Supplementary Materials:

Challenges to the Adaptation of Double Cropping Agricultural Systems in Brazil under Changes in Climate and Land Cover

Livia Maria Brumatti *, Gabrielle Ferreira Pires and Ana Beatriz Santos

Department of Agricultural Engineering, Federal University of Viçosa, Av. P. H. Rolfs, s/n, Viçosa, MG 36570-900, Brazil; gabrielle.pires@ufv.br (G.F.P.); ana.bsantos15@gmail.com (A.B.S.)
* Correspondence: livia.brumatti.ufv@gmail.com

Received: 24 October 2020; Accepted: 1 December 2020; Published: date

S1 - Average percentage change of maize off-season yield (120 days of cycle length) for each region and each climate scenario.

Table S1. Percentage change of maize off-season yield for all sowing dates simulated to MATOPIBA in RCP 8.5 scenario.

MATOPIBA			
2011–2020 sowing date	**No adaptation**	**10-day delay on 2041–2050**	**20-day delay on 2041–2050**
Jan 13	25.2*	16.4*	4.3
Jan 23	23.1*	10.3*	−5.7
Feb 02	19.8*	2.4	−17.2*
Feb 12	16.0*	−6.7	−23.9*
Feb 22	11.6	−14.2*	−34.7*
Mar 04	5.9	−19.4*	−36.2*
Mar 14	−1.1	−21.8*	−32.5*
Mar 24	−6.6	−19.4*	−25.8*
Apr 03	−8.1*	−15.4*	−22.1*
Apr 13	−6.3	−13.7*	−22.2*
Apr 23	−4.4	−13.8*	−23.2*
May 03	−5.3	−15.6*	−23.2*
May 13	−9.4*	−17.4*	−21.5*
May 23	−12.4	−16.6*	−17.8*
Jun 02	−14.6	−15.8	−12.1
Jun 12	−17.4	−13.9	-
Jun 22	−16.8	-	-

* Statistically significant changes on maize yield according to Student's t-test (α = 5 %).

Table S2. Percentage change of maize off-season yield for all sowing dates simulated to MT in RCP 8.5 scenario.

MT			
2011–2020 sowing date	**No adaptation**	**10-day delay on 2041–2050**	**20-day delay on 2041–2050**
Jan 13	16.8*	7.5	−3.7
Jan 23	14.5*	2.5	−11.2*
Feb 02	12.7*	−2.4	−18.1*
Feb 12	11.6*	−6.4	−25.2*
Feb 22	10.8	−11.5	−31.8*
Mar 04	8.1	−16.9*	−36.9*
Mar 14	2.9	−22.0*	−39.3*
Mar 24	−3.6	−24.9*	−39.6*
Apr 03	−7.9	−25.9*	−35.5*
Apr 13	−13.8	−25.1*	−26.8*
Apr 23	−19.9*	−21.8*	−17.0
May 03	−23.7*	−19.1	−7.1
May 13	−25.3*	−14.3	0.8
May 23	−23.6	−10.1	7.5
Jun 02	−19.3	−3.6	11.2
Jun 12	−11.9	1.6	-
Jun 22	−4.2	-	-

* Statistically significant changes on maize yield according to Student's t-test (α = 5 %).

Table S3. Percentage change of maize off-season yield for all sowing dates simulated to MATOPIBA in RCP 8.5 + HLU scenario.

MATOPIBA			
2011–2020 sowing date	**No adaptation**	**10-day delay on 2041–2050**	**20-day delay on 2041–2050**
Jan 13	27.4*	21.5*	12.2*
Jan 23	28.6*	18.7*	5.2
Feb 02	29.6*	14.8*	−3.4
Feb 12	31.7*	10.7	−13.7*
Feb 22	33.2*	3.8	−24.2*
Mar 04	30.1*	−5.0	−31.8*
Mar 14	20.0*	−13.9	−32.7*
Mar 24	8.6	−15.2*	−26.8*
Apr 03	2.7	−11.3	−16.5*
Apr 13	1.9	−4.1	−8.4
Apr 23	5.6	0.9	−4.3

May 03	5.6	0.2	−4.8
May 13	2.3	−2.8	−4.5
May 23	0.1	−1.7	0.1
Jun 02	0.5	2.6	3.3
Jun 12	4.8	5.7	-
Jun 22	8.8	-	-

* Statistically significant changes on maize yield according to Student's t-test (α = 5 %).

Table S4. Percentage change of maize off-season yield for all sowing dates simulated to MT in RCP 8.5 + HLU scenario.

