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Supplementary Material

The ETH field phenotyping platform FIP: a cable-suspended multi-sensor system

Norbert Kirchgessner[A,B], *Frank Liebisch*[A], *Kang Yu*[A], *Johannes Pfeifer*[A], *Michel Friedli*[A], *Andreas Hund*[A] *and Achim Walter*[A]

[A]Institute of Agricultural Sciences, Group of Crop Sciences, ETH Zürich, Universitätstrasse 2, LFW C58, 8092 Zürich, Switzerland.

[B]Corresponding author: Email: norbert.kirchgessner@usys.ethz.ch

Optimization of Collimation lens and adjustment of measurement position

Adjustment of the collimation lens was done in a dark room with the collimation lens mounted on a fibre connected to a DH-2000-BAL (Ocean Optics Inc., USA) light source (a Balanced Deuterium, Halogen Light Source for the UV-Vis-NIR) pointing horizontally towards a white wall. Then the projected light circle was sharped and the diameter measured at 2, 3 and 4 m and interpolated for other distances.

The direction and position of the target fibre was adjusted to the IP camera (1920x1080 pixel). Therefore the camera was pointed horizontally towards a white upright background (3*2 m Kömatex plate) with a distance of 3 m and the middle of the IP camera image was marked with a red point on the plate. Then a black round target plate (Kömatex) with a diameter of 65 cm was fixed with its middle to this point. Subsequently the target fibre direction was adjusted to the black target plate using the position with the minimal reflectance. The edges of this position were checked by holding a laser pointer on the white plate and pointing it towards the fibre and moving it slowly from outside of the black target to the middle (done for 0, 90, 180 and 270°) and the noting the distance from the edge in cm. In this way we could ensure the fibre points to the middle of the target and determined the core diameter of the measurements of ~ 49 cm diameter (distance of laser source and non-sharp edge and variation in manual pointing affect this method).

Table S1. Measuring dates of the FIP including climate data.

Date	T mean	T min	T max	Rel. humidity	rainfall	wind speed mean	wind speed max.	global irradiance
yyyymmdd	ºC	ºC	ºC	%	mm	m/sec	m/sec	Wh/m2
20141203	3	2.5	3.7	94.7	0.2	1.8	5.8	512
20150416	15.4	10.9	21.6	46.6	0	1.4	8.3	4483
20150423	11	4.8	17	51.1	0	1.9	6.3	7491
20150427	14.8	9	20.9	73.1	17.4	1	5.2	4724
20150430	11.6	7.8	16.8	61.8	5	1.4	5.6	5893
20150504	16.4	13.8	20.3	86.7	2.4	1.2	4	3104
20150506	13.5	9.4	19.4	73.9	17.4	1.1	4.6	5316
20150507	13.3	8.2	18.8	60.7	0	0.8	3.5	7519
20150511	18	8.4	26.6	54.8	0	0.8	3.9	7267
20150513	21.2	15.6	26.8	56.4	0	0.8	4.4	6333
20150514	17.8	10	21.4	60.9	6.4	1.4	7.2	6176
20150518	16.9	8.3	24	61	0	1.2	8.2	8327
20150522	11.2	6.9	15.5	69.9	0	1.3	6.4	6497
20150527	11.1	6	17.4	65.9	0	0.8	2.9	6717
20150528	14.4	4.7	22.2	57.8	0	1	5	8631
20150601	18.6	13.3	24.3	66.3	0.8	1.2	6.7	7871
20150604	22.1	15.4	28	58.9	0	1.4	4.2	8531
20150608	17.1	13.4	22.2	81.1	2.6	1.8	6.9	5832
20150609	13	11.7	14.6	86	0.2	2.6	6.9	1412
20150610	15.1	11.5	18.8	81.9	0	1.8	6.2	4072
20150611	19.2	13.7	24.8	71.6	0	1.1	4.9	7870
20150612	21.3	13.8	29.7	63.1	0	0.9	4.5	7335
20150616	16.2	13.6	20.3	80.8	1.2	1.2	4.8	3260
20150617	16.5	12.2	21.6	62.5	0	1	4.8	8324
20150619	15.8	12.4	20.6	69	0.2	1.1	5.8	6989
20150622	16.6	12.2	21.5	76.7	13.6	1.6	9	4609
20150624	15.1	6.8	20.7	60	0	1.1	4.1	9008
20150625	17.6	8.9	24.9	55.5	0	0.8	3.9	7914

