

Supplementary Information for “Characterizing land use/land cover from multi-sensor time series from the perspective of land surface phenology” by Lan H. Nguyen (lan.nguyen@sdstate.edu) & Geoffrey M. Henebry (henebryg@msu.edu)

Table S1. Reclassification of CDL land use/land cover classes for Robert County, SD.

CDL Code	CDL Class	New Class	CDL Code	CDL Class	New Class
0	Background	NoData	53	Peas	Other Crops
1	Corn	Corn	59	Sod/Grass Seed	Grassland
4	Sorghum	Other Crops	61	Fallow/Idle Cropland	Grassland
5	Soybeans	Soybean	111	Open Water	Water
6	Sunflower	Other Crops	121	Developed/Open Space	Barren/Dev.
21	Barley	Other Crops	122	Developed/Low Intensity	Barren/Dev.
22	Durum Wheat	Wheat	123	Developed/Med Intensity	Barren/Dev.
23	Spring Wheat	Wheat	124	Developed/High Intensity	Barren/Dev.
24	Winter Wheat	Wheat	131	Barren	Barren/Dev.
27	Rye	Other Crops	141	Deciduous Forest	Forest
28	Oats	Other Crops	142	Evergreen Forest	Forest
29	Millet	Other Crops	143	Mixed Forest	Forest
36	Alfalfa	Alfalfa	176	Grassland/Pasture	Grassland
37	Other Hay/Non Alfalfa	Grassland	190	Woody Wetlands	Wetland
39	Buckwheat	Other Crops	195	Herbaceous Wetlands	Wetland
41	Sugarbeets	Other Crops	205	Triticale	Wheat
42	Dry Beans	Other Crops	241	Dbl Crop Corn/Soybeans	Other Crops
44	Other Crops	Other Crops			

Table S2. Overall accuracy (in percent), kappa for location and quantity of 2017 RFC models summarized by sample pools, sample sizes, and input sets. A particular scenario (current row) was compared to a scenario right above it (row above) using the nonparametric Mann–Whitney U test and the TOST equivalence test. The null hypothesis of the U test is that a random accuracy metric of the first scenario (row above) will be less than a random accuracy metric of the second scenario (current row). Significance level of the U test are indicated by ***, ** and * for p-values of less than 0.001, 0.01, 0.05, respectively, and NS for “not significant”. Results of the TOST equivalence test are highlighted in light blue for “not equivalent” and light yellow for “equivalent”.

	Scenario	ARD				HLS			
		OA	k_L	k_Q		OA	k_L	k_Q	
Sample Pool	C1S	89.0		0.909	0.913	87.9		0.898	0.908
	C1M	90.2	***	0.921	*** 0.920	89.6	***	0.915	*** 0.917
	C2S	90.5	**	0.923	NS 0.924	90.3	***	0.922	*** 0.920
	C2M	91.6	***	0.933	*** 0.929	91.3	***	0.932	*** 0.927
Sample Size	P01	87.1		0.907	0.871	86.3		0.899	0.866
	P05	90.2	***	0.918	*** 0.926	89.7	***	0.914	*** 0.923
	P15	91.7	***	0.928	*** 0.942	91.3	***	0.924	*** 0.939
	P25	92.2	***	0.932	** 0.947	91.9	***	0.929	*** 0.944
Input Set	CxQ	88.2		0.892	0.923	87.9		0.887	0.924
	HPLM	89.1	***	0.901	*** 0.926	88.8	***	0.901	*** 0.921
	SPL	89.9	***	0.931	*** 0.899	88.6	NS	0.919	*** 0.890
	CMB	94.1	***	0.961	*** 0.938	93.8	***	0.958	*** 0.936

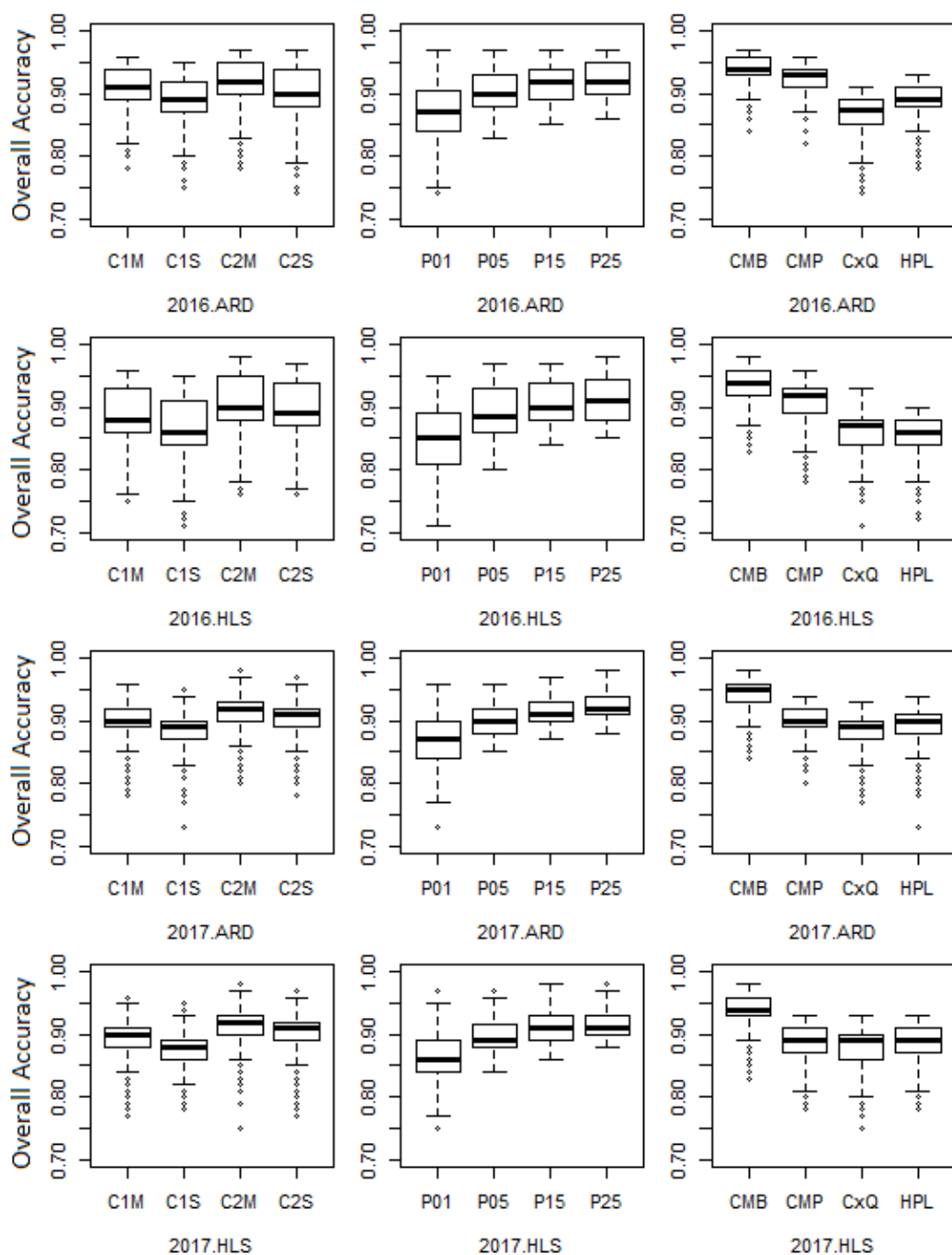


Figure S1. Boxplots of overall accuracy (OA) metrics from different scenarios for each combination of year and data source.

