Supplementary materials

Sentinel-1 time series applications over agricultural fields: proposal, evaluation and comparison of different methodologies

María Arias Cuenca

November 2022

Supervisors:

Jesús Álvarez Mozos

Miguel Ángel Campo Bescós

Universidad Pública de Navarra
Nafarroako Unibertsitate Publikoa

https://doi.org/10.48035/Tesis/2454/45156

Supplementary materials
Chapter 3

Crop classification based on Sentinel-1 time series

1. Ground truth data for the different regions of Navarre.

In this section, the ground truth data of the different regions is presented. The number of agricultural fields and their area in the declarations and inspections datasets is showed.

Table S1. Ground truth data. Number of agricultural fields and their area in the declarations and inspections. a) Region 1

Region 1						
Crop	Declarations			Inspections		
	Nº of fields	Area (ha)	Mean area (ha)	Nº of fields	Area (ha)	Mean area (ha)
Alfalfa	6	8	1.36	9	8	0.92
Aasparagus	0	0	0.00	0	0	0.00
Barley	93	171	1.83	3	1	0.39
Corn	313	618	1.98	120	216	1.80
Fallow	27	38	1.42	8	14	1.72
Grasslands	8336	14263	1.71	141	189	1.34
Legumes	68	146	2.15	2	5	2.51
Oats	89	180	2.02	14	15	1.05
other crops	49	253	5.17	19	70	3.68
Permanent crops	16	16	1.02	29	29	0.99
Rapeseed	16	30	1.85	7	4	0.63
Rice	0	0	0.00	0	0	0.00
Sunflower	18	23	1.30	4	1	0.33
Wheat	224	526	2.35	12	28	2.32
Total	9255	16274	1.76	368	580	1.58

Table S1 (cont.). Ground truth data. Number of agricultural fields and their area in the declarations and inspections. b) Region 2

Region 2						
Crop	Declarations			Inspections		
	Nº of fields	Area (ha)	Mean area (ha)	Nº of fields	Area (ha)	Mean area (ha)
Alfalfa	0	0	0.00	2	1	0.39
Aasparagus	0	0	0.00	0	0	0.00
Barley	1169	3304	2.83	90	175	1.94
Corn	24	63	2.64	6	9	1.56
Fallow	330	561	1.70	25	42	1.67
Grasslands	6359	19497	3.07	144	310	2.15
Legumes	416	1401	3.37	43	76	1.76
Oats	503	1336	2.66	39	64	1.63
other crops	108	3062	28.35	24	67	2.81
Permanent crops	37	76	2.06	0	0	0.00
Rapeseed	114	352	3.09	9	20	2.20
Rice	0	0	0.00	0	0	0.00
Sunflower	113	299	2.65	6	13	2.08
Wheat	2242	6883	3.07	162	350	2.16
Total	11415	36835	3.23	550	1126	2.05

Table S1 (cont.). Ground truth data. Number of agricultural fields and their area in the declarations and inspections. c) Region 3

Region 3						
Crop	Declarations			Inspections		
	Nº of fields	Area (ha)	Mean area (ha)	Nº of fields	Area (ha)	Mean area (ha)
Alfalfa	8	16	2.03	8	6	0.71155
Aasparagus	30	63	2.09	4	11	2.80
Barley	2080	5583	2.68	169	370	2.19
Corn	190	482	2.54	20	43	2.14
Fallow	227	415	1.83	28	35	1.24
Grasslands	1333	5213	3.91	9	25	2.73
Legumes	636	1822	2.86	103	258	2.50
Oats	721	1874	2.60	48	106	2.20
other crops	46	119	2.58	11	51	4.68
Permanent crops	183	562	3.07	48	73	1.52
Rapeseed	375	1018	2.72	44	132	3.01
Rice	0	0	0.00	0	0	0.00
Sunflower	176	562	3.19	29	63	2.17
Wheat	3279	9162	2.79	203	434	2.14
Total	9284	26890	2.90	724	1606	2.22

Table S1 (cont.). Ground truth data. Number of agricultural fields and their area in the declarations and inspections. d) Region 4

Region 4						
Crop	Declarations			Inspections		
	Nº of fields	Area (ha)	Mean area (ha)	Nº of fields	Area (ha)	Mean area (ha)
Alfalfa	33	38	1.16	9	7	0.81
Aasparagus	175	327	1.87	18	27	1.50
Barley	6057	12391	2.05	606	971	1.60
Corn	41	103	2.51	1	0	0.31
Fallow	1017	1489	1.46	151	136	0.90
Grasslands	3161	7397	2.34	53	79	1.50
Legumes	1220	3091	2.53	195	332	1.70
Oats	793	1659	2.09	99	151	1.52
other crops	197	403	2.05	48	206	4.30
Permanent crops	1583	2343	1.48	413	364	0.88
Rapeseed	365	859	2.35	69	149	2.16
Rice	0	0	0.00	0	0	0.00
Sunflower	85	229	2.70	5	8	1.67
Wheat	5792	12833	2.22	641	1034	1.61
Total	20519	43163	2.10	2308	3465	1.50

Table S1 (cont.). Ground truth data. Number of agricultural fields and their area in the declarations and inspections. e) Region 5

Region 5						
Crop	Declarations			Inspections		
	Nº of fields	Area (ha)	Mean area (ha)	Nº of fields	Area (ha)	Mean area (ha)
Alfalfa	158	305	1.93	23	47	2.03
Aasparagus	39	79	2.04	3	5	1.64
Barley	4272	10054	2.35	697	1189	1.71
Corn	791	3204	4.05	146	570	3.91
Fallow	1078	2100	1.95	323	468	1.45
Grasslands	2582	11285	4.37	78	73	0.94
Legumes	701	2268	3.24	219	319	1.46
Oats	385	1016	2.64	40	105	2.63
other crops	281	815	2.90	62	351	5.66
Permanent crops	1327	2194	1.65	290	353	1.22
Rapeseed	331	846	2.56	96	233	2.42
Rice	0	0	0.00	0	0	0.00
Sunflower	243	859	3.53	25	127	5.08
Wheat	4310	10550	2.45	709	1157	1.63
Total	16498	45578	2.76	2711	4998	1.84

Table S1 (cont.). Ground truth data. Number of agricultural fields and their area in the declarations and inspections. f) Region 6

Region 6						
Crop	Declarations			Inspections		
	Nº of fields	Area (ha)	Mean area (ha)	Nº of fields	Area (ha)	Mean area (ha)
Alfalfa	562	1042	1.85	41	37	0.91
Aasparagus	132	310	2.35	24	21	0.86
Barley	5717	15907	2.78	359	1042	2.90
Corn	1436	4038	2.81	135	431	3.19
Fallow	2161	5022	2.32	259	616	2.38
Grasslands	2027	8379	4.13	35	69	1.98
Legumes	553	2110	3.81	40	135	3.39
Oats	417	1154	2.77	26	32	1.23
other crops	971	2479	2.55	76	323	4.25
Permanent crops	3063	4937	1.61	426	588	1.38
Rapeseed	49	213	4.35	1	6	6.09
Rice	338	563	1.67	27	30	1.10
Sunflower	39	226	5.80	10	64	6.36
Wheat	2471	6800	2.75	279	471	1.69
Total	19936	53181	2.67	1738	3866	2.22

Table S1 (cont.). Ground truth data. Number of agricultural fields and their area in the declarations and inspections. g) Region 7

Region 7						
Crop	Declarations			Inspections		
	Nº of fields	Area (ha)	Mean area (ha)	Nº of fields	Area (ha)	Mean area (ha)
Alfalfa	980	1656	1.69	305	376	1.23
Aasparagus	54	81	1.50	12	20	1.68
Barley	2323	5017	2.16	781	1300	1.66
Corn	1019	2185	2.14	161	413	2.56
Fallow	7049	13721	1.95	2295	3475	1.51
Grasslands	1809	15196	8.40	52	78	1.50
Legumes	182	707	3.88	35	86	2.46
Oats	61	117	1.91	2	6	3.01
other crops	1373	2963	2.16	598	851	1.42
Permanent crops	2120	3213	1.52	804	783	0.97
Rapeseed	0	0	0.00	0	0	0.00
Rice	299	852	2.85	45	95	2.11
Sunflower	125	182	1.46	23	35	1.53
Wheat	2404	6748	2.81	876	1742	1.99
Total	19798	52636	2.66	5989	9259	1.55

2. Temporal signatures of crops in the regions of Navarre

In this section, the median temporal signatures of crops for VH, VV and VH/VV in the different regions are displayed. The three relative orbits are represented in different colors: 103ASC (red), 8DESC (blue) and 81DESC (green). The interquartile range is represented for all the time series as a colored shadow. The horizontal axes represent the period of study, from September 1, 2015 (day 0) to December 30, 2016 (day 487).

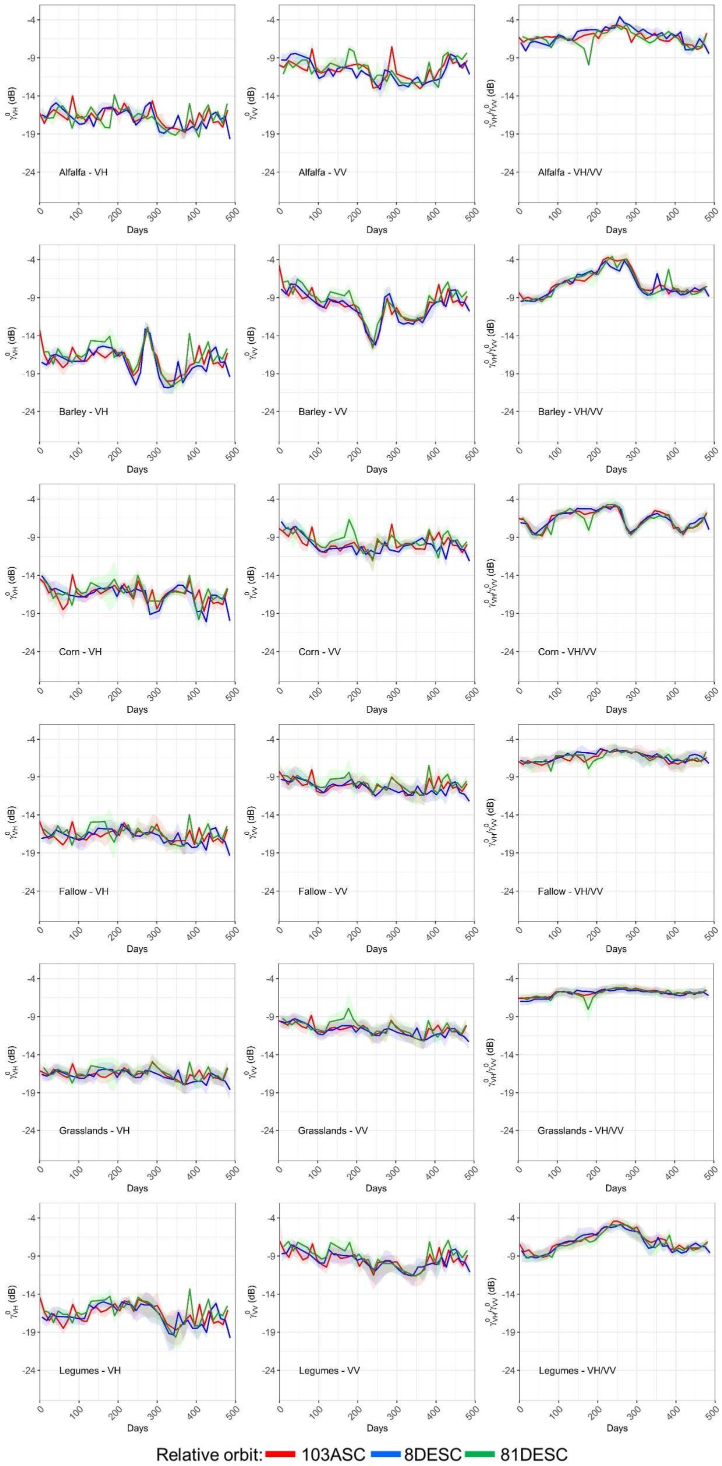


Figure S1. Median temporal signatures of crops for VH, VV and VH/VV. a) Region 1.

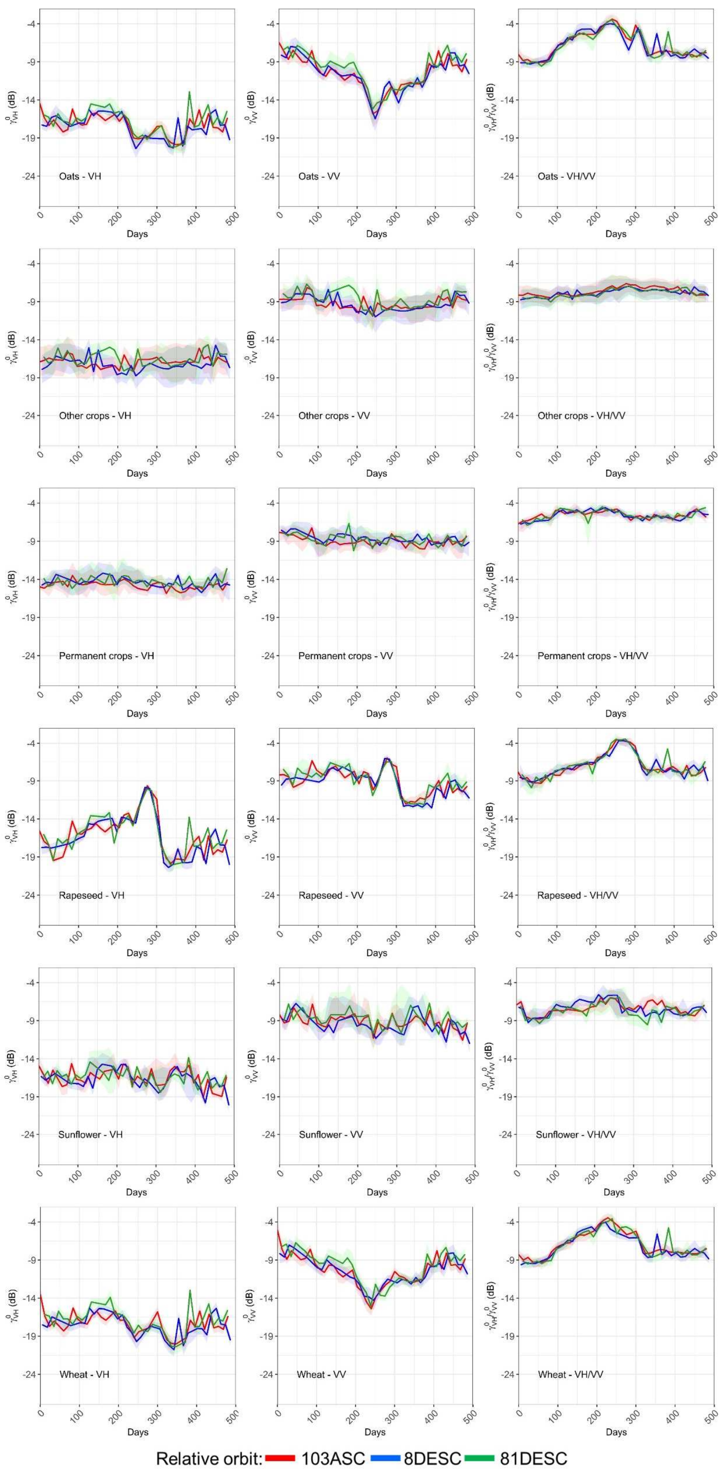


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. a) Region 1.

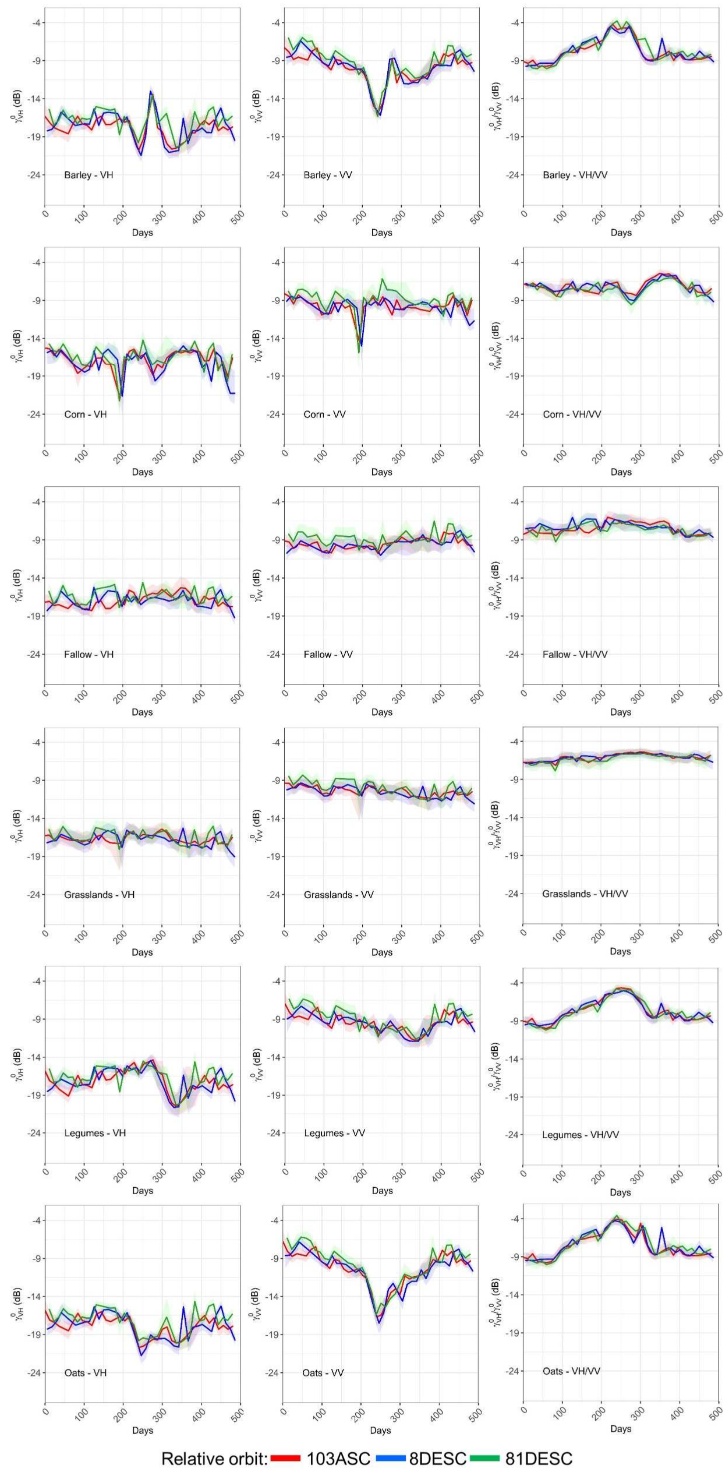


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. b) Region 2.

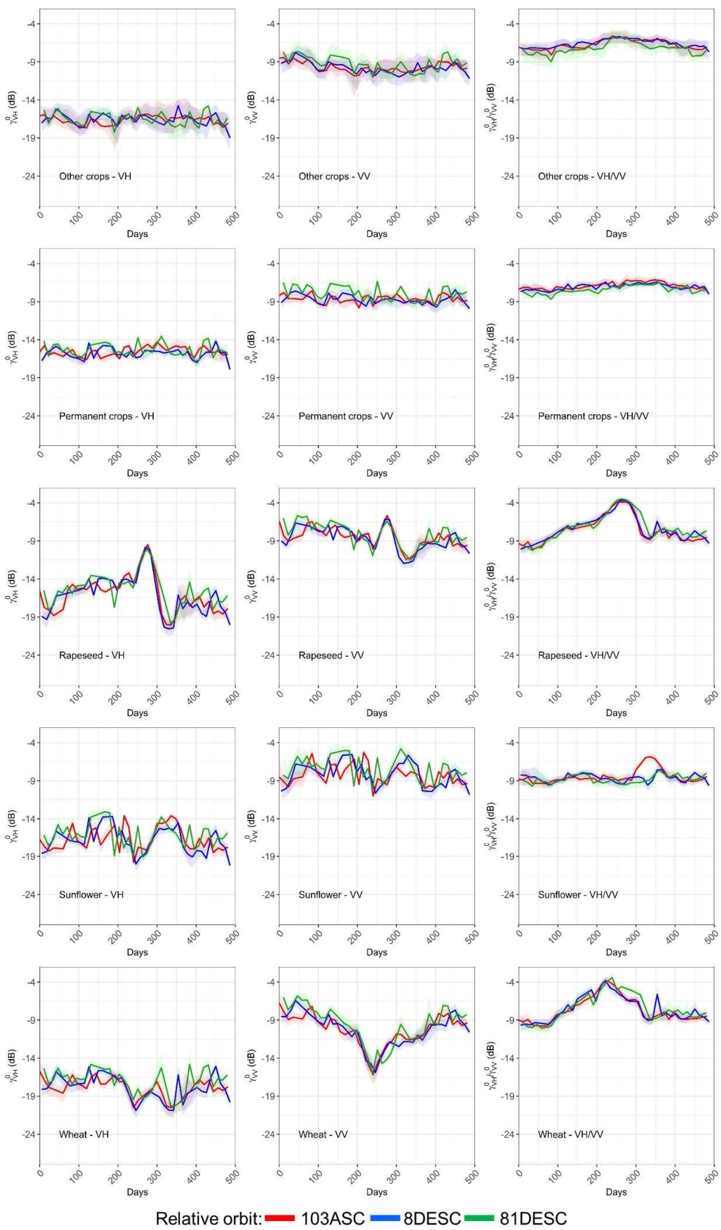


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. b) Region 2.

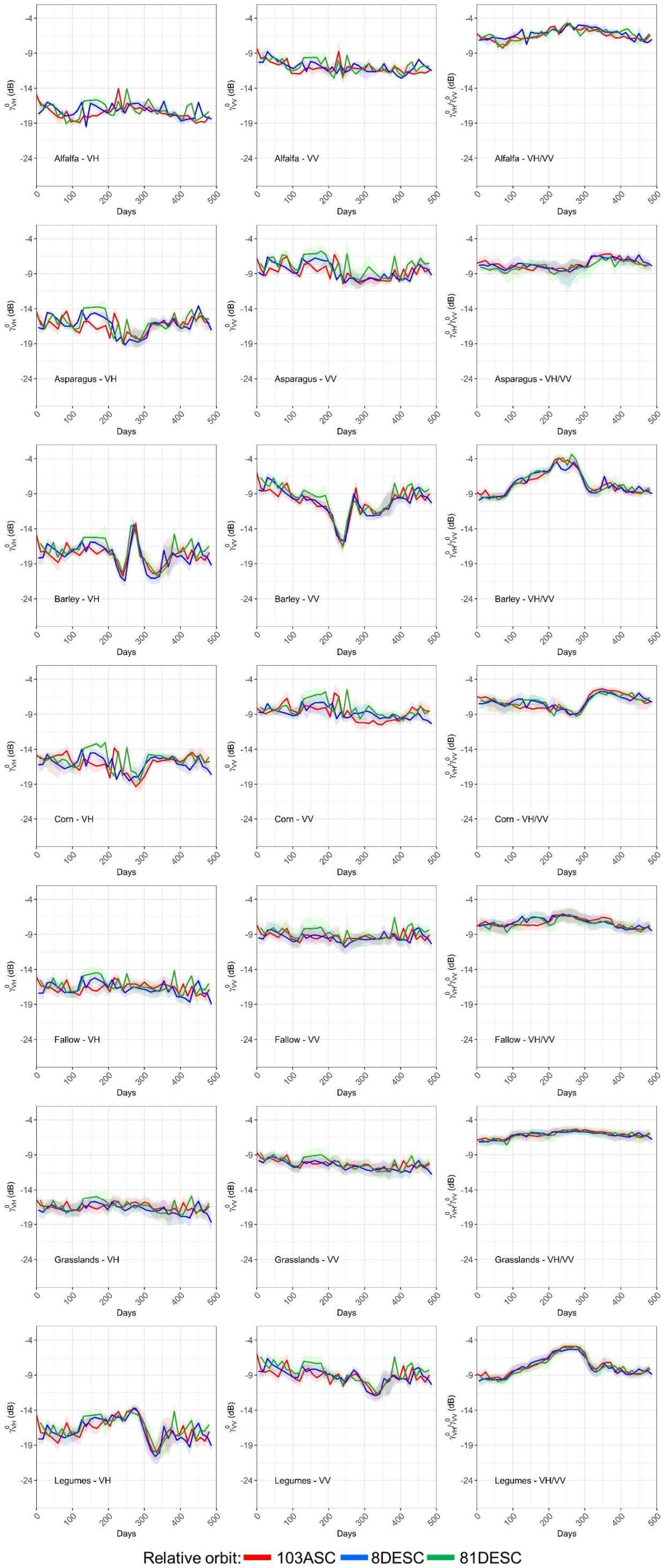


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. c) Region 3.

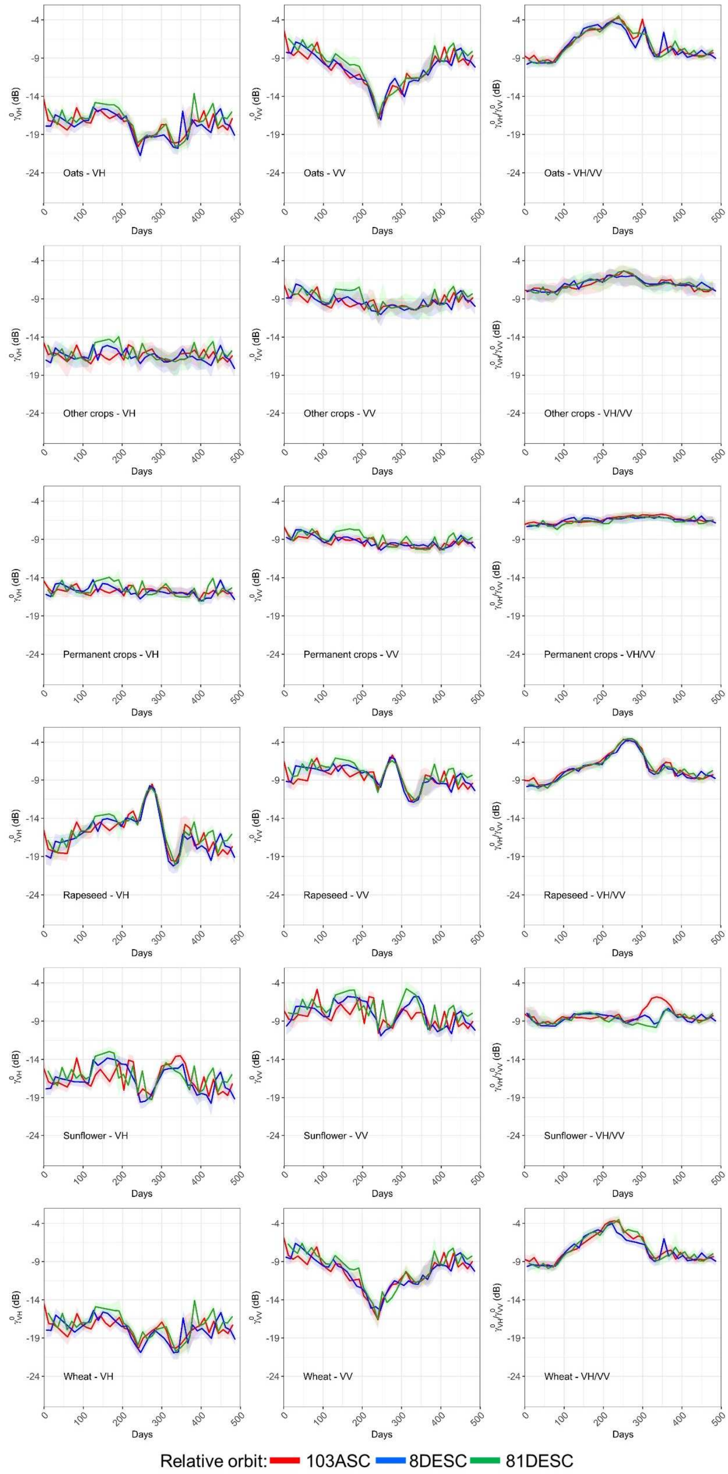


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. c) Region 3.

