

Assessing the added value of Sentinel-1 PolSAR data for crop classification (Supplementary Material)

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Table S1. Information about Sentinel-1 and Sentinel-2 images

Mission	Feature type	#features	#acquisitions	#total features
Sentinel 1	H/A/ $\bar{\alpha}$ polarimetric parameters	23	24	$23 \times 24 = 552$
Sentinel 2	Multispectral bands (Reflectance values)	10	19	$10 \times 19 = 190$
	Vegetation Indices	4		$4 \times 19 = 76$
Total				818

Table S2. GA's parametrization.

Parameter	Value
Population Size	100
Elitism ratio	0.2
Crossover probability	0.9
Mutation probability (chromosome level)	0.1
Mutation probability (gene level)	0.01
Maximum number of iterations	100
Maximum successive generations for improved fitness value	5

Table S3. SVM parametrization for each classification scenario.

Classification scenario	#features	C	$coef_0$	$gamma$
Sentinel-1	552	4	1	0.001
Sentinel-1/2	818	1	1	0.001
$t = 20$	23	0.25	1	0.1
$t = 15$	71	128	0.1	0.001
$t = 12$	125	0.25	10	0.01
$t = 10$	35	0.25	10	0.005

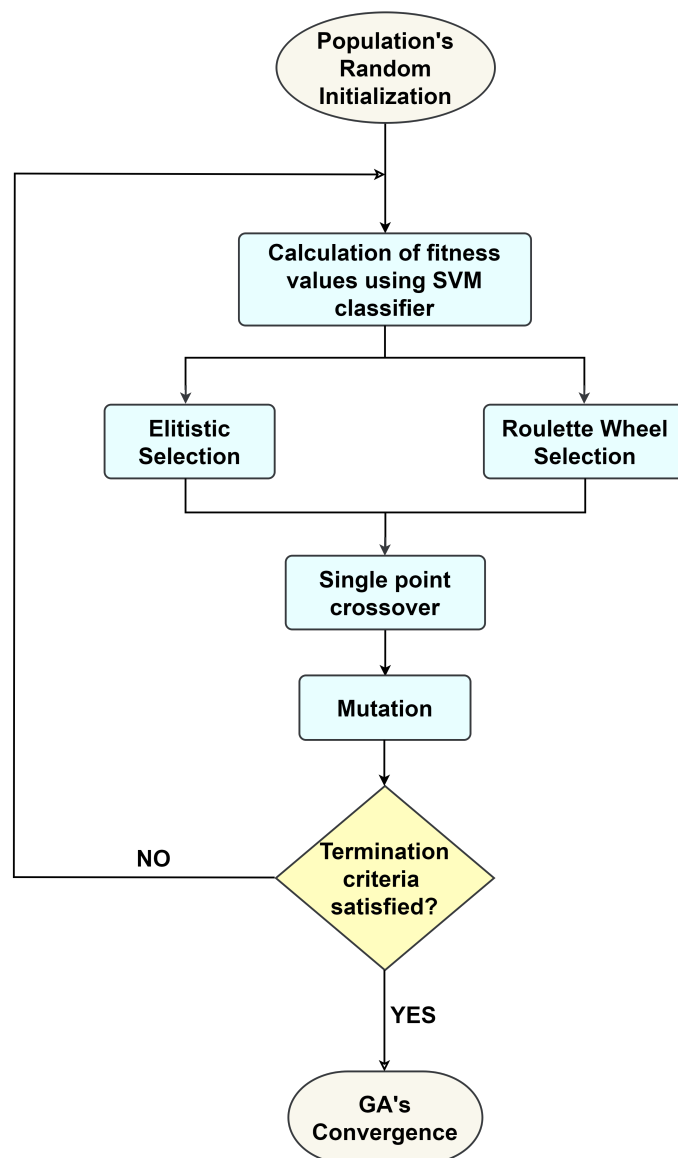


Figure S1. Flowchart of genetic algorithm's implementation

Table S4. SVM classification report using as input only the Sentinel-2 features

Crop Type	UA	PA	f1-score	support
soft wheat	92.87	94.82	93.84	3823
maize	95.68	94.36	94.99	156
barley	92.51	92.48	92.50	2526
oats	91.86	87.51	89.63	820
sunflower	95.72	92.30	93.97	200
rapeseed	94.32	91.98	93.13	496
broad beans	92.66	87.35	89.91	147
shrub grass	84.19	79.08	81.51	228
vineyards	83.71	88.08	85.74	146
cherry trees	87.10	81.57	84.09	89
macro avg	91.06	88.95	89.93	8631
weighted avg	92.42	92.42	92.40	8631

