{max} values and fitted function with the 95 % confidence intervals in 2015 – 2019 at Kaamanen. The red dots indicate the fixed start and end points in the fitting.

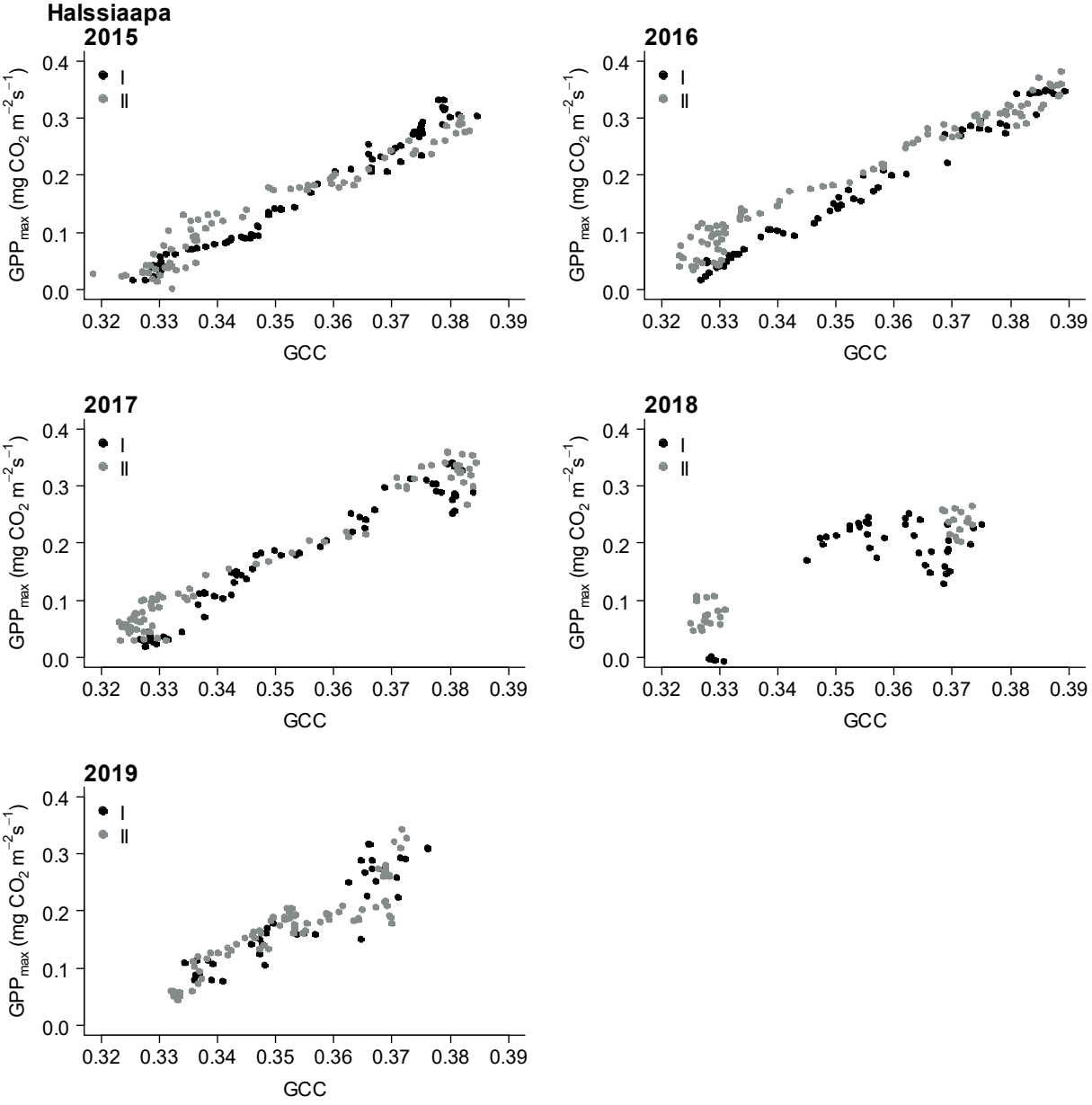

Figure S16: The relationship between GCC and GPP_{max} at Halssiaapa in 2015–2019. The first part of the growing season is denoted with black circles, the latter half with red circles.