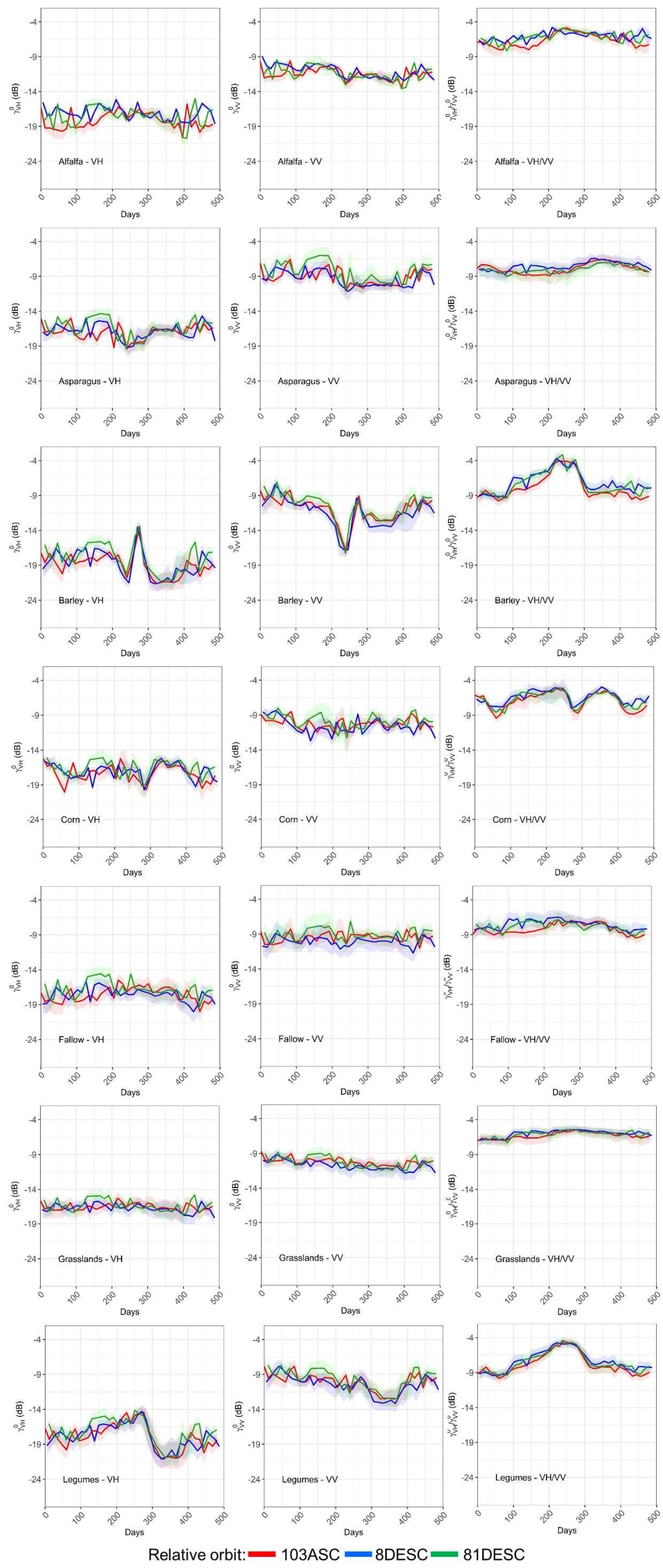


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. d) Region 4.

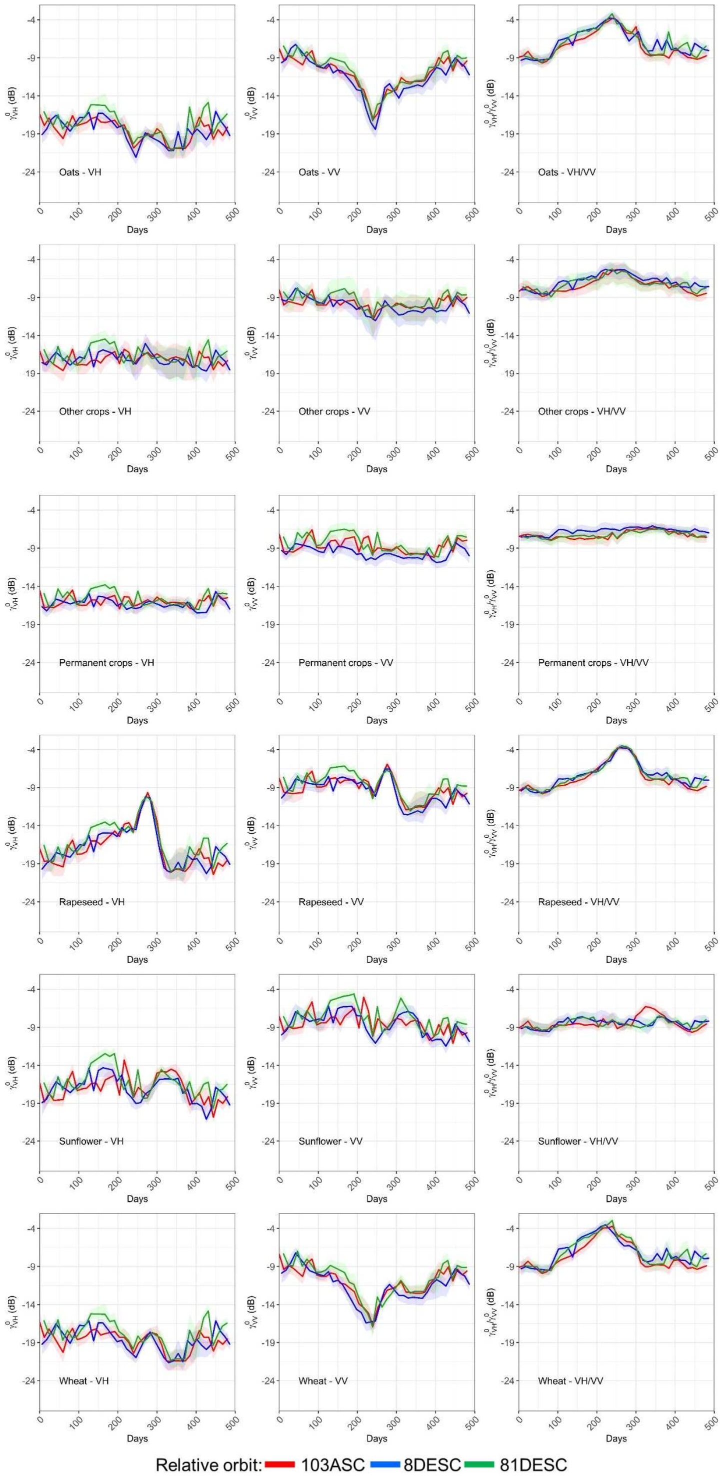


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. d) Region 4.

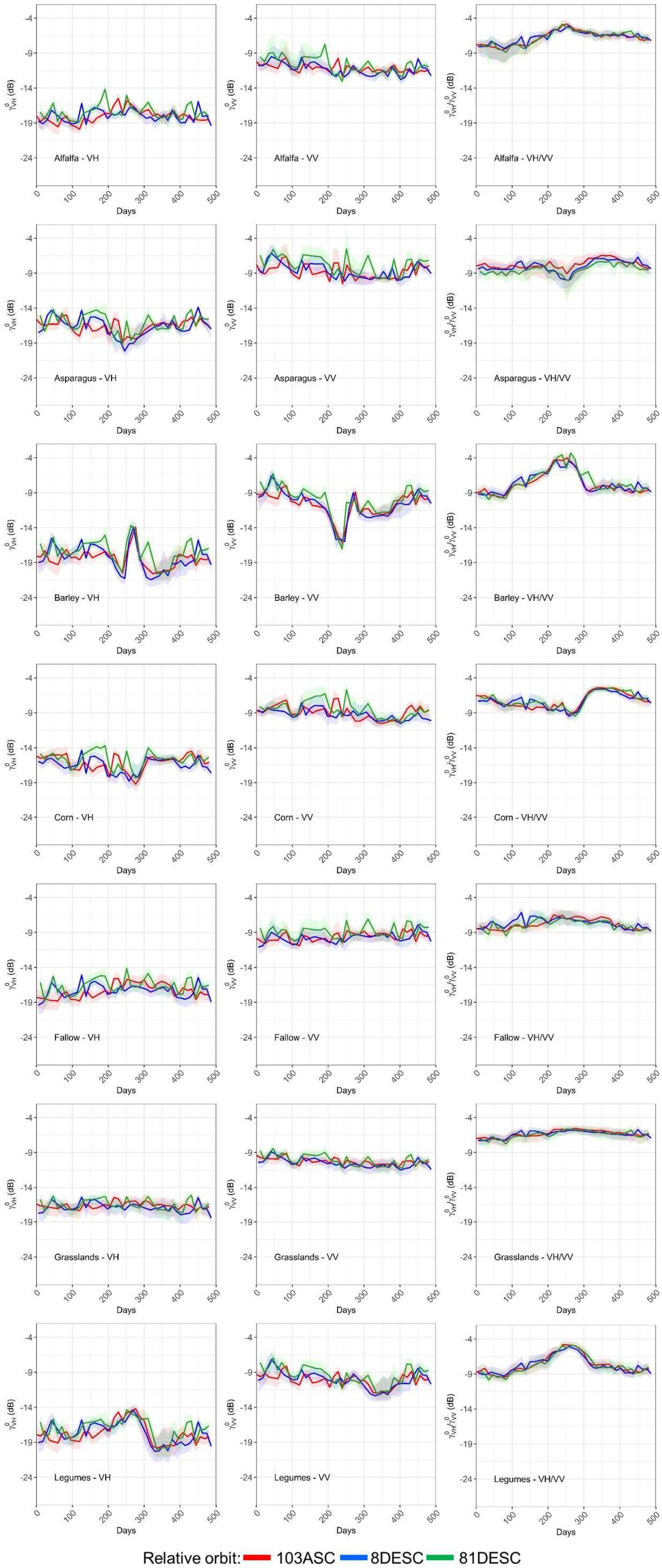


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. e) Region 5.

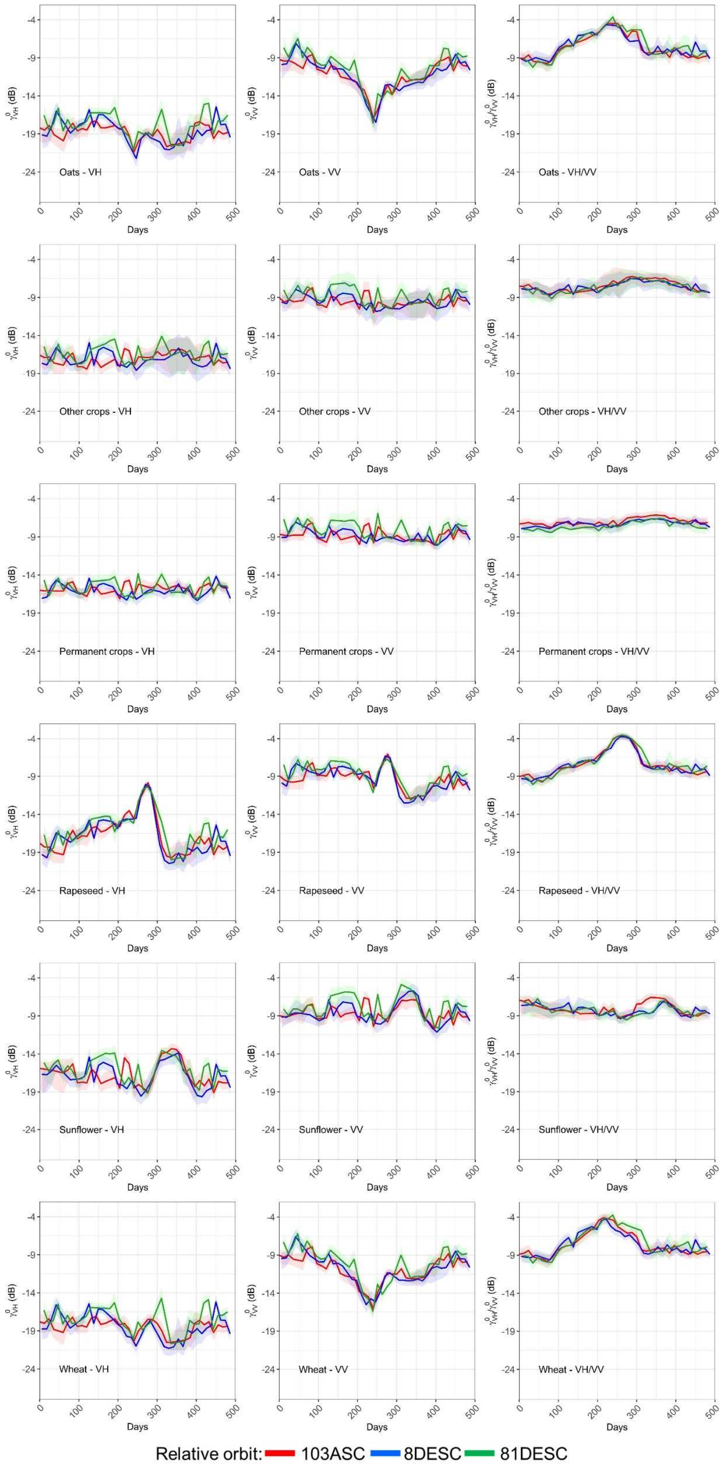


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. e) Region 5.

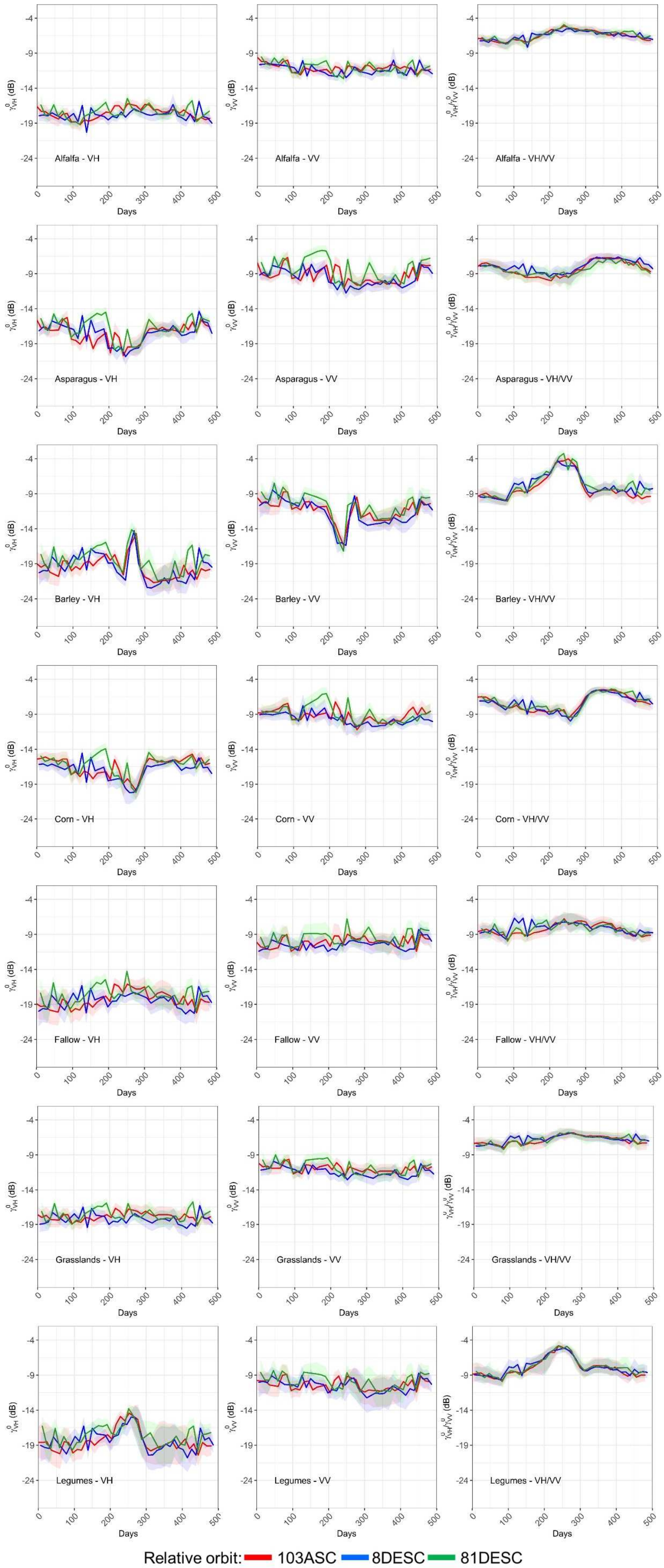


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. f) Region 6.

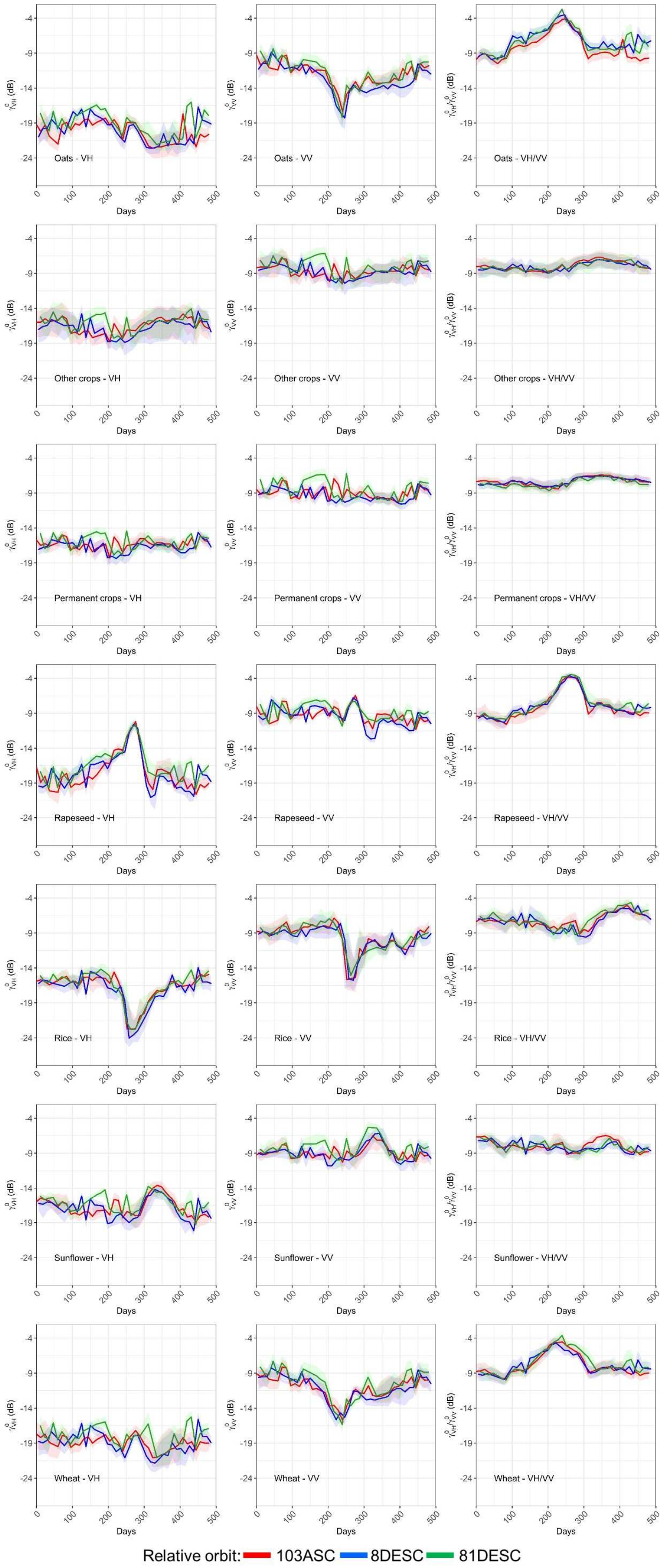


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. f) Region 6.

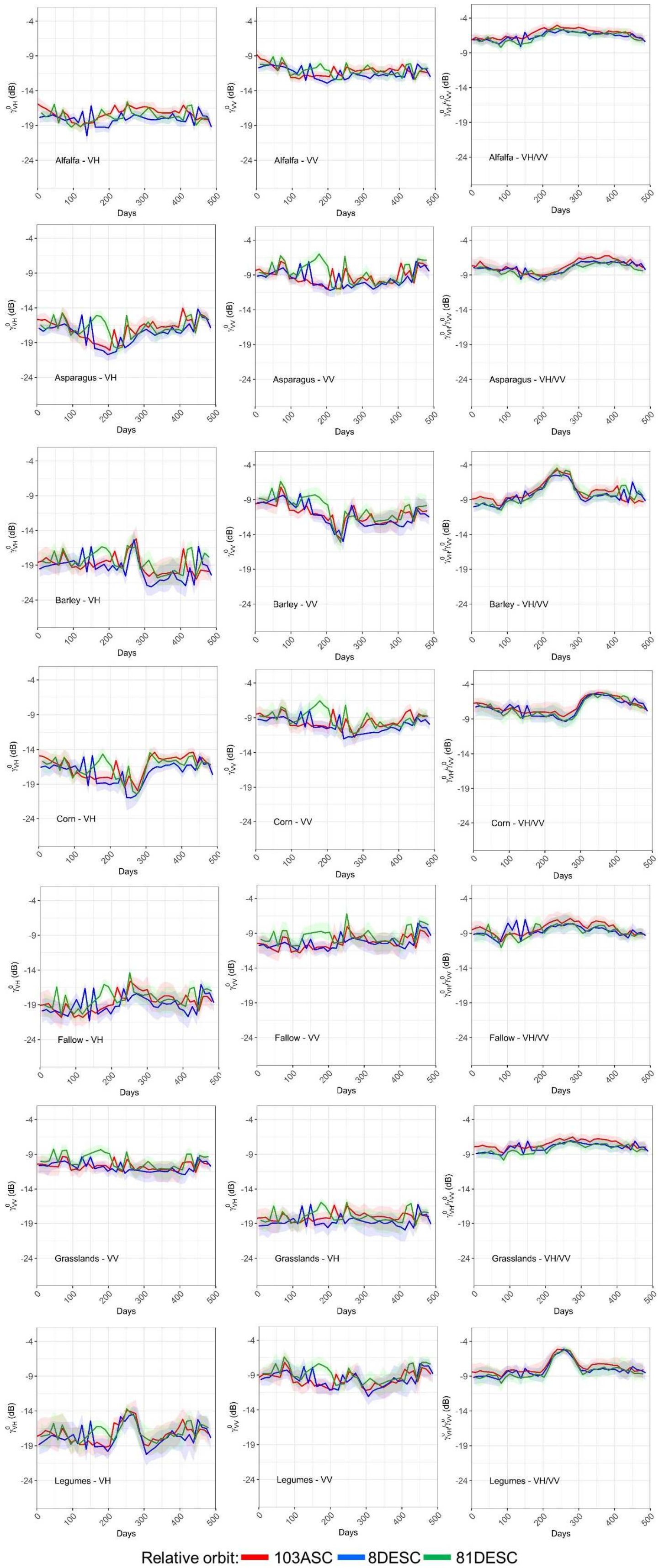


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. g) Region 7.

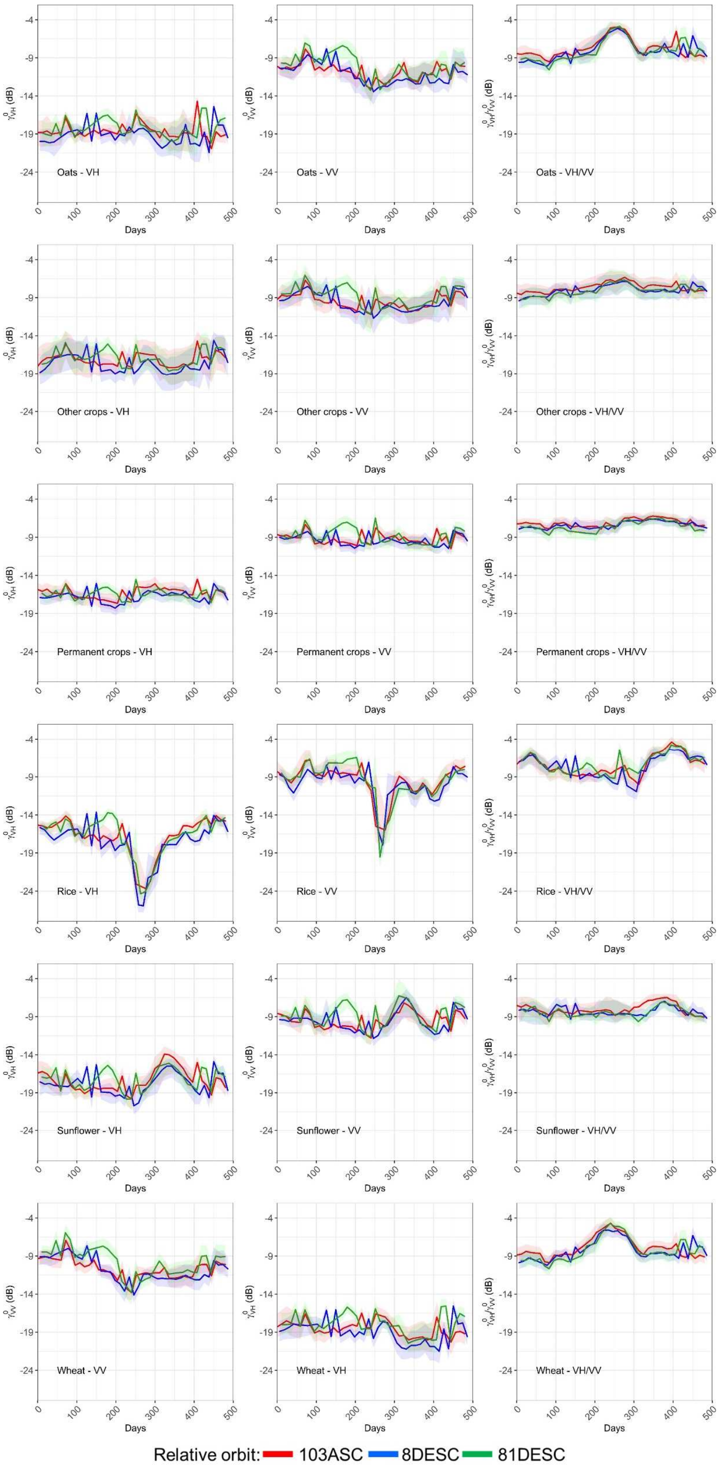


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. g) Region 7.

3. Confusion matrix of Ens and R^2 for cross-validation in the regions

Table S2. Confusion matrix of Ens and R^2 classification for cross-validation. a) Region 1.

	Alfalfa	Barley	Corn	Fallow	Grasslands	Legumes	Oats	Other crops	Permanent crops	Rapeseed	Sunflower	Wheat	UA
Alfalfa	1	0	0	0	47	0	0	0	0	0	0	0	2%
Barley	0	28	3	0	51	1	0	1	0	0	1	3	32%
Corn	0	0	96	2	38	3	0	1	0	0	1	0	68%
Fallow	0	0	0	1	100	1	0	1	0	0	1	0	1%
Grasslands	0	0	0	4	2154	2	0	6	1	0	0	0	99%
Legumes	0	1	1	2	36	11	0	0	0	0	1	2	20%
Oats	0	1	0	0	36	1	27	1	0	0	0	7	37%
Other crops	0	0	1	0	125	0	0	3	2	0	0	0	2%
Permanent crops	0	0	0	0	114	0	0	4	2	0	0	0	2%
Rapeseed	0	0	0	0	1	0	0	0	0	5	0	0	83%
Sunflower	0	0	1	0	53	0	0	0	0	0	2	0	4%
Wheat	0	1	1	0	24	3	2	0	0	0	0	63	67%
PA	100%	90%	93%	11%	78%	50%	93%	18%	40%	100%	33%	84%	

Table S2 (cont.).. Confusion matrix of Ens and R^2 classification for cross-validation. b) Region 2.

	Barley	Corn	Fallow	Grasslands	Legumes	Oats	Other crops	Permanent crops	Rapeseed	Sunflower	Wheat	UA
Barley	382	0	2	6	2	0	0	0	0	0	9	95%
Corn	0	7	0	15	0	0	5	0	0	0	0	26%
Fallow	0	0	58	4	2	0	1	1	0	0	0	88%
Grasslands	0	0	14	1781	0	0	9	0	0	0	0	99%
Legumes	1	0	12	116	120	1	9	1	0	0	13	44%
Oats	1	0	3	19	5	150	3	0	0	0	107	52%
Other crops	0	0	4	43	0	0	1	1	0	0	0	2%
Permanent crops	0	0	8	112	0	0	3	10	0	1	0	7%
Rapeseed	0	0	0	3	4	0	0	0	38	0	0	84%
Sunflower	0	1	5	7	0	0	1	0	0	37	0	73%
Wheat	5	0	4	12	5	16	5	0	0	0	618	93%
PA	98%	88%	53%	84%	87%	90%	3%	77%	100%	97%	83%	

Table S2 (cont.).. Confusion matrix of Ens and R^2 classification for cross-validation. c) Region 3.