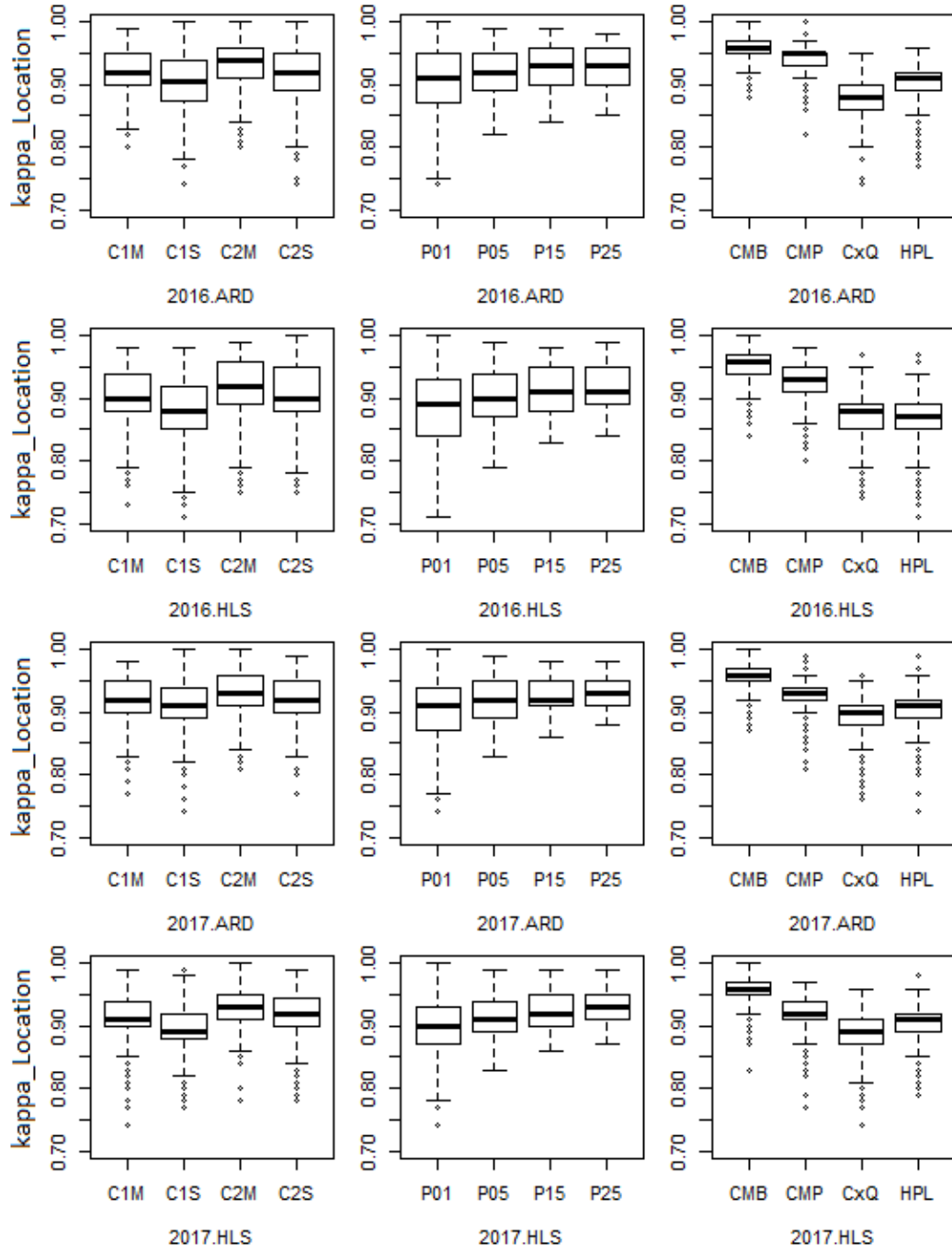


Figure S2. Boxplots of kappa_Location (k_L) metrics from different scenarios for each combination of year and data source.

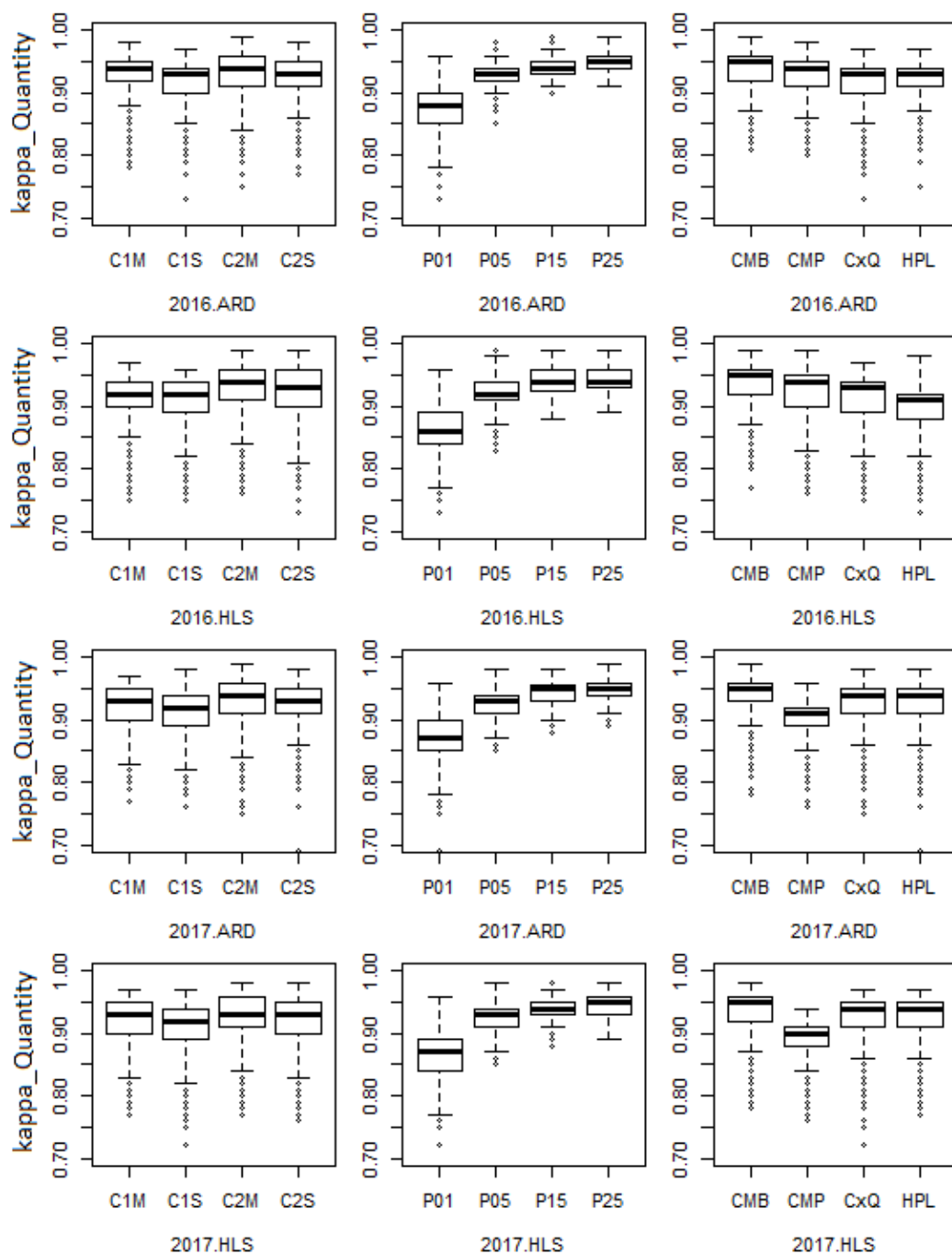


Figure S3. Boxplots of kappa_Quantity (k_Q) metrics from different scenarios for each combination of year and data source.

