

Supplementary Materials

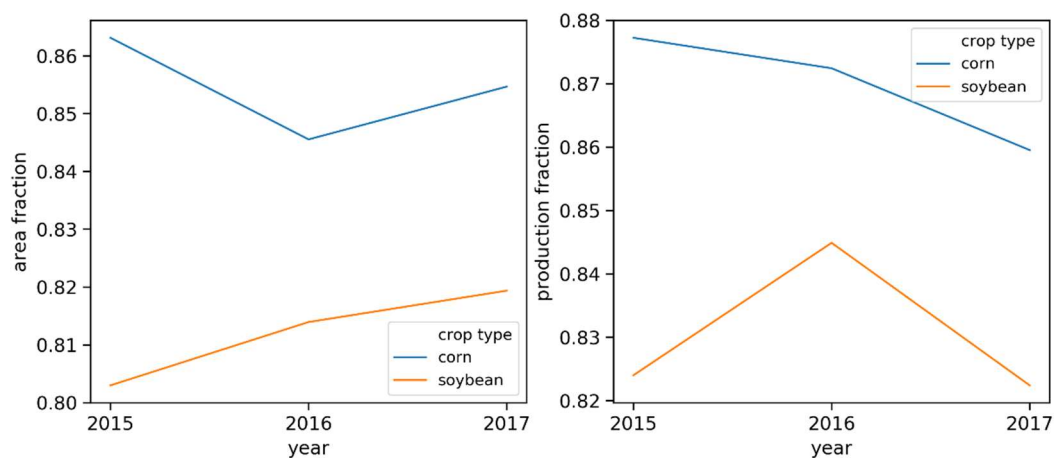


Figure S1. Corn and soybean harvested area fraction and production fraction of the 12 Midwest states in the U.S. from 2015 to 2017. The data were compiled from USDA NASS crop data layer (CDL) and crop yield datasets.

