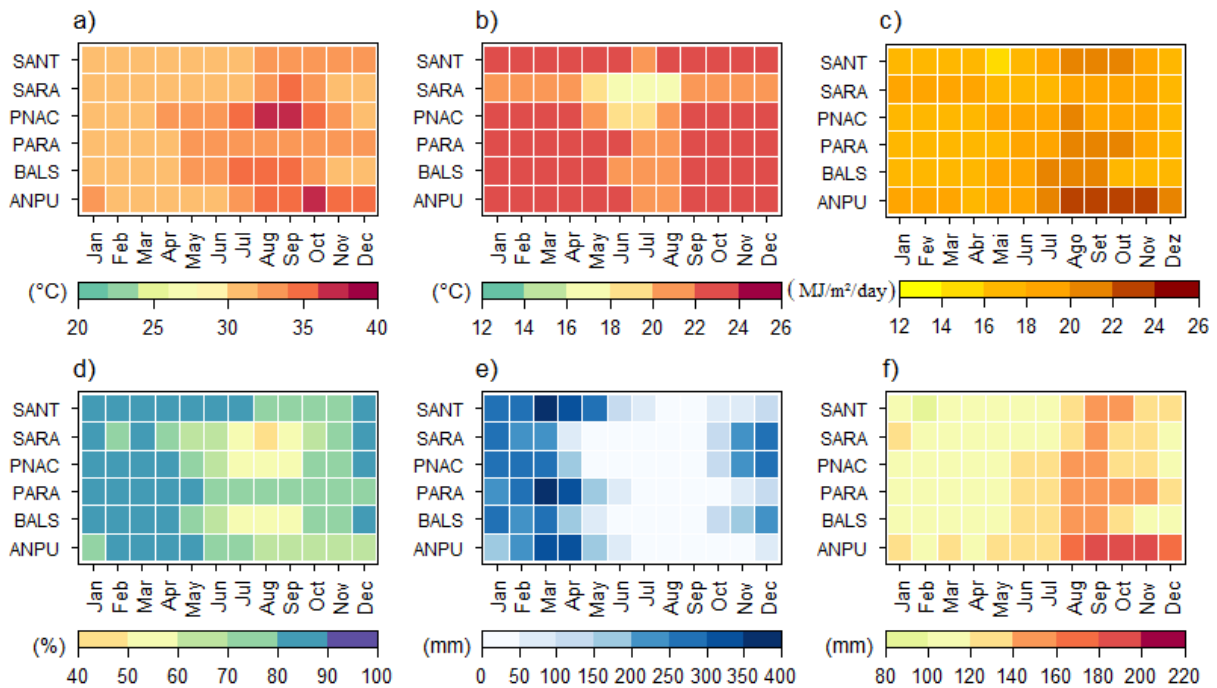**Supplementary materials**

Figure S1 – Climatology by month from 1980 to 2015 for six sites used in the study. (a) Mean maximum air temperature; (b) Mean minimum air temperature; (c) Solar radiation; (d) Mean relative humidity; (e) Rainfall; and (f) Reference evapotranspiration estimated by Penman-Monteith. Sites were denominated as Santarém (SANT), Santana do Araguaia (SARA), Porto Nacional (PNAC), Paragominas (PARA), Balsas (BALS), Anapurus (ANPU), Brazil. The data used were obtain from 1980 to 2015 from Xavier et al. (2015). Xavier, A.C., King, C.W., Scanlon, B.R., 2015. Daily gridded meteorological variables in Brazil (1980-2013). Int. J. Climatol. 36, 2644–2659. https://doi.org/10.1002/joc.4518.
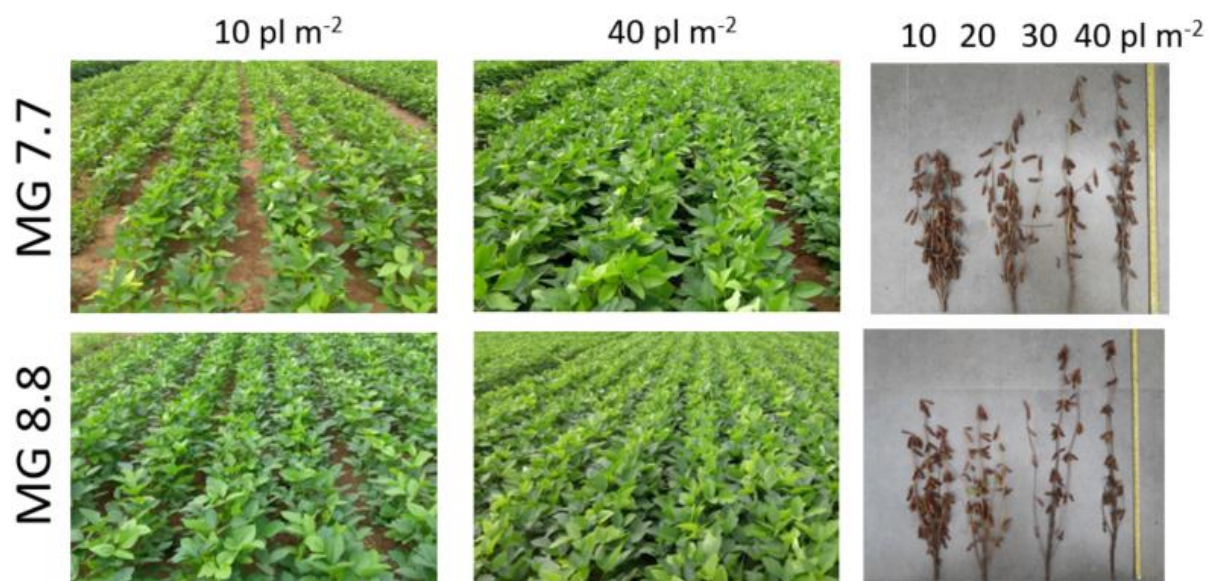