Table S3. Significance level of the nonparametric Mann–Whitney U test for pairwise OA, k_L and k_Q comparison. ***, ** and * indicate p-values of less than 0.001, 0.01, 0.05, respectively. NS means “not significant”. Area colored in light yellow (upper right) show results computed on ARD-RFC models, and light blue (lower left) show results from HLS-RFC models. The null hypothesis is that a random accuracy metric of the first scenario will be less than a random accuracy metric of the second scenario (or the first population has smaller values than the second population). For the test on ARD-RFC models, the first scenario is selected from the table’s row, and second scenarios is selected from the column. Scenario selection for the test on HLS-RFC models is in the opposite direction (column → row). For example, the significance level for comparison of k_L between C1M and C2M are “NS” and “***” for ARD- and HLS-RFC models, respectively.

		Overall Accuracy				Kappa for Location				Kappa for Quantity			
		C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M
2016	C1S	-	***	***	***	-	***	***	***	-	***	***	***
	C1M	***	-	NS	***	***	-	NS	***	***	-	NS	***
	C2S	***	***	-	***	***	**	-	***	***	***	-	***
	C2M	***	***	***	-	***	***	***	-	***	***	***	-
2017	C1S	-	***	***	***	-	***	***	***	-	***	***	***
	C1M	***	-	**	***	***	-	NS	***	***	-	**	***
	C2S	***	***	-	***	***	***	-	***	***	**	-	***
	C2M	***	***	***	-	***	***	***	-	***	***	***	-
		P01	P05	P15	P25	P01	P05	P15	P25	P01	P05	P15	P25
2016	P01	-	***	***	***	-	***	***	***	-	***	***	***
	P05	***	-	***	***	***	-	***	***	***	-	***	***
	P15	***	***	-	***	***	***	-	*	***	***	-	***
	P25	***	***	***	-	***	***	**	-	***	***	***	-
2017	P01	-	***	***	***	-	***	***	***	-	***	***	***
	P05	***	-	***	***	***	-	***	***	***	-	***	***
	P15	***	***	-	***	***	***	-	**	***	***	-	***
	P25	***	***	***	-	***	***	***	-	***	***	***	-
		CxQ	HPLM	SPL	CMB	CxQ	HPLM	SPL	CMB	CxQ	HPLM	SPL	CMB
2016	CxQ	-	***	***	***	-	***	***	***	-	NS	***	***
	HPLM	NS	-	***	***	NS	-	***	***	NS	-	***	***
	SPL	***	***	-	***	***	***	-	***	***	***	-	***
	CMB	***	***	***	-	***	***	***	-	***	***	***	-
2017	CxQ	-	***	***	***	-	***	***	***	-	NS	NS	***
	HPLM	***	-	***	***	***	-	***	***	NS	-	NS	***
	SPL	***	NS	-	***	***	***	-	***	NS	NS	-	***
	CMB	***	***	***	-	***	***	***	-	***	***	***	-

Table S4. TOST equivalence tests. “E” indicates that the two sets of accuracy metrics are equivalent or differences between those are within a user-defined range of Cohen’s d. “x” that the two sets of accuracy metric are not equivalent. Area colored in light yellow (upper right) and light blue (lower left) show results computed on ARD- and HLS-RFC models, respectively. For the test on ARD-RFC models, the first scenario is selected from the table’s row, and second scenarios is selected from the column. Scenario selection for the test on HLS-RFC models is on the opposite direction (column → row). For example, the results of equivalence test between C1S and C2S are “x” and “E” for ARD- and HLS-RFC models, respectively.

		Overall Accuracy				Kappa for Allocation				Kappa for Quantity			
		C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M
2016	C1S	-	x	x	x	-	x	x	x	-	E	E	x
	C1M	x	-	E	E	x	-	E	E	E	-	E	E
	C2S	x	E	-	x	x	E	-	E	x	E	-	E
	C2M	x	x	E	-	x	x	E	-	x	E	E	-
2017	C1S	-	x	x	x	-	E	x	x	-	E	E	x
	C1M	x	-	E	x	x	-	E	x	E	-	E	E
	C2S	x	E	-	E	x	E	-	E	E	E	-	E
	C2M	x	x	E	-	x	x	E	-	x	E	E	-
		P01	P05	P15	P25	P01	P05	P15	P25	P01	P05	P15	P25
2016	P01	-	x	x	x	-	E	x	x	-	x	x	x
	P05	x	-	x	x	x	-	E	E	x	-	x	x
	P15	x	x	-	E	x	E	-	E	x	x	-	x
	P25	x	x	E	-	x	x	E	-	x	x	E	-
2017	P01	-	x	x	x	-	E	x	x	-	x	x	x
	P05	x	-	x	x	x	-	E	x	x	-	x	x
	P15	x	x	-	E	x	E	-	E	x	x	-	E
	P25	x	x	E	-	x	x	E	-	x	x	E	-
		CxQ	HPLM	SPL	CMP	CxQ	HPLM	SPL	CMP	CxQ	HPLM	SPL	CMP
2016	CxQ	-	x	x	x	-	x	x	x	-	E	E	x
	HPLM	E	-	x	x	E	-	x	x	E	-	E	x
	SPL	x	x	-	x	x	x	-	x	E	x	-	E
	CMP	x	x	x	-	x	x	x	-	x	x	E	-
2017	CxQ	-	E	x	x	-	x	x	x	-	E	x	x
	HPLM	E	-	E	x	x	-	x	x	E	-	x	E
	SPL	E	E	-	x	x	x	-	x	x	x	-	x
	CMP	x	x	x	-	x	x	x	-	E	x	x	-

Table S5. Accuracy assessment of RFC models summarized by sample pool scenarios.