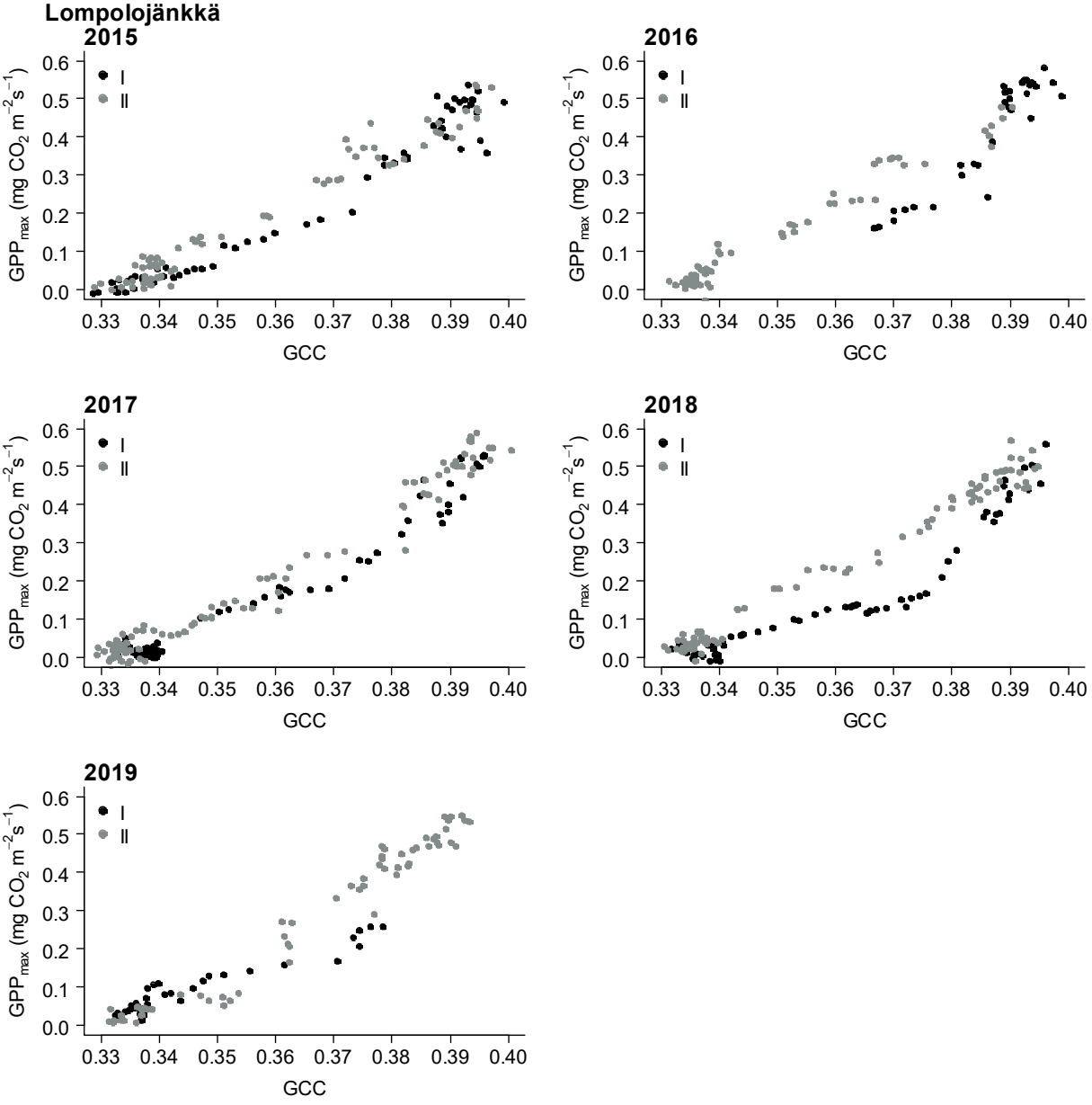

Figure S17: The relationship between GCC and GPP_{max} at Lompoljänkkä in 2015–2019. The first part of the growing season is denoted with black circles, the latter half with red circles.

