Figure S1. Daily average temperature (a), solar radiation (b) and total precipitation (c) during the growing season (left) and separated into the phenological stage (right) in the experimental dataset for calibration. No observation weather data of solar radiation in Champaign (US)
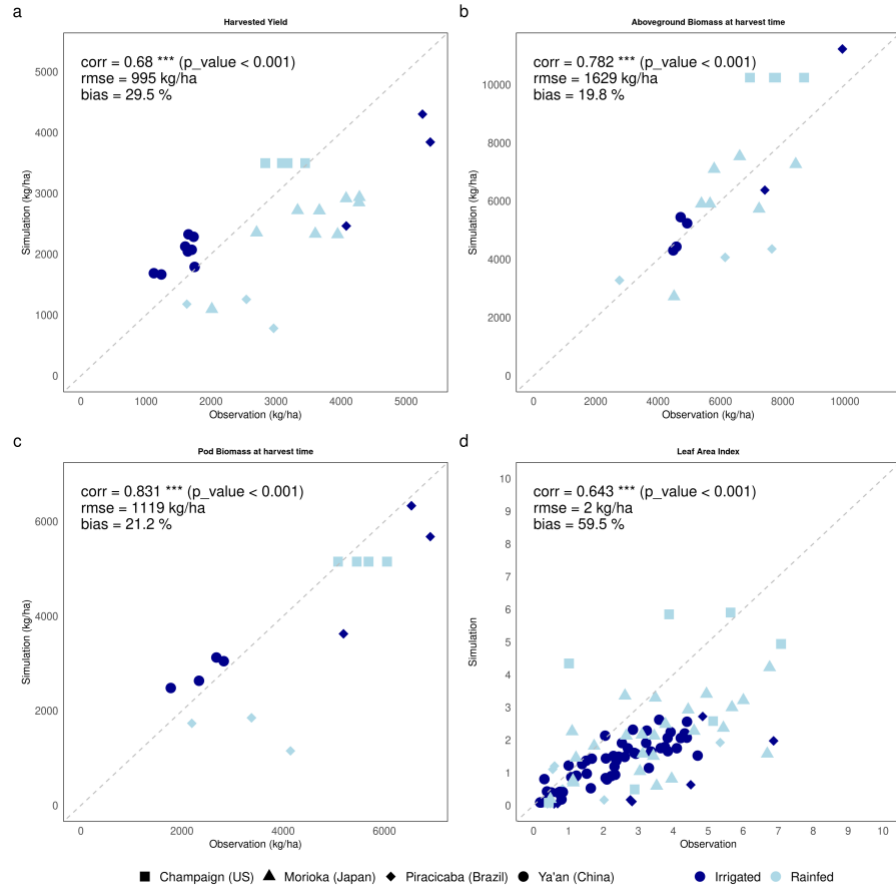
Figure S2. Comparison of simulated and observed soybean yield (a), aboveground biomass (b), pod (c), and leaf area index (d). The dark blue shows the data under irrigated management, while light blue shows the data under rainfed management. The shape of square represents Champaign (US) data, triangle represents Morioka (Japan), diamond represents Piracicaba (Brazil), and circle represents Ya'an (China). Calculation of statistical correlation used Pearson-correlation (corr) with *** denotes the regression is statistically significant at *p < 0.001*, root mean square error (RMSE), and bias.
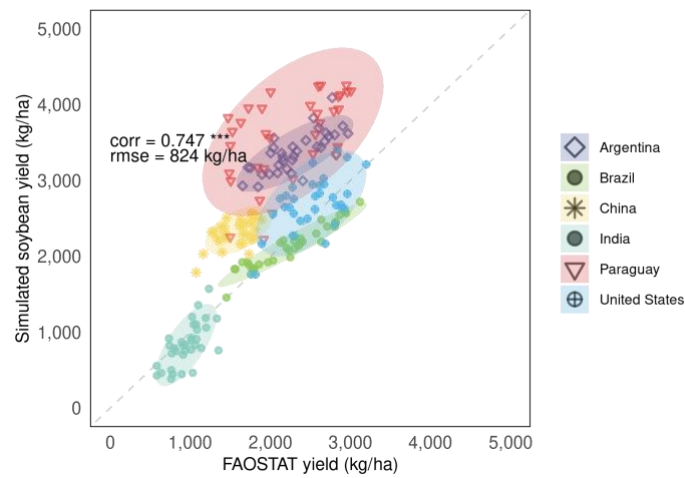
Figure S3. Comparison between simulated yield by MATCRO-Soy and FAOSTAT of the country mean yield during 1981-2014 in 6 major soybean producing countries (e.g., Argentina, Brazil, China, India, Paraguay, and the United States). Ellipsoid shows 90% confidence range of annual yield.

