

Crop classification based on temporal signatures of Sentinel-1 observations over Navarra province, Spain

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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		
	N° of fields	Area (ha)	Mean area (ha)	N° 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		
	N° of fields	Area (ha)	Mean area (ha)	N° 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		
	N° of fields	Area (ha)	Mean area (ha)	N° 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

	N° of fields	Area (ha)	Mean area (ha)	N° 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		
	N° of fields	Area (ha)	Mean area (ha)	N° 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		
	N° of fields	Area (ha)	Mean area (ha)	N° 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).

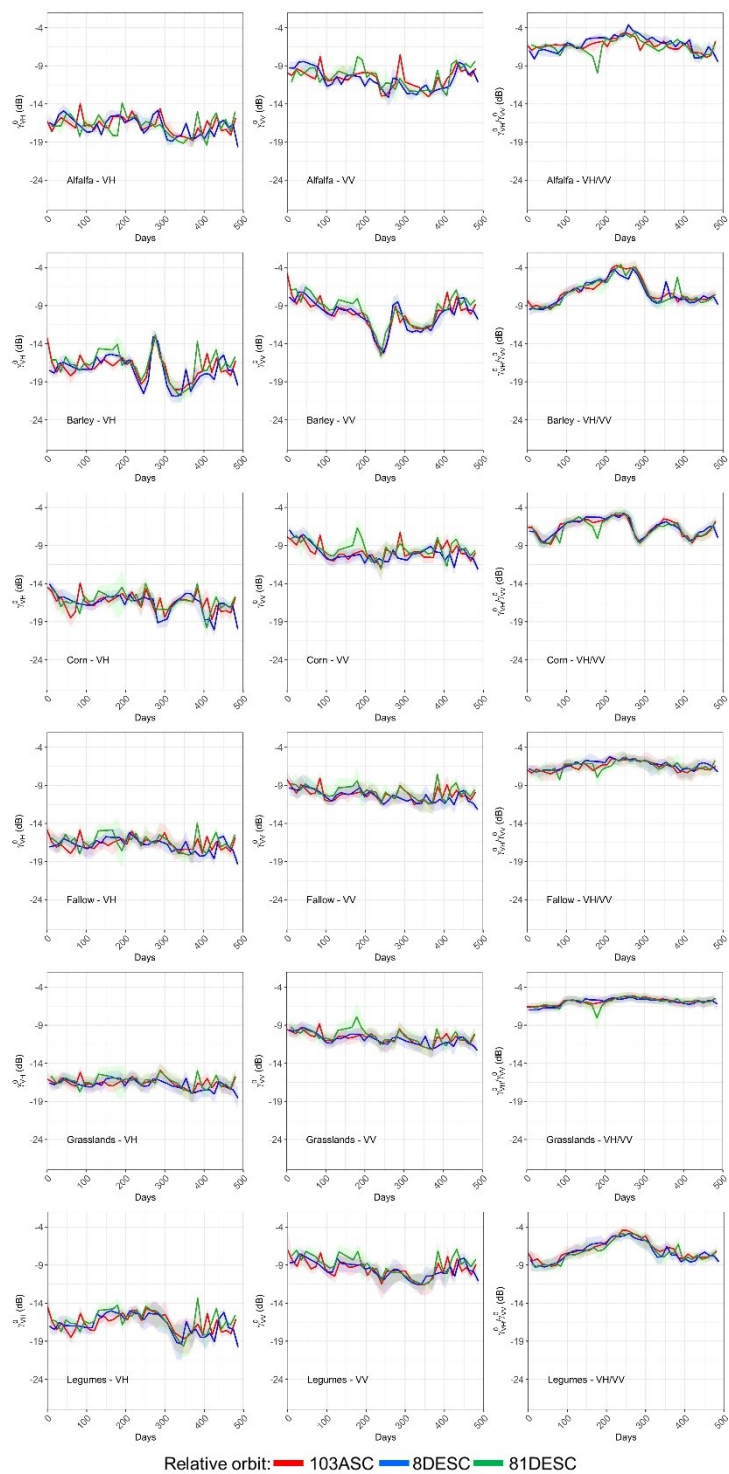


Figure S1. Median temporal signatures of crops for VH, VV and VH/VV. a) Region 1.

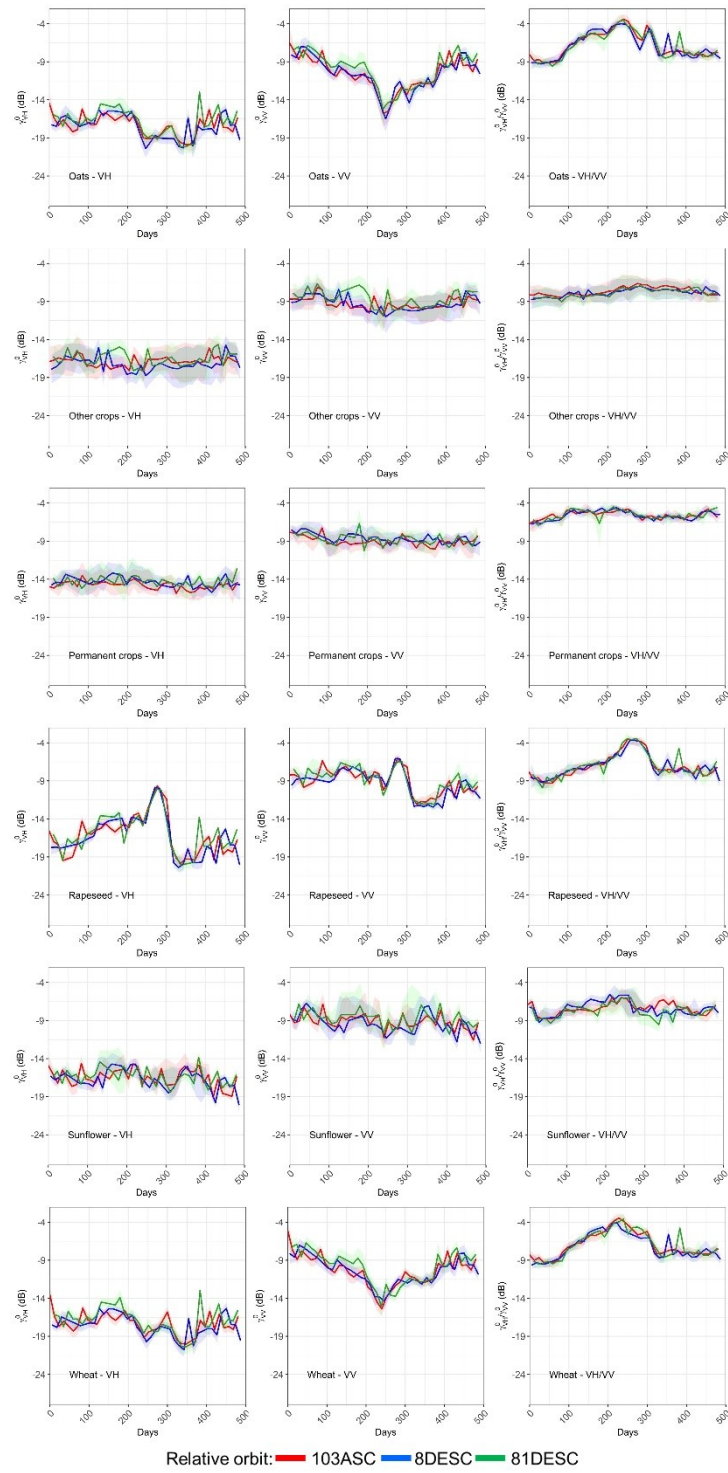


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. a) Region 1.

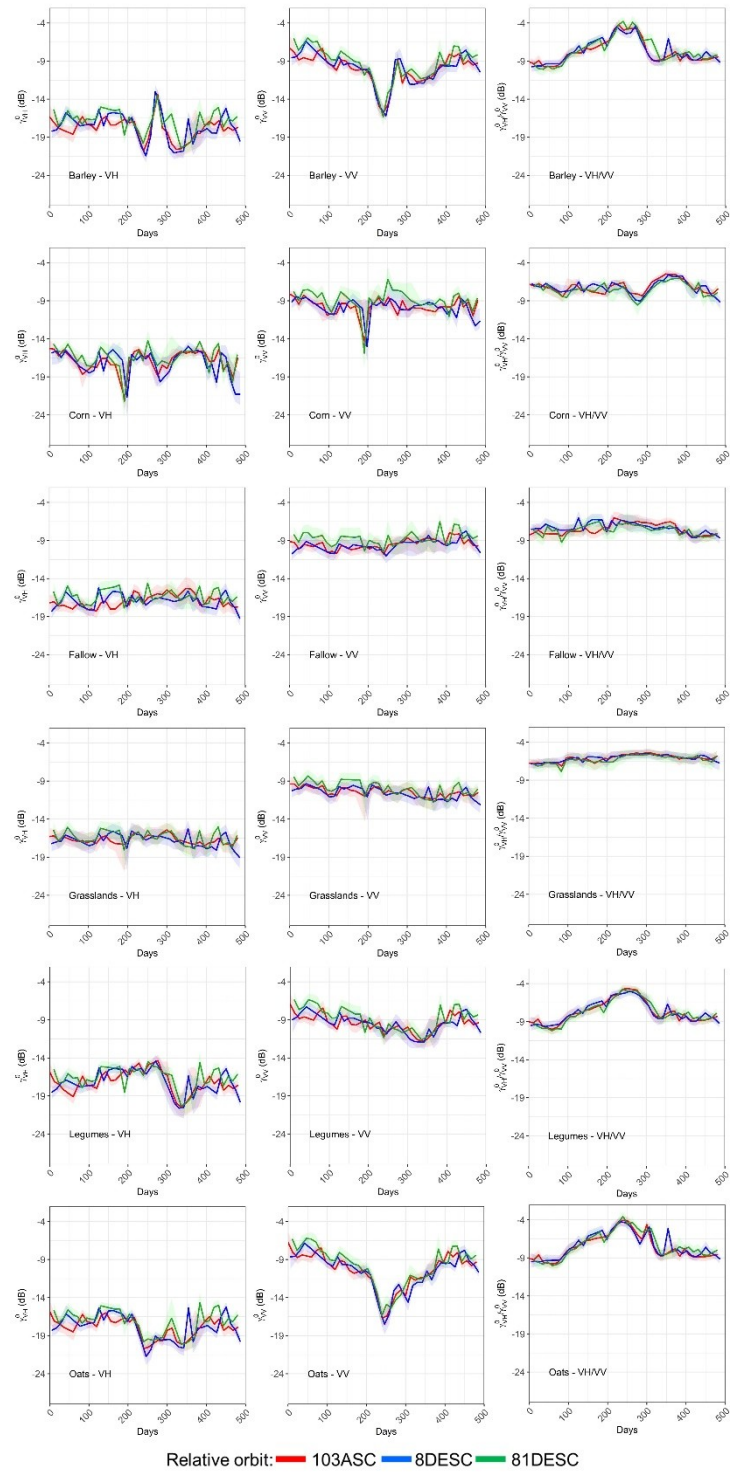


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. b) Region 2.

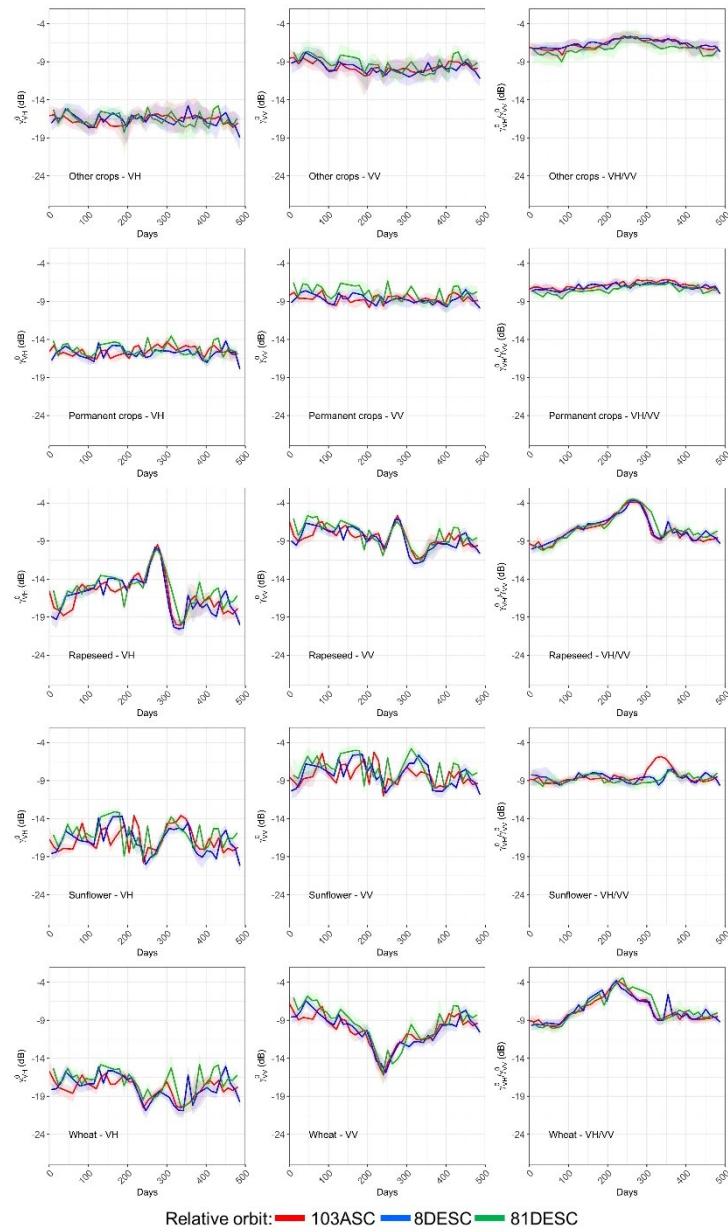


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. b) Region 2.

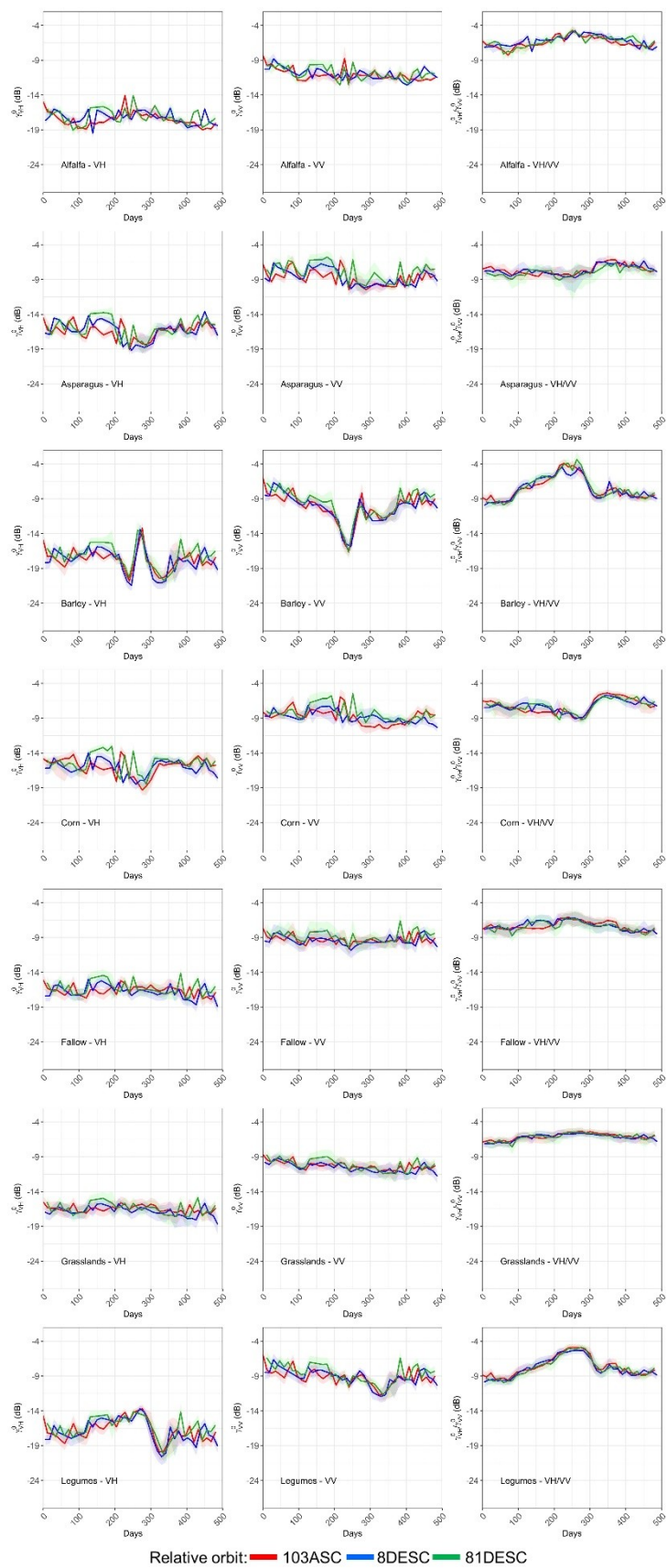


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. c) Region 3.