Metrics	2016								2017							
	ARD				HLS				ARD				HLS			
	C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M
PA_Corn	94.6	95.3	95.3	95.7	91.2	92.1	92.3	92.6	93.9	94.5	94.7	95.4	91.8	93.2	93.4	94.0
PA_Wheat	75.4	77.9	78.3	78.6	70.2	72.9	73.1	74.4	59.0	63.4	63.8	66.3	57.0	62.5	61.3	63.3
PA_Alalfa	73.5	80.3	79.1	82.6	69.3	77.1	77.2	79.9	74.2	80.2	78.2	82.7	71.2	80.1	76.4	82.8
PA_Soybean	95.4	96.1	96.1	96.6	90.3	91.1	91.8	92.1	95.3	95.7	95.7	96.2	93.6	94.6	94.6	95.1
PA_Other Crops	11.2	35.4	19.7	50.9	15.3	43.9	25.2	55.0	15.6	21.2	22.3	29.7	15.6	25.1	21.2	33.2
PA_Water	97.4	98.4	98.2	98.3	96.2	97.9	97.8	98.2	96.4	97.1	97.6	97.5	95.4	96.8	97.3	97.3
PA_Barren/Dev.	55.1	58.6	59.7	60.9	47.4	47.2	54.3	56.1	54.3	55.6	57.6	58.5	48.6	44.6	50.8	51.9
PA_Forest	87.7	89.5	93.1	94.0	84.3	87.8	93.1	94.5	83.3	84.2	87.5	88.3	81.6	84.4	88.9	90.8
PA_Grassland	93.0	94.1	93.8	94.9	93.6	95.0	95.1	96.1	93.4	94.2	94.2	94.9	94.0	94.7	95.2	95.8
PA_Wetland	66.8	74.4	72.1	79.2	73.9	80.4	82.0	87.7	67.7	72.8	74.6	78.9	69.9	76.7	79.8	84.2
UA_Corn	94.8	95.5	95.4	95.9	89.8	90.6	91.3	91.5	94.7	95.3	95.3	95.9	91.8	93.0	93.1	93.4
UA_Wheat	84.4	89.3	87.6	90.2	82.0	86.5	85.5	89.1	80.6	84.2	83.1	86.1	80.4	82.8	83.3	84.3
UA_Alalfa	83.7	88.8	87.7	91.2	79.8	87.2	86.6	89.6	87.9	91.0	90.9	92.9	85.0	91.5	90.0	93.6
UA_Soybean	93.6	94.7	94.7	95.2	90.4	91.6	91.7	92.2	92.7	93.1	93.4	93.9	91.5	92.6	92.9	93.4
UA_Other Crops	35.8	61.3	49.9	70.2	46.6	67.0	54.0	71.0	41.0	43.8	50.3	52.8	40.4	47.6	45.0	55.1
UA_Water	97.5	97.6	97.7	97.6	96.3	96.2	96.4	96.9	96.4	96.0	96.2	96.5	95.9	96.0	95.8	96.3
UA_Barren/Dev.	77.0	80.2	77.1	79.0	72.4	74.1	74.0	75.9	77.0	78.5	77.7	78.6	75.7	73.4	76.2	77.1
UA_Forest	86.7	88.5	90.4	91.1	84.8	87.5	90.6	92.4	80.7	82.9	85.4	86.6	82.4	84.3	88.3	89.7
UA_Grassland	84.9	87.2	86.4	88.6	85.6	87.6	88.9	90.4	85.5	87.4	88.0	89.3	85.3	87.5	88.6	90.0
UA_Wetland	74.2	79.5	80.1	84.4	76.3	81.6	83.4	87.5	73.9	77.7	78.8	82.1	75.1	79.5	81.6	84.9
OA	88.8	90.7	90.4	91.8	86.8	88.7	89.4	90.7	89.0	90.2	90.5	91.6	87.9	89.6	90.3	91.3
k_L	0.904	0.923	0.921	0.935	0.884	0.904	0.909	0.922	0.909	0.921	0.923	0.933	0.898	0.915	0.922	0.932
k_Q	0.917	0.926	0.924	0.932	0.906	0.914	0.921	0.927	0.913	0.920	0.924	0.929	0.908	0.917	0.920	0.927

Table S6. The nonparametric Mann–Whitney U test and the TOST equivalence test for the (P01 versus P25 RFC models) and (C1S versus C2M RFC models) comparison. The null hypothesis is that a random accuracy metric of the first scenario will be less than a random accuracy metric of the second scenario (or the first population has smaller values than the second population). Significance level of the U test are indicated by ***, ** and * for p-values of less than 0.001, 0.01, 0.05, respectively, and NS for “not significant”. Results of the TOST equivalence test are highlighted in light blue for “not equivalent” and light yellow for “equivalent”.

Metrics	P01 versus P25				C1S versus C2M			
	2016		2017		2016		2017	
	ARD	HLS	ARD	HLS	ARD	HLS	ARD	HLS
PA_Corn	***	***	***	***	***	***	***	***
PA_Wheat	***	***	***	***	***	***	***	***
PA_Alalfa	***	***	***	***	***	***	***	***
PA_Soybean	***	***	***	***	***	***	***	***
PA_Other Crops	***	***	***	***	***	***	***	***
PA_Water	NS	NS	NS	NS	***	***	***	***
PA_Barren/Dev.	***	***	***	***	***	***	***	**
PA_Forest	NS	NS	NS	NS	***	***	***	***
PA_Grassland	***	***	***	***	***	***	***	***
PA_Wetland	***	***	***	***	***	***	***	***
UA_Corn	***	***	***	***	***	***	***	***
UA_Wheat	NS	NS	NS	NS	***	***	***	***
UA_Alalfa	NS	NS	NS	NS	***	***	***	***
UA_Soybean	***	***	***	***	***	***	***	***
UA_Other Crops	***	***	***	***	***	***	***	***
UA_Water	NS	NS	NS	NS	***	***	*	***
UA_Barren/Dev.	**	***	*	**	***	***	**	**
UA_Forest	NS	NS	NS	NS	***	***	***	***
UA_Grassland	***	***	***	***	***	***	***	***
UA_Wetland	***	***	***	***	***	***	***	***
OA	***	***	***	***	***	***	***	***
k_L	***	***	***	***	***	***	***	***
k_Q	***	***	***	***	***	***	***	***

Table S7. Accuracy assessment of RFC models summarized by sample size scenarios.

Metrics	2016								2017							
	ARD				HLS				ARD				HLS			
	P01	P05	P15	P25	P01	P05	P15	P25	P01	P05	P15	P25	P01	P05	P15	P25
PA_Corn	94.1	94.8	95.8	96.2	89.8	91.8	93.1	93.6	93.3	94.4	95.2	95.6	90.7	93.2	94.1	94.5
PA_Wheat	58.1	79.2	85.3	87.4	49.6	73.7	82.4	85.0	45.8	64.0	70.3	72.5	44.4	62.4	67.4	69.9
PA_Alalfa	61.9	79.9	85.7	87.9	55.0	77.9	84.2	86.5	56.8	81.4	87.5	89.7	55.0	80.0	87.1	88.5
PA_Soybean	94.6	96.2	96.6	96.8	88.5	91.6	92.5	92.8	93.3	95.8	96.7	97.1	92.1	94.4	95.5	96.0
PA_Other Crops	7.1	21.8	40.0	48.3	9.1	27.2	47.3	55.9	0.0	16.6	31.6	40.6	0.0	18.8	33.2	43.0
PA_Water	97.5	98.1	98.3	98.5	97.0	97.4	97.9	97.9	96.3	96.9	97.6	97.8	96.0	96.3	97.1	97.4
PA_Barren/Dev.	49.6	58.2	62.4	64.2	38.8	50.7	56.5	58.9	47.0	55.8	60.8	62.5	36.1	48.0	54.8	57.0
PA_Forest	86.6	91.4	92.8	93.4	84.5	90.3	92.0	92.8	77.9	86.7	89.0	89.7	79.1	87.0	89.4	90.3
PA_Grassland	92.6	94.0	94.5	94.7	93.7	94.9	95.5	95.7	93.1	94.1	94.5	94.9	93.9	94.8	95.4	95.6
PA_Wetland	64.8	73.7	76.4	77.6	74.5	81.3	83.6	84.5	64.4	73.8	77.3	78.6	69.2	78.3	81.0	82.2
UA_Corn	93.0	95.6	96.4	96.7	87.4	91.1	92.2	92.6	92.8	95.4	96.4	96.7	89.9	92.8	94.0	94.6
UA_Wheat	84.5	87.5	89.4	90.2	80.6	85.6	88.0	89.0	70.5	84.9	88.7	89.8	67.6	82.0	89.9	91.3
UA_Alalfa	75.2	91.2	92.1	92.9	69.9	90.1	91.1	92.0	81.3	92.8	94.0	94.6	79.1	92.4	93.9	94.7
UA_Soybean	92.2	94.3	95.6	96.1	87.9	91.3	93.0	93.6	91.0	93.0	94.3	94.8	89.8	92.6	93.8	94.3
UA_Other Crops	7.0	48.0	77.6	84.7	9.0	55.8	84.3	89.5	0.0	27.1	73.9	86.9	0.0	29.4	73.2	85.5
UA_Water	97.4	97.6	97.7	97.8	96.1	96.2	96.6	96.8	94.9	96.2	96.9	97.1	95.0	96.0	96.4	96.5
UA_Barren/Dev.	72.5	78.3	80.7	81.7	66.0	73.7	77.9	78.9	70.5	78.1	81.0	82.2	67.1	75.7	79.1	80.4
UA_Forest	85.3	89.0	90.8	91.6	84.7	88.2	90.8	91.6	80.0	83.4	85.6	86.7	82.1	85.8	87.9	88.9
UA_Grassland	83.7	86.9	87.9	88.5	84.8	88.1	89.5	90.1	84.5	87.6	88.8	89.3	84.8	87.8	89.2	89.7
UA_Wetland	72.8	79.6	82.4	83.5	74.6	82.7	85.2	86.3	72.2	77.7	80.7	81.9	73.8	79.9	83.1	84.2
OA	87.1	90.5	91.8	92.3	84.8	89.0	90.6	91.2	87.1	90.2	91.7	92.2	86.3	89.7	91.3	91.9
k_L	0.906	0.919	0.927	0.931	0.883	0.903	0.914	0.919	0.907	0.918	0.928	0.932	0.899	0.914	0.924	0.929
k_Q	0.877	0.929	0.944	0.949	0.862	0.922	0.940	0.945	0.871	0.926	0.942	0.947	0.866	0.923	0.939	0.944

