

VIS-NIR, Red-Edge and NIR-Shoulder based Normalized Vegetation Indices response to co-varying leaf and canopy structural traits in heterogeneous grasslands

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Figure S1. RGB images of the different plots at the IT-MBo study site used for spatial analysis.

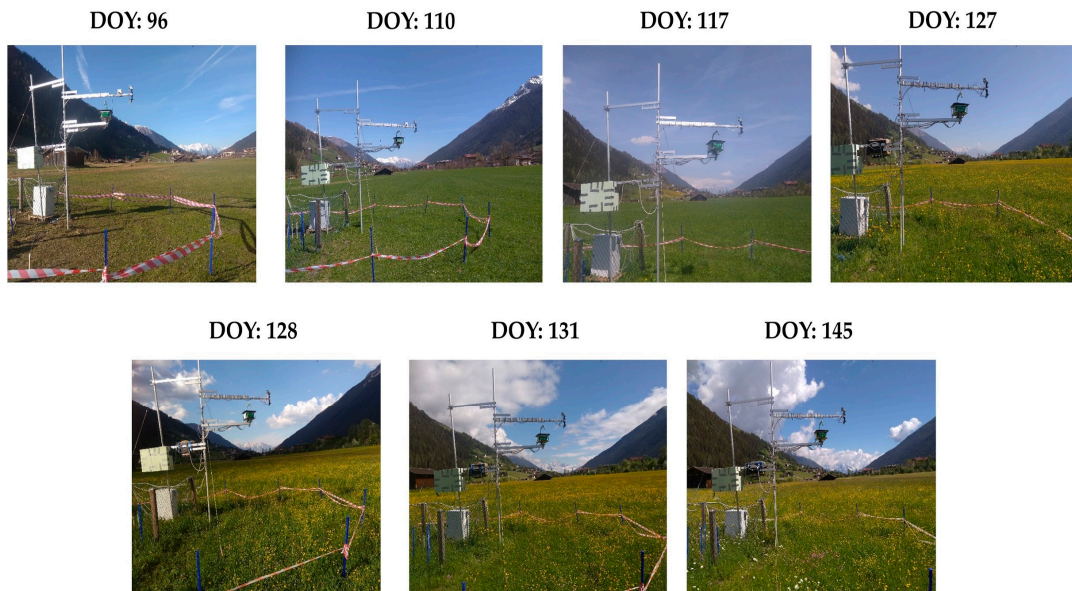


Figure S2. RGB images of the plot at the AT-Neu study site used for temporal analysis.

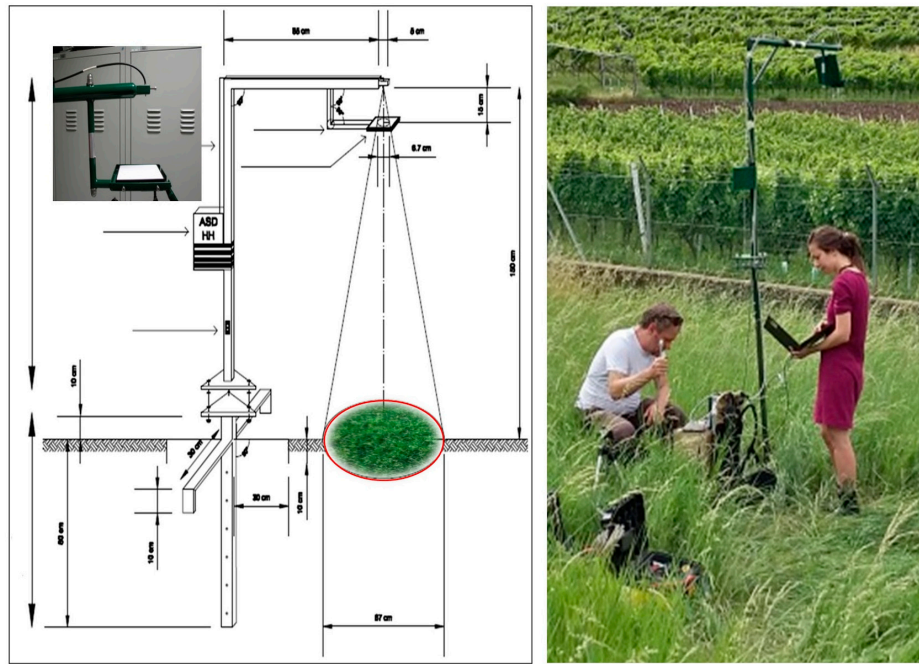


Figure S3. The portable system used for spectral measurements at the IT-MBo for spatial scale observations.

