Supplemental Material

The GGCMI phase II emulators: global gridded crop model responses to changes in CO_2, temperature, water, and nitrogen (version 1.0)

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1 Experiment Simulation Sampling in Variable Space

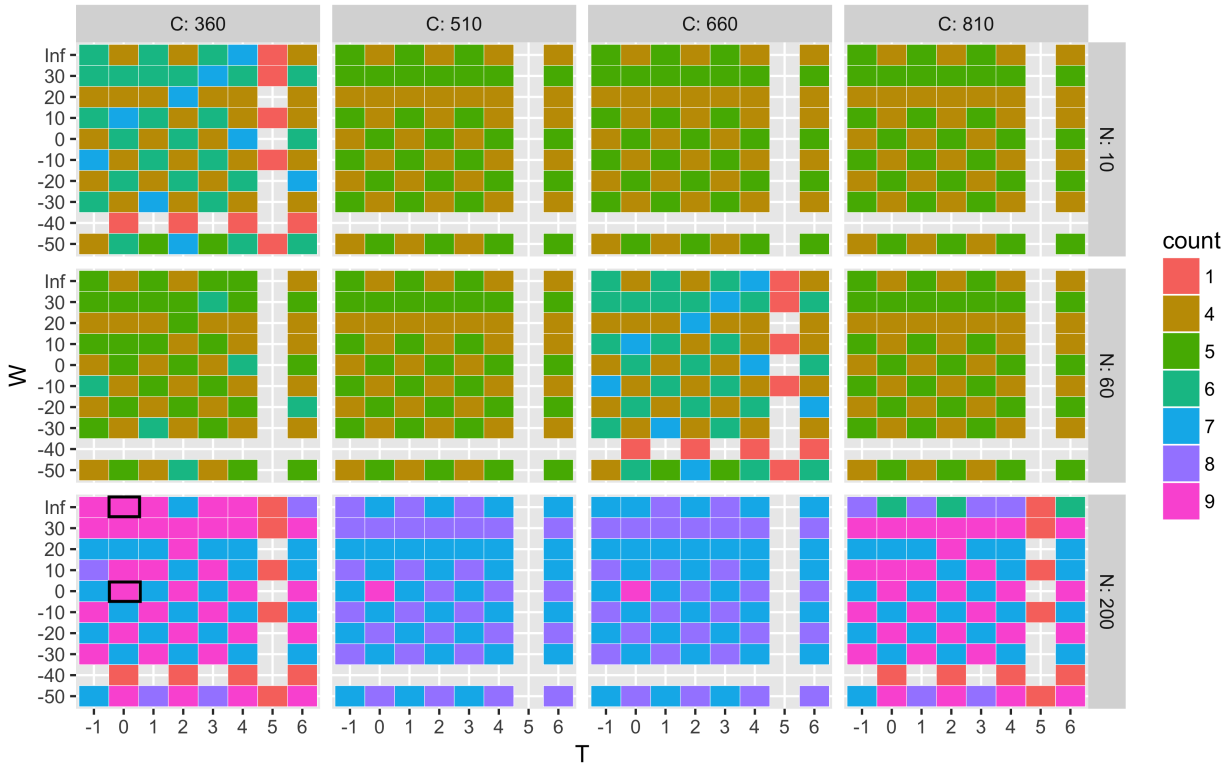

Figure S1: Tile heatmap illustrates number of model simulations provided for each of the scenarios in the variable space. The max number is 9, the number of models included in the emulator analysis (excluding three models not included in the emulator analysis). Normalized error calculations are run over scenarios with max number of models.

2 Cultivation Areas

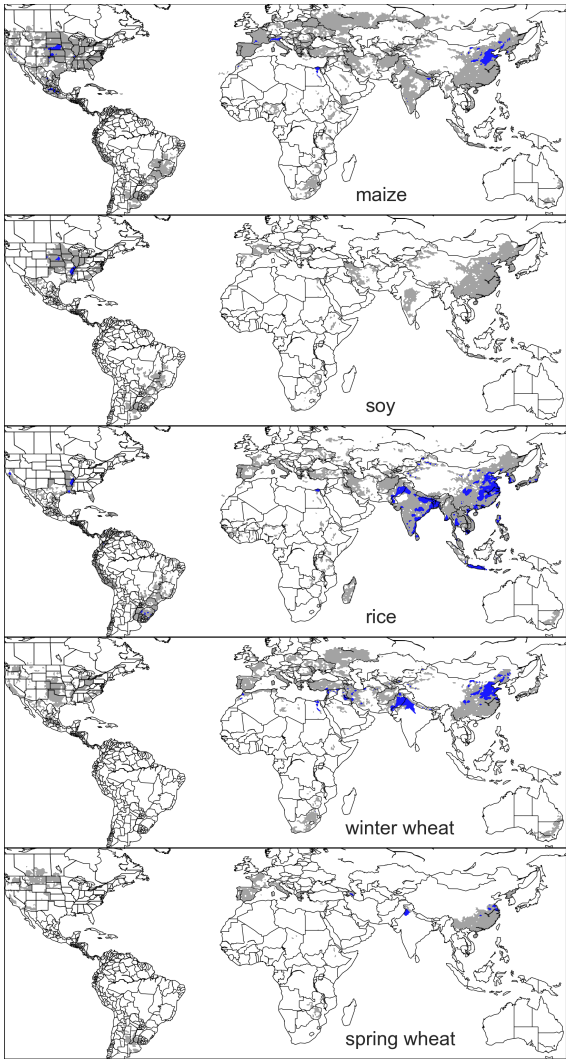

Figure S2: Presently cultivated area for irrigated crops in the real world. The blue contour area indicates grid-cells with more that 20,00 hectares of crop cultivated. The gray contour shows area with more that 10 hectares cultivated. Data from the MIRCA2000 data set for maize, rice, and soy. Winter and spring wheat areas are adapted from MIRCA2000 data and sorted by growing season.

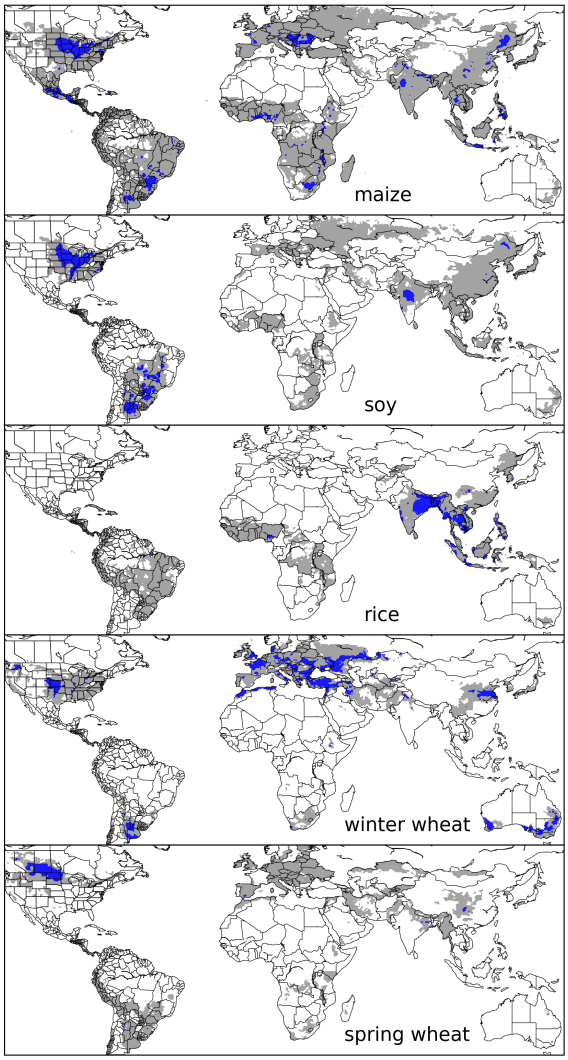

Figure S3: Presently cultivated area for rain fed crops in the real world. Conventions as in Figure S1.

2.1 Year-to-year vs climatological mean

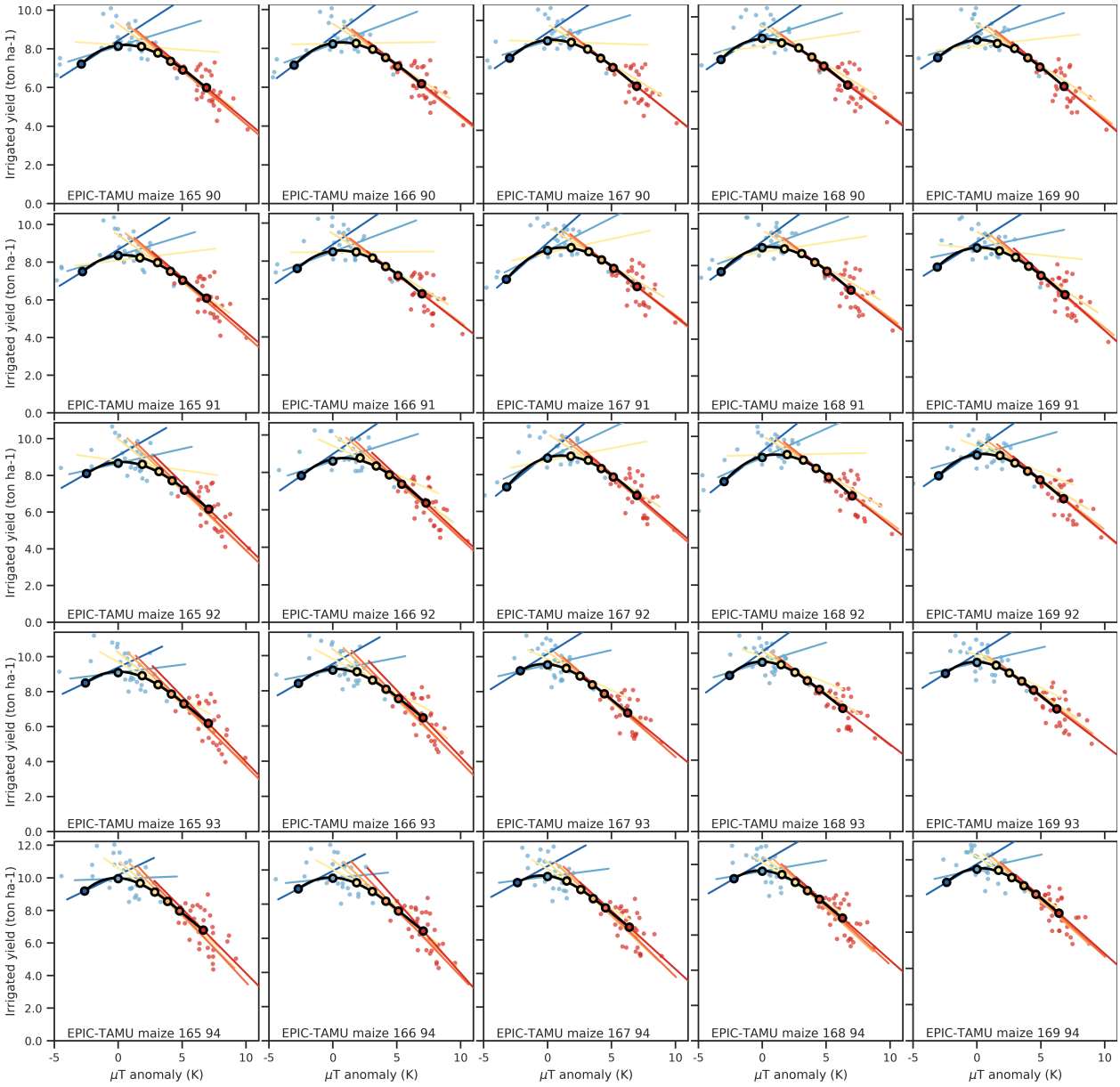

Figure S4: Same convention as main text Figure 1 except for multiple gricells in Iowa for maize for the EPIC-TAMU model.