	Alfalfa	Asparagus	Barley	Corn	Fallow	Grasslands	Legumes	Oats	Other crops	Permanent crops	Rapeseed	Sunflower	Wheat	UA
Alfalfa	2	0	0	0	2	4	0	0	1	0	0	0	0	22%
Asparagus	0	6	0	0	2	1	0	0	2	3	0	0	0	43%
Barley	0	1	677	0	0	6	5	0	2	0	0	0	25	95%
Corn	0	2	0	61	0	0	0	0	1	0	0	0	0	95%
Fallow	0	0	0	0	38	9	0	0	2	2	0	0	0	75%
Grasslands	0	0	0	0	13	333	2	0	2	10	0	0	0	93%
Legumes	0	0	1	0	4	15	191	0	2	1	2	0	0	88%
Oats	0	0	5	0	3	8	4	216	0	1	0	0	126	60%
Other crops	0	0	0	0	3	6	2	0	1	0	0	0	1	8%
Permanent crops	0	1	0	0	8	57	0	0	1	43	0	0	0	39%
Rapeseed	0	0	0	0	0	0	4	0	1	0	123	0	0	96%
Sunflower	0	0	0	2	3	1	0	0	0	0	0	58	0	91%
Wheat	0	0	10	0	1	5	4	24	0	1	0	0	940	95%
PA	100%	60%	98%	97%	49%	75%	90%	90%	7%	70%	98%	100%	86%	

Table S2 (cont.).. Confusion matrix of Ens and R^2 classification for cross-validation. d) Region 4.

	Alfalfa	Asparagus	Barley	Corn	Fallow	Grasslands	Legumes	Oats	Other crops	Permanent crops	Rapeseed	Sunflower	Wheat	UA
Alfalfa	9	0	0	0	4	26	2	1	3	2	0	0	2	18%
Asparagus	0	43	0	2	6	5	0	0	9	65	0	1	0	33%
Barley	0	2	1919	1	6	9	17	11	11	0	0	0	70	94%
Corn	0	0	0	10	4	1	0	0	6	0	0	2	0	43%
Fallow	0	1	0	0	174	9	1	0	2	14	0	0	0	87%
Grasslands	1	2	0	0	35	844	3	0	7	71	0	0	1	88%
Legumes	0	0	19	0	23	40	302	4	8	4	2	0	18	72%
Oats	0	0	13	0	4	11	12	195	5	1	0	0	257	39%
Other crops	0	2	8	0	21	48	6	2	3	12	0	0	11	3%
Permanent crops	0	8	0	0	32	45	0	0	2	356	0	1	0	80%
Rapeseed	0	0	5	0	5	7	49	0	3	0	120	0	0	63%
Sunflower	0	0	0	1	18	3	0	0	2	1	0	23	0	48%
Wheat	0	0	55	0	6	8	14	51	5	1	0	1	1571	92%
PA	90%	74%	95%	71%	51%	80%	74%	74%	5%	68%	98%	82%	81%	

Table S2 (cont.).. Confusion matrix of Ens and R^2 classification for cross-validation. e) Region 5.

	Alfalfa	Asparagus	Barley	Corn	Fallow	Grasslands	Legumes	Oats	Other crops	Permanent crops	Rapeseed	Sunflower	Wheat	UA
Alfalfa	35	0	0	1	4	25	1	1	2	4	0	0	1	47%
Asparagus	0	6	0	1	1	1	0	0	6	18	0	0	0	18%
Barley	1	0	1353	0	7	17	7	4	3	1	0	0	58	93%
Corn	0	3	0	248	0	1	0	0	11	8	0	0	0	92%
Fallow	0	0	0	0	200	7	6	0	3	12	0	1	0	87%
Grasslands	2	0	1	0	41	635	3	1	12	50	0	0	1	85%
Legumes	12	0	17	0	35	83	178	1	10	10	7	0	15	48%
Oats	1	1	13	1	3	14	4	101	5	1	0	0	190	30%
Other crops	1	0	0	2	27	18	3	0	16	23	0	1	0	18%
Permanent crops	0	3	0	1	30	48	1	0	6	308	0	0	0	78%
Rapeseed	0	0	3	0	2	1	20	0	1	0	104	0	0	79%
Sunflower	0	0	0	8	3	0	0	0	10	4	0	79	0	76%
Wheat	0	0	37	1	5	11	10	20	8	3	0	0	1172	93%
PA	67%	46%	95%	94%	56%	74%	76%	79%	17%	70%	94%	98%	82%	

Table S2 (cont.). Confusion matrix of Ens and R^2 classification for cross-validation. f) Region 6.

	Alfalfa	Asparagus	Barley	Corn	Fallow	Grasslands	Legumes	Oats	Other crops	Permanent crops	Rapeseed	Rice	Sunflower	Wheat	UA
Alfalfa	129	0	0	0	26	99	3	1	6	17	0	0	0	1	46%
Asparagus	0	31	0	27	8	1	0	0	18	35	0	0	1	0	26%
Barley	1	0	1708	0	19	13	6	6	14	1	0	0	0	59	93%
Corn	0	3	0	383	1	0	2	0	31	8	0	1	0	0	89%
Fallow	6	0	0	0	361	10	8	0	2	13	0	0	0	0	90%
Grasslands	6	0	3	0	118	448	2	5	11	76	0	0	0	4	67%
Legumes	28	0	21	3	68	31	106	6	16	6	0	0	1	11	36%
Oats	3	1	32	2	19	8	16	107	19	23	0	0	0	119	31%
Other crops	1	4	0	32	16	10	2	0	77	49	0	0	0	0	40%
Permanent crops	0	4	0	14	38	21	3	0	29	777	0	0	0	0	88%
Rapeseed	1	0	21	0	13	3	19	0	6	1	16	0	0	0	20%
Rice	0	0	0	4	0	1	3	0	14	1	0	111	0	0	83%
Sunflower	0	0	0	7	14	2	3	0	55	5	0	0	9	0	9%
Wheat	11	1	120	6	19	28	11	15	27	10	0	0	1	627	72%
PA	69%	70%	90%	80%	50%	66%	58%	76%	24%	76%	100%	99%	75%	76%	

Table S2 (cont.). Confusion matrix of Ens and R^2 classification for cross-validation. g) Region 7.

	Alfalfa	Asparagus	Barley	Corn	Fallow	Grasslands	Legumes	Oats	Other crops	Permanent crops	Rice	Sunflower	Wheat	UA
Alfalfa	265	0	1	15	30	51	3	0	6	60	0	0	3	61%
Asparagus	2	15	0	18	12	0	0	0	23	42	0	1	0	13%
Barley	2	0	523	2	265	1	2	0	46	0	0	3	110	55%
Corn	0	0	0	262	3	0	0	0	31	2	1	1	1	87%
Fallow	5	0	2	1	1419	12	3	0	4	13	0	1	1	97%
Grasslands	3	0	9	4	194	460	1	0	17	42	0	1	12	62%
Legumes	7	0	50	1	159	4	38	2	55	6	0	2	21	11%
Oats	13	0	46	2	69	20	5	12	32	15	0	3	116	4%
Other crops	2	0	16	2	34	2	1	0	87	14	0	2	13	50%
Permanent crops	4	2	1	3	108	37	1	1	8	505	0	0	0	75%
Rice	0	0	0	5	0	0	0	0	10	0	99	0	0	87%
Sunflower	1	0	0	5	7	0	0	0	38	4	0	26	0	32%
Wheat	22	0	126	17	50	15	7	4	100	4	0	1	525	60%
PA	81%	88%	68%	78%	60%	76%	62%	63%	19%	71%	99%	63%	65%	

4. Producer's Accuracy (PA), User's Accuracy (UA) and F1-score for the different classification schemes in Navarre and regions.

In this section, Producer's Accuracy (PA), User's Accuracy (UA) and F1-score for Navarre and regions are presented. In each figure, results for R^2 metric are shown on left side and results for RMSE metric are shown on right side.

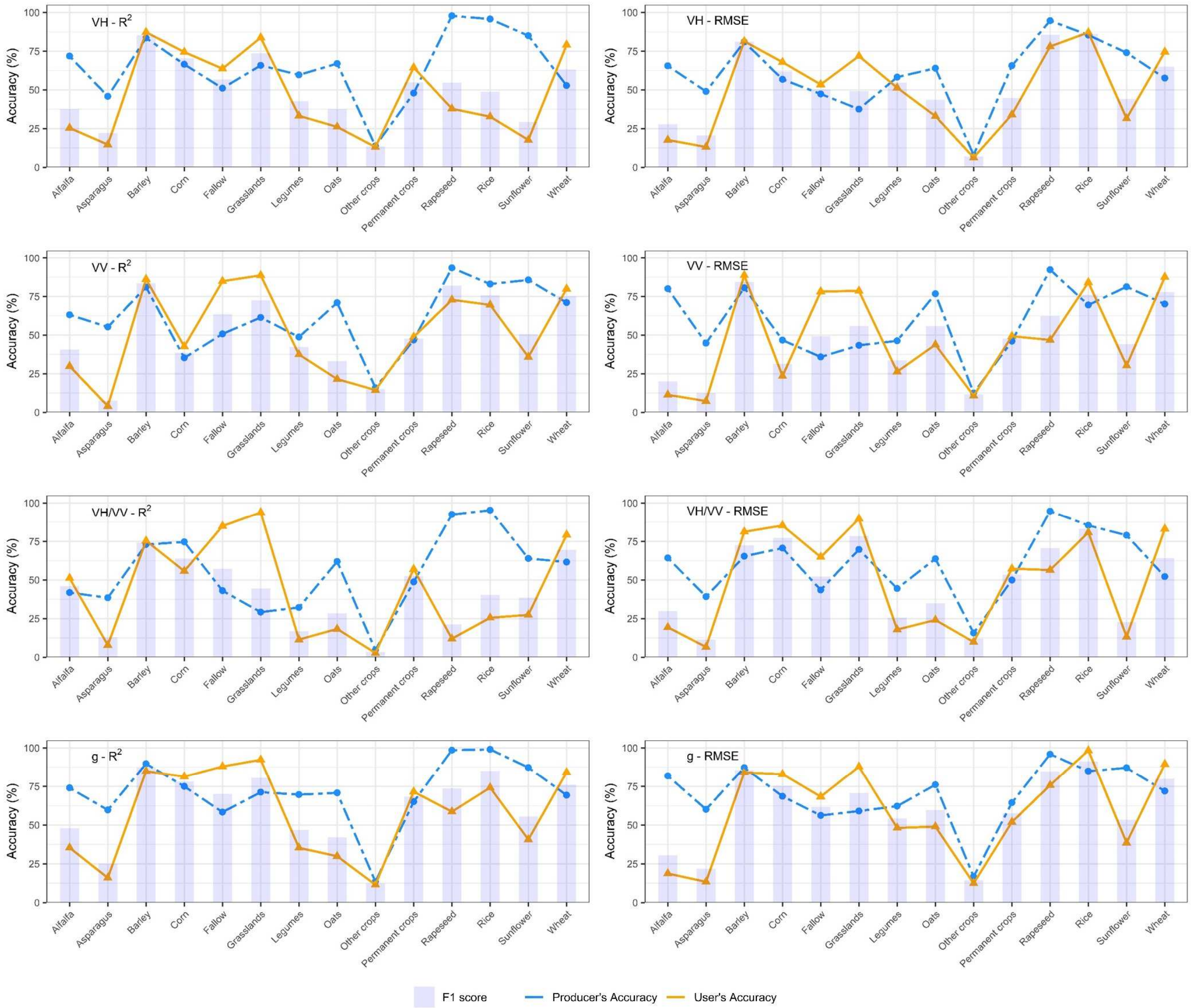


Figure S2. F1-score, PA and UA for the different polarization channels. a) Cross-Validation in Navarre

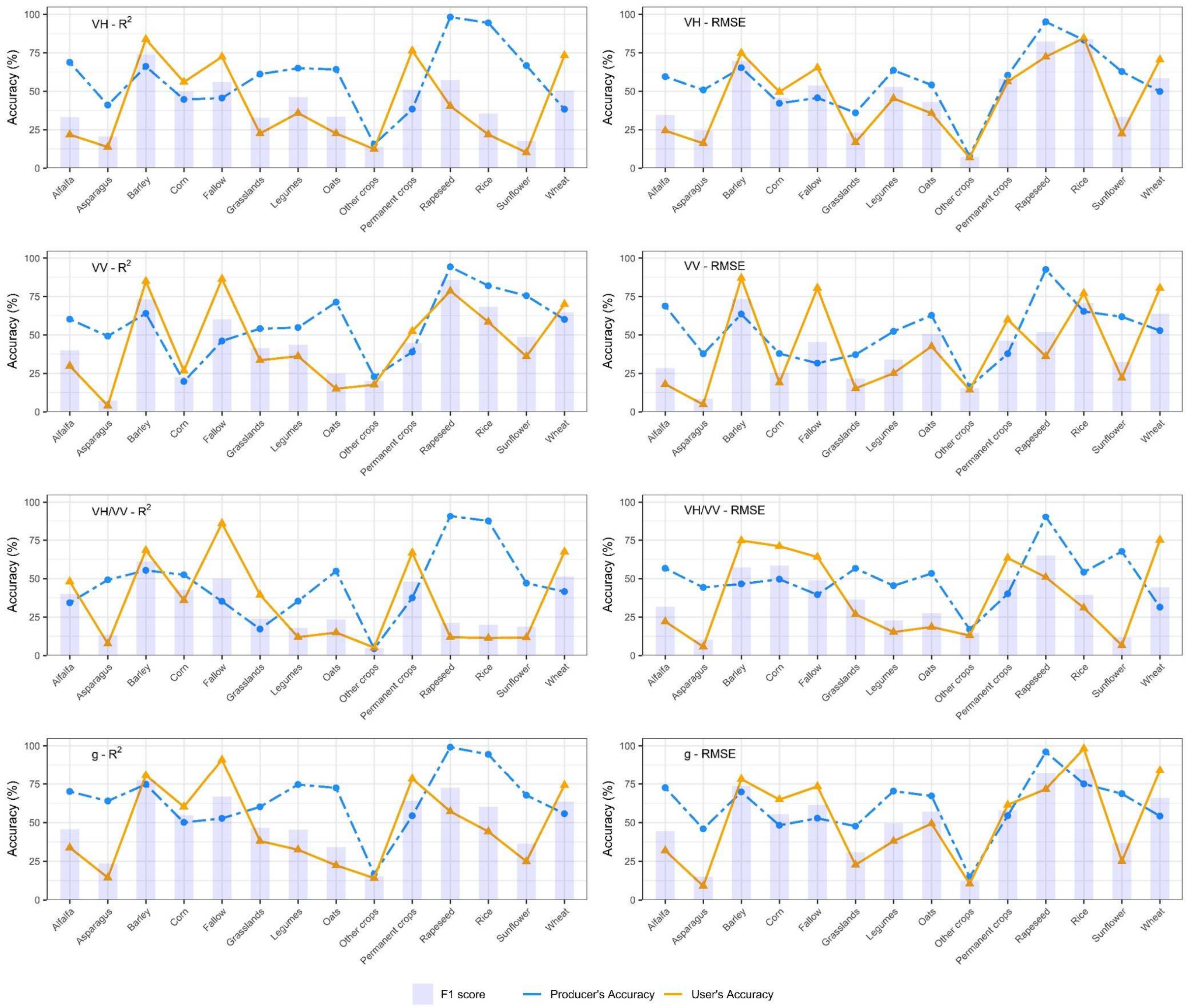


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. b) External-validation in Navarre

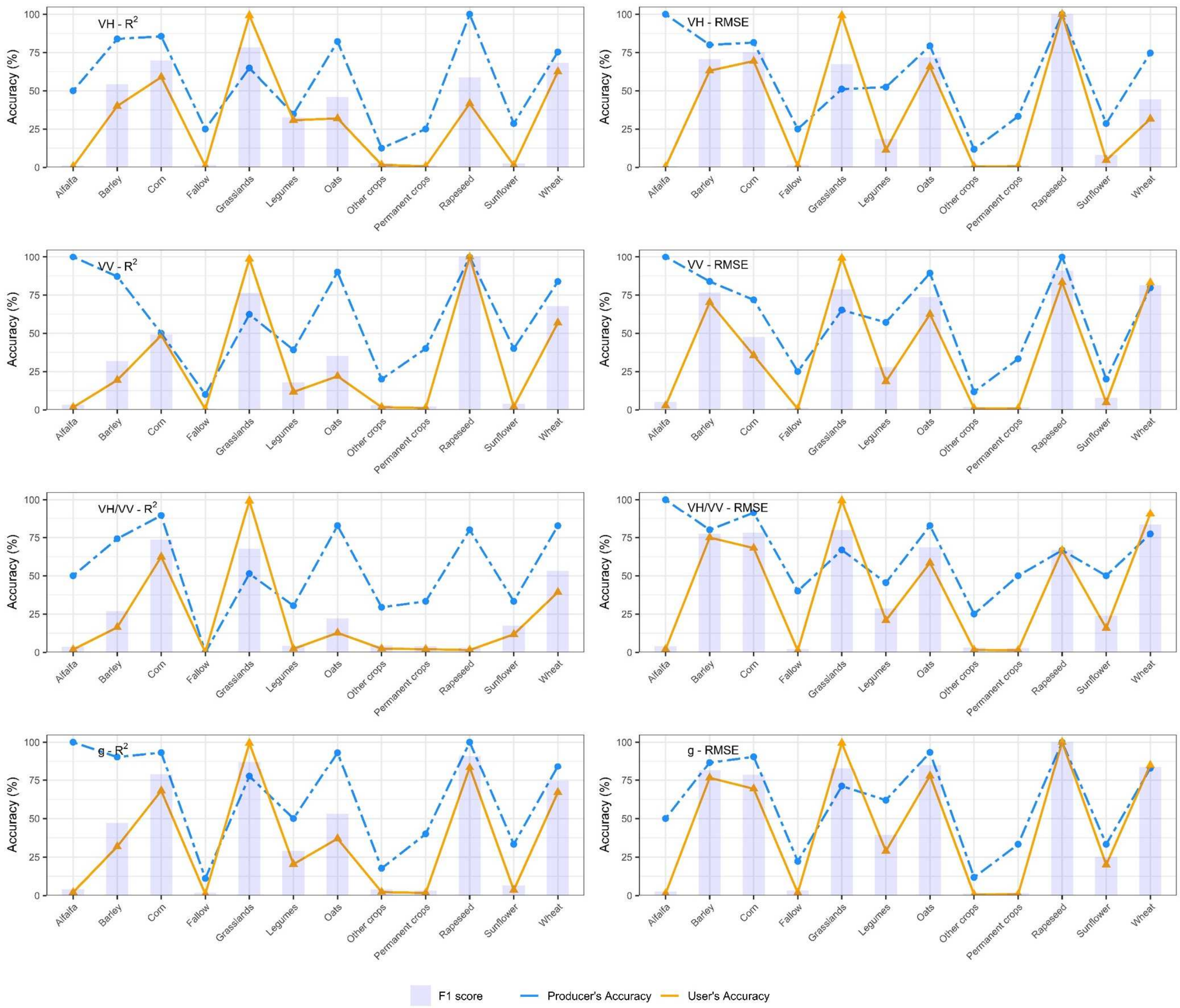


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. c) Cross-validation in Region 1

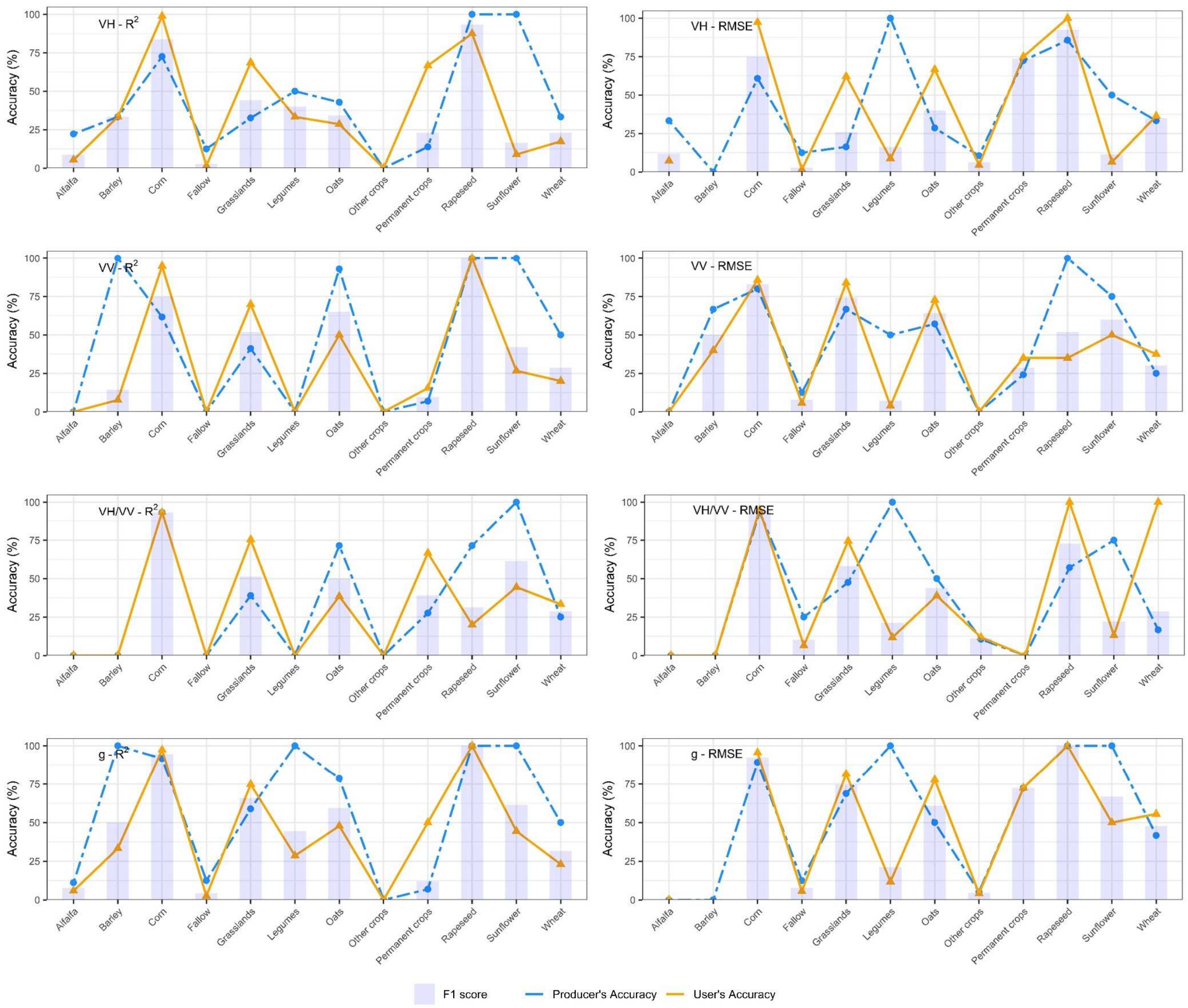


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. d) External-validation in Region 1

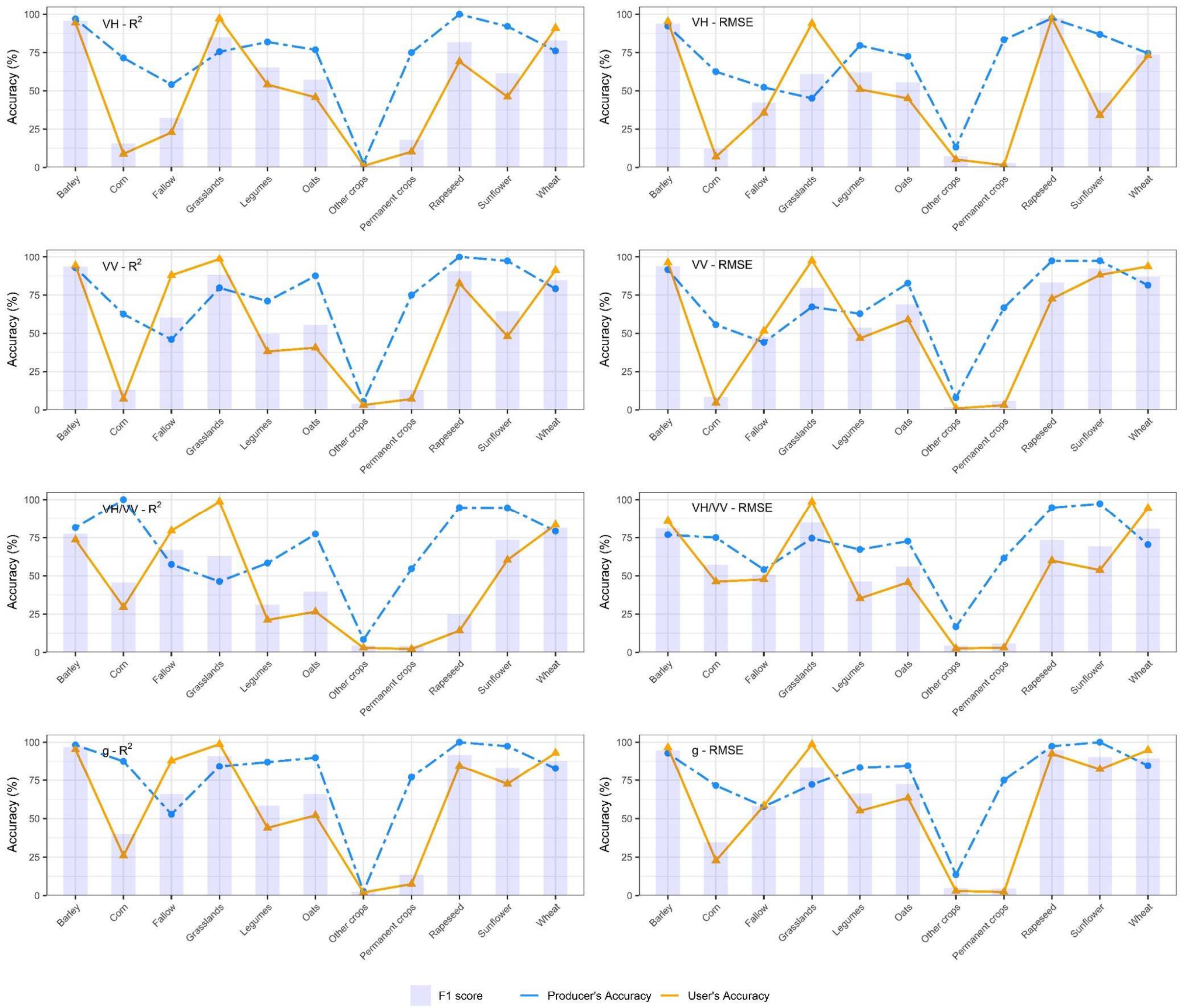


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. e) Cross-validation in Region 2