Table S1. Statistical comparison on model performance using components of mean squared deviation (MSD) and RMSE for global yield simulation (X) and global yield observation from FAOSTAT (Y). *n* means number of years.

Metrics	Squared bias (SB)	Pearson correlation coefficient (corr)	Sum of difference in standard deviation (SDSD)	Lack of positive correlation (LCS)	Mean squared deviation (MSD)	Root mean square error (RMSE)
equation	$(\bar{X} - \bar{Y})^2$	$\dfrac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 (Y_i - \bar{Y})^2}}$	$(SD_X - SD_Y)^2$	$2SD_XSD_Y(1 - corr)$	$SB_y + SDSD_y + LCS_y$	$\sqrt{\dfrac{1}{n}\sum_{i=1}^{n}(X_i - Y_i)^2}$
Yield	106,162*	0.810	3,098	21,793	131,053	362 kg/ha
Long term yield trend	106,162*	1	9,491	0	115,653	340 kg/ha
Detrended yield	0	0.512	3,405	11.996*	15,400	124 kg/ha

*the metric contributed to major error in MSD components

Table S2. Statistical comparison on model performance in 10 major soybean-producing countries using components of mean squared deviation (MSD) and RMSE for yield.

Countries	SB	Corr	SDSD	LCS	MSD	RMSE (kg/ha)
Argentina	1,106,551	0.730	8,871	50,303	1,165,725	1,080
Bolivia	2,967,126	-0.060	46,435	247,001	3,260,562	1,806
Brazil	13,666	0.954	32,692	11,688	58,046	241
Canada	809,166	0.125	1,071	181,678	991,916	996
China	540,260	0.558	1,471	32,083	573,814	758
India	14,461	0.673	6,957	35,646	57,065	239
Italy	3,593	0.438	8,156	169,495	181,244	426
Paraguay	1,810,520	0.525	1,138	278,896	2,090,554	1,446
Russia	1,423,259	-0.040	14,494	144,423	1,582,175	1,258
United States	29,982	0.621	514	98,832	129,329	360

*country with bold font has RMSE below 500 kg/ha

Table S3. Statistical comparison on model performance in 10 major soybean-producing countries using components of mean squared deviation (MSD) and RMSE for detrended yield.

Countries	SB	Corr	SDSD	LCS	MSD	RMSE (kg/ha)
Argentina	0	0.541	5,530	50,291*	55,821	236
Bolivia	0	(0.107)	44,881	246,981*	291,853	540
Brazil	0	0.793	1,962	10,195*	12,159	110
Canada	0	(0.035)	2,325	179,582*	181,907	427
China	0	0.136	54	29,840*	29,894	173
India	0	0.544	12,461	30,045*	42,505	206
Italy	0	0.442	11,129	171,508*	171,508	414
Paraguay	0	0.562	9,425	224,938*	234,363	484
Russia	0	0.277	49,821*	47,357*	97,179	312
United States	0	0.600	29,242	46,165*	75,407	275

*the metric contributed to major error in MSD components

Table S4. Statistical comparison on model performance in 10 major soybean-producing countries using components of mean squared deviation (MSD) and RMSE for long-term trend.