	MT		
2011−2020 sowing date	**No adaptation**	**10-day delay on 2041−2050**	**20-day delay on 2041−2050**
Jan 13	19.7*	10.9*	−1.6
Jan 23	16.0*	2.9	−11.2
Feb 02	10.2	−4.9	−19.3*
Feb 12	4.5	−11.3	−26.5*
Feb 22	0.9	−16.4	−29.9*
Mar 04	−2.7	−18.4*	−30.4*
Mar 14	−3.3	−17.6*	−28.5*
Mar 24	−0.7	−13.9*	−22.5*
Apr 03	2.8	−7.4	−15.7
Apr 13	4.1	−5.3	−12.1
Apr 23	−1.4	−8.5	−13.4
May 03	−10.9	−15.8	−17.9
May 13	−19.9	−22.0	−20.8
May 23	−26.5*	−25.3*	−22.5
Jun 02	−28.4*	−25.7*	−22.5*
Jun 12	−27.7*	−24.7*	-
Jun 22	−25.3*	-	-

* Statistically significant changes on maize yield according to Student's t-test (α = 5 %).

S2 - Percentage change of maize off-season yield (cycle length ~ 120 days) considering a delay in soybean sowing date (10 and 20 days).

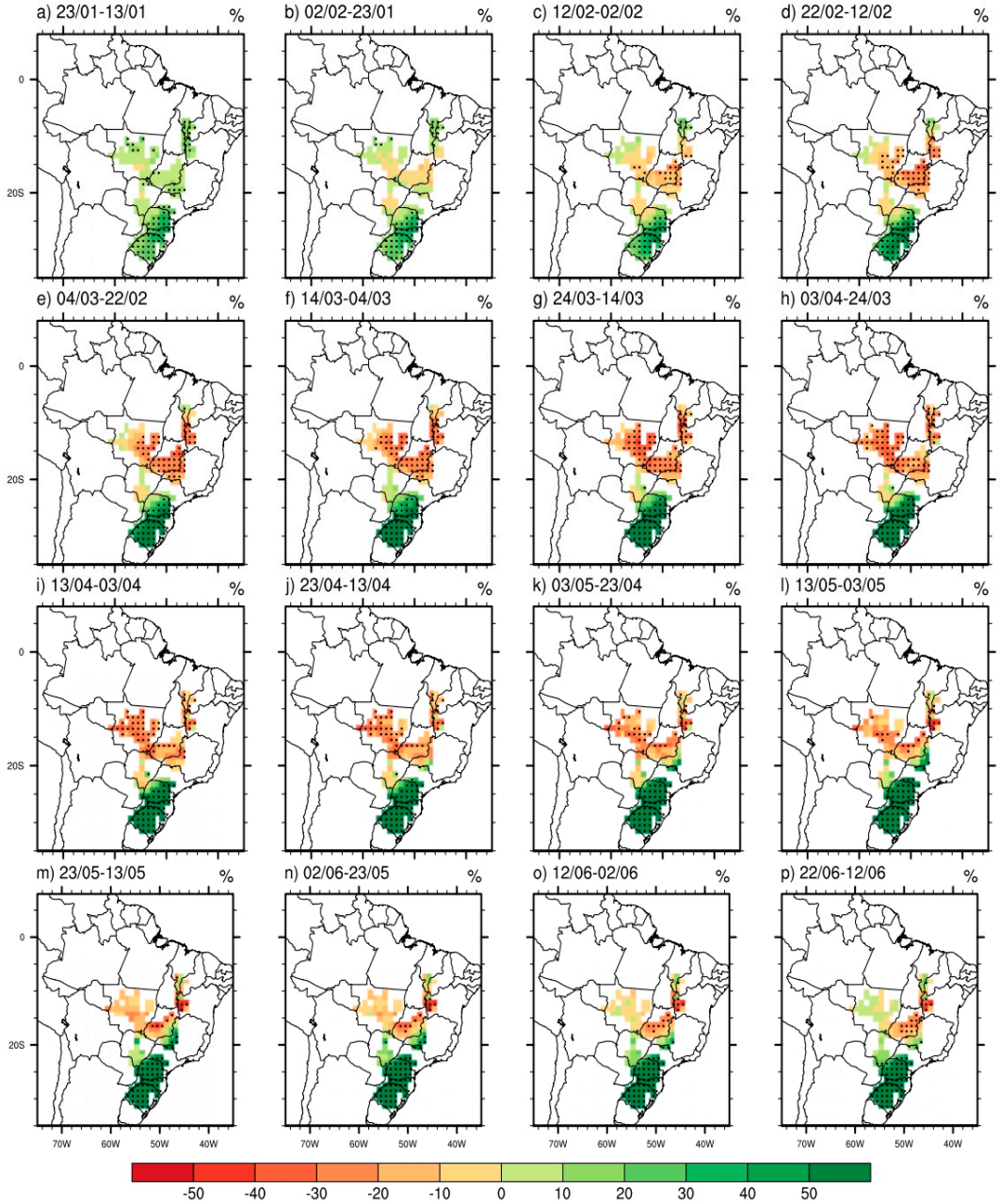

Figure S1. –Percentage change in maize off-season yield from 2011-2020 to 2041-2050, considering a delay in sowing date of 10 days for RCP 8.5 scenario. Pixels that have statistically significant changes in productivity according to Student's t-test (α = 5 %) are represented with a dot.

