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Can adaptations of crop and soil management prevent yield losses during water scarcity? A modeling study

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S1 Results global sensitivity analysis

Figure S1. Sobol Indices for all tested parameters with respect to crop yield (top) and seasonal irrigation amounts (bottom). Barplots show the uncertainty (%) that each parameter conveys. By bootstrapping the Sobol' indices, we derive the confidence intervals (Puy et al., 2022). Red bars for individual and blue bar for total effects (parameter interactions). Horizontal line indicates threshold for significance. As the model in non-additive, the variance cannot be fully composed of the first-order effects of the parameters and parameter interactions play a role.

Table S1. All 29 parameters tested in the GSA with definition, default value and the upper and lower ranges used in the analysis.

Parameter	Definition	Unit	Default value	Lower range	Upper range
CF	crop factor for DVS=0 (for DVS=1, CF*1.1)		1	0.85	1.15
RSC	minimum canopy resistance	$s\ m^{-1}$	100	85	115
TDWI	inital crop dry weight	$kg\ ha^{-1}$	75	64	86
RGRLAI	maximum relative increase in LAI	$m^2\ m^{-2}\ d^{-1}$	0.0120	0.0108	0.0132
SPAN	life span of leaves (optimum)	d	37	33	41
SLATB	specific leaf area for DVS=0 (for DVS=2, SLATB*0.5)	$ha\ kg^{-1}$	0.0030	0.0027	0.00330
AMAXTB	max. CO2 assimilation rate	$kg\ ha^{-1}\ h^{-1}$	30	25.5	34.5
Q10	doubles the maintenance respiration for each 10 degrees increase in temperature.		2	1.7	2.3
HLIM1	no extraction at higher pressure heads	cm	-10	-8.5	-11.5
HLIM2U	h below which optim. Water extraction starts for top layer	cm	-25	-21.25	-28.75
HLIM2L	h below which optim. Water extraction starts for for sublayer	cm	-25	-21.25	-28.75
HLIM3H	h below which water uptake starts at high atmospheric demand	cm	-300	-255	-345
HLIM3L	h below which water uptake starts at low transpiration	cm	-500	-425	-575
HLIM4	h at wilting point	cm	-10000	-8500	-11500
ADCRH	level of high atmospheric demand (HLIM3H)	$cm\ d^{-1}$	0.50	0.43	0.58
ADCRL	level of low atmospheric demand (HLIM3L)	$cm\ d^{-1}$	0.10	0.09	0.12
ALPHACRIT	critical stress index to compensate root water uptake		1	0.85	1.15
RRI	ma. Daily increase in rooting depth	$cm\ d^{-1}$	1.20	1.02	1.38
RDC	max. rooting depth of crop	cm	50	42.5	57.5
RDCTBa	RDCTB = root density as function of rel. rooting depth (here RDCTB = RDCTBa*ln(x) + 0.9966)		-0.414	-0.380	-0.476
TMPFTB	reduction factor of CO2 assimilation rate as function of average daily temperature (at 10 °C and 26 °C)		0.75	0.64	0.86
FRTB	dry matter partitioning to roots	%	0.2	0.17	0.23
FOTBa	regulates steepness of dry matter partitioning function to storage organs		7	5.95	8.05
FOTBb	regulates location of centre point of dry matter partitioning function to storage organs		1.05	0.89	1.21
FOTBc	regulates fraction of dry matter partitioning function to storage organs at DVS=2		1	0.85	1.15
FLTBa	regulates steepness of dry matter partitioning function to leaves		20	17	23
FLTBb	regulates location of centre point of dry matter partitioning function to leaves		1.05	0.89	1.21
FLTBc	regulates fraction of dry matter partitioning to leaves at DVS=0		0.83	0.71	0.95

S2 Calibrated biomass partitioning

Table S2. Values for the partitioning functions over DVS, derived by the calibration of the function parameters FOTBc, FLTBc and FLTBb.