Table S5. SVM classification report using as input all the available features

Crop Type	UA	PA	f1-score	support
soft wheat	92.17	95.02	93.57	3823
maize	96.22	95.96	96.08	156
barley	92.81	92.88	92.85	2526
oats	92.33	84.56	88.27	820
sunflower	97.30	91.60	94.36	200
rapeseed	96.20	92.82	94.48	496
broad beans	94.50	85.58	89.79	147
shrub grass	81.67	78.46	79.98	228
vineyards	80.03	86.16	82.93	146
cherry trees	87.64	76.85	81.81	89
macro avg	91.09	87.99	89.41	8631
weighted avg	92.31	92.28	92.25	8631

Table S6. SVM classification report using as input only the Sentinel-1 features

Crop Type	UA	PA	f1-score	support
soft wheat	81.99	90.66	86.11	3823
maize	92.85	88.59	90.65	156
barley	87.82	86.81	87.31	2526
oats	77.49	60.39	67.87	820
sunflower	91.99	84.60	88.10	200
rapeseed	87.63	85.18	86.37	496
broad beans	68.99	48.44	56.85	147
shrub grass	51.68	32.68	39.90	228
vineyards	57.30	54.11	55.50	146
cherry trees	63.25	45.39	52.50	89
macro avg	76.10	67.68	71.12	8631
weighted avg	82.39	82.83	82.29	8631

Table S7. SVM classification report using as input the optimal 80-feature subset derived from a single genetic algorithm implementation.

Crop Type	UA	PA	f1-score	support
soft wheat	94.09	95.80	94.94	3823
maize	95.23	95.26	95.23	156
barley	93.95	93.92	93.93	2526
oats	93.62	88.70	91.09	820
sunflower	97.09	91.45	94.18	200
rapeseed	95.65	94.72	95.18	496
broad beans	94.91	88.37	91.51	147
shrub grass	83.75	81.97	82.84	228
vineyards	80.61	87.74	83.97	146
cherry trees	86.90	79.66	83.04	89
macro avg	91.58	89.76	90.59	8631
weighted avg	93.62	93.60	93.59	8631

Table S8. Most important features with the relevant numbers of occurrences (c) among the 100 different feature sets acquired from the 100 different GA runs, for the scenario with no artificial clouds