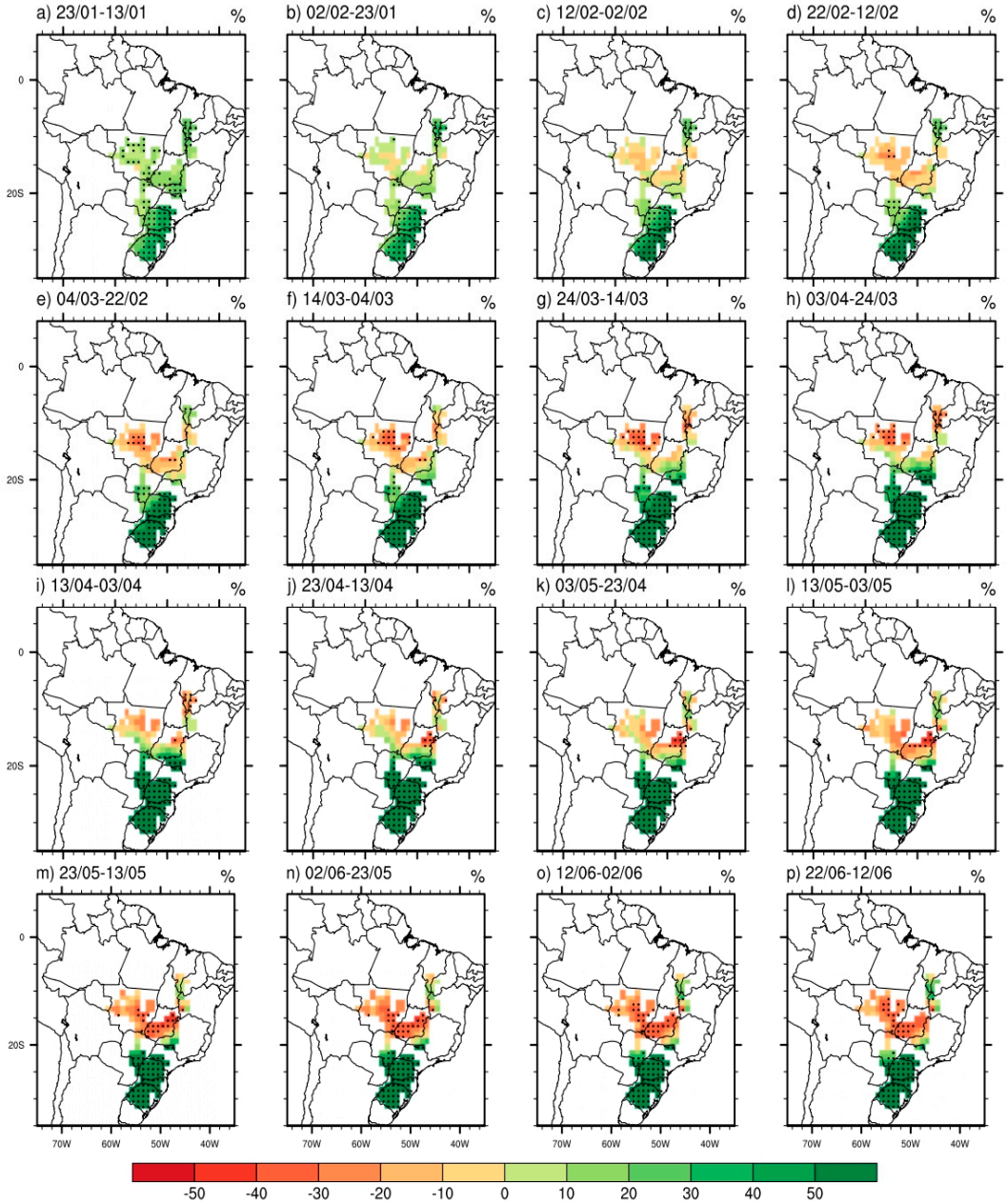

Figure S2. – Percentage change in maize off-season yield from 2011-2020 to 2041-2050, considering a delay in sowing date of 10 days for RCP 8.5 + HLU scenario. Pixels that have statistically significant changes in productivity according to Student's t-test (α = 5 %) are represented with a dot.