Countries	SB*	Corr	SDSD	LCS	MSD	RMSE (kg/ha)
Argentina	1,106,551	1	3,351	0	1,109,902	1,054
Bolivia	2,967,126	1	1,575	0	2,968,701	1,723
Brazil	13,666	1	32,213*	0	45,879	214
Canada	809,166	1	838	0	810,004	900
China	540,260	1	3,665	0	543,925	738
India	14,461	1	103	0	14,565	121
Italy	3,593	1	6,131*	0	9,725	99
Paraguay	1,810,520	1	45,621	0	1,856,141	1,362
Russia	1,423,259	-1	14,406	47,330	1,437,664	1,199
United States	29,982	1	23,954*	0	53,936	232

*the metric contributed to major error in MSD components
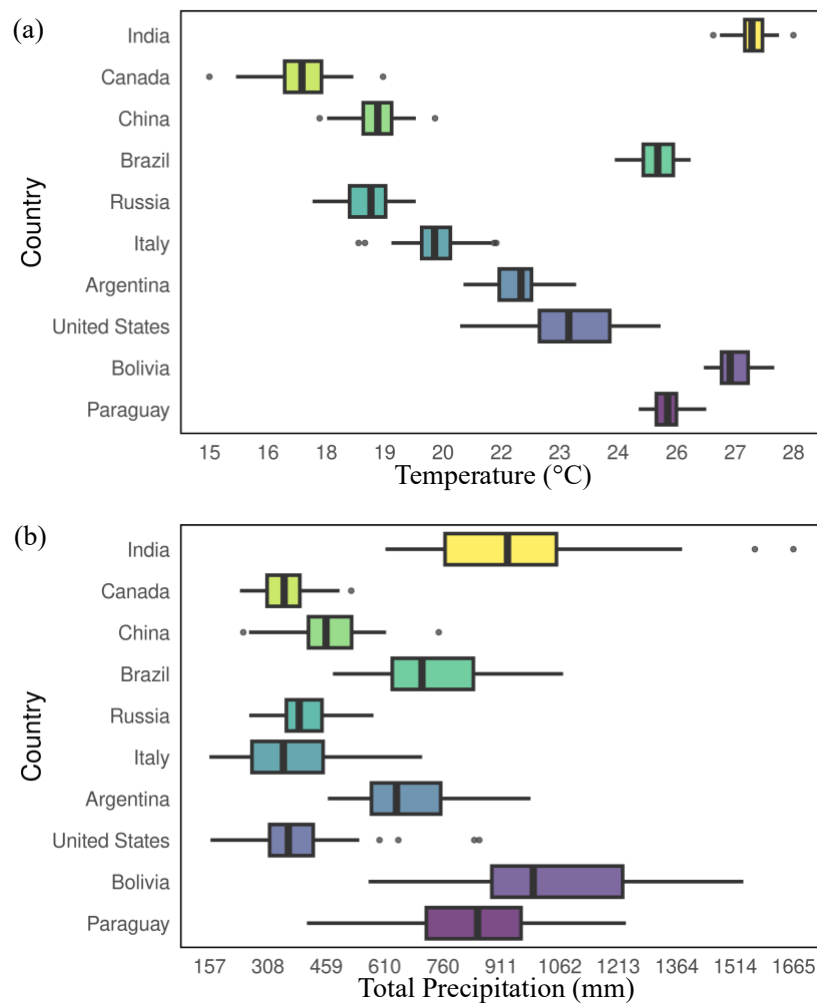
Figure S4. Daily average temperature (a) and total precipitation (b) during the growing season in 10 major soybean-producing countries averaged from 1981-2014 in the represented specific point-scale.
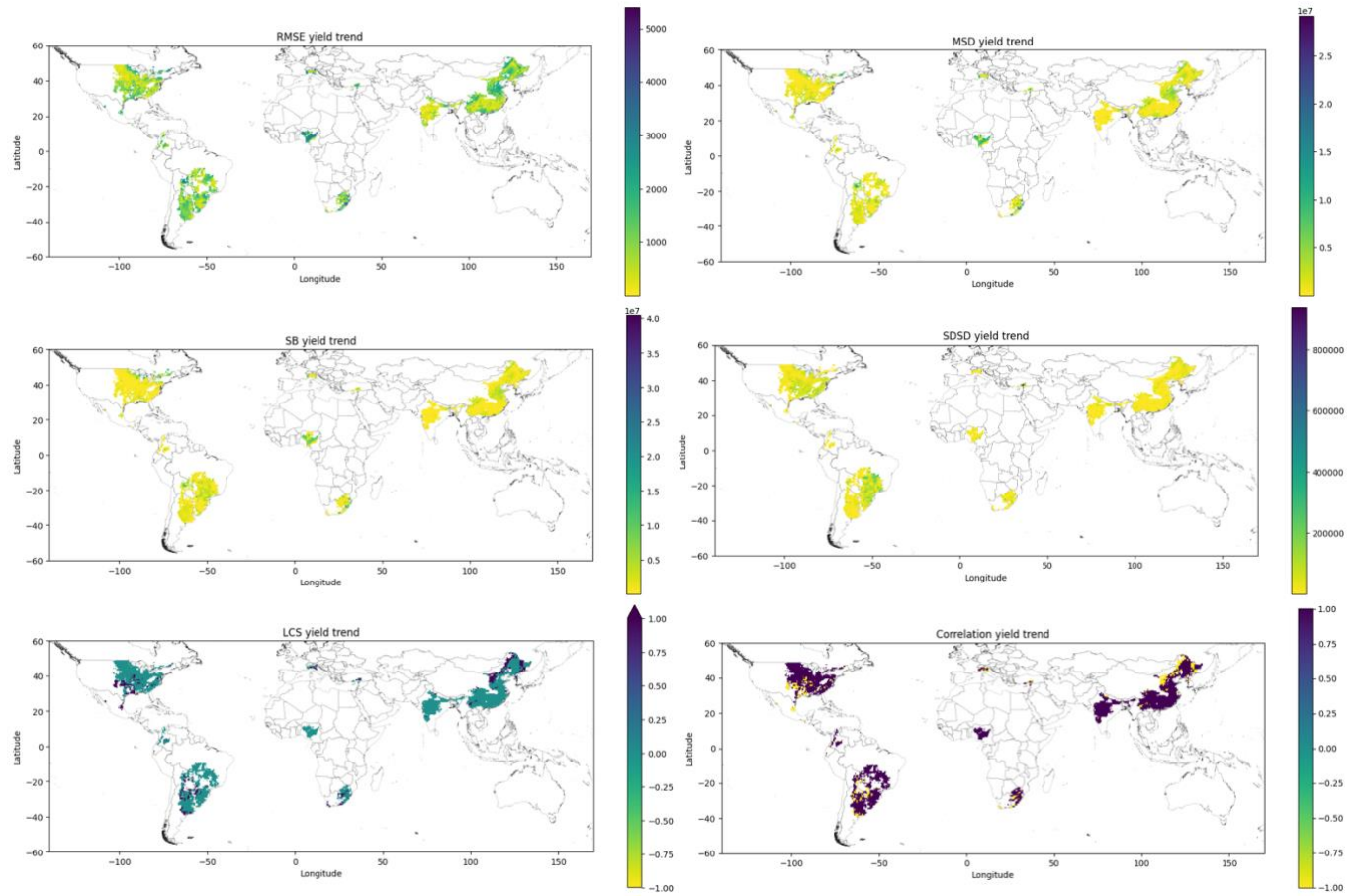