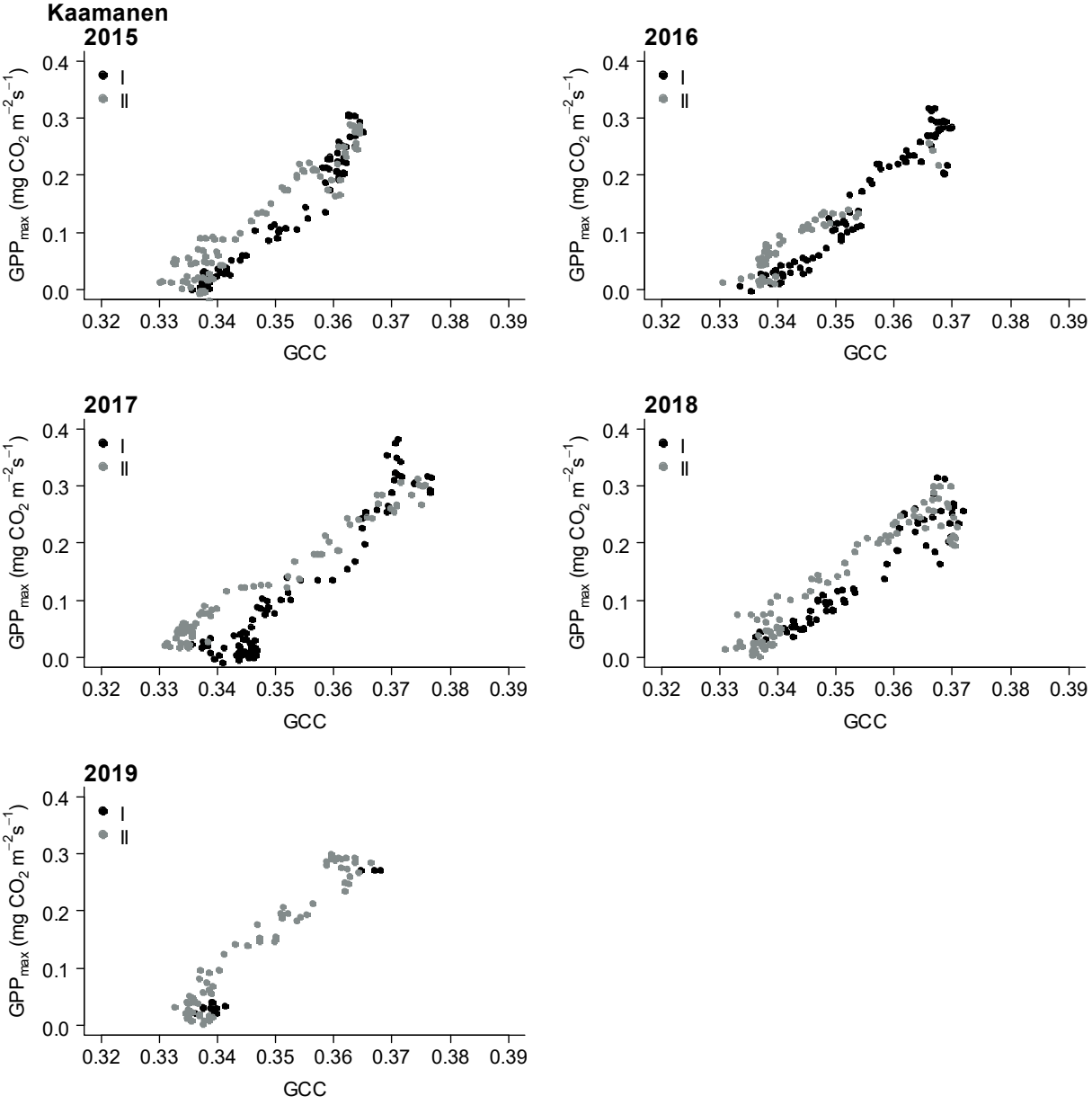

Figure S18: The relationship between GCC and GPP_{max} at Kaamanen in 2015–2019. The first part of the growing season is denoted with black circles, the latter half with red circles.