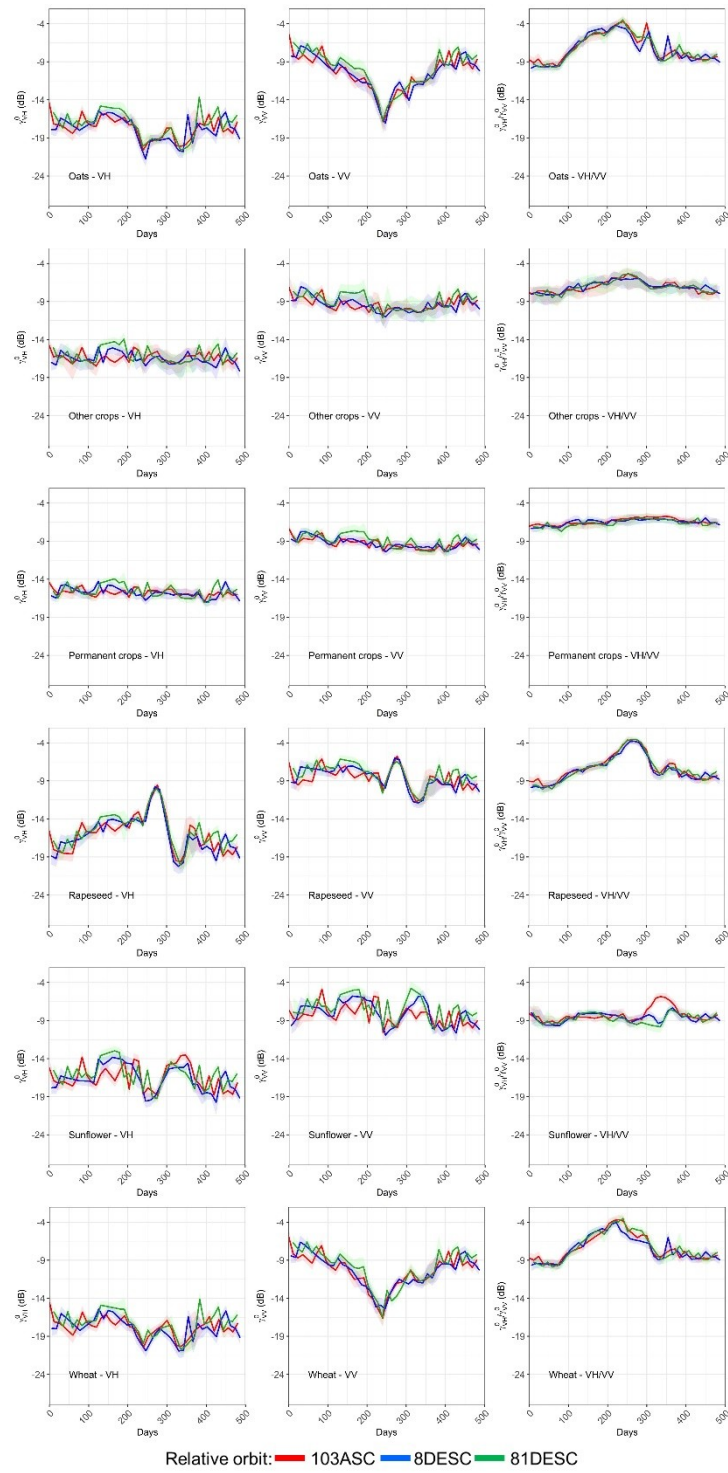


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. c) Region 3.

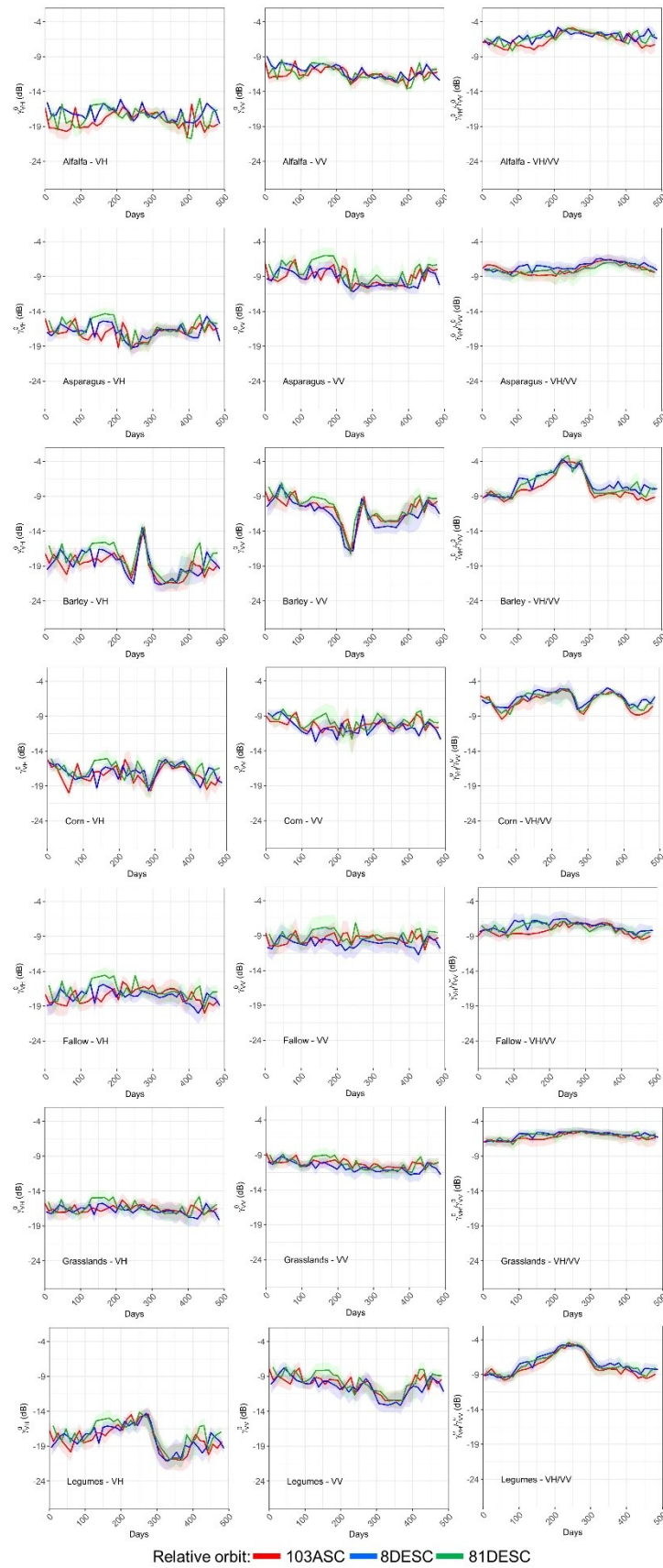


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. d) Region 4.

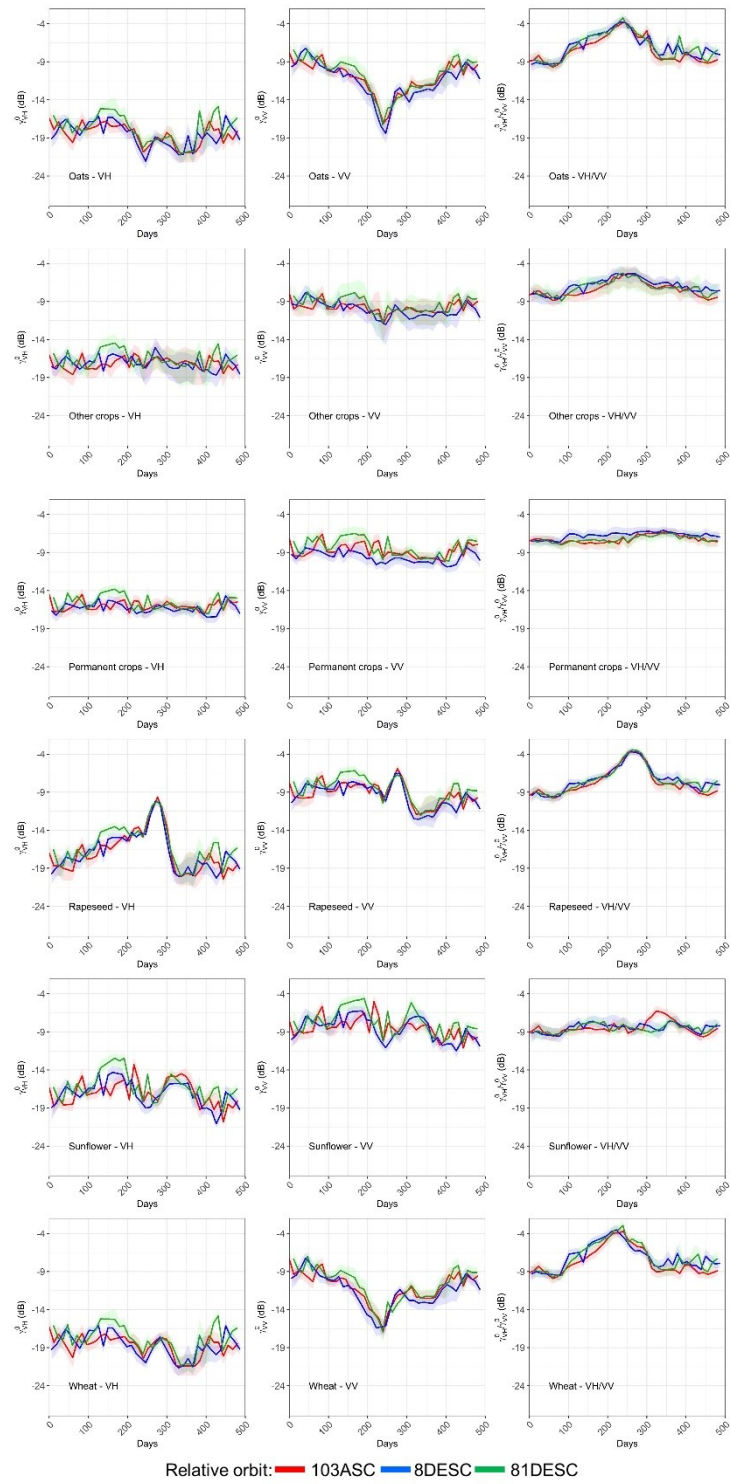


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. d) Region 4.

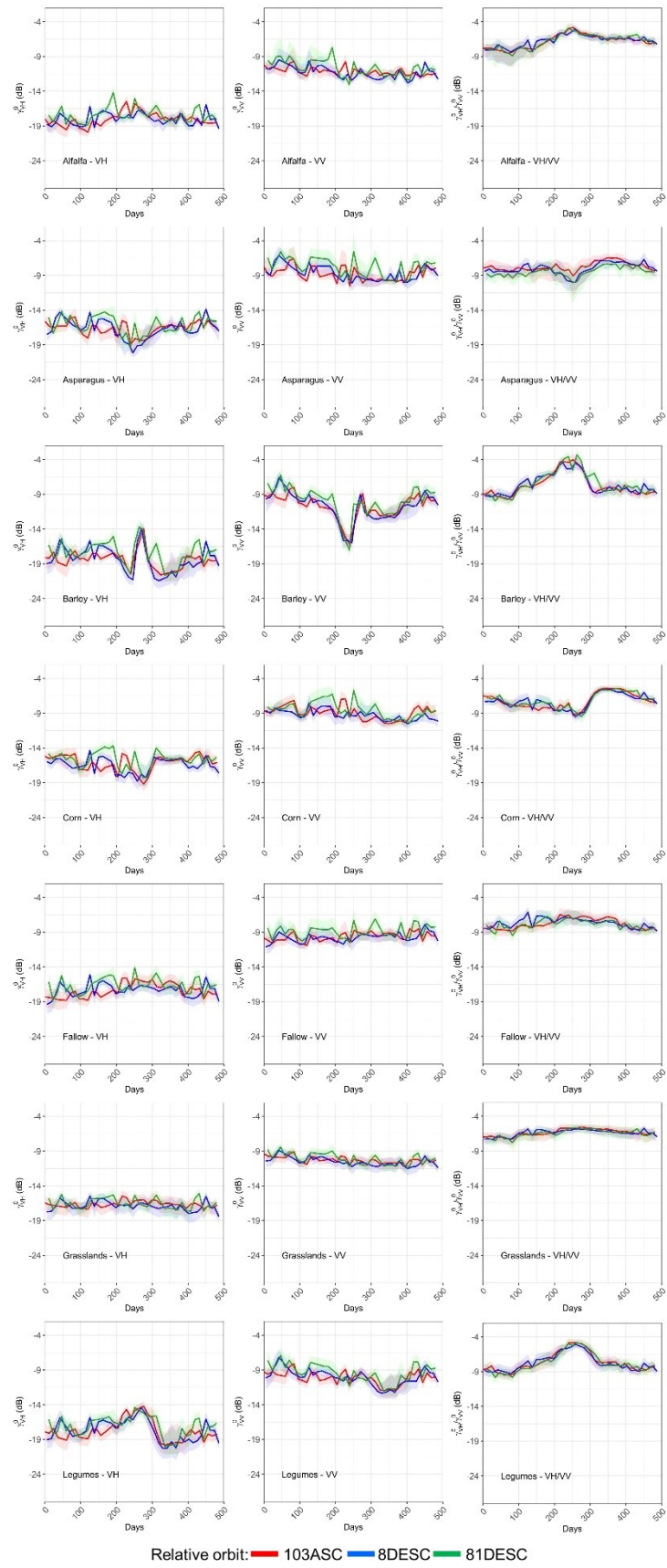


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. e) Region 5.

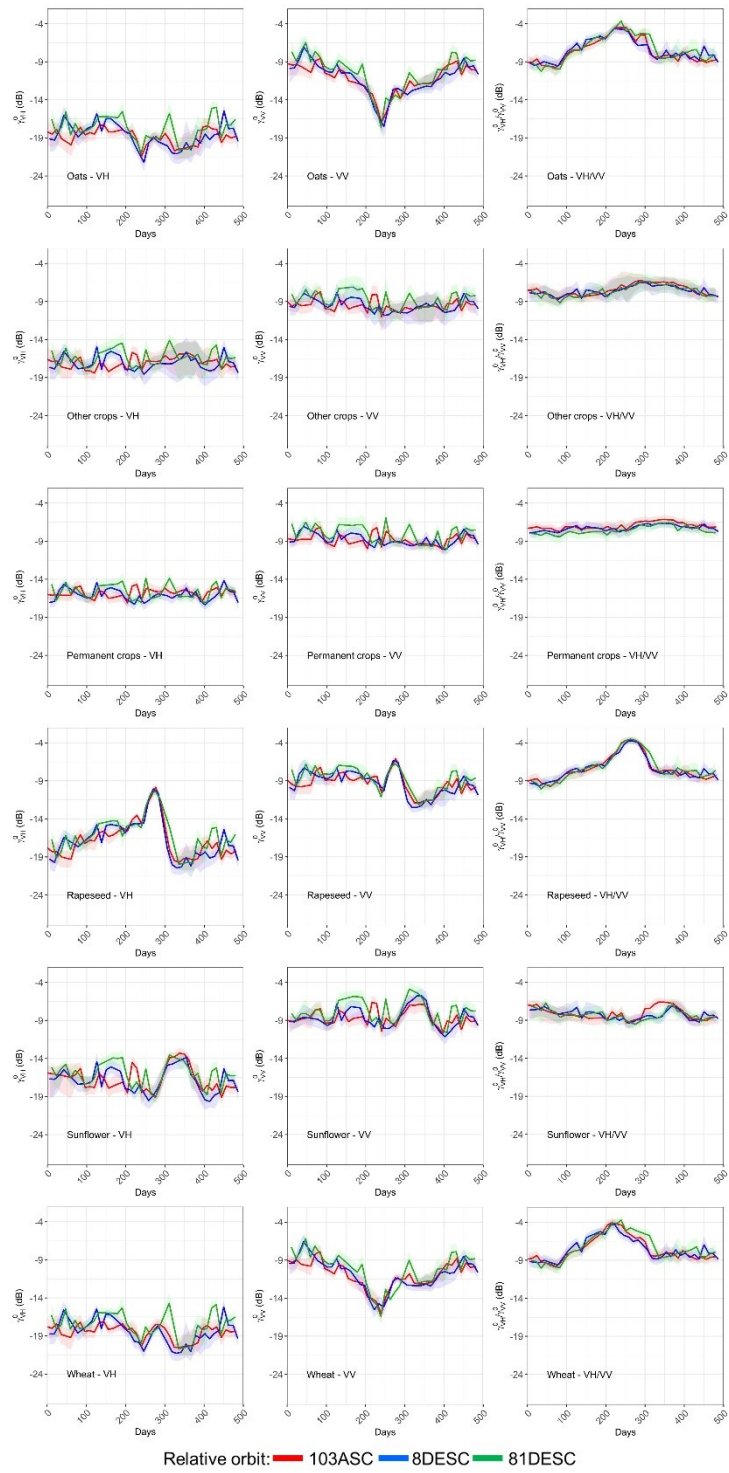


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. e) Region 5.