Feature	t	Feature	t	Feature	t
Jul08_PSRI	90	Oct21_NDVI	21	Sep11_NDVI	16
Jul23_PSRI	82	Jan29_B03	21	Jan12_entropy_shannon_norm	16
Jun23_PSRI	82	Sep11_NDWI	20	Jul29_entropy_shannon_I	16
Jul08_NDWI	79	Jun23_entropy_shannon_I	20	Mar31_I2	16
Apr24_PSRI	69	May30_I2	20	Jun23_entropy_shannon_norm	16
Jul08_B08	56	Mar30_B05	20	Sep11_SAVI	16
Apr24_B06	56	Apr19_B8A	20	Oct16_B02	16
Jul08_SAVI	49	Aug27_PSRI	20	Jul23_B03	15
Apr24_B05	47	Jul23_B12	19	May30_entropy_shannon_I	15
Apr24_B08	45	May06_entropy_shannon_I_norm	19	Apr19_SAVI	15
Apr19_B06	43	Oct16_B8A	19	Mar30_B06	15
Jun23_NDWI	40	Jun11_entropy_shannon_norm	19	Apr12_combination_HA	15
Jul08_B8A	40	Jul08_B12	19	May06_entropy_shannon	15
Jul08_B02	37	Jul08_B04	19	Apr19_NDVI	15
Jun23_B05	37	Aug27_B05	19	Jul17_entropy_shannon_I_norm	15
Apr24_B8A	36	Jun03_SAVI	19	Jan29_NDWI	15
Aug02_PSRI	35	May18_entropy_shannon	18	Oct21_B02	15
Oct16_SAVI	35	Oct21_B12	18	Apr24_B04	15
Jul08_B11	34	Aug02_NDWI	18	Apr12_combination_H1mA	15
Apr24_B07	33	Jun11_entropy_shannon	18	Jul23_NDVI	15
Jul08_NDVI	32	Jun11_I1	18	Feb05_combination_H1mA	15
Apr24_B03	32	Apr19_B03	18	Jul23_SAVI	15
Apr19_PSRI	31	Jul23_B05	18	Jan12_entropy_shannon_I	14
Sep16_PSRI	30	Aug27_B06	18	Jan24_NDVI	14
Oct21_B8A	29	Apr24_NDWI	18	May19_B12	14
Jun23_B11	29	Aug27_B02	18	Jan29_B05	14
Jul23_B02	28	May30_entropy_shannon_I_norm	18	Jul05_entropy_shannon	14
Oct16_NDVI	27	Oct21_B08	18	May04_NDWI	14
Jun23_NDVI	27	May04_SAVI	18	Jun23_I2	14
Oct16_PSRI	27	Oct16_B03	18	Jul05_combination_1mHA	14
Apr24_B11	26	Aug27_B8A	17	Apr24_entropy_shannon_norm	14
May30_entropy_shannon_norm	25	Mar30_NDVI	17	Mar15_PSRI	14
Jul23_B8A	25	Jun03_B06	17	Oct16_B08	14
Jun03_NDWI	25	Jun03_PSRI	17	Jan24_anisotropy	14
May30_entropy_shannon	25	Jan29_B06	17	Jun23_combination_1mH1mA	14
May19_NDWI	24	Sep15_entropy_shannon_I_norm	17	Jul05_p2	14
Oct21_PSRI	24	Oct16_B04	17	May24_SAVI	14
Apr24_B02	24	Jun23_B06	17	Oct21_NDWI	14
Jan29_B02	23	Jun23_B04	17	Mar31_anisotropy	13
Jul08_B05	23	Aug27_NDWI	17	May30_I1	13
May19_PSRI	23	Apr19_B12	17	Jan29_B11	13
Apr24_NDVI	23	Jun03_B07	17	Jul17_I1	13
Apr19_B05	22	Jun03_B12	17	Jan29_B07	13
Aug02_B02	22	Aug27_B11	17	Jul29_entropy_shannon	13
Jun23_SAVI	22	May06_entropy_shannon_norm	16	Aug10_entropy_shannon_I	13
Apr24_SAVI	22	Jun11_I2	16	Aug27_B12	13
Jul23_B08	22	Oct16_B12	16	Sep11_B12	13
Jul08_B03	21	Jan12_I1	16	Jul05_delta2	13
May19_SAVI	21	Aug27_B08	16	Mar30_B11	13
Jun23_B07	21	Jan24_NDWI	16	Jul23_B11	13
May19_NDVI	21	Jun23_I1	16	Jun03_NDVI	13
Aug02_B03	21	May06_entropy_shannon_I	16	Jan12_alpha	13

Table S8. Most important features with the relevant numbers of occurrences (c) among the 100 different feature sets acquired from the 100 different GA runs, for the scenario with no artificial clouds (continued)

