Supplementary Materials for

Spectral Response Analysis: An Indirect and Non-Destructive Methodology for Biocrusts Chlorophyll Quantification

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Table S1. Soil texture, pH, electrical conductivity, total organic carbon (TOC) and total nitrogen (TN) of the of the three soils employed in this study: Las Amoladeras, El Cautivo and Gádor quarry (from Román et al., 2018).

Soil types	Soil texture			pH	Electrical Conductivity (mS/cm)	TOC (g/Kg)	TN (g/Kg)
	Sand (%)	Silt (%)	Clay (%)				
Las Amoladeras	61.50 ± 5.10	28.40 ± 4.20	10.10 ± 2.10	8.03 ± 0.04	0.16 ± 0.01	21.41 ± 0.96	2.07 ± 0.11
El Cautivo	29.20 ± 5.40	58.60 ± 5.80	12.20 ± 4.20	8.28 ± 0.12	0.13 ± 0.01	3.87 ± 0.09	0.57 ± 0.04
Gádor quarry	31.20 ± 4.65	43.10 ± 2.34	25.70 ± 2.80	8.57 ± 0.03	1.98 ± 0.18	0.24 ± 0.21	0.17 ± 0.09

Table S2. Summary of the different spectral indices used in this study. R: reflectance; ϱ: the first derivative of reflectance; RBLUE: reflectance in the blue region, RGREEN: reflectance in the green region, RNIR: reflectance in near-infrared region.

Index	Formulation	Reference
Simple ratio or modified simple ratio of reflectance or derivatives		
YCAR	R_{600}/R_{680}	Schlemmer et al. (2005)
OCAR	R_{630}/R_{680}	Schlemmer et al. (2005)
Vogelman3	R_{740}/R_{720}	Vogelman et al. (1993)
SRPI (Simple Ratio Pigment Index)	R_{430}/R_{680}	Peñuelas et al. (1994)
Vogelman1	$\varrho_{715}/\varrho_{705}$	Vogelman et al. (1993)
dSR1*	$\varrho_{725}/\varrho_{702}$	Kochubey and Kazantsev (2007)
dSR2*	$\varrho_{705}/\varrho_{722}$	Zarco-Tejada et al. (2002)
Datt-CabCx+c	$R_{860}/(R_{550} * R_{708})$	Datt (1998)
PSRI	$(R_{680} - R_{500})/R_{750}$	Merzlyak et al. (1999)
mSR705	$(R_{750} - R_{445})/(R_{705} - R_{445})$	Sims and Gamon (2002)
BmSR	$(\varrho_{722} - \varrho_{502})/(\varrho_{700} - \varrho_{502})$	le Maire et al. (2004)

Table S2 (Continuation)

Index	Formulation	Reference
	Normalized difference of derivatives	
BND	$(\varrho_{722} - \varrho_{700})/(\varrho_{722} + \varrho_{700})$	le Maire et al. (2004)
	Modified normalized difference of derivatives	
BmND	$(\varrho_{722} - \varrho_{700})/(\varrho_{722} + \varrho_{700} - 2\varrho_{502})$	le Maire et al. (2004)
	Indices related with red edge derived with derivatives	
dRE	First derivative maxima in red-edge region (680-780 nm)	Filella and Peñuelas (1994)
∑dRE	Sum of first derivative reflectance in red-edge region (680-780 nm)	Filella and Peñuelas (1994)
EGFR (Ratio of first derivative maxima in red-edge region and green region (530-570 nm))	dRE/dG	Penuelas et al. (1994)
EGFN	(dRE − dG)/(dRE + dG)	Penuelas et al. (1994)
EBAR (Ratio of Sum of first derivative reflectance in red-edge region (680-780 nm) and blue region (490-530 nm))	∑dRE/∑dB	Xue et al. (2009)
EBAN	(∑dRE − ∑dB)/(∑dRE + ∑dB)	Xue et al. (2009)
EBFR	dRE/dB	Xue et al. (2009)
EBFN	(dRE − dB)/(dRE + dB)	Xue et al. (2009)

6 **Table S2 (Continuation)**

Index	Formulation	Reference
	Broad band indices	
Normalized Difference Vegetation Index(NDVI)	$(R_{NIR} - R_{RED} / R_{NIR} + R_{RED})$	Rouse et al. (1973)
Enhanced Vegetation Index (EVI)	$2.5 * (R_{NIR} - R_{RED}) / (R_{NIR} + 6R_{RED} - 7.5R_{BLUE} + 1)$	Huete et al. (2002)
Soil-adjusted vegetation index (SAVI)	$(R_{NIR} - R_{RED} / R_{NIR} + R_{RED} + 0.5) * (1+ 0.5)$	Huete (1988)
Optimized soil-adjusted vegetation index (OSAVI)	$(R_{NIR} - R_{RED} / R_{NIR} + R_{RED} + 0.16) * (1 + 0.16)$	Rondeaux et al. (1996)
Modified Chlorophyll Absorption in Reflectance Index (MCARI)	$[(R_{NIR} - R_{RED}) - 0.2(R_{NIR} + R_{GREEN})] * (R_{NIR} /R_{RED})$	Daughtry et al. (2000)
MCARI/OSAVI	MCARI/OSAVI	Daughtry et al. (2000)
Simple Ratio Index (SR)	(R_{NIR} / R_{RED})	Jordan (1969)
Modified Simple Ratio Index (MSR)	$[(R_{NIR} / R_{RED}) - 1] / [(R_{NIR} / R_{RED}) -1]^{1/2}$	Chen (1996)
Crust Index (CI)	$1 - (R_{RED} - R_{BLUE})/(R_{RED} - R_{BLUE})$	Karnieli, 1997
Biological Soil Crust Index (BSCI)	$\frac{1 - 2 \times \lvert R_{RED} - R_{GREEN} \rvert}{R_{GRNIR}^{mean}}$	Chen et al. (2005)