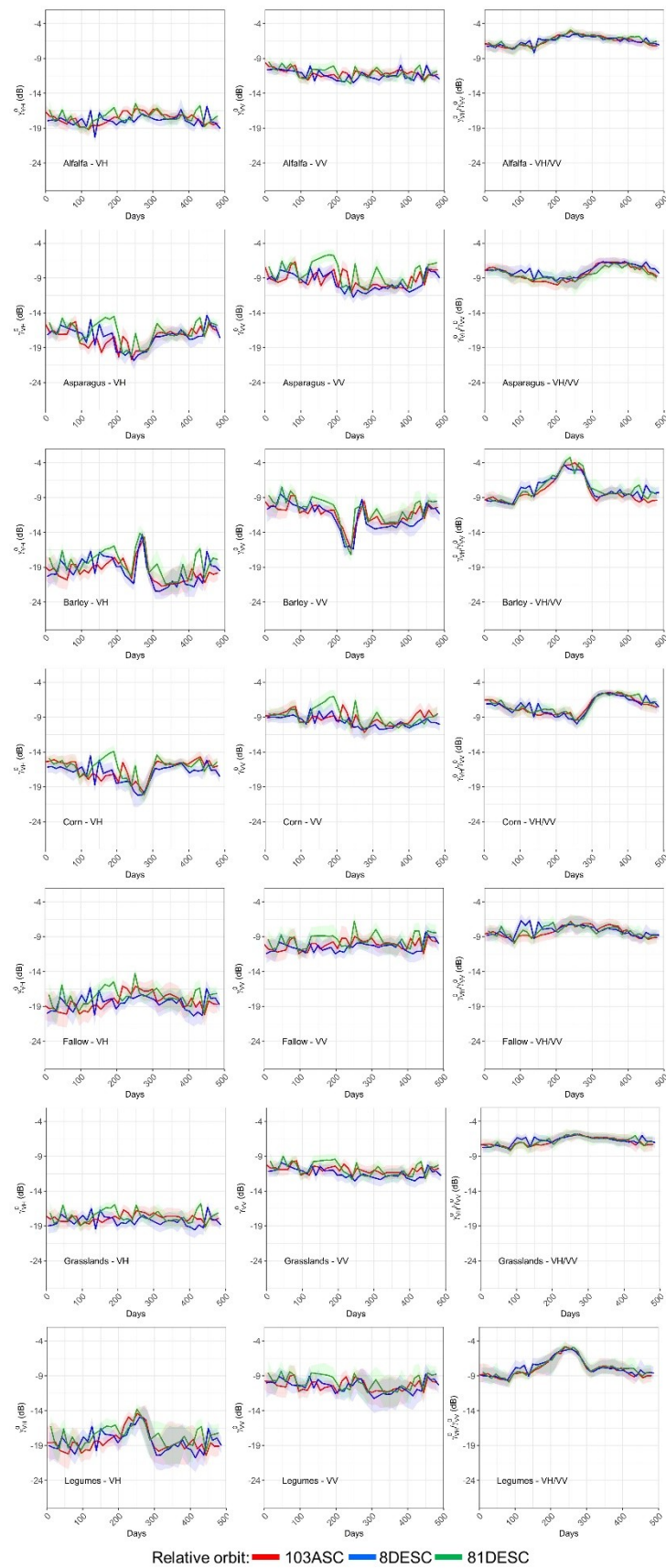


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. f) Region 6.

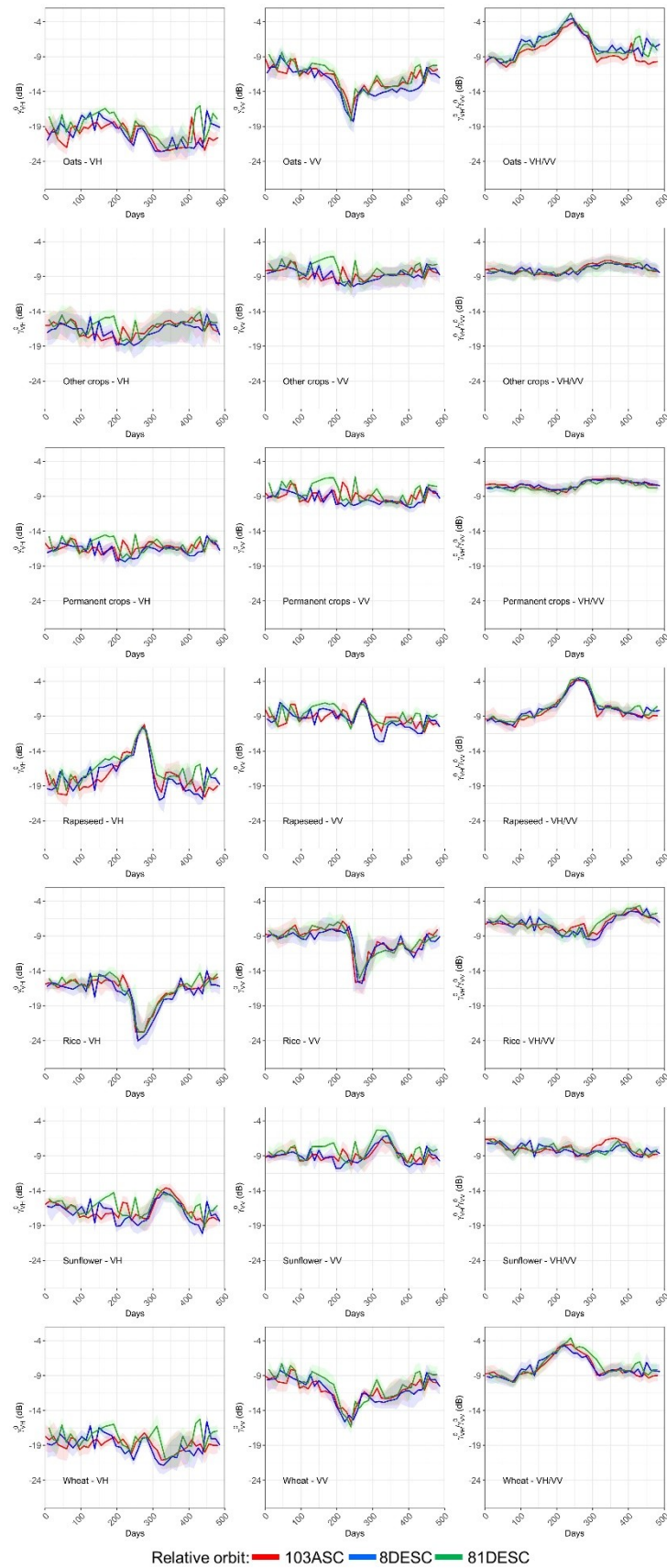


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. f) Region 6.

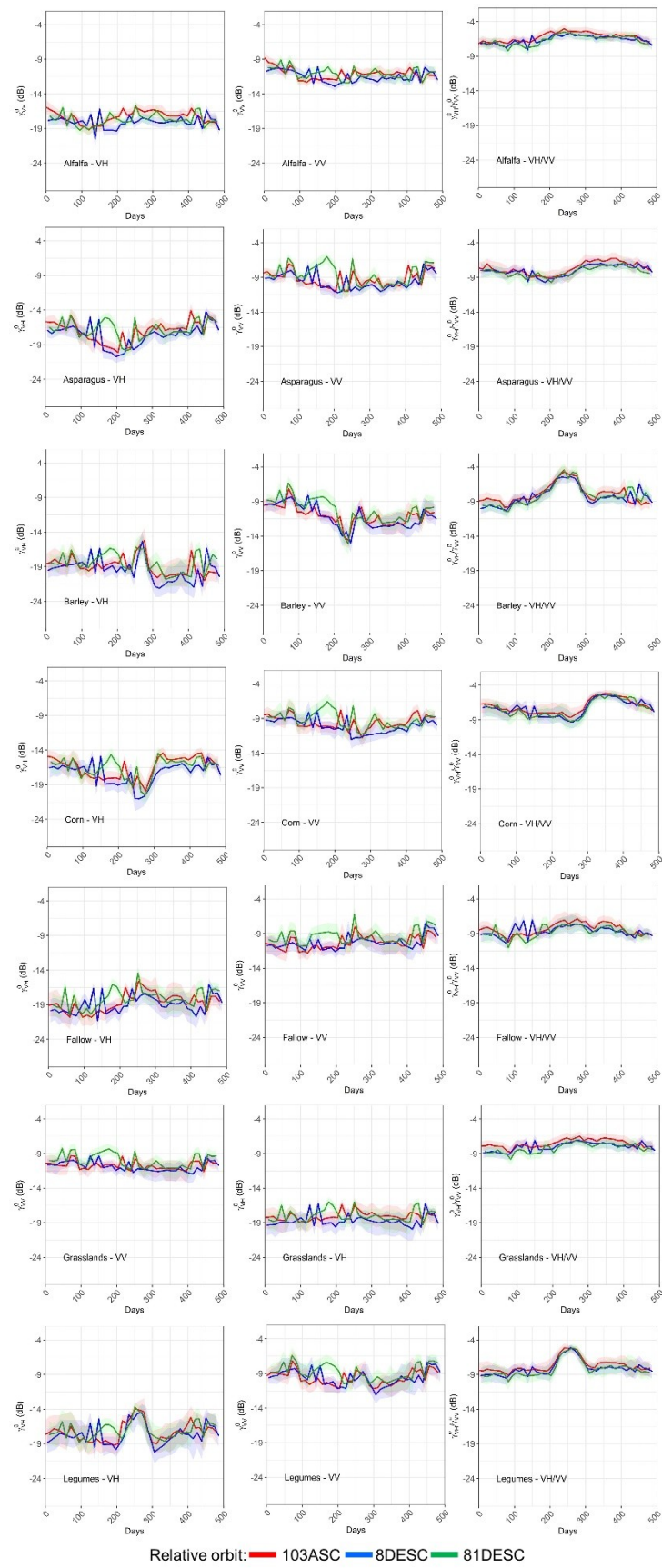


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. g) Region 7.

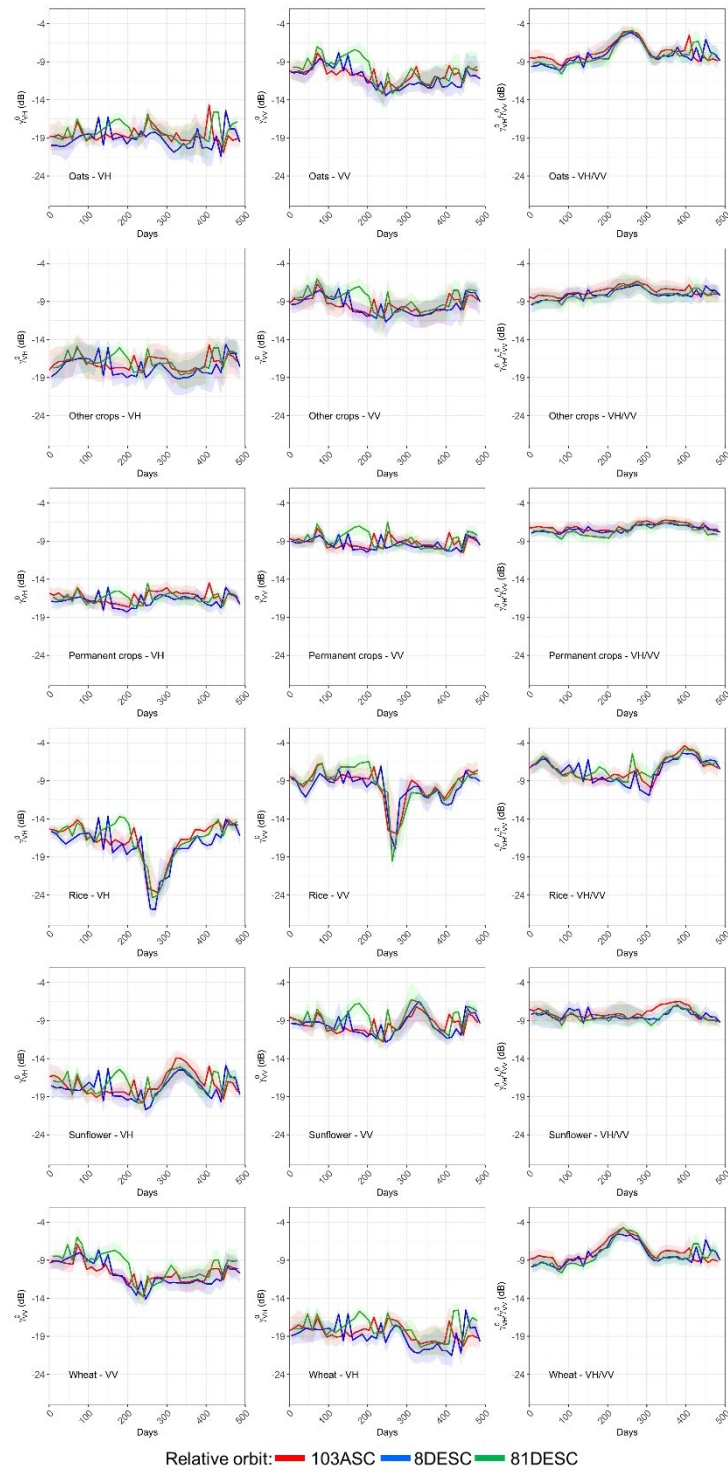


Figure S1 (cont.). Median temporal signatures of crops for VH, VV and VH/VV. g) Region 7.

3. Confusion matrix of Ens and R² for cross-validation in the regions

Table S2. Confusion matrix of Ens and R² 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 R² 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 R² 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 R² 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 R² 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 R² 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 R² 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.

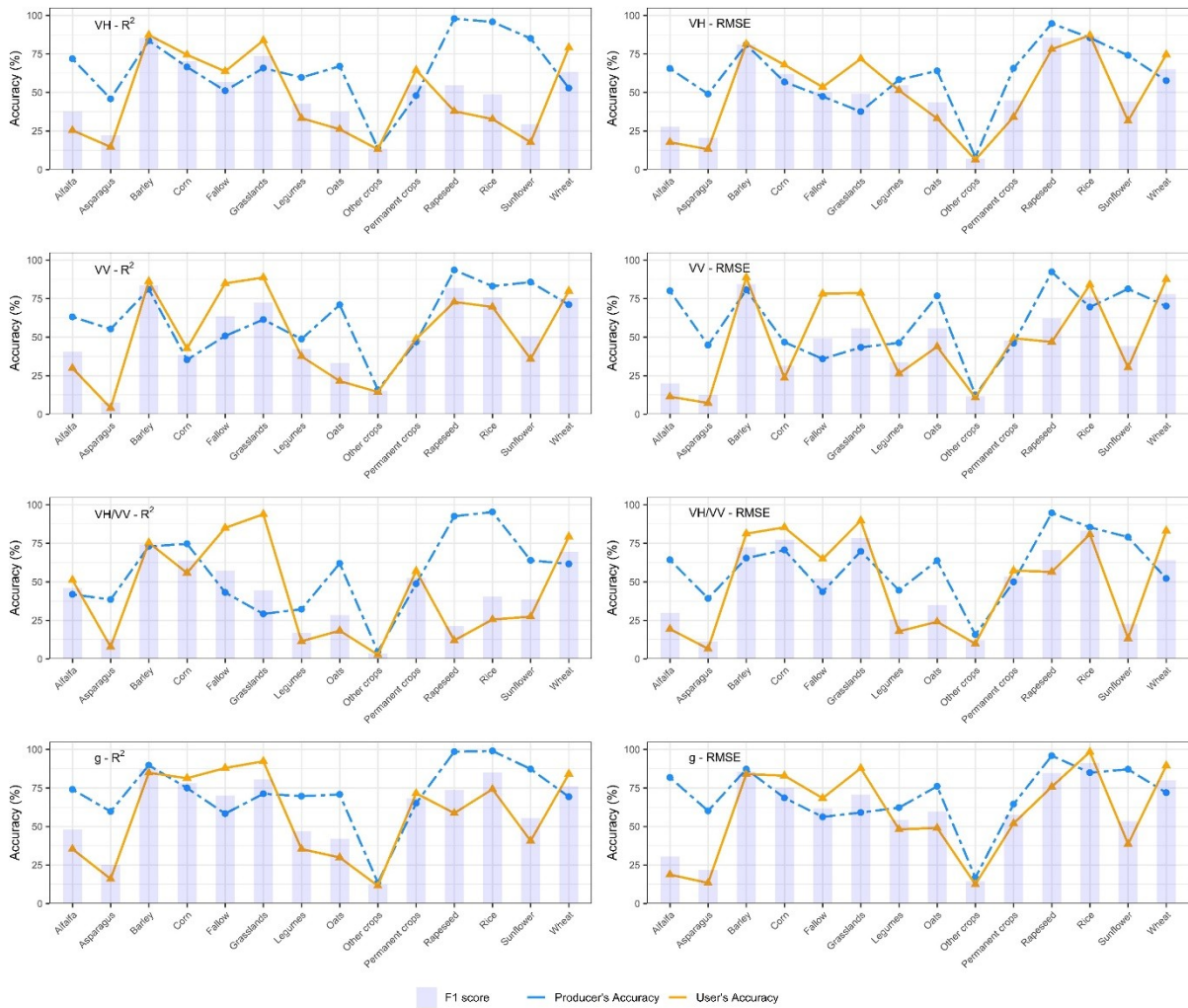


Figure S2. F1-score, PA and UA for the different polarization channels. a) Cross-Validation in Navarre

