

Drone-Based Identification and Monitoring of Two Invasive Alien Plant Species in Open Sand Grasslands by Six RGB Vegetation Indices

László Bakacsy ^{1,*}, Zalan Tobak ², Boudewijn van Leeuwen ², Péter Szilassi ², Csaba Biró ³ and József Szatmári ²

¹ Department of Plant Biology, University of Szeged, Közép Fasor 52, H-6727 Szeged, Hungary

² Department of Geoinformatics, Physical and Environmental Geography, University of Szeged, Egyetem utca 2-6, H-6722 Szeged, Hungary

³ Kiskunság National Park Directorate, Liszt Ferenc utca 19, H-6000 Kecskemét, Hungary

* Correspondence: bakacsy@bio.u-szeged.hu

Supplement

Table S1. RGB based indices intervals used to generate binary maps and to which species a given index can be applied.

Indices Intervals		R-G	R-B	G-B	TGI	IF	SSI
STAND I.	1.study area	-37 – 65	2 – 159	-3 – 123	-845 – 8240	0.416 – 212.5	0 – 150
	2.study area	-32 – 65	0 – 150	-2 – 137	-780 – 9105	0.333 – 213.524	0 – 163
	3.study area	-47 – 72	-3 – 168	-4 – 132	-920 – 9110	-26.479 – 237.628	0 – 166
	4.study area	-46 – 61	-7 – 151	-4 – 127	-1080 – 8915	-33.606 – 202.526	0 – 164
	5.study area	-41 – 65	4 – 151	0 – 122	-620 – 8515	-10.061 – 206.562	0 – 159
	6.study area	-39 – 77	-1 – 160	-3 – 141	-870 – 9625	-10.73 – 216.724	0 – 175
	7.study area	-33 – 82	11 – 179	1 – 130	-645 – 8500	7 – 260.651	0 – 150
	8.study area	-39 – 66	2 – 135	-3 – 141	-875 – 9615	-20.675 – 184.485	0 – 174
	9.study area	-43 – 75	1 – 165	-1 – 129	-565 – 8555	-3.346 – 238.529	0 – 158
	10.study area	-38 – 64	4 – 116	-6 – 136	-1060 – 8860	0.102 – 155.329	0 – 160
STAND II.	1.study area	-59 – 60	-1 – 152	0 – 137	-490 – 9310	-37.656 – 206.494	0 – 173
	2.study area	-53 – 64	-3 – 155	-3 – 139	-390 – 9740	-26.545 – 205.526	0 – 179
	3.study area	-44 – 53	1 – 151	-3 – 126	-635 – 8540	-9.218 – 200.677	0 – 154
	4.study area	-40 – 58	15 – 136	5 – 132	-420 – 8780	-4.817 – 188.485	0 – 158
	5.study area	-51 – 50	-12 – 122	-3 – 98	-540 – 7455	-34.736 – 171.521	0 – 143
	6.study area	-46 – 49	-6 – 134	-8 – 116	-675 – 8185	-29.642 – 180.543	0 – 151
	7.study area	-37 – 59	10 – 137	1 – 125	-570 – 8435	4.419 – 185.464	0 – 156
	8.study area	-40 – 65	11 – 147	8 – 136	-650 – 9385	-0.081 – 190.628	0 – 171
	9.study area	-47 – 60	-3 – 125	-6 – 135	-765 – 9325	-27.614 – 173.455	0 – 170
	10.study area	-48 – 45	-2 – 136	-5 – 126	-700 – 8785	-36.684 – 178.563	0 – 161
Applicability to Species		milkweed and blanket flower	blanket flower	milkweed	milkweed	blanket flower	milkweed

Table S2. The area of common milkweed shoots area per study areas. The percentages indicate the percentage of overlap between the Index Polygons (R-G, G-B, TGI and SSI Polygons) and the Manual Polygons (M.P.). SD - standard deviation, n = 20.