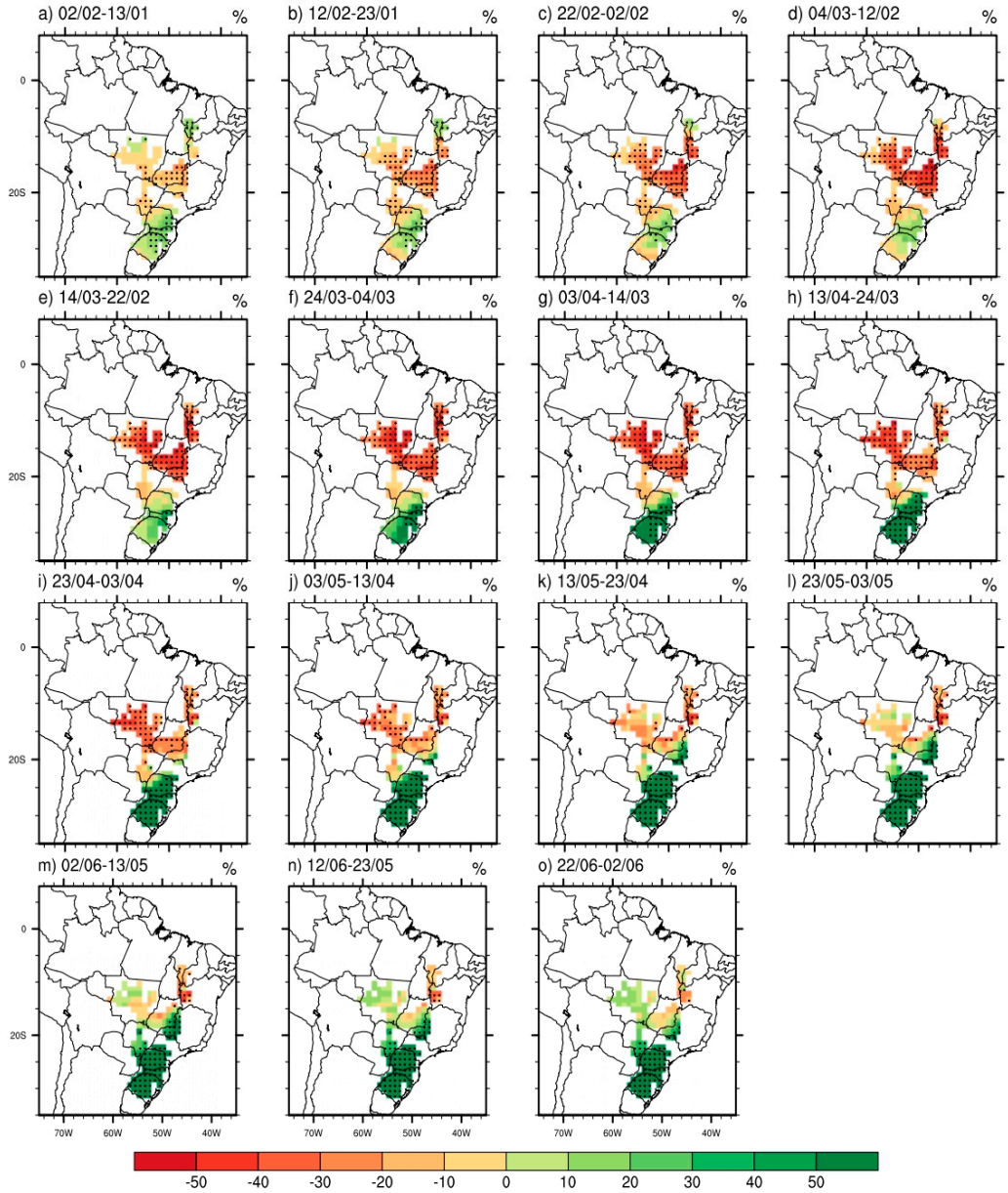

Figure S3. - Percentage change in maize off-season yield from 2011-2020 to 2041-2050, considering a delay in sowing date of 20 days for RCP 8.5 scenario. Pixels that have statistically significant changes in productivity according to Student's t-test (α = 5 %) are represented with a dot.