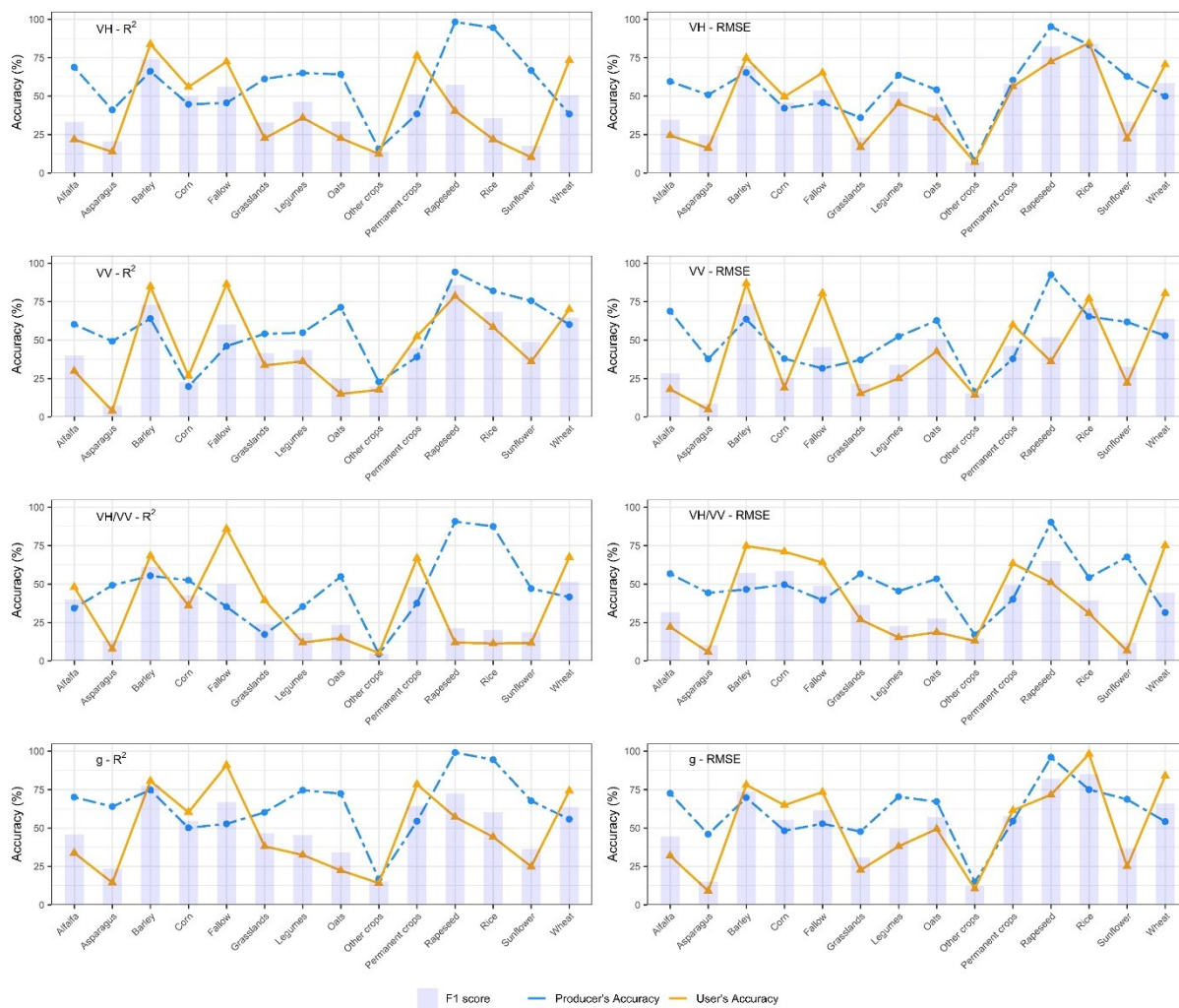


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. b) External-validation in Navarre

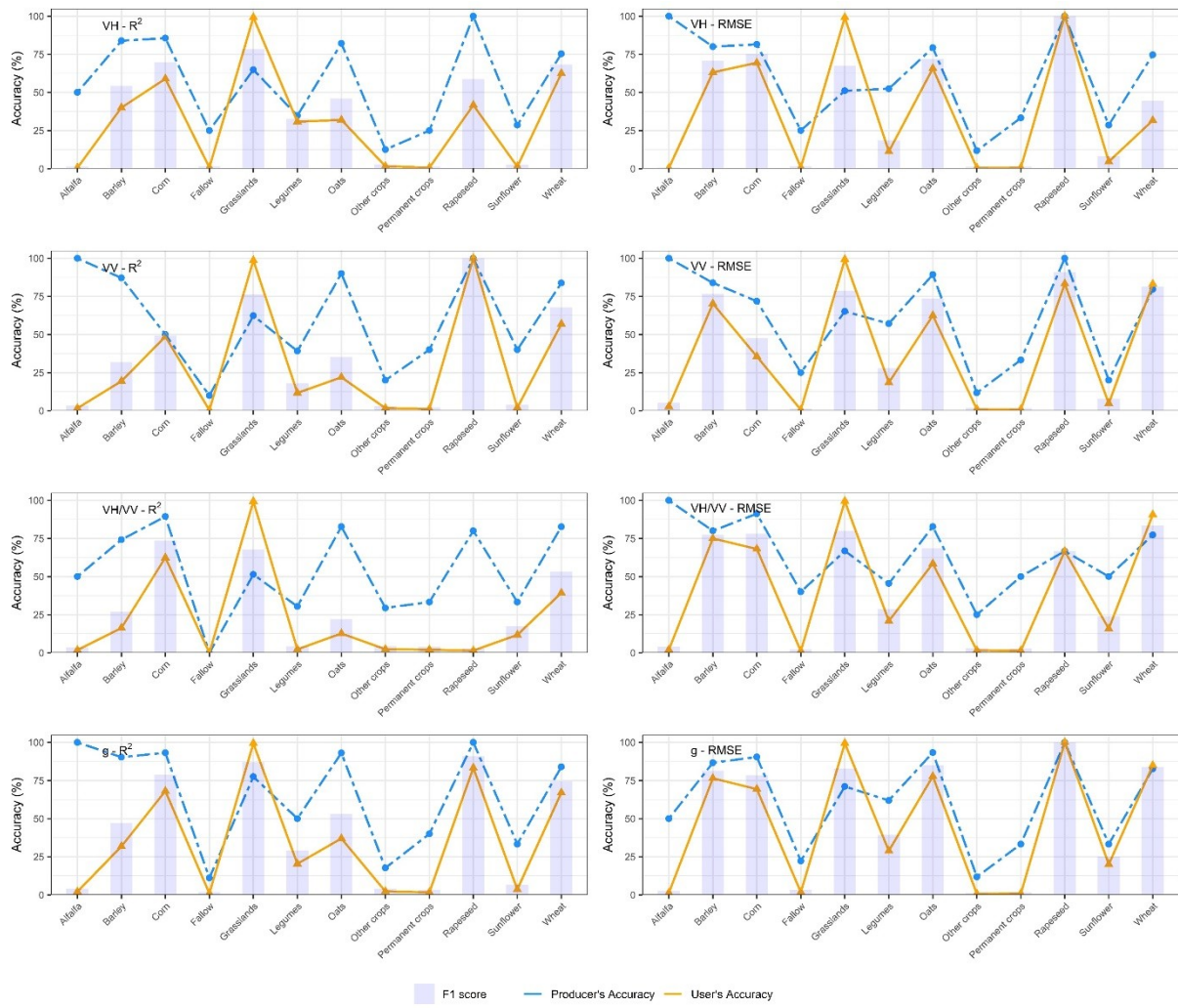


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. c) Cross-validation in Region 1

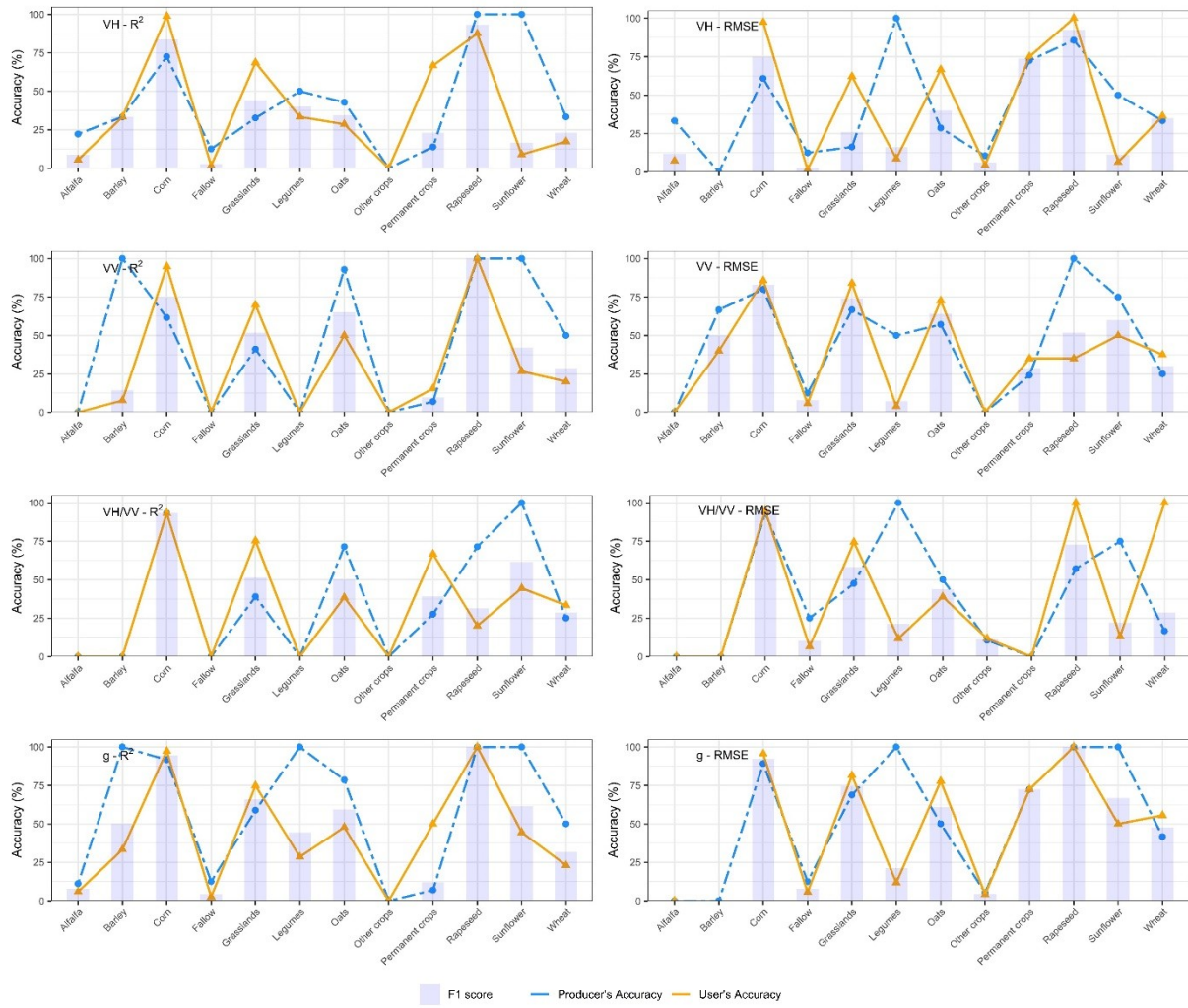


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. d) External-validation in Region 1

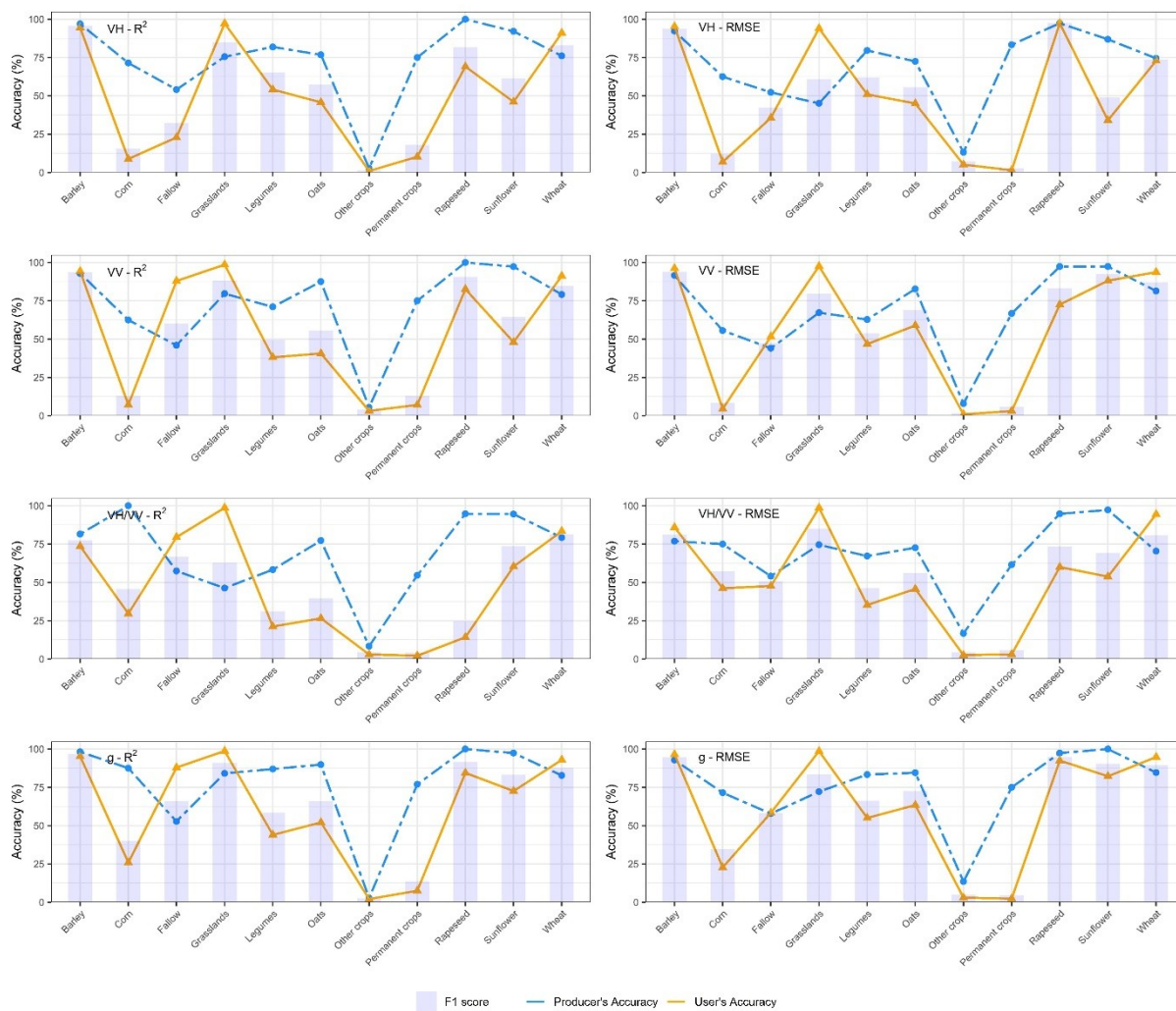


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. e) Cross-validation in Region 2

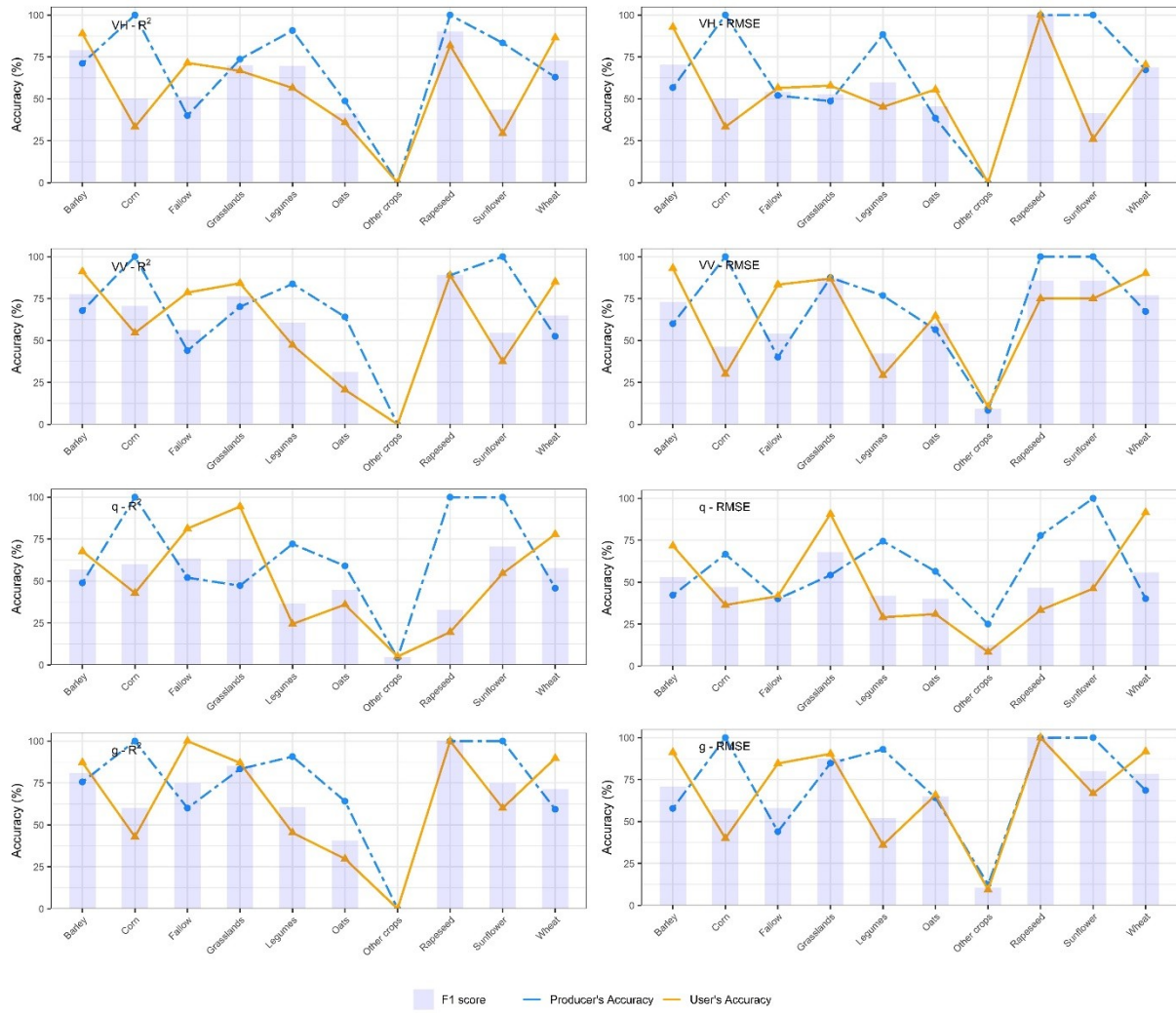


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. f) External-validation in Region 2