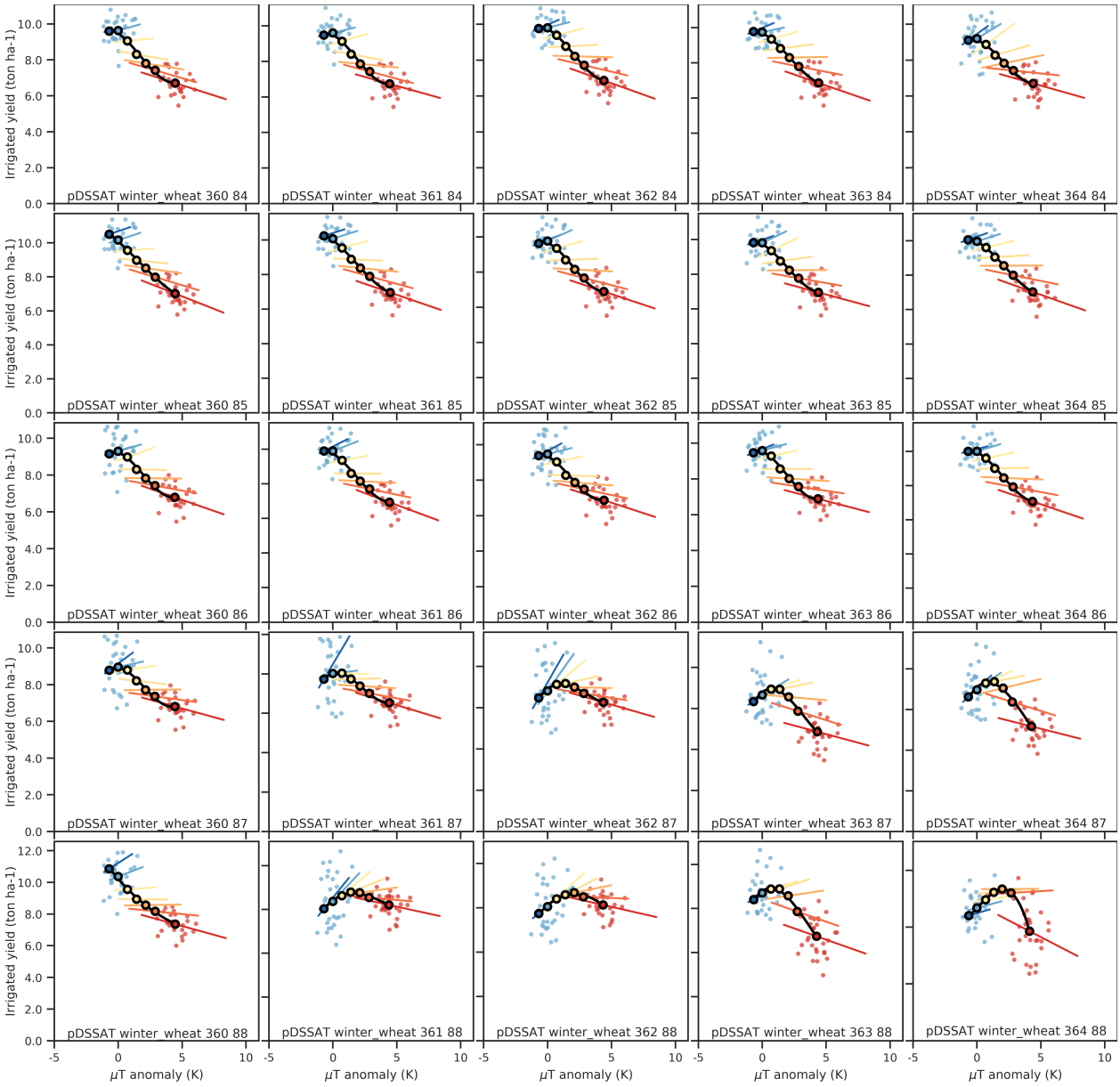

Figure S5: Same convention as above except for winter wheat in France for the pDSSAT model.

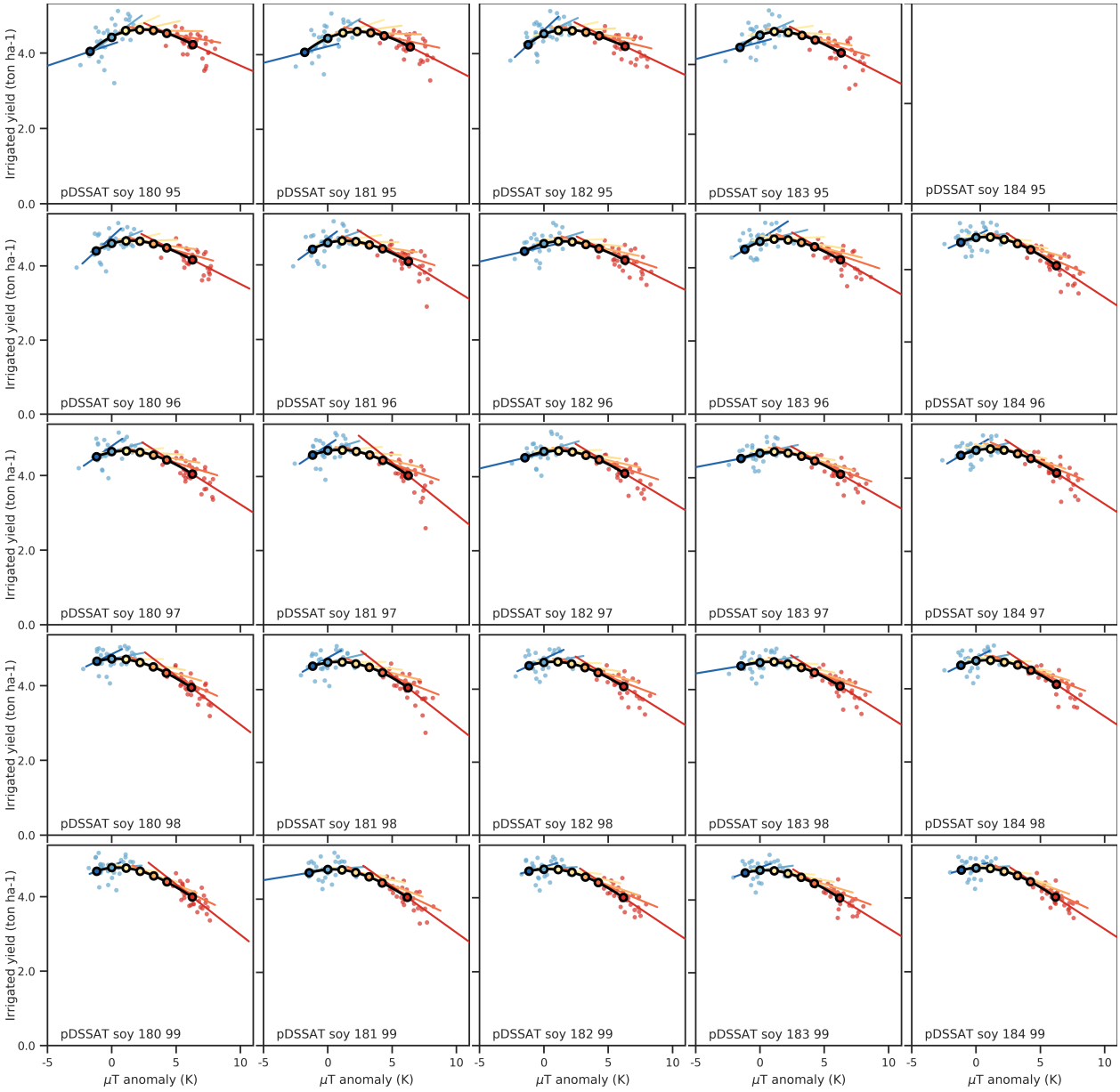

Figure S6: Same convention as above except for soy in Illinois for the pDSSAT model.

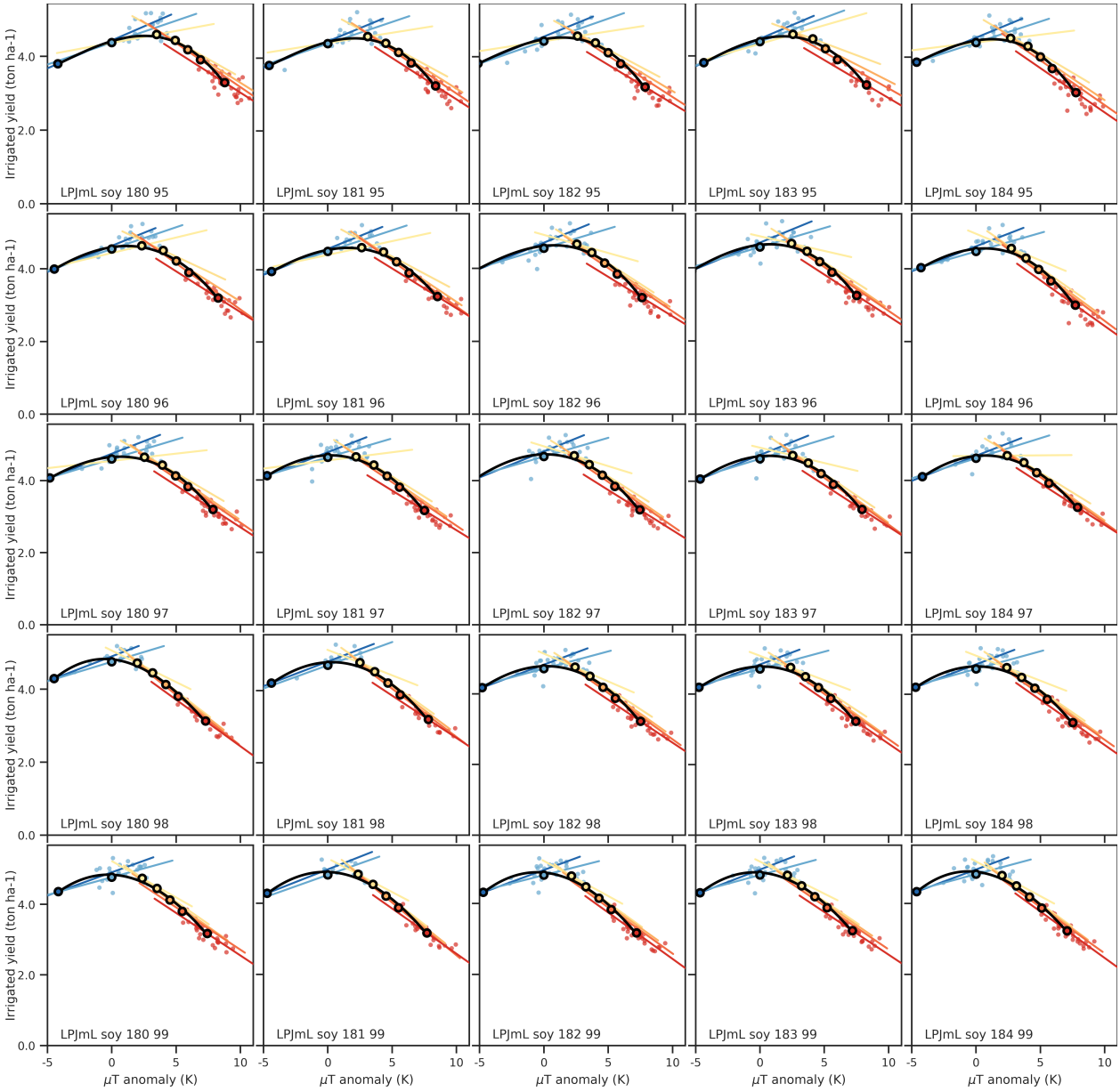

Figure S7: Same convention as above except for soy in Illinois for the LPJmL model.

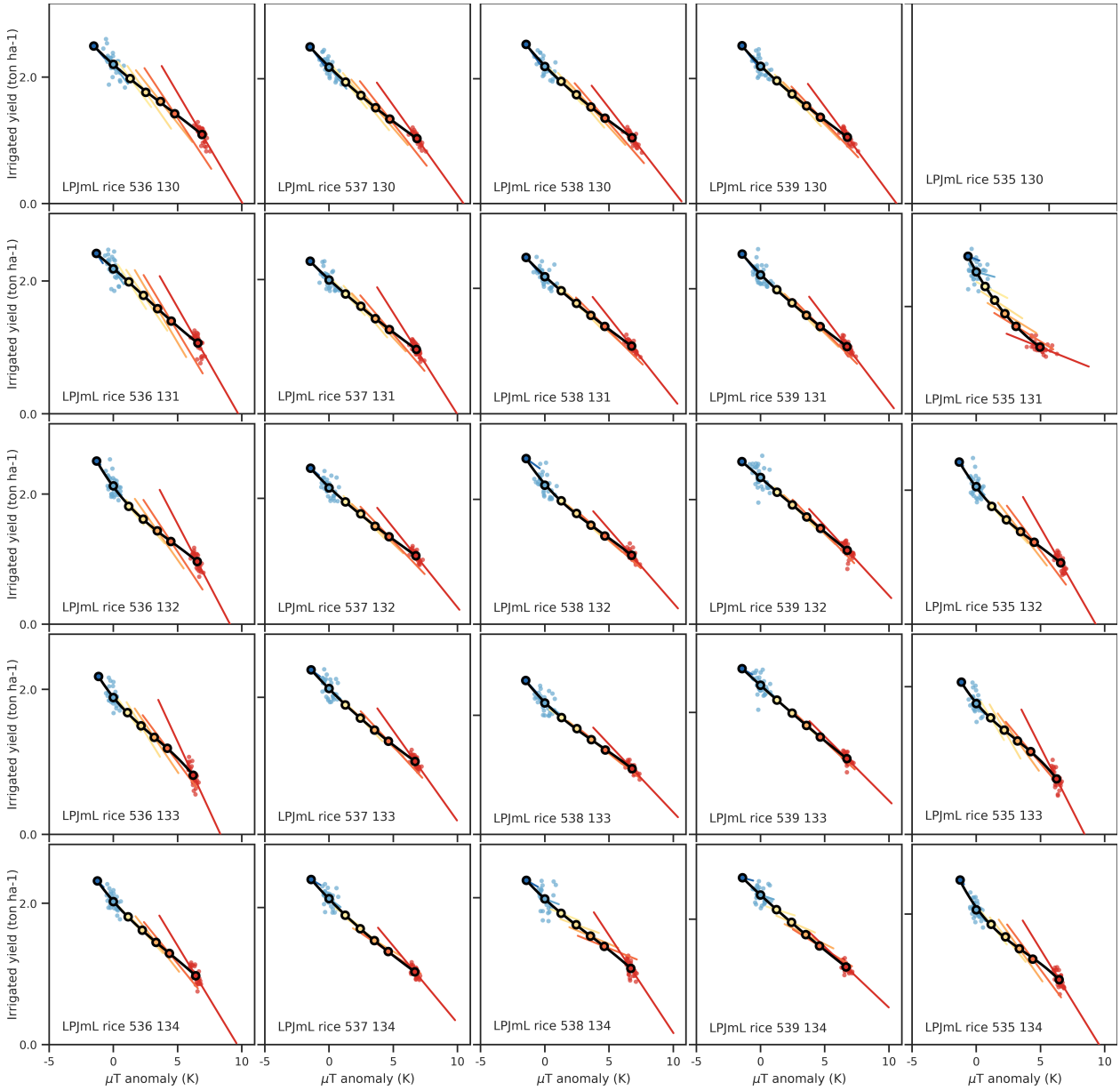

Figure S8: Same convention as above except for rice in India/Bangladesh for the LPJmL model.