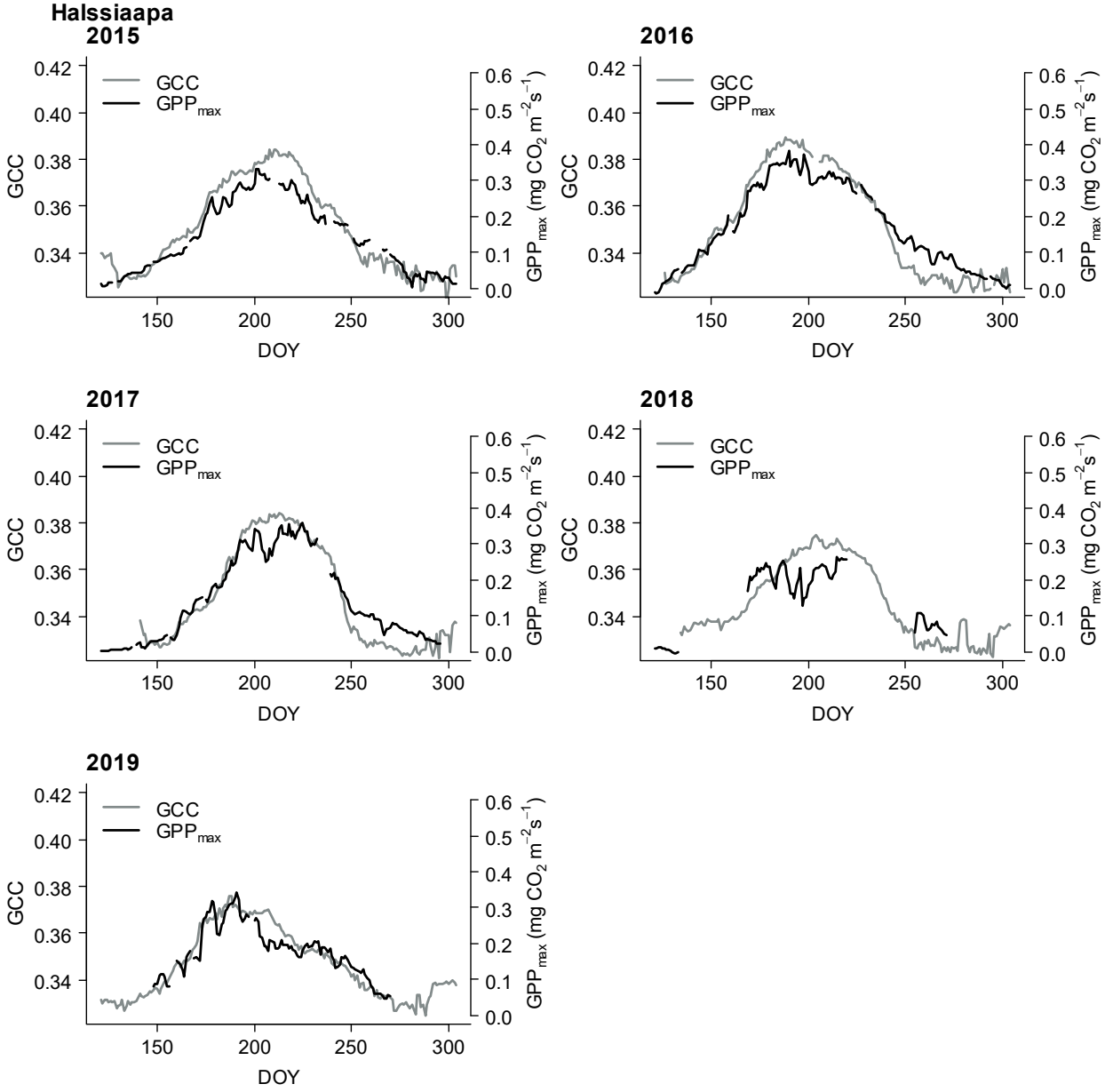

Figure S19: The scaled GCC and GPP_{max} data at Halssiaapa in 2015–2019.