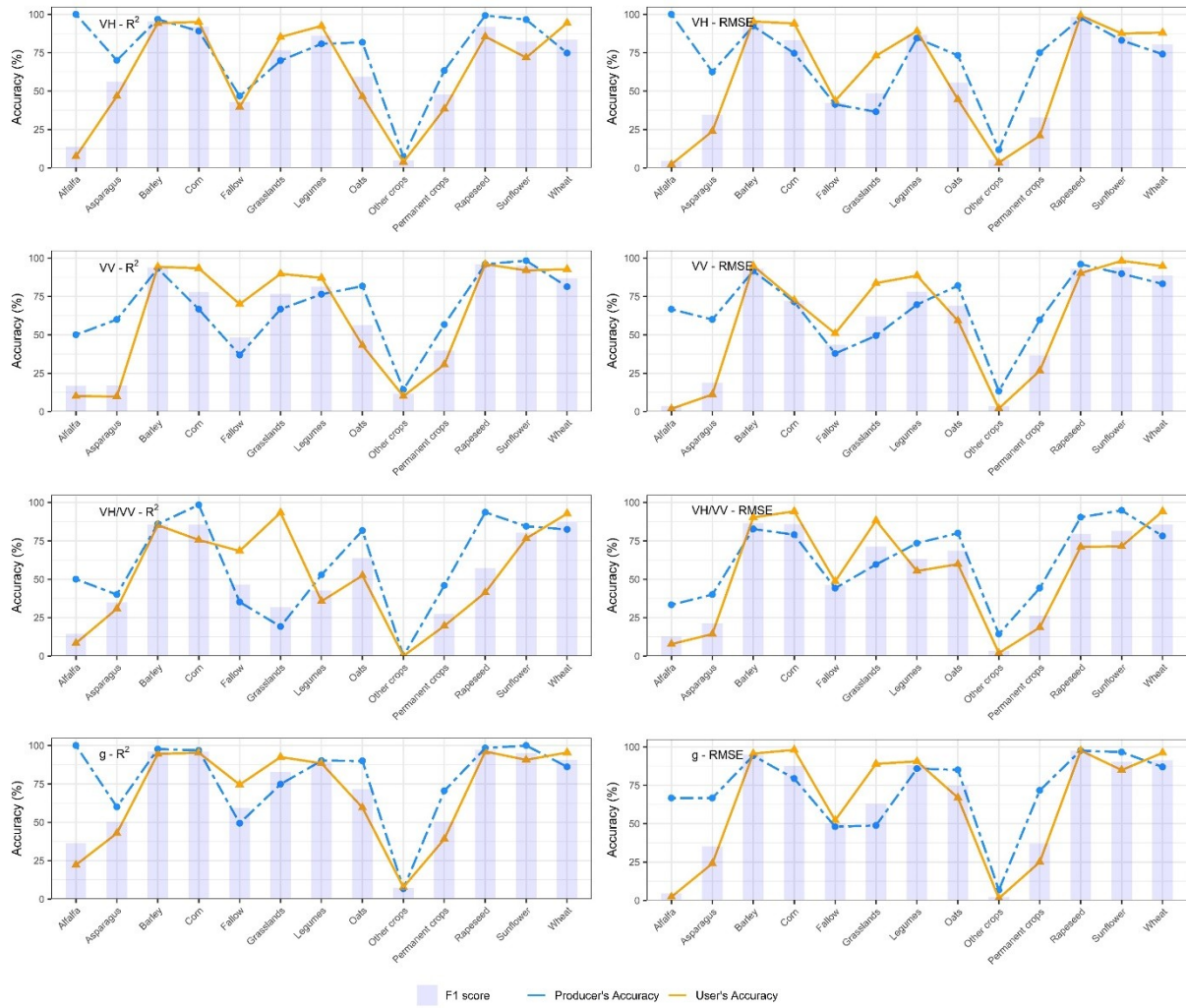


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. g) Cross-validation in Region 3

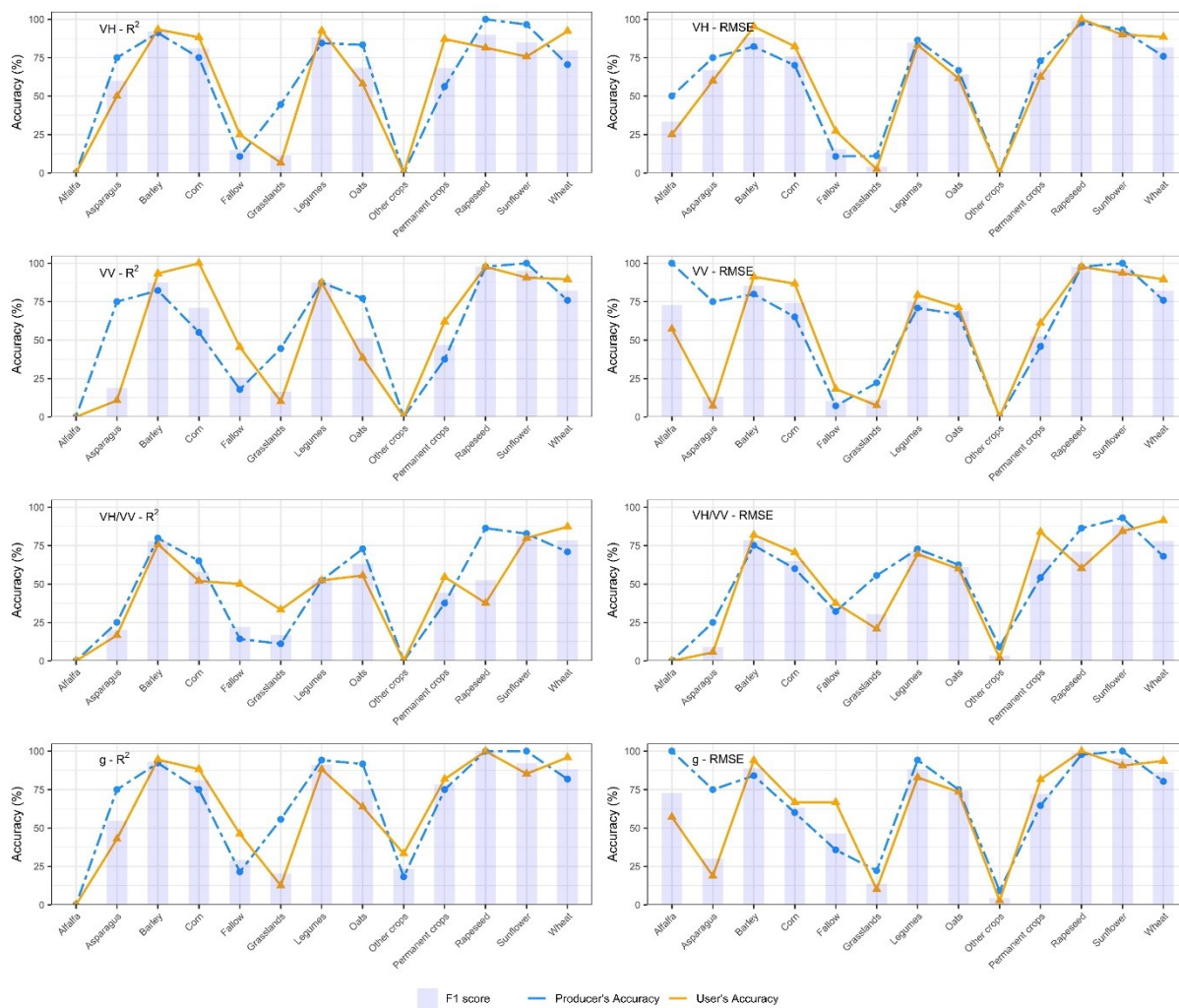


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. h) External-validation in Region 3

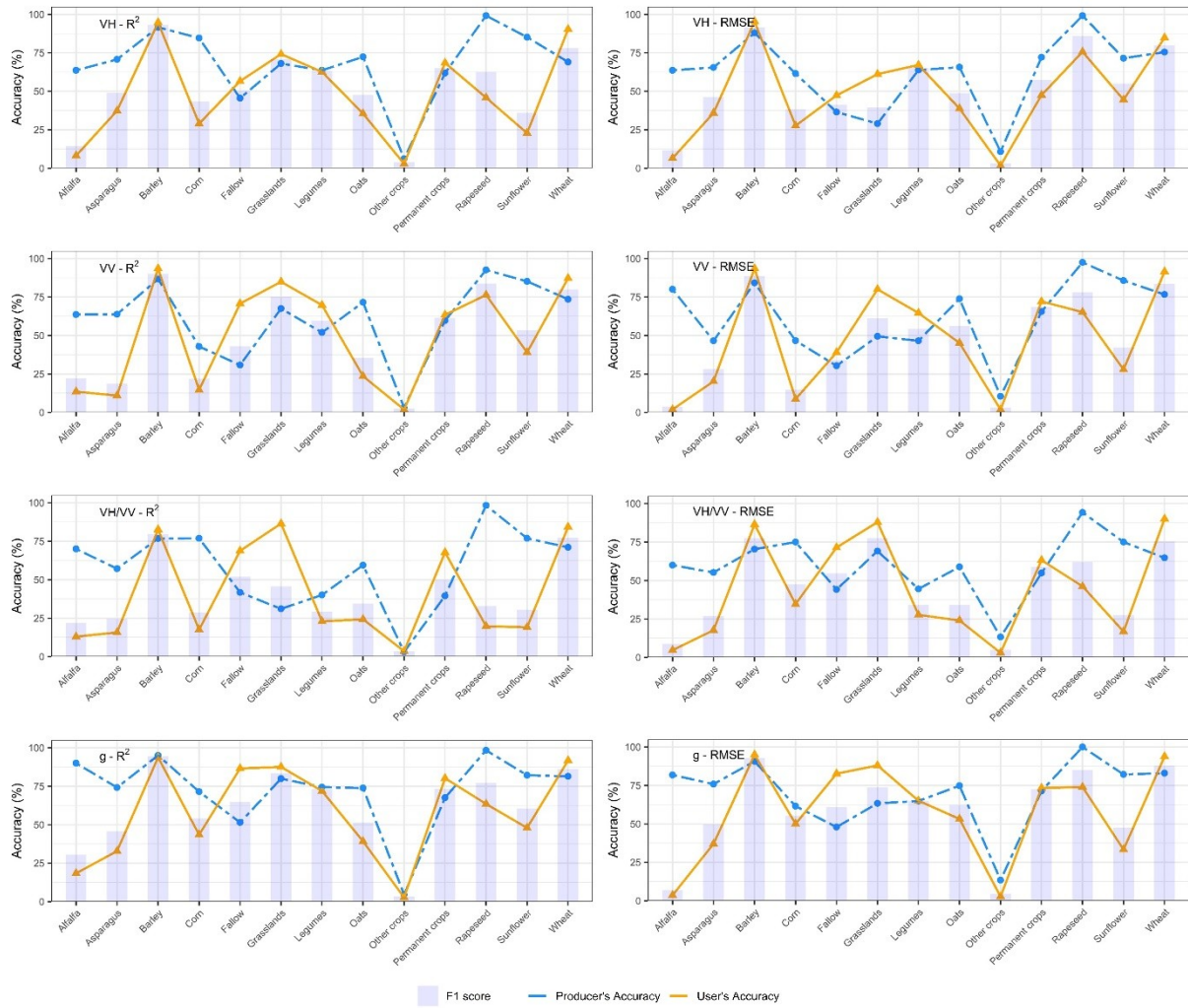


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. i) Cross-validation in Region 4

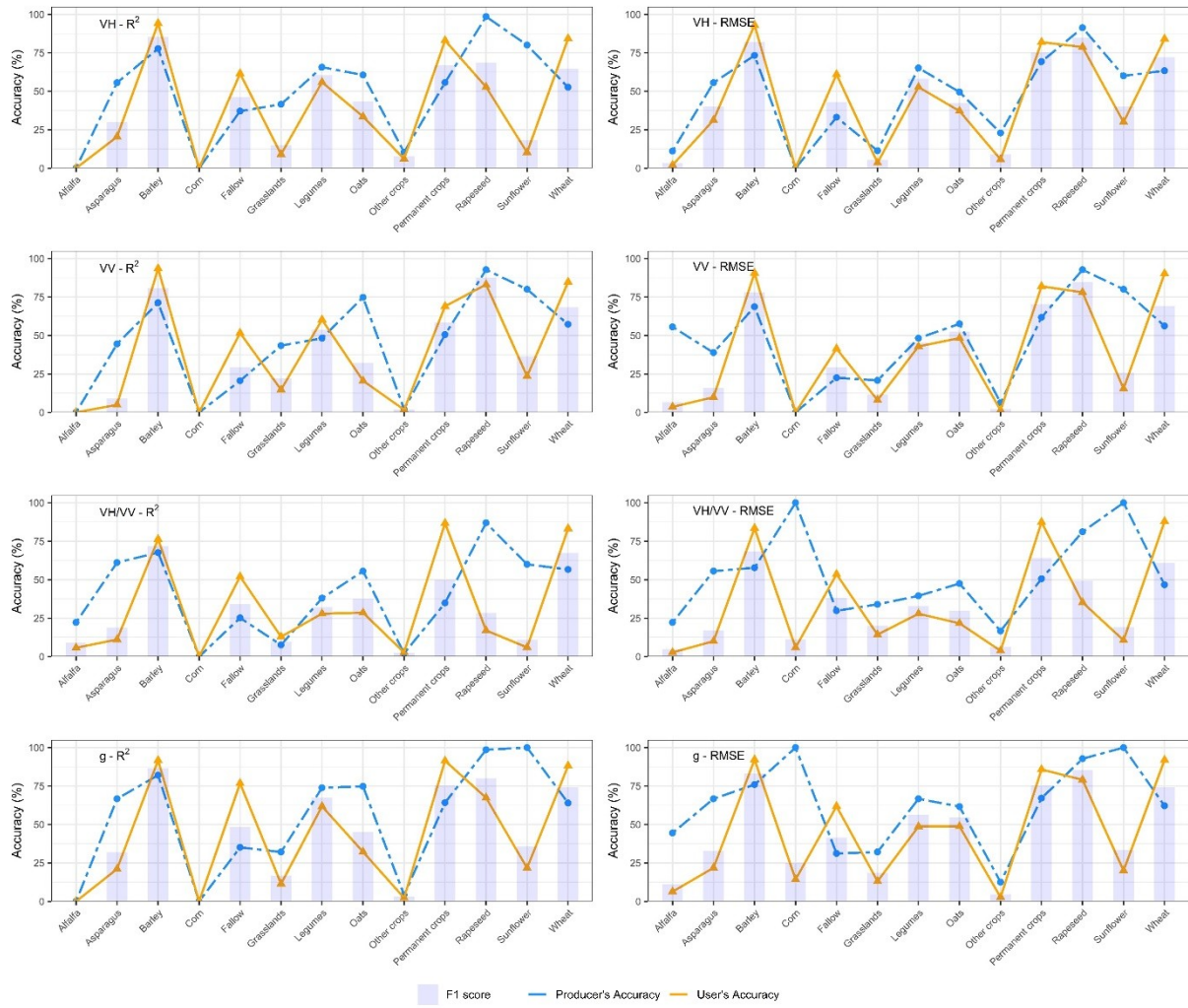


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. j) External-validation in Region 4