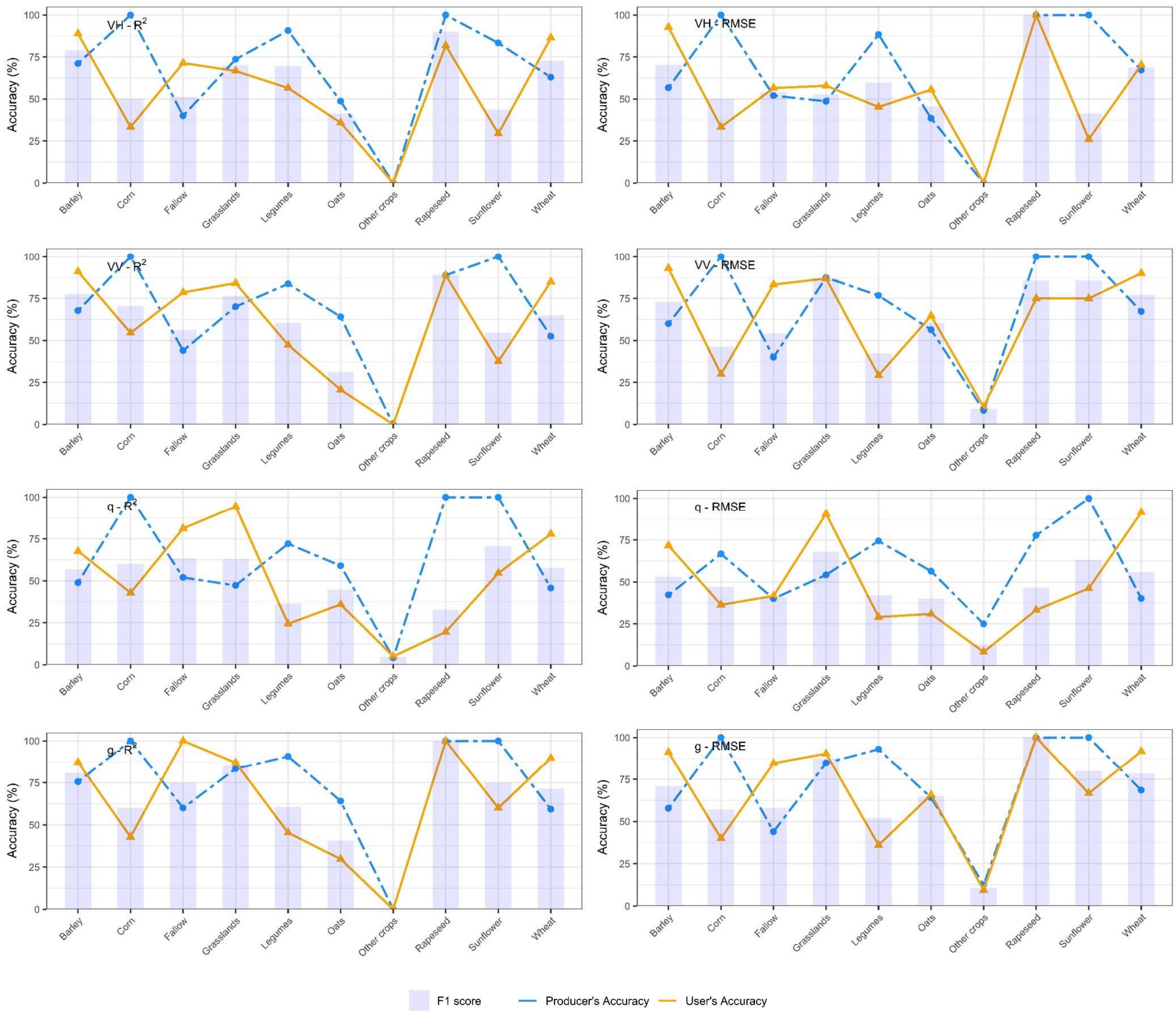


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. f) External-validation in Region 2

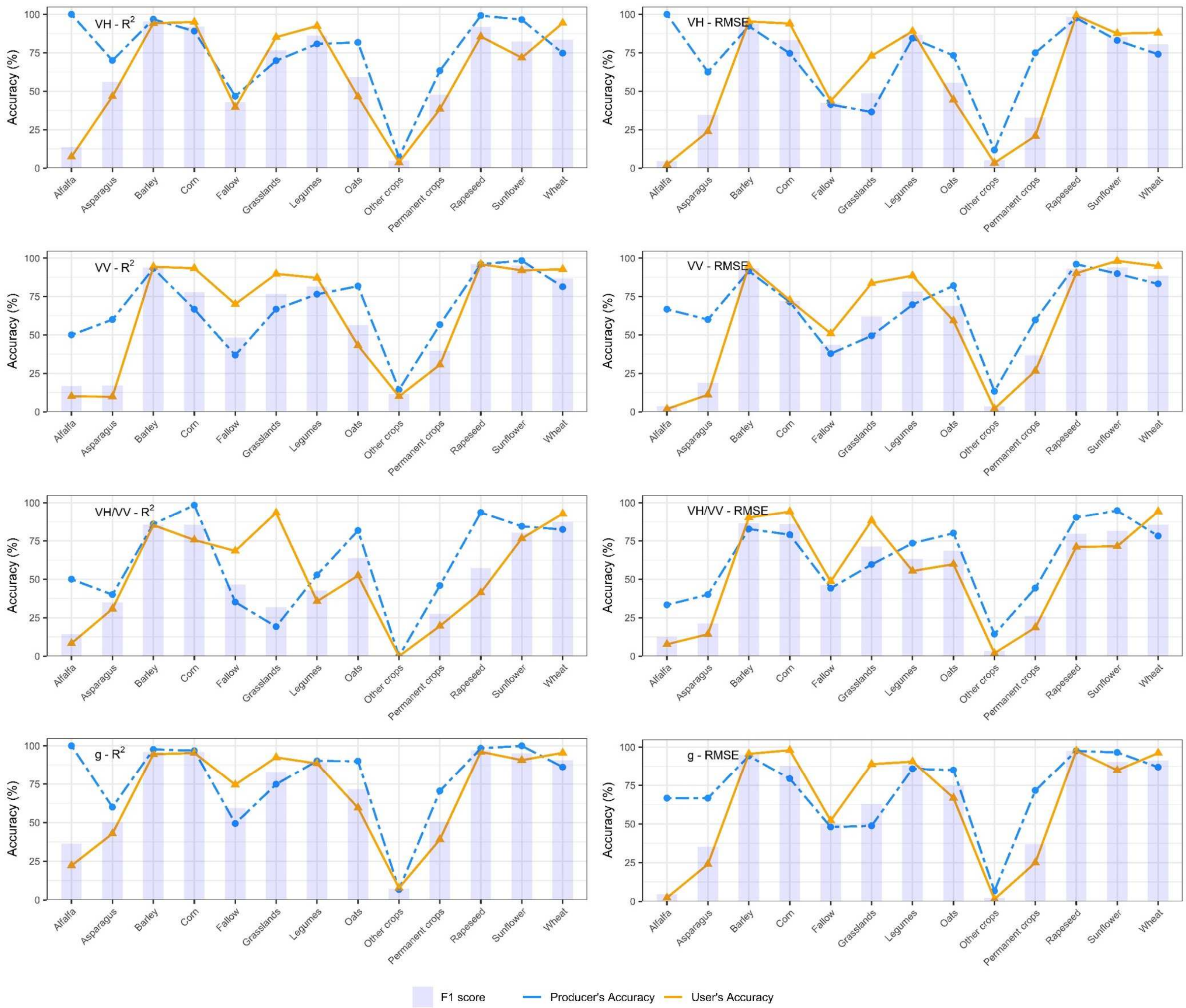


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. g) Cross-validation in Region 3

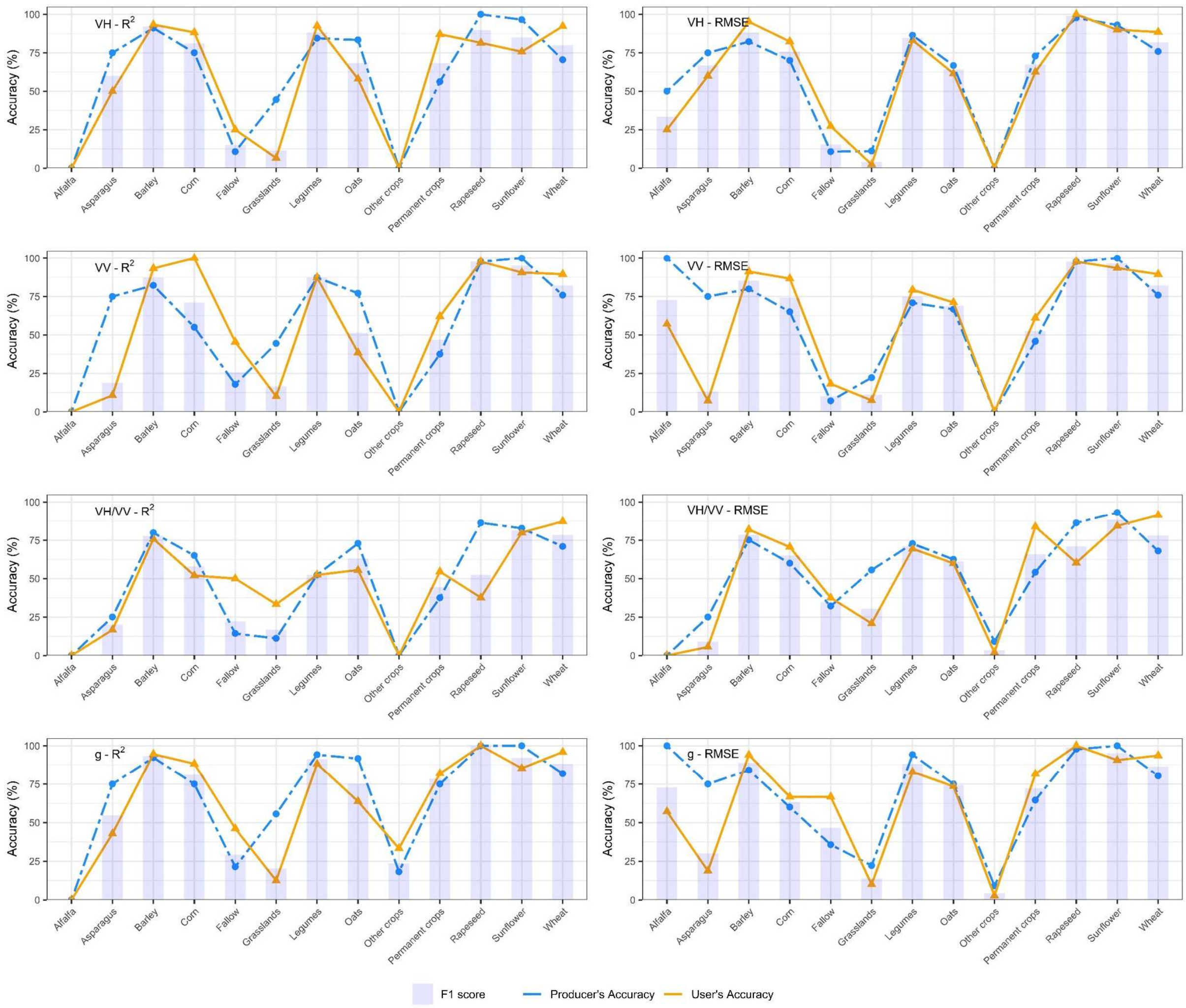


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. h) External-validation in Region 3

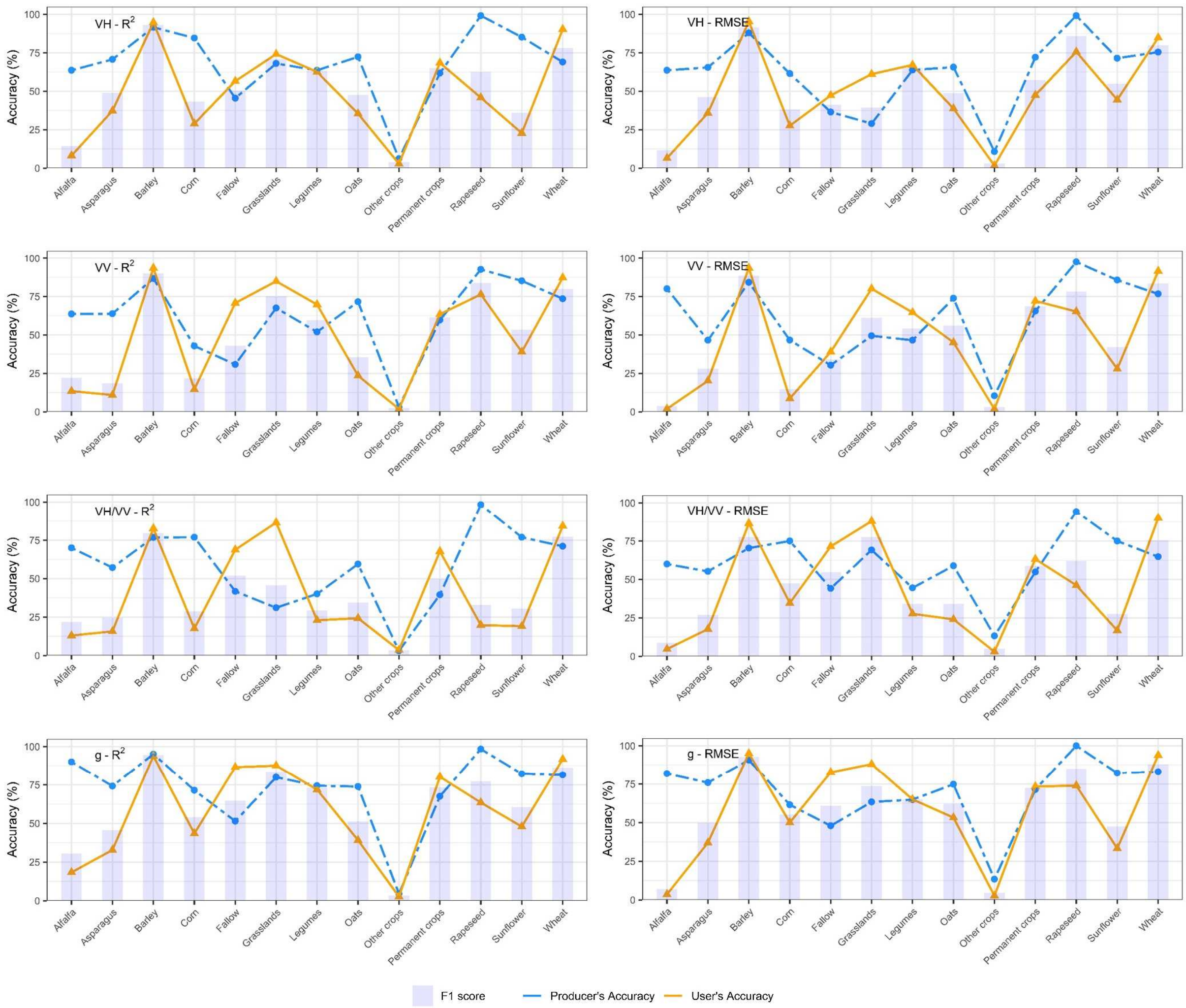


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. i) Cross-validation in Region 4

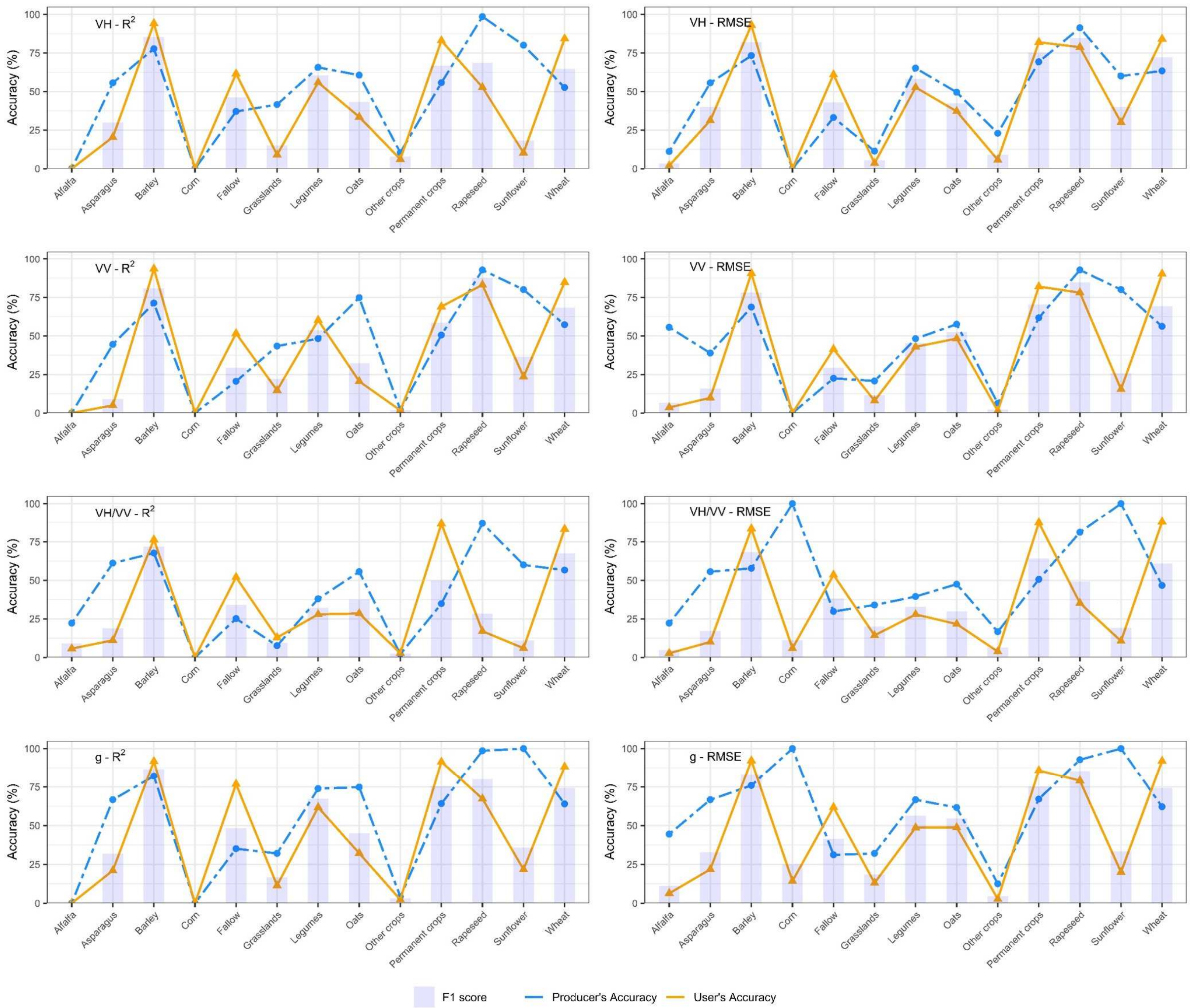


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. j) External-validation in Region 4

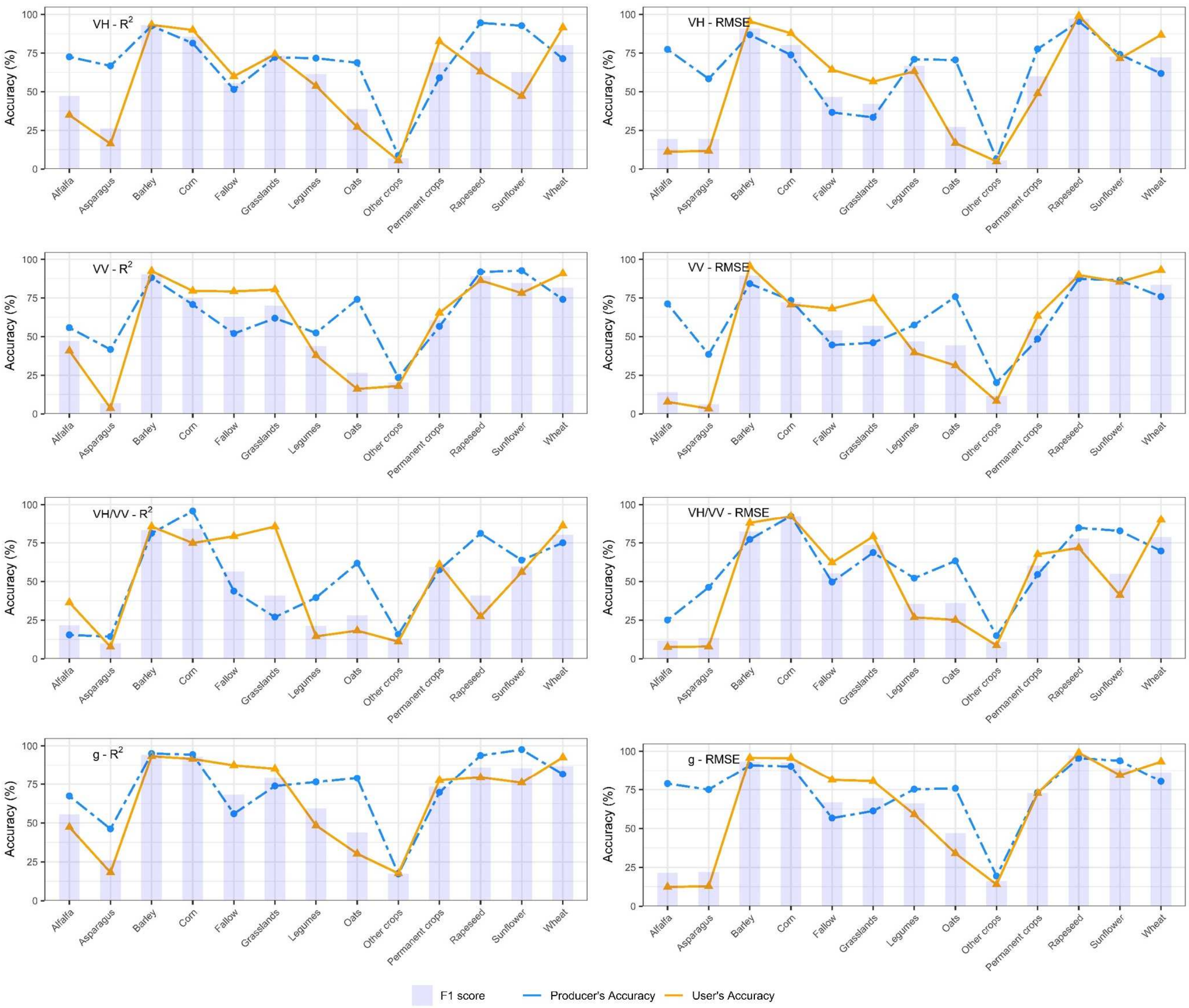


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. k) Cross-validation in Region 5

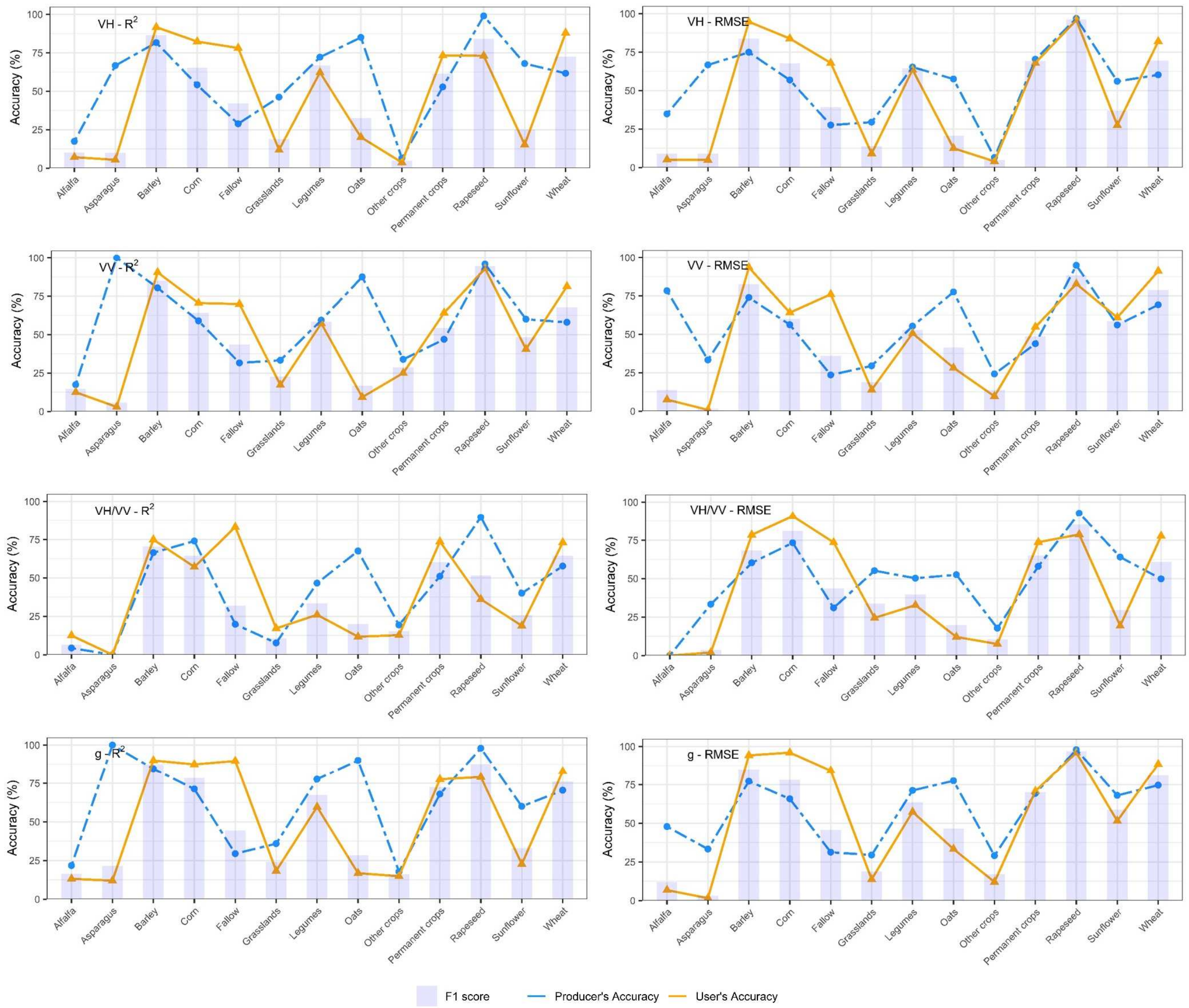


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. l) External-validation in Region 5

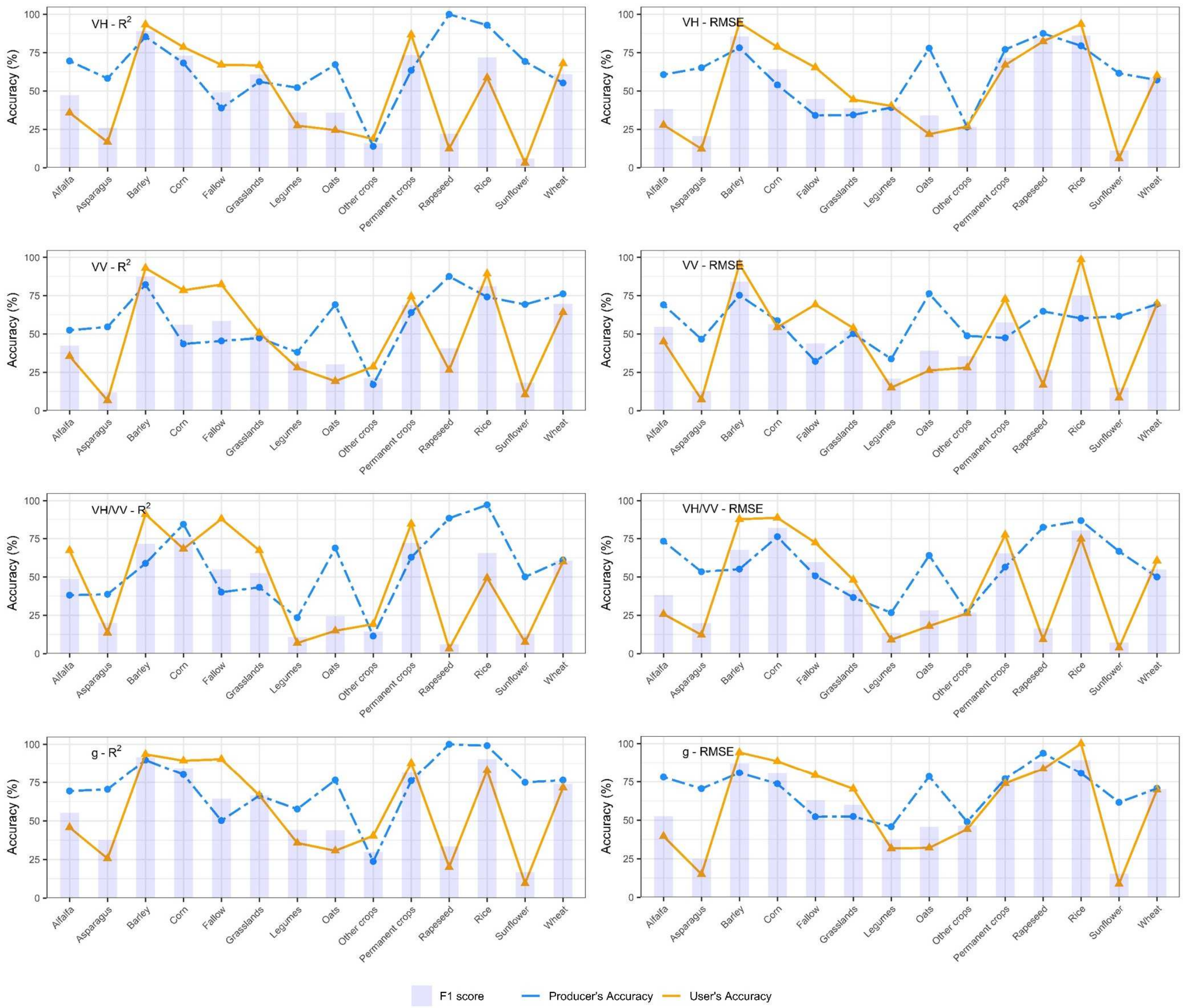


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. m) Cross-validation in Region 6