Figure S5. RMSE and MSD components of long-term yield trend between MATCRO-Soy and GDHY dataset during 1980-2014. Major contributor in MSD components is squared bias (SB).
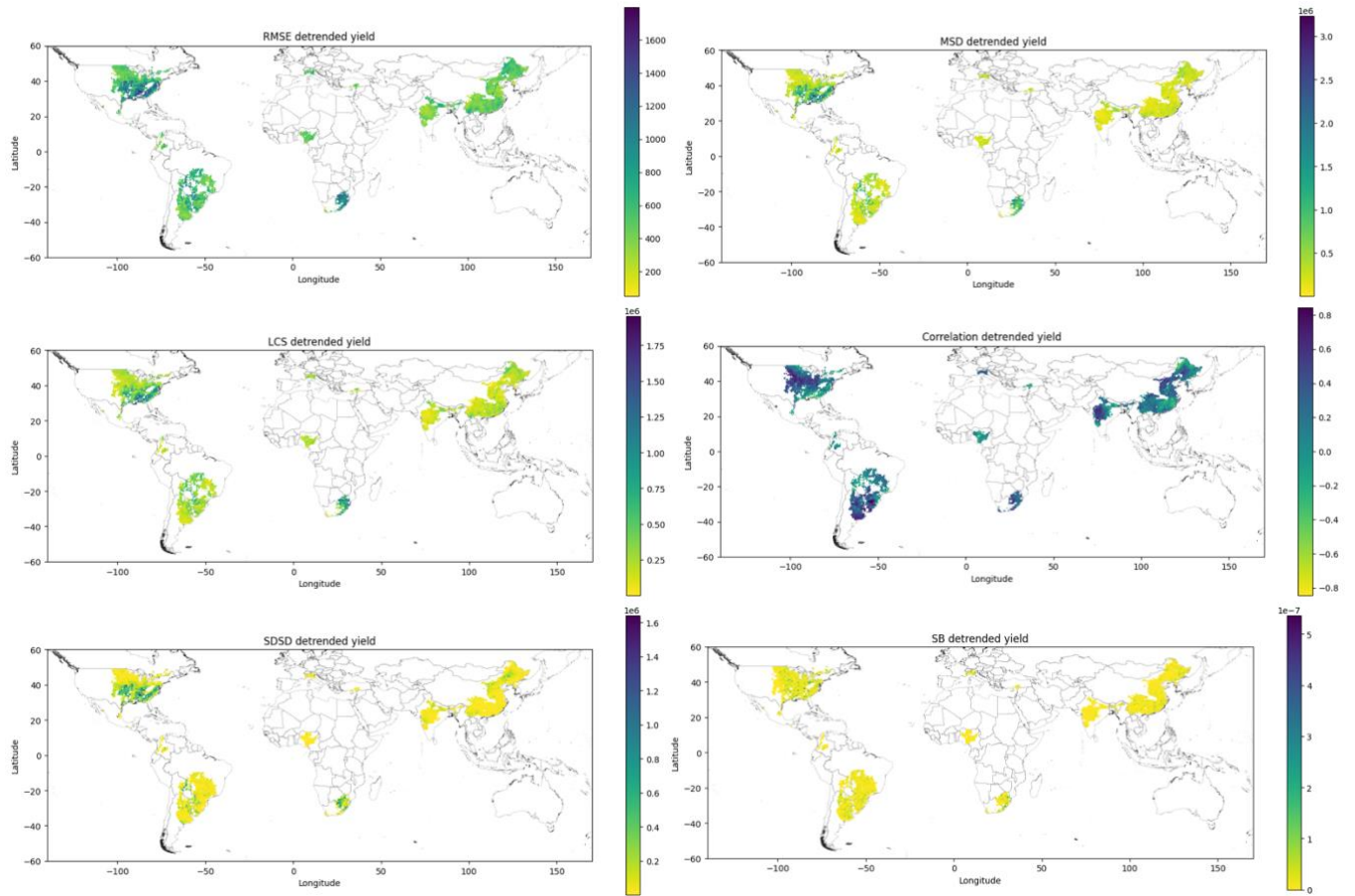
Figure S6. RMSE and MSD components of detrended yield between MATCRO-Soy and GDHY dataset during 1980-2014. Major contributor of error in MSD components is LCS where mostly higher in South Africa, southeastern of the United States, Bolivia, and Paraguay