7 **Table S2 (Continuation)**

Index	Formulation	Reference
	Others	
$MCARI_{[705,750]}$	$[(R_{750} - R_{705}) - 0.2(R_{750} - R_{550})] * (R_{750}/R_{705})$	Wu et al. (2008)
Blog 1/R737	the first derivative of logarithm $1/R_{737}$	Yoder and Pettigrew-Crosby (1995)
DD	$(R_{749} - R_{720})/(R_{701} - R_{672})$	le Maire et al. (2004)
SIPI (Structure Insensitive Pigment Index)	$(R_{800} - R_{445})/(R_{800} - R_{680})$	Peñuelas et al. (1995)
Vogelman2	$(R_{734} - R_{747})/(R_{715} + 726)$	Vogelman et al. (1993)
PRI (Photochemical reflectance index) * Ci (chlorophyll ratio index)	$[(R_{570} - R_{530})/(R_{570} + R_{530})] * [(R_{760}/R_{700}) - 1]$	Garrity et al., (2011)
DFDS_ICCW	sum of $\rho_{675\text{-}680}$ − sum of $\rho_{640\text{-}674}$	Zhang et al. (2014)

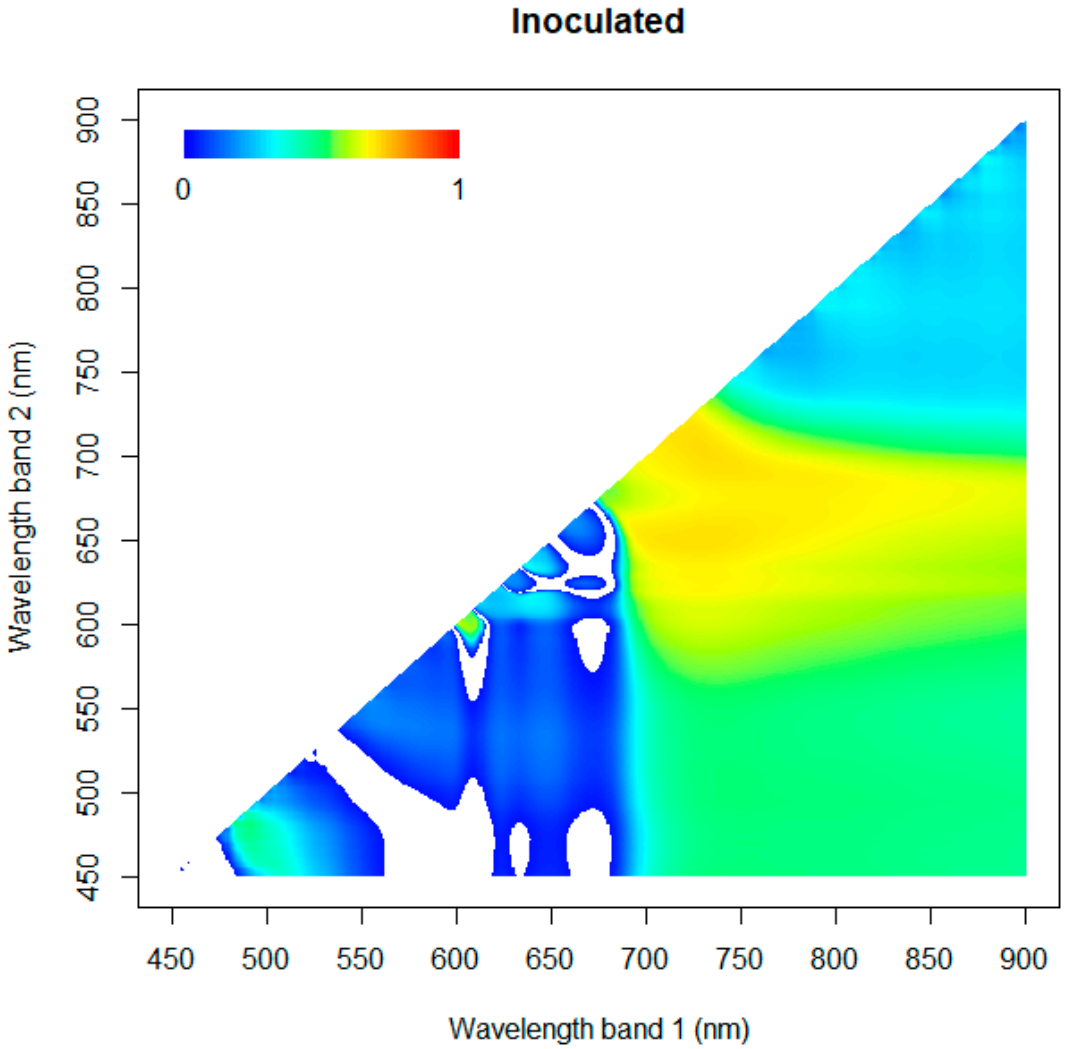


Figure S1. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at hyperspectral resolution, for cyanobacteria artificially inoculated. Only the significant values ($P < 0.05$) are represented.