2.2 Yield Response

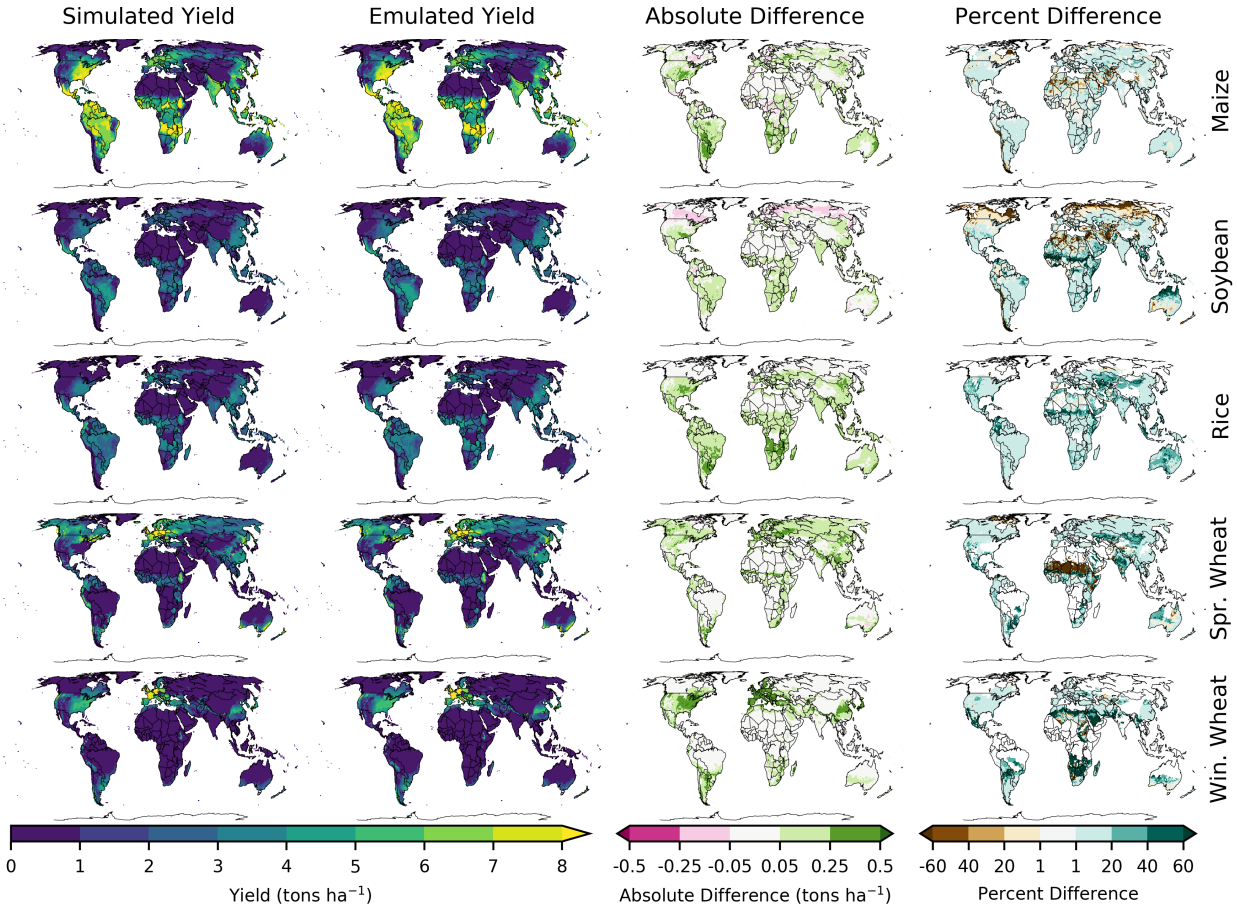

Figure S9: Same convention as Figure 4 in the main text except now for all crops.

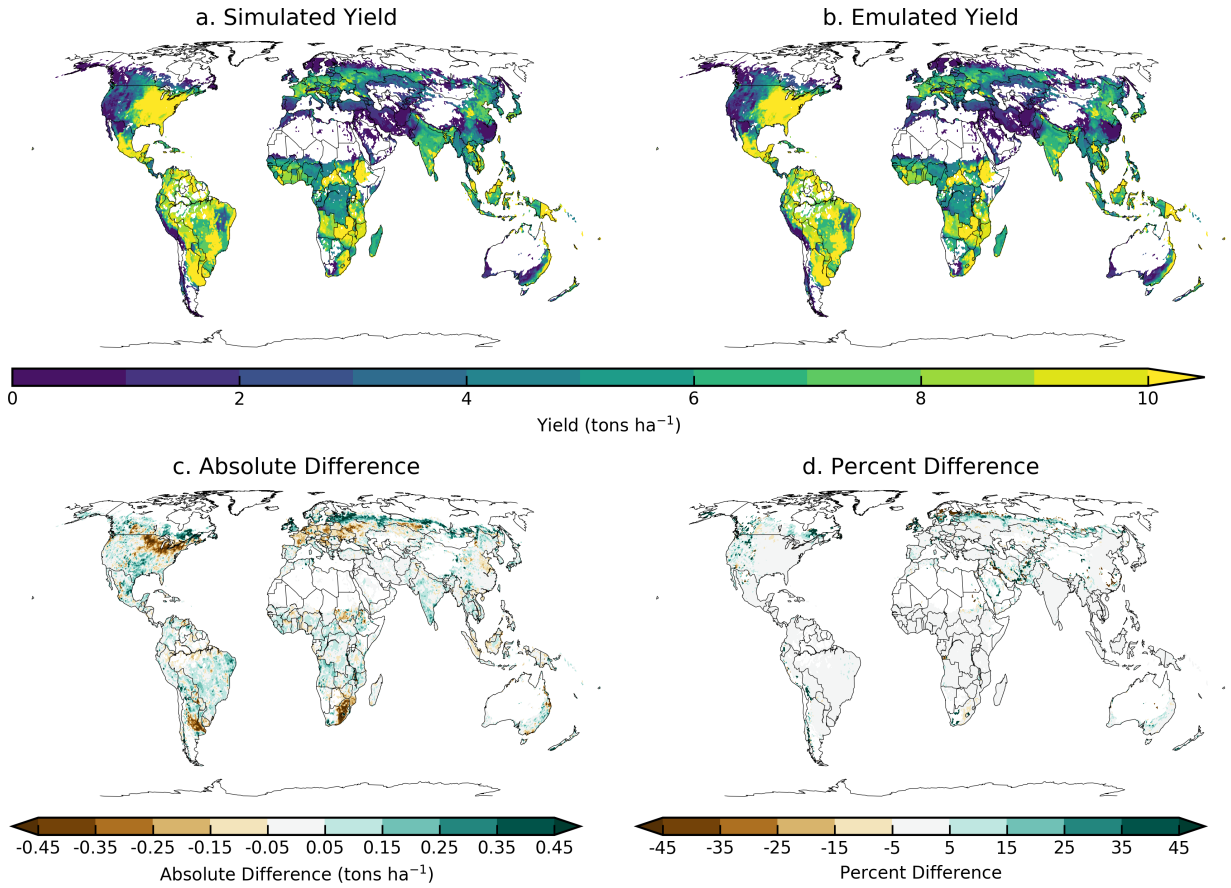

Figure S10: Same convention as Figure 4 in the main text except now pDSSAT maize.

2.3 Normalized Error

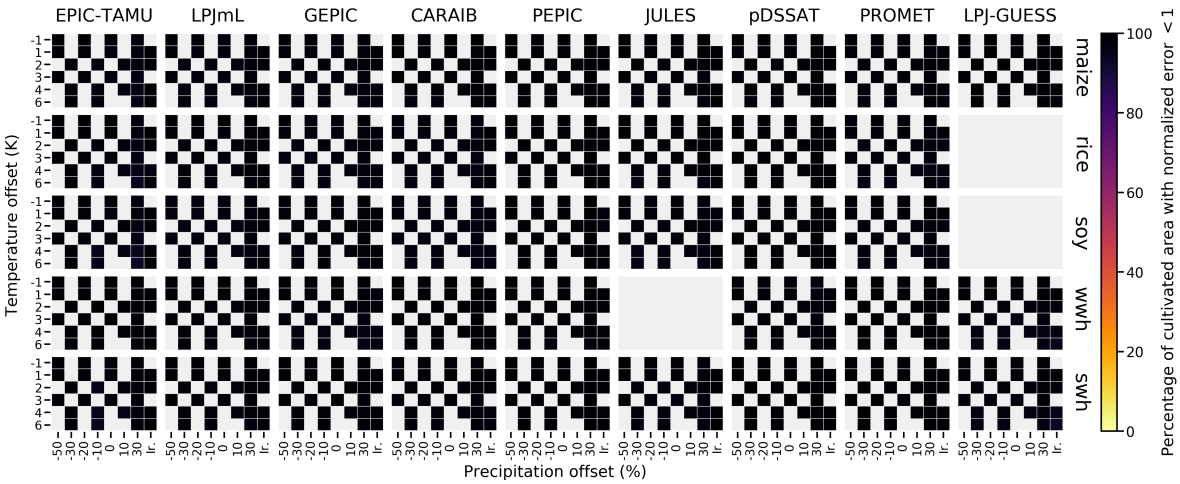

Figure S11: The fraction of grid cells (across all grid cells) with normalized emulation error less than 1 for the CO_2=360 ppm and 200 kg N ha^{-1} yr^{-1} case for the temperature and precipitation perturbations scenarios provided by all 9 models included in the emulator analysis. This is in contrast to the fraction of currently cultivated hectares shown in the C360 case in the manuscript and for the C810 case show in the supplemental material. The emulator is marginally more successful over currently cultivated areas than over all grid cells in general.

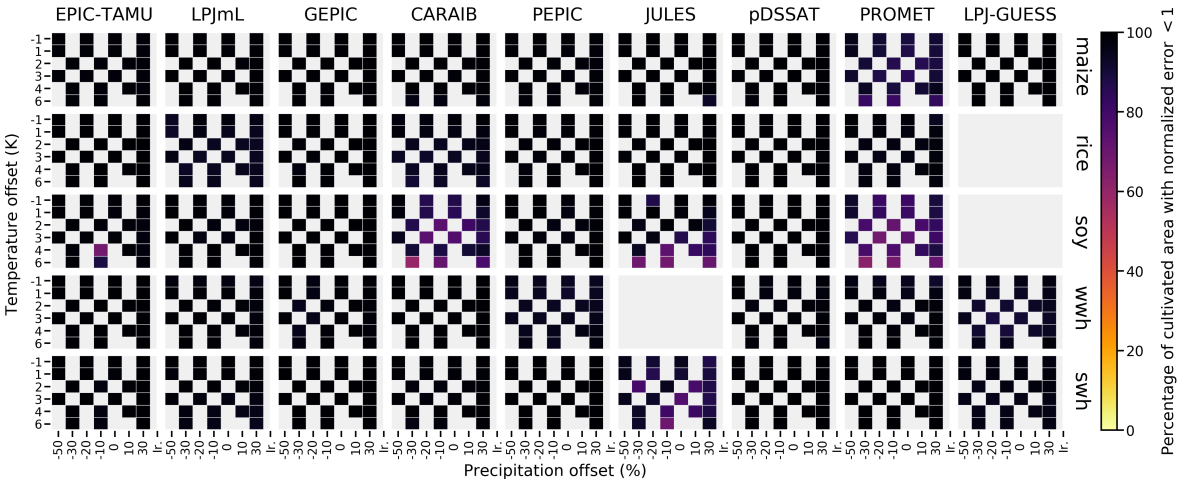

Figure S12: The fraction of currently cultivated hectares with normalized emulation error less than 1 (blue colors contours in Figure A2) for the CO_2=810 ppm and 200 kg N ha^{-1} yr^{-1} case for the temperature and precipitation perturbations scenarios provided by all 9 models included in the emulator analysis. See Equations A1 and A2 for normalized error calculation. The yield response is generally easy to emulate over currently cultivated areas (dark blue and light blue).

