

Supplementary Materials: Mapping Arctic Tundra Vegetation Communities Using Field Spectroscopy and Multispectral Satellite Data in North Alaska, USA

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1. Dark Object Subtraction

We tested whether it was necessary to do atmospheric correction using a dark object subtraction method [1,2], as recommended in the Digital Globe “Radiometric Use of WorldView-2 imagery” [3]. It assumes that as dark objects will reflect no light, any value greater than zero must result from atmospheric scattering, this value is subtracted from each pixel in each band removing any atmospheric scattering. For each known location on the ground, we regressed the reflectance at each WorldView band against the reflectance post dark pixel subtraction (See Figure S1 below). We found a one-to-one relationship between the pre and post processed reflectance. Because of this we do not think that the atmospheric correction would change our results.

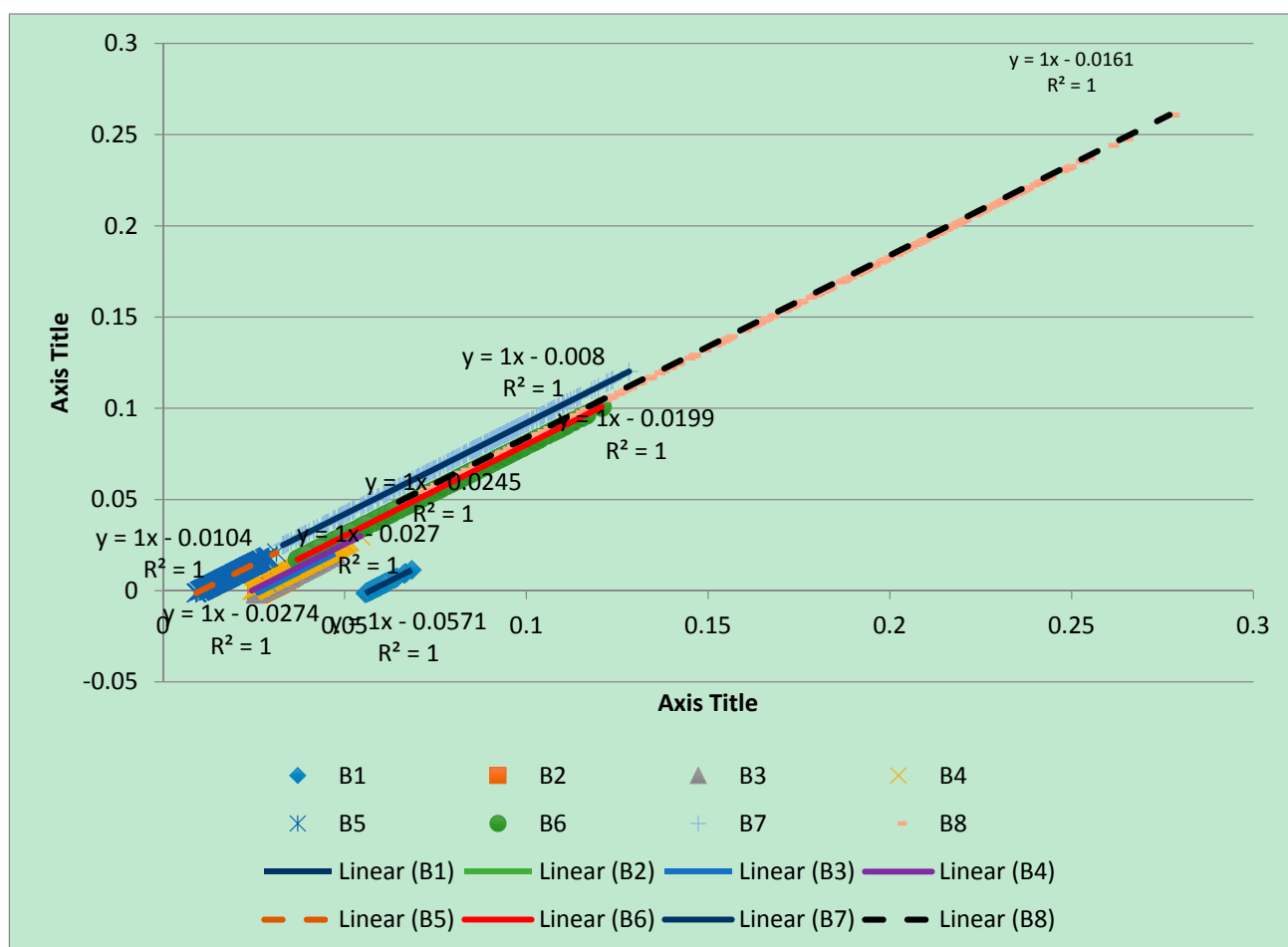


Figure S1. Regression of reflectance at known locations before and after dark object subtraction. Reflectance at all bands was strongly correlated showing that the TOA reflectance can be compared with in situ reflectance.

2. Additional Figures

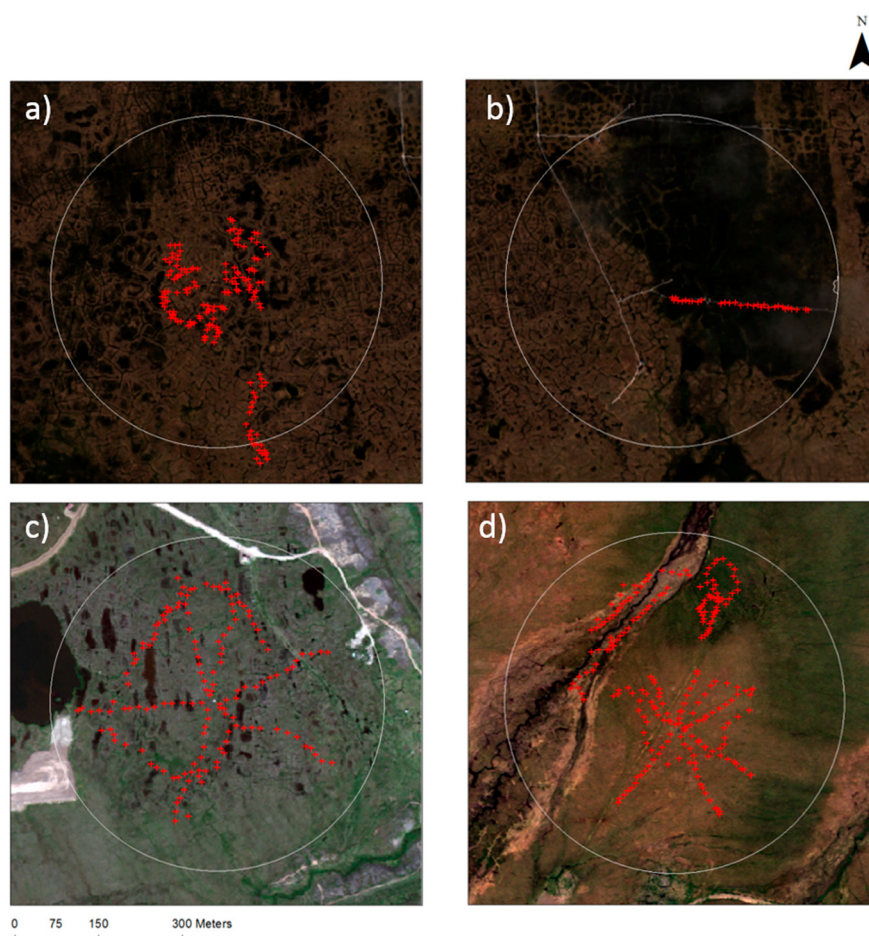


Figure S2. Maps showing spatial locations of the vegetation community analysis and field spectroscopy survey points within the eddy covariance tower footprints (red cross) at (a) Barrow-BEO (b) Barrow-BES (c) Atqasuk and (d) Ivotuk (base satellite imagery: Orthorectified multispectral WorldView-2 (2.0 m resolution)). Due to the waterlogged nature of Barrow-BES, spectroscopy measurements were collected adjacent to the boardwalk.