Parameter	Definition	Default	Optimized	DVS
FOTB	dry matter partitioning to storage organs as function of DVS	0	0	0
		0.4133842	0.413415	1
		0.8234647	0.823430	1.27
		0.8975230	0.897594	1.36
		1	1	2
FLTB	dry matter partitioning to leaves as function of DVS	0.83000	0.94838	0
		0.5866170	0.130745	1
		0.0100666	0	1.27
		0	0	1.36
		0	0	2
FSTB	dry matter partitioning to stem as function of DVS	0.17000	0.05162	0
		0	0.455840	1
		0.1664687	0.176470	1.27
		0.1024770	0.102406	1.36
		0	0	2

S3 Subsample results with and without irrigation bans

Table S3. Results for the representative subsample. Transpiration gain = how much more water is transpired in relation to a reference scenario (drought-induced transpiration reduction reference - drought-induced transpiration reduction scenario). Scenarios without irrigation ban always relate to reference scenario I, those with to reference scenario II. * indicates a significant deviation, tested with the wilcoxon rank sum test (wilcox.test function of the R package stats).

Scenario	Maturity, growing season length (d)	Irrigation ban	SOC +1% increased	Mean yield (dt ha^{-1})	Δ in yield relative to reference scenario I/II (%)	Mean irrigation amount (mm)	Δ in irrigation amount relative to reference scenario I/II (%)	Cumulative seasonal transpiration (mm)	Mean transpiration gain* relative to reference scenario I/II (mm)	Irrigation water productivity (kg mm^{-1})
reference scenario I	140			298		120		211.4		2.5
reference scenario II	140	x		251		54		183.7		4.6
3	140		x	340	14*	126	5*	236.7	4.2	2.8
4		x	x	287	14*	57	6*	204.5	0.3	5.4
5	130			269	-10*	112	-7	195.2	2.9	2.4
6		x		234	-7*	53	-2	171.4	7.4	4.4
7			x	308	3	117	-3	216.3	4.9	2.6
8		x	x	269	7*	53	-2*	191.0	7.9	5.1
9	120			239	-20*	100	-17*	177.3	6.1	2.4
10		x		214	-15*	47	-13*	159.1	15.4	4.6
11			x	273	-8*	105	-13*	199.2	7.3	2.6
12		x	x	246	-2	47	-13	175.8	15.6	5.2
13	110			204	-32*	88	-27*	153.9	10	2.3
14		x		188	-25*	38	-30*	143.6	29.9	4.9
15			x	232	-22*	92	-23*	175.9	11.8	2.5
16		x	x	215	-14*	41	-24*	155.9	30.7	5.2

S4 Regional results with and without irrigation bans

Table S4. Regional modeling results for 2022 with and without considering irrigation bans. Transpiration gain = how much more water is transpired in relation to a reference scenario (drought-induced transpiration reduction reference - drought-induced transpiration reduction scenario). Scenarios without irrigation ban always relate to reference scenario I, those with to reference scenario II.

Scenario	Maturity, growing season length (d)	SOC +1% increased	Total irrigation amount (m^3)	Δ in irrigation amount relative to reference scenario I/II (%)	total yield (dt)	Δ in yield relative to reference scenario I/II (%)	Irrigation water productivity ($dt\ m^3$)	transpiration gain* relative to reference scenario I/II (mm)
not considering irrigation bans								
reference scenario I	140		697389		184940		0.27	
3	140	x	706948	1	205337	11	0.29	27964
7	130	x	676818	-3	173525	-6	0.26	14280
11	120	x	604560	-13	153990	-17	0.25	27639
15	110	x	531137	-24	130456	-29	0.25	50610
best scenario	all	(x)	635101	-9	188907	2	0.3	84797
considering irrigation bans								
reference scenario II	140		285836		154518		0.54	
4	140	x	280367	-2	171951	11	0.61	-676
8	130	x	308692	8	150842	-2	0.49	58476
12	120	x	281643	-2	137934	-11	0.49	118767
16	110	x	238512	-17	121250	-22	0.51	190598
best scenario	all	(x)	212507	-26	157523	2	0.74	299456

5 References

Puy, A., Piano, S. L., Saltelli, A., and Levin, S. A.: sensobol: An R Package to Compute Variance-Based Sensitivity Indices, Journal of Statistical Software, 102, https://doi.org/10.18637/jss.v102.i05, 2022.