20150701	24.8	16.8	32.1	51.2	0	0.9	3.5	8602
20150708	19.6	16.5	22.3	59.9	0.8	1.5	6.2	4358
20150709	18.6	15.3	23.4	50.1	0	1.6	5.9	6825
20150710	19.3	12.6	25.1	50	0	1.6	5.5	8827
20150713	21.6	18.3	25.8	52	0	1.1	5.8	5232
20150724	22.3	16.5	30.6	70.7	6	1.4	8.6	7248
20150730	16.4	10.4	21.8	59.7	0	0.9	4.5	7318
20150812	25	18	31.6	59	0	1	4.1	7176
20150817	16.2	11.9	20.6	71.9	0	0.6	3.1	3924
20150820	16.3	9.8	23.8	75.4	0	0.9	3.8	5767
20150825	16.4	11.7	22.1	64.5	0.2	1.1	5.1	6447
20150827	23.3	15.7	30.9	54.6	0	0.9	3.2	6165
20150828	24.5	18.8	31.4	52.7	0	1.2	6.7	6411
20150902	16.7	13.6	20.6	75.2	0	1	4.1	4540
20150909	13.7	7.4	20	61.4	0	1.7	6.5	6052
20150916	16	12.4	21	72	0.2	0.9	3.7	2931
20150924	11.1	7.3	16.1	76.2	0	0.8	3.9	3820
20150930	9.6	6.2	14.6	66.2	0	2.2	7.2	2767
20151002	11.2	5.3	16.1	70.4	0	1.1	5.2	3878
20151008	11.8	7.8	15.4	77.6	0	0.6	3.1	2033
20151014	6.5	3.7	9.9	77.5	0	1.4	4.9	2427
20151021	5.4	2	8.9	81.1	0	0.7	4	1321
20151022	7.5	1.4	12.2	77.6	0	1.2	4.5	2444
20151105	10.4	5.3	16.4	78.2	0	0.6	2.9	2789
20151109	13.6	9.6	19.5	70.1	0	1.3	6.8	1882
20151112	5.5	4.1	6.2	99	0.2	0.9	3.1	858
20151116	10.7	5.5	16.8	68.6	0	1.2	4.7	1890
20151119	13.2	10.9	15.6	59.4	0	3.4	11.3	2002
20151124	-0.8	-5	2.7	75.3	0.4	1.2	4.5	2148
20151127	1.1	0.1	2	80	0	1.6	6.2	734
20151202	4.7	0.1	10	84.8	0	0.7	2.4	2009

20151203	0.4	-0.5	1.5	97.8	0.2	0.9	3.4	546
20151207	3.4	-0.2	7.8	89.1	0	0.8	3.1	1887
20151210	0.8	-1.2	2	97	0	1.2	3.5	699
20151214	-1.1	-3.7	3.5	91.1	0	0.7	2.8	1676
20151217	9.1	5.2	15.9	85.3	0	0.8	3.1	1716
20151223	7.9	3.6	12.7	73.8	0	1.3	6.7	1502
20160125	5	-0.4	12.1	70.3	0	0.8	2.5	2375
20160126	6.5	2.3	13.4	69.2	0	1.2	4.1	1952
20160128	8.4	6.1	11.4	72	0.4	0.9	3.5	1122
20160201	10.4	5.9	13.2	78.6	1.8	3.1	14.3	2010
20160205	5.3	2.1	10.7	88.2	2.2	1	5	1481
20160215	2.3	1.3	3.9	91.2	2	0.6	3.9	632
20160216	1.5	0.8	2.4	82.2	0.8	2.7	10.3	479
20160218	3.1	-0.8	7.6	73.5	0	0.7	4.7	2563
20160222	10.5	4.8	16.5	67.6	0	1.8	7.6	3001
20160304	1.9	-1.4	5.5	78.2	1	0.9	3.7	1992
20160307	2	-1.3	6.6	68.7	0	1.1	4.3	3494
20160310	3	-3.2	8.8	70.9	0	1.4	5.5	4739
20160314	3.7	1.5	5.2	69.3	0	2.3	7.5	1206
20160317	3.9	-1.3	10.7	72	0	1.8	7.1	4991
20160321	4.1	1.5	8.7	74.5	0	1.6	5.3	2189
20160323	4.2	0.9	6.9	71.9	0	1.1	4.2	1859
20160330	12.7	8.5	19.3	65	0	1.8	7.9	3915
20160406	10.5	7.6	15.5	74.7	9.4	1.6	6.5	4705
20160408	5.4	4.5	7.2	84.3	3.6	1.6	4.8	1734
20160411	11.3	4.3	19	63.1	0	1.3	4.8	6575
20160414	9.5	6.3	15.3	76.8	12.8	1.4	5.3	4233
20160419	7.8	3	14.2	72.7	0	1	3.9	5616
20160421	12.9	3.8	20.1	59	0	1.1	4.3	7048
20160425	3.6	0.3	7.2	72.6	2.4	2.5	8.4	4169
20160428	6.1	-0.9	11.6	57	0	1.1	5.6	5255