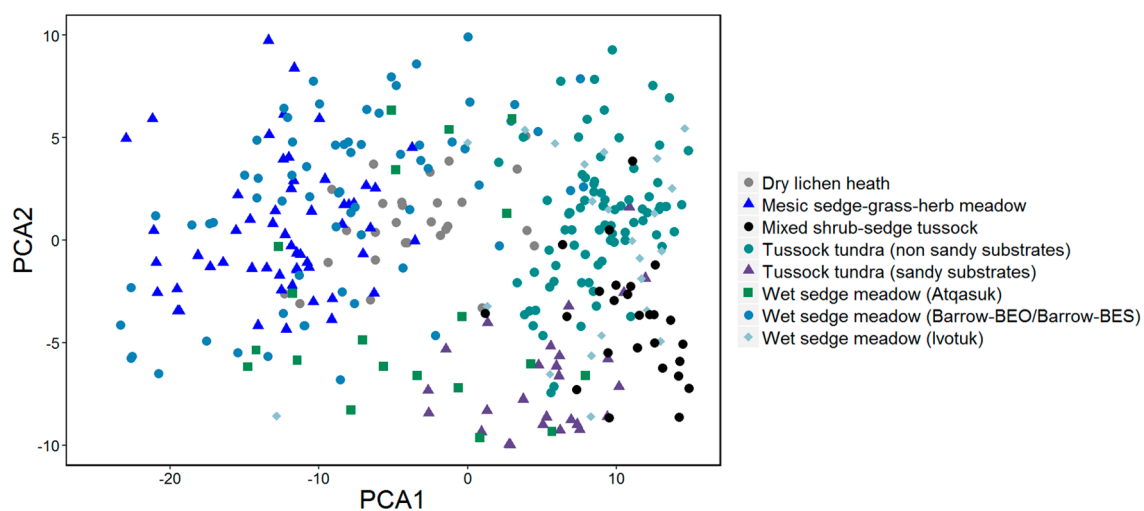


Figure S3. Principal component analysis of UniSpec DC reflectance data using all narrow bands (402–1040 nm); PCA 1, PCA axis 1; PCA 2, PCA axis 2.