Table S8. Producer’s and user’s accuracies in percent (%) of 2017 RFC models summarized by sets of input variables. A particular scenario (current column) was compared to a scenario on the left (left column) using the nonparametric Mann–Whitney U test and the TOST equivalence tests. The null hypothesis of the U test is that a random accuracy metric of the first scenario (left column) will be less than a random accuracy metric of the second scenario (current column). Significance level of the U test are indicated by ***, ** and * for p-values of less than 0.001, 0.01, 0.05, respectively, and NS for “not significant”. Results of the TOST equivalence test are highlighted in light blue for “not equivalent” and light yellow for “equivalent”.

Metrics	ARD								HLS							
	CxQ	HPLM	SPL		CMB		CxQ	HPLM	SPL		CMB		CxQ	HPLM	SPL	
PA_Corn	92.2	95.2	***	94.0	NS	97.1	***	91.5	94.2	***	90.9	NS	95.9	***	92.2	95.2
PA_Wheat	81.2	77.7	NS	14.7	NS	79.0	***	74.9	81.1	***	8.1	NS	80.0	***	81.2	77.7
PA_Alalfa	71.5	86.2	***	75.9	NS	81.9	***	70.4	88.8	***	69.9	NS	81.4	***	71.5	86.2
PA_Soybean	94.5	92.7	NS	97.0	***	98.8	***	92.5	93.0	**	94.6	***	97.8	***	94.5	92.7
PA_Other Crops	34.6	25.4	NS	5.9	NS	22.9	***	31.7	29.3	NS	4.6	NS	29.4	***	34.6	25.4
PA_Water	93.8	96.1	***	99.4	***	99.4	NS	93.1	94.7	***	99.5	***	99.3	NS	93.8	96.1
PA_Barren/Dev.	43.4	43.5	NS	69.5	***	69.7	NS	40.1	35.1	NS	59.3	***	61.4	**	43.4	43.5
PA_Forest	73.7	78.7	***	94.8	***	96.1	***	75.2	80.7	***	94.4	***	95.4	***	73.7	78.7
PA_Grassland	92.1	93.2	***	95.0	***	96.3	***	93.0	93.2	*	96.2	***	97.3	***	92.1	93.2
PA_Wetland	71.0	71.4	NS	72.7	***	78.9	***	77.7	72.2	NS	77.5	***	83.2	***	71.0	71.4
UA_Corn	95.1	94.7	NS	93.3	NS	98.2	***	92.8	94.4	***	87.2	NS	97.0	***	95.1	94.7
UA_Wheat	89.8	90.7	NS	61.4	NS	92.1	***	88.7	91.1	***	57.5	NS	93.6	***	89.8	90.7
UA_Alalfa	87.3	91.4	NS	89.7	*	94.4	***	86.7	93.3	NS	86.0	NS	94.1	***	87.3	91.4
UA_Soybean	92.9	94.2	***	89.4	NS	96.6	***	92.2	93.7	***	88.3	NS	96.1	***	92.9	94.2
UA_Other Crops	55.0	51.5	NS	28.4	NS	52.9	***	52.8	53.7	NS	24.7	NS	56.9	***	55.0	51.5
UA_Water	92.3	93.2	***	99.9	***	99.8	NS	91.2	93.3	***	99.8	***	99.6	NS	92.3	93.2
UA_Barren/Dev.	62.2	63.8	***	93.3	***	92.4	NS	59.2	63.0	***	91.8	***	88.3	NS	62.2	63.8
UA_Forest	72.0	77.1	***	93.1	***	93.4	NS	76.7	82.8	***	91.3	***	94.0	***	72.0	77.1
UA_Grassland	86.2	86.4	NS	88.1	***	89.6	***	87.6	85.2	NS	88.8	***	89.9	***	86.2	86.4
UA_Wetland	70.7	74.5	***	81.0	***	86.3	***	73.0	74.5	***	85.5	***	87.9	***	70.7	74.5

Table S9. The nonparametric Mann–Whitney U test and the TOST equivalence test for the comparison between phenometrically-based and combined RFC models. The null hypothesis of the U test is that a random accuracy metric of the first scenario (left column) will be less than a random accuracy metric of the second scenario (current column). Significance level of the U test are indicated by ***, ** and * for p-values of less than 0.001, 0.01, 0.05, respectively, and NS for “not significant”. Results of the TOST equivalence test are highlighted in light blue for “not equivalent” and light yellow for “equivalent”.

Metrics	CxQ versus SPL				HPLM versus SPL			
	2016		2017		2016		2017	
	ARD	HLS	ARD	HLS	ARD	HLS	ARD	HLS
PA_Corn	***	***	***	NS	***	***	NS	NS
PA_Wheat	NS	NS	NS	NS	NS	NS	NS	NS
PA_Alalfa	***	***	NS	NS	NS	NS	NS	NS
PA_Soybean	***	***	***	***	***	***	***	***
PA_Other Crops	NS	NS	NS	NS	NS	NS	NS	NS
PA_Water	***	***	***	***	***	***	***	***
PA_Barren/Dev.	***	***	***	***	***	***	***	***
PA_Forest	***	***	***	***	***	***	***	***
PA_Grassland	***	***	***	***	***	***	***	***
PA_Wetland	***	***	***	NS	***	***	***	***
UA_Corn	***	***	NS	NS	***	***	NS	NS
UA_Wheat	NS	NS	NS	NS	NS	NS	NS	NS
UA_Alalfa	***	**	NS	NS	***	***	*	NS
UA_Soybean	***	***	NS	NS	NS	NS	NS	NS
UA_Other Crops	NS	***	NS	NS	NS	***	NS	NS
UA_Water	***	***	***	***	***	***	***	***
UA_Barren/Dev.	***	***	***	***	***	***	***	***
UA_Forest	***	***	***	***	***	***	***	***
UA_Grassland	***	***	***	***	***	***	***	***
UA_Wetland	***	***	***	***	***	***	***	***
OA	***	***	***	***	***	***	***	NS
k_L	***	***	***	***	***	***	***	***
k_Q	***	***	NS	NS	***	***	NS	NS

Table S10. The nonparametric Mann–Whitney U test and the TOST equivalence test for the comparison between phenometrically-based and combined RFC models. The null hypothesis of the U test is that a random accuracy metric of the first scenario (left column) will be less than a random accuracy metric of the second scenario (current column). Significance level of the U test are indicated by ***, ** and * for p-values of less than 0.001, 0.01, 0.05, respectively, and NS for “not significant”. Results of the TOST equivalence test are highlighted in light blue for “not equivalent” and light yellow for “equivalent”.