Feature	t	Feature	t	Feature	t
Sep27_entropy_shannon_norm	13	Mar30_B03	11	Sep16_B02	10
Mar31_alpha	13	Mar31_entropy_shannon_I	11	Jul05_anisotropy	10
May24_NDWI	13	Aug10_entropy_shannon_norm	11	May30_lambda	10
May18_entropy_shannon_I	13	Jun23_entropy_shannon_I_norm	11	Apr24_B12	10
Jan29_SAVI	13	Jun23_combination_H1mA	11	May18_entropy_shannon_norm	10
Mar31_combination_1mH1mA	13	Apr19_B04	11	Mar15_B07	10
May18_lambda	13	May06_alpha	11	Apr24_entropy_shannon_I_norm	10
Jul17_entropy_shannon_norm	13	May18_I1	11	Mar31_p2	10
Jul08_B07	13	Apr19_B07	11	Jan24_alpha1	10
Aug22_entropy_shannon_I_norm	13	Mar15_B12	11	Aug02_B08	10
Jun03_B04	13	Mar31_I1	11	Feb05_entropy_shannon_I	10
May24_PSRI	13	May30_entropy_shannon_P	11	May18_p1	10
Mar30_B07	13	Mar31_alpha2	11	Sep03_I2	10
May06_entropy_shannon_P_norm	13	Mar31_lambda	11	Feb17_alpha2	10
Jan29_B12	13	Jun23_p1	11	Jan24_B11	10
Jul05_I2	13	Feb05_entropy_shannon_norm	11	Sep03_entropy_shannon_I_norm	10
Jul05_combination_1mH1mA	13	Sep27_p1	11	May18_alpha	10
Mar30_B02	12	Sep16_B03	11	Mar13_entropy_shannon_norm	10
Jul23_NDWI	12	Mar30_B8A	11	Sep27_entropy_shannon_P	10
Apr19_B08	12	Aug02_B11	11	Apr12_delta	10
Oct16_B05	12	Jun03_B11	11	Apr12_I1	10
Aug02_NDVI	12	May30_entropy	11	May04_B08	10
Oct21_B04	12	Sep11_B8A	11	Mar01_lambda	10
Sep03_delta1	12	Jun23_alpha	11	Aug10_entropy_shannon_I_norm	10
Aug27_SAVI	12	Jun23_B08	11	Feb17_entropy_shannon_I_norm	10
Jul29_entropy_shannon_norm	12	Jul05_p1	11	Sep03_alpha	10
Oct21_SAVI	12	Aug02_B06	11	Jul17_I2	10
Jun23_entropy_shannon_P_norm	12	Sep16_B8A	11	Sep03_anisotropy	10
Jan12_I2	12	Jan12_entropy_shannon_I_norm	11	Oct09_entropy_shannon_norm	10
Aug02_SAVI	12	Mar01_entropy_shannon_norm	11	Sep16_SAVI	10
Mar15_B05	12	Aug22_entropy_shannon	11	Jul17_entropy_shannon_I	10
May18_entropy_shannon_I_norm	12	Oct21_I2	11	Mar31_entropy_shannon_P_norm	10
Sep03_combination_1mHA	12	Mar13_entropy_shannon_P_norm	11	Sep16_B08	10
Jun11_lambda	12	Jul08_B06	11	Jul05_entropy	10
Sep16_NDWI	12	May30_combination_1mHA	11	Sep03_entropy_shannon	10
Mar30_B04	12	Mar31_entropy_shannon_P	11	Jun23_entropy_shannon	10
Jun23_p2	12	Aug02_B04	11	Jun03_B05	10
Jun11_entropy_shannon_I_norm	12	Jul29_I2	11	May30_p2	10
Oct21_B07	12	Sep11_B05	11	May24_NDVI	10
Jun23_B12	12	Mar13_entropy_shannon	11	Jul05_I1	10
Mar01_I2	12	Apr12_entropy_shannon_I	11	Jan29_B04	10
Mar15_B06	12	Jun11_entropy_shannon_I	11	Mar01_entropy_shannon_P	10
Jun23_combination_HA	12	Oct21_B11	11	Jan12_entropy_shannon	10
Jun23_B03	12	Oct09_entropy_shannon	11	Jan12_combination_H1mA	10
May06_I2	12	Mar31_entropy_shannon_I_norm	11	Sep11_B04	10
Mar15_NDVI	12	Jul23_B04	11	May19_B05	10
Oct16_B06	12	Jan24_combination_1mHA	11	Feb05_I2	10
Jul29_I1	12	May18_entropy_shannon_P	11	Jul23_B06	10
May18_I2	12	Mar30_B12	11	May04_B12	10
Feb05_delta	12	May04_NDVI	10	Aug02_B12	10
Jul23_B07	12	Jan12_entropy_shannon_P_norm	10	Jul05_lambda	10
Aug27_B04	11	Feb05_p2	10		

Table S9. Most important features with the relevant numbers of occurrences (c) among the 100 different feature sets acquired from the 100 different GA runs, for the scenario with artificial clouds