mean	11.6	7.1	16.5	70.8	1.2	1.3	5.3	4335.6
min	-1.1	-5	1.5	46.6	0	0.6	2.4	479
max	25	18.8	32.1	99	17.4	3.4	14.3	9008

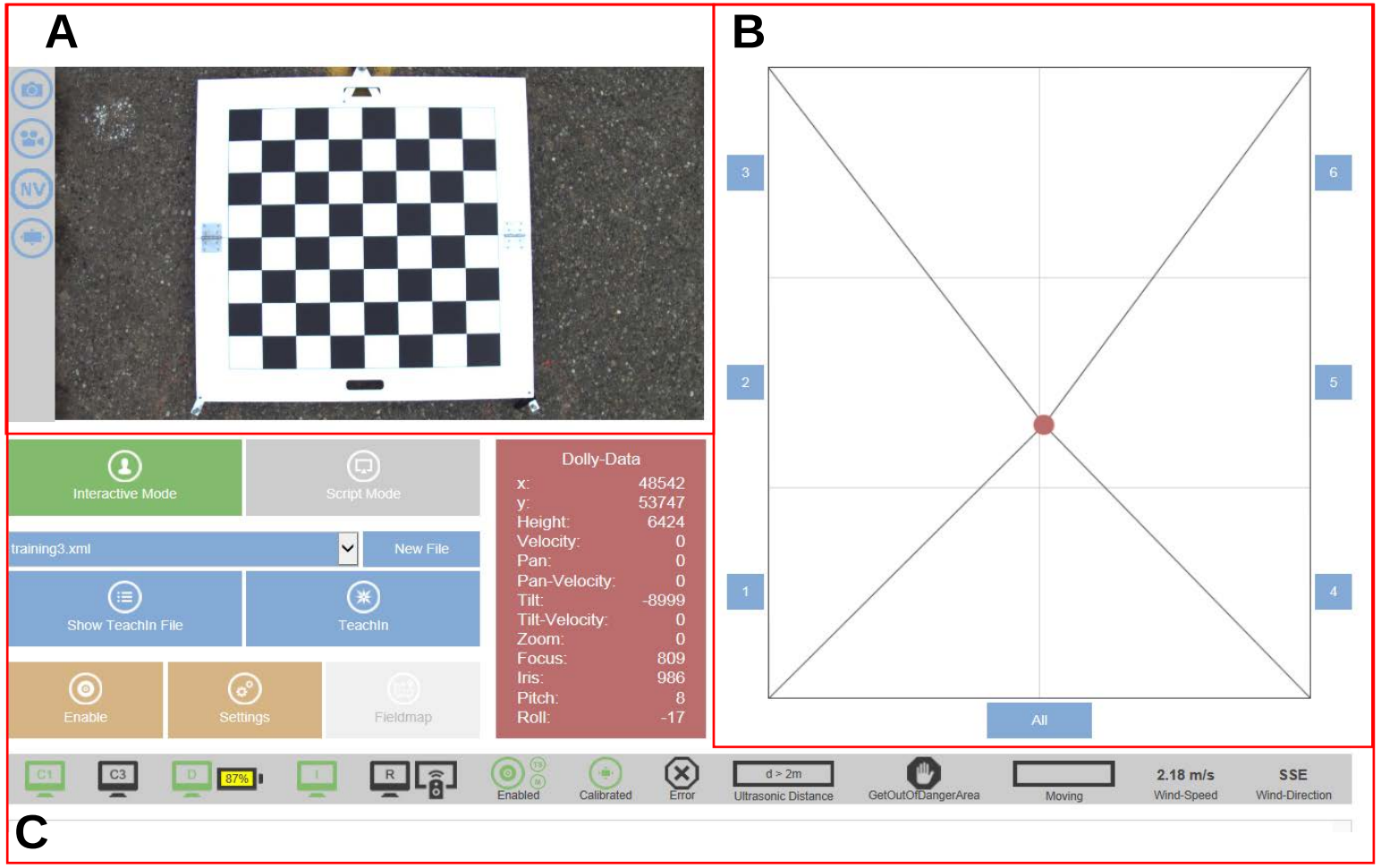


Figure S1. Screenshot of the GUI on C2, A: live image of operator camera on the sensor head with image of the checkerboard for position calibration. B: Field map for fast overview of sensor head position on the field. C: Status display with current mode, sensor head coordinates, pitch, roll (in hundredth degrees) battery status, wind speed etc.