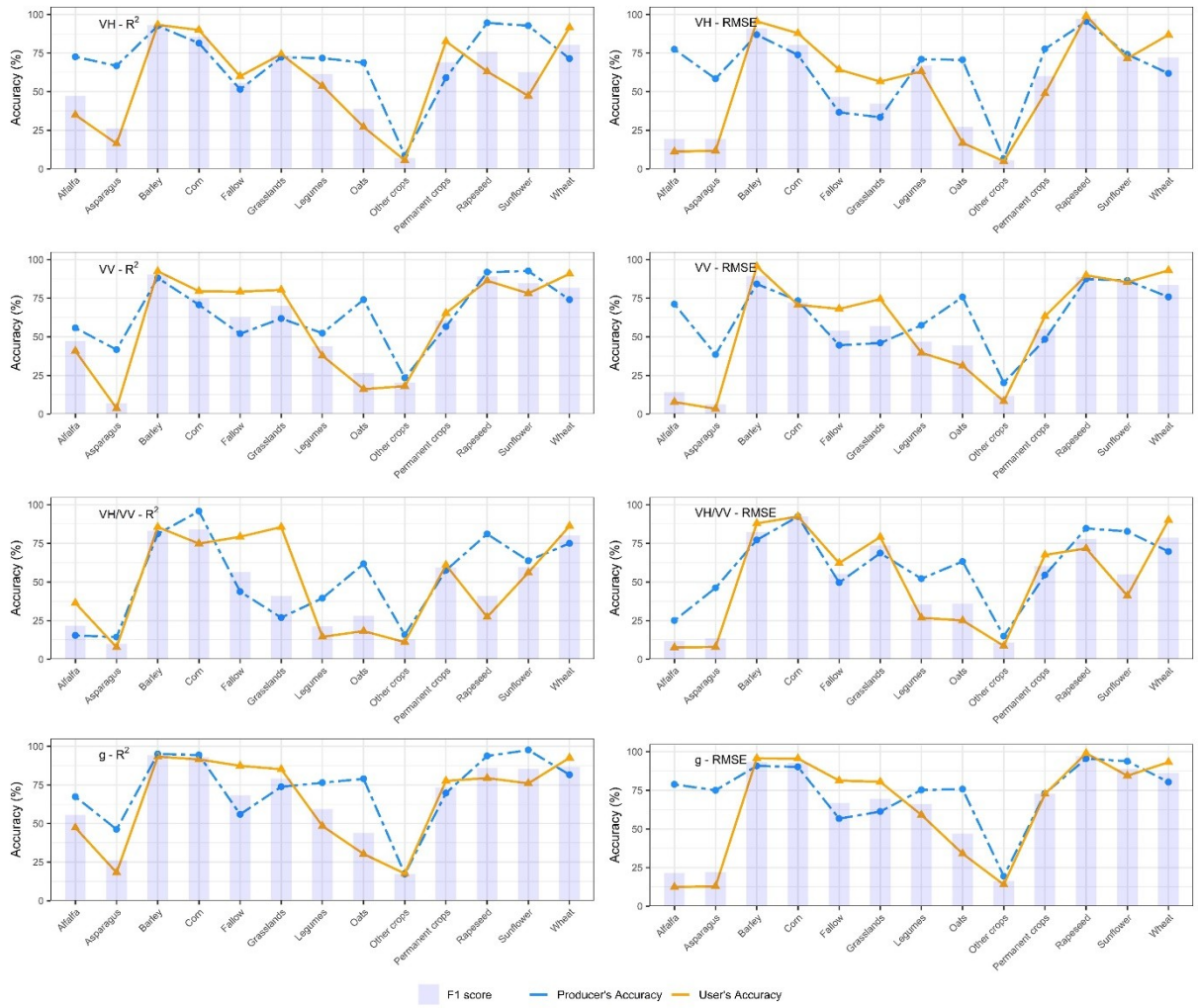


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. k) Cross-validation in Region 5

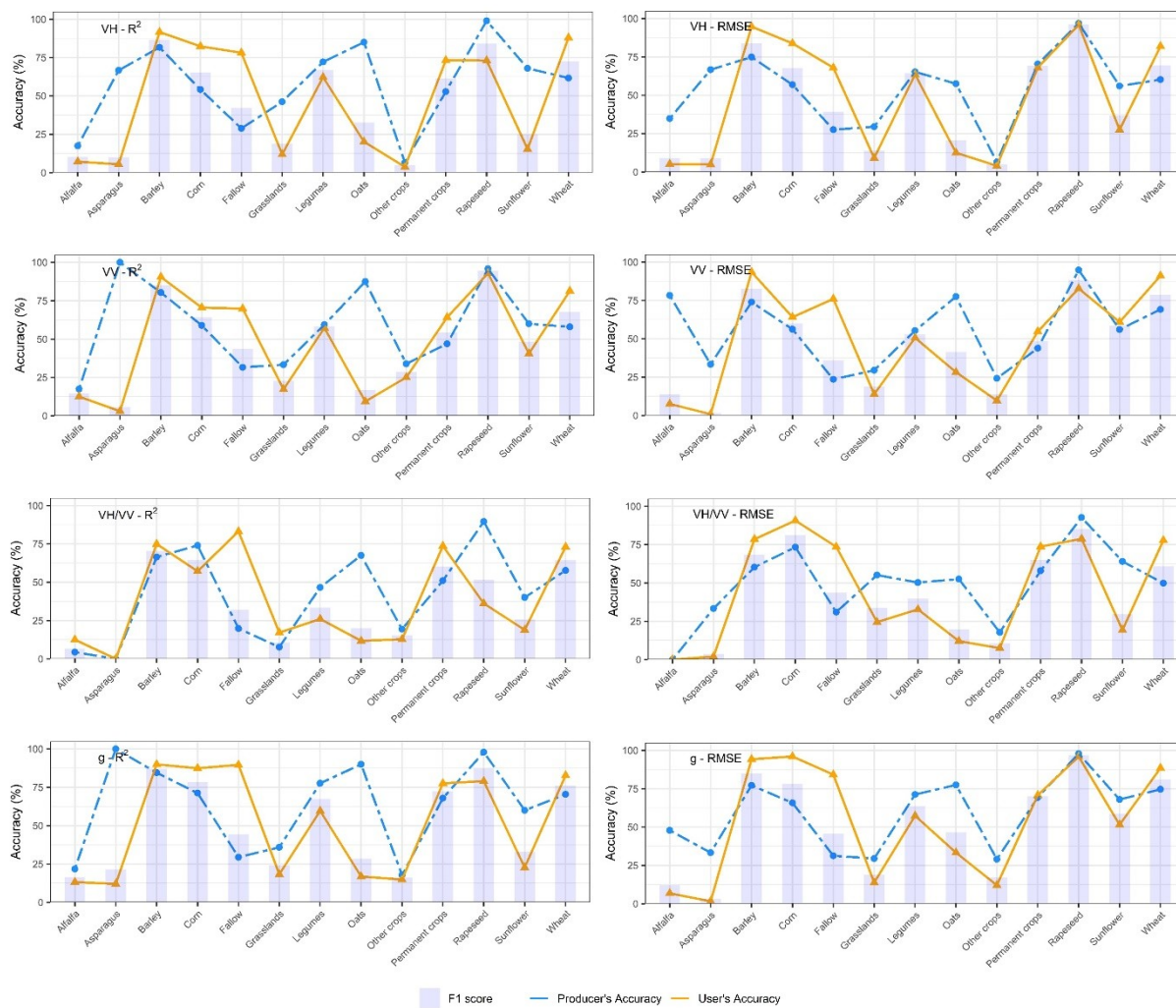


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. 1) External-validation in Region 5

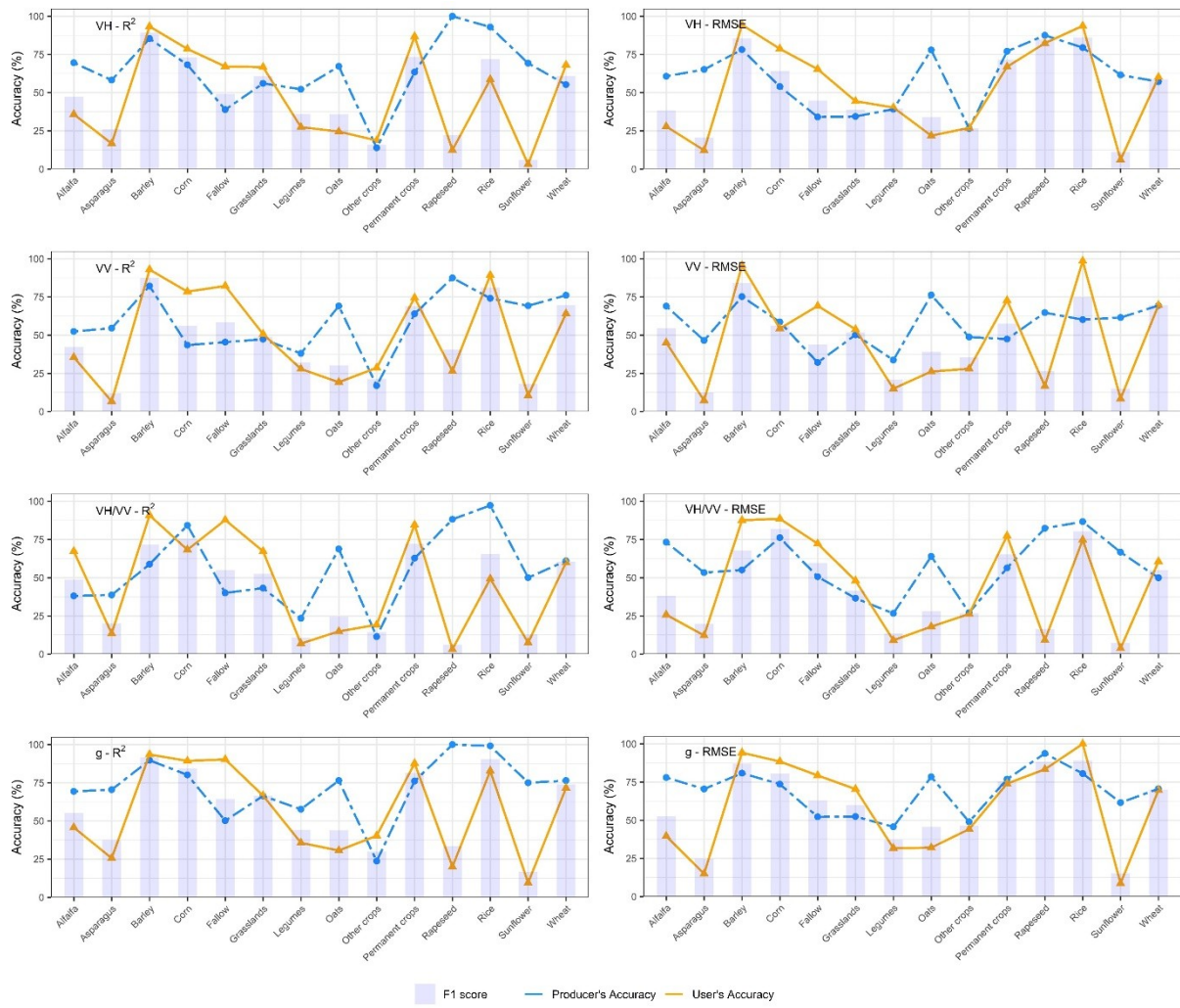


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. m) Cross-validation in Region 6

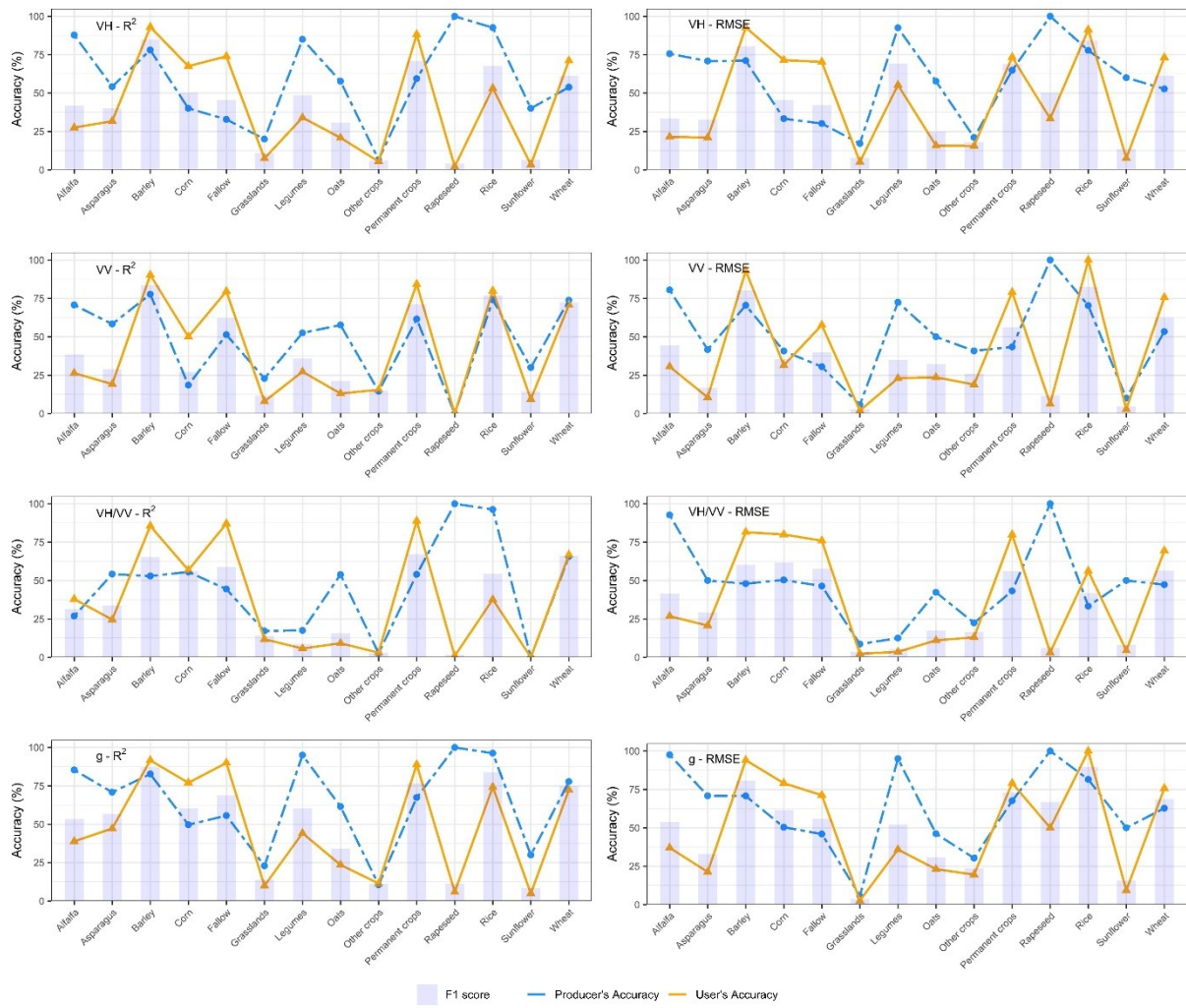


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. n) External-validation in Region 6

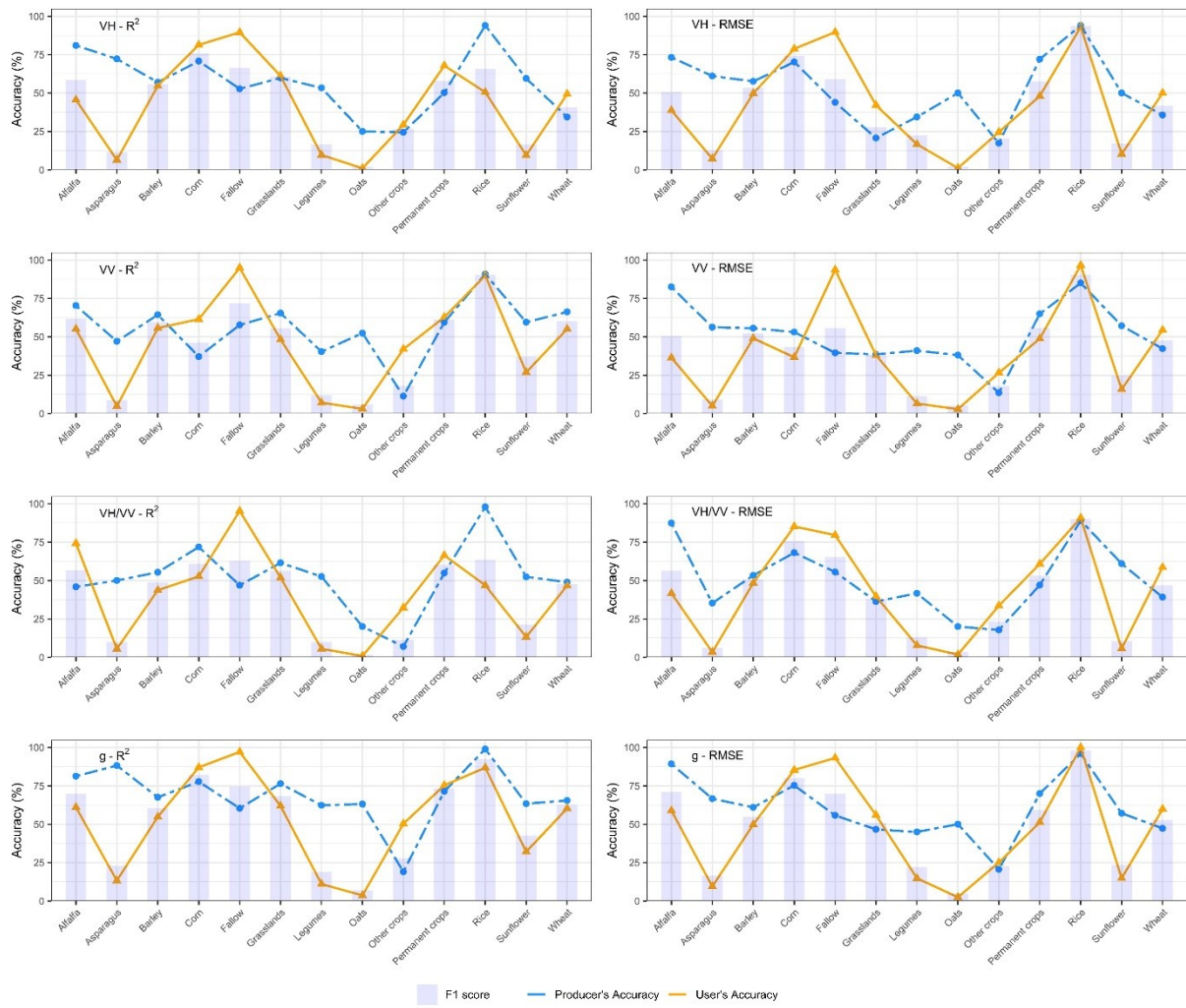


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. o) Cross-validation in Region 6