Feature	t	Feature	t	Feature	t
Jul08_PSRI	90	Oct21_NDVI	21	Sep11_NDVI	16
Jul23_PSRI	82	Jan29_B03	21	Jan12_entropy_shannon_norm	16
Jun23_PSRI	82	Sep11_NDWI	20	Jul29_entropy_shannon_I	16
Jul08_NDWI	79	Jun23_entropy_shannon_I	20	Mar31_I2	16
Apr24_PSRI	69	May30_I2	20	Jun23_entropy_shannon_norm	16
Jul08_B08	56	Mar30_B05	20	Sep11_SAVI	16
Apr24_B06	56	Apr19_B8A	20	Oct16_B02	16
Jul08_SAVI	49	Aug27_PSRI	20	Jul23_B03	15
Apr24_B05	47	Jul23_B12	19	May30_entropy_shannon_I	15
Apr24_B08	45	May06_entropy_shannon_I_norm	19	Apr19_SAVI	15
Apr19_B06	43	Oct16_B8A	19	Mar30_B06	15
Jun23_NDWI	40	Jun11_entropy_shannon_norm	19	Apr12_combination_HA	15
Jul08_B8A	40	Jul08_B12	19	May06_entropy_shannon	15
Jul08_B02	37	Jul08_B04	19	Apr19_NDVI	15
Jun23_B05	37	Aug27_B05	19	Jul17_entropy_shannon_I_norm	15
Apr24_B8A	36	Jun03_SAVI	19	Jan29_NDWI	15
Aug02_PSRI	35	May18_entropy_shannon	18	Oct21_B02	15
Oct16_SAVI	35	Oct21_B12	18	Apr24_B04	15
Jul08_B11	34	Aug02_NDWI	18	Apr12_combination_H1mA	15
Apr24_B07	33	Jun11_entropy_shannon	18	Jul23_NDVI	15
Jul08_NDVI	32	Jun11_I1	18	Feb05_combination_H1mA	15
Apr24_B03	32	Apr19_B03	18	Jul23_SAVI	15
Apr19_PSRI	31	Jul23_B05	18	Jan12_entropy_shannon_I	14
Sep16_PSRI	30	Aug27_B06	18	Jan24_NDVI	14
Oct21_B8A	29	Apr24_NDWI	18	May19_B12	14
Jun23_B11	29	Aug27_B02	18	Jan29_B05	14
Jul23_B02	28	May30_entropy_shannon_I_norm	18	Jul05_entropy_shannon	14
Oct16_NDVI	27	Oct21_B08	18	May04_NDWI	14
Jun23_NDVI	27	May04_SAVI	18	Jun23_I2	14
Oct16_PSRI	27	Oct16_B03	18	Jul05_combination_1mHA	14
Apr24_B11	26	Aug27_B8A	17	Apr24_entropy_shannon_norm	14
May30_entropy_shannon_norm	25	Mar30_NDVI	17	Mar15_PSRI	14
Jul23_B8A	25	Jun03_B06	17	Oct16_B08	14
Jun03_NDWI	25	Jun03_PSRI	17	Jan24_anisotropy	14
May30_entropy_shannon	25	Jan29_B06	17	Jun23_combination_1mH1mA	14
May19_NDWI	24	Sep15_entropy_shannon_I_norm	17	Jul05_p2	14
Oct21_PSRI	24	Oct16_B04	17	May24_SAVI	14
Apr24_B02	24	Jun23_B06	17	Oct21_NDWI	14
Jan29_B02	23	Jun23_B04	17	Mar31_anisotropy	13
Jul08_B05	23	Aug27_NDWI	17	May30_I1	13
May19_PSRI	23	Apr19_B12	17	Jan29_B11	13
Apr24_NDVI	23	Jun03_B07	17	Jul17_I1	13
Apr19_B05	22	Jun03_B12	17	Jan29_B07	13
Aug02_B02	22	Aug27_B11	17	Jul29_entropy_shannon	13
Jun23_SAVI	22	May06_entropy_shannon_norm	16	Aug10_entropy_shannon_I	13
Apr24_SAVI	22	Jun11_I2	16	Aug27_B12	13
Jul23_B08	22	Oct16_B12	16	Sep11_B12	13
Jul08_B03	21	Jan12_I1	16	Jul05_delta2	13
May19_SAVI	21	Aug27_B08	16	Mar30_B11	13
Jun23_B07	21	Jan24_NDWI	16	Jul23_B11	13
May19_NDVI	21	Jun23_I1	16	Jun03_NDVI	13
Aug02_B03	21	May06_entropy_shannon_I	16	Jan12_alpha	13

Table S9. Most important features with the relevant numbers of occurrences (c) among the 100 different feature sets acquired from the 100 different GA runs, for the scenario with artificial clouds (continued)