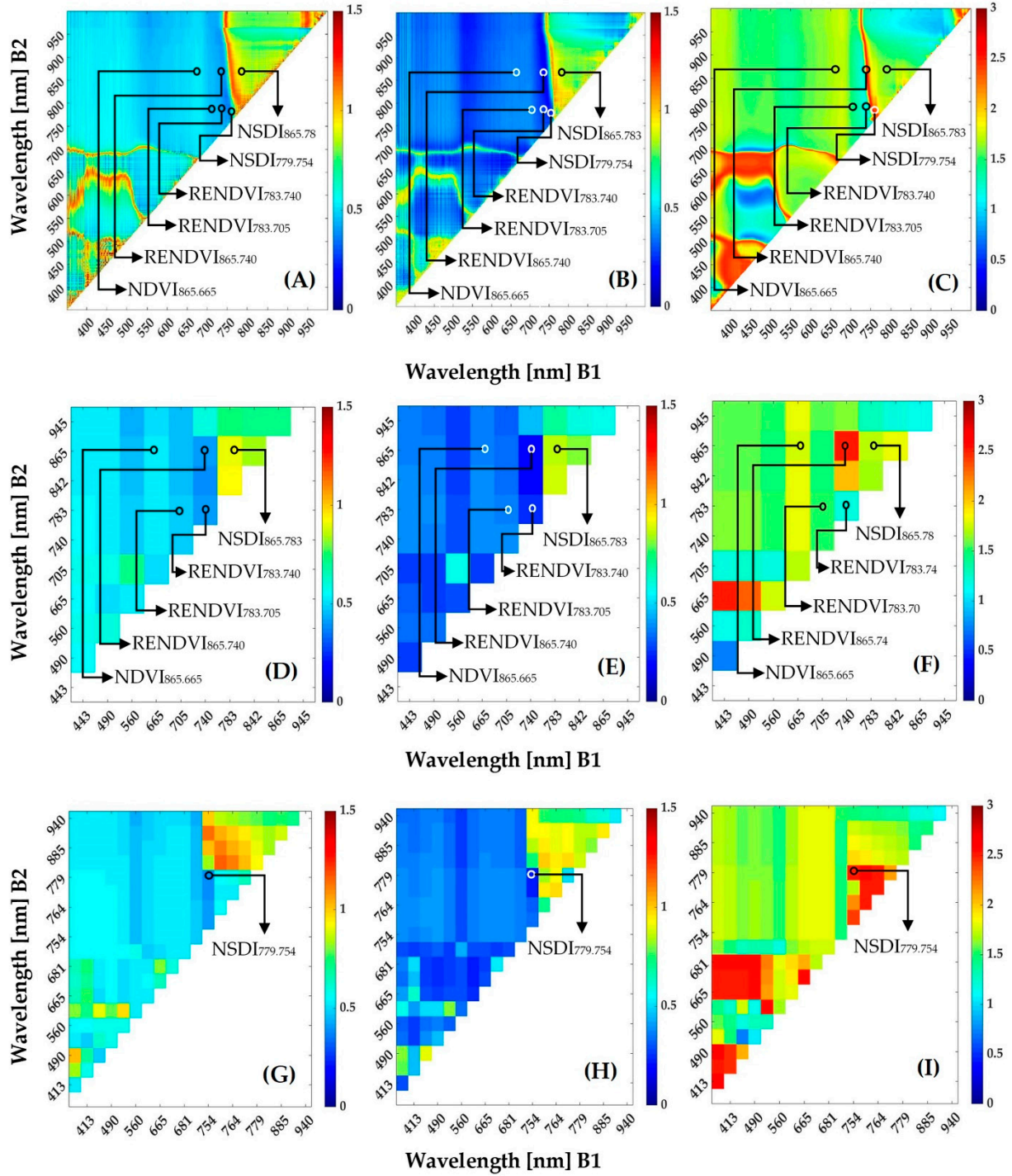


Figure S4. RMSE values based on linear regression between the normalized difference of all two-band combinations and LAI for both study sites (IT-MBo 2013 (a); IT-MBo 2014 (b); and AT-Neu 2018 (c)) considering the temporal scale hyperspectral observations. RMSE obtained using: (a–c) the hyperspectral data; (d–f) S-2 simulated bands; (g–i) S-3 simulated bands. Black/white circles refer to the position of the indices in the correlogram and arrows are indicating the name of the respective indices.