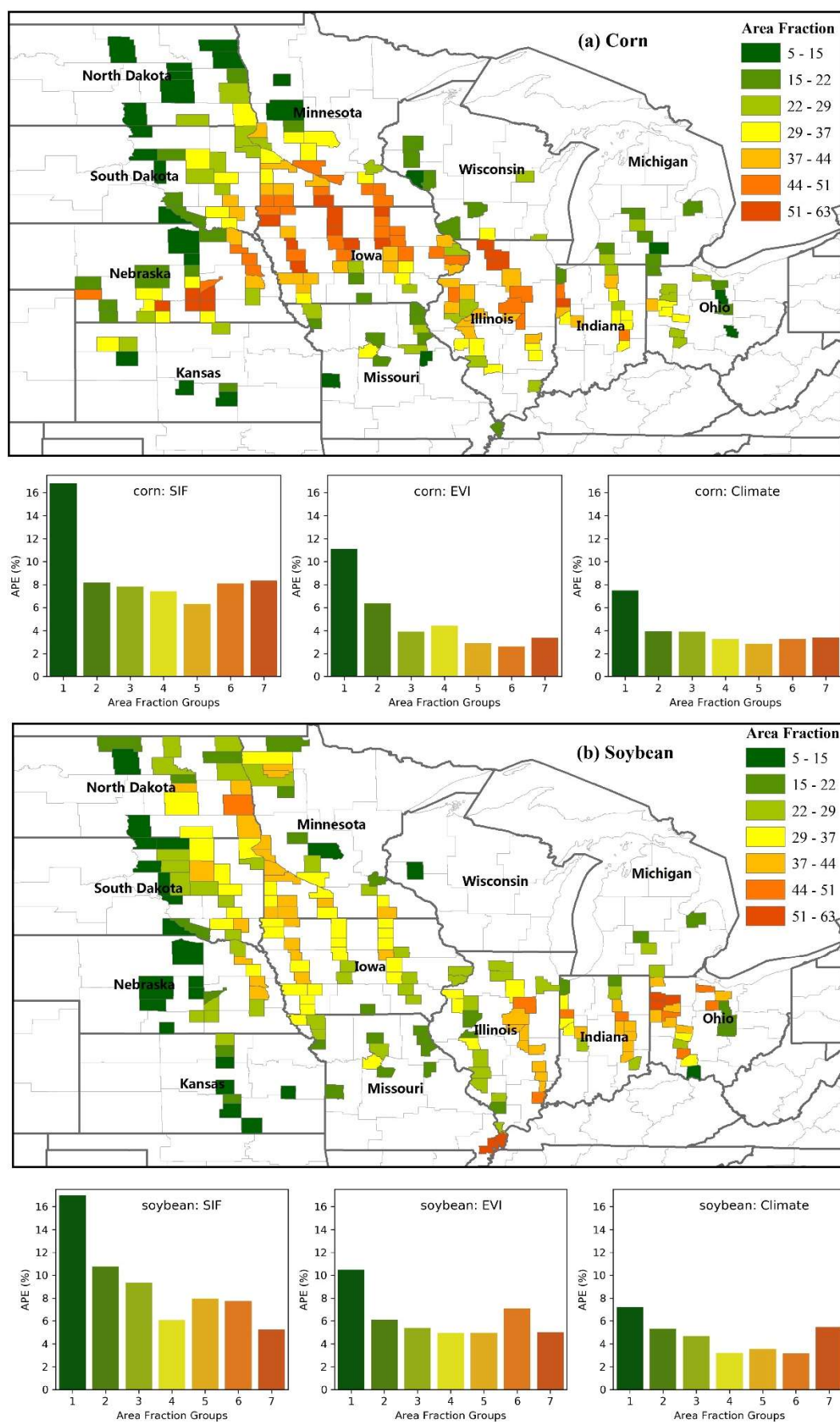


Figure S2. Corn and soybean growing area fraction in each county. The fractions were three-year-mean values

(from 2015 to 2017) calculated using USDA NASS CDL. APE (absolute percentage error) in the barplots were calculated by averaging county-level absolute PE values of 'SIF', 'EVI', and 'Climate' models. In the groups with area fraction equal to 5% - 15%, APE values of both 'SIF' and 'EVI' models were significantly lower than the 'Climate' models for corn and soybean.

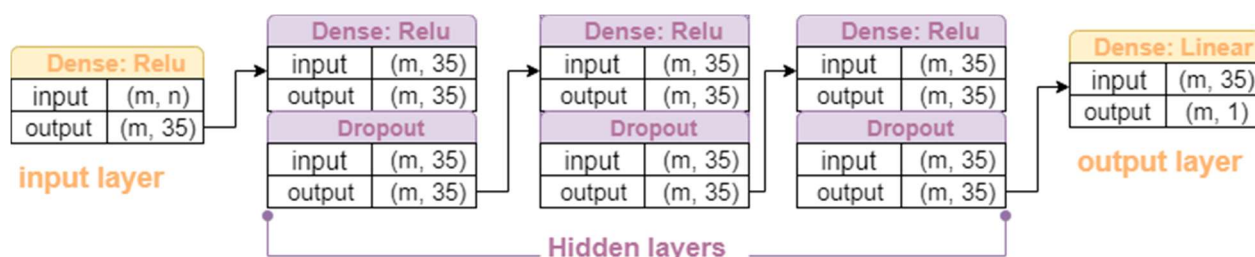


Figure S3. DNN structure employed in this study. The neural network consisted of one input layer, three hidden layers, and one output layer. (n = the number of input variables; m = the number of records)