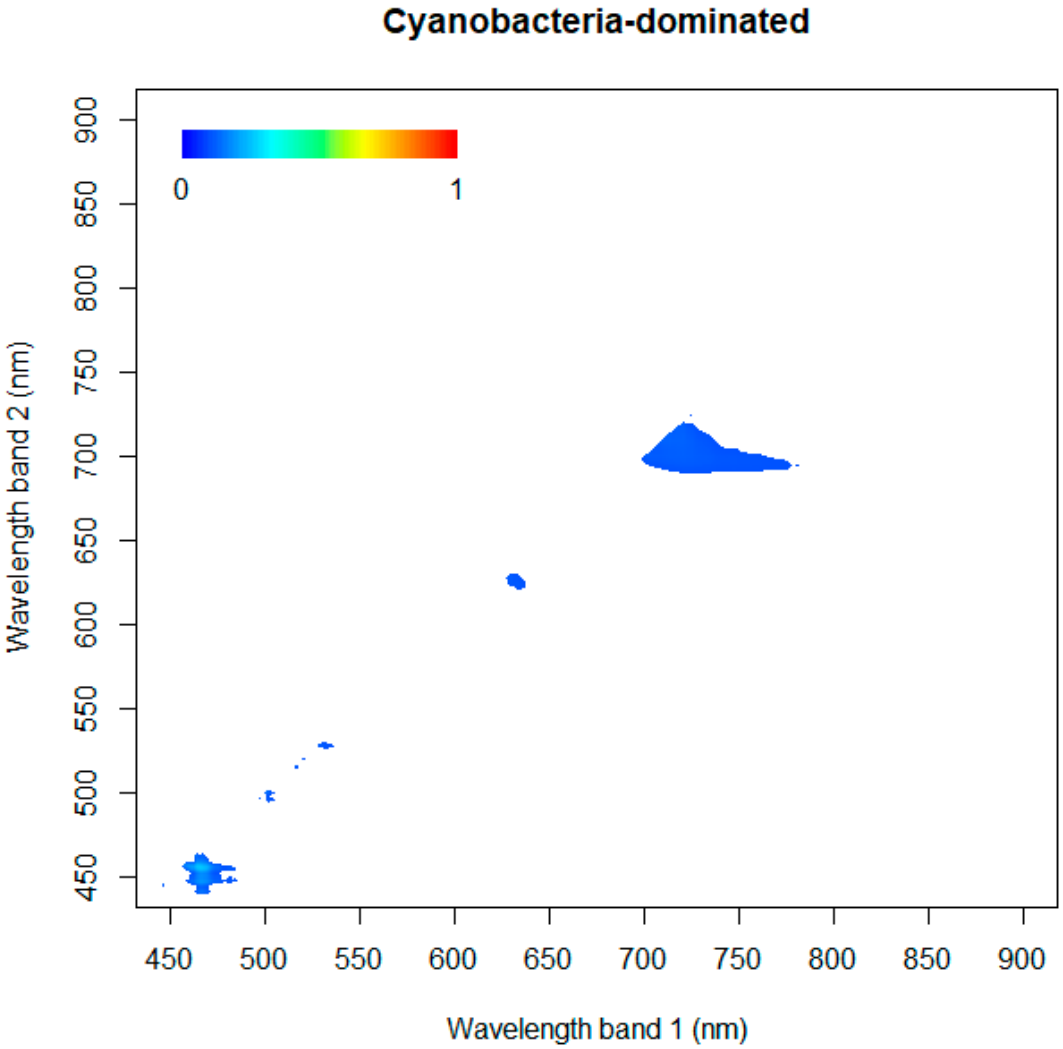


Figure S2. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at hyperspectral resolution, for natural cyanobacteria-dominated subsamples. Only the significant values ($P < 0.05$) are represented.