Figure S2 – Two maturity groups at four plant density treatments at field experiment in R1/R2 and R9 stages.

Table S1 - Soil layer characteristics used to simulated long-term management for soybean with the CSM-CROPGRO.

Depth (cm)	Sand	Silt	Clay	BD[1]	KSAT[2]	SAT[3]	DUL[4]	LL[5]
		%		g cm^{-3}	cm h^{-1}		cm³ cm^{-3}	
Clayey								
0-10	9	16	75	1.15	0.56	0.578	0.458	0.296
10-20	9	16	75	1.15	0.56	0.578	0.458	0.296
20-30	8	15	77	1.15	0.18	0.582	0.453	0.298
30-50	8	11	81	1.30	0.88	0.622	0.488	0.284
50-70	8	11	81	1.30	0.88	0.622	0.488	0.284
70-300	8	11	81	1.30	0.88	0.622	0.488	0.284
Sand-Clayey								
0-10	48	11	41	1.35	1.50	0.438	0.260	0.160
10-20	48	11	41	1.35	1.50	0.438	0.260	0.160
20-30	48	11	41	1.35	1.50	0.438	0.260	0.160
30-50	48	11	41	1.50	1.50	0.389	0.260	0.160
50-70	48	11	41	1.50	1.50	0.389	0.260	0.160
70-300	48	11	41	1.50	1.50	0.389	0.260	0.160

Soil Layer	SRGF[6]	Soil Layer	SRGF[6]
1 (0 - 5 cm)	1	7 (60 - 70 cm)	0.18
2 (5 - 15 cm)	1	8 (70 - 100 cm)	0.16
3 (15 - 30 cm)	0.42	9 (100 - 125 cm)	0.04
4 (30 - 40 cm)	0.34	10 (125 - 150 cm)	0.04
5 (40 - 50 cm)	0.23	11 (150 - 160 cm)	0.00
6 (50 - 60 cm)	0.20	12 (160 - 300 cm)	0.00

[1]BD: soil bulk density; [2]KSAT= hydraulic conductivity at saturation; [3]SAT = soil water content at soil saturation; [4]DUL = soil water content at drained upper limit; and [5]LL = soil water content at lower limit. [6]SRGF = Soil root growth factor, obtained from Battisti et al. (2017).

Table S2 - Leaf area index performance (m^2 m^{-2}) as a function of sowing date, plant density and maturity group for time-series data.