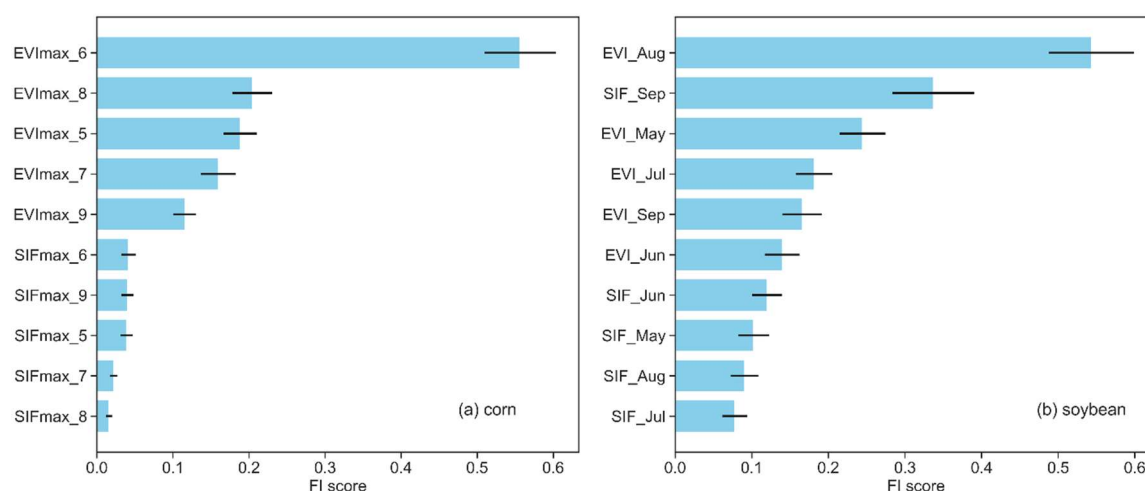


Figure S4. Feature importance (FI) scores of predictors of the 'SIF+EVI' model for corn (left panels) and soybean (right panels). Values of the x-axis are feature importance scores, and the variable with larger FI score carries more importance in predicting the crop yield.

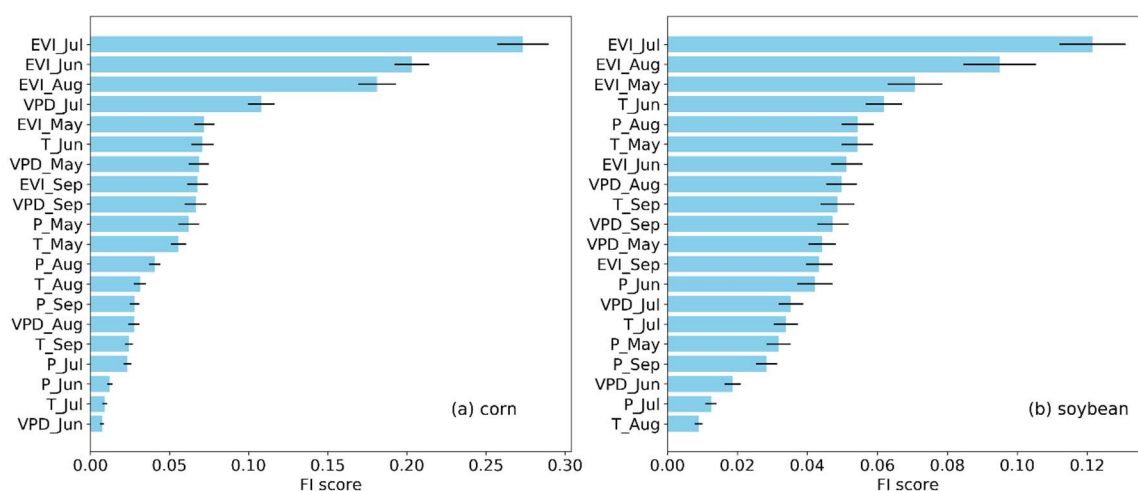


Figure S5. Feature importance (FI) scores of predictors of the ‘EVI + Climate’ model for corn (left panels) and soybean (right panels). Values of the x-axis are feature importance scores, and the variable with larger FI score carries more importance in predicting the crop yield. (P = precipitation; T = temperature; VPD = vapor pressure deficit)

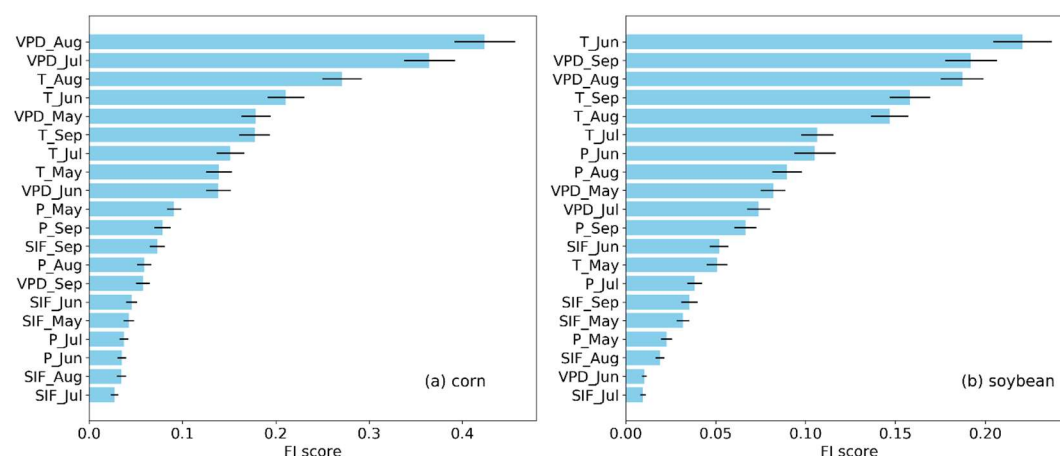


Figure S6. Feature importance (FI) scores of predictors of the ‘SIF + Climate’ model for corn (left panels) and soybean (right panels). Values of the x-axis are feature importance scores, and the variable with larger FI score carries more importance in predicting the crop yield. (P = precipitation; T = temperature; VPD = vapor pressure deficit)