Common milkweed shoot AREA		M.P. m ²	R-G Polygons % (M.P.)		G-B Polygons % (M.P.)		TGI Polygons % (M.P.)		SSI Polygons % (M.P.)	
STAND I.	1.study area	8.601	8.539	99.28	8.563	99.56	8.550	99.41	8.566	99.59
	2.study area	7.594	7.435	97.89	7.559	99.53	7.596	100.01	7.489	98.61
	3.study area	8.446	8.560	101.34	8.331	98.63	8.471	100.29	8.414	99.62
	4.study area	10.098	9.840	97.45	10.322	102.22	10.185	100.86	10.017	99.19
	5.study area	1.984	1.878	94.66	2.029	102.27	2.021	101.86	2.026	102.12
	6.study area	16.944	17.073	100.75	16.566	97.76	16.955	100.06	16.954	100.05
	7.study area	2.393	2.382	99.52	2.291	95.70	2.361	98.63	2.382	99.51
	8.study area	7.596	7.858	103.45	7.545	99.32	7.641	100.59	7.695	101.30
	9.study area	9.456	9.219	97.49	9.327	98.63	9.593	101.45	9.399	99.39
	10.study area	4.232	4.052	95.75	4.258	100.63	4.237	100.12	4.175	98.65
STAND II.	1.study area	22.422	23.010	102.62	22.743	101.42	22.367	99.75	22.301	99.45
	2.study area	24.573	24.151	98.27	24.775	100.81	24.550	99.90	24.719	100.59
	3.study area	11.129	10.963	98.51	11.184	100.49	11.034	99.15	11.092	99.67
	4.study area	4.222	4.440	105.16	4.292	101.65	4.248	100.62	4.217	99.87
	5.study area	3.200	3.008	94.00	3.112	97.26	3.130	97.81	3.277	102.42
	6.study area	5.904	5.768	97.70	6.016	101.91	6.005	101.71	5.846	99.02
	7.study area	3.389	3.304	97.48	3.480	102.66	3.371	99.46	3.490	102.98
	8.study area	8.088	7.718	95.42	7.991	98.79	8.176	101.09	8.165	100.95
	9.study area	13.992	14.112	100.85	13.843	98.93	13.875	99.16	14.105	100.81
	10.study area	20.889	20.945	100.27	21.173	101.36	20.739	99.28	20.842	99.77
Average %			98.89		99.98		100.06		100.18	
SD %			2.92		1.87		1.03		1.23	

Table S3. The inflorescence area of blanket flower per study areas. The percentage values: Index Polygons (R-G, R-B and IF Polygons) are referred to the Manual Polygons (M.P.). SD - standard deviation, n = 20.

Blanket flower inflorescence AREA		M.P. m ²	R-G Polygons % (M.P.)		R-B Polygons % (M.P.)		IF Polygons % (M.P.)	
STAND I.	1.study area	1.406	1.377	97.96	1.423	101.21	1.396	99.31
	2.study area	1.402	1.515	108.09	1.411	100.65	1.466	104.58
	3.study area	0.899	0.821	91.34	0.931	103.48	0.880	97.86
	4.study area	1.439	1.315	91.41	1.449	100.72	1.432	99.50
	5.study area	0.949	0.965	101.71	0.930	97.93	0.933	98.25
	6.study area	1.445	1.472	101.85	1.473	101.88	1.434	99.21
	7.study area	5.505	5.638	102.41	5.479	99.53	5.440	98.82
	8.study area	2.316	2.340	101.01	2.399	103.54	2.305	99.53
	9.study area	1.706	1.696	99.40	1.690	99.05	1.716	100.53
	10.study area	1.169	1.139	97.39	1.167	99.78	1.187	101.54
STAND II.	1.study area	1.506	1.439	95.59	1.459	96.87	1.500	99.59

2.study area	1.413	1.468	103.88	1.399	99.00	1.434	101.51
3.study area	0.421	0.428	101.77	0.399	94.87	0.419	99.55
4.study area	1.043	0.958	91.91	1.044	100.17	1.070	102.59
5.study area	0.629	0.654	103.87	0.622	98.81	0.632	100.46
6.study area	0.509	0.537	105.48	0.490	96.22	0.505	99.15
7.study area	1.046	1.092	104.46	1.083	103.61	1.076	102.90
8.study area	0.436	0.407	93.51	0.455	104.48	0.437	100.21
9.study area	0.731	0.701	95.79	0.731	99.95	0.720	98.38
10.study area	0.336	0.338	100.54	0.315	93.53	0.332	98.68
Average %		99.47		99.76		100.11	
SD %		4.92		2.92		1.73	