Sowing dates	pl m^{-2}	Mean (m^2 m^{-2}) Measured	Simulated	Bias (m^2 m^{-2})	RMSE	RRMSE (%)	Mean Measured	Simulated	Bias (m^2 m^{-2})	RMSE	RRMSE (%)
		MG 7.7 – Calibration					MG 8.8 – Calibration				
Jan. 6, 2018	10	1.77	1.37	-0.40	0.50	28	2.13	2.01	-0.12	0.26	12
	20	2.18	1.96	-0.22	0.47	22	2.85	2.77	-0.08	0.31	11
	30	2.38	2.43	0.05	0.60	25	-	-	-	-	-
	40	2.89	2.80	-0.09	0.43	15	2.99	3.65	0.66	0.83	28
Jan. 19, 2018	10	2.06	1.58	-0.47	0.65	32	2.34	2.30	-0.04	0.12	5
	20	3.73	2.65	-1.08	1.23	33	2.87	3.33	0.46	0.46	16
Feb. 16, 2018	10	-	-	-	-	-	2.42	2.67	0.25	0.31	13
	20	2.78	2.76	-0.02	0.73	26	-	-	-	-	-
	30	3.22	2.94	-0.28	0.68	21	-	-	-	-	-
	40	-	-	-	-	-	3.55	4.17	0.62	0.68	19
		MG 7.7 – Evaluation					MG 8.8 – Evaluation				
Jan. 12, 2019	10	1.96	1.72	-0.24	0.58	30	2.34	2.30	-0.04	0.12	5
	20	3.62	2.58	-1.04	1.16	32	2.87	3.33	0.46	0.46	16
	30	4.02	3.22	-0.80	0.85	21	3.41	4.04	0.63	0.68	20
	40	4.63	3.73	-0.91	1.09	24	3.39	4.48	1.09	1.10	32

Table S3 - Above-ground dry biomass performance (kg ha^{-1}) as a function of sowing date, plant density and maturity group for time-series data.

Sowing dates	pl m^{-2}	Mean (m² m$^{-2)}$) Measured	Simulated	Bias (m² m$^{-2)}$)	RMSE	RRMSE (%)	Mean Measured	Simulated	Bias (m² m$^{-2)}$)	RMSE	RRMSE (%)
		MG 7.7 – Calibration					MG 8.8 – Calibration				
Jan. 6, 2018	10	2833	2505	-328	549	19	3699	3619	-79	499	13
	20	3576	3058	-517	785	22	4113	4195	82	646	16
	30	3680	3407	-273	519	14	-	-	-	-	-
	40	4390	3637	-753	838	19	4692	4709	16	652	14
Jan. 19, 2018	10	3821	3269	-552	975	26	4283	3992	-291	597	14
	20	4611	3990	-621	911	20	4934	4578	-356	476	10
Feb. 16, 2018	10	-	-	-	-	-	3964	4223	258	291	7
	20	4420	4876	456	878	20	-	-	-	-	-
	30	4852	4498	-354	909	19	-	-	-	-	-
	40	-	-	-	-	-	4853	4651	-202	357	7
		MG 7.7 – Evaluation					MG 8.8 – Evaluation				
Jan. 12, 2019	10	3471	3439	-32	432	12	3843	4289	446	798	21
	20	4576	4226	-351	704	15	4338	4987	649	966	22
	30	4845	4675	-170	261	5	4515	5365	850	1244	28
	40	5840	4982	-858	1220	21	4558	5569	1011	1206	26

Table S4 - Leaf dry biomass performance (kg ha^{-1}) as a function of sowing date, plant density and maturity group for time-series data.

Sowing dates	pl m^{-2}	Mean (m² m^{-2}) Measured	Simulated	Bias (m² m^{-2})	RMSE	RRMSE (%)	Mean Measured	Simulated	Bias (m² m^{-2})	RMSE	RRMSE (%)
		MG 7.7 – Calibration					MG 8.8 – Calibration				
Jan. 6, 2018	10	854	611	-243	254	30	973	1006	32	221	23
	20	1122	819	-303	317	28	1160	1242	82	192	17
	30	1081	984	-97	170	16	-	-	-	-	-
	40	1330	1113	-217	226	17	1336	1499	163	255	19
Jan. 19, 2018	10	808	486	-322	396	49	961	934	-27	210	22
	20	1195	864	-331	402	34	1254	1272	17	158	13
Feb. 16, 2018	10	-	-	-	-	-	1021	1136	114	159	16
	20	1002	986	-17	234	23	-	-	-	-	-
	30	1178	996	-181	271	23	-	-	-	-	-
	40	-	-	-	-	-	1306	1436	131	182	14
		MG 7.7 – Evaluation					MG 8.8 – Evaluation				
Jan. 12, 2019	10	639	559	-80	127	20	859	871	12	83	10
	20	1187	792	-395	469	39	1032	1120	88	130	13
	30	1287	966	-320	373	29	1118	1288	170	241	22
	40	1526	1105	-421	565	37	1060	1383	324	346	33

Table S5 - Pod dry biomass performance (kg ha^{-1}) as a function of sowing date, plant density and maturity group for time-series data.