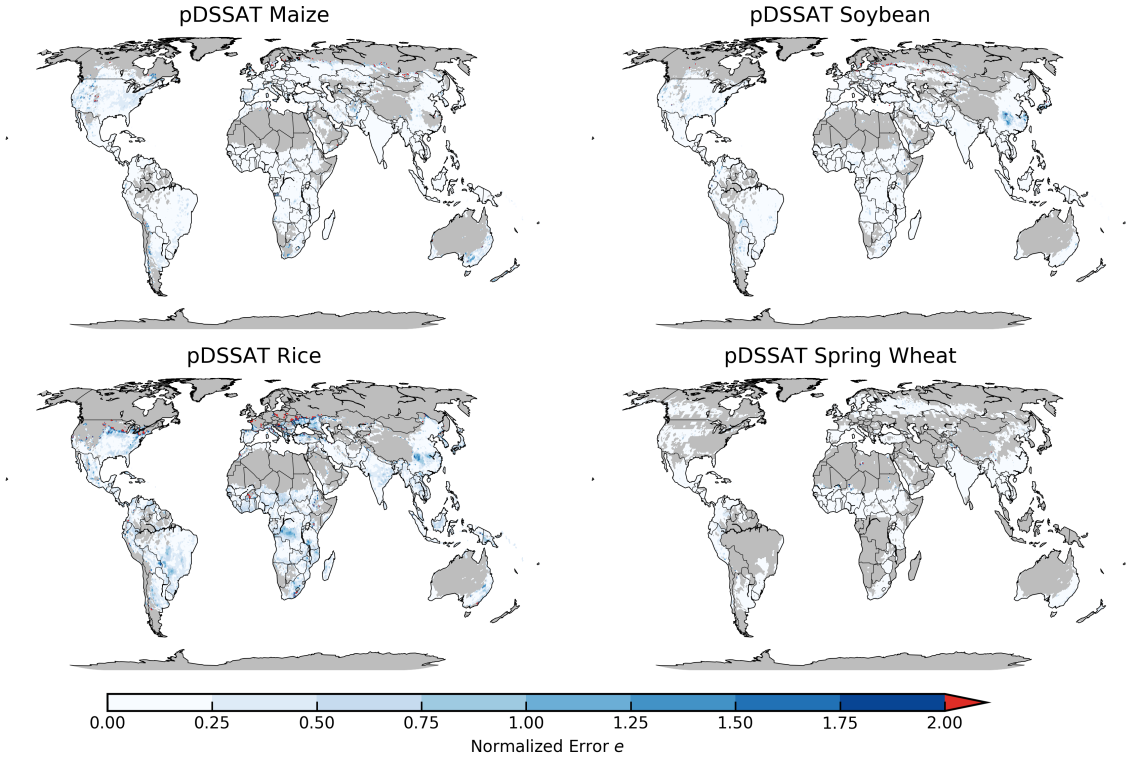

Figure S13: Same convention as main text Figure 8 except now for pDSSAT.

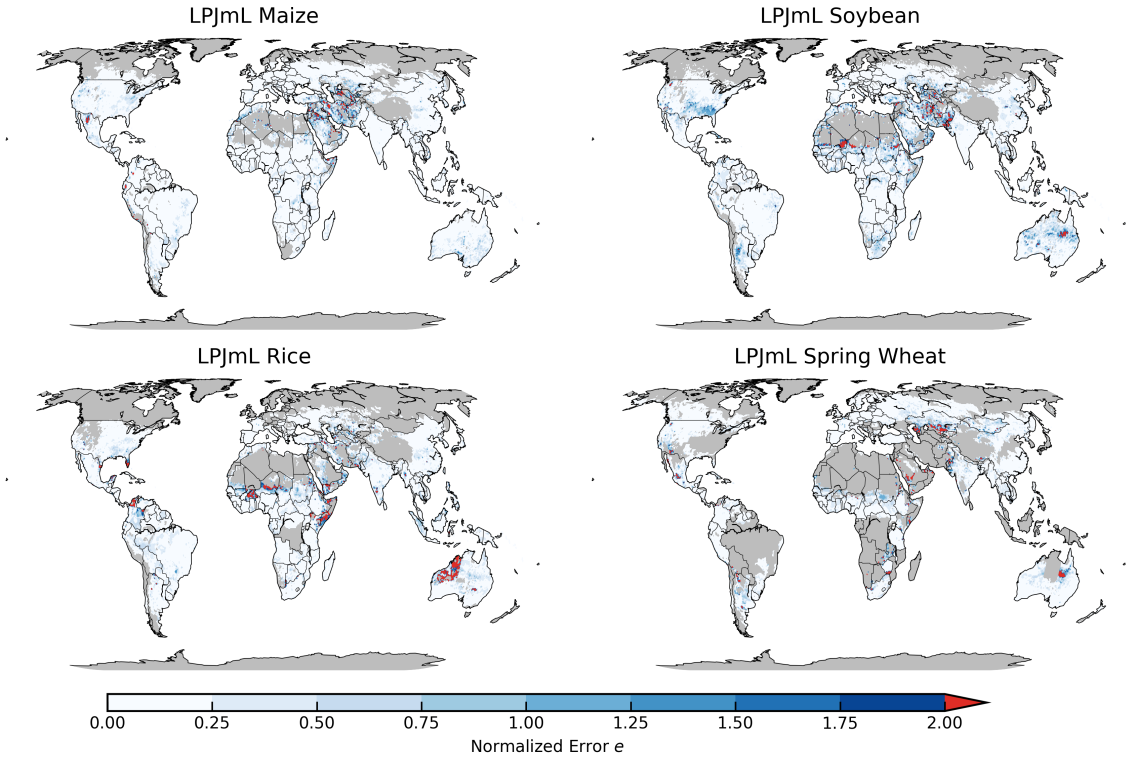

Figure S14: Same convention as main text Figure 8 except now for LPJmL.

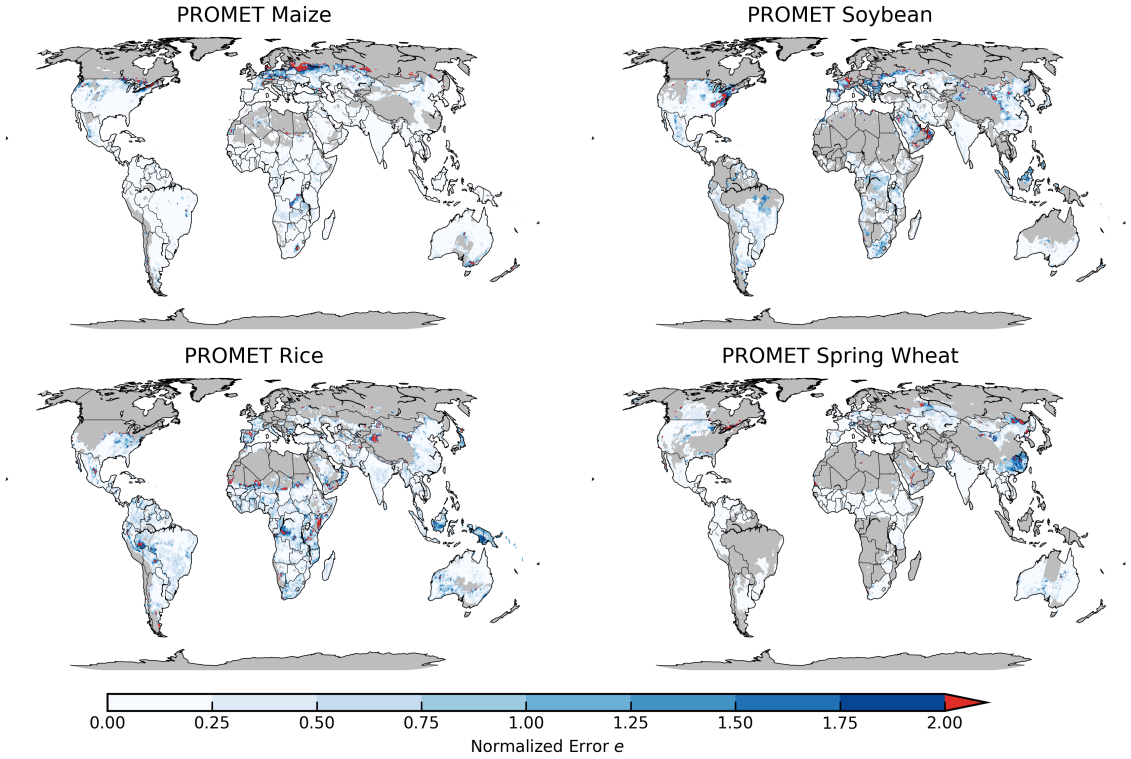

Figure S15: Same convention as main text Figure 8 except now for PROMET.

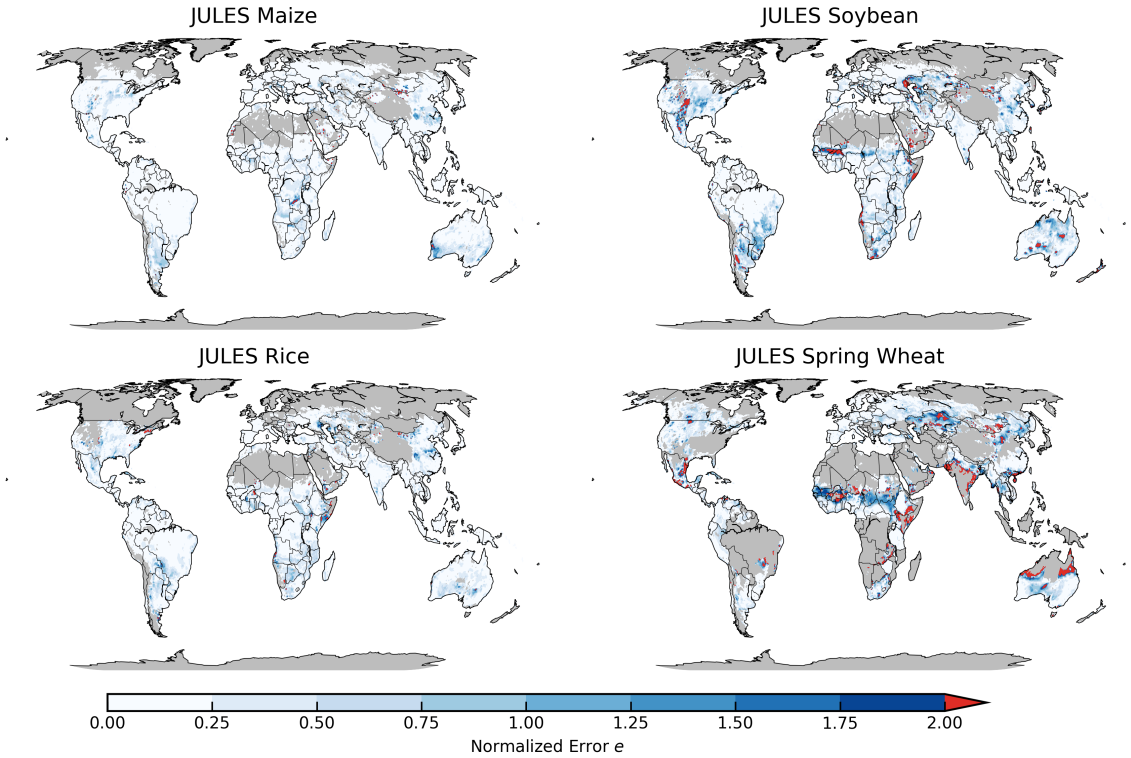

Figure S16: Same convention as main text Figure 8 except now for JULES.

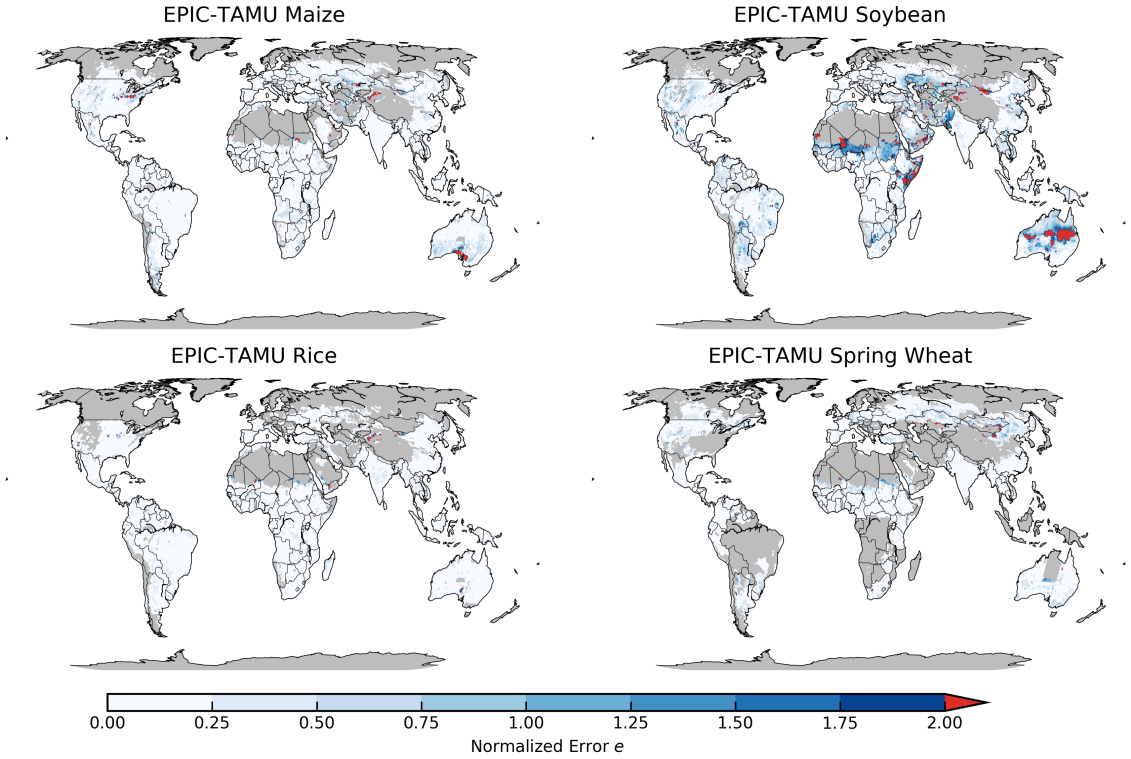

Figure S17: Same convention as main text Figure 8 except now for EPIC-TAMU.