Table S1. Trained and tested R^2 of different model architectures. The best DNN has a hidden layer of three with 35 neurons in each layer.

hidden layers	neurons	tested R^2	tested STD ^a	trained R^2	trained STD
3	35	0.683	0.013	0.704	0.012
2	35	0.675	0.026	0.682	0.013
5	35	0.671	0.026	0.685	0.013
4	35	0.667	0.032	0.668	0.014
1	35	0.663	0.025	0.670	0.026

hidden layers	neurons	tested R^2	tested STD	trained R^2	trained STD
3	35	0.683	0.013	0.704	0.012
3	40	0.674	0.027	0.685	0.004
3	28	0.664	0.025	0.674	0.010
3	21	0.634	0.039	0.643	0.019
3	14	0.603	0.036	0.609	0.033
3	7	0.532	0.038	0.529	0.037

^a STD = standard deviation.

Table S1. Summary of Tukey HSD test between adjusted R^2 values of different models in 100 experiments for corn. ‘Group1’ and ‘Group2’ are the targeting pair of models for comparison. ‘MeanDiff’ is the difference between group means. ‘Lower’ and ‘Upper’ are the lower and upper boundaries of confidence intervals for the pairwise mean differences. ‘Reject’ is TRUE means that there is a significant difference (at 95% confidence level) between two models; FALSE means that the null hypothesis is true that the averaged model performances measured by R^2 are equal.

Group1	Group2	MeanDiff	lower	upper	reject
Climate	EVI	-0.04	-0.05	-0.03	True
Climate	EVI+Climate	0.09	0.08	0.10	True

Climate	SIF	-0.34	-0.35	-0.33	True
Climate	SIF+Climate	0.04	0.03	0.05	True
Climate	SIF+EVI	-0.01	-0.02	0.01	False
Climate	SIF+EVI+Climate	0.08	0.07	0.10	True
EVI	EVI+Climate	0.13	0.12	0.14	True
EVI	SIF	-0.30	-0.31	-0.29	True
EVI	SIF+Climate	0.08	0.07	0.09	True
EVI	SIF+EVI	0.03	0.02	0.04	True
EVI	SIF+EVI+Climate	0.12	0.11	0.13	True
EVI+Climate	SIF	-0.43	-0.45	-0.42	True
EVI+Climate	SIF+Climate	-0.05	-0.07	-0.04	True
EVI+Climate	SIF+EVI	-0.10	-0.11	-0.09	True
EVI+Climate	SIF+EVI+Climate	-0.01	-0.02	0.00	False
SIF	SIF+Climate	0.38	0.37	0.39	True
SIF	SIF+EVI	0.34	0.33	0.35	True
SIF	SIF+EVI+Climate	0.43	0.42	0.44	True
SIF+Climate	SIF+EVI	-0.04	-0.05	-0.03	True
SIF+Climate	SIF+EVI+Climate	0.05	0.04	0.06	True
SIF+EVI	SIF+EVI+Climate	0.09	0.08	0.10	True

^a The ANOVA result for the difference among all the models: $F=2700.47$, $P < 0.001$.

Table S3 Summary of Tukey HSD test between adjusted R^2 values of different models in 100 experiments for soybean. ‘Group1’ and ‘Group2’ are the targeting pair of models for comparison. ‘MeanDiff’ is the difference between group means. ‘Lower’ and ‘Upper’ are the lower and upper confidence interval boundaries for the pairwise mean differences. ‘Reject’ is TRUE means that there is a significant difference (at 95% confidence level) between two models; FALSE means that the null hypothesis is true that the averaged model performances measured by R^2 are equal.