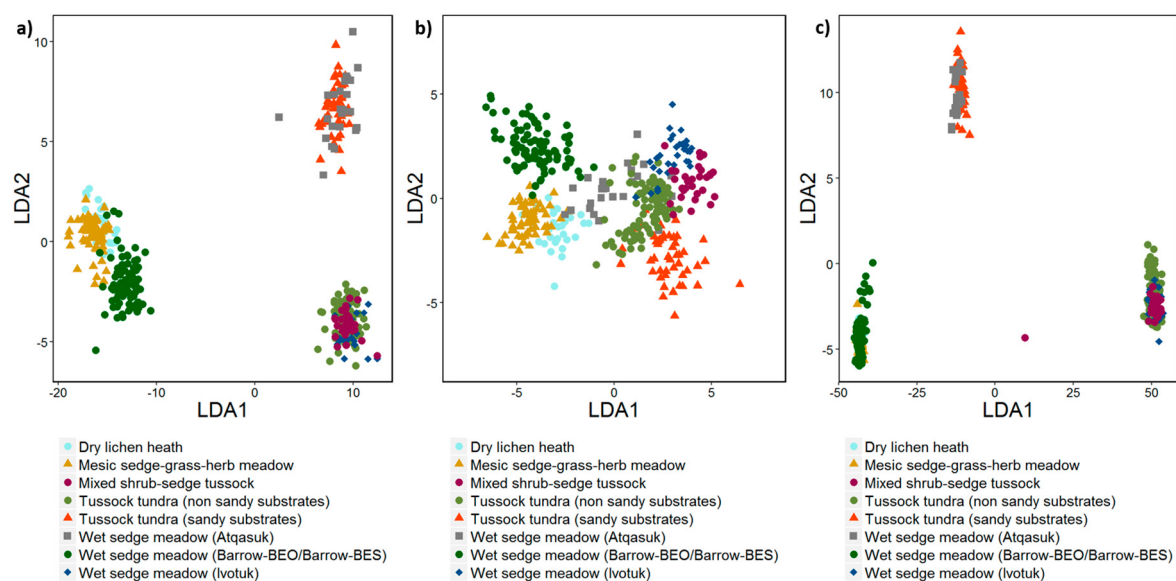


Figure S4. Linear Discriminant Analysis (LDA) plots for Barrow-BEO/Barrow-BES, Atqasuk and Ivotuk using (a) UniSpec reflectance (b) UniSpecWV2 reflectance and (c) WorldView-2 extracted reflectance.

3. Additional Tables

Table S1. Floristics table of all vegetation communities. Species list is ordered by frequency across all quadrats. Data are frequency (I–V) within each community and abundance range (% cover). Quadrats per community = (however many in the smallest group to however many in the largest group).

Species	Barrow-BEO			Barrow-BES		Atkasuk		Ivotuk	
	Wet Sedge Meadow	Mesic Sedge-Grass-Herb Meadow	Dry Lichen Heath	Wet Sedge Meadow	Tussock Tundra (Sandy Substrates)	Wet Sedge Meadow	Wet Sedge Meadow	Mixed Shrub-Sedge Tussock	Tussock Tundra (Non-Sandy Substrates)
<i>Carex aquatilis</i>	I (3–40)	I (0.1–15)	III (0.1–1)	III (0.1–5)	I (1–5)	III (0.1–5)	V (10–25)		
<i>Dactylina arctica</i>		I (0.1–10)	V (0.1–3)		I (0.1–1)			III (0.1)	II (0.1–3)
<i>Eriophorum russeolum</i>	I (0.1–10)	I (0.1–15)	I (0.1)	IV (1–30)	I (1)	IV (1–20)	V (0.1–35)		
<i>Dicranum species</i>		I (1–90)	V (10–60)		I (1–60)			I (3)	III (0.1–5)
<i>Polytrichum species</i>	I (0.1–3)	I (1–60)	V (5–70)	I (0.1–1)	I (0.1–3)	I (0.1–1)	I (3)		II (0.1–5)
<i>Sphagnum species</i>	I (1–50)	I (0.1–5)			I (20)		V (0.1–75)	III (3–50)	V (3–85)
<i>Thamnomia subuliformis</i>		I (0.1–1)	V (0.1–3)		I (0.1–1)			I (0.1)	I (0.1)
<i>Ledum palustre</i>				I (0.1)	I (1–25)	I (0.1)	II (0.1–1)	V (0.1–30)	V (1–15)
<i>Cetraria cucullata</i>		I (0.1–1)	IV (0.1–3)		I (0.1–3)			II (0.1–3)	IV (0.1–1)
<i>Vaccinium vitis-idaea</i>			I (20)		I (5–30)		I (0.1)	V (3–10)	V (3–10)
<i>Aulacomnion turgidum</i>		I (1–10)	I (1)		I (1–70)		I (0.1)	IV (0.1–30)	IV (0.1–5)
<i>Rubus chamaemorus</i>					I (1–40)		I (0.1)	III (10–40)	V (5–35)
<i>Betula nana</i>					I (1–40)		IV (0.1–15)	V (3–25)	V (0.1–5)
<i>Eriophorum vaginatum</i>					I (5–40)			III (1–10)	V (5–70)
<i>Luzula arctica</i>		I (0.1–10)	V (1–5)		I (0.1–1)			I (0.1)	
<i>Cetraria islandica</i>		I (0.1–5)	III (0.1)		I (0.1)			I (0.1)	I (0.1)
<i>Poa arctica</i>		I (0.1–10)	III (0.1–3)		I (1–5)				
<i>Salix pulchra</i>				II (0.1–3)	I (1–10)	II (0.1–3)	V (3–30)	IV (1–50)	
Bare ground	I (25–50)	I (5–10)	II (5–20)		I (3–10)			I (5)	I (5)
Unknown lichen crustose		I (0.1–15)	II (1–5)		I (5–20)			I (1)	
<i>Eriophorum angustifolium</i>	I (1–5)	I (0.1)	I (0.1)	III (3–20)	I (0.1)	III (3–20)	V (0.1–40)	I (0.1)	
<i>Luzula confusa</i>		I (0.1–10)	V (0.1–10)		I (0.1–3)				
<i>Sphaerophorus globosus</i>		I (0.1–5)	III (0.1–3)		I (0.1–0.1)			I (0.1)	
<i>Carex bigelowii</i>				I (5–10)	I (0.1–3)	I (5–10)		IV (5–40)	
<i>Cladonia pyxidata</i>		I (0.1)	IV (0.1)						
<i>Cladina mitis</i>		I (0.1–1)			I (0.1)			II (0.1–5)	III (0.1–3)
<i>Alectoria nigricans</i>		I (0.1–5)	V (0.1–15)		I (0.1)				
<i>Drepanocladus species</i>	I (10–95)				I (1–3)				
<i>Dupontia fisheri</i>	I (0.1–40)	I (0.1–3)							
<i>Petasites frigidus</i>	I (10)	I (0.1–10)	III (1–10)					IV (1–40)	