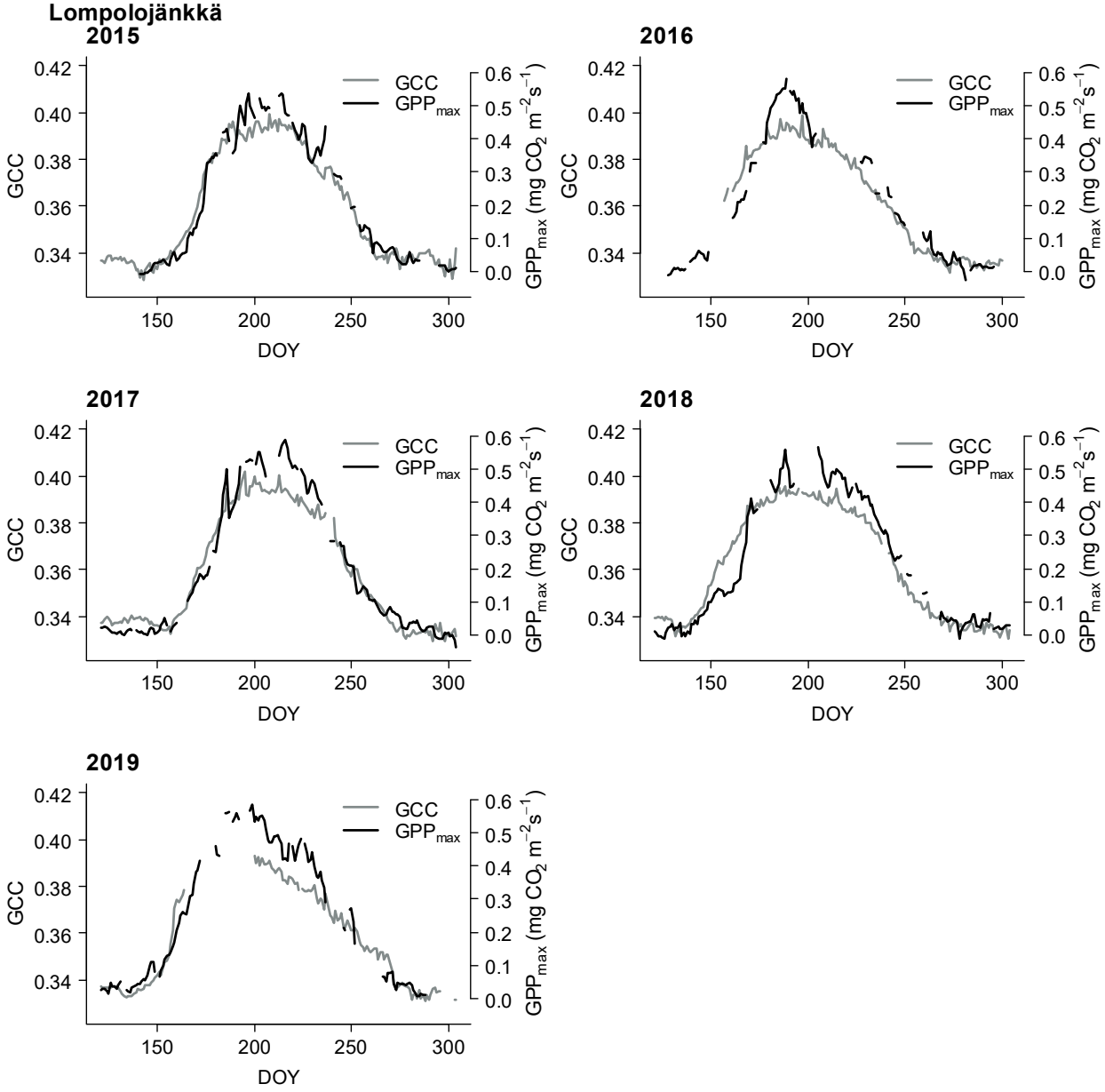

Figure S20: The scaled GCC and GPP_{max} data at Lompolojänkkä in 2015–2019.