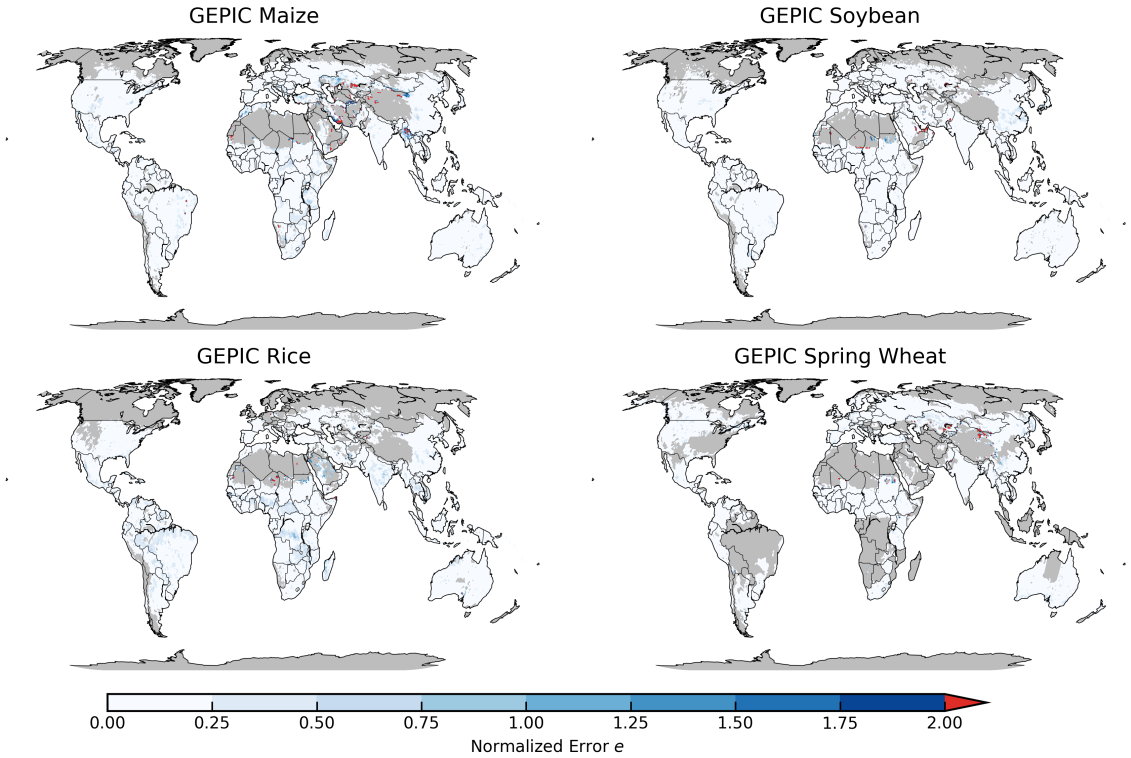

Figure S18: Same convention as main text Figure 8 except now for GEPIC.

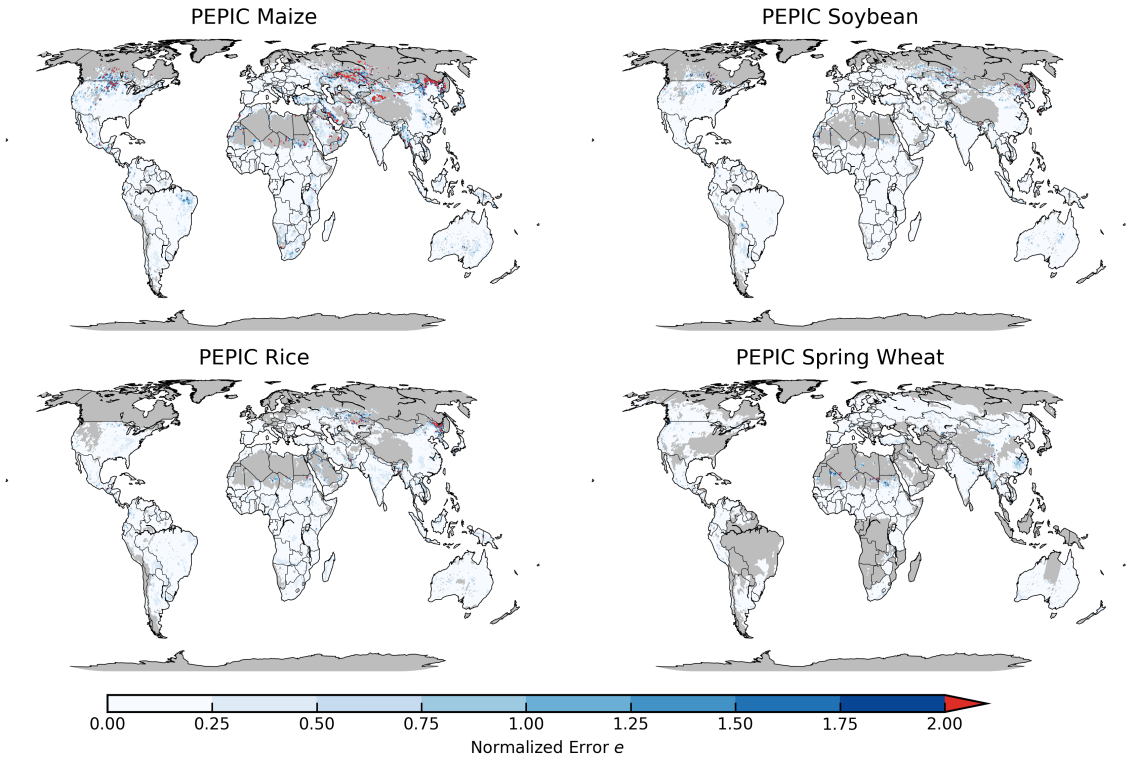

Figure S19: Same convention as main text Figure 8 except now for PEPIC.

2.4 Cross Validation

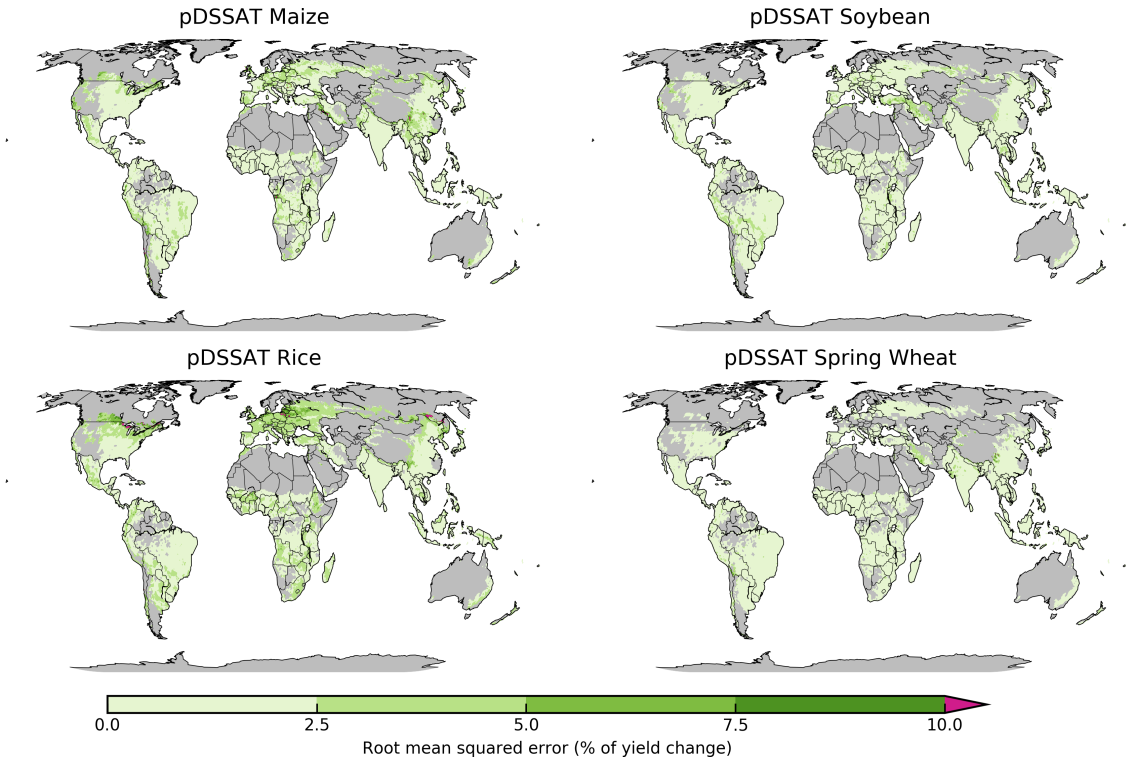

Figure S20: Root mean squared error for three-fold cross validation for the pDSSAT model for rainfed crops.

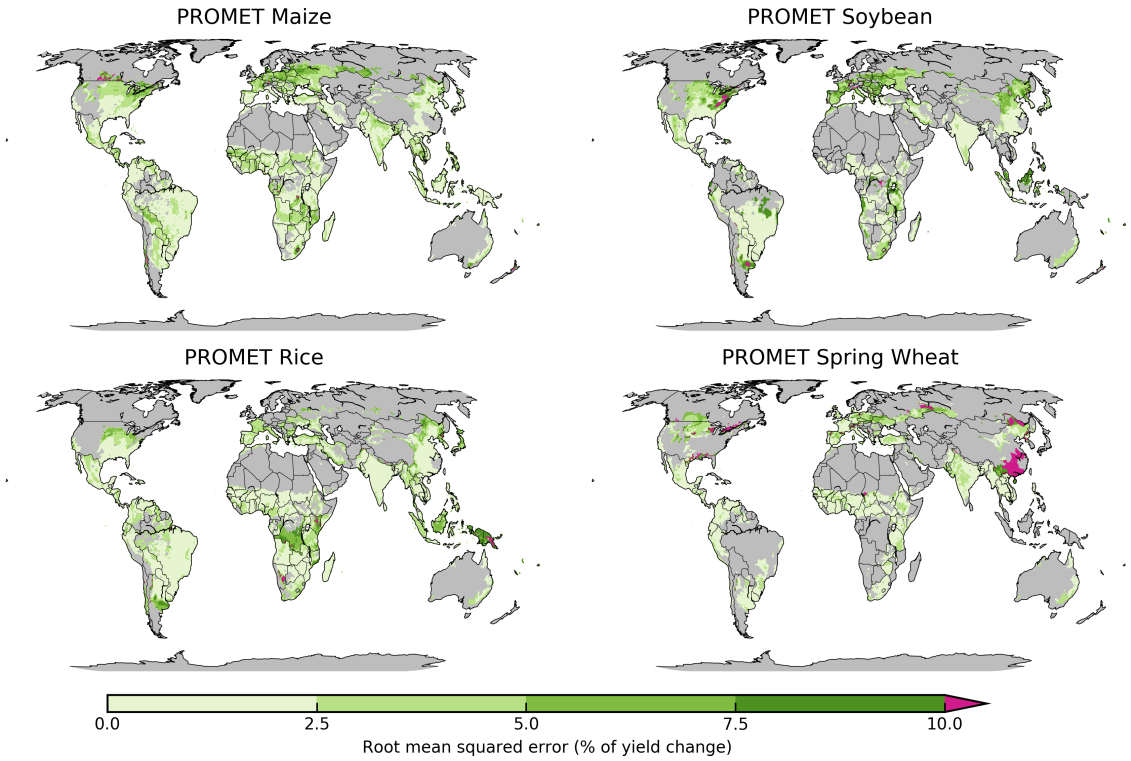

Figure S21: Map of root mean squared error for three fold cross validation process for the PROMET model for rainfed crops. Values shown as a percentage of baseline yield in each gridcell.

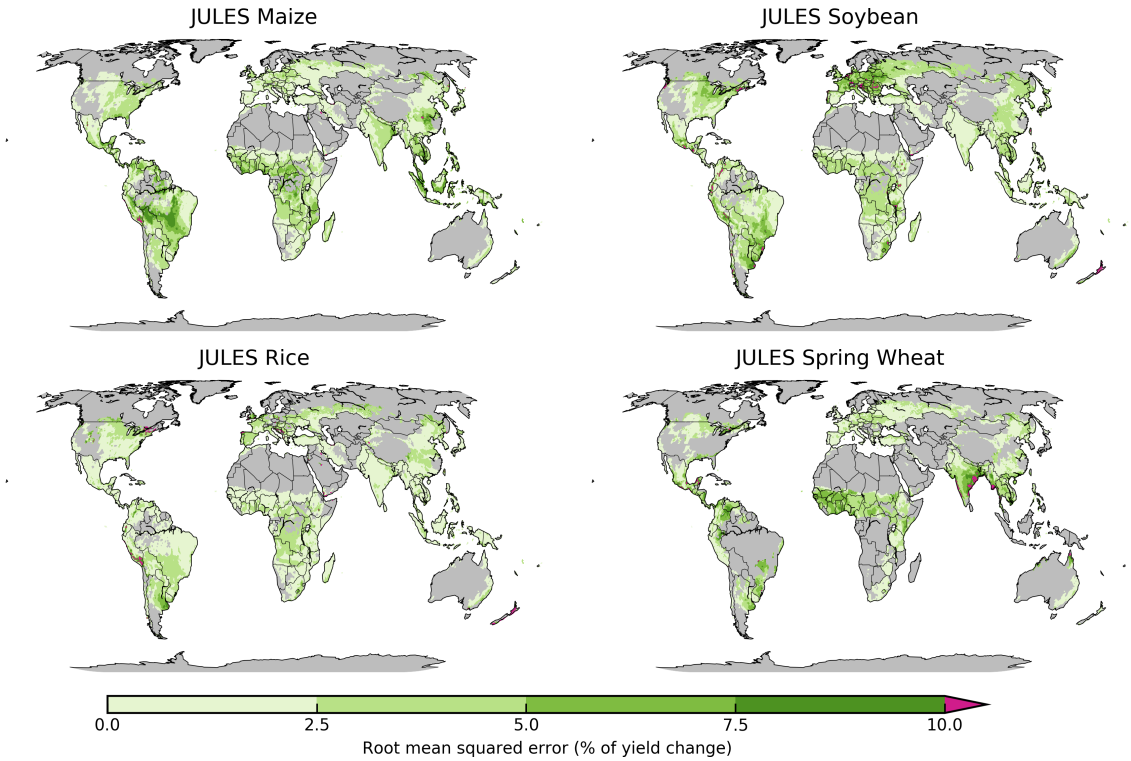

Figure S22: Map of root mean squared error for three fold cross validation process for the JULES model for rainfed crops. Values shown as a percentage of baseline yield in each gridcell.