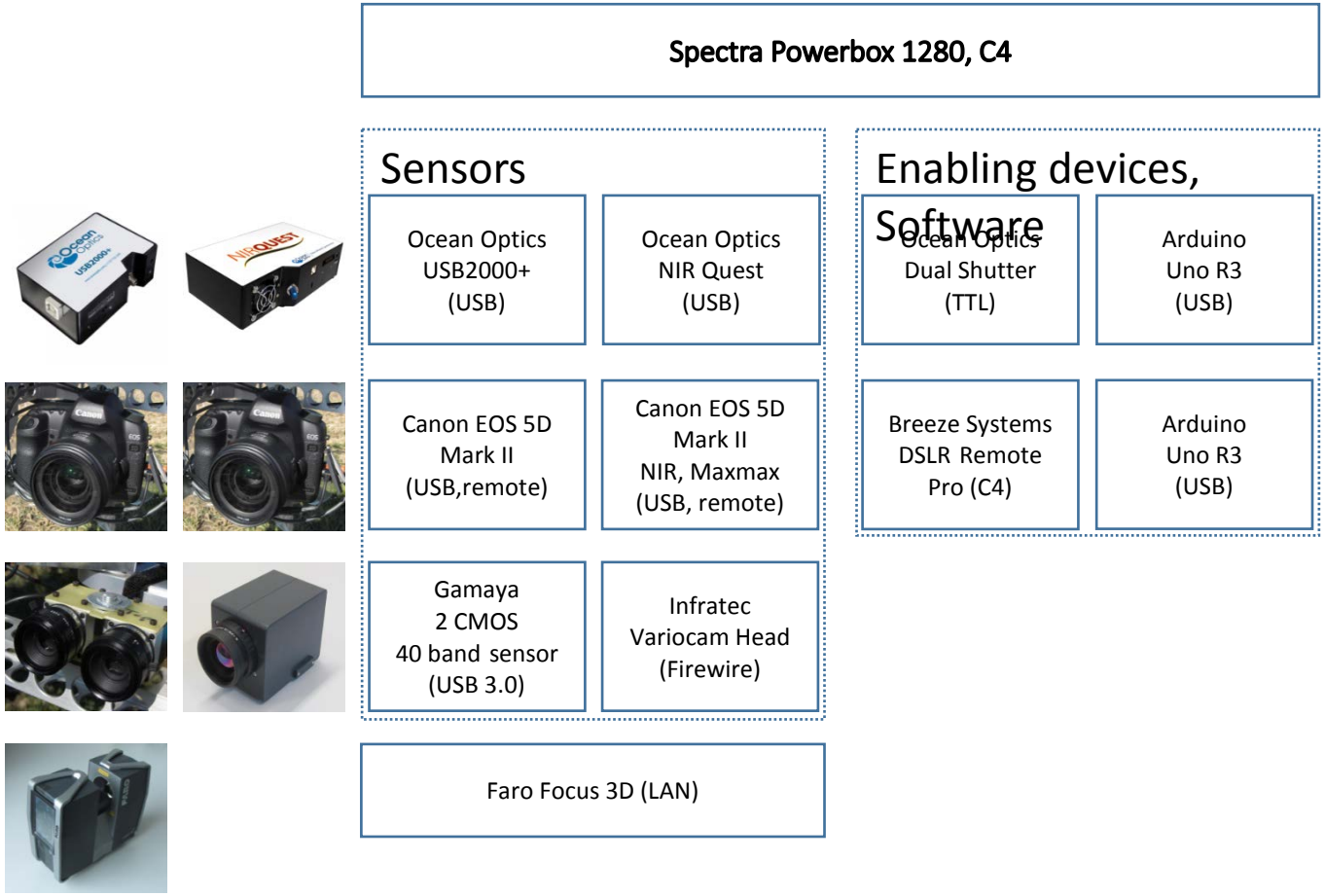


Figure S2. Sensor concept: all sensors except the laser scanner Faro Focus 3D are controlled by the computer C4 (Spectra Powerbox 1280) which is mounted on the sensor head. Additional interface devices and software are shown right of the respective sensor. Images of Ocean Optics devices by Stefano Okretic, GMP, Switzerland.