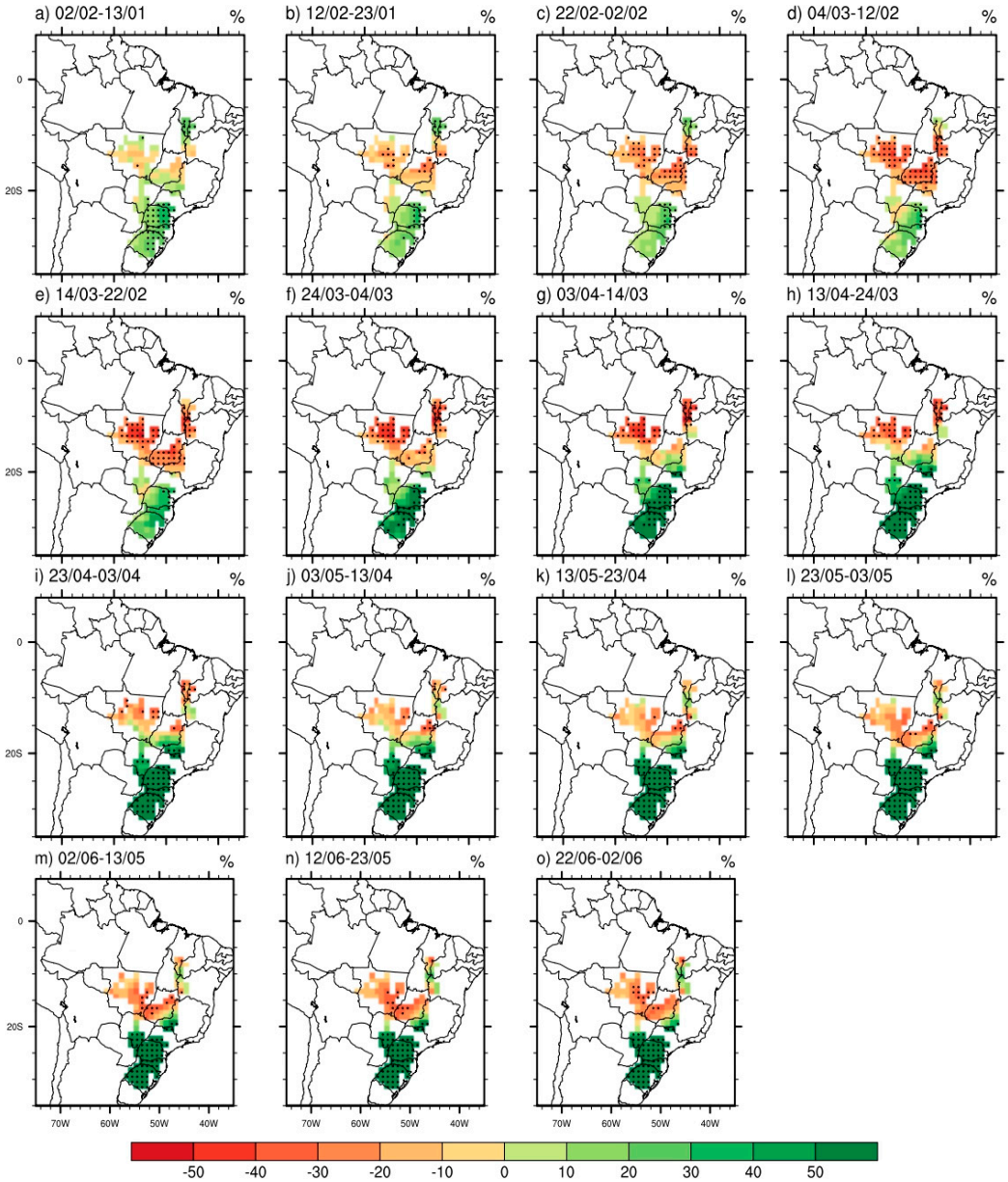

Figure S4. - Percentage change in maize off-season yield from 2011-2020 to 2041-2050, considering a delay in sowing date of 20 days for RCP 8.5 + HLU scenario. Pixels that have statistically significant changes in productivity according to Student's t-test (α = 5 %) are represented with a dot.

S3 – Average daily climatic conditions (precipitation and mean temperature) in 2011-2020.

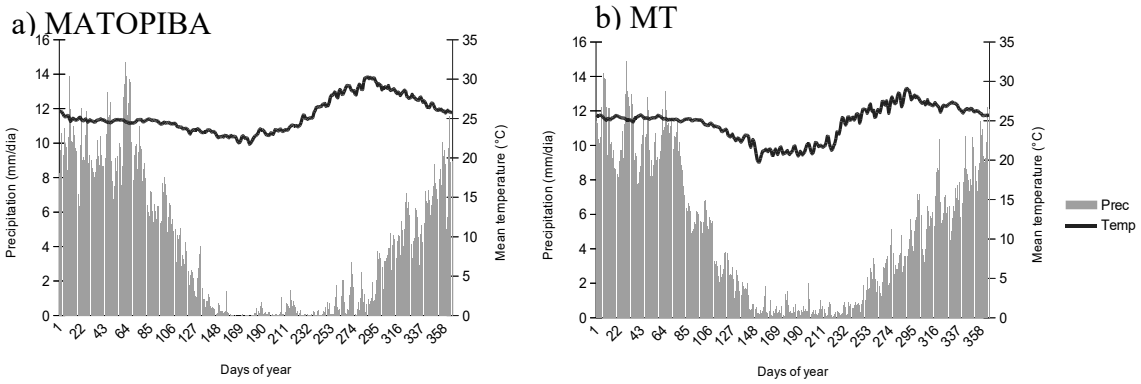

Figure S5. - Daily mean temperature and precipitation in 2011-2020 represented by HadGEM2-ES. The likelihood of Asian rust infestation in soybean is higher after middle of November (~ 316 days) due to increase in temperature and precipitation.