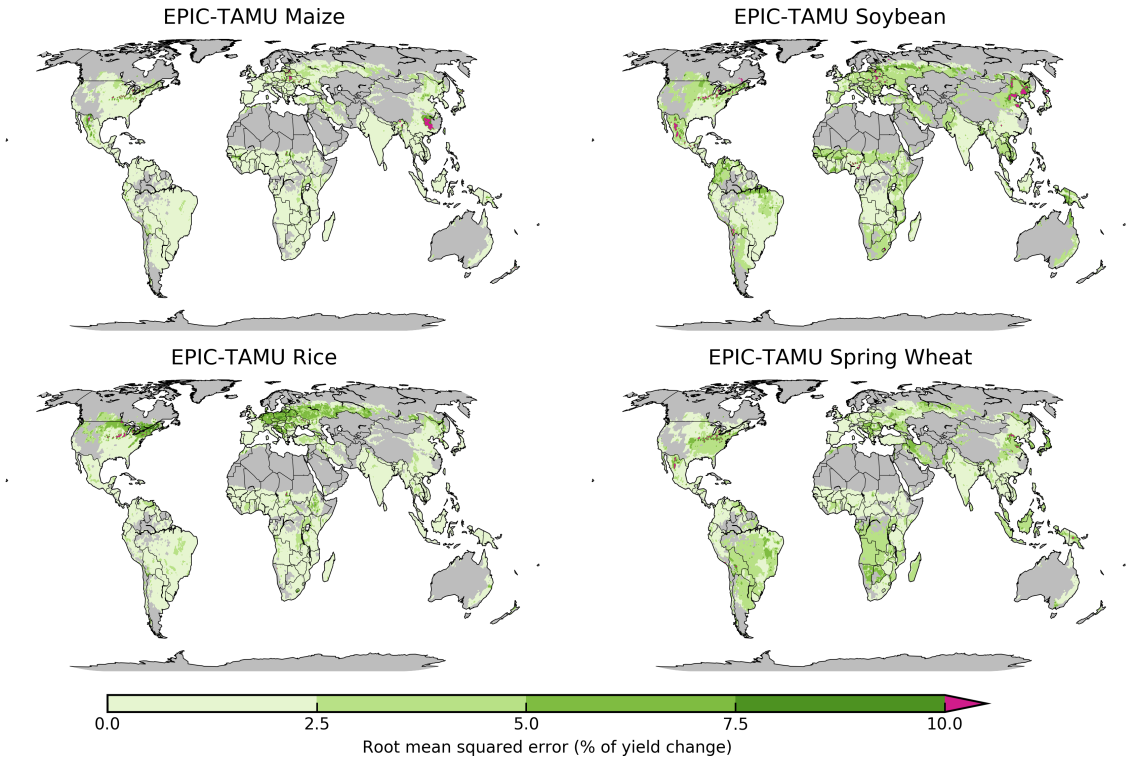

Figure S23: Map of root mean squared error for three fold cross validation process for the EPIC-TAMU model for rainfed crops. Values shown as a percentage of baseline yield in each gridcell.

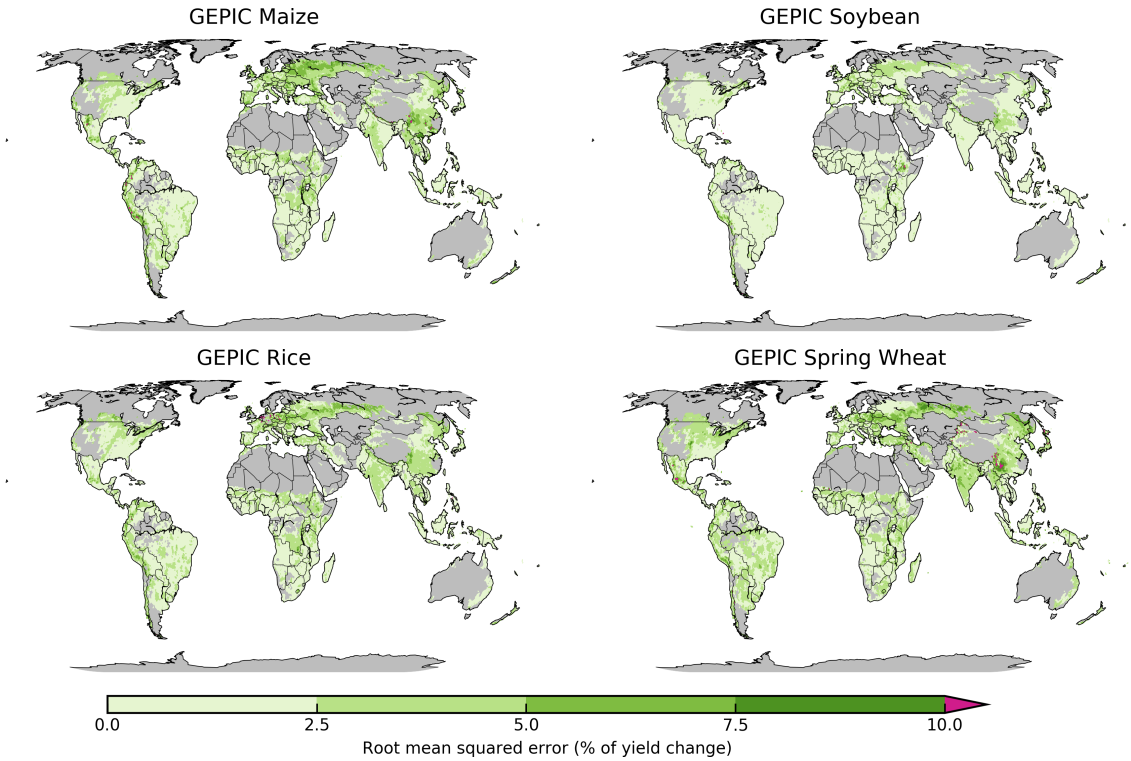

Figure S24: Map of root mean squared error for three fold cross validation process for the GEPIC model for rainfed crops. Values shown as a percentage of baseline yield in each gridcell.

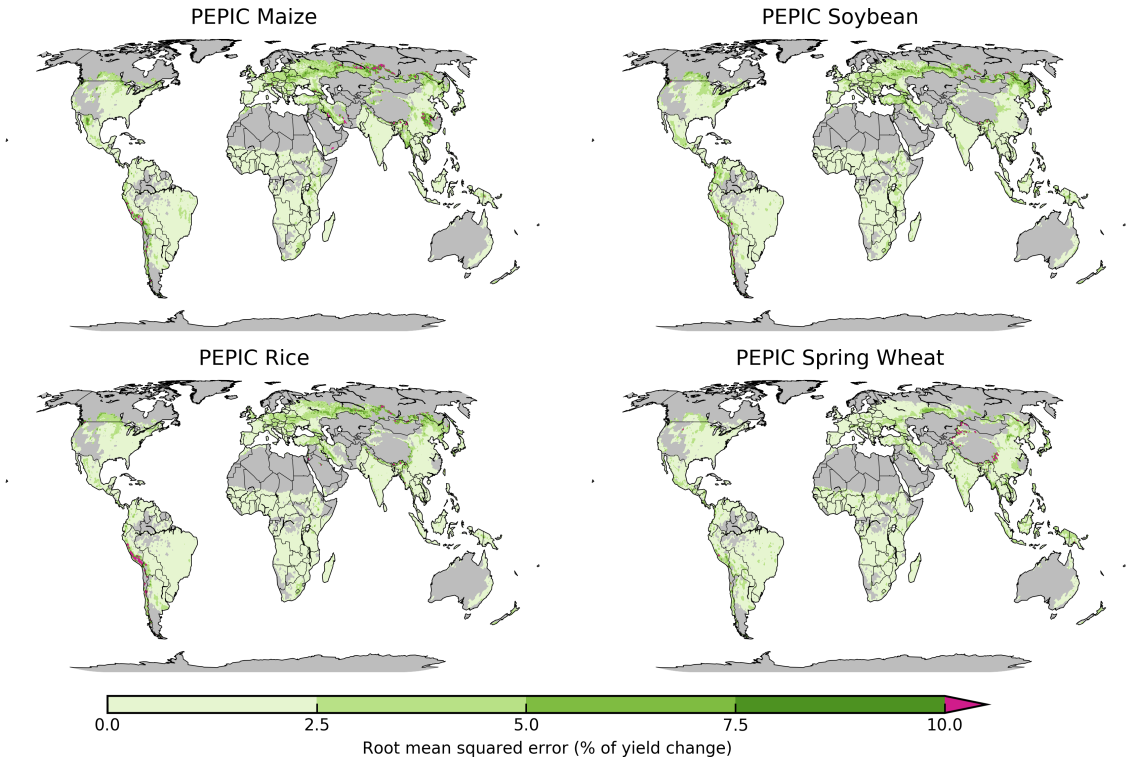

Figure S25: Map of root mean squared error for three fold cross validation process for the PEPIC model for rainfed crops. Values shown as a percentage of baseline yield in each gridcell.

2.5 Emulator products

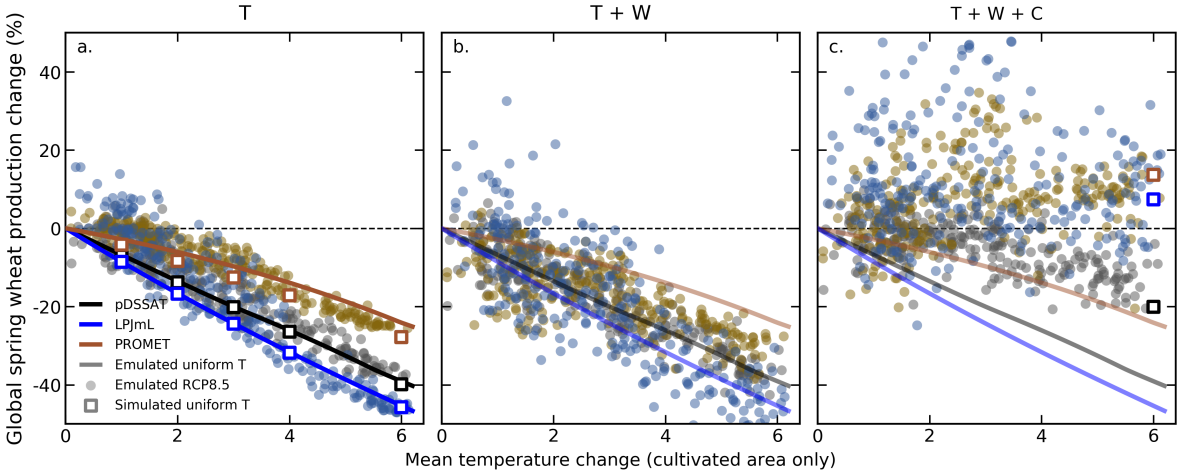

Figure S26: Same convention as Figure 11 in the main text except now for spring wheat. PROMET spring wheat emulator fails in China, resulting in the bias.

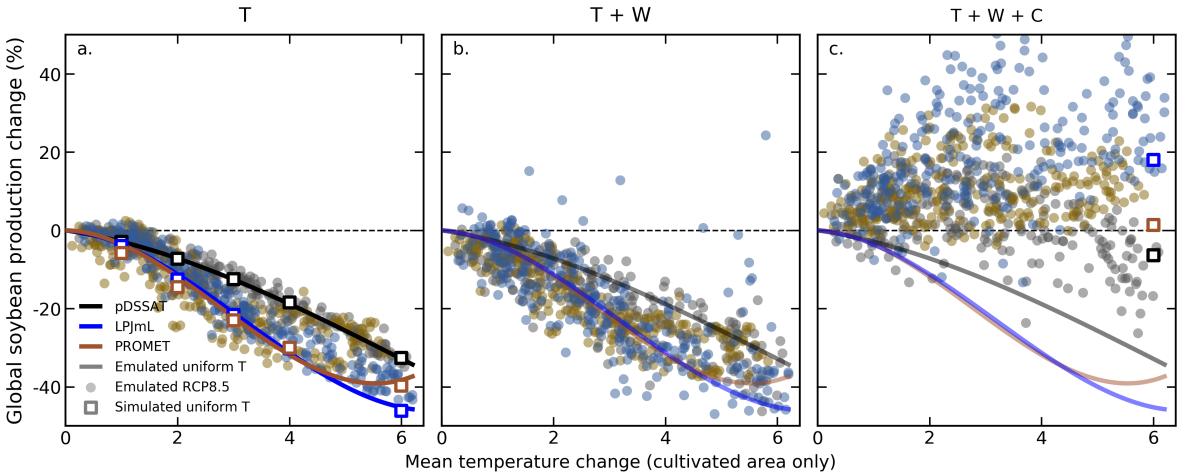

Figure S27: Same convention as Figure 11 in the main text except now for soybean.