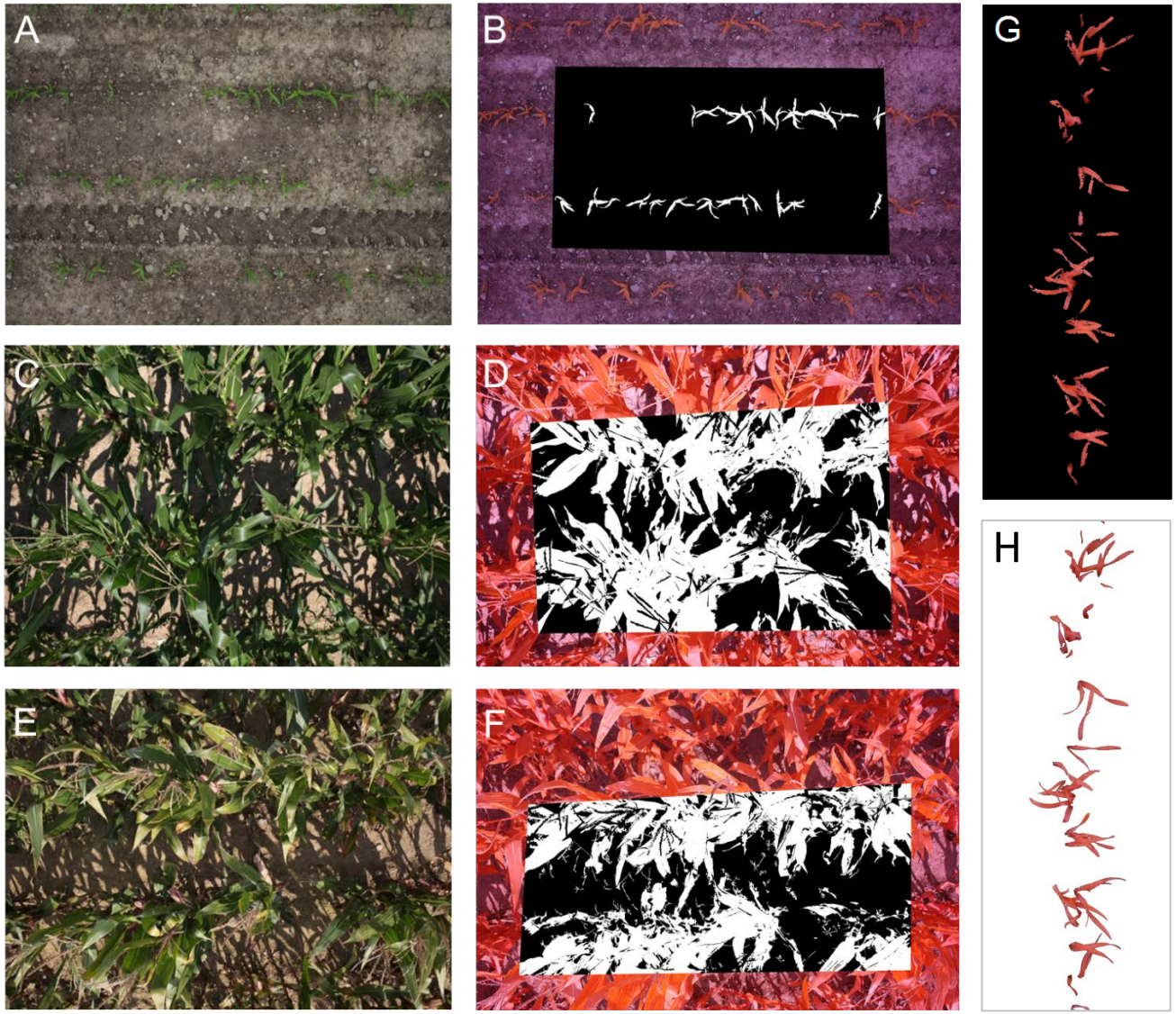

A
B
C
D
E
F
G
H

Figure S3. Example images in maize (Hybrid ´Thriller´, DSP, CH) for RGB (A, C, E) and IGB camera containing the selected region of interest (ROI) and the plant coverage mask resulting