S4 – Percentage change in maize off-season yield for additional simulated sowing dates

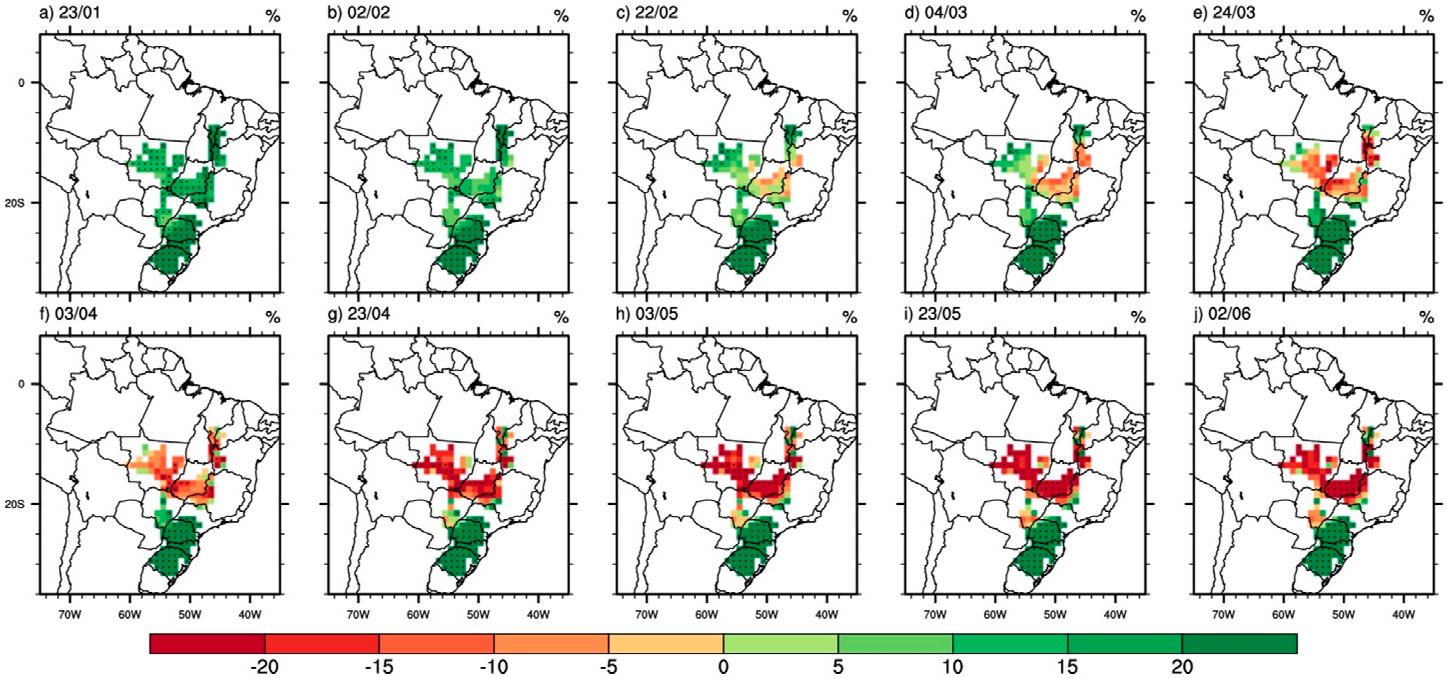

Figure S6. - Percentage change in maize off-season yield from 2011-2020 to 2041-2050. In a) to j) results for RCP 8.5 scenario. Pixels that have statistically significant changes in productivity according to Student's t-test (α = 5 %) are represented with a dot.