2.6 Reduced specification emulator

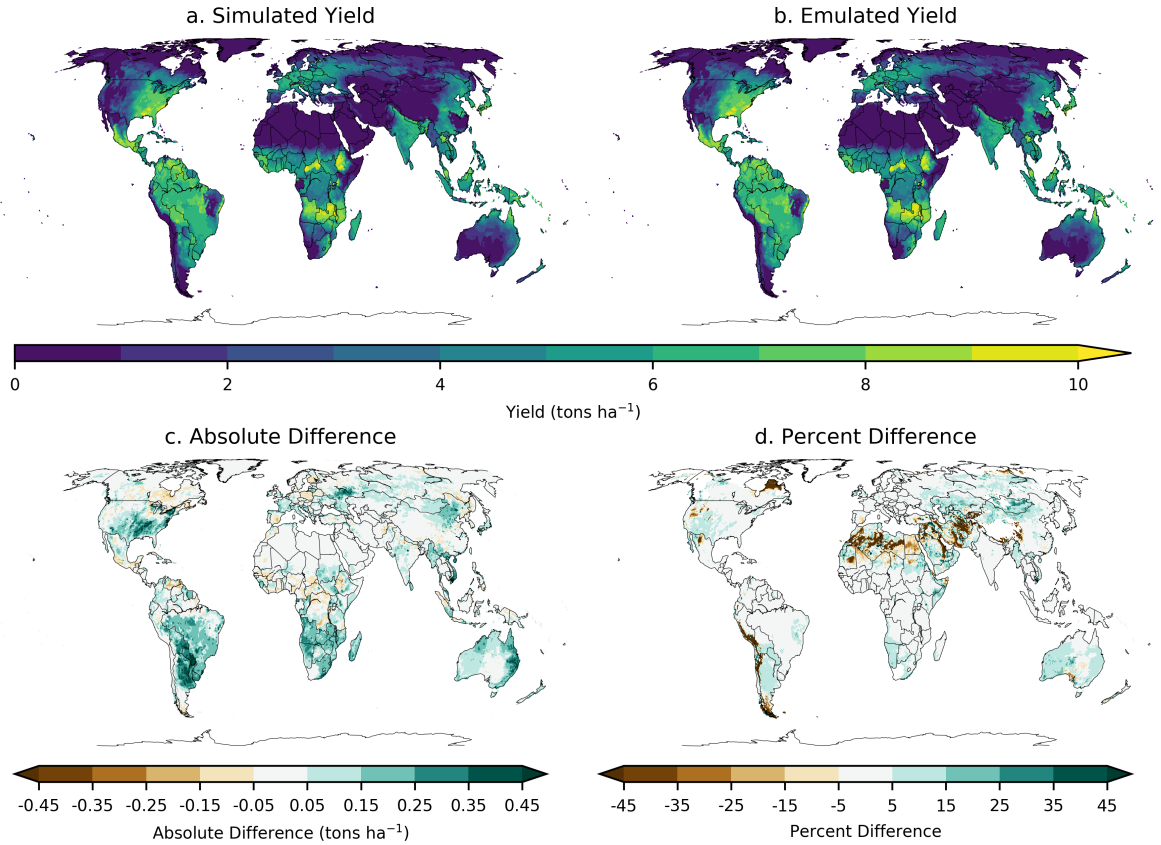

Figure S28: Same convention as Figure 4 in the main text except now with the reduced (23-term) emulator specification.

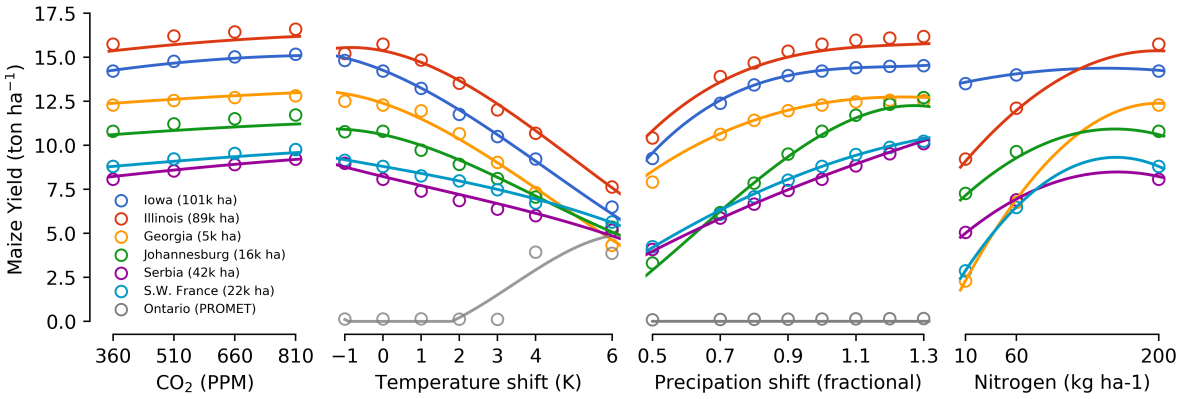

Figure S29: Same convention as Figure 5 in the main text except now with the reduced (23-term) emulator specification.

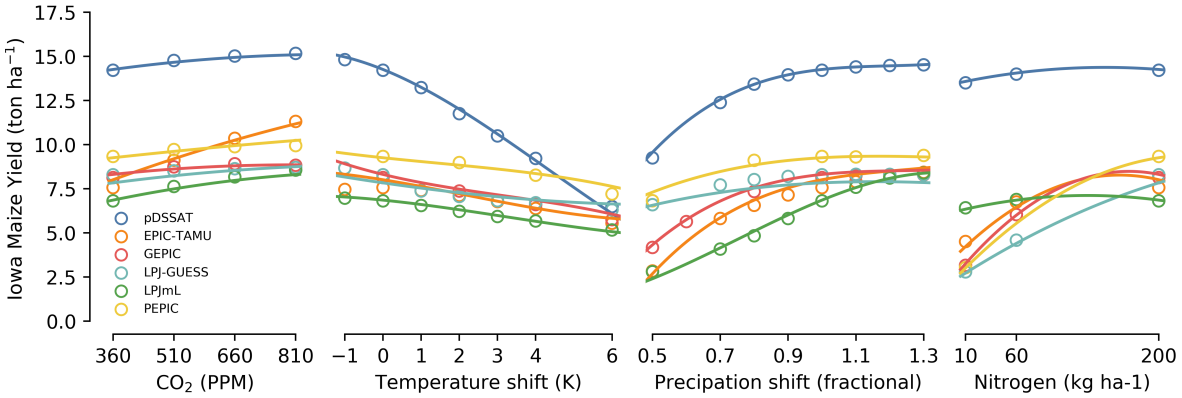

Figure S30: Same convention as Figure 6 in the main text except now with the reduced (23-term) emulator specification.

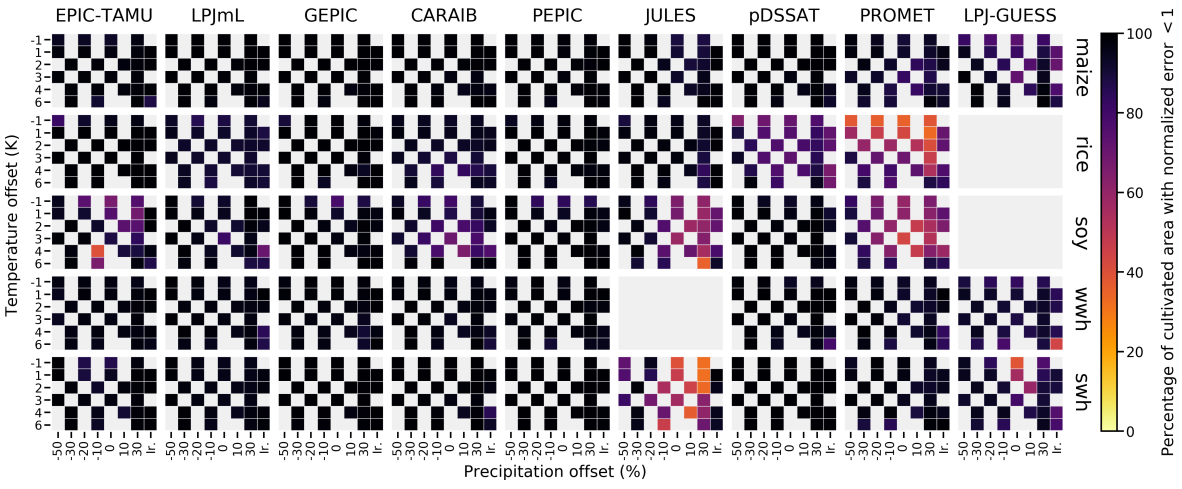

Figure S31: Same convention as Figure 7 in the main text except now with the reduced (23-term) emulator specification.

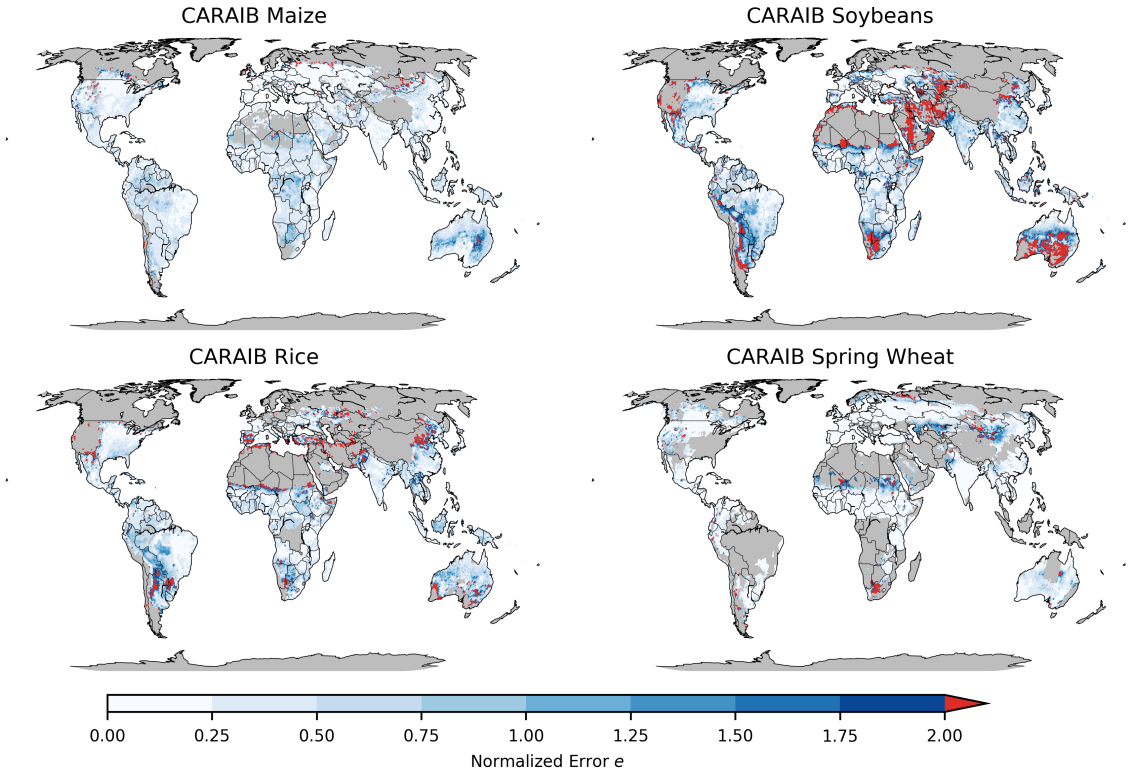

Figure S32: Same convention as Figure 8 in the main text except now with the reduced (23-term) emulator specification.

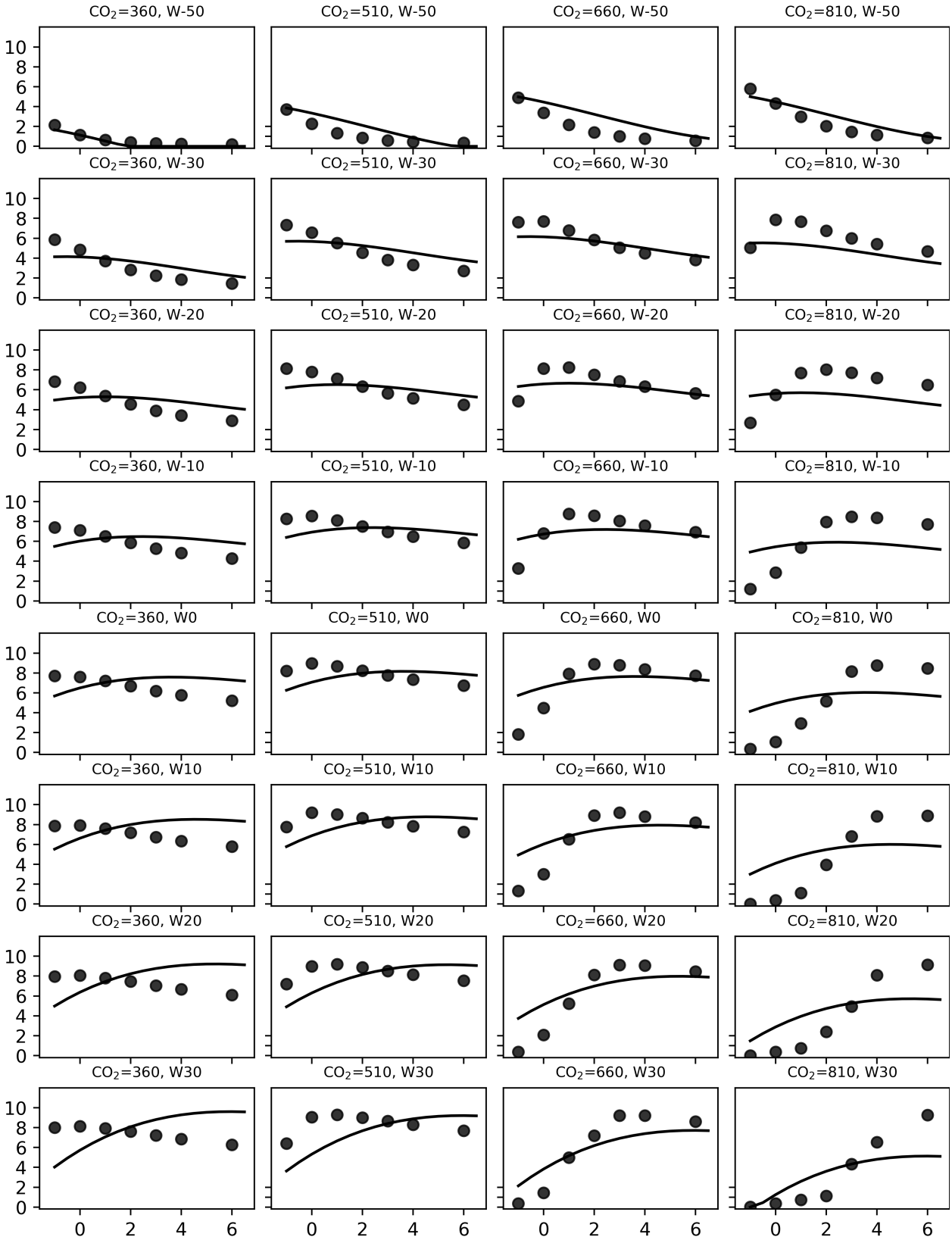

Figure S33: Example of emulator failure. Simulated and emulated values for JULES soybean in Southern Germany. RMSE = 41% of baseline yield.