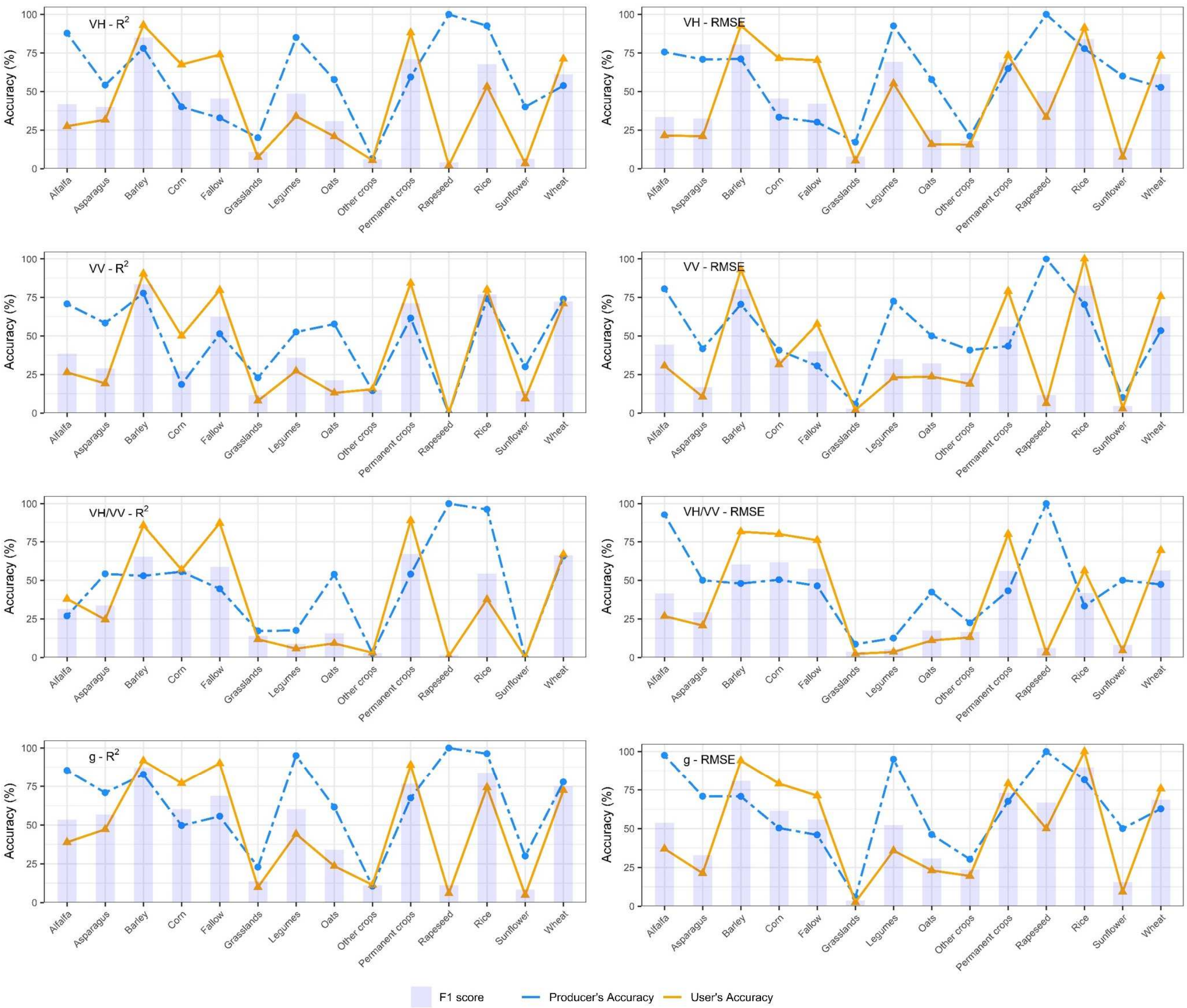


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. n) External-validation in Region 6

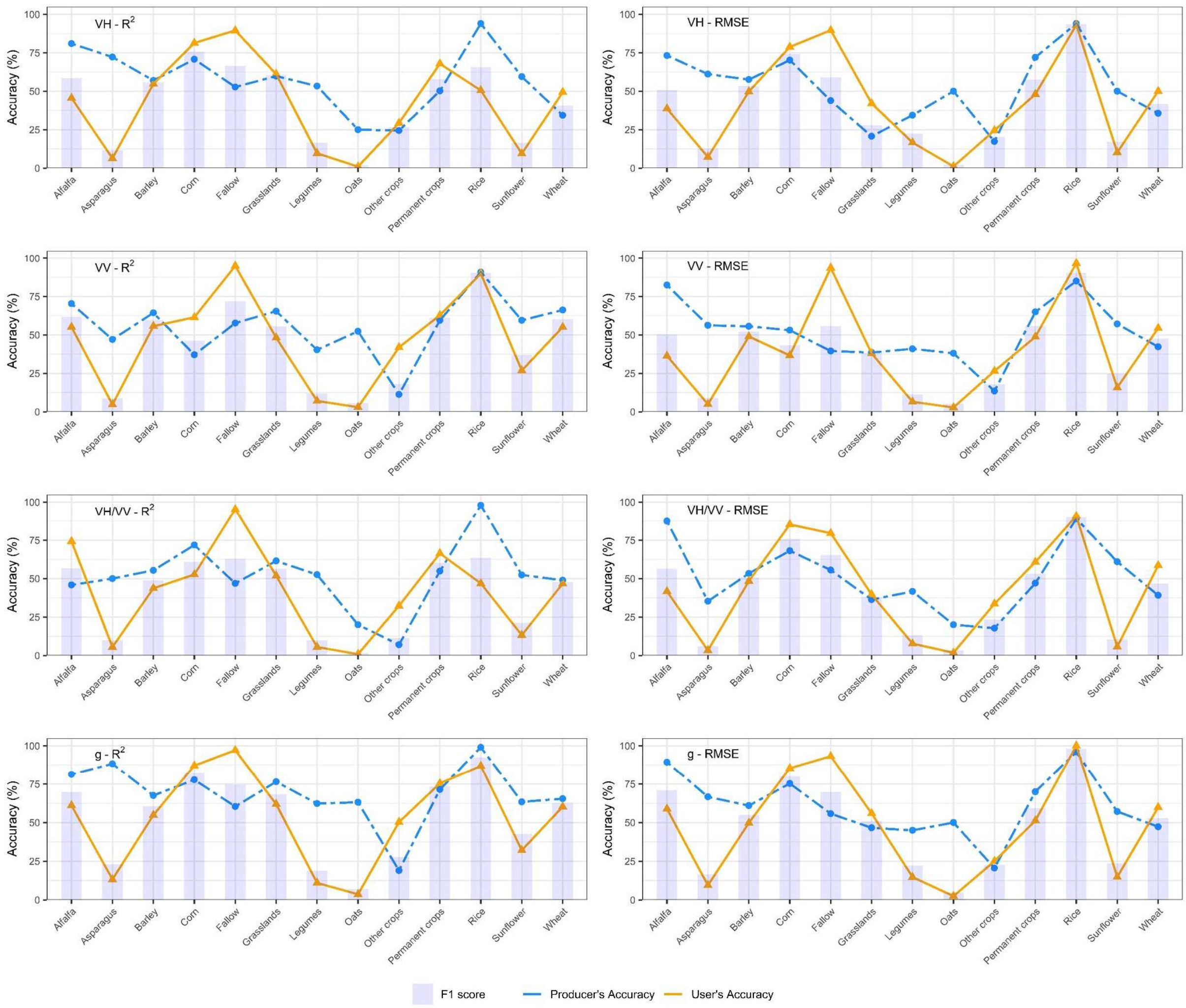


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. o) Cross-validation in Region 7

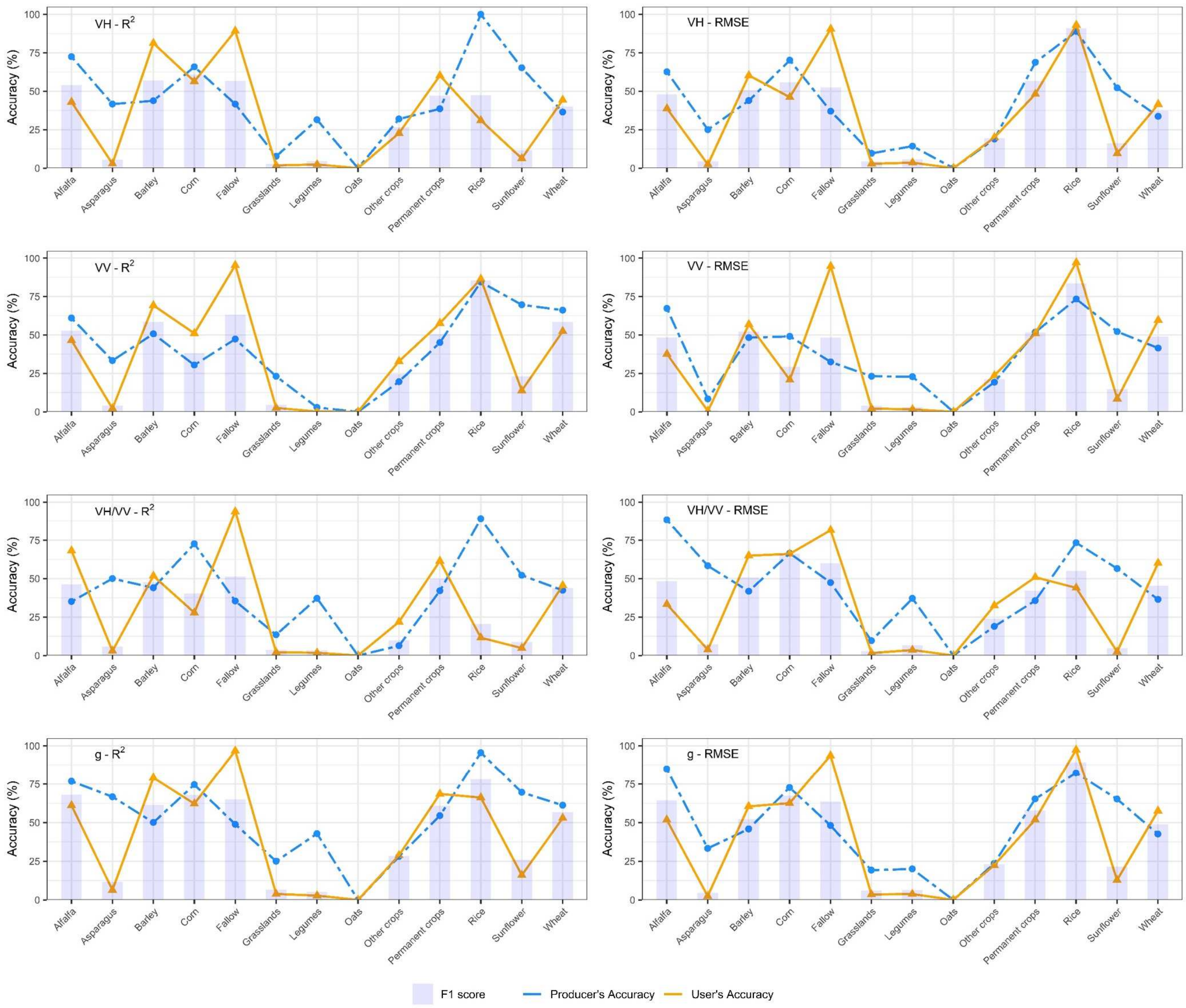


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. p) External-validation in Region 7

5. Influence of field size on classification results

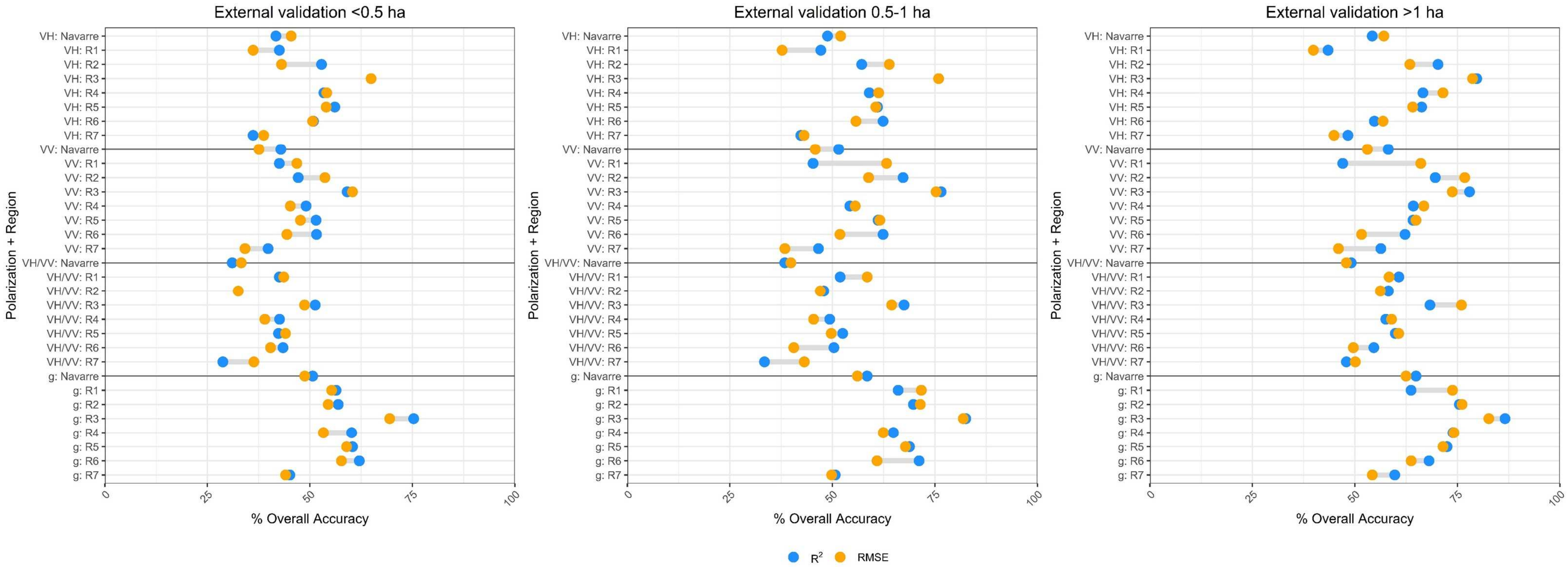


Figure S3. Overall Accuracy of External validation based on field size: <0.5 ha (left), 0.5-1ha (middle) and >1ha (right).

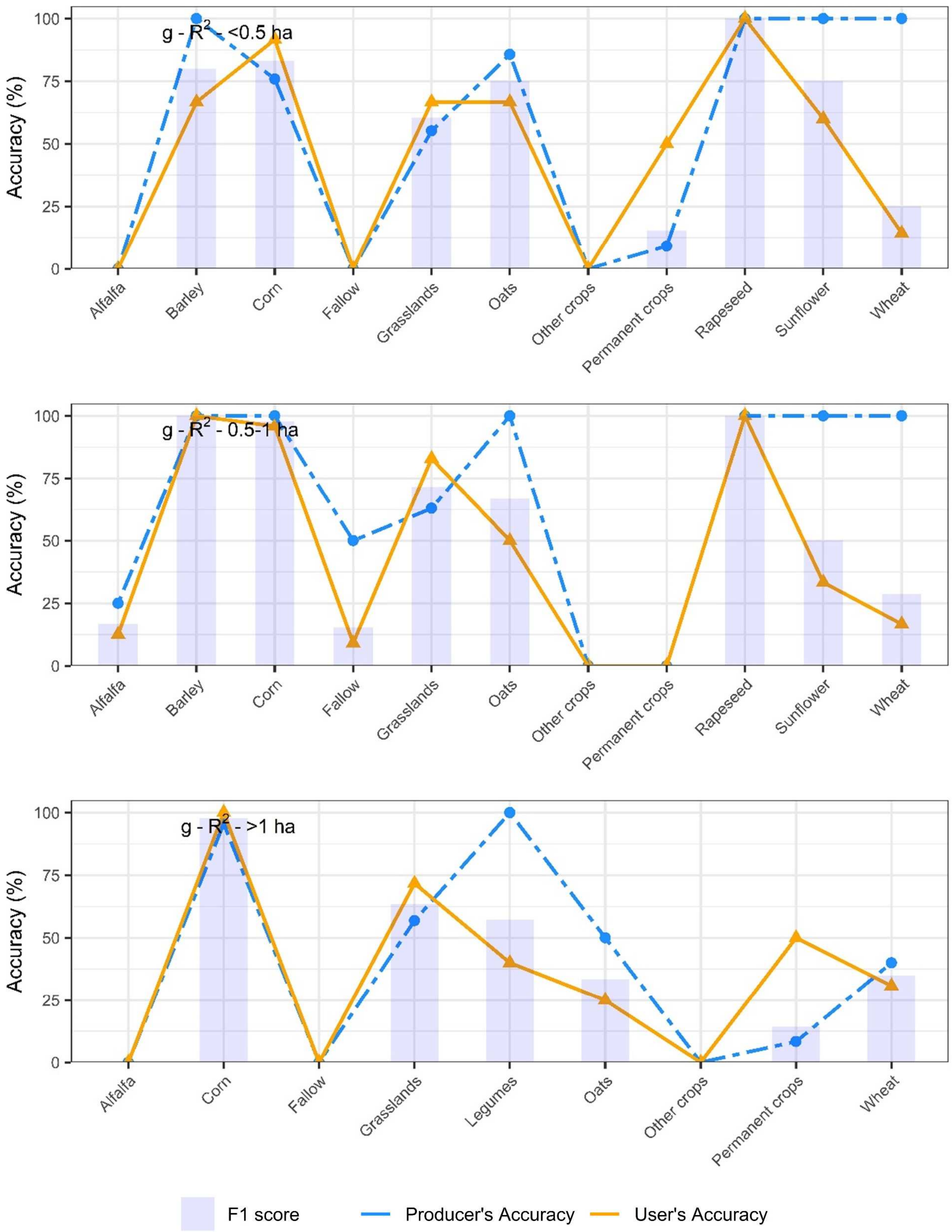


Figure S4. F1-score, PA and UA of Ens and R2 classification based on field size for external validation. a) Region 1

