Supplementary Materials

Table S1. List of 38 layers used as potential predictors for the land cover classification of a polar desert area near Alert, Nunavut, Canada. The specificity, the source or method of acquisition, and the range of values (mean, and sometimes standard deviation and minimum) are given for each layer.

Spatial Predictor	Specificity	Source/Method	Range
Spectral predictors (*n*=4)			
Blue (mean)	Used for discrimination of soil and rock surfaces [156].	Extract Bands function (ArcGIS pro) from the multispectral pansharpened picture	Mean: 0 to 252.81
Green (mean)	Associated with vegetation vigor. Used for vegetation mapping [156].	Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean"	Mean: 0 to 253
Red (mean)	Associated with chlorophyll absorption. Used for vegetation mapping [156].		Mean: 0 to 255
Near infra-red (NIR) (mean)	Used to delineate waterbodies (rivers, ponds, and lakes) and for discrimination of dry and moist soils [156].		Mean: 0 to 255
Vegetation predictors (*n*=10)			
Green Normalized Difference Vegetation Index (GNDVI) (mean and std)	Used to estimate photosynthetic activity and for assessing senescent vegetation [77].	Index implemented in the Band Indices of the Spatial Analyst functions (ArcGIS pro): GNDVI = (NIR - Green)/(NIR + Green) [77] Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: -1 to 1 Std: 0 to 0.88
Modified Soil-adjusted Vegetation Index 2 (MSAVI2) (mean and std)	Used to minimize the effects of bare soil on the SAVI [86].	Index implemented in the Band Indices of the Spatial Analyst functions (ArcGIS pro): MSAVI2 = (1/2) × (2 × (Nir +1) - sqrt((2 × Nir + 1)2-8(Nir - Red))) [78] Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: -10 to 1 Std: 0 to 4.18
Normalized Difference Vegetation Index (NDVI) (mean and std)	Used to display greenness or plant productivity [86].	Index implemented in the Band Indices of the Spatial Analyst functions (ArcGIS pro): NDVI = ((Nir - Red)/(Nir + Red)) [79]	Mean : -1 to 1 Std : 0 to 0.92

		Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	
Soil-adjusted Vegetation Index (SAVI) (mean and std)	Used to minimize soil brightness influences using a soil-brightness correction factor [86].	Index implemented in the Band Indices of the Spatial Analyst functions (ArcGIS pro): SAVI = ((NIR - Red)/(NIR + Red + L)) × (1 + L) L: correction factor which ranges from 0 for very high vegetation cover to 1 for very low vegetation cover. Here, we used 0.8 [80] Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: -1.77 to 1.55 Std: 0 to 1.34
Transformed Soil-adjusted Vegetation Index (TSAVI) (mean and std)	Used to minimize soil brightness influences by assuming the soil line has an arbitrary slope and intercept [85].	Index implemented in the Band Indices of the Spatial Analyst functions (ArcGIS pro): TSAVI = (s × (Nir - s × Red - a)) / (a × Nir + Red - a × s + X × (1 + s^2)) s = The slope of the soil line (0.7) a= The soil line intercept (-0.32). X= The adjustment factor that is set to minimize soil noise (set to default value of 1.5) [81] The slightly modified BSL function from the Landsat package version 3.2.5 [90] was used in R to obtain the intercept and the slope (method was set to "minimum") Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: -668.01 to 1017.67 Std: 0 to 4981.03
Topographic predictors (*n*=16)			
Aspect (mean and std)	Used to display the compass direction that each pixel or a surface is facing (measured in degrees from north).	Aspect function of the Raster functions (ArcGIS pro) with the DEM as input layer	Mean: 0 to 359

		Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Std: 0 to 179.5
Aspect-slope (mean and std)	Used to display simultaneously the aspect and the slope of a surface.	Aspect-slope function of the Raster functions (ArcGIS pro) with the DEM as input layer Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: 19 to 48 Std: 0 to 14
Curvature (mean and std)	Used to display the shape or convexity/concavity of a slope. Positive values of curvature indicate convex surfaces while negative surfaces indicate concave surfaces. Curvature values near zero indicate flat surfaces.	Curvature function of the Raster functions (ArcGIS pro) with the DEM as input layer Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: -976.79 to 756.30 Std: 0 to 4427.10
Elevation (mean and std)	Used to display terrain height (in meters).	From the DEM Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: 15.74 to 543.16 Std: 0 to 29.82
Slope (mean and std)	Used to represent the steepness of the surface (in degrees).	Surface Raster Function (ArcGIS pro) set to Slope (in degrees) Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: 0 to 66.42 Std: 0 to 36.93
Relief (mean and std)	Used to display the difference between the highest and lowest elevations within the sampling region.	Focal statistics tool (ArcGIS pro) using the DEM layer and a moving window of 3 by 3 pixels (Neighborhood) with statistics type set to "Range"	Mean: 0 to 7.14 Std: 0 to 8.71

		Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	
Topographic position index (TPI) (mean and std)	Used to automate landform classifications. Positive TPI values indicate that the central point is located higher than its average surroundings (often associated with ridgetops and peaks), while negative values indicate a position lower than the average (often associated with valleys and canyon bottoms). TPI values near zero are either flat areas (where the slope is near zero) or areas of constant slope [93,157,158]	Raster calculator tool (ArcGIS pro): TPI= DEM-mean Mean = Focal statistics tool (ArcGIS pro) using the DEM layer and a moving window of 3 by 3 pixels (Neighborhood) with statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: -0.56 to 0.63 Std: 0 to 3.69
Terrain Ruggedness Index (TRI) (mean and std)	Used as measure of topographical heterogeneity through the amount of elevation difference between adjacent cells of a DEM [94]	Raster calculator tool (ArcGIS pro): TRI = Sqrt([r2]) 1. Compute s: Focal statistics tool (ArcGIS pro) using the DEM layer and a moving window of 3 by 3 pixels (Neighborhood) with statistics type set to "Sum" 2. Compute DEM2: Raster calculator tool (ArcGIS pro): DEM × DEM 3. Compute t: Focal statistics tool (ArcGIS pro) using the DEM2 layer and a moving window of 3 by 3 pixels (Neighborhood) with statistics type set to "Sum" 4. Compute r2: Raster calculator tool (ArcGIS pro): t + (9 × DEM2) – (2 × DEM × s) Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: 0 to 11.93 Std: 0 to 15.07
Hydrological predictors (*n*=8)			

Distance to lakes and ponds (minimum)	Used to estimate the proximity to the nearest lake and permanent pond (in meters).	Distance Accumulation tool (ArcGIS pro) applied to the manually digitized lakes and permanent ponds Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Minimum"	Minimum: 0 to 4359.86
Distance to ocean (minimum)	Used to estimate the proximity to the ocean shore (in meters).	Distance Accumulation tool (ArcGIS pro) applied to the manually digitized ocean shore Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Minimum"	Minimum: 0 to 8939.99
Distance to rivers (minimum)	Used to estimate the proximity to the nearest active river (in meters).	Distance Accumulation tool (ArcGIS pro) applied to the manually digitized active rivers Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Minimum"	Minimum: 0 to 4375.36
Distance to snowbanks (minimum)	Used to estimate the proximity to the nearest perennial snowbank (in meters).	Distance Accumulation tool (ArcGIS pro) applied to the digitized perennial snowbanks. Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Minimum"	Minimum: 0 to 2292.96
Normalized Difference Water Index (NDWI) (mean and std)	Used for waterbody mapping [95,159].	Index implemented in the Band Indices of the Spatial Analyst functions (ArcGIS pro): (Green − Nir)/(Green+ Nir) [95] Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"	Mean: -1 to 1 Std: 0 to 0.88
Topographic wetness index (TWI) (mean and std)	Used to determine the spatial distribution of soil moisture and surface saturation with regard to the influence of topography. Areas prone to water accumulation and characterized by low slope angle will be linked to high TWI values, while well-drained dry areas (steep slopes) are associated to low TWI values	Raster calculator tool (ArcGIS pro): TWI= ln(((α+1) × Cellsize)/(Tan(β)+C)) [96] α = Flow accumulation (specific catchment area) 1. Flow direction tool (ArcGIS pro) using the DEM with the output name set to "Fd" 2. Flow accumulation tool (ArcGIS pro) using the Fd layer created in the first step, with the output name set to "alpha"	Mean: -0.77 to 16.38 Std: 0 to 8.34

	[160].	β = Local slope (in radians) 1. Slope tool (ArcGIS pro) using the DEM with the output measurement set to "Degree" 2. Transform the Slope (in degrees) to Slope (in radians) by using Raster calculator tool (ArcGIS pro): Slope × π/180 or Slope × 0.017453, with the output name set to "beta" Cellsize = 0.5 C = 0.001 is a tip to avoid the denominator = 0 Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Mean" Zonal statistics tool using the segment layer (in shapefile) and the statistics type set to "Standard deviation"

Table S2. Mean values and standard deviations of the 38 potential predictors per land cover class.