<i>Cladonia coccifera</i>		I (0.1–1)	III (0.1–1)	I (0.1)		I (0.1)	
<i>Cladonia uncialis</i>		I (0.1–3)		I (0.1)		I (0.1)	
<i>Alectoria ochroleuca</i>				I (0.1–1)			
<i>Cladonia cornuta</i>		I (0.1–10)					
<i>Empetrum nigrum</i>				I (1–5)		V (1–60)	I (0.1)
<i>Saxifraga foliolosa</i>	I (0.1)	I (0.1–0.1)	I (0.1)				
<i>Cassiope tetragona</i>				I (0.1–5)		III (0.1–3)	
<i>Hylocomnium splendens</i>						V (3–60)	I (5)
<i>Bryocaulon divergens</i>				I (0.1–3)			
<i>Cladonia squamosa</i>		I (0.1)	II (0.1–1)				
<i>Arctagrostis latifolia</i>	I (0.1)	I (5)	III (0.1–3)	I (0.1)			
<i>Cladonia amaurocraea</i>			IV (0.1–5)	I (0.1)			
<i>Carex rotundata</i>					IV (5–30)	IV (5–25)	
<i>Hierochloe alpina</i>				I (0.1–3)			
<i>Peltigera canina</i>						IV (0.1–10)	I (0.1)
<i>Distichium species</i>		I (1)				I (3)	
<i>Unknown bryophyte</i>		I (20–80)		I (1–10)			
<i>Andromeda polifolia</i>						I (5)	III (0.1–1)
<i>Bryum species</i>	I (3–5)		I (0.1–1)		I (0.1–1)	I (0.1)	
<i>Cladonia rangiferina</i>			III (0.1–10)				
<i>Racomitrium species</i>				I (0.1–30)		I (5–10)	
<i>Cetraria delisei</i>		I (0.1)				I (0.1)	
<i>Peltigera apthosa</i>						II (0.1–10)	I (0.1)
<i>Polygonum bistorta</i>				I (0.1–1)		I (0.1)	
<i>Saxifraga cernua</i>		I (0.1–0.1)	II (0.1)				
<i>Unknown bryophyte</i>						II (0.1–15)	
<i>Vaccinium uliginosum</i>						I (10)	I (3)
<i>Cetraria laevigata</i>		I (1–10)				I (0.1–3)	
<i>Cladonia gracilis</i>							II (0.1–1)
<i>Pedicularis lapponica</i>				I (0.1–0.1)			
<i>Potentilla hyparctica</i>			II (0.1–3)				
<i>Ranunculus nivalis</i>		I (0.1–0.1)	I (0.1)				
<i>Unknown bryophyte</i>						I (1)	I (0.1)
<i>Unknown bryophyte</i>						II (0.1–5)	
<i>Calliergon sarmentosum</i>	I (20)			I (3)	I (3)		
<i>Cetraria nivalis</i>				I (0.1)			
<i>Unknown bryophyte</i>				I (1)			
<i>Unknown bryophyte</i>							
<i>Unknown bryophyte</i>						I (1–5)	
<i>Alopercurus alpinus</i>	I (1)					I (0.1)	