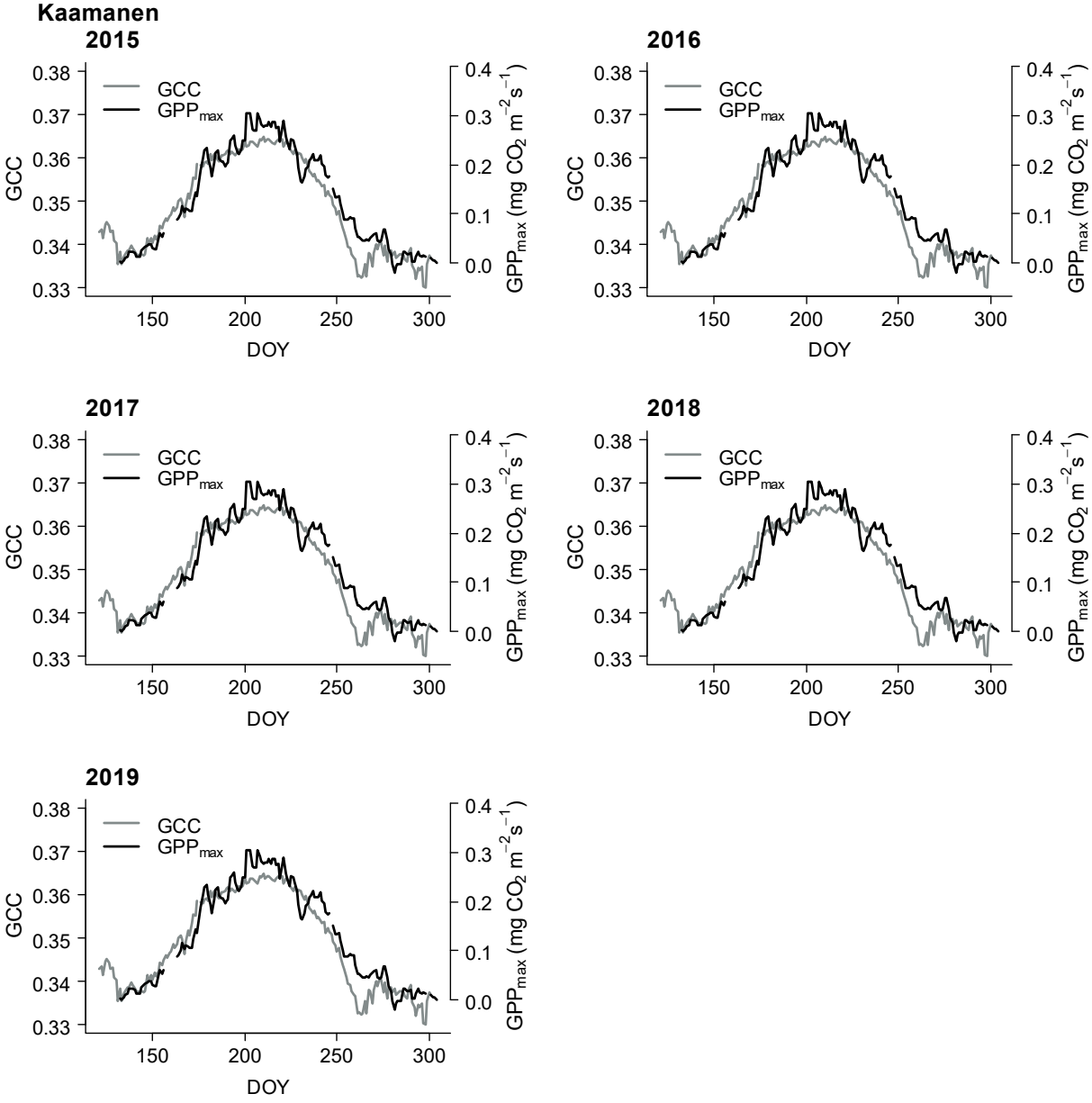

Figure S21: The scaled GCC and GPP_{max} data at Kaamanen in 2015–2019.