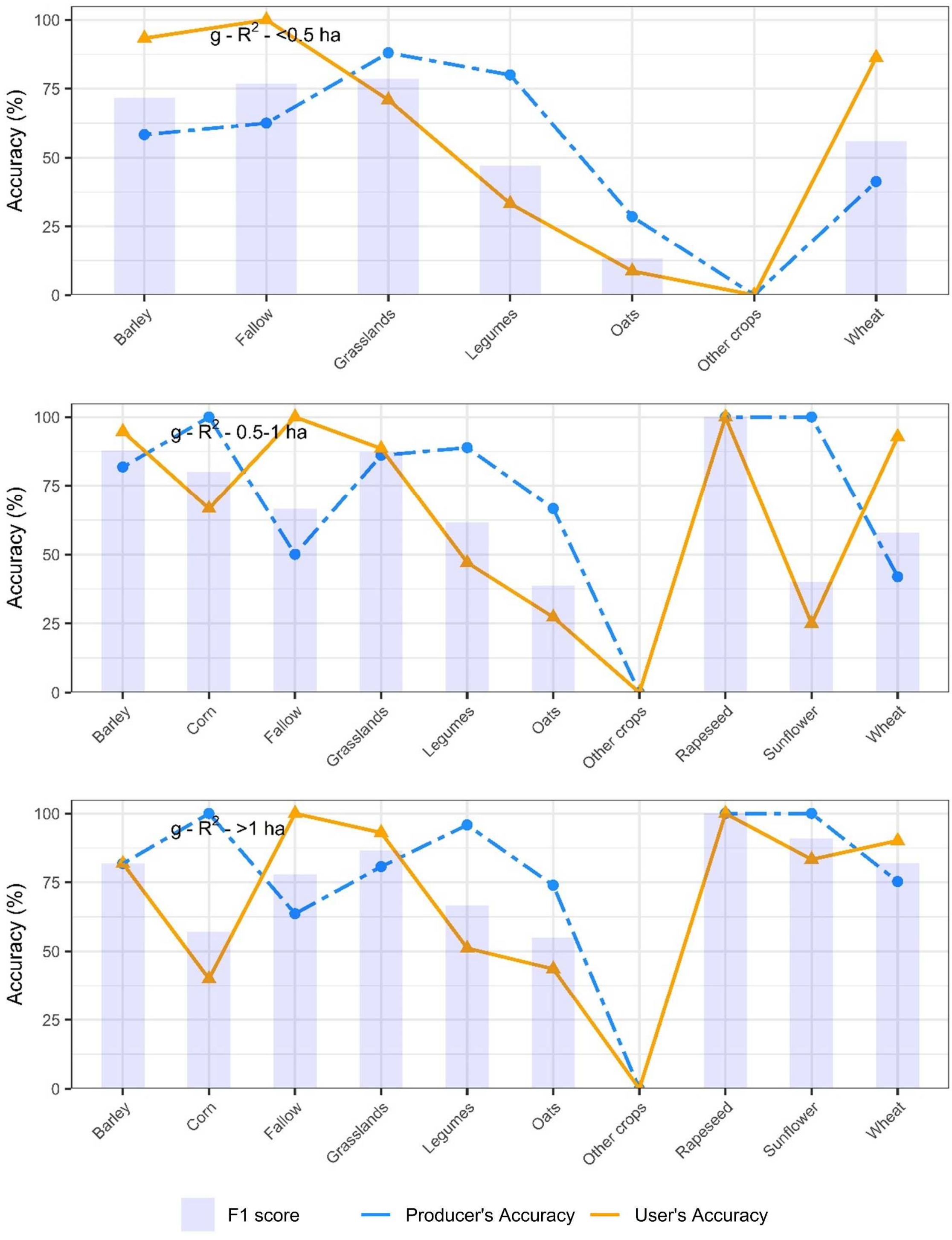


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. b) Region 2

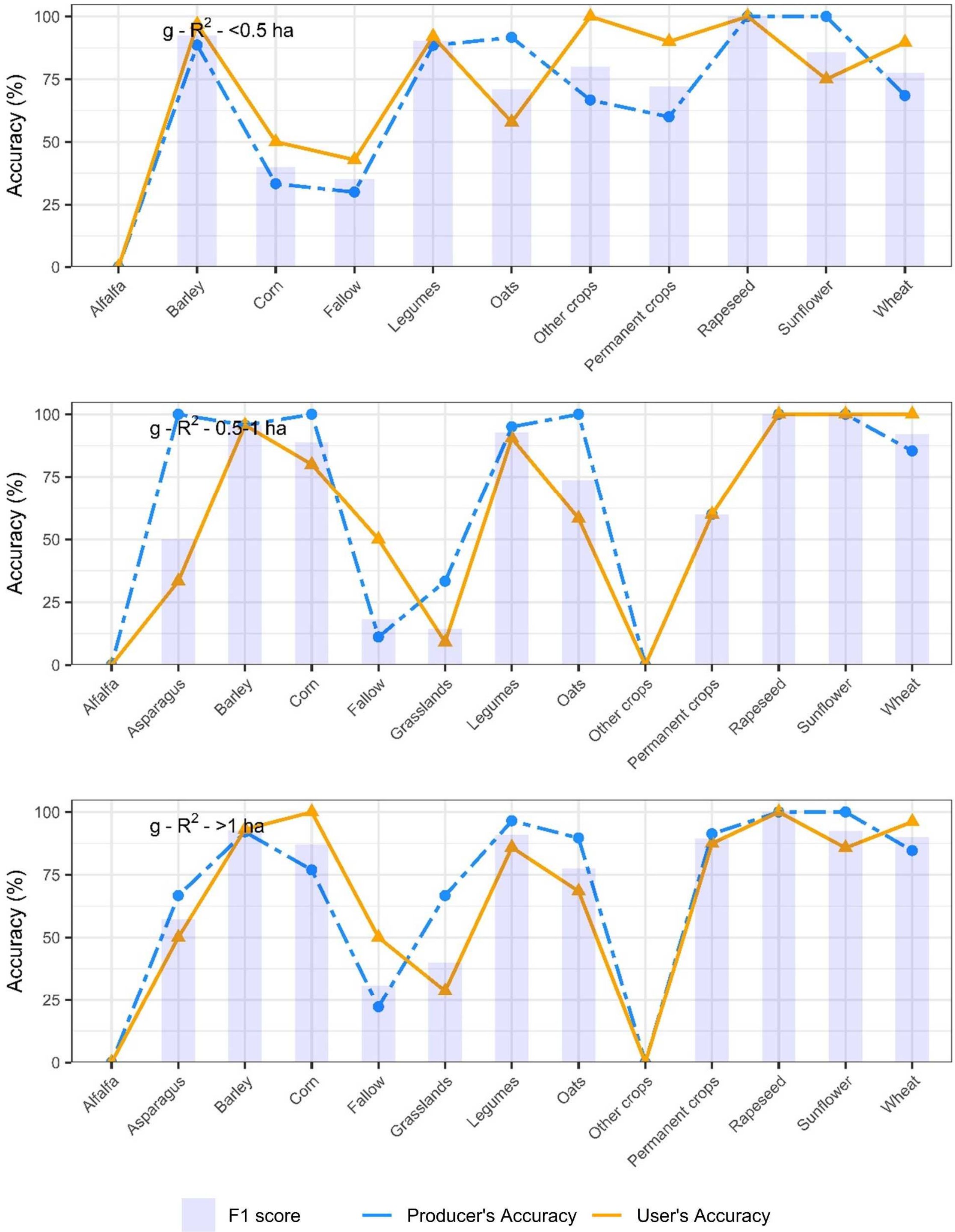


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. c) Region 3

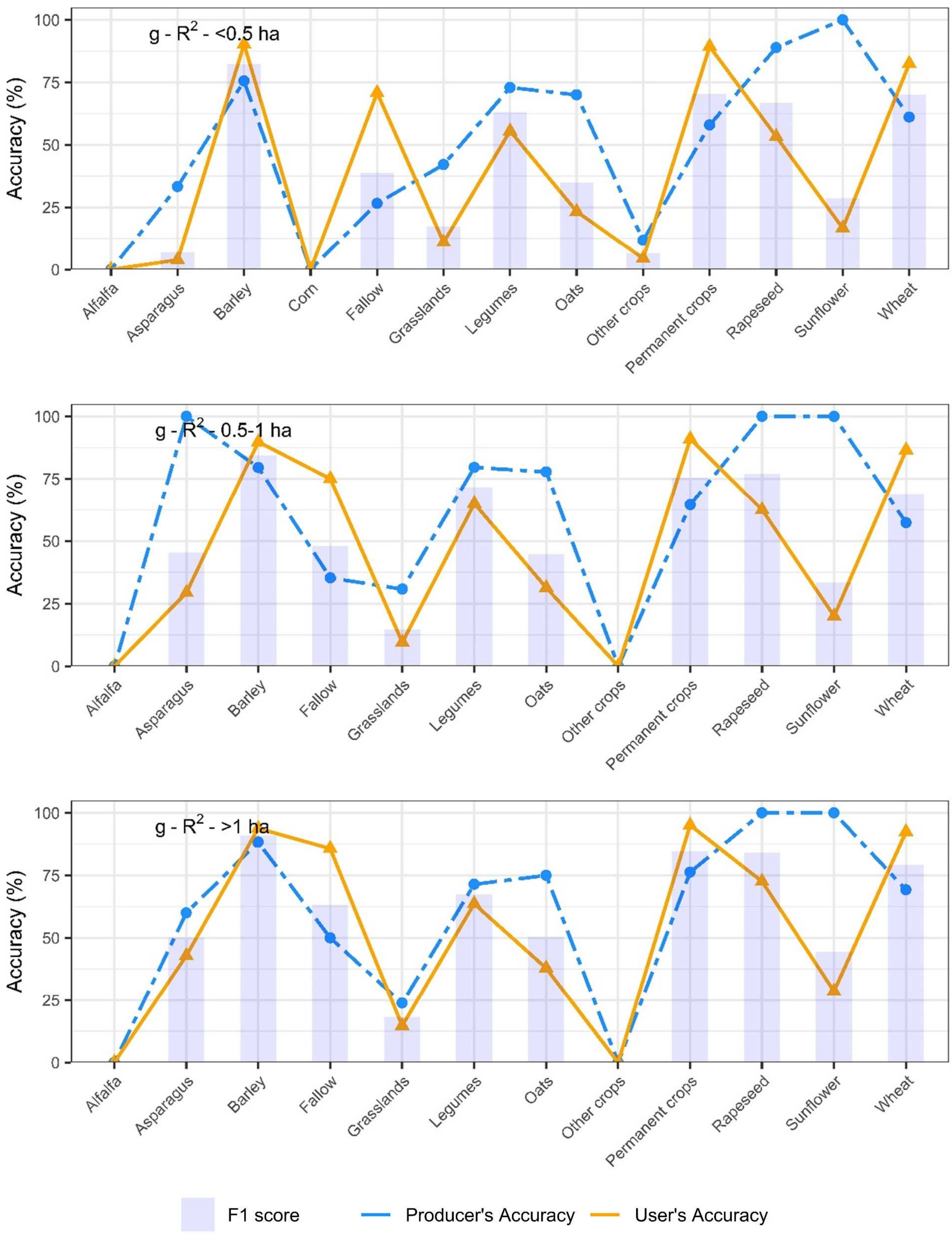


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. d) Region 4

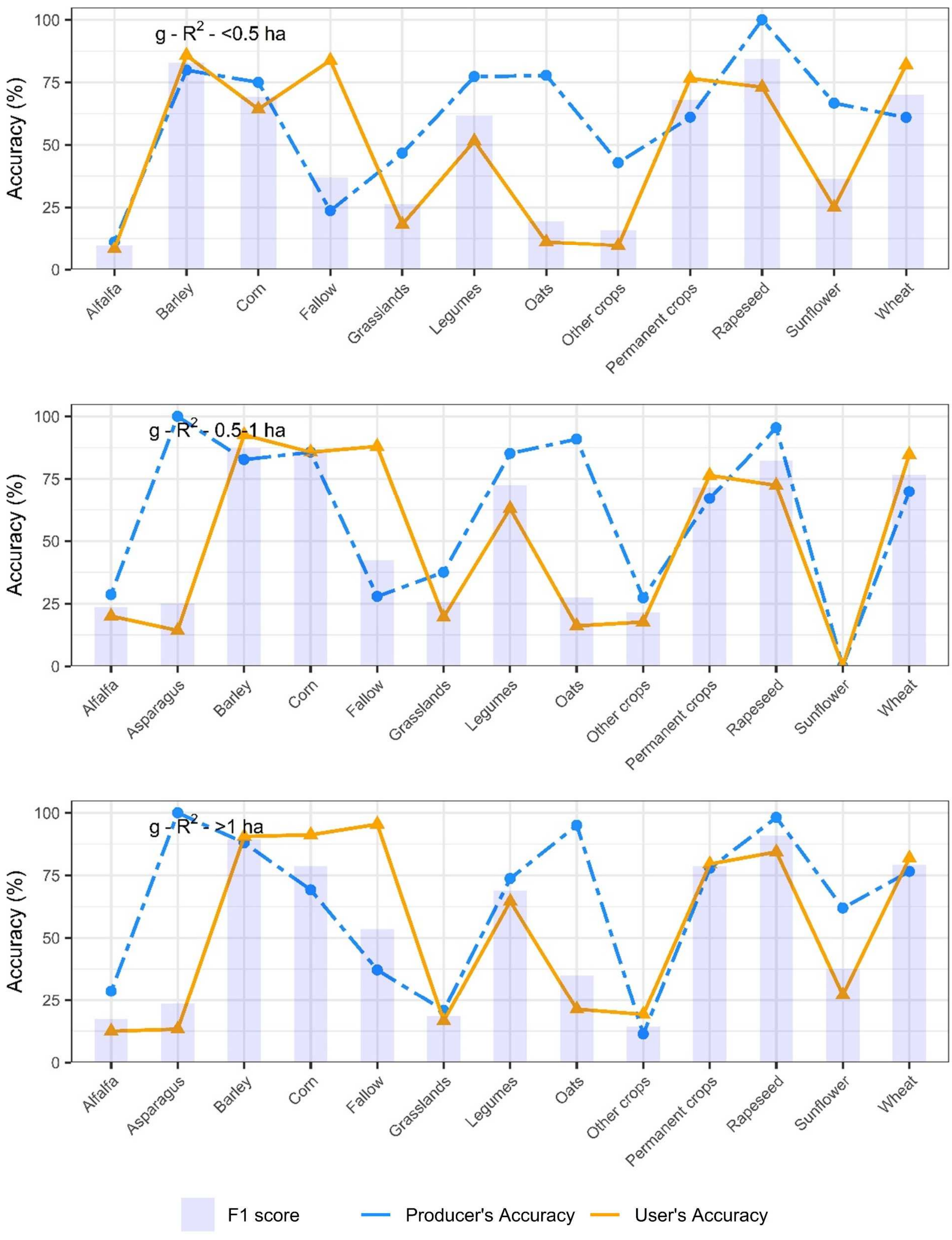


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. e) Region 5

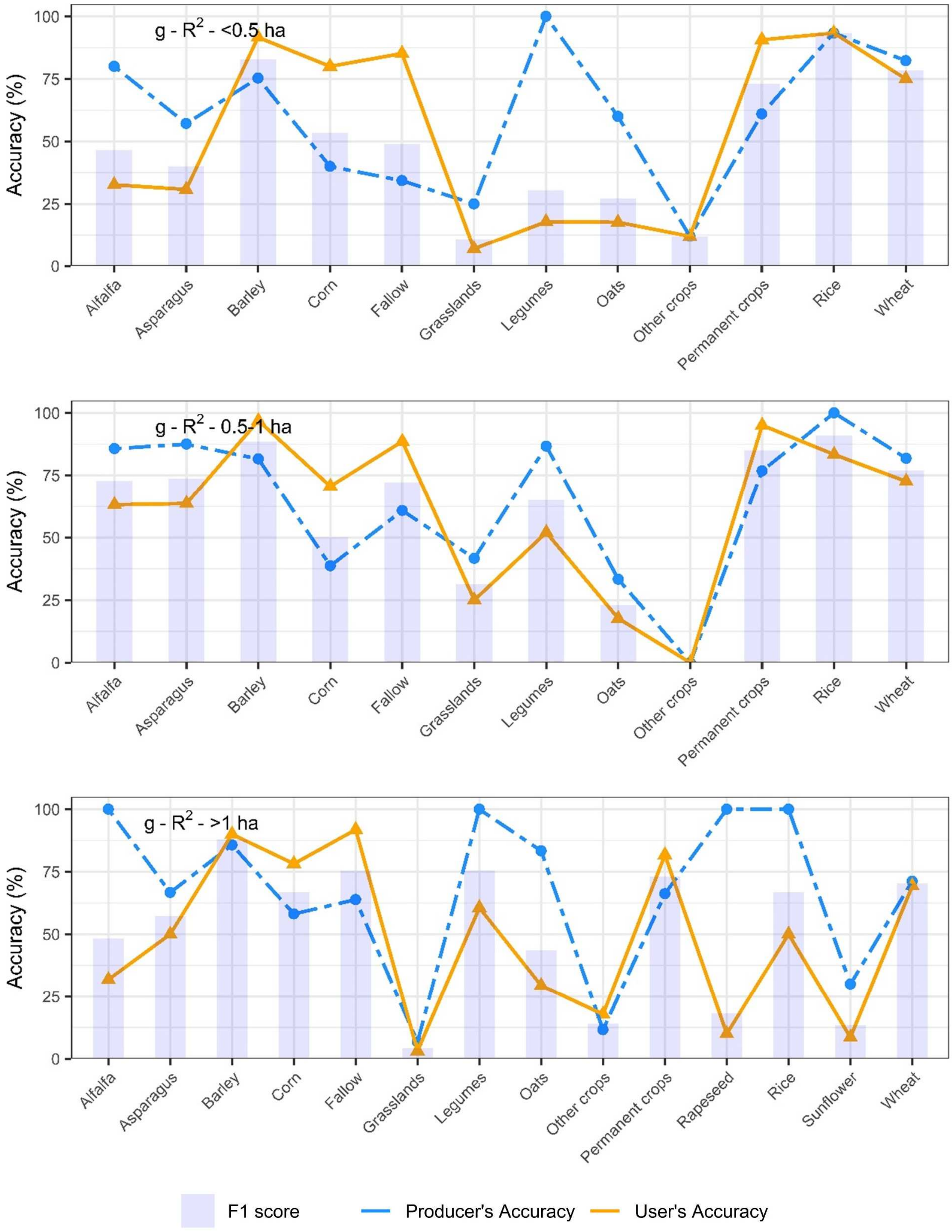


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. f) Region 6

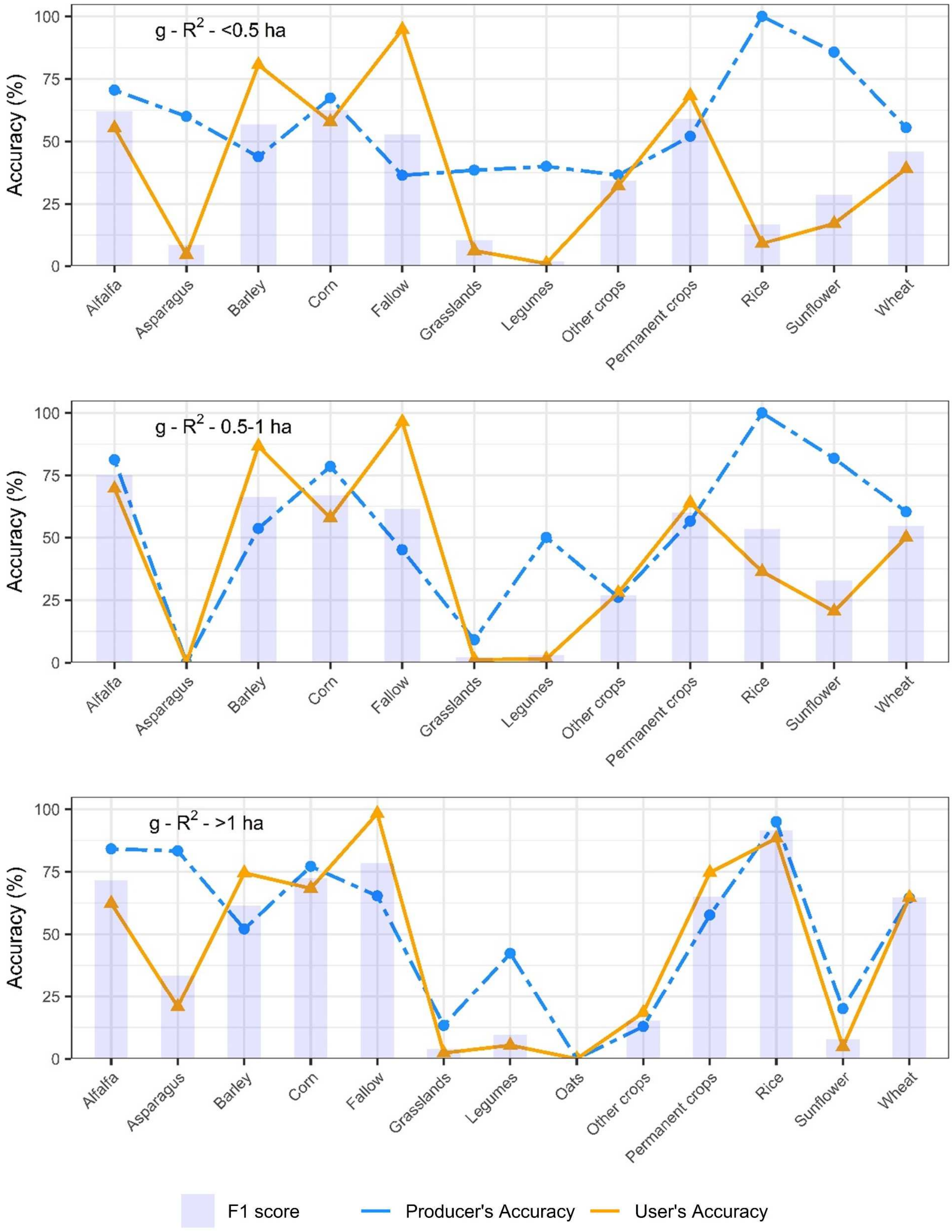


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. g) Region 7

Supplementary materials
Chapter 5

A new methodology for wheat attenuation correction at VV-polarized backscatter time series

1. Autocorrelation functions plots for the agricultural regions

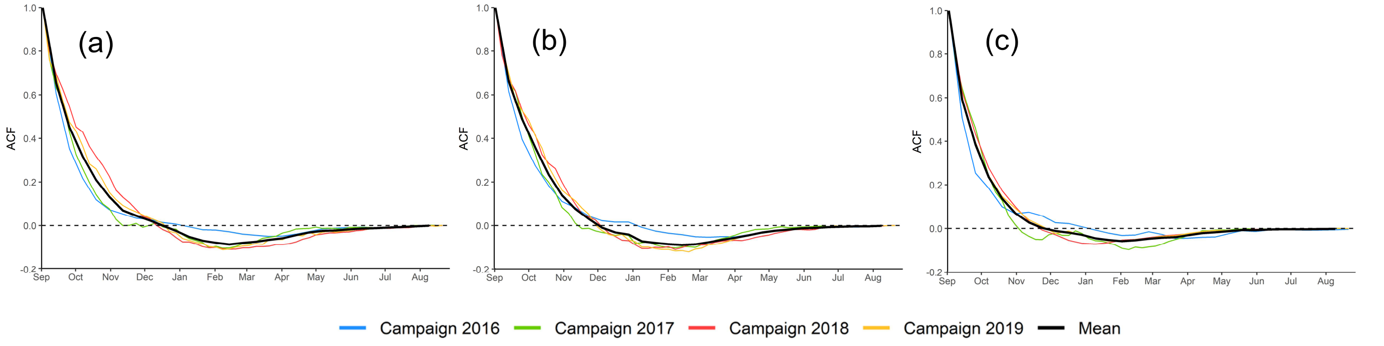


Fig. S1. Autocorrelation function plots of median wheat time series for Region 1. (a) Autocorrelation plot for 8DESC. (b) Autocorrelation plot for 81DESC. (c) Autocorrelation plot for 103ASC.

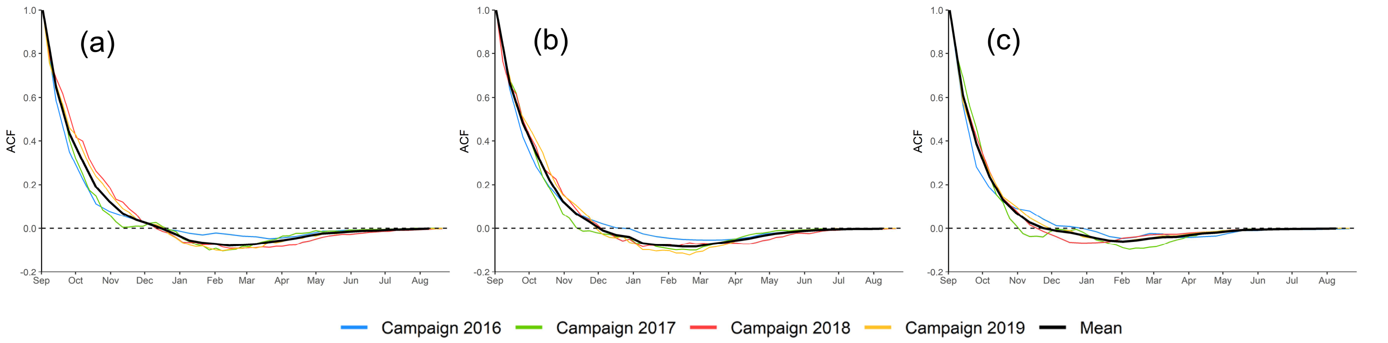


Fig. S2. Autocorrelation function plots of median wheat time series for Region 2. (a) Autocorrelation plot for 8DESC. (b) Autocorrelation plot for 81DESC. (c) Autocorrelation plot for 103ASC.

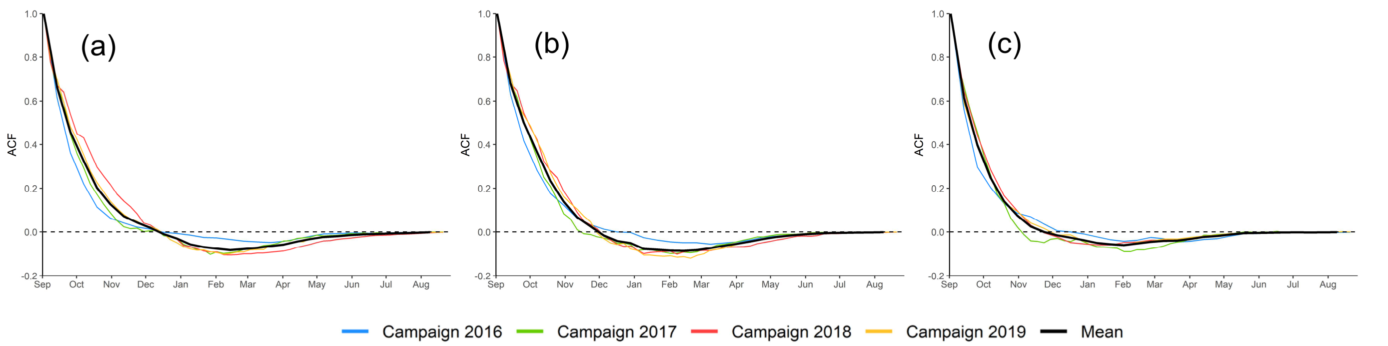


Fig. S3. Autocorrelation function plots of median wheat time series for Region 3. (a) Autocorrelation plot for 8DESC. (b) Autocorrelation plot for 81DESC. (c) Autocorrelation plot for 103ASC.

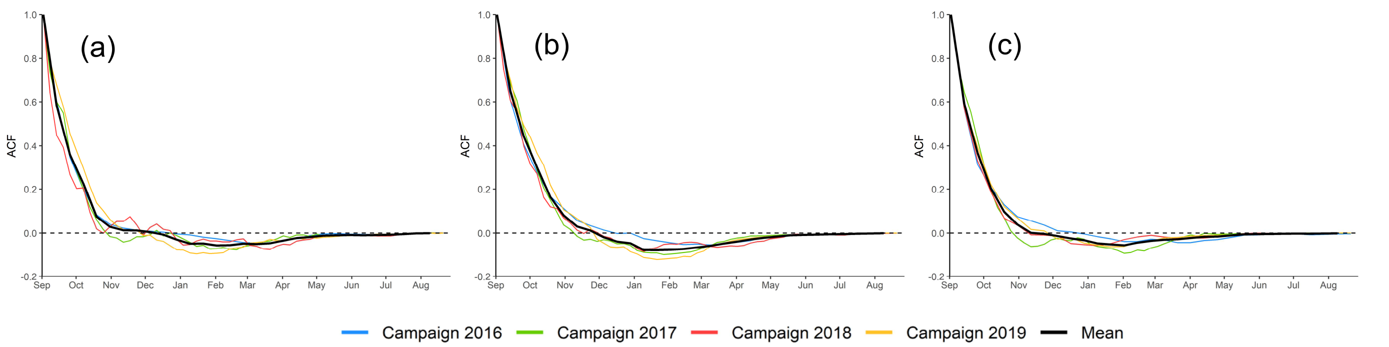


Fig. S4. Autocorrelation function plots of median wheat time series for Region 4. (a) Autocorrelation plot for 8DESC. (b) Autocorrelation plot for 81DESC. (c) Autocorrelation plot for 103ASC.

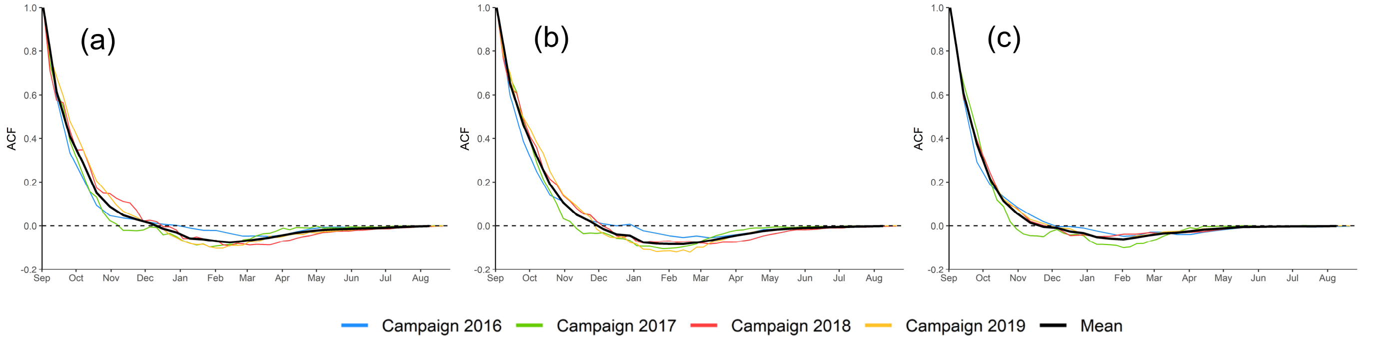


Fig. S5. Autocorrelation function plots of median wheat time series for Region 5. (a) Autocorrelation plot for 8DESC. (b) Autocorrelation plot for 81DESC. (c) Autocorrelation plot for 103ASC.

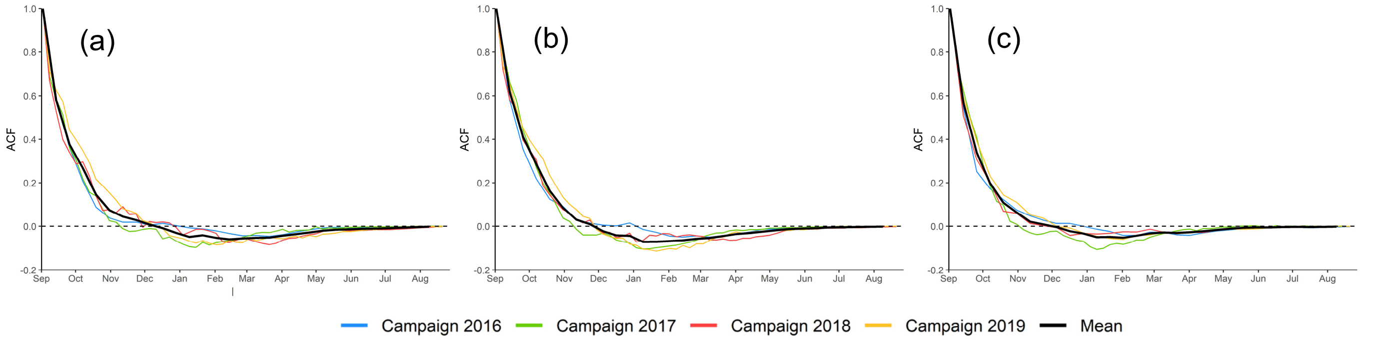


Fig. S6. Autocorrelation function plots of median wheat time series for Region 6. (a) Autocorrelation plot for 8DESC. (b) Autocorrelation plot for 81DESC. (c) Autocorrelation plot for 103ASC.

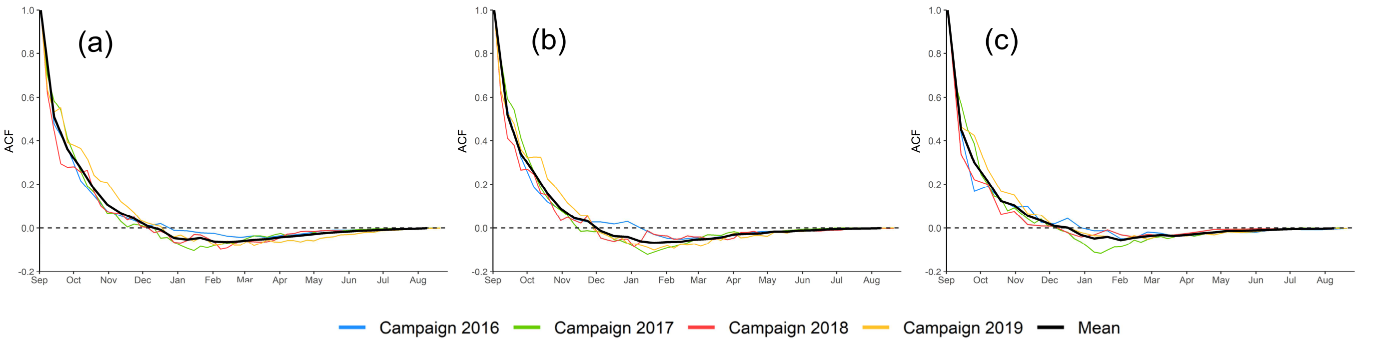


Fig. S7. Autocorrelation function plots of median wheat time series for Region 7. (a) Autocorrelation plot for 8DESC. (b) Autocorrelation plot for 81DESC. (c) Autocorrelation plot for 103ASC.

2. Moving average time series for the agricultural regions

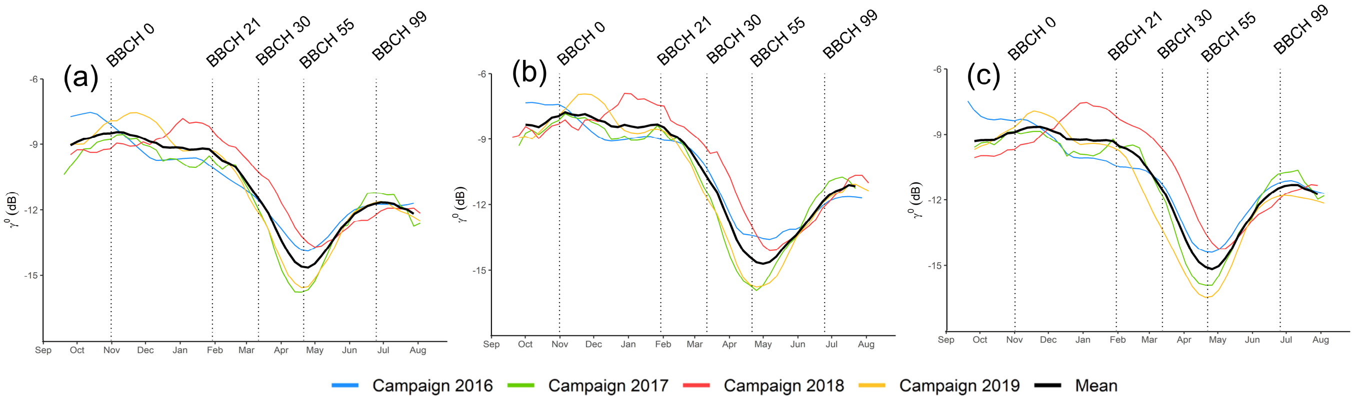


Fig. S8. Median smoothed Sentinel-1 VV time series for all wheat parcels in Region 1. Main phenological stages (BBCH scale) are represented by vertical lines (a) orbit 8DESC, (b) orbit 81DESC, (c) orbit 103ASC.

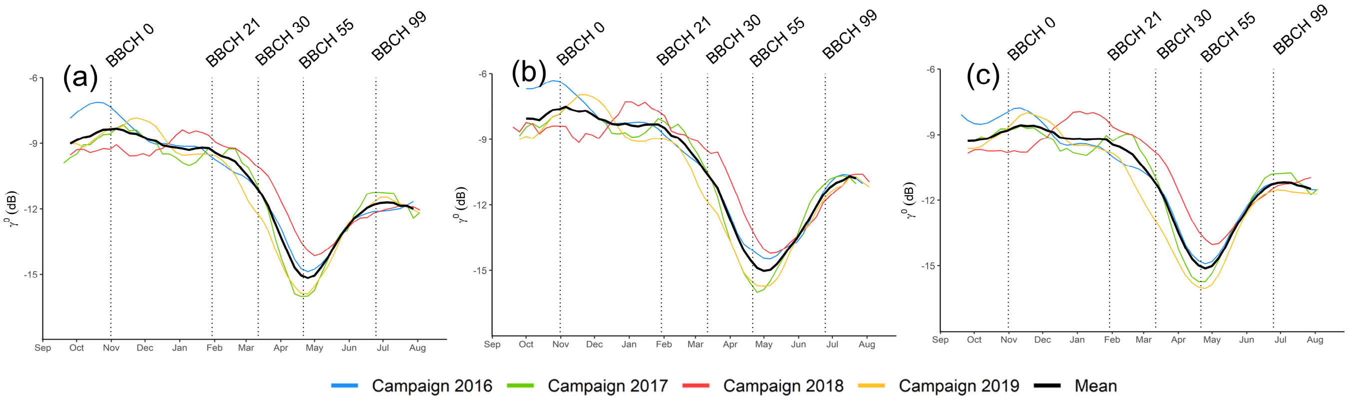


Fig. S9. Median smoothed Sentinel-1 VV time series for all wheat parcels in Region 2. Main phenological stages (BBCH scale) are represented by vertical lines (a) orbit 8DESC, (b) orbit 81DESC, (c) orbit 103ASC.