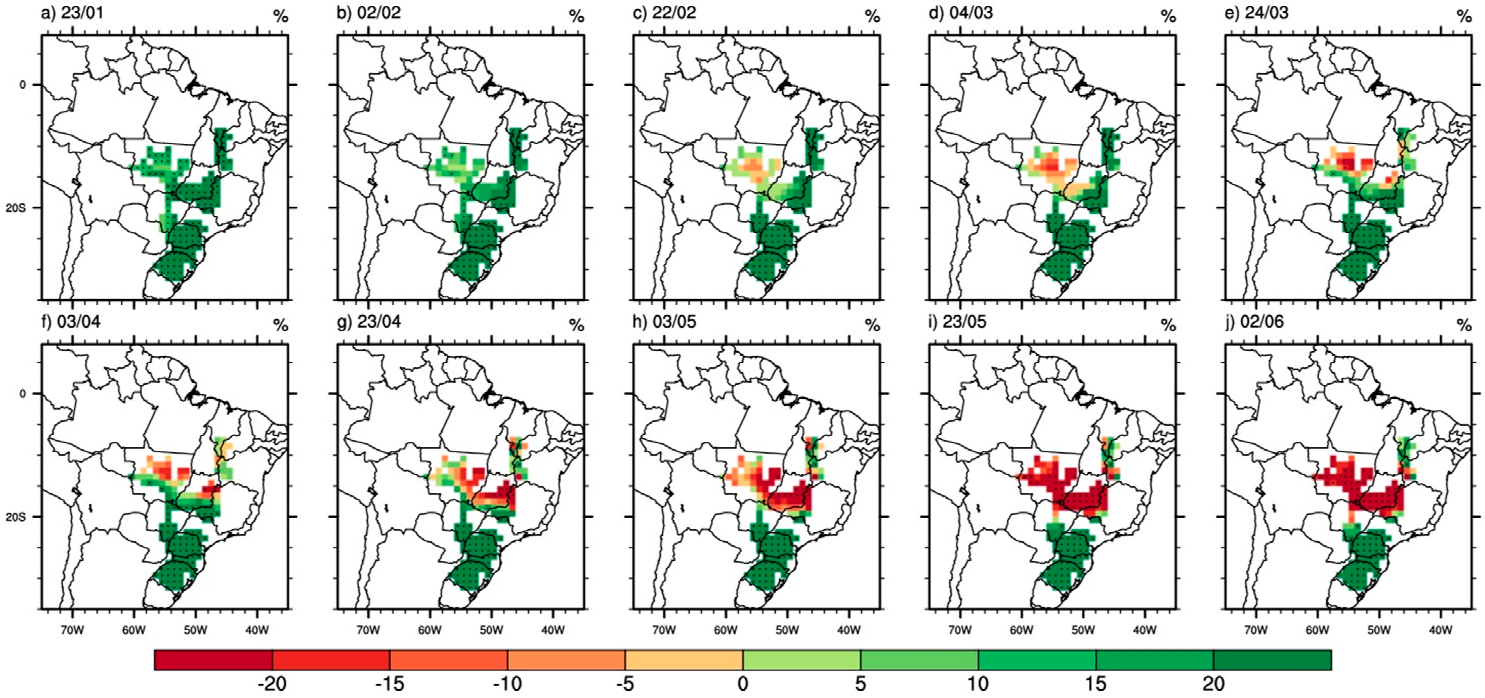

Figure S7. - Percentage change in maize off-season yield from 2011-2020 to 2041-2050. In a) to j) results for RCP 8.5 + HLU scenario. Pixels that have statistically significant changes in productivity according to Student's t-test (α = 5 %) are represented with a dot.

S5 – Average cycle length of each cultivar of maize for each scenario, region, period and sowing date

Table S5. – Maize cultivar with 1900 GDD.

Cultivar 1900 GDD								
Sowing date	RCP 8.5				RCP 8.5 + HLU			
	2011–2020 period		2041–2050 period		2011–2020 period		2041–2050 period	
	MATOPIBA	MT	MATOPIBA	MT	MATOPIBA	MT	MATOPIBA	MT
Jan 13	129	126	119	115	130	126	117	112
Jan 23	131	128	120	116	131	128	118	112
Feb 02	133	131	121	117	133	131	118	114
Feb 12	135	134	122	119	134	134	119	115
Feb 22	136	136	123	121	136	137	120	117
Mar 04	138	139	125	124	137	139	121	120
Mar 14	140	141	127	126	139	141	123	122
Mar 24	141	142	128	127	139	142	124	124
Apr 03	141	143	130	129	139	143	125	125
Apr 13	141	143	130	129	139	143	125	126

Table S6. – Maize cultivar with 1600 GDD.

Cultivar 1600 GDD								
Sowing date	RCP 8.5				RCP 8.5 + HLU			
	2011–2020 period		2041–2050 period		2011–2020 period		2041–2050 period	
	MATOPIBA	MT	MATOPIBA	MT	MATOPIBA	MT	MATOPIBA	MT
Jan 13	108	105	100	97	108	104	98	94
Jan 23	108	105	100	97	109	105	99	94
Feb 02	109	107	101	97	110	107	99	94
Feb 12	111	109	101	98	111	109	99	95
Feb 22	112	112	102	99	113	112	100	97
Mar 04	115	115	103	101	115	116	101	99
Mar 14	117	118	105	104	116	119	102	101
Mar 24	119	120	107	106	118	121	103	103
Apr 03	121	122	109	108	119	123	105	105
Apr 13	122	123	110	110	120	124	106	107

Table S7. – Maize cultivar with 1500 GDD.