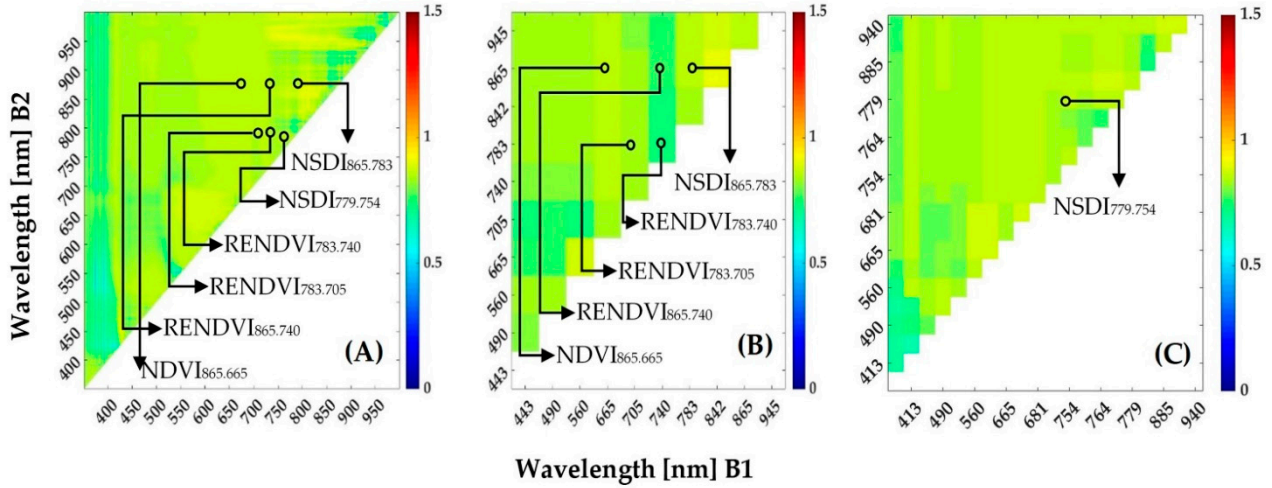


Figure 5. RMSE values based on linear regression between the normalized difference of all two-band combinations and LAI for IT-MBo 2017 considering the spatial scale observations: (a) RMSE obtained using the hyperspectral data; and (b,c) RMSE obtained using S-2 and S-3 simulated bands, respectively. Black circles refer to the position of the indices in the correlogram and arrows are indicating the name of the respective indices.

Table S1. Specifications of the multispectral instrument (MSI) and ocean and land color instrument (OLCI) on the S-2 and S-3 satellite system respectively, The NIR-shoulder bands investigated in this study shown in bold.

S-2 Spectral Bands	Central wavelength (nm)	Spectral region	S-3 Spectral Bands	Central wavelength (nm)	Spectral region
B1	443	Blue-1	O1	400	
B2	490	Blue-2	O2	412.5	
B3	560	Green	O3	443	
B4	665	Red	O4	490	
B5	705	RE-1	O5	510	
B6	740	RE-2	O6	560	
B7	783	NIR-shoulder	O7	620	
B8	842	NIR-shoulder	O8	665	
B8a	865	NIR-shoulder	O9	673.75	
B9	945	NIR	O10	681	
B10	1375	SWIR-1	O11	709	
B11	1610	SWIR-2	O12	754	NIR-shoulder
B12	2190	SWIR-3	O13	761	
			O14	764.375	
			O15	767.5	
			O16	779	NIR-shoulder
			O17	865	
			O18	885	
			O19	900	
			O20	940	
			O21	1020	

Table S2. Summary of the statistics (N: Number of observations; R^2 : Coefficient of determination; Adj. R^2 : adjusted coefficient of determination; RMSE: Root mean square error) of the second order polynomial regression between leaf area index (LAI, $m^2 \cdot m^{-2}$) estimated from fraction of absorbed photosynthetically active radiation (fAPAR) and the spectral vegetation indices (SVIs) calculated from measured spectra for IT-MBo 2013, IT-MBo 2014, AT-Neu 2018 at temporal scale observations and for IT-MBo 2017 at spatial scale observations. The three best-fitting models are highlighted in bold. Asterisk indicates significance of correlation: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; n.s.:not significant (Pearson's correlation test).

SVIs	Temporal scale observation									Spatial scale observations		
	IT-MBo 2013 (N=8)			IT-MBo 2014 (N=14)			AT-Neu 2018 (N=49)			IT-MBo 2017 (N=10)		
	R^2	Adj. R^2	RMSE ($m^2 \cdot m^{-2}$)	R^2	Adj. R^2	RMSE ($m^2 \cdot m^{-2}$)	R^2	Adj. R^2	RMSE ($m^2 \cdot m^{-2}$)	R^2	Adj. R^2	RMSE ($m^2 \cdot m^{-2}$)
VIS-NIR												
NDVI _{865.665}	0.83*	0.77	0.43	0.97***	0.97	0.14	0.71***	0.70	1.37	0.15 ^{n.s.}	-0.10	0.71
MTCI	0.86**	0.80	0.40	0.91***	0.90	0.26	0.84***	0.83	1.03	0.05 ^{n.s.}	-0.23	0.75
Red-edge (RE)												
RENDVI _{L783.740}	0.87**	0.82	0.37	0.98***	0.97	0.13	0.80***	0.79	1.15	0.11 ^{n.s.}	-0.15	0.73
RENDVI _{L783.705}	0.84**	0.78	0.41	0.96***	0.96	0.17	0.82***	0.81	1.08	0.00 ^{n.s.}	-0.28	0.77
RENDVI _{865.740}	0.88**	0.84	0.36	0.98***	0.97	0.14	0.20**	0.16	2.28	0.16 ^{n.s.}	-0.07	0.70
NIR-shoulder												
^x NSDI _{779.754}	0.89**	0.85	0.35	0.97***	0.97	0.15	0.13**	0.09	2.38	0.07 ^{n.s.}	-0.19	0.74
NSDI _{865.783}	0.37 ^{n.s.}	0.12	0.83	0.15 ^{n.s.}	0.00	0.82	0.67***	0.66	1.47	0.39 ^{n.s.}	0.22	0.60