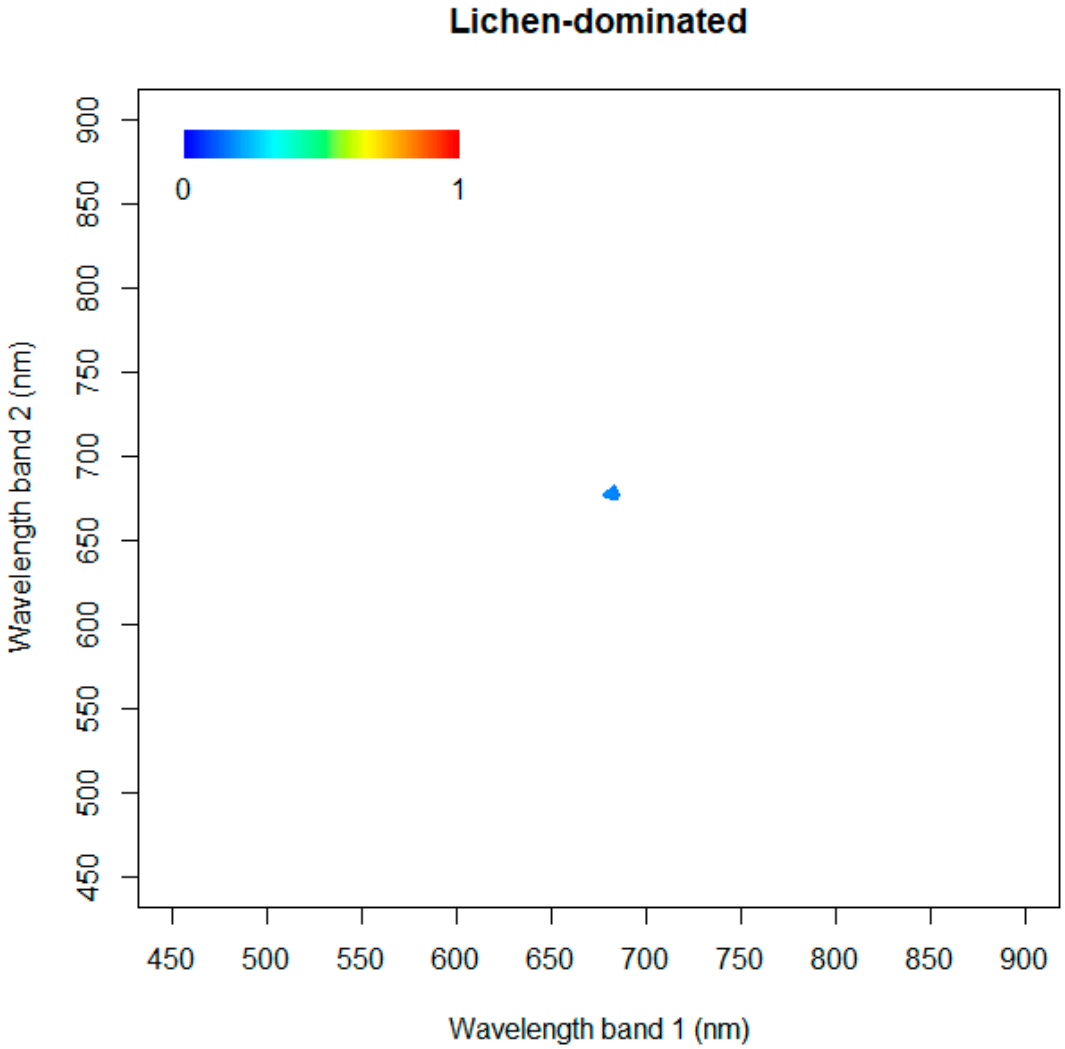
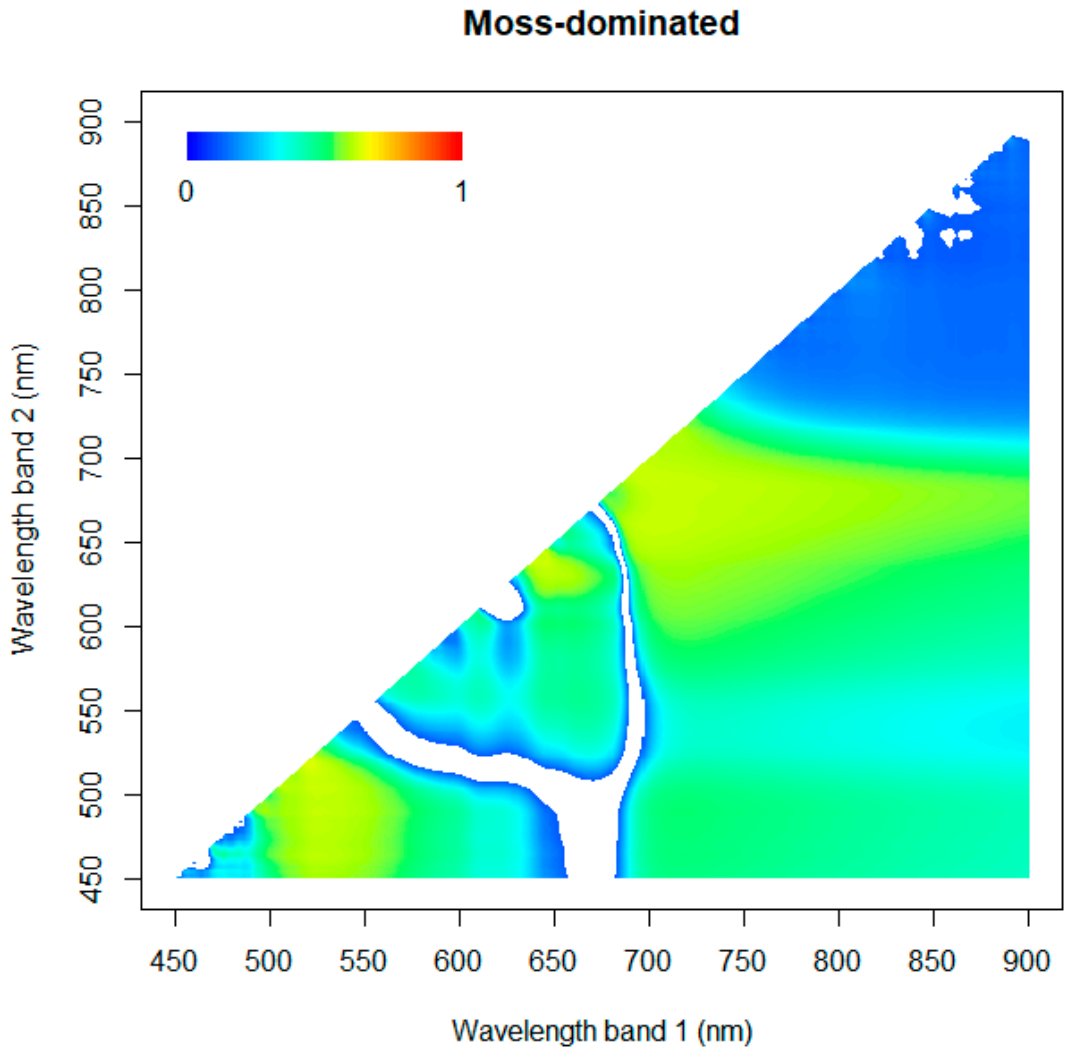


Figure S3. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at hyperspectral resolution, for natural lichen-dominated subsamples. Only the significant values ($P < 0.05$) are represented.



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22 **Figure S4.** 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised
23 difference indices for all possible band combinations between 450 – 900 nm at hyperspectral resolution, for
24 moss-dominated subsamples. Only the significant values ($P < 0.05$) are represented.