Cultivar 1500 GDD								
Sowing date	RCP 8.5				RCP 8.5 + HLU			
	2011-2020 period		2041-2050 period		2011-2020 period		2041-2050 period	
	MATOPIBA	MT	MATOPIBA	MT	MATOPIBA	MT	MATOPIBA	MT
Jan 13	101	98	94	91	101	97	92	88
Jan 23	101	98	94	91	101	98	92	88
Feb 02	102	99	94	91	102	99	92	88
Feb 12	103	101	94	91	103	101	93	89
Feb 22	105	103	95	92	105	104	93	90
Mar 04	107	106	96	94	107	107	94	92
Mar 14	109	109	98	96	109	111	95	94
Mar 24	111	112	100	99	110	113	96	96
Apr 03	113	114	101	101	112	116	98	98
Apr 13	114	116	103	103	113	117	99	100

S6 – Change in rainfall during 2011-2020 to 2041-2050 period for the growing season of maize off-season

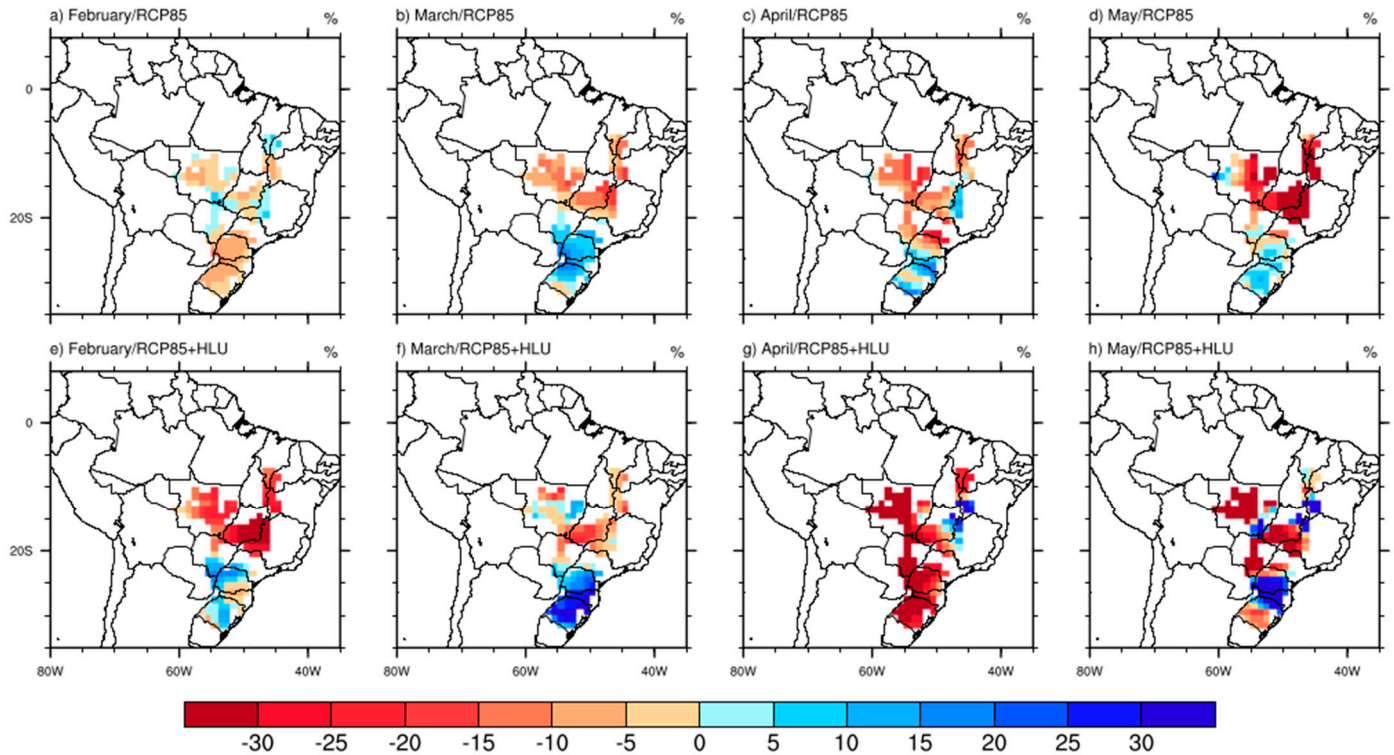

Figure S8. – Monthly rainfall change during the growing season of maize off-season for 2011-2020 to 2041-2050 period. In ***a*** to ***d*** are represented the rainfall change for February to May in RCP 8.5 scenario. In ***e*** to ***h*** are represented the rainfall change for February to May in RCP 8.5 + HLU scenario.