from the segmentation process (B, D, E). The images A and B were captured on the 10.06.2015, C and D on the 24.07.2015 and E and F on the 30.09.2015.

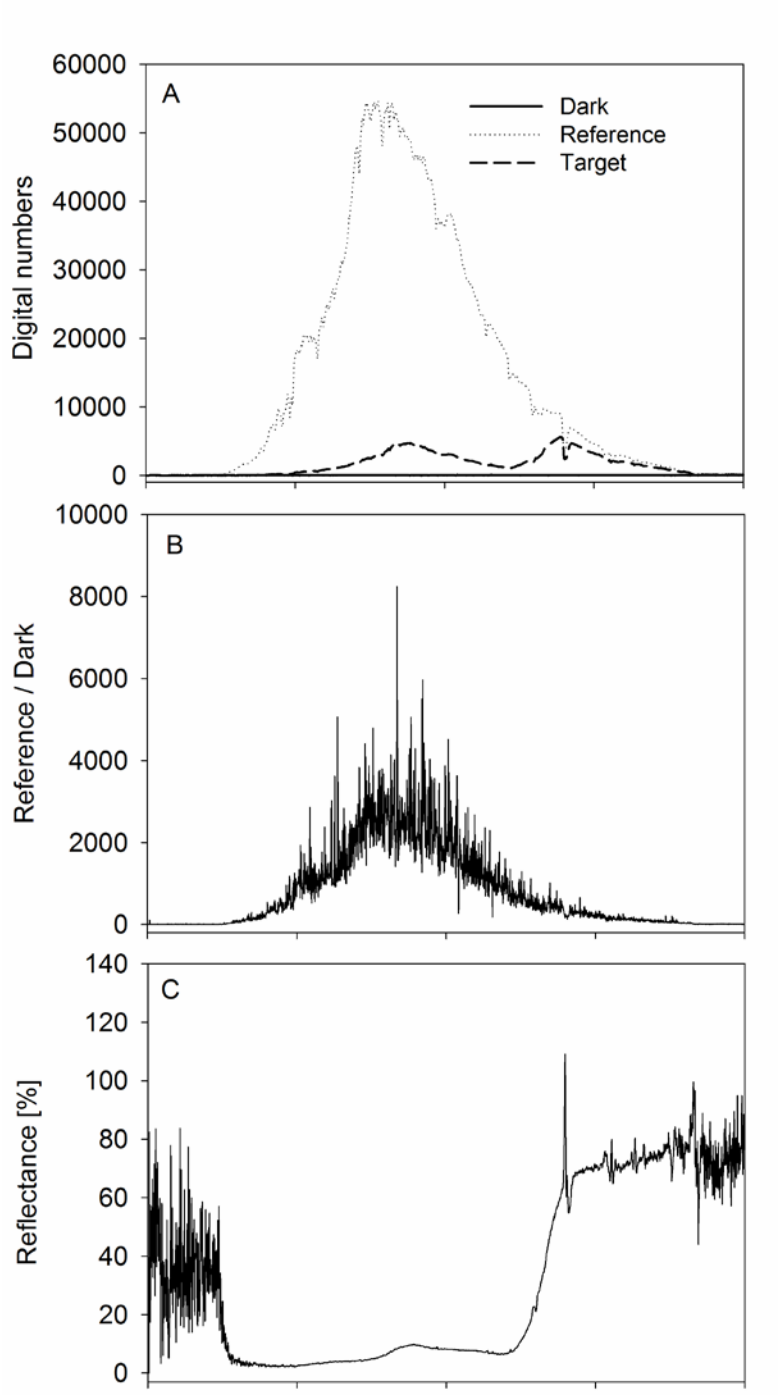
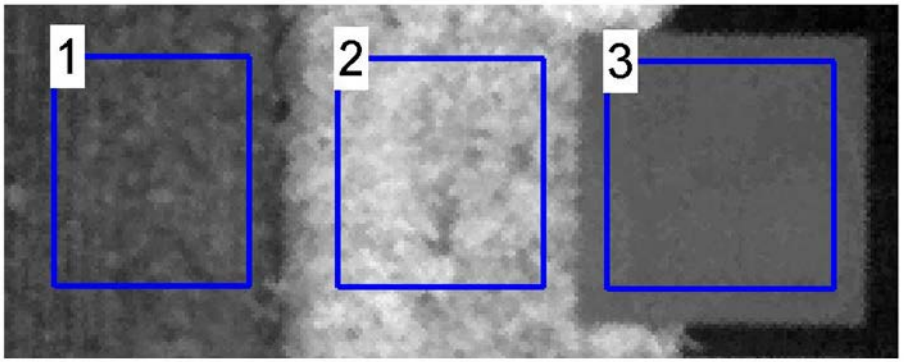