Table S2. Tukey HSD Comparison for each vegetation community and WorldView-2 multispectral imagery bands.

Barrow-BEO/Barrow-BES						
Waveband	Comparisons	Difference	Lower Bound	Upper Bound	HSD	p Value
Blue (450–510 nm)	Mesic sedge-grass-herb meadow-Dry lichen heath	0.0210221	0.012245	0.029799	0.007909	<0.001
	Wet sedge meadow-Dry lichen heath	0.0033605	−0.00498	0.011703		0.61
	Wet sedge meadow-Mesic sedge-grass-herb meadow	−0.0176615	−0.02407	−0.01126		<0.001
Green (510–580 nm)	Mesic sedge-grass-herb meadow-Dry lichen heath	0.0241602	0.015428	0.032892	0.007869	<0.001
	Wet sedge meadow-Dry lichen heath	0.0002529	−0.00805	0.008553		0.99
	Wet sedge meadow-Mesic sedge-grass-herb meadow	−0.0239073	−0.03028	−0.01753		<0.001
Yellow (585–625 nm)	Mesic sedge-grass-herb meadow-Dry lichen heath	0.0274508	0.018097	0.036805	0.008429	<0.001
	Wet sedge meadow-Dry lichen heath	−0.0068343	−0.01573	0.002057		0.17
	Wet sedge meadow-Mesic sedge-grass-herb meadow	−0.0342851	−0.04111	−0.02746		<0.001
Red (630–690 nm)	Mesic sedge-grass-herb meadow-Dry lichen heath	0.033265	0.022689	0.043841	0.009531	<0.001
	Wet sedge meadow-Dry lichen heath	−0.005727	−0.01578	0.004326		0.37
	Wet sedge meadow-Mesic sedge-grass-herb meadow	−0.038992	−0.04671	−0.03127		<0.001
Red Edge (705–745 nm)	Mesic sedge-grass-herb meadow-Dry lichen heath	0.0099485	0.000233	0.019664	0.008755	0.04
	Wet sedge meadow-Dry lichen heath	−0.0181859	−0.02742	−0.00895		0.000019
	Wet sedge meadow-Mesic sedge-grass-herb meadow	−0.0281344	−0.03523	−0.02104		<0.001
Near-IR1 (770–895 nm)	Mesic sedge-grass-herb meadow-Dry lichen heath	0.0051968	−0.00442	0.014816	0.008669	0.41
	Wet sedge meadow-Dry lichen heath	−0.00357	−0.01271	0.005573		0.63
	Wet sedge meadow-Mesic sedge-grass-herb meadow	−0.0087668	−0.01579	−0.00175		0.01
Near-IR2 (860–1040 nm)	Mesic sedge-grass-herb meadow-Dry lichen heath	−0.0055648	−0.01557	0.004444	0.009019	0.39
	Wet sedge meadow-Dry lichen heath	−0.0301145	−0.03963	−0.0206		<0.001
	Wet sedge meadow-Mesic sedge-grass-herb meadow	−0.0245498	−0.03185	−0.01725		<0.001
Atqasuk						