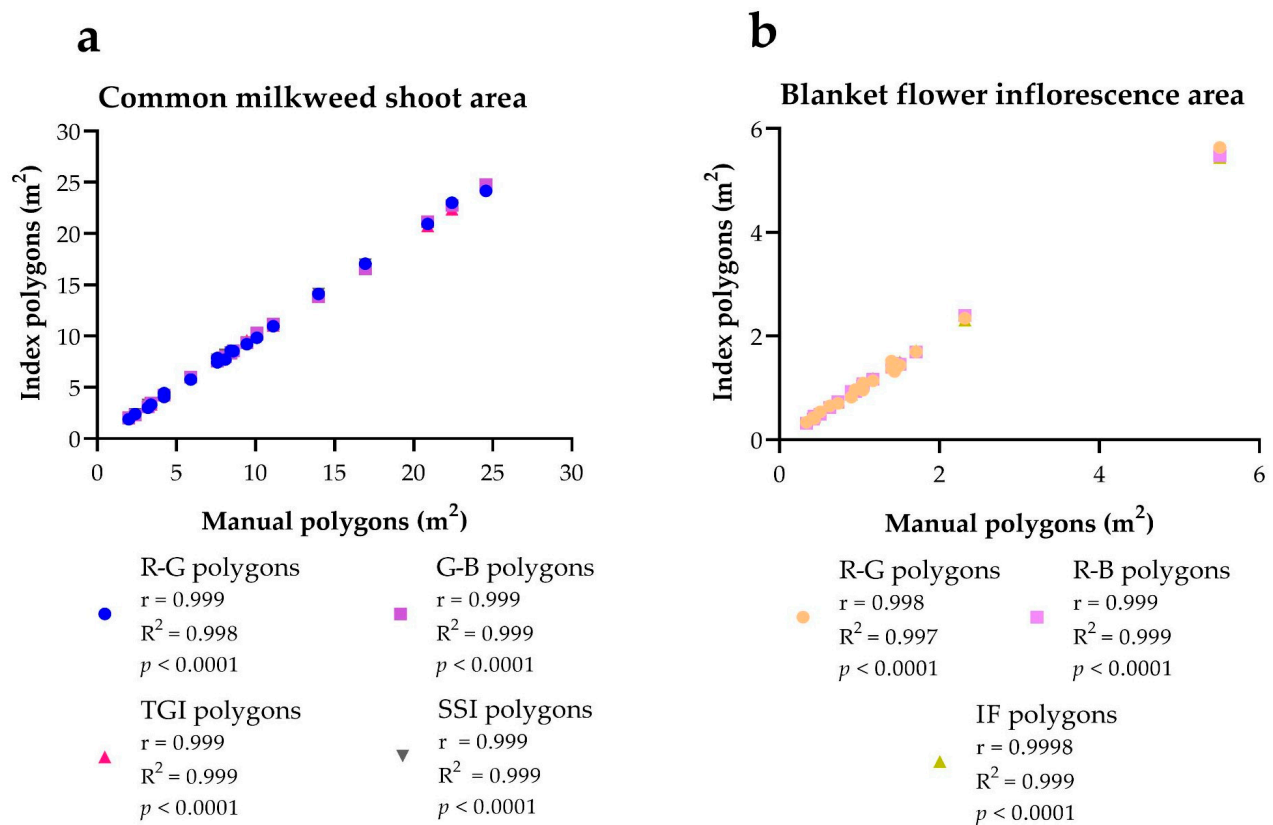


Figure S1. The correlation between the Manual Polygons (manually delineated polygons) and Index Polygons in the case of the common milkweed (a) and blanket flower (b). Pearson r correlation (two-tailed) was used, n = 20. Significance was applied from a value of $p = 0.05$, values higher than this were not significant.

Table S4. The confusion matrix of the classification of milkweed shoots. The overall accuracy, omission error and commission error values were used to evaluate the classification results of the pixels of the remotely sensed images. SD – standard deviation.

R-G			G-B			TGI			SSI		
Overall acc. %	Omission error %	Commission error %	Overall acc. %	Omission error %	Commission error %	Overall acc. %	Omission error %	Commission error %	Overall acc. %	Omission error %	Commission error %

STAND I.	99.33	48.49	36.47	99.44	42.55	28.34	99.48	40.38	25.69	99.48	40.56	25.73
STAND II.	99.59	34.33	33.33	99.69	26.21	25.33	99.71	24.86	23.48	99.71	25.04	24.03
Average	99.46	41.41	34.90	99.57	34.38	26.83	99.60	32.62	24.58	99.60	32.80	24.88
SD	0.18	10.01	2.22	0.18	11.56	2.13	0.16	10.98	1.56	0.16	10.97	1.20

Table S5. The confusion matrix of the classification of blanket flower inflorescence. The overall accuracy, omission error and commission error values were used to evaluate the classification results of the pixels of the remotely sensed images. SD - standard deviation.

	R-G			R-B			IF		
	<i>Overall acc. %</i>	<i>Omission error %</i>	<i>Commission error %</i>	<i>Overall acc. %</i>	<i>Omission error %</i>	<i>Commission error %</i>	<i>Overall acc. %</i>	<i>Omission error %</i>	<i>Commission error %</i>
STAND I.	99.80	65.46	52.04	99.79	66.39	54.10	99.82	58.98	43.98
STAND II.	99.95	60.94	60.56	99.95	61.33	60.65	99.96	53.54	53.23
Average	99.88	63.20	56.30	99.87	63.86	57.38	99.89	56.26	48.60
SD	0.11	3.20	6.02	0.11	3.58	4.63	0.10	3.85	6.54