Metrics	CxQ versus HPLM				SPL versus CMB			
	2016		2017		2016		2017	
	ARD	HLS	ARD	HLS	ARD	HLS	ARD	HLS
PA_Corn	***	***	***	***	***	***	***	***
PA_Wheat	NS	NS	NS	***	***	***	***	***
PA_Alalfa	***	***	***	***	***	***	***	***
PA_Soybean	***	***	NS	**	***	***	***	***
PA_Other Crops	NS	NS	NS	NS	***	**	***	***
PA_Water	***	***	***	***	NS	NS	NS	NS
PA_Barren/Dev.	***	***	NS	NS	NS	NS	NS	**
PA_Forest	***	***	***	***	*	NS	***	***
PA_Grassland	***	NS	***	*	***	***	***	***
PA_Wetland	NS	NS	NS	NS	***	***	***	***
UA_Corn	***	***	NS	***	***	***	***	***
UA_Wheat	*	NS	NS	***	***	***	***	***
UA_Alalfa	NS	NS	NS	NS	***	***	***	***
UA_Soybean	***	***	***	***	***	***	***	***
UA_Other Crops	***	NS	NS	NS	***	*	***	***
UA_Water	***	***	***	***	NS	NS	NS	NS
UA_Barren/Dev.	***	***	***	***	NS	NS	NS	NS
UA_Forest	***	***	***	***	**	***	NS	***
UA_Grassland	***	NS	NS	NS	NS	***	***	***
UA_Wetland	NS	NS	***	***	***	***	***	***
OA	***	NS	***	***	***	***	***	***
k_L	***	NS	***	***	***	***	***	***
k_Q	NS	NS	NS	NS	***	***	***	***

Table S11. The nonparametric Mann–Whitney U test and the TOST equivalence test for the comparison between phenometrically-based and combined RFC models. The null hypothesis of the U test is that a random accuracy metric of the first scenario (left column) will be less than a random accuracy metric of the second scenario (current column). Significance level of the U test are indicated by ***, ** and * for p-values of less than 0.001, 0.01, 0.05, respectively, and NS for “not significant”. Results of the TOST equivalence test are highlighted in light blue for “not equivalent” and light yellow for “equivalent”.

Metrics	CxQ versus CMB				HPLM versus CMB			
	2016		2017		2016		2017	
	ARD	HLS	ARD	HLS	ARD	HLS	ARD	HLS
PA_Corn	***	***	***	***	***	***	***	***
PA_Wheat	***	***	**	***	***	***	***	**
PA_Alalfa	***	***	***	***	NS	NS	NS	NS
PA_Soybean	***	***	***	***	***	***	***	***
PA_Other Crops	NS	NS	NS	NS	NS	NS	NS	NS
PA_Water	***	***	***	***	***	***	***	***
PA_Barren/Dev.	***	***	***	***	***	***	***	***
PA_Forest	***	***	***	***	***	***	***	***
PA_Grassland	***	***	***	***	***	***	***	***
PA_Wetland	***	***	***	***	***	***	***	***
UA_Corn	***	***	***	***	***	***	***	***
UA_Wheat	***	***	***	***	***	***	***	***
UA_Alalfa	***	***	***	***	***	***	***	***
UA_Soybean	***	***	***	***	***	***	***	***
UA_Other Crops	***	***	NS	***	***	***	*	***
UA_Water	***	***	***	***	***	***	***	***
UA_Barren/Dev.	***	***	***	***	***	***	***	***
UA_Forest	***	***	***	***	***	***	***	***
UA_Grassland	***	***	***	***	***	***	***	***
UA_Wetland	***	***	***	***	***	***	***	***
OA	***	***	***	***	***	***	***	***
k_L	***	***	***	***	***	***	***	***
k_Q	***	***	***	***	***	***	***	***

Table S12. Pixel-based comparison between 2016 predicted land cover maps and the CDL summarized by sample pools. Areal units are km².

Land Cover	Info.	CDL	ARD				HLS			
			C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M
Corn	Area	662	643	639	643	639	668	666	670	670
	UA		92.7	92.9	92.6	92.7	86.2	86.0	85.9	85.8
	PA		90.2	89.6	90.0	89.5	87.0	86.6	87.0	86.8
Wheat	Area	103	100	104	103	105	97	101	102	105
	UA		82.5	80.2	80.9	79.7	79.5	77.1	76.1	74.1
	PA		80.6	81.5	81.2	81.6	75.1	75.6	75.7	76.1
Alfalfa	Area	45	30	32	31	33	31	33	31	35
	UA		76.5	74.0	75.1	72.6	69.5	66.1	68.3	64.4
	PA		51.0	52.5	52.1	53.7	47.2	48.8	47.6	49.5
Soybean	Area	746	730	721	721	714	712	696	696	688
	UA		90.9	91.4	91.4	91.8	87.3	88.2	88.2	88.7
	PA		88.9	88.4	88.3	87.9	83.3	82.2	82.3	81.7
Other Crops	Area	13	0	0	0	0	0	1	1	1
	UA		0.0	0.0	0.0	0.0	0.0	0.0	89.1	0.0
	PA		0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Water	Area	154	127	123	121	119	131	126	125	125
	UA		96.7	97.2	97.4	97.5	93.0	94.1	94.4	94.5
	PA		79.7	77.7	76.3	75.6	79.2	77.1	76.6	76.5
Barren/Dev.	Area	131	51	50	47	51	47	53	48	58
	UA		51.0	48.6	49.5	46.6	41.6	36.3	38.7	33.1
	PA		20.1	18.6	17.8	18.4	15.0	14.8	14.2	14.7
Forest	Area	64	62	64	64	67	63	65	63	65
	UA		68.3	67.1	66.7	64.8	62.9	61.6	62.2	61.0
	PA		65.7	66.2	66.1	67.2	61.1	61.8	60.6	61.3
Grassland	Area	761	923	918	924	916	933	939	944	955
	UA		74.6	74.6	74.5	74.7	72.9	72.5	71.9	71.2
	PA		90.5	90.1	90.4	90.0	89.5	89.5	89.2	89.5
Wetland	Area	262	274	290	288	295	259	262	262	240
	UA		48.0	45.5	45.3	43.9	51.9	50.3	50.4	51.2
	PA		50.0	50.3	49.7	49.5	51.3	50.2	50.3	46.9
OA			80.8	80.4	80.4	80.1	77.9	77.4	77.4	77.0
k_L			0.820	0.819	0.819	0.817	0.782	0.777	0.779	0.780
k_Q			0.878	0.868	0.867	0.863	0.875	0.871	0.866	0.857

Table S13. Pixel-based comparison between 2017 predicted land cover maps and the CDL summarized by sample pools. Areal units are km².