Waveband	Comparisons	Difference	Lower bound	Upper bound	HSD	p Value
Blue (450–510 nm)	Wet sedge meadow-Tussock tundra (sandy substrates)	0.0179269	0.011057	0.024797	0.00687	<0.001
Green (510–580 nm)	Wet sedge meadow-Tussock tundra (sandy substrates)	0.0204379	0.012762	0.028114	0.007676	<0.001
Yellow (585– 625 nm)	Wet sedge meadow-Tussock tundra (sandy substrates)	0.0186921	0.010582	0.026803	0.008111	<0.001
Red (630–690 nm)	Wet sedge meadow-Tussock tundra (sandy substrates)	0.0232224	0.013961	0.032484	0.009261	<0.001
Red Edge (705–745 nm)	Wet sedge meadow-Tussock tundra (sandy substrates)	−0.0115332	−0.01752	−0.00554	0.005991	<0.001
Near-IR1 (770–895 nm)	Wet sedge meadow-Tussock tundra (sandy substrates)	−0.005917	−0.01134	−0.0005	0.005418	0.03
Near-IR2 (860–1040 nm)	Wet sedge meadow-Tussock tundra (sandy substrates)	−0.0177898	−0.02683	−0.00875	0.009043	<0.001
Ivotuk						
Waveband	Comparisons	Difference	Lower Bound	Upper Bound	HSD	p Value
Blue (450–510 nm)	Tussock tundra (non sandy substrates)-Mixed shrub-sedge tussock	0.006003	0.001116	0.01089	0.005278	0.01
	Wet sedge meadow-Mixed shrub-sedge tussock	0.0112833	0.005298	0.017269		<0.001
	Wet sedge meadow-Tussock tundra (non sandy substrates)	0.0052803	0.000393	0.010167		0.03
Green (510–580 nm)	Tussock tundra (non sandy substrates)-Mixed shrub-sedge tussock	0.003106	−0.00263	0.008841	0.006195	0.41
	Wet sedge meadow-Mixed shrub-sedge tussock	0.011072	0.004048	0.018096		<0.001
	Wet sedge meadow-Tussock tundra (non sandy substrates)	0.007966	0.002231	0.013701		0.004
Yellow (585–625 nm)	Tussock tundra (non sandy substrates)-Mixed shrub-sedge tussock	0.0148618	0.009602	0.020122	0.005682	<0.001
	Wet sedge meadow-Mixed shrub-sedge tussock	0.008558	0.002116	0.015		0.006
	Wet sedge meadow-Tussock tundra (non sandy substrates)	−0.0063037	−0.01156	−0.00104		0.014
Red (630–690 nm)	Tussock tundra (non sandy substrates)-Mixed shrub-sedge tussock	0.0215464	0.015826	0.027266	0.006178	<0.001
	Wet sedge meadow-Mixed shrub-sedge tussock	0.0083355	0.00133	0.015341		0.015
	Wet sedge meadow-Tussock tundra (non sandy substrates)	−0.013211	−0.01893	−0.00749		<0.001
Red Edge (705–745 nm)	Tussock tundra (non sandy substrates)-Mixed shrub-sedge tussock	−0.0109304	−0.01751	−0.00436	0.007102	<0.001
	Wet sedge meadow-Mixed shrub-sedge tussock	−0.010344	−0.0184	−0.00229		0.007
	Wet sedge meadow-Tussock tundra (non sandy substrates)	0.0005865	−0.00599	0.007162		0.98
Near-IR1 (770–895 nm)	Tussock tundra (non sandy substrates)-Mixed shrub-sedge tussock	−0.0209637	−0.0287	−0.01323	0.008357	<0.001
	Wet sedge meadow-Mixed shrub-sedge tussock	−0.0103159	−0.01979	−0.00084		0.029
	Wet sedge meadow-Tussock tundra (non sandy substrates)	0.0106478	0.002911	0.018385		0.004
Near-IR2 (860–1040 nm)	Tussock tundra (non sandy substrates)-Mixed shrub-sedge tussock	0.0008748	−0.00142	0.003173	0.002482	0.64
	Wet sedge meadow-Mixed shrub-sedge tussock	−0.0002062	−0.00302	0.002608		0.98
	Wet sedge meadow-Tussock tundra (non sandy substrates)	−0.0010809	−0.00338	0.001217		0.51

References

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