Feature	t	Feature	t	Feature	t
Sep27_entropy_shannon_norm	13	Mar30_B03	11	Sep16_B02	10
Mar31_alpha	13	Mar31_entropy_shannon_I	11	Jul05_anisotropy	10
May24_NDWI	13	Aug10_entropy_shannon_norm	11	May30_lambda	10
May18_entropy_shannon_I	13	Jun23_entropy_shannon_I_norm	11	Apr24_B12	10
Jan29_SAVI	13	Jun23_combination_H1mA	11	May18_entropy_shannon_norm	10
Mar31_combination_1mH1mA	13	Apr19_B04	11	Mar15_B07	10
May18_lambda	13	May06_alpha	11	Apr24_entropy_shannon_I_norm	10
Jul17_entropy_shannon_norm	13	May18_I1	11	Mar31_p2	10
Jul08_B07	13	Apr19_B07	11	Jan24_alpha1	10
Aug22_entropy_shannon_I_norm	13	Mar15_B12	11	Aug02_B08	10
Jun03_B04	13	Mar31_I1	11	Feb05_entropy_shannon_I	10
May24_PSRI	13	May30_entropy_shannon_P	11	May18_p1	10
Mar30_B07	13	Mar31_alpha2	11	Sep03_I2	10
May06_entropy_shannon_P_norm	13	Mar31_lambda	11	Feb17_alpha2	10
Jan29_B12	13	Jun23_p1	11	Jan24_B11	10
Jul05_I2	13	Feb05_entropy_shannon_norm	11	Sep03_entropy_shannon_I_norm	10
Jul05_combination_1mH1mA	13	Sep27_p1	11	May18_alpha	10
Mar30_B02	12	Sep16_B03	11	Mar13_entropy_shannon_norm	10
Jul23_NDWI	12	Mar30_B8A	11	Sep27_entropy_shannon_P	10
Apr19_B08	12	Aug02_B11	11	Apr12_delta	10
Oct16_B05	12	Jun03_B11	11	Apr12_I1	10
Aug02_NDVI	12	May30_entropy	11	May04_B08	10
Oct21_B04	12	Sep11_B8A	11	Mar01_lambda	10
Sep03_delta1	12	Jun23_alpha	11	Aug10_entropy_shannon_I_norm	10
Aug27_SAVI	12	Jun23_B08	11	Feb17_entropy_shannon_I_norm	10
Jul29_entropy_shannon_norm	12	Jul05_p1	11	Sep03_alpha	10
Oct21_SAVI	12	Aug02_B06	11	Jul17_I2	10
Jun23_entropy_shannon_P_norm	12	Sep16_B8A	11	Sep03_anisotropy	10
Jan12_I2	12	Jan12_entropy_shannon_I_norm	11	Oct09_entropy_shannon_norm	10
Aug02_SAVI	12	Mar01_entropy_shannon_norm	11	Sep16_SAVI	10
Mar15_B05	12	Aug22_entropy_shannon	11	Jul17_entropy_shannon_I	10
May18_entropy_shannon_I_norm	12	Oct21_I2	11	Mar31_entropy_shannon_P_norm	10
Sep03_combination_1mHA	12	Mar13_entropy_shannon_P_norm	11	Sep16_B08	10
Jun11_lambda	12	Jul08_B06	11	Jul05_entropy	10
Sep16_NDWI	12	May30_combination_1mHA	11	Sep03_entropy_shannon	10
Mar30_B04	12	Mar31_entropy_shannon_P	11	Jun23_entropy_shannon	10
Jun23_p2	12	Aug02_B04	11	Jun03_B05	10
Jun11_entropy_shannon_I_norm	12	Jul29_I2	11	May30_p2	10
Oct21_B07	12	Sep11_B05	11	May24_NDVI	10
Jun23_B12	12	Mar13_entropy_shannon	11	Jul05_I1	10
Mar01_I2	12	Apr12_entropy_shannon_I	11	Jan29_B04	10
Mar15_B06	12	Jun11_entropy_shannon_I	11	Mar01_entropy_shannon_P	10
Jun23_combination_HA	12	Oct21_B11	11	Jan12_entropy_shannon	10
Jun23_B03	12	Oct09_entropy_shannon	11	Jan12_combination_H1mA	10
May06_I2	12	Mar31_entropy_shannon_I_norm	11	Sep11_B04	10
Mar15_NDVI	12	Jul23_B04	11	May19_B05	10
Oct16_B06	12	Jan24_combination_1mHA	11	Feb05_I2	10
Jul29_I1	12	May18_entropy_shannon_P	11	Jul23_B06	10
May18_I2	12	Mar30_B12	11	May04_B12	10
Feb05_delta	12	May04_NDVI	10	Aug02_B12	10
Jul23_B07	12	Jan12_entropy_shannon_P_norm	10	Jul05_lambda	10
Aug27_B04	11	Feb05_p2	10		