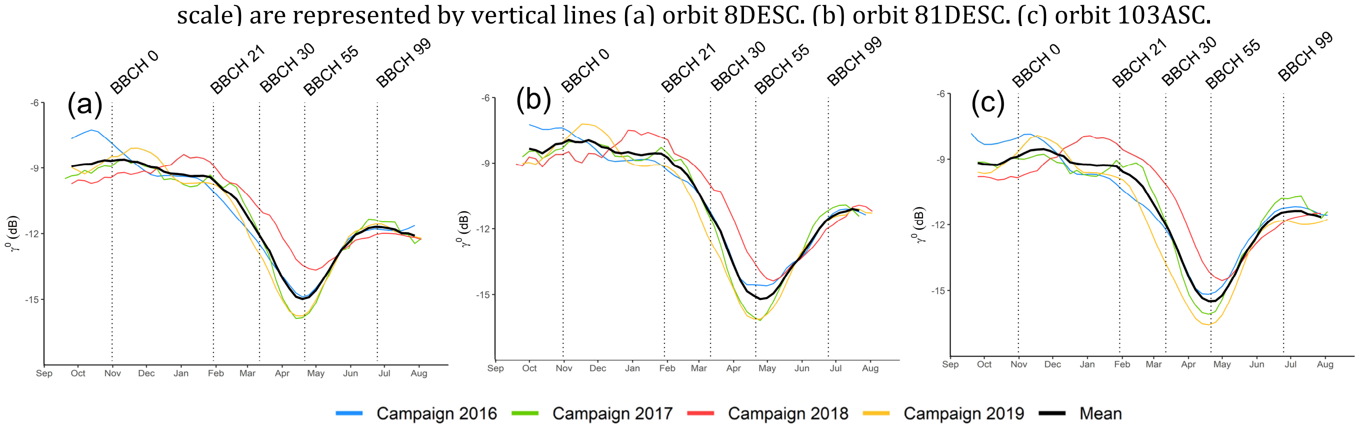


Fig. S10. Median smoothed Sentinel-1 VV time series for all wheat parcels in Region 3. Main phenological stages (BBCH scale) are represented by vertical lines (a) orbit 8DESC, (b) orbit 81DESC, (c) orbit 103ASC.

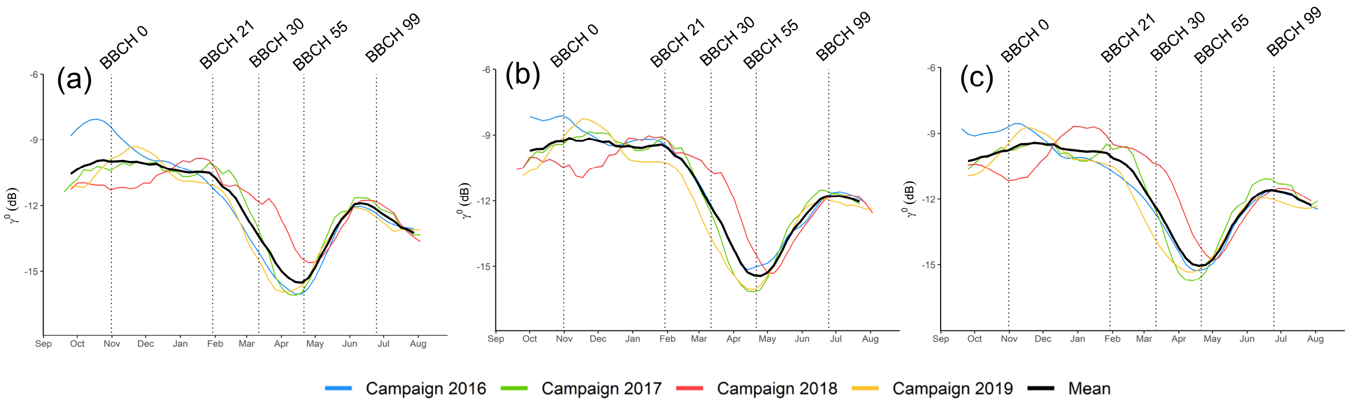


Fig. S11. Median smoothed Sentinel-1 VV time series for all wheat parcels in Region 4. Main phenological stages (BBCH scale) are represented by vertical lines (a) orbit 8DESC, (b) orbit 81DESC, (c) orbit 103ASC.

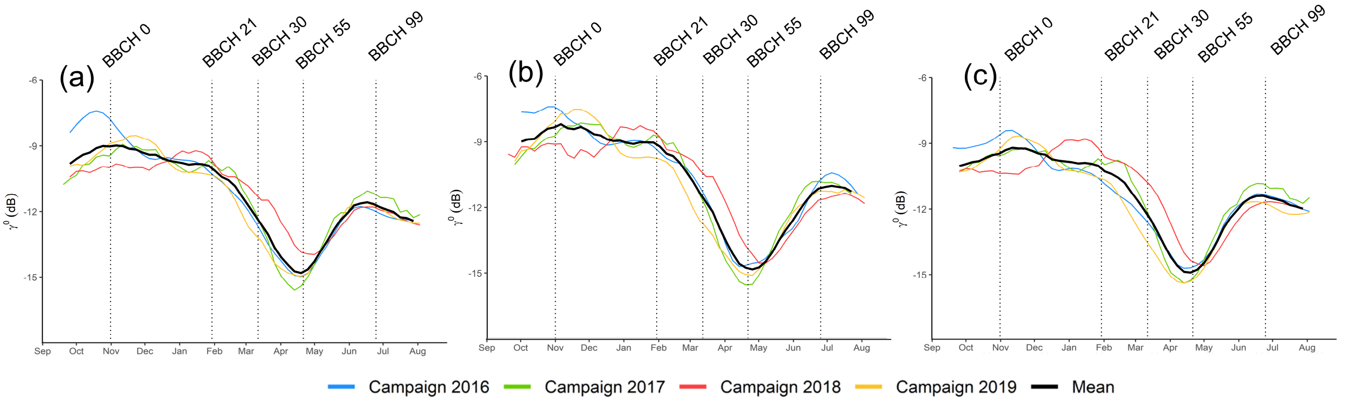


Fig. S12. Median smoothed Sentinel-1 VV time series for all wheat parcels in Region 5. Main phenological stages (BBCH scale) are represented by vertical lines (a) orbit 8DESC. (b) orbit 81DESC. (c) orbit 103ASC.

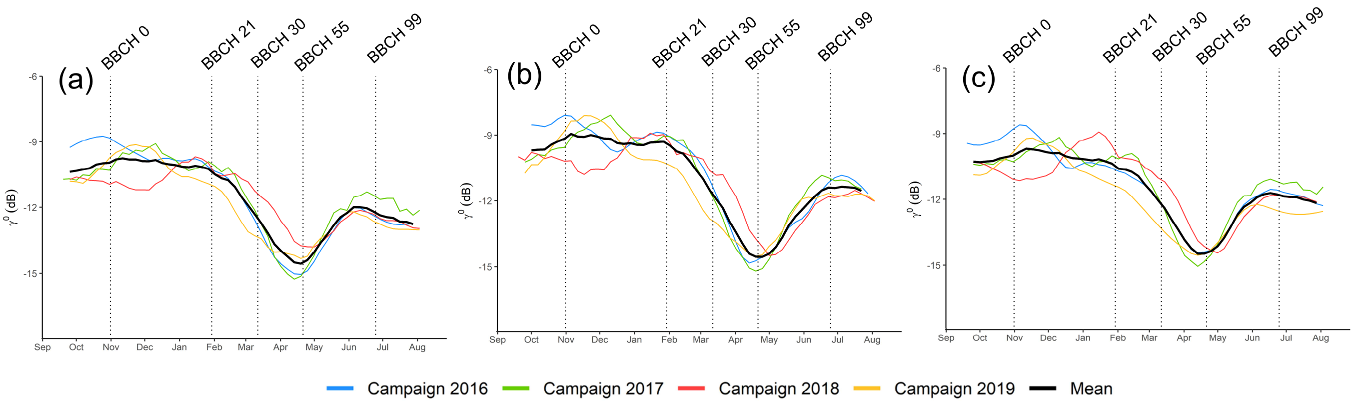


Fig. S13. Median smoothed Sentinel-1 VV time series for all wheat parcels in Region 6. Main phenological stages (BBCH scale) are represented by vertical lines (a) orbit 8DESC. (b) orbit 81DESC. (c) orbit 103ASC.

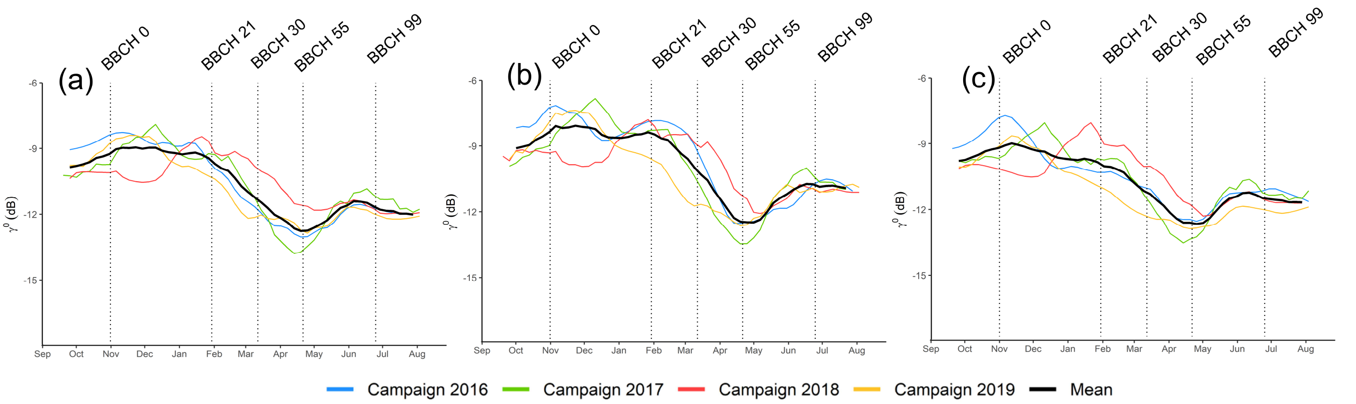


Fig. S14. Median smoothed Sentinel-1 VV time series for all wheat parcels in Region 7. Main phenological stages (BBCH scale) are represented by vertical lines (a) orbit 8DESC. (b) orbit 81DESC. (c) orbit 103ASC.

3. Effects of varying the parameters of S-G filter in the backscatter time series

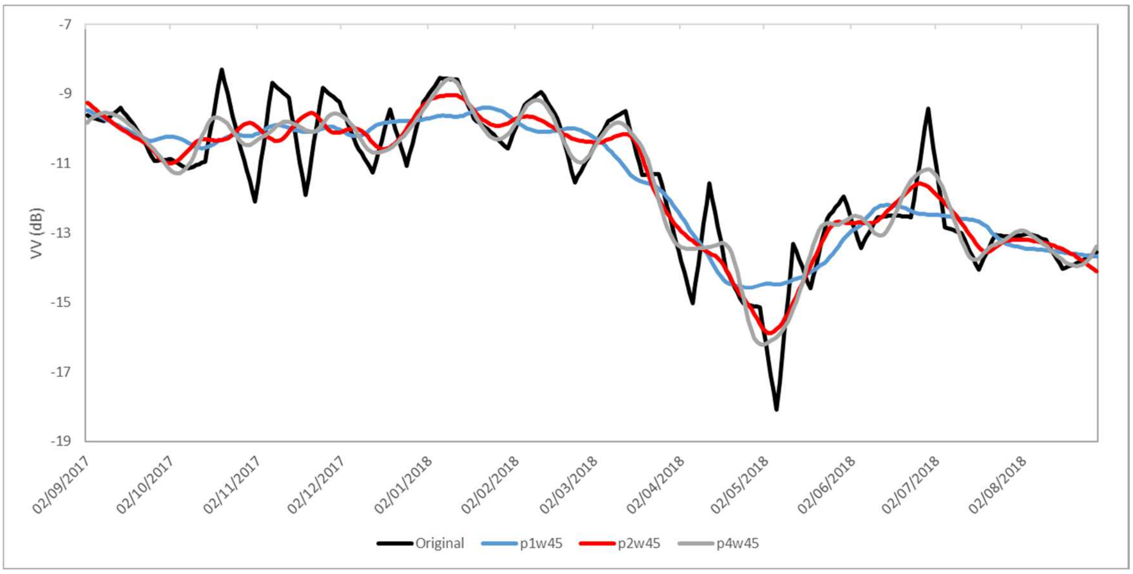


Fig. S15. Effect of varying *p* parameter in S-G filter in one wheat field

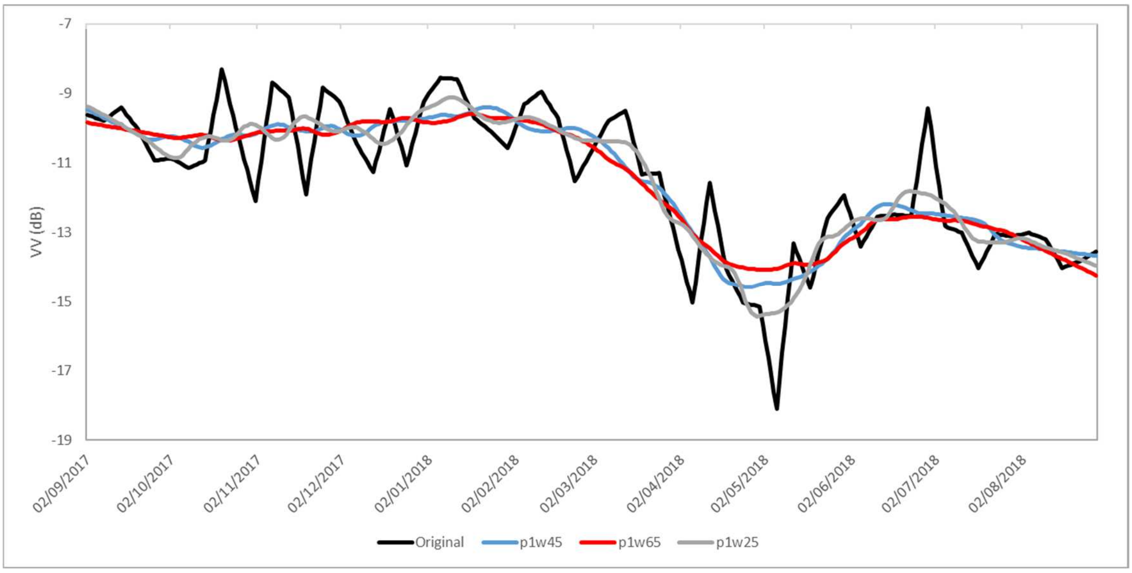


Fig. S16. Effect of varying *w* parameter in S-G filter in one wheat field

4. WCM parameters and validation results

TABLE S1
WCM PARAMETERS FOR NDVI DESCRIPTOR

Cross validation fold	A parameter	B parameter	C parameter	D parameter
1	0.000	0.543	2.363	0.072
2	0.000	0.533	2.130	0.075
3	0.000	0.525	2.233	0.073
4	0.000	0.546	2.024	0.079
5	0.000	0.532	2.218	0.074
6	0.000	0.538	2.226	0.074
Mean	0.000	0.536	2.199	0.074

TABLE S2
WCM PARAMETERS FOR NDWI DESCRIPTOR

Cross validation fold	A parameter	B parameter	C parameter	D parameter
1	0.000	0.622	2.209	0.047
2	0.000	0.607	2.044	0.048
3	0.000	0.603	2.144	0.047
4	0.000	0.620	1.897	0.051
5	0.000	0.604	2.068	0.048
6	0.000	0.609	2.087	0.048
Mean	0.000	0.611	2.075	0.048

TABLE S3
WCM PARAMETERS FOR VH/VV DESCRIPTOR

Cross validation fold	A parameter	B parameter	C parameter	D parameter
1	0.000	1.891	1.900	0.109
2	0.000	1.878	1.596	0.117
3	0.000	1.879	1.786	0.111
4	0.000	1.864	1.581	0.118
5	0.000	1.891	1.842	0.111
6	0.000	1.856	1.697	0.114
Mean	0.000	1.877	1.734	0.113

TABLE S4
WCM VALIDATION RESULTS FOR NDVI DESCRIPTOR

Cross validation fold	RMSE (dB)	R	BIAS (dB)
1	1.885	0.766	0.345
2	1.673	0.841	0.258
3	2.072	0.717	0.679
4	1.470	0.769	0.041
5	1.417	0.812	0.363
6	1.694	0.777	0.341
Mean	1.702	0.780	0.338

TABLE S5
WCM VALIDATION RESULTS FOR NDWI DESCRIPTOR

Cross validation fold	RMSE (dB)	R	BIAS (dB)
1	1.847	0.771	0.245
2	1.629	0.837	0.185
3	2.047	0.709	0.611
4	1.378	0.796	0.014
5	1.409	0.811	0.333
6	1.556	0.817	0.326
Mean	1.645	0.790	0.286

TABLE S6
WCM VALIDATION RESULTS FOR VH/VV DESCRIPTOR

Cross validation fold	RMSE (dB)	R	BIAS (dB)
1	1.853	0.776	0.374
2	1.860	0.781	0.182
3	2.046	0.683	0.248
4	1.505	0.770	0.358
5	1.441	0.799	0.304
6	1.723	0.783	0.486
Mean	1.738	0.765	0.325

5. Corrected backscatter time series

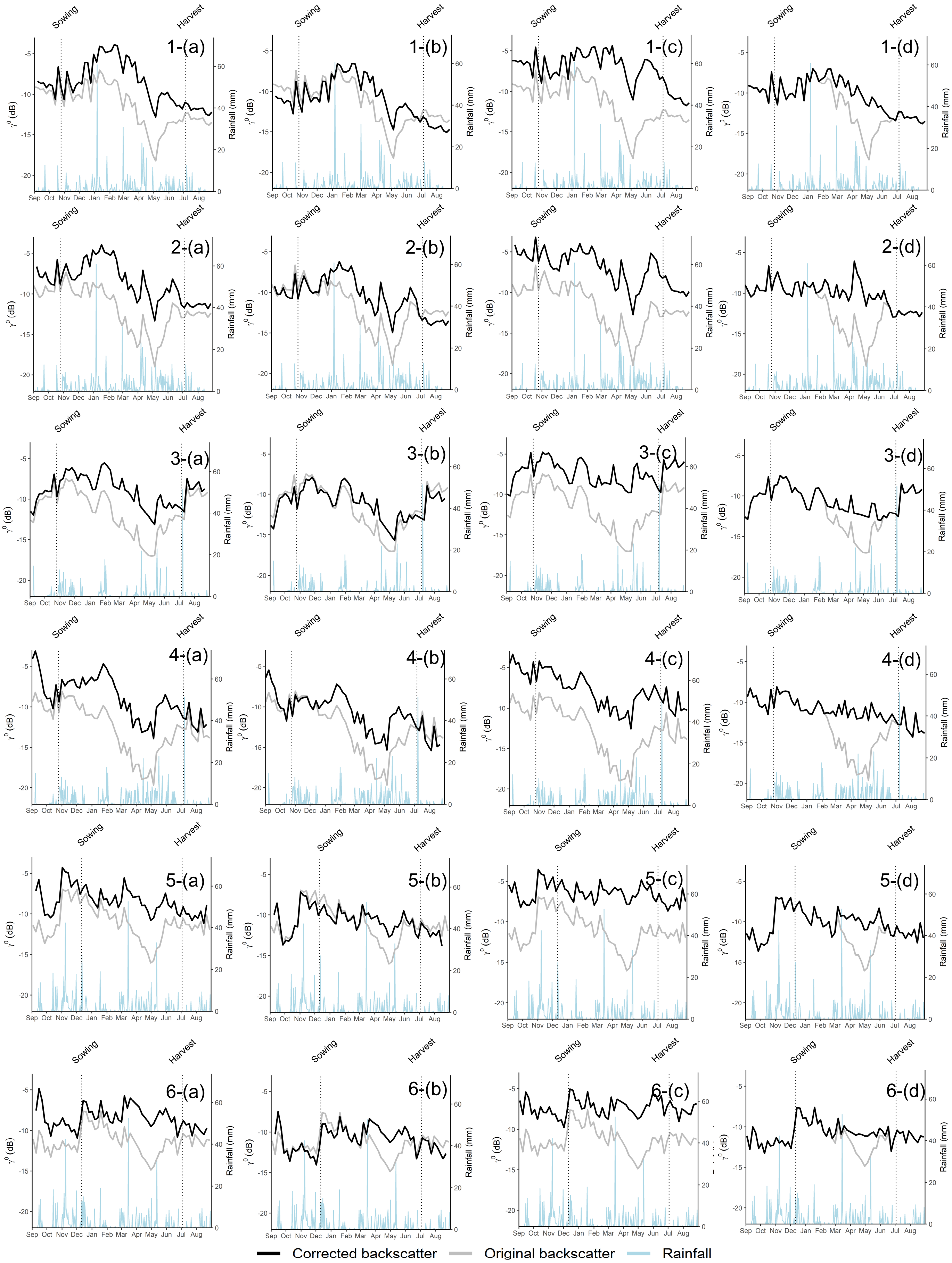


Fig. S17. Original and corrected backscatter time series for fields 1-6 for orbit 81DESC. The backscatter corrections are: (a) WCM-NDVI, (b) WCM-NDWI, (c) WCM-VH/VV (d,) WATCOR. Rainfall representation includes irrigation in irrigated fields

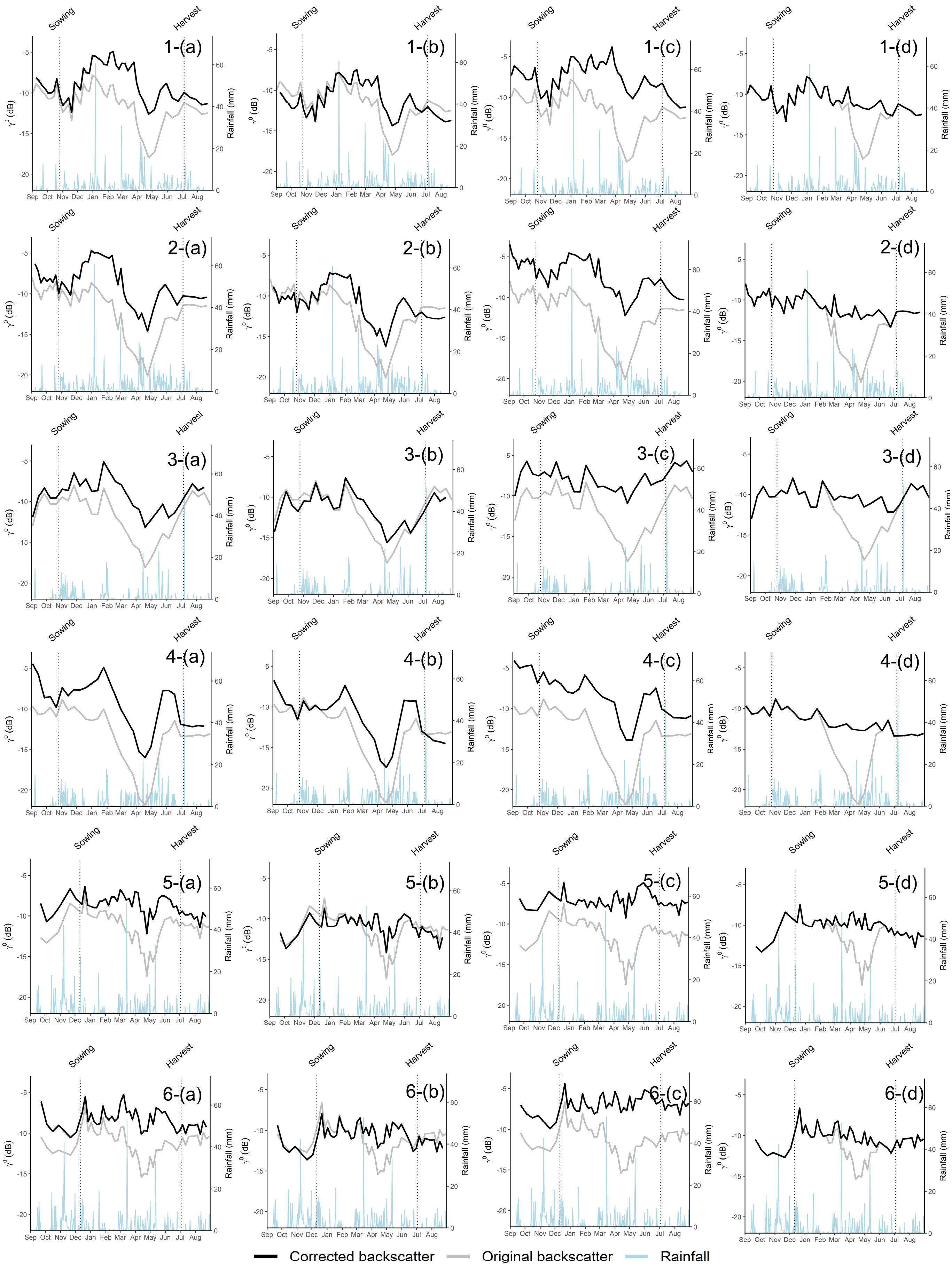


Fig. S18. Original and corrected backscatter time series for fields 1-6 for orbit 103ASC. The backscatter corrections are: (a) WCM-NDVI, (b) WCM-NDWI, (c) WCM-VH/VV (d,) WATCOR. Rainfall representation includes irrigation in irrigated fields.