Land Cover	Info.	CDL	ARD				HLS			
			C1S	C1M	C2S	C2M	C1S	C1M	C2S	C2M
Corn	Area	685	607	597	601	595	616	602	606	602
	UA		95.4	95.8	95.8	95.9	92.0	92.9	92.6	92.7
	PA		84.6	83.6	84.1	83.3	82.8	81.6	81.9	81.5
Wheat	Area	87	63	65	65	65	63	63	63	63
	UA		88.0	87.7	87.6	87.7	87.6	87.5	87.5	87.4
	PA		64.3	65.6	65.4	65.8	63.8	63.9	63.9	63.8
Alfalfa	Area	50	37	36	39	38	36	36	38	38
	UA		83.8	82.2	81.0	80.2	80.1	79.1	78.4	76.8
	PA		61.4	60.1	64.0	61.1	57.9	56.6	59.6	57.8
Soybean	Area	803	817	806	811	803	820	811	812	808
	UA		89.7	90.3	90.1	90.5	87.1	87.6	87.5	87.7
	PA		91.3	90.7	90.9	90.4	89.0	88.5	88.5	88.2
Other Crops	Area	8	0	0	1	0	0	0	0	0
	UA		0.0	0.0	99.0	0.0	0.0	0.0	0.0	0.0
	PA		0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0
Water	Area	153	121	120	116	115	125	122	119	119
	UA		97.0	97.2	97.8	97.8	93.7	94.2	95.1	95.1
	PA		76.7	75.9	73.8	73.7	76.2	75.2	73.8	73.6
Barren/Dev.	Area	111	46	50	48	53	44	49	46	51
	UA		52.4	50.0	51.3	48.7	46.2	43.4	43.3	40.7
	PA		21.6	22.5	22.5	23.5	18.3	19.1	18.1	18.8
Forest	Area	63	66	69	72	73	60	63	62	61
	UA		63.6	62.4	60.7	59.5	63.2	61.6	61.8	62.0
	PA		67.0	68.2	69.2	69.4	60.3	61.6	60.6	60.0
Grassland	Area	744	920	914	911	905	938	937	946	949
	UA		73.6	73.7	73.7	73.8	72.0	71.8	71.3	70.9
	PA		91.1	90.6	90.3	89.8	90.7	90.4	90.6	90.5
Wetland	Area	237	263	283	277	293	239	258	248	250
	UA		48.7	45.6	46.1	43.8	50.5	47.0	47.5	46.3
	PA		54.0	54.5	54.0	54.3	50.9	51.3	49.9	48.9
OA			81.2	80.8	80.8	80.4	79.5	79.0	78.9	78.6
k_L			0.841	0.838	0.838	0.833	0.814	0.811	0.810	0.806
k_Q			0.852	0.846	0.848	0.843	0.858	0.851	0.851	0.851

Table S14. Pixel-based comparison between 2016 predicted land cover maps and the CDL summarized by sample sizes. Areal units are km².

Land Cover	Info.	CDL	ARD				HLS			
			P01	P05	P15	P25	P01	P05	P15	P25
Corn	Area	662	651	638	640	642	690	661	661	662
	UA		91.0	92.8	93.0	93.1	82.9	86.3	87.0	87.1
	PA		89.5	89.5	90.0	90.3	86.5	86.3	86.9	87.2
Wheat	Area	103	75	103	111	112	66	100	111	113
	UA		87.6	79.0	77.4	77.4	86.3	75.0	72.8	73.1
	PA		64.4	79.6	83.7	84.6	55.7	73.0	79.1	80.6
Alfalfa	Area	45	24	31	34	34	23	32	35	35
	UA		82.2	74.1	72.9	72.9	75.8	66.3	64.6	64.9
	PA		43.3	51.9	54.4	55.8	39.5	47.8	50.0	50.9
Soybean	Area	746	724	722	721	722	683	702	704	706
	UA		90.0	91.2	91.6	91.8	86.7	87.6	88.2	88.5
	PA		87.3	88.2	88.6	88.8	79.4	82.4	83.3	83.7
Other Crops	Area	13	0	0	0	0	0	0	1	1
	UA		0.0	0.0	0.0	0.0	0.0	0.0	87.9	83.4
	PA		0.0	0.0	0.0	0.0	0.0	0.0	4.2	6.4
Water	Area	154	119	121	123	125	125	126	127	128
	UA		97.3	97.4	97.3	97.1	93.9	94.3	94.2	94.1
	PA		75.6	76.6	77.6	78.6	76.2	76.9	77.7	78.0
Barren/Dev.	Area	131	46	49	53	55	44	50	52	54
	UA		44.8	49.8	50.7	51.1	32.8	37.2	40.2	40.7
	PA		15.7	18.7	20.7	21.6	11.0	14.2	16.0	16.7
Forest	Area	64	64	65	64	64	62	65	64	64
	UA		65.8	66.0	66.9	67.3	61.8	61.0	62.0	62.3
	PA		65.1	66.6	66.8	66.8	59.0	61.8	61.9	61.9
Grassland	Area	761	966	917	903	897	988	949	930	925
	UA		71.9	74.6	75.5	76.0	69.6	71.7	72.9	73.3
	PA		91.3	90.0	89.7	89.7	90.4	89.5	89.2	89.2
Wetland	Area	262	272	294	291	289	260	256	255	253
	UA		43.5	44.7	46.4	47.3	47.8	50.5	51.9	52.7
	PA		45.0	50.0	51.5	52.1	47.4	49.2	50.4	50.8
OA			78.9	80.1	80.7	81.0	75.5	77.2	78.0	78.3
k_L			0.808	0.817	0.821	0.823	0.776	0.776	0.783	0.786
k_Q			0.853	0.866	0.872	0.876	0.828	0.868	0.874	0.876

Table S15. Pixel-based comparison between 2017 predicted land cover maps and the CDL summarized by sample sizes. Areal units are km².

Land Cover	Info.	CDL	ARD				HLS			
			P01	P05	P15	P25	P01	P05	P15	P25
Corn	Area	685	598	596	604	608	603	604	609	612
	UA		94.4	95.6	95.8	95.8	91.2	92.5	92.7	92.8
	PA		82.4	83.3	84.5	85.0	80.3	81.5	82.5	82.9
Wheat	Area	87	41	62	69	70	44	62	67	69
	UA		92.3	87.3	86.8	86.6	91.4	87.3	86.2	85.9
	PA		43.6	62.7	68.7	70.4	46.0	62.2	66.9	68.3
Alfalfa	Area	50	24	37	41	41	25	37	39	40
	UA		90.1	80.1	80.1	80.5	86.6	76.5	77.0	77.1
	PA		42.6	59.7	65.3	66.6	43.4	56.8	59.8	61.3
Soybean	Area	803	825	810	806	806	823	810	812	813
	UA		88.0	89.9	90.7	90.8	85.6	87.5	87.8	88.0
	PA		90.4	90.6	90.9	91.1	87.7	88.2	88.8	89.0
Other Crops	Area	8	0	0	0	1	0	0	0	0
	UA		0.0	0.0	0.0	99.4	0.0	0.0	0.0	0.0
	PA		0.0	0.0	0.0	7.2	0.0	0.0	0.0	0.0
Water	Area	153	115	117	119	120	119	120	121	122
	UA		97.7	97.6	97.4	97.2	94.8	94.7	94.5	94.3
	PA		73.5	74.4	75.4	76.0	73.4	74.2	74.9	75.4
Barren/Dev.	Area	111	43	51	53	54	35	49	53	54
	UA		49.4	49.9	51.5	51.7	44.0	42.6	43.6	44.2
	PA		19.2	22.8	24.8	25.5	14.1	18.8	20.8	21.5
Forest	Area	63	67	72	71	71	58	64	63	62
	UA		61.7	60.5	61.4	62.0	62.8	60.9	62.0	62.8
	PA		65.6	69.0	69.6	69.7	58.1	61.5	61.7	61.4
Grassland	Area	744	964	909	896	894	989	937	928	923
	UA		70.8	73.8	74.7	74.9	69.1	71.6	72.3	72.6
	PA		91.7	90.1	89.9	90.0	91.9	90.2	90.1	90.1
Wetland	Area	237	264	287	282	276	245	259	249	247
	UA		43.2	44.5	46.7	48.1	44.1	46.2	49.1	50.2
	PA		48.3	54.0	55.7	56.0	45.6	50.5	51.6	52.2
OA			79.0	80.4	81.3	81.6	77.3	78.7	79.4	79.7
k_L			0.830	0.834	0.838	0.839	0.805	0.806	0.810	0.812
k_Q			0.821	0.842	0.857	0.863	0.823	0.851	0.862	0.866

Table S16. Pixel-based comparison between 2017 predicted land cover maps and the CDL summarized by sets of input variables. Areal units are km².