Sowing dates	pl m^{-2}	Mean (m² m$^{-2)}$) Measured	Simulated	Bias (m² m$^{-2)}$)	RMSE	RRMSE (%)	Mean Measured	Simulated	Bias (m² m$^{-2)}$)	RMSE	RRMSE (%)
		MG 7.7 – Calibration					MG 8.8 – Calibration				
Jan. 6, 2018	10	2603	2348	-256	332	13	2505	2155	-351	407	16
	20	3038	2782	-256	378	12	2474	2501	26	496	20
	30	3095	2998	-97	338	11	-	-	-	-	-
	40	3580	3119	-460	471	13	2573	2754	180	474	18
Jan. 19, 2018	10	3520	3134	-386	466	13	2432	2038	-394	459	19
	20	2940	2845	-94	184	6	1984	1685	-299	320	16
Feb. 16, 2018	10	-	-	-	-	-	1880	1635	-246	256	14
	20	2190	2812	622	719	33	-	-	-	-	-
	30	2671	3047	375	502	19	-	-	-	-	-
	40	-	-	-	-	-	2457	2270	-186	197	8
		MG 7.7 – Evaluation					MG 8.8 – Evaluation				
Jan. 12, 2019	10	3058	3273	215	218	7	2902	3228	326	645	22
	20	3420	3856	436	436	13	3004	3712	708	876	29
	30	3630	4118	488	667	18	2764	3926	1162	1356	49
	40	4196	4278	82	187	4	2892	4046	1153	1224	42

Table S6 – Stem dry biomass performance (kg ha^{-1}) as a function of sowing date, plant density and maturity group for time-series data.

Sowing dates	pl m^{-2}	Mean (m² m^{-2}) Measured	Mean (m² m^{-2}) Simulated	Bias (m² m^{-2})	RMSE	RRMSE (%)	Mean Measured	Mean Simulated	Bias (m² m^{-2})	RMSE	RRMSE (%)
		MG 7.7 – Calibration					MG 8.8 – Calibration				
Jan. 6, 2018	10	934	886	-48	157	17	1645	1789	144	410	25
	20	1319	1084	-236	305	23	2005	2006	1	280	14
	30	1428	1222	-206	253	18	-	-	-	-	-
	40	1750	1313	-437	454	26	2467	2203	-263	406	16
Jan. 19, 2018	10	935	824	-110	303	32	1614	1700	86	225	14
	20	1510	1178	-332	497	33	2257	2043	-213	260	12
Feb. 16, 2018	10	-	-	-	-	-	1606	1962	356	374	23
	20	1477	1300	-176	308	21	-	-	-	-	-
	30	1716	1239	-477	623	36	-	-	-	-	-
	40	-	-	-	-	-	2271	2030	-240	266	12
		MG 7.7 – Evaluation					MG 8.8 – Evaluation				
Jan. 12, 2019	10	905	843	-62	229	25	1334	1515	180	280	21
	20	1505	1071	-434	550	37	1647	1714	67	161	10
	30	1567	1219	-348	433	28	1926	1833	-94	151	8
	40	2024	1320	-704	915	45	1923	1894	-29	165	9

Table S7 – Specific leaf area performance (g m^{-2}) as a function of sowing date, plant density and maturity group for time-series data.

Sowing dates	pl m^{-2}	Mean (m² m^{-2}) Measured	Simulated	Bias (m² m^{-2})	RMSE	RRMSE (%)	Mean Measured	Simulated	Bias (m² m^{-2})	RMSE	RRMSE (%)
		MG 7.7 – Calibration					MG 8.8 – Calibration				
Jan. 6, 2018	10	227	303	76	91	40	255	246	-9	67	26
	20	256	327	71	89	35	277	268	-9	61	22
	30	291	332	42	63	22	-	-	-	-	-
	40	287	324	37	39	14	275	280	5	27	10
Jan. 19, 2018	10	288	307	19	20	7	276	269	-8	74	27
	20	309	305	-4	6	2	303	290	-14	61	20
Feb. 16, 2018	10	-	-	-	-	-	246	236	-10	17	7
	20	274	281	7	20	7	-	-	-	-	-
	30	275	301	26	34	12	-	-	-	-	-
	40	-	-	-	-	-	282	303	21	29	10
		MG 7.7 – Evaluation					MG 8.8 – Evaluation				
Jan. 12, 2019	10	269	322	53	54	20	291	318	27	62	21
	20	319	332	13	18	6	292	333	41	60	21
	30	325	337	13	21	6	318	341	23	35	11
	40	325	341	16	33	10	329	346	17	38	12