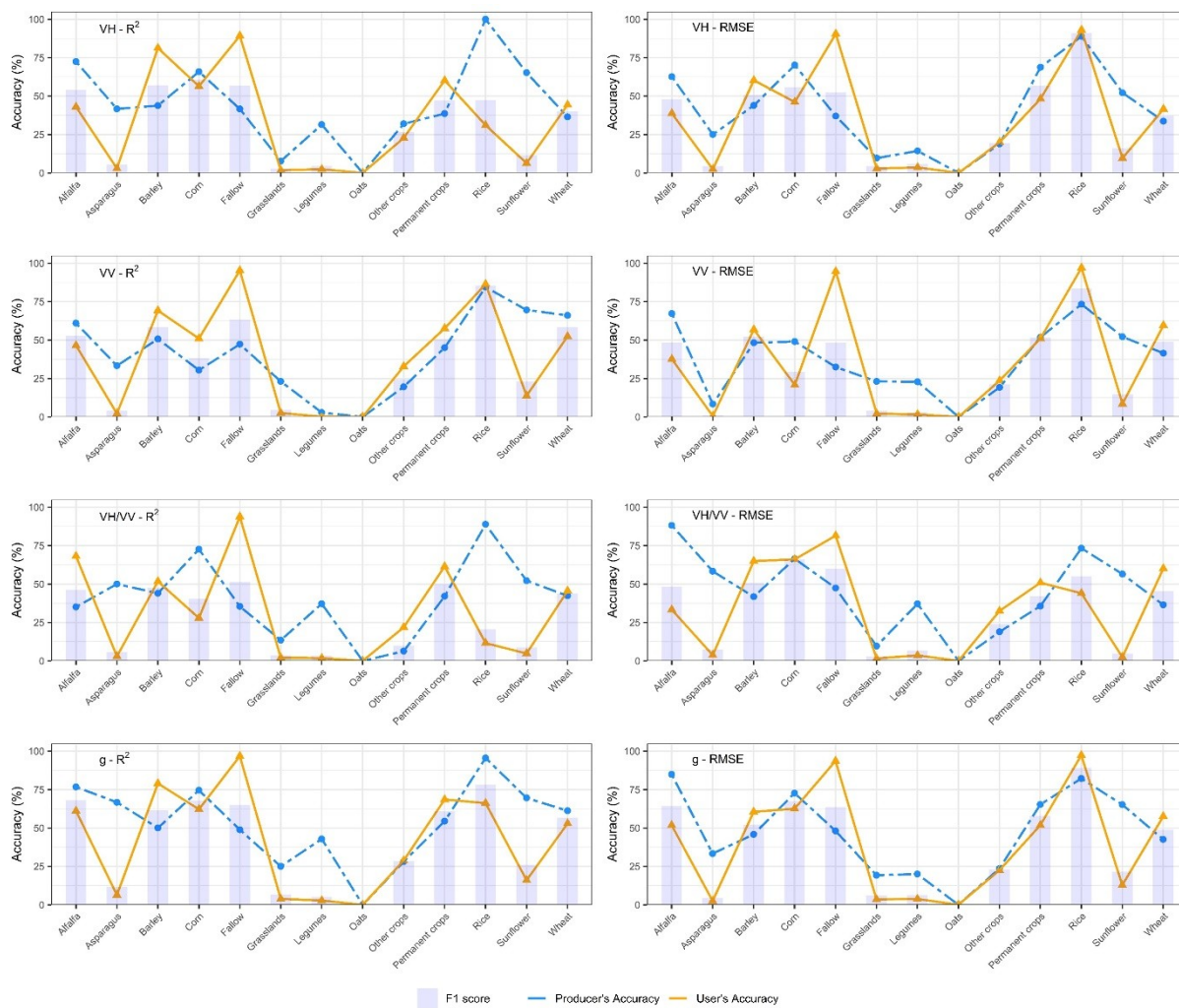


Figure S2 (cont.). F1-score, PA and UA for the different polarization channels. p) External-validation in Region

7

5. Influence of field size on classification results

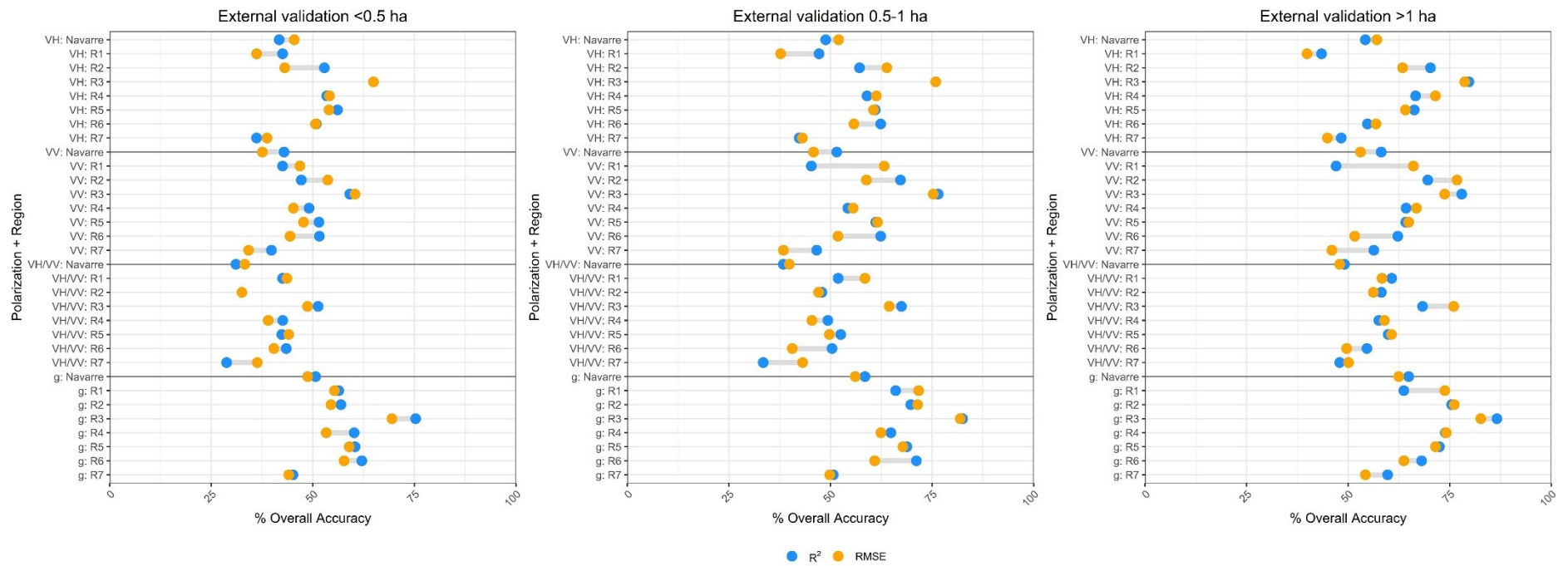


Figure S3. Overall Accuracy of External validation based on field size: <0.5 ha (left), 0.5-1ha (middle) and >1ha (right).

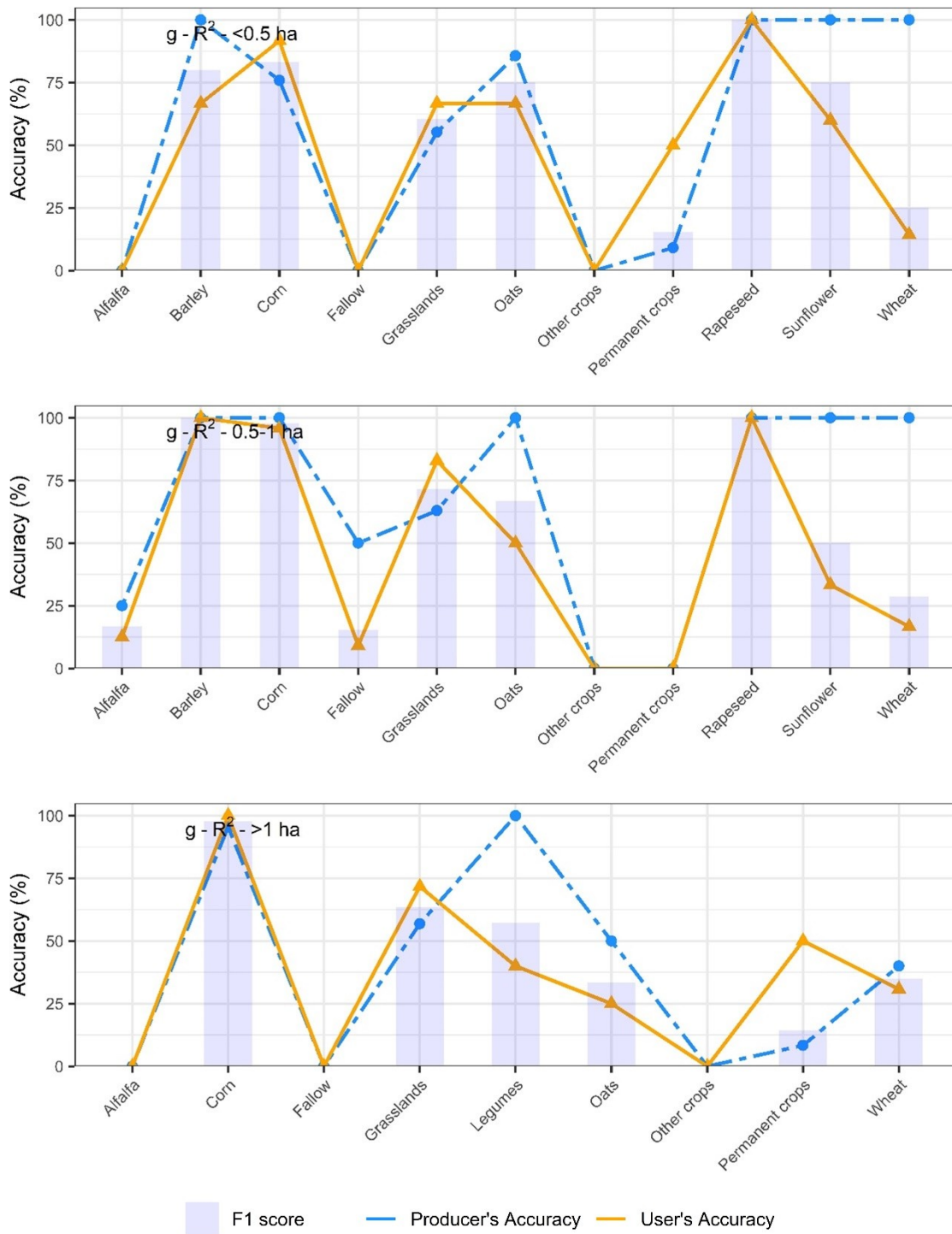


Figure S4. F1-score, PA and UA of Ens and R2 classification based on field size for external validation. a) Region 1