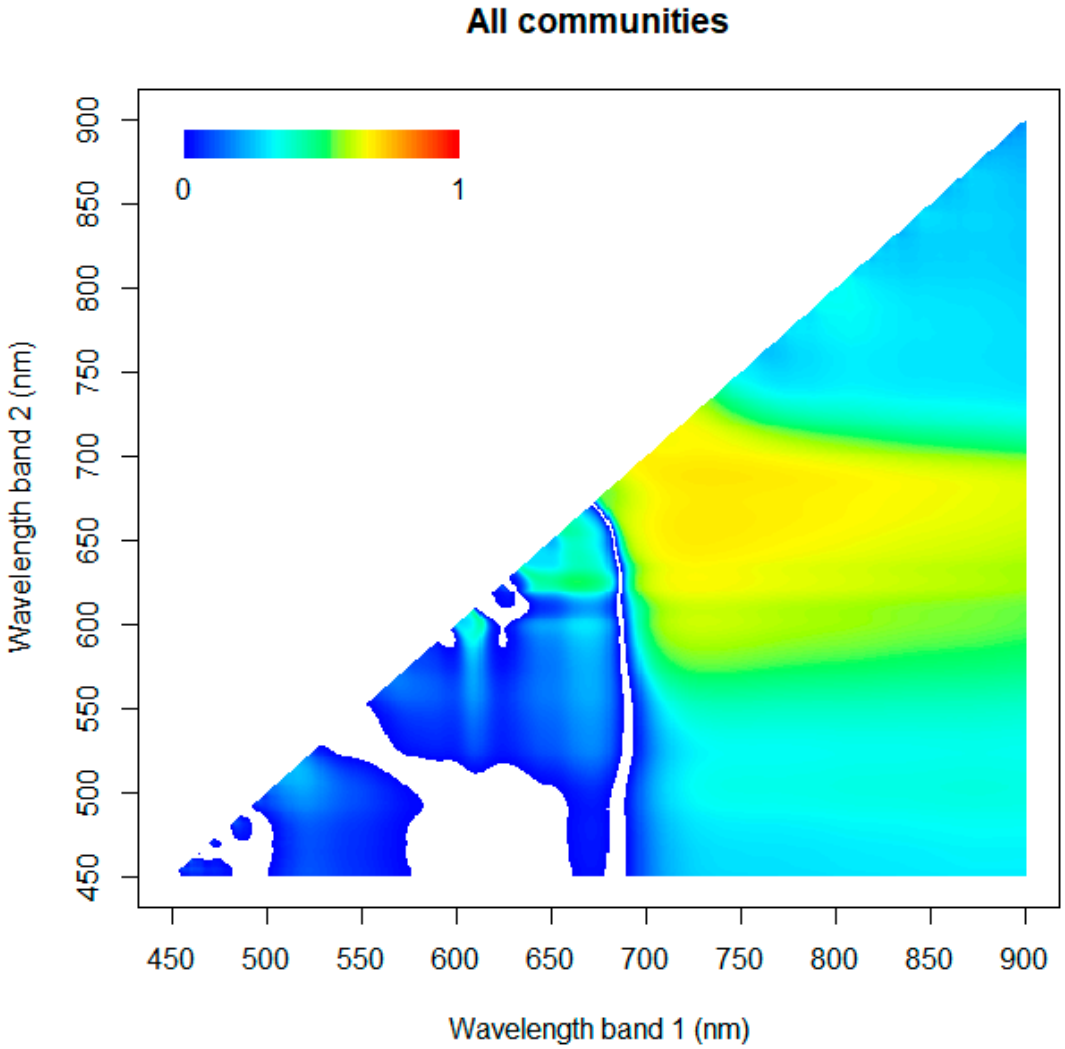


Figure S5. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at hyperspectral resolution, for the entire dataset. Only the significant values ($P < 0.05$) are represented.

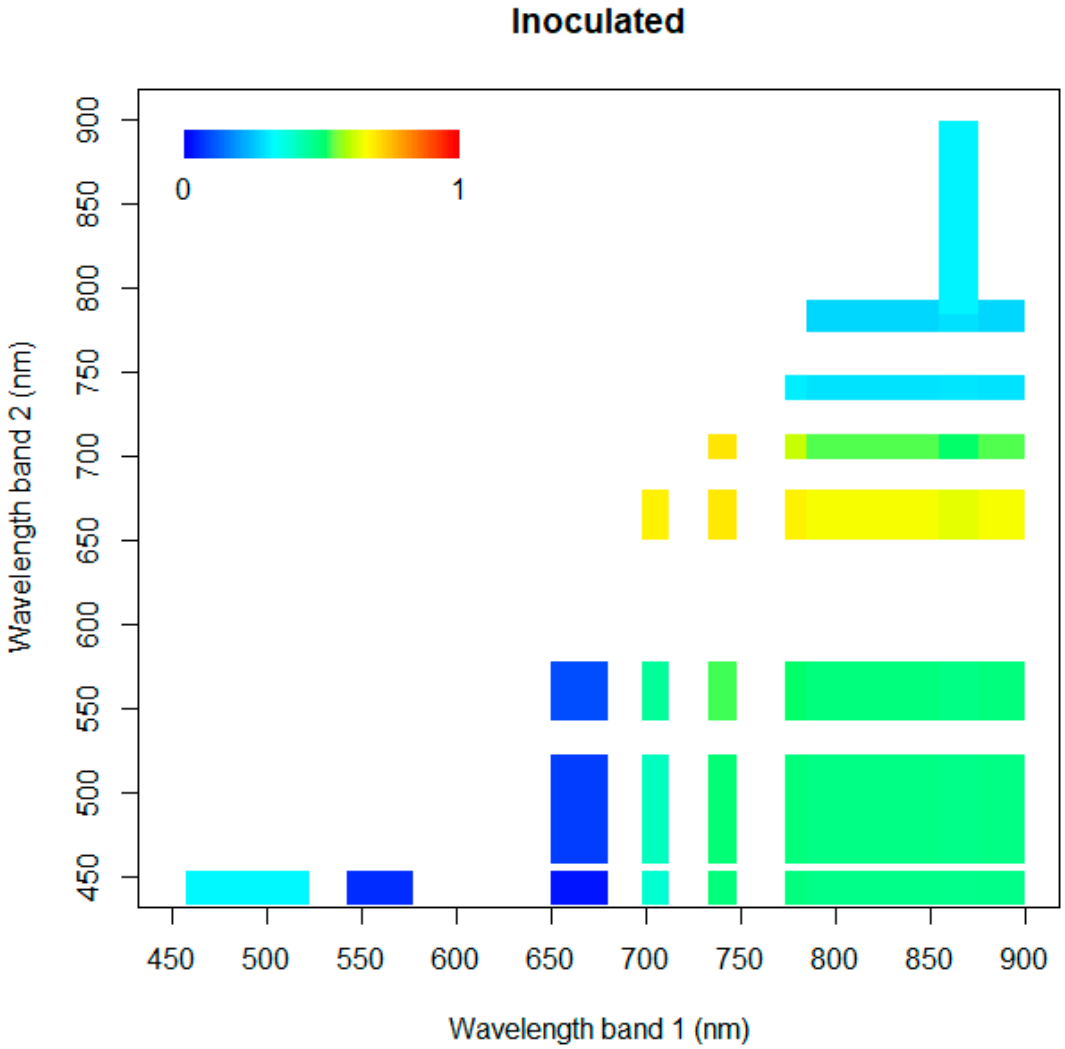


Figure S6. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at Sentinel-2 spectral resolution, for artificially inoculated cyanobacteria subsamples. Only the significant values are represented ($P < 0.05$).