6. Correlation results for individual fields

TABLE S7

PEARSON CORRELATION (R) RESULTS BETWEEN BACKSCATTER AND VOLUMETRIC SOIL MOISTURE FOR ALL FIELDS AND CORRECTION

Field	Orbit	R - Original	R - WCM NDVI	R- WCM NDWI	R – WCM VH/VV	R - WATCOR
1	8DESC	0.468	0.732	0.739	0.608	0.539
1	81DESC	0.665	0.835	0.844	0.694	0.797
1	103ASC	0.606	0.784	0.776	0.863	0.660
2	8DESC	-0.291	0.132	0.009	-0.093	0.645
2	81DESC	0.135	0.613	0.506	0.354	0.623
2	103ASC	0.055	0.336	0.246	0.479	0.632
3	8DESC	0.140	0.209	0.133	0.248	0.350
3	81DESC	0.303	0.208	0.139	0.560	0.304
3	103ASC	-0.078	0.005	-0.090	0.149	0.121
4	8DESC	-0.065	0.055	-0.008	0.091	0.348
4	81DESC	0.175	0.329	0.283	0.152	0.404
4	103ASC	0.019	0.136	0.078	0.239	-0.053
5	8DESC	0.063	0.321	0.326	0.185	0.470
5	81DESC	0.090	0.211	0.236	0.108	0.156
5	103ASC	-0.081	0.188	0.201	-0.060	0.437
6	8DESC	0.497	0.521	0.564	0.347	0.693
6	81DESC	0.440	0.357	0.417	0.165	0.477
6	103ASC	0.323	0.441	0.544	0.258	0.718

TABLE S8

PEARSON CORRELATION (R) RESULTS BETWEEN THE DIFFERENCES OF CONSECUTIVE DAYS OF BACKSCATTER AND VOLUMETRIC SOIL MOISTURE FOR ALL FIELDS AND CORRECTION

Field	Orbit	R - Original	R - WCM NDVI	R- WCM NDWI	R – WCM VH/VV	R - WATCOR
1	8DESC	0.530	0.513	0.530	0.548	0.473
1	81DESC	0.368	0.341	0.360	0.393	0.386
1	103ASC	0.408	0.355	0.387	0.478	0.279
2	8DESC	0.632	0.630	0.639	0.632	0.611
2	81DESC	0.604	0.612	0.608	0.620	0.641
2	103ASC	0.475	0.481	0.485	0.572	0.618
3	8DESC	0.538	0.586	0.581	0.586	0.627
3	81DESC	0.552	0.581	0.554	0.610	0.548
3	103ASC	0.043	0.058	-0.049	0.135	0.087
4	8DESC	0.552	0.585	0.575	0.568	0.636
4	81DESC	0.191	0.211	0.205	0.232	0.027
4	103ASC	0.242	0.589	0.571	0.347	0.031
5	8DESC	0.489	0.497	0.534	0.535	0.565
5	81DESC	-0.036	-0.042	0.008	0.025	-0.054
5	103ASC	0.385	0.398	0.438	0.407	0.401
6	8DESC	0.553	0.553	0.578	0.574	0.592
6	81DESC	0.233	0.189	0.246	0.265	0.245
6	103ASC	0.627	0.625	0.658	0.656	0.686

Supplementary materials
Chapter 6

Evaluation of soil moisture estimation techniques based on Sentinel-1 observation over wheat fields

1. Monthly ESA CCI values

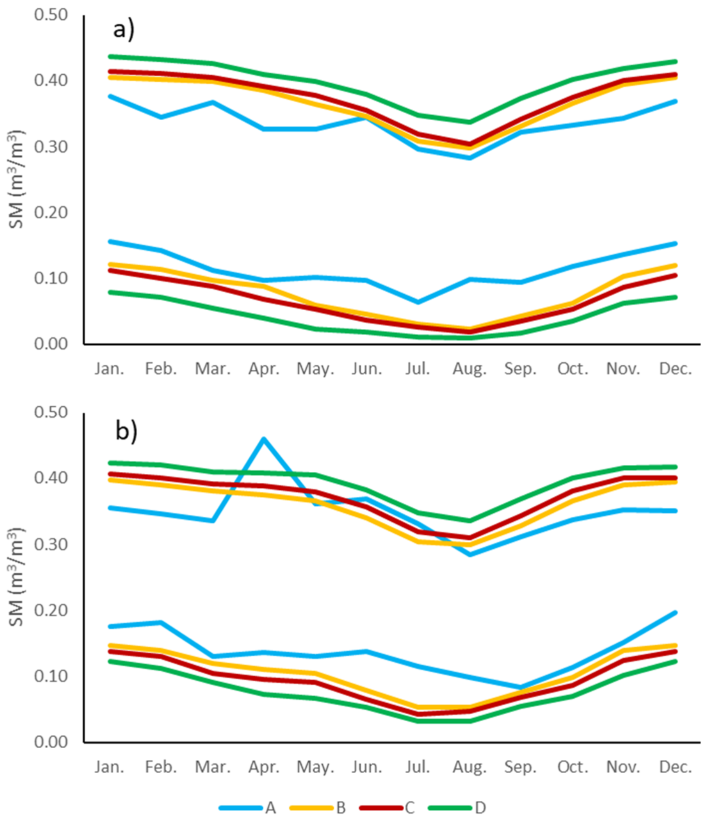


Figure S1. Monthly ESA CCI SM values for the different schemes considered. a) SM for fields 1, 2, 3, 4, 5 and 6; b) SM for fields 7 and 8.

2. Calibration results

In this section, the results for the calibration of the different techniques are presented. The best schemes are selected for further comparison among methodologies.

2.1. Short Term Change Detection (STCD) approach

Figure S2 represents the calibration results for the STCD approach. Bars show RMSE and R values obtained after comparing SM_{est} with SM_{obs} for the different N values tested, different schemes for constraining maximum and minimum SM conditions and for the two backscatter time series: γ^0_{CAN} and γ^0_{SOIL}. Obtained RMSE values ranged between 0.09 and 0.12, and R values between 0.15 and 0.45. Best results were obtained for short N values (N=4 observations), since for longer values RMSE increased, and R mostly decreased, although the behavior of R was not as consistent. Regarding the schemes tested for constraining maximum and minimum SM conditions, scheme A (max and min values in the ESA CCI SM time series) produced the highest RMSE values and the lowest correlations. Schemes B, C and D provided similar results in terms of RMSE, but in terms of R values better results were obtained as the considered maximum and minimum SM values were more extreme, with best results for scheme D. In most cases, γ^0_{SOIL} produces better results than γ^0_{CAN}, but differences were not very significant.

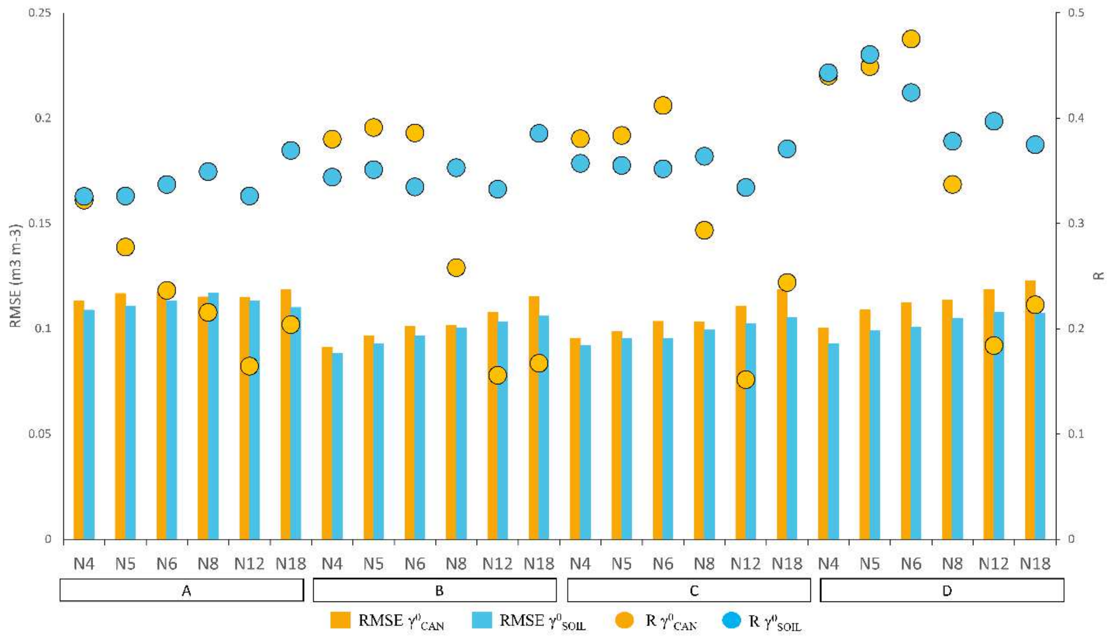


Fig. S2. Median RMSE and Correlation values between θ_{real} and θ_{est} for the STCD approach calibration schemes (A, B, C, D).

Considering both the RMSE and R results, scheme D and N=4 was chosen as the best option with almost the same results for γ^0_{SOIL} and γ^0_{CAN}.

2.2. TU Wien Change Detection (TUWCD) Model

Figure S3 shows the RMSE and R values obtained for the different schemes tested when implementing the TU Wien Change Detection Model. In this case, results improved clearly when applying the method to vegetation corrected γ^0_{SOIL} time series, with RMSE values of 0.083-0.189 m^3/m^3 and R values of ~0.45. With no vegetation correction (γ^0_{CAN}), RMSE values increased to 0.101-0.173 m^3/m^3 and correlation coefficients clearly decreased to ~0.20. Regarding the different schemes tested, optimum results were obtained for scheme 3, where the lower boundary (γ^0_{min}) corresponded to the absolute minimum, and the lower boundary (γ^0_{max}) to the 0.99 percentile. Results worsened when considering narrower higher percentiles for the minimum.

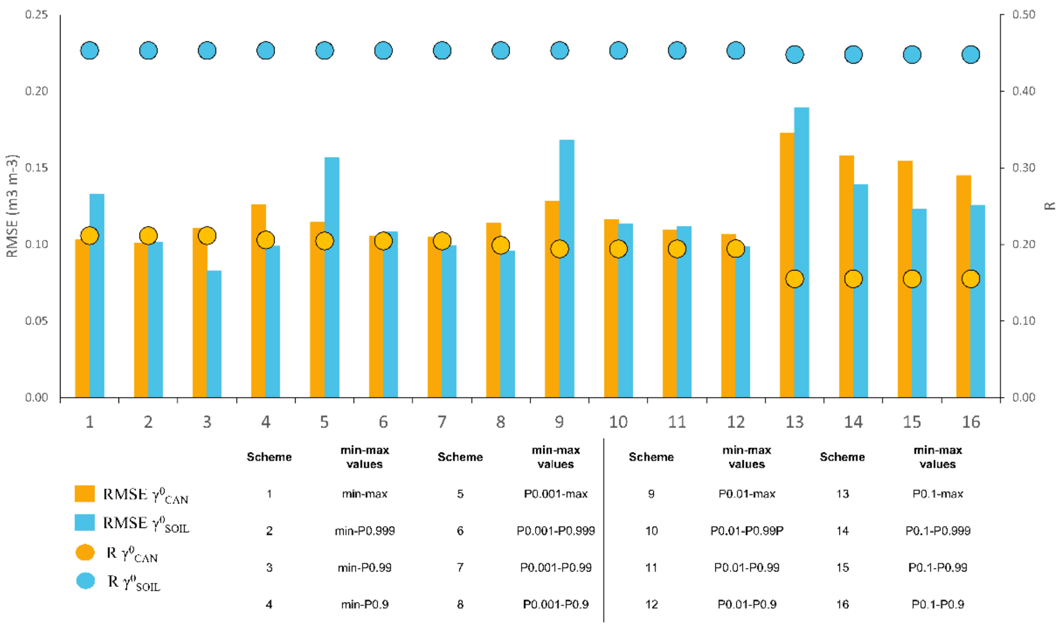


Fig. S3. Median RMSE and Correlation values between θ_{real} and θ_{est} for the Change Detection calibration schemes (1-16).

2.3. Multitemporal Bayesian change detection (MTBCD) approach

The optimization results for the roughness parameters *s* and *l* are presented in Figure S4. Low RMSE values (< 2dB) were obtained with different combinations of *s* and *l* for γ^0_{SOIL}. However, for higher *s* values, the number of (*s*,*l*) pairs with RMSE below 3 dB decreased. The lowest RMSE (2.17 dB) was achieved with *s*=0.4 and *l*=3, therefore, this set of roughness parameters was used for the implementation of the Multitemporal Bayesian approach, even though it still represents a relevant difference between measured and estimated values. This may have an impact on the retrieved variables. The RMSE values between γ^0_{CAN} and the IEM were worse, with higher minimum values (< 3dB).

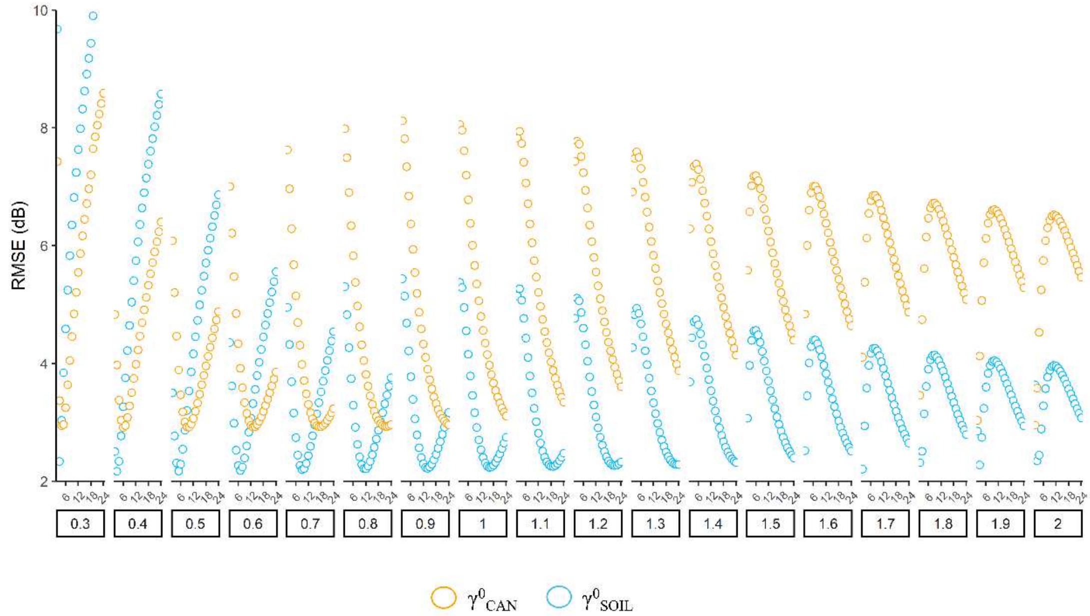
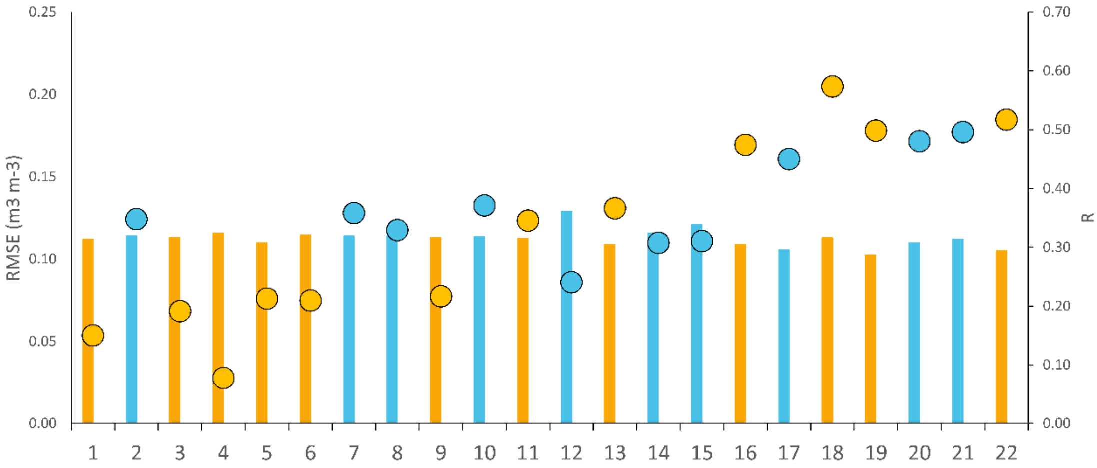


Fig. S4. RMSE between γ^0_{CAN} and γ^0_{SOIL} backscatter time series and IEM simulated time series for all wheat fields and every combination of roughness parameters (*s* and *l*)

2.4. Support Vector Regression

The RMSE and correlation results for the different SVR models fitted are displayed in figure S5. There were not great differences for RMSE and almost every set of input variables obtained a RMSE~0.11 cm^3/cm^3. In contrast, the correlation results clearly increased as further input variables were added to the SVR model. When using individual backscatter time series as predictors, γ^0_{SOIL} obtained better results than γ^0_{CAN}, γ^0_{VH} or the ratio VH/VV. Then, the combination of these four variables did not clearly enhance results. However, the addition of NDVI improved the correlation when combined with γ^0_{CAN} but interestingly it lowered R when combined with γ^0_{SOIL}. Furthermore, the addition of the variable "month" as input to the SVR models improved quite significantly the results, reaching correlation values ~0.5, independently of whether γ^0_{SOIL} or γ^0_{CAN} were used. Altogether, the combination of input variables γ^0_{CAN}, NDVI and month obtained the highest correlations (R=0.57), followed by γ^0_{CAN}, γ^0_{VH}, VH/VV, NDVI and month (R=0.52), and next by γ^0_{CAN}, γ^0_{VH}, VH/VV and month (R=0.50).



Scheme	Input variables	Scheme	Input variables
1	γ^0_{CAN}	12	γ^0_{SOIL}, NDVI
2	γ^0_{SOIL}	13	γ^0_{CAN}, γ^0_{VH}, VH/VV, NDVI
3	γ^0_{VH}	14	γ^0_{SOIL}, γ^0_{VH}, VH/VV, NDVI
4	VH/VV	15	γ^0_{CAN}, γ^0_{SOIL}, γ^0_{VH}, VH/VV, NDVI
5	γ^0_{CAN}, γ^0_{VH}	16	γ^0_{CAN}, month
6	γ^0_{CAN}, VH/VV	17	γ^0_{SOIL}, month
7	γ^0_{SOIL}, γ^0_{VH}	18	γ^0_{CAN}, NDVI, month
8	γ^0_{SOIL}, VH/VV	19	γ^0_{CAN}, γ^0_{VH}, VH/VV, month
9	γ^0_{CAN}, γ^0_{VH}, VH/VV	20	γ^0_{SOIL}, γ^0_{VH}, VH/VV, month
10	γ^0_{SOIL}, γ^0_{VH}, VH/VV	21	γ^0_{CAN}, γ^0_{SOIL}, γ^0_{VH}, VH/VV, month
11	γ^0_{CAN}, NDVI	22	γ^0_{CAN}, γ^0_{VH}, VH/VV, NDVI, month

Fig. S5. Median RMSE and Correlation values between θ_{real} and θ_{est} for the different input variables in SVR.

For further analysis, the best schemes based on Sentinel-1 were selected (avoiding the inclusion of Sentinel-2 derived NDVI, which might not be always available). Therefore, the outputs of scheme 19 (γ^0_{CAN}, γ^0_{VH}, VH/VV and month) and scheme 20 (γ^0_{SOIL}, γ^0_{VH}, VH/VV and month) were chosen. In this study, SVR models provided best results when considering all the backscatter input variables and, very importantly, when adding the month as an input variable. In this case, the vegetation correction did not provide any benefits in the estimations.

3. Comparison between methodologies

Table S1. RMSE results for the different SM estimation techniques

Field	Orbit Pass	RMSE (m^3/m^3) STCD γ^0_{CAN}	STCD γ^0_{SOIL}	TUWCD γ^0_{CAN}	TUWCD γ^0_{SOIL}	MTBCD γ^0_{CAN}	MTBCD γ^0_{SOIL}	SVR γ^0_{CAN}	SVR γ^0_{SOIL}
1	8DESC	0.116	0.114	0.154	0.165	0.119	0.115	0.141	0.158
1	81DESC	0.116	0.113	0.119	0.134	0.129	0.123	0.138	0.133
1	103ASC	0.098	0.106	0.121	0.134	0.109	0.114	0.112	0.127
2	8DESC	0.095	0.091	0.141	0.104	0.159	0.096	0.107	0.119
2	81DESC	0.091	0.084	0.128	0.113	0.136	0.119	0.116	0.115
2	103ASC	0.103	0.092	0.143	0.100	0.151	0.120	0.107	0.103
3	8DESC	0.064	0.063	0.055	0.056	0.106	0.103	0.086	0.099
3	81DESC	0.070	0.069	0.055	0.052	0.072	0.078	0.098	0.113
3	103ASC	0.085	0.076	0.065	0.060	0.099	0.052	0.083	0.081
4	8DESC	0.078	0.079	0.133	0.075	0.178	0.146	0.110	0.161
4	81DESC	0.067	0.072	0.137	0.066	0.124	0.088	0.114	0.120
4	103ASC	0.122	0.073	0.147	0.075	0.147	0.115	0.081	0.076
5	8DESC	0.122	0.122	0.073	0.050	0.085	0.122	0.108	0.117
5	81DESC	0.118	0.118	0.077	0.065	0.077	0.074	0.097	0.096
5	103ASC	0.123	0.125	0.077	0.054	0.094	0.088	0.150	0.132
6	8DESC	0.107	0.108	0.059	0.062	0.063	0.119	0.090	0.100
6	81DESC	0.096	0.093	0.062	0.069	0.073	0.081	0.076	0.079
6	103ASC	0.104	0.103	0.074	0.059	0.077	0.089	0.104	0.089
7	8DESC	0.131	0.144	0.112	0.154	0.117	0.105	0.115	0.115
7	81DESC	0.134	0.147	0.109	0.165	0.125	0.165	0.099	0.106
7	103ASC	0.128	0.141	0.106	0.137	0.128	0.142	0.101	0.131
8	8DESC	0.081	0.081	0.120	0.137	0.132	0.097	0.082	0.093
8	81DESC	0.084	0.090	0.115	0.132	0.138	0.140	0.089	0.104
8	103ASC	0.092	0.092	0.100	0.091	0.130	0.091	0.087	0.093

Table S2. BIAS results for the different SM estimation techniques

Field	Orbit Pass	BIAS (m^3/m^3)							
		STCD γ^0_{CAN}	STCD γ^0_{SOIL}	TUWCD γ^0_{CAN}	TUWCD γ^0_{SOIL}	MTBCD γ^0_{CAN}	MTBCD γ^0_{SOIL}	SVR γ^0_{CAN}	SVR γ^0_{SOIL}
1	8DESC	0.045	0.041	0.099	0.119	0.049	0.033	0.103	0.109
1	81DESC	0.034	0.034	0.054	0.095	0.089	0.092	0.107	0.104
1	103ASC	0.017	0.013	0.059	0.070	0.057	0.018	0.063	0.103
2	8DESC	-0.028	-0.026	0.001	0.044	-0.048	-0.028	0.028	0.007
2	81DESC	-0.020	-0.018	-0.026	0.054	0.004	0.062	0.037	0.036
2	103ASC	-0.035	-0.033	-0.063	0.004	-0.077	-0.057	-0.010	0.017
3	8DESC	-0.020	-0.016	0.013	0.031	-0.089	-0.090	-0.002	-0.040
3	81DESC	-0.028	-0.025	-0.002	0.012	-0.018	-0.057	-0.013	-0.028
3	103ASC	-0.058	-0.045	-0.003	0.038	-0.042	-0.023	-0.045	-0.049
4	8DESC	-0.014	-0.023	-0.095	-0.041	-0.157	-0.133	-0.094	-0.140
4	81DESC	-0.051	-0.047	-0.118	-0.042	-0.104	-0.077	-0.105	-0.107
4	103ASC	-0.072	-0.056	-0.101	-0.050	-0.102	-0.104	-0.066	-0.044
5	8DESC	-0.107	-0.108	0.022	0.006	-0.022	-0.108	-0.073	-0.081
5	81DESC	-0.101	-0.100	0.023	0.021	0.014	-0.044	-0.065	-0.069
5	103ASC	-0.106	-0.108	-0.004	0.015	-0.020	-0.070	-0.106	-0.105
6	8DESC	-0.091	-0.092	-0.030	-0.046	-0.016	-0.109	-0.056	-0.068
6	81DESC	-0.077	-0.075	-0.015	-0.038	0.038	-0.058	-0.042	-0.056
6	103ASC	-0.089	-0.090	-0.040	-0.035	0.004	-0.073	-0.066	-0.055
7	8DESC	0.066	0.079	0.058	0.107	0.068	0.011	0.068	0.070
7	81DESC	0.051	0.065	0.059	0.110	0.094	0.117	0.044	0.047
7	103ASC	0.050	0.063	0.062	0.073	0.100	0.097	0.056	0.068
8	8DESC	0.014	0.018	0.032	0.103	0.031	0.017	0.034	0.047
8	81DESC	0.002	0.011	0.036	0.093	0.064	0.102	0.004	0.012
8	103ASC	0.022	0.031	0.041	0.043	0.072	0.047	0.021	0.015

Table S3. ubRMSE results for the different SM estimation techniques

Field	Orbit Pass	ubRMSE (m^3/m^3)							
		STCD γ^0_{CAN}	STCD γ^0_{SOIL}	TUWCD γ^0_{CAN}	TUWCD γ^0_{SOIL}	MTBCD γ^0_{CAN}	MTBCD γ^0_{SOIL}	SVR γ^0_{CAN}	SVR γ^0_{SOIL}
1	8DESC	0.107	0.106	0.118	0.114	0.108	0.111	0.096	0.115
1	81DESC	0.111	0.108	0.106	0.095	0.094	0.082	0.088	0.083
1	103ASC	0.096	0.105	0.106	0.114	0.093	0.112	0.092	0.074
2	8DESC	0.091	0.087	0.141	0.095	0.151	0.092	0.103	0.119
2	81DESC	0.088	0.082	0.126	0.099	0.136	0.102	0.110	0.109
2	103ASC	0.097	0.086	0.128	0.100	0.130	0.105	0.107	0.102
3	8DESC	0.061	0.061	0.053	0.046	0.058	0.049	0.086	0.091
3	81DESC	0.063	0.064	0.055	0.051	0.070	0.053	0.098	0.110
3	103ASC	0.062	0.061	0.065	0.047	0.090	0.046	0.070	0.065
4	8DESC	0.076	0.076	0.094	0.062	0.084	0.060	0.056	0.079
4	81DESC	0.044	0.054	0.070	0.051	0.067	0.042	0.045	0.054
4	103ASC	0.099	0.046	0.108	0.055	0.106	0.048	0.047	0.062
5	8DESC	0.059	0.056	0.069	0.049	0.083	0.055	0.079	0.085
5	81DESC	0.061	0.061	0.074	0.061	0.075	0.060	0.072	0.067
5	103ASC	0.063	0.063	0.077	0.052	0.092	0.053	0.107	0.080
6	8DESC	0.056	0.056	0.051	0.042	0.061	0.047	0.070	0.074
6	81DESC	0.057	0.055	0.060	0.057	0.063	0.056	0.063	0.056
6	103ASC	0.053	0.052	0.062	0.048	0.077	0.052	0.081	0.070
7	8DESC	0.114	0.120	0.095	0.111	0.095	0.104	0.092	0.091
7	81DESC	0.124	0.132	0.092	0.123	0.082	0.117	0.088	0.095
7	103ASC	0.118	0.126	0.087	0.116	0.079	0.104	0.084	0.112
8	8DESC	0.079	0.079	0.116	0.090	0.128	0.096	0.075	0.080
8	81DESC	0.083	0.089	0.109	0.094	0.122	0.096	0.089	0.103
8	103ASC	0.089	0.087	0.091	0.080	0.108	0.077	0.085	0.092

Table S4. Correlation results for the different SM estimation techniques

Field	Orbit Pass	R							
		STCD γ^0_{CAN}	STCD γ^0_{SOIL}	TUWCD γ^0_{CAN}	TUWCD γ^0_{SOIL}	MTBCD γ^0_{CAN}	MTBCD γ^0_{SOIL}	SVR γ^0_{CAN}	SVR γ^0_{SOIL}
1	8DESC	0.618	0.639	0.468	0.539	0.591	0.630	0.903	0.503
1	81DESC	0.675	0.748	0.665	0.797	0.752	0.843	0.843	0.886
1	103ASC	0.764	0.712	0.606	0.660	0.718	0.718	0.758	0.856
2	8DESC	0.658	0.719	-0.291	0.645	-0.432	0.665	0.621	0.248
2	81DESC	0.779	0.826	0.135	0.623	0.030	0.553	0.428	0.451
2	103ASC	0.594	0.735	0.055	0.734	0.035	0.604	0.440	0.513
3	8DESC	0.183	0.197	0.140	0.350	0.039	0.215	0.050	0.221
3	81DESC	0.160	0.100	0.303	0.304	0.114	0.223	-0.103	-0.107
3	103ASC	-0.128	0.024	-0.078	0.121	-0.077	0.310	0.373	0.457
4	8DESC	0.178	0.182	-0.065	0.348	-0.171	0.291	0.554	0.523
4	81DESC	0.671	0.534	0.175	0.404	0.236	0.784	0.747	0.641
4	103ASC	0.039	0.484	0.019	-0.053	0.007	0.423	0.644	0.627
5	8DESC	0.417	0.429	0.063	0.470	-0.016	0.358	0.347	0.304
5	81DESC	0.310	0.315	0.090	0.156	0.188	0.273	0.470	0.556
5	103ASC	0.281	0.259	-0.081	0.437	-0.107	0.362	-0.033	0.187
6	8DESC	0.615	0.603	0.497	0.693	0.425	0.594	0.490	0.451
6	81DESC	0.589	0.605	0.440	0.477	0.441	0.521	0.586	0.697
6	103ASC	0.624	0.634	0.323	0.718	0.197	0.576	0.386	0.417
7	8DESC	0.367	0.251	0.631	0.488	0.671	0.580	0.687	0.704
7	81DESC	0.345	0.225	0.716	0.367	0.784	0.489	0.802	0.697
7	103ASC	0.360	0.168	0.760	0.496	0.779	0.603	0.821	0.511
8	8DESC	0.473	0.457	0.127	0.099	0.147	0.049	0.507	0.434
8	81DESC	0.463	0.381	0.248	0.117	0.254	0.119	0.375	0.238
8	103ASC	0.223	0.257	0.325	0.407	0.324	0.510	0.415	0.208