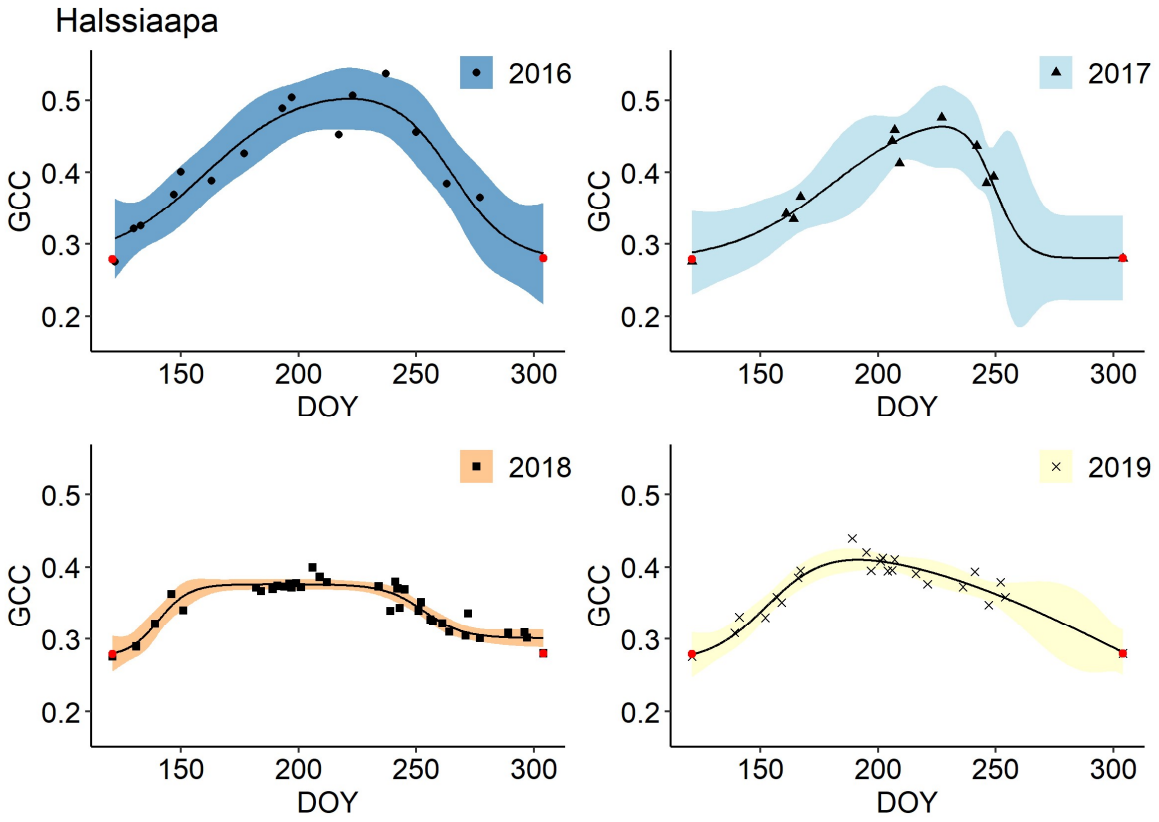

Figure S22: The Sentinel-2 derived GCC values and fitted function with the 95 % confidence intervals in 2016 – 2019 at Halssiaapa. The red dots indicate the fixed start and end points in the fitting.