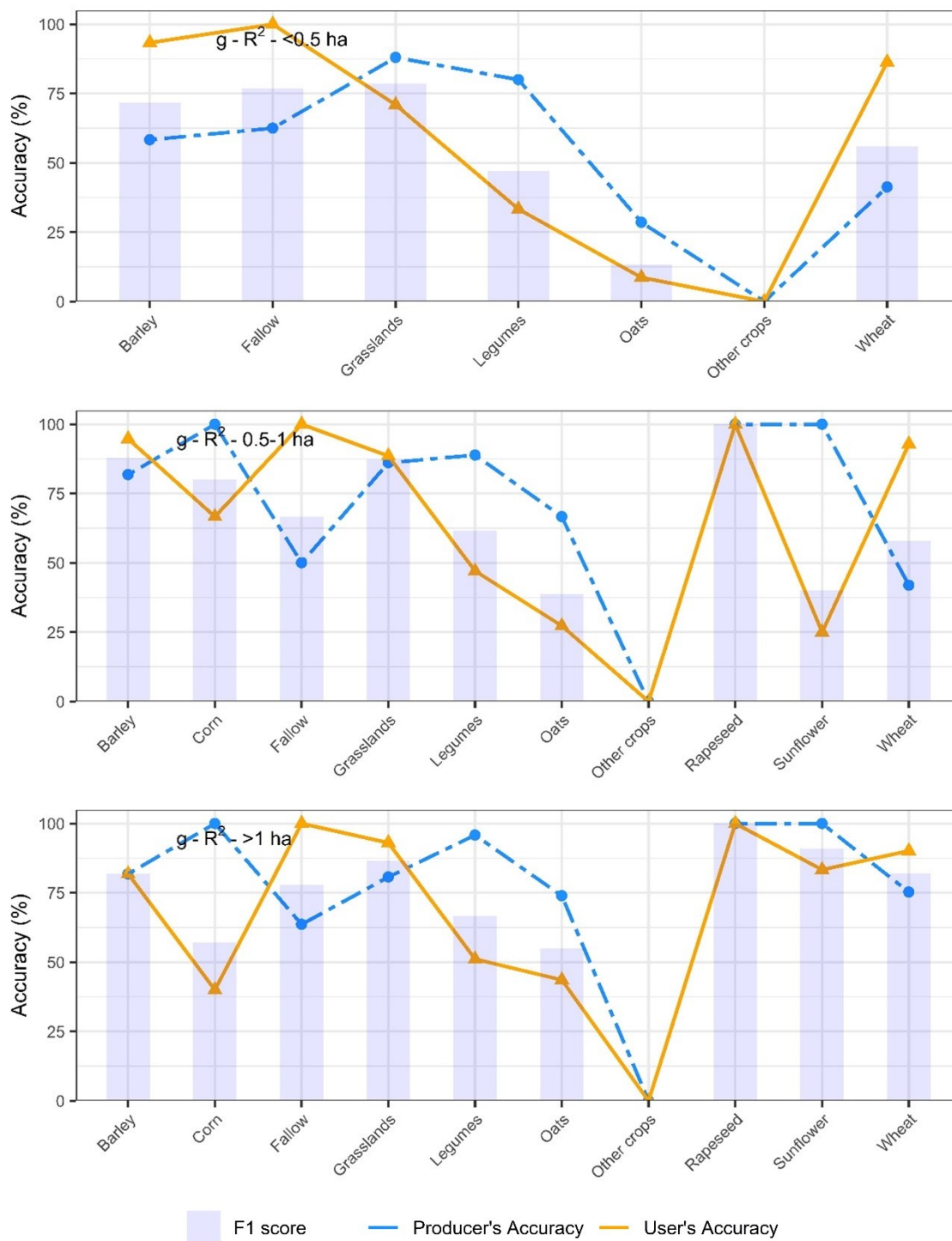


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. b) Region 2

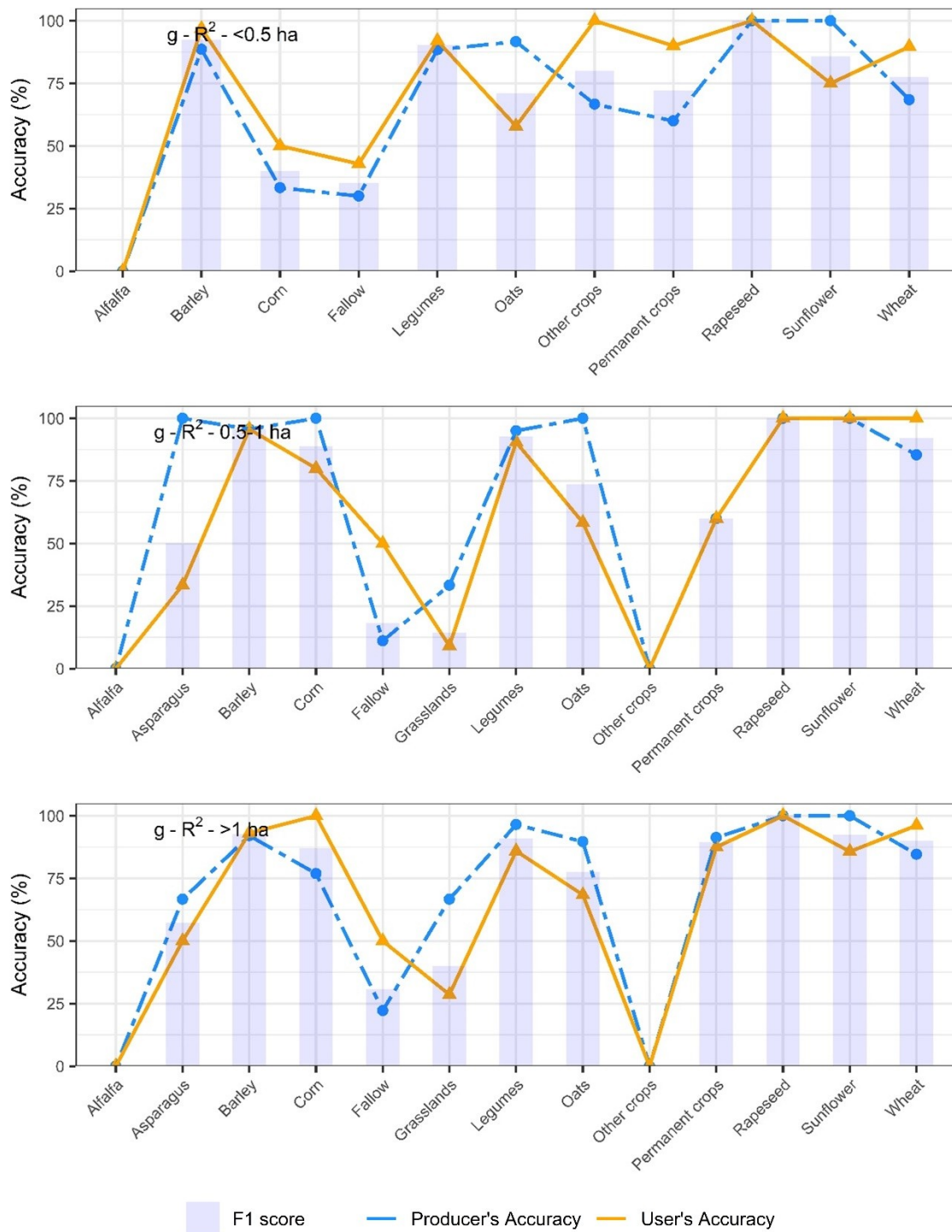


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. c) Region 3

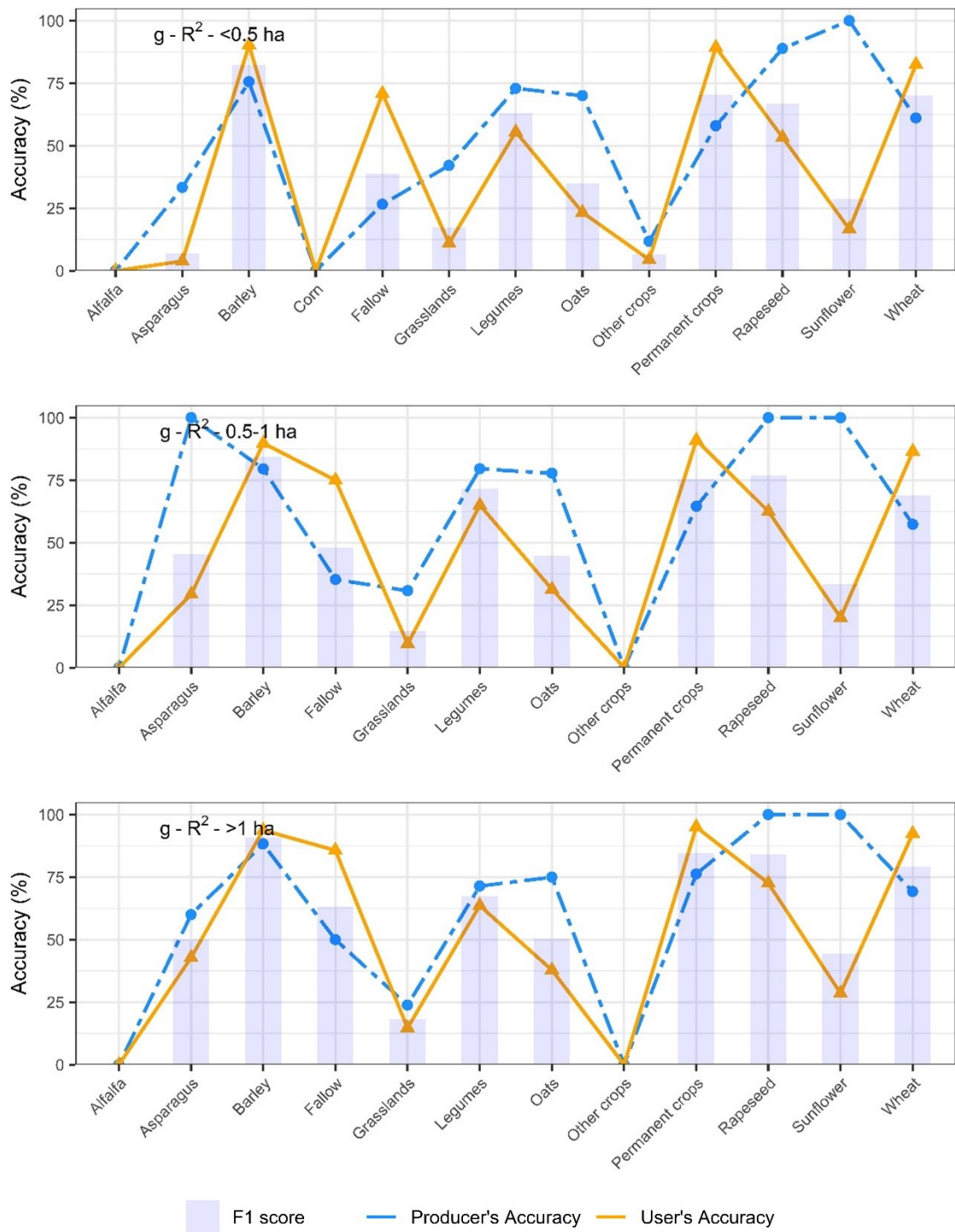


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. d) Region 4

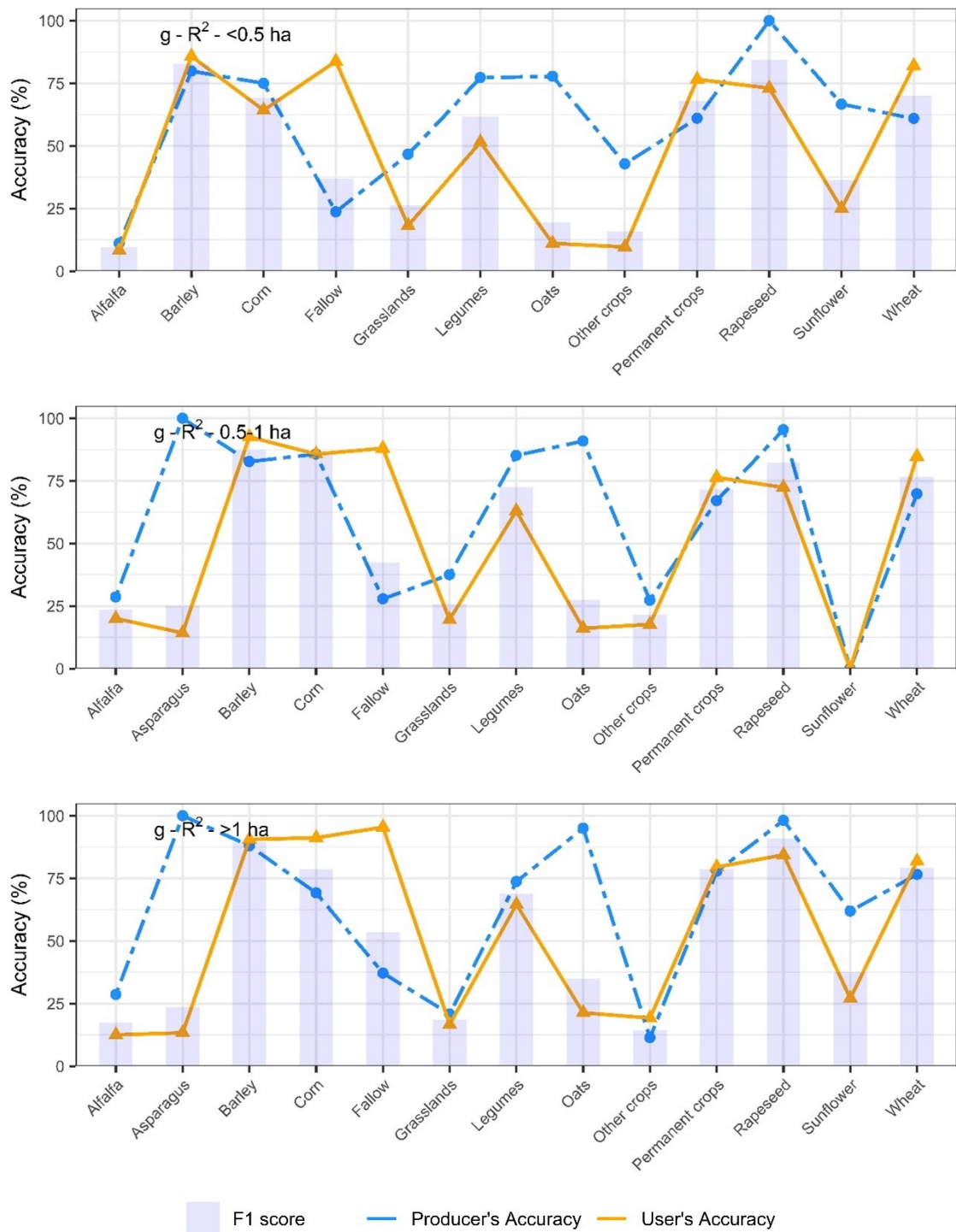


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. e) Region 5

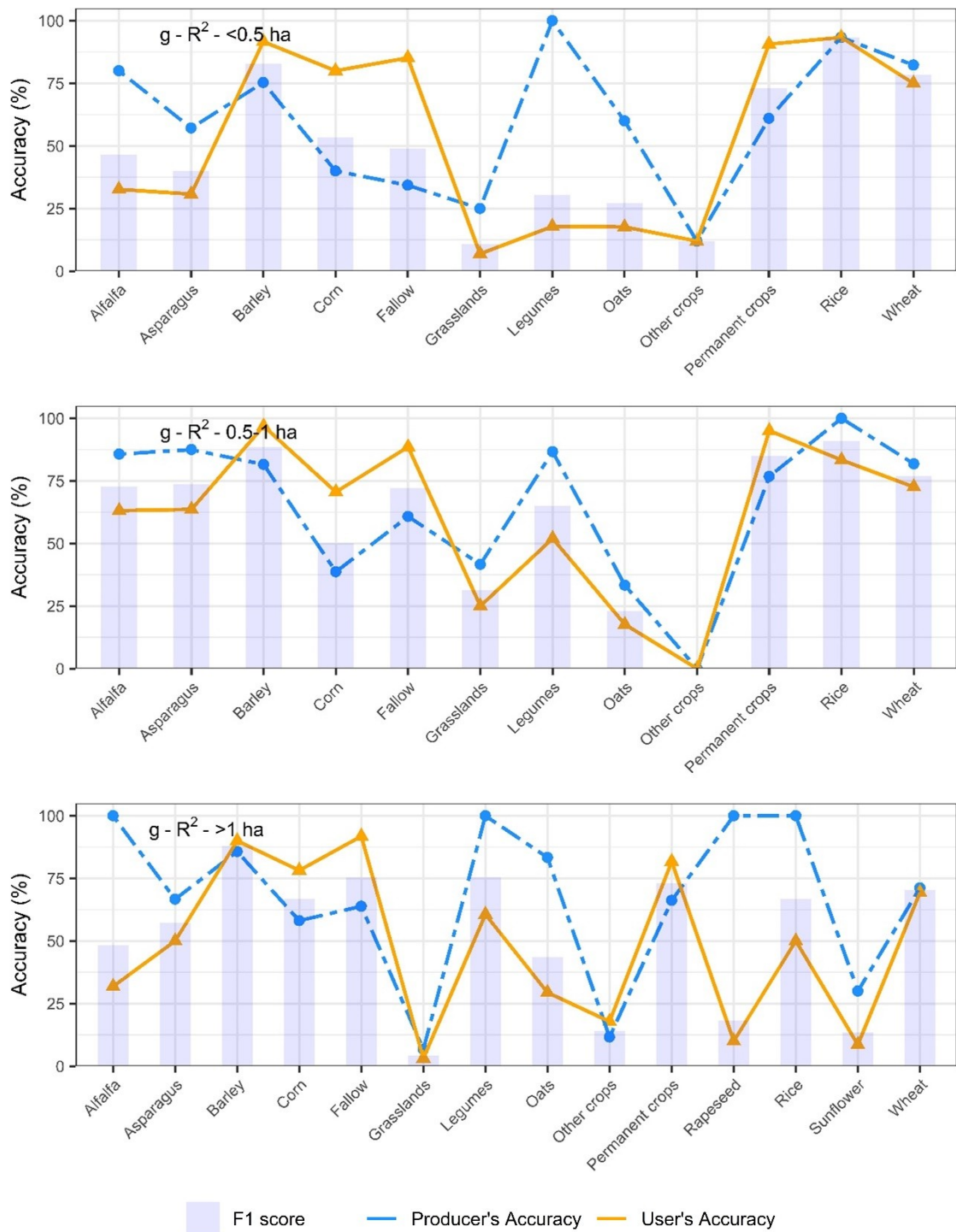


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. f) Region 6

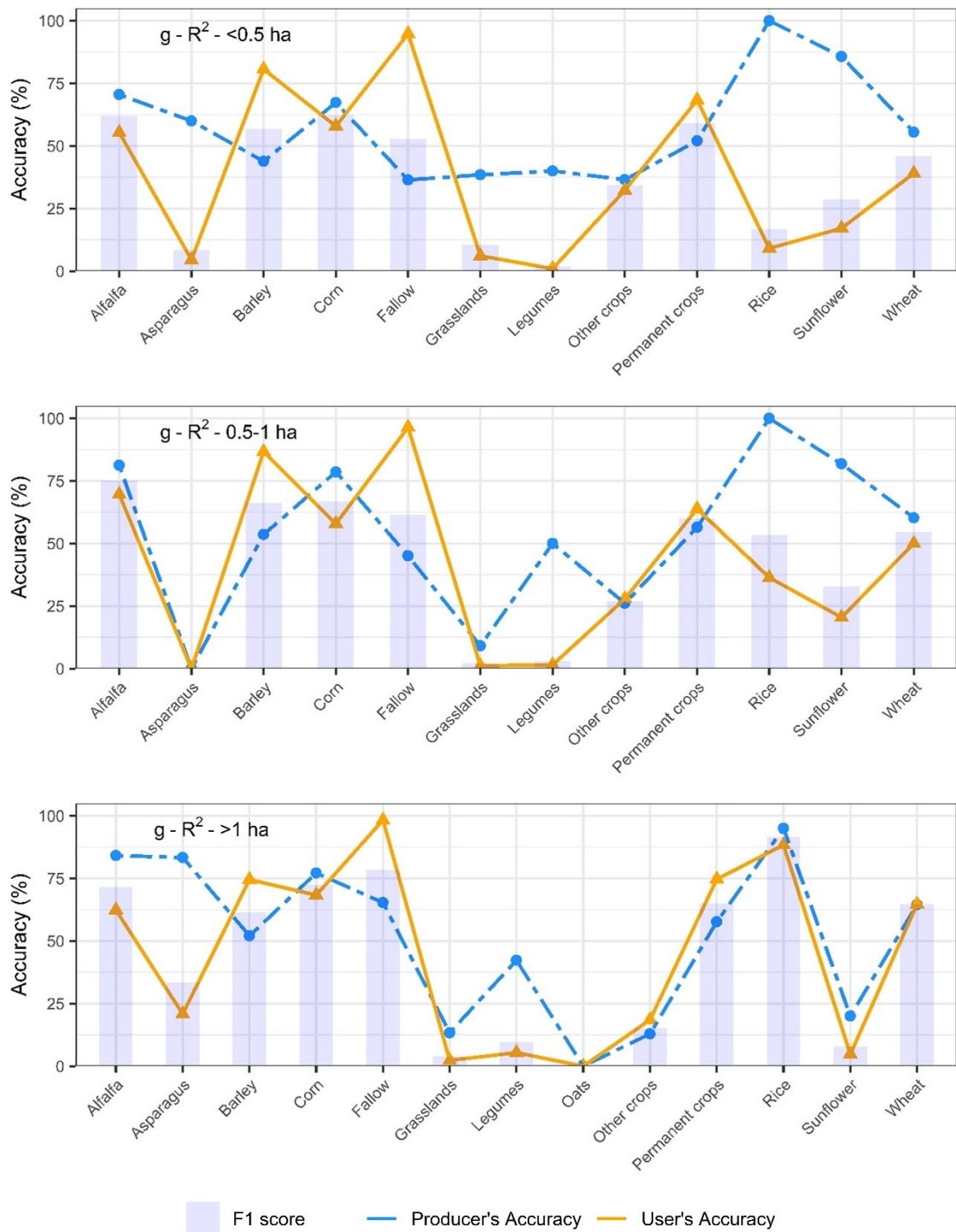


Figure S4 (cont.). F1-score, PA and UA of Ens and R2 classification based on field size for external validation. g) Region 7