Group1	Group2	MeanDiff	lower	upper	reject
Climate	EVI	-0.12	-0.13	-0.11	True
Climate	EVI+Climate	0.05	0.04	0.07	True
Climate	SIF	-0.29	-0.30	-0.28	True
Climate	SIF+Climate	0.02	0.01	0.03	True
Climate	SIF+EVI	-0.03	-0.04	-0.02	True
Climate	SIF+EVI+Climate	0.06	0.05	0.07	True
EVI	EVI+Climate	0.18	0.17	0.19	True
EVI	SIF	-0.17	-0.18	-0.16	True
EVI	SIF+Climate	0.14	0.13	0.15	True
EVI	SIF+EVI	0.09	0.08	0.10	True
EVI	SIF+EVI+Climate	0.18	0.17	0.19	True
EVI+Climate	SIF	-0.35	-0.36	-0.34	True
EVI+Climate	SIF+Climate	-0.03	-0.05	-0.02	True
EVI+Climate	SIF+EVI	-0.08	-0.09	-0.07	True
EVI+Climate	SIF+EVI+Climate	0.00	-0.01	0.02	False
SIF	SIF+Climate	0.31	0.30	0.32	True
SIF	SIF+EVI	0.26	0.25	0.27	True
SIF	SIF+EVI+Climate	0.35	0.34	0.36	True
SIF+Climate	SIF+EVI	-0.05	-0.06	-0.04	True
SIF+Climate	SIF+EVI+Climate	0.04	0.03	0.05	True

SIF+EVI	SIF+EVI+Climate	0.09	0.08	0.10	True
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^a The ANOVA result for the difference among all the models: F= 1991.90, P < 0.001.

Table S4. Summary of R² values of 100 experiments of different models. Q1, Q2, and Q3 represent the first, second, and third quantiles separately; IQR is the interquartile range; min = Q1-1.5*IQR, max = Q3+1.5*IQR; range = max-min.

corn	min	Q1	Q2	Q3	max	IQR	range
SIF	0.37	0.41	0.42	0.44	0.48	0.03	0.11
EVI	0.70	0.73	0.74	0.75	0.78	0.02	0.08
SIF+EVI	0.70	0.74	0.77	0.78	0.82	0.04	0.13
Climate	0.63	0.75	0.77	0.79	0.86	0.04	0.23
SIF+Climate	0.66	0.78	0.81	0.82	0.86	0.04	0.20
EVI+Climate	0.78	0.85	0.86	0.87	0.90	0.02	0.12
SIF+EVI+Climate	0.77	0.84	0.85	0.86	0.89	0.03	0.12

soybean	min	Q1	Q2	Q3	max	IQR	range
SIF	0.45	0.51	0.53	0.55	0.59	0.04	0.14
EVI	0.62	0.67	0.71	0.73	0.76	0.05	0.14
SIF+EVI	0.65	0.78	0.80	0.81	0.85	0.04	0.20
Climate	0.70	0.80	0.82	0.84	0.88	0.03	0.18
SIF+Climate	0.75	0.82	0.83	0.85	0.88	0.04	0.13
EVI+Climate	0.78	0.86	0.87	0.88	0.91	0.02	0.13
SIF+EVI+Climate	0.80	0.86	0.87	0.89	0.90	0.02	0.10

Table S5. P values of correlation relationships between variables and crop yield. The shaded area represent the predictors that were included in DNN models. Bold numbers are the model predictors of which the p values are less than 0.05.

corn	SIFmean	SIFmax	EVImean	EVImax	P	T	VPD
3	0.19	0.23	0.52	0.04	0.03	0.24	0.00
4	0.35	0.53	0.26	0.21	0.01	0.36	0.00
5	0.41	0.10	0.98	0.20	0.00	0.67	0.13
6	0.00	0.00	0.00	0.00	0.00	0.98	0.05
7	0.00	0.00	0.00	0.00	0.00	0.00	0.05
8	0.00	0.00	0.00	0.00	0.00	0.00	0.05
9	0.00	0.00	0.22	0.00	0.00	0.22	0.03
10	0.23	0.06	0.00	0.00	0.00	0.73	0.04

soybean	SIFmean	SIFmax	EVImean	EVImax	P	T	VPD
3	0.33	0.45	0.33	0.40	0.00	0.00	0.16
4	0.68	0.90	0.58	0.67	0.00	0.00	0.00
5	0.83	0.42	0.46	0.91	0.00	0.00	0.13
6	0.00	0.00	0.00	0.00	0.00	0.00	0.05
7	0.00	0.00	0.00	0.00	0.00	0.90	0.05
8	0.00	0.00	0.00	0.00	0.00	0.83	0.05
9	0.00	0.00	0.80	0.27	0.00	0.00	0.00
10	0.03	0.00	0.03	0.01	0.00	0.00	0.00



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