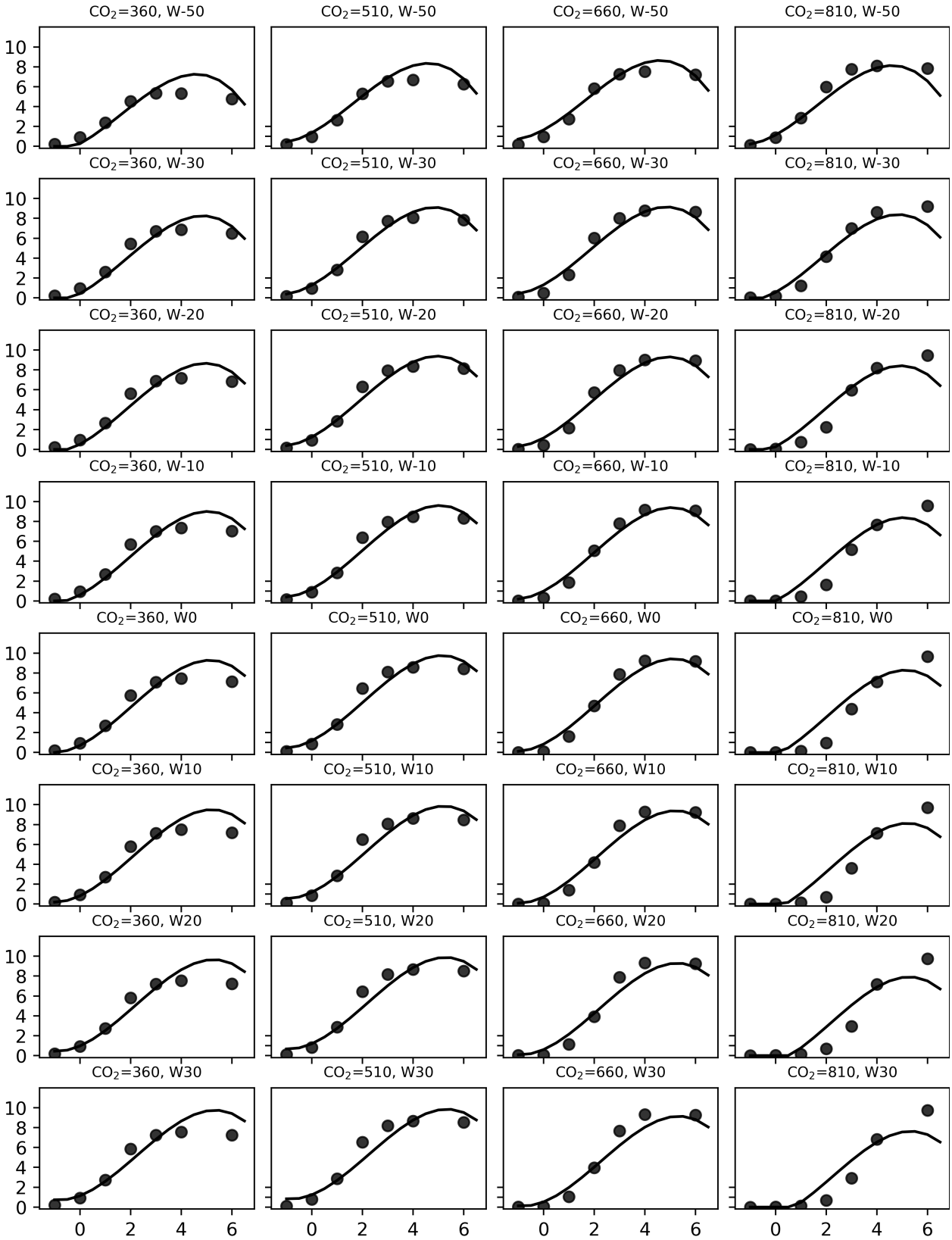

Figure S34: Example of emulator failure. Simulated and emulated values for JULES soybean in Southern Germany (one grid-cell south of Figure S10). RMSE = 10% of baseline yield.

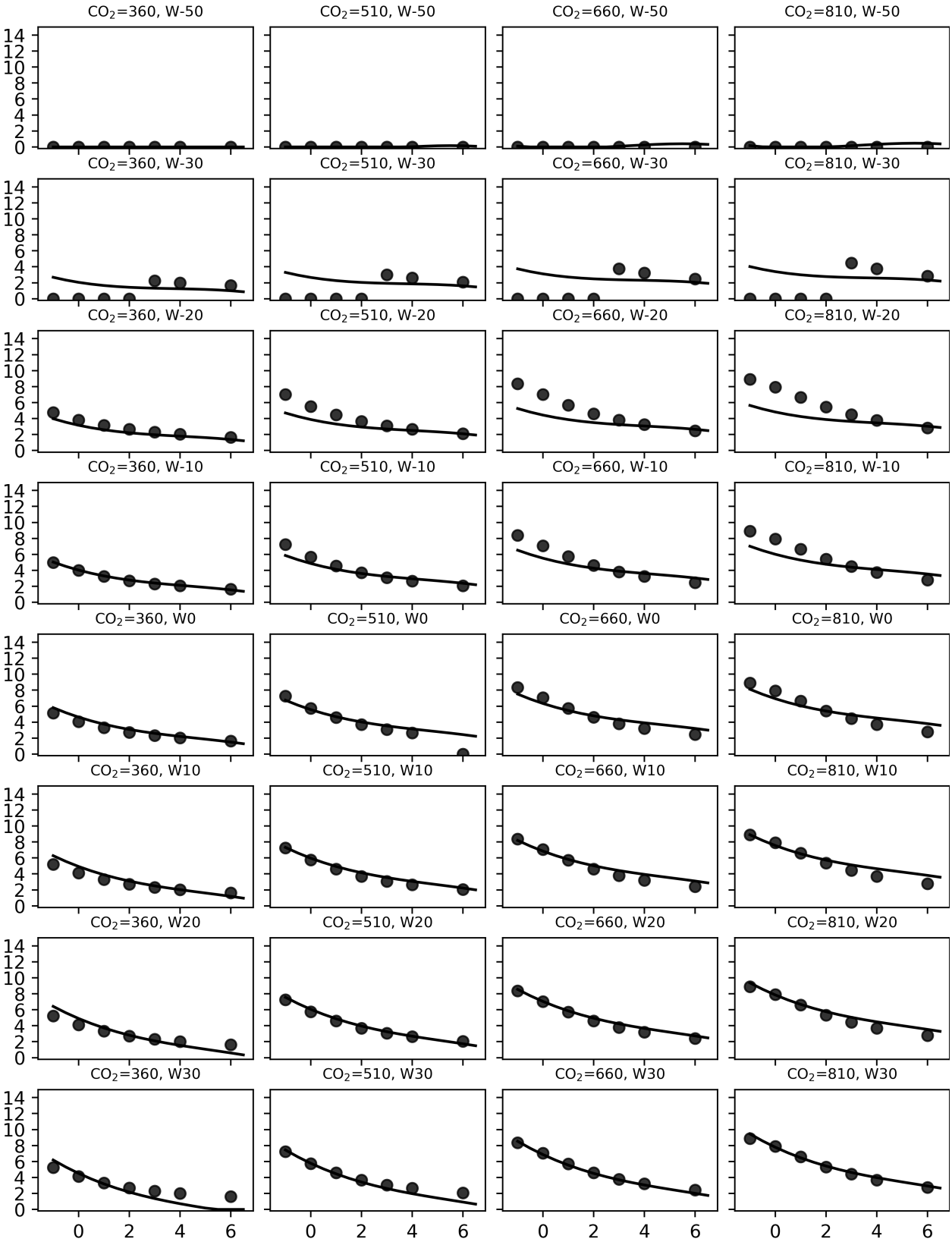

Figure S35: Example of emulator failure. Simulated and emulated values for PROMET rice in Papua New Guinea. RMSE = 67% of baseline yield.

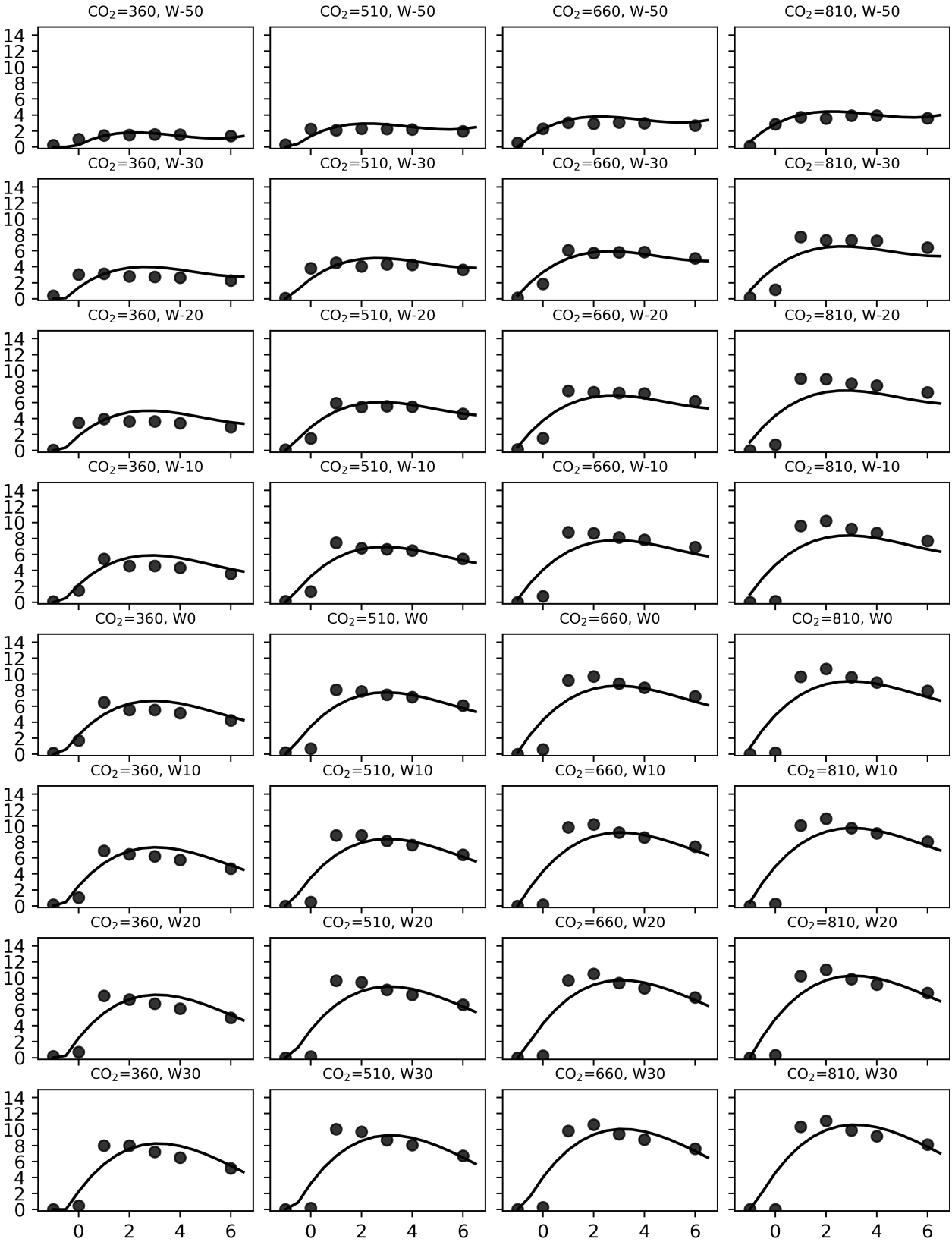

Figure S36: Example of emulator failure. Simulated and emulated values for PROMET rice in Arunachal Pradesh. RMSE = 132% of baseline yield.