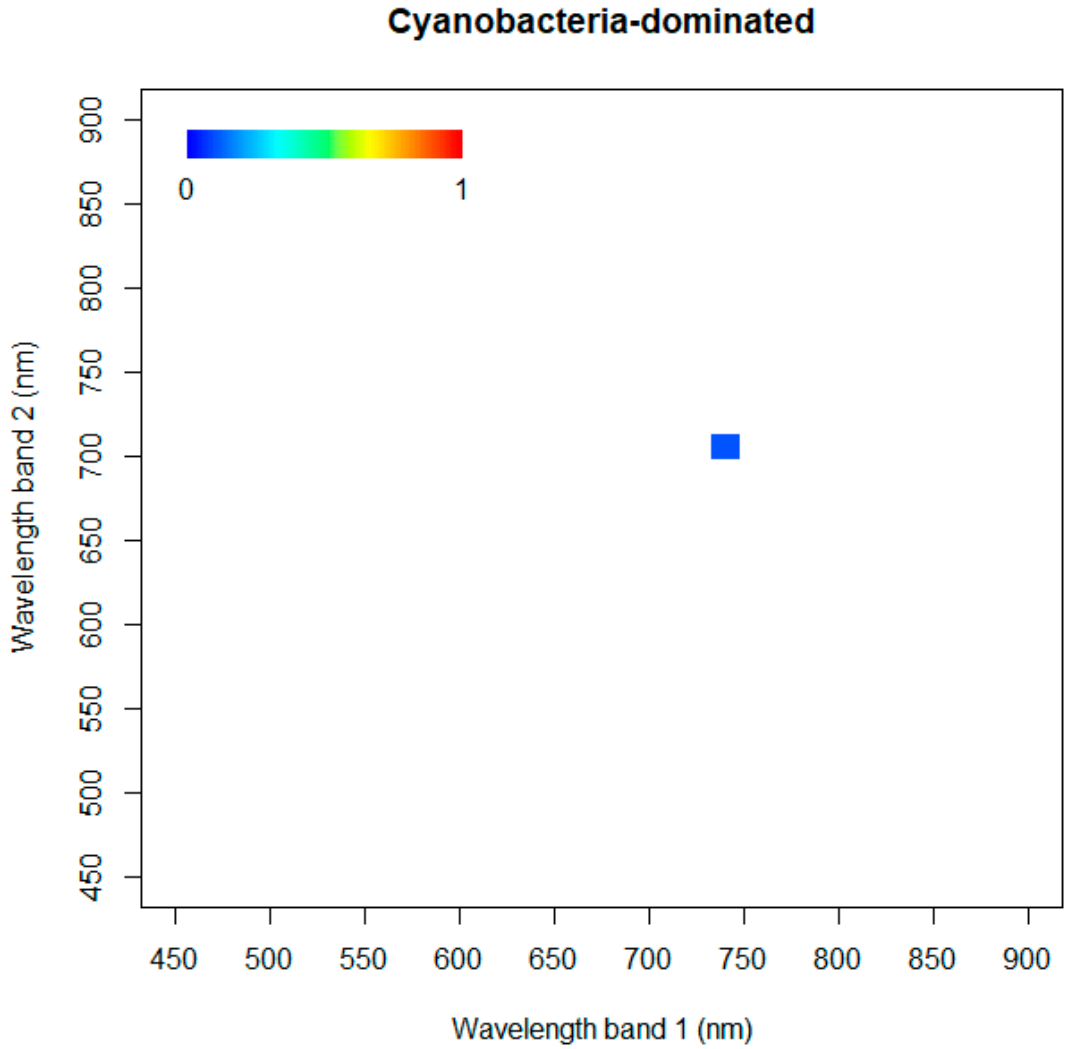


Figure S7. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at Sentinel-2 spectral resolution, for natural cyanobacteria-dominated subsamples. Only the significant values ($P < 0.05$) are represented.