Land Cover	Info.	CDL	ARD				HLS			
			CxQ	HPLM	SPL	CMB	CxQ	HPLM	SPL	CMB
Corn	Area	685	597	625	602	604	613	627	641	608
	UA		91.6	90.7	90.9	95.1	88.3	88.4	82.7	92.1
	PA		79.9	82.8	80.0	83.9	79.1	81.0	77.4	81.8
Wheat	Area	87	64	66	14	70	59	70	2	67
	UA		81.7	84.5	55.2	83.4	80.9	81.6	76.7	84.7
	PA		60.0	64.5	8.7	67.1	55.4	66.2	1.8	65.8
Alfalfa	Area	50	38	42	39	36	34	43	35	36
	UA		81.2	73.6	69.0	82.1	80.2	70.6	67.9	78.8
	PA		62.3	61.3	53.7	59.0	54.9	61.0	47.7	56.9
Soybean	Area	803	765	755	912	816	769	762	910	812
	UA		88.2	89.5	80.2	89.6	85.7	87.1	77.7	87.4
	PA		84.1	84.0	91.1	91.0	82.1	82.6	88.1	88.4
Other Crops	Area	8	0	0	0	0	0	0	0	0
	UA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water	Area	153	118	121	119	116	119	115	124	120
	UA		91.6	91.7	97.5	97.8	89.1	92.3	94.1	94.9
	PA		70.5	72.1	75.5	74.2	69.5	69.0	76.3	74.5
Barren/Dev.	Area	111	71	64	53	57	65	46	46	61
	UA		25.1	31.1	55.5	52.9	24.8	28.4	50.6	43.6
	PA		16.1	17.9	26.6	27.1	14.7	11.9	21.1	24.1
Forest	Area	63	56	73	76	74	37	65	73	67
	UA		46.2	48.1	60.5	61.0	55.7	49.7	55.0	60.1
	PA		40.9	55.7	73.0	72.1	32.4	51.1	63.9	64.1
Grassland	Area	744	833	886	906	915	866	927	931	938
	UA		76.1	73.8	72.5	73.3	73.9	70.4	70.4	71.5
	PA		85.2	87.9	88.2	90.1	86.0	87.6	88.1	90.1
Wetland	Area	237	399	310	220	253	377	286	178	231
	UA		33.7	38.5	51.0	49.9	35.4	38.8	56.1	49.8
	PA		56.7	50.4	47.4	53.3	56.4	46.9	42.1	48.6
OA			75.7	77.1	77.3	80.9	74.6	75.5	74.8	78.9
k_L			0.778	0.787	0.810	0.834	0.766	0.767	0.780	0.805
k_Q			0.831	0.845	0.818	0.857	0.826	0.842	0.811	0.861

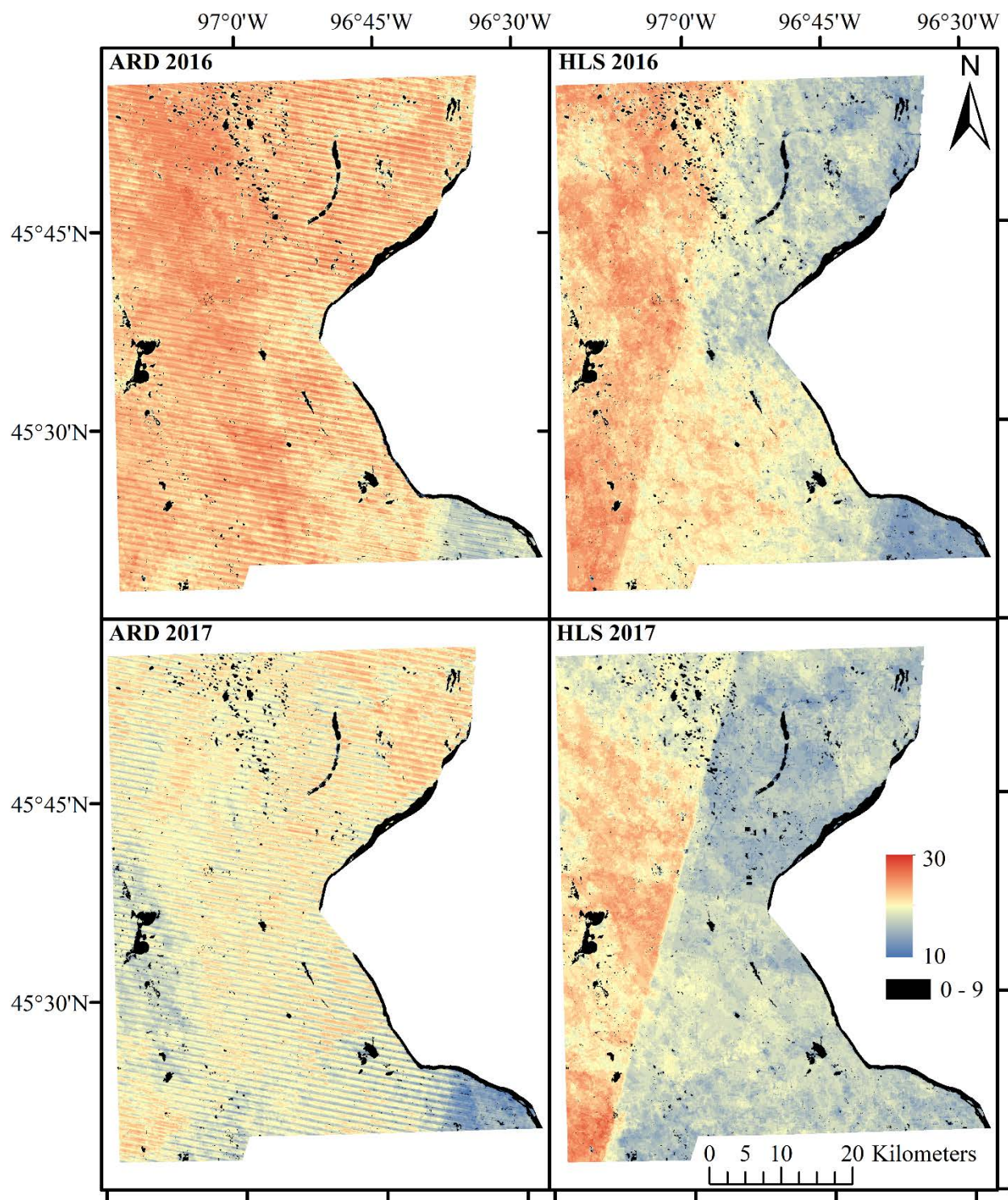


Figure S4. Number of valid observations (cloud/snow/shadow-free, $EVI_2 > 0$) over the study area for each combination of year and data source.