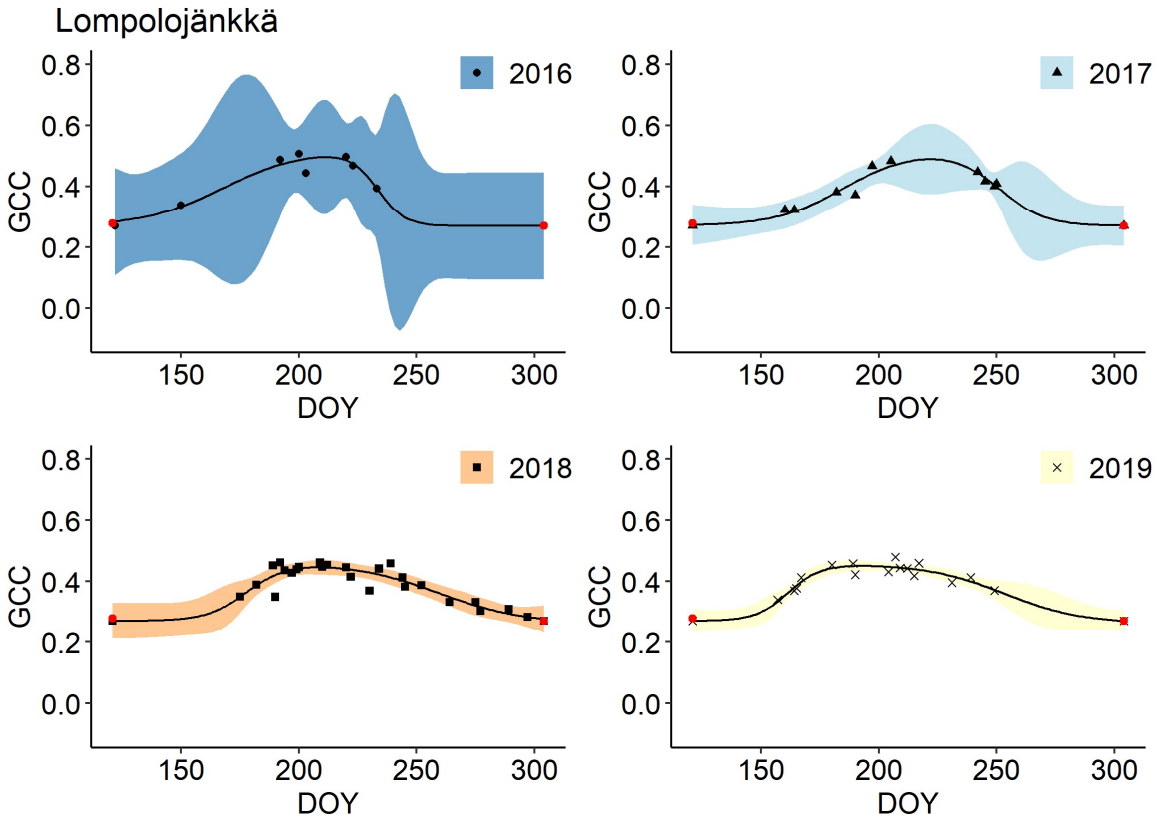

Figure S23: The Sentinel-2 derived GCC values and fitted function with the 95 % confidence intervals in 2016 – 2019 at Lompolojänkkä. The red dots indicate the fixed start and end points in the fitting.

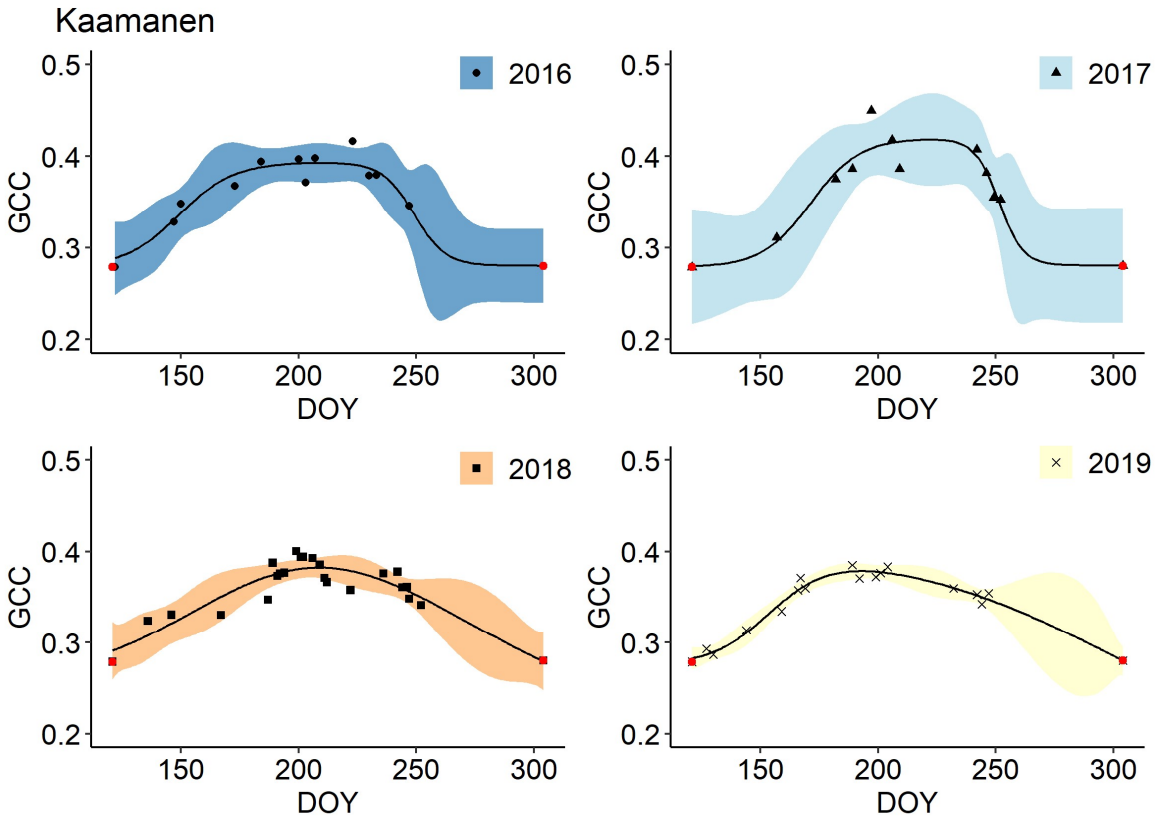

Figure S24: The Sentinel-2 derived GCC values and fitted function with the 95 % confidence intervals in 2016 – 2019 at Kaamanen. The red dots indicate the fixed start and end points in the fitting.