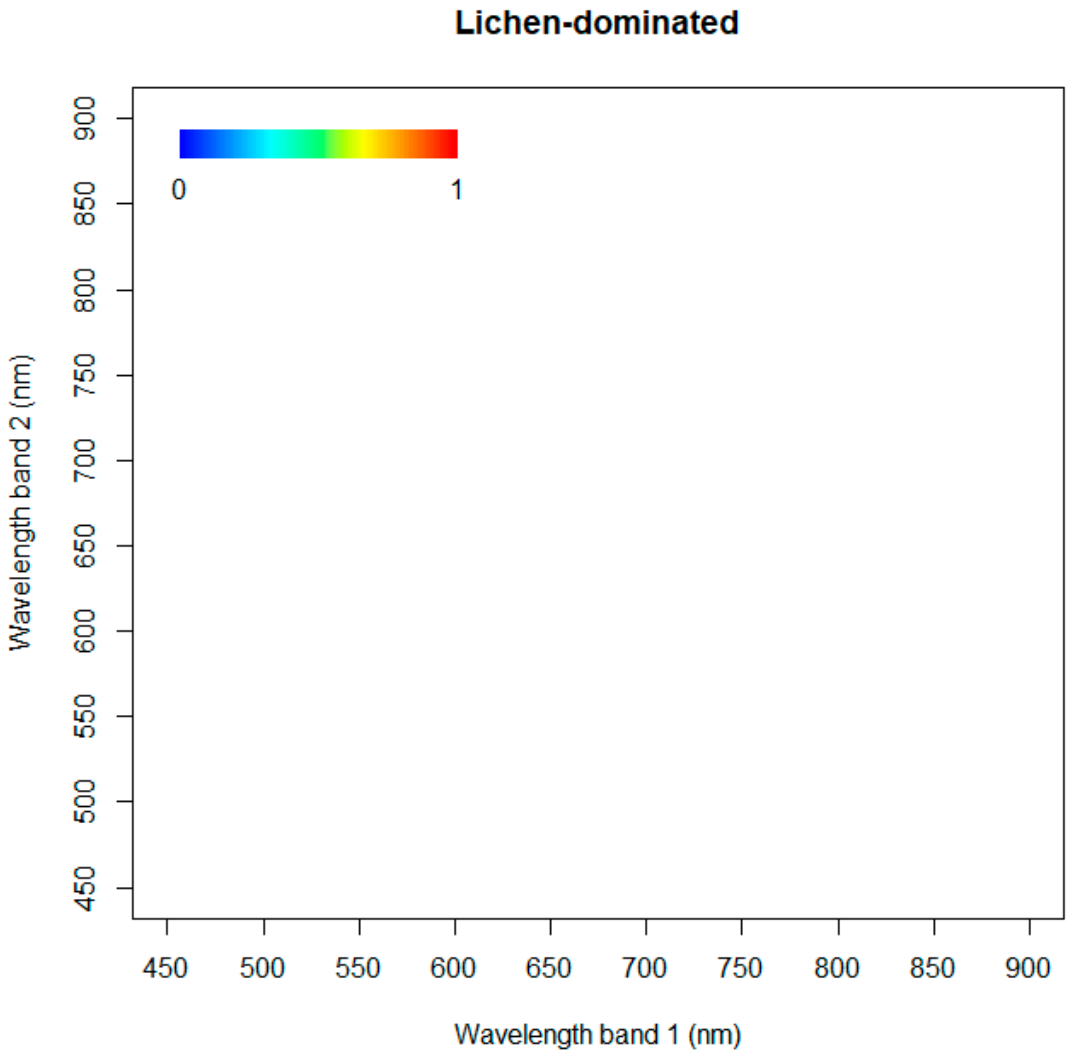
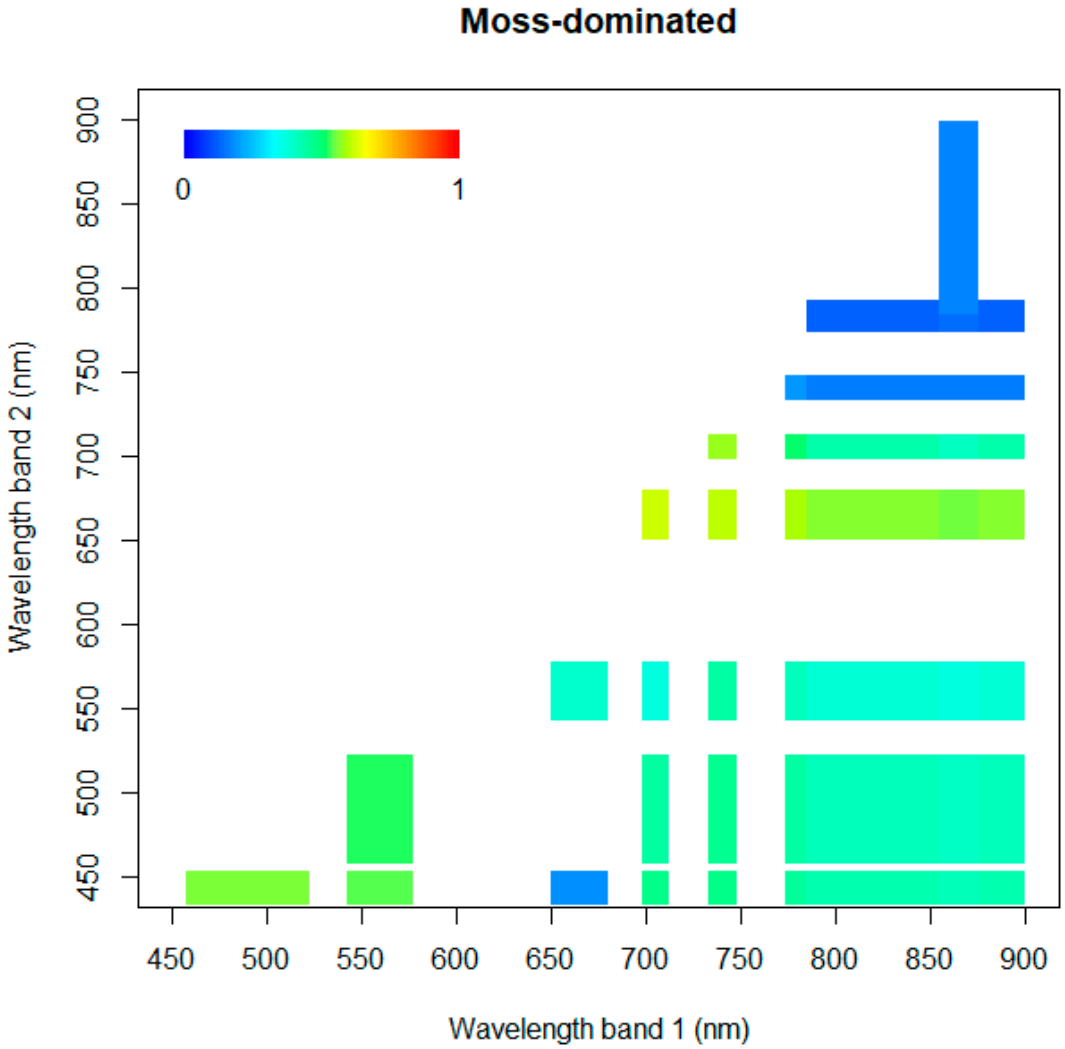


Figure S8. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at Sentinel-2 spectral resolution, for lichen-dominated subsamples. Only the significant values ($P < 0.05$) are represented.



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44 **Figure S9.** 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised
45 difference indices for all possible band combinations between 450 – 900 nm at Sentinel-2 spectral
46 resolution, for moss-dominated subsamples. Only the significant values ($P < 0.05$) are represented.