A
Dark
Reference
Target
Digital numbers
60000
50000
40000
30000
20000
10000
0
B
Reference / Dark
10000
8000
6000
4000
2000
0
C
Reflectance [%]
140
120
100
80
60
40
20
0

Figure S4. Spectral processing pipeline: measured radiation for dark, reference and target fibre (A), signal to noise ratio (B) and calculated target reflectance (C) as related to wavelength. The x axis was slightly shifted to negative values for clarity.

A


1
2
3

B

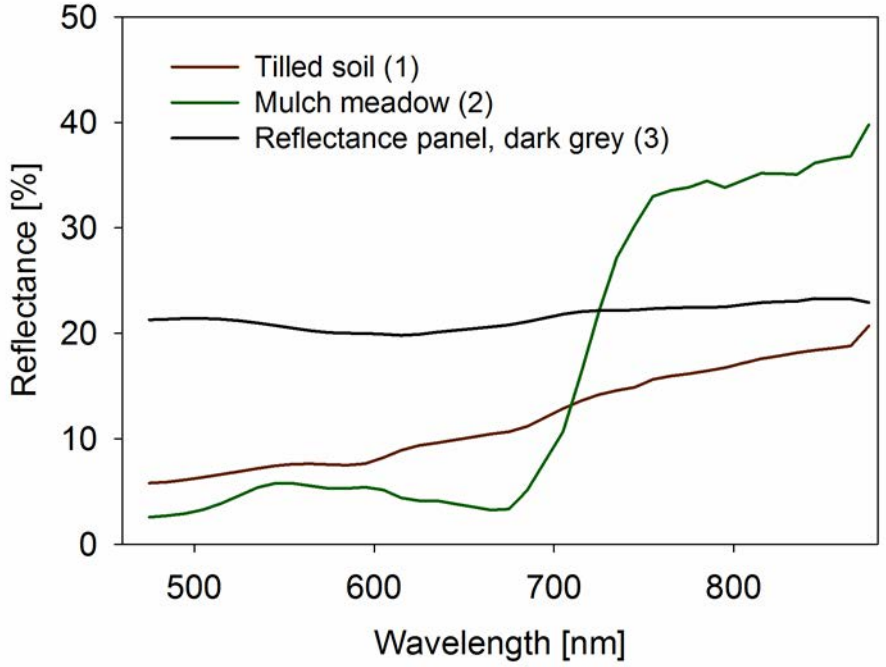

Tilled soil (1)
Mulch meadow (2)
Reflectance panel, dark grey (3)
Reflectance [%]
0
10
20
30
40
50
500
600
700
800
Wavelength [nm]

Figure S5. Example image region captured on the 22.10.2015 with the MSC sensor (A) after deconvolution, demosaicing and spectral calibration. Displayed are tilled soil (ROI 1), a mulch meadow (ROI 2) and a dark grey reflectance panel (ROI 3) and their corresponding reflectance spectra (B).