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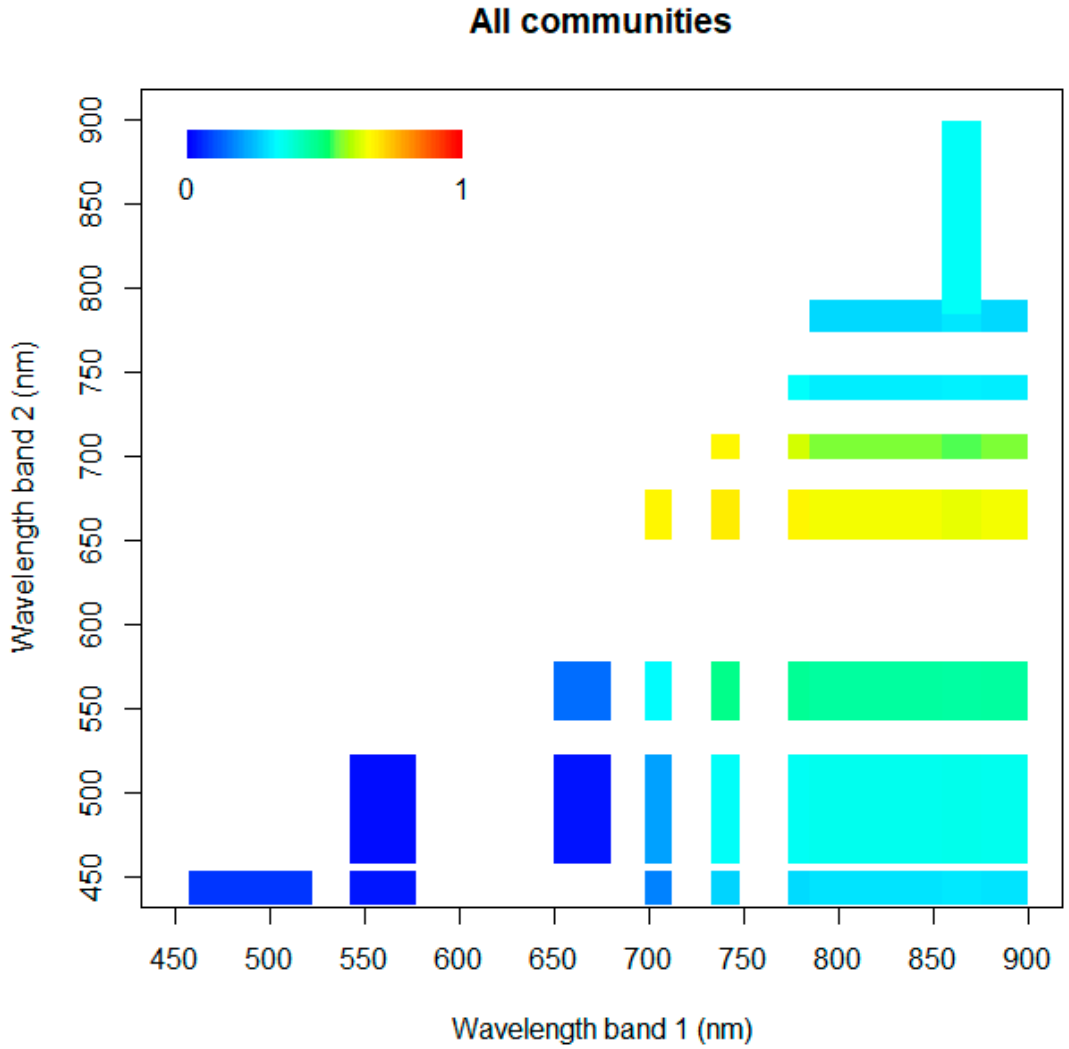

Figure S10. 2-D correlation plot illustrating the coefficient of determination (R^2) of the normalised difference indices for all possible band combinations between 450 – 900 nm at Sentinel-2 spectral resolution for the entire dataset. Only significant values ($P < 0.05$) are represented.

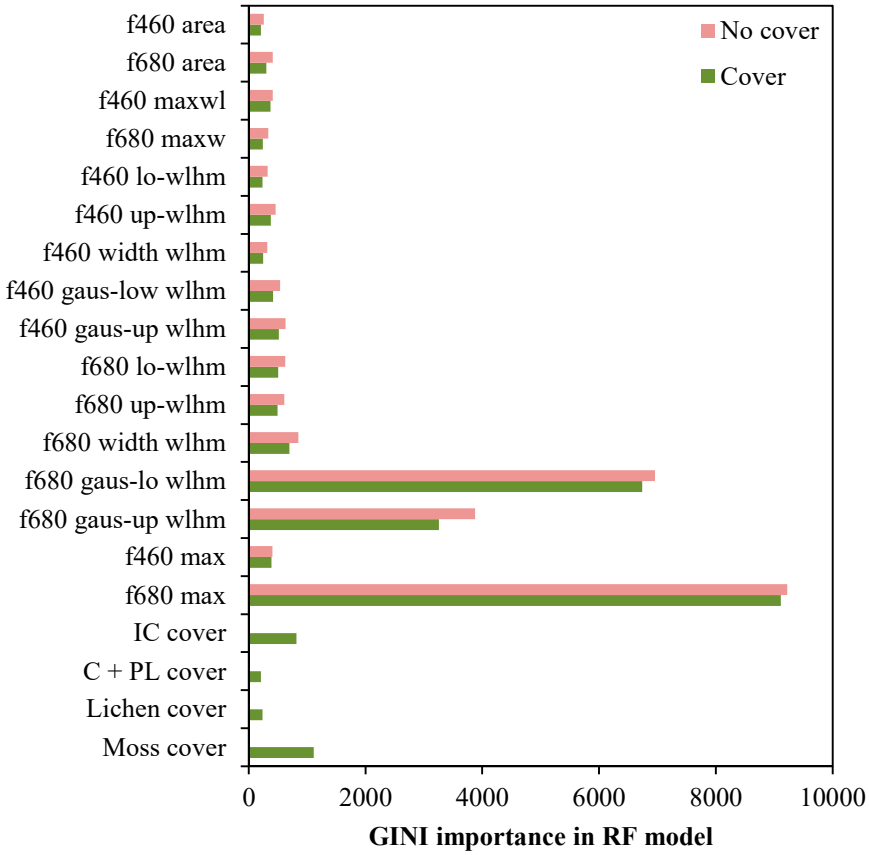

Figure S11. GINI importance of each variable in Random Forest model. Two options were tested: a) with cover (green bars) and, b) without cover (pink bars). IC: Incipient cyanobacteria, C + PL: mix of cyanobacteria and pioneer lichens.

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