Predictor	Forb-dominated barren	Forb-dominated tundra	Grass-dominated wetland	Sedge-dominated wetland	Moss-dominated wetland	Water	Snow
Spectral predictors (*n*=4)							
Blue	95.27 (± 19.03)	70.55 (± 9.12)	53.02 (± 11.41)	49.55 (± 6.53)	26.84 (± 6.73)	50.14 (± 13.14)	159.52 (± 37.04)
Green	111.76 (± 23.39)	84.90 (± 10.31)	66.21 (± 9.27)	63.03 (± 5.13)	58.57 (± 9.91)	63.37 (± 10.61)	170.55 (± 39.16)
Red	125.89 (± 31.17)	96.67 (± 10.97)	78.30 (± 8.58)	78.15 (± 4.95)	73.94 (± 9.59)	66.69 (± 9.08)	185.09 (± 44.98)
Near-infrared	119.50 (± 28.09)	108.68 (± 7.99)	110.82 (± 10.11)	120.50 (± 7.45)	155.25 (± 20.72)	36.41 (± 17.19)	152.08 (± 37.04)
Vegetation predictors (*n*=10)							
GNDVI	0.03 (± 0.04)	0.13 (± 0.05)	0.26 (± 0.07)	0.32 (± 0.04)	0.46 (± 0.04)	-0.32 (± 0.24)	-0.06 (± 0.05)
GNDVI std	0.05 (± 0.02)	0.06 (± 0.01)	0.07 (± 0.02)	0.07 (± 0.02)	0.08 (± 0.03)	0.14 (± 0.06)	0.03 (± 0.02)
MSAVI2	-0.06 (± 0.07)	0.11 (± 0.07)	0.29 (± 0.08)	0.35 (± 0.04)	0.52 (± 0.05)	-1.57 (± 1.40)	-0.22 (± 0.09)
MSAVI2 std	0.06 (± 0.03)	0.05 (± 0.01)	0.05 (± 0.03)	0.03 (± 0.01)	0.04 (± 0.01)	0.87 (± 0.76)	0.06 (± 0.02)
NDVI	-0.02 (± 0.03)	0.06 (± 0.04)	0.17 (± 0.05)	0.21 (± 0.03)	0.35 (± 0.04)	-0.35 (± 0.21)	-0.10 (± 0.04)
NDVI std	0.03 (± 0.01)	0.03 (± 0.01)	0.03 (± 0.01)	0.03 (± 0.01)	0.04 (± 0.01)	0.12 (± 0.06)	0.02 (± 0.01)
SAVI	-0.04 (± 0.06)	0.11 (± 0.08)	0.31 (± 0.10)	0.38 (± 0.05)	0.64 (± 0.08)	-0.63 (± 0.38)	-0.17 (± 0.06)
SAVI std	0.05 (± 0.01)	0.05 (± 0.01)	0.06 (± 0.02)	0.05 (± 0.02)	0.06 (± 0.02)	0.21 (± 0.10)	0.04 (± 0.01)

TSAVI	0.26	0.48	0.92	1.17	3.64	-0.11	0.12
	(± 0.07)	(± 0.13)	(± 0.37)	(± 0.22)	(± 2.30)	(± 0.18)	(± 0.06)
TSAVI std	0.07	0.10	0.60	0.25	7.32	0.11	0.04
	(± 0.03)	(± 0.05)	(± 3.09)	(± 0.21)	(± 10.96)	(± 0.06)	(0.02)
Topographic predictors (*n*=16)							
Aspect (degree)	168.41	153.49	131.08	123.37	143.34	138.17	135.64
	(± 48.51)	(± 47.20)	(45.25)	(± 35.62)	(± 50.68)	(± 40.60)	(± 54.20)
Aspect std (degree)	109.65	120.79	105.97	119.05	106.00	93.73	116.96
	(± 25.22)	(± 23.34)	(± 36.22)	(± 28.22)	(± 26.57)	(± 23.99)	(± 32.08)
Aspect-slope	26.01	21.49	21.31	22.39	25.20	21.11	28.91
	(± 6.61)	(± 1.81)	(± 2.13)	(± 3.01)	(± 4.50)	(± 4.35)	(± 4.82)
Aspect-slope std	5.34	2.96	2.67	3.29	5.04	1.84	7.42
	(± 3.18)	(± 1.41)	(± 1.79)	(± 2.05)	(± 2.89)	(± 2.64)	(± 2.60)
Curvature	-0.23	0.00	-0.15	0.06	-0.57	-0.52	1.35
	(± 2.91)	(± 0.55)	(± 0.45)	(± 0.98)	(± 1.98)	(± 4.76)	(± 6.52)
Curvature std	133.45	43.36	41.68	59.30	111.60	43.23	180.51
	(± 178.44)	(± 24.66)	(± 30.48)	(± 39.09)	(± 132.66)	(± 92.75)	(± 117.57)
Elevation (meter)	121.38	175.09	143.67	67.12	251.55	109.91	172.93
	(± 93.53)	(± 86.31)	(± 81.49)	(± 37.99)	(± 64.50)	(± 58.08)	(± 94.76)
Elevation std (meter)	1.25	1.77	0.71	0.34	0.22	0.15	0.62
	(± 2.13)	(± 2.54)	(± 1.59)	(± 0.37)	(± 0.24)	(± 0.25)	(± 0.59)
Relief	0.26	0.08	0.08	0.12	0.21	0.08	0.34
	(± 0.35)	(± 0.05)	(± 0.06)	(± 0.08)	(± 0.23)	(± 0.19)	(± 0.21)
Relief std	0.17	0.06	0.05	0.07	0.14	0.06	0.23
	(± 0.22)	(± 0.03)	(± 0.04)	(± 0.05)	(± 0.18)	(± 0.11)	(± 0.15)
Slope (degree)	9.23	3.48	3.34	4.88	7.96	3.21	13.15
	(± 10.02)	(± 1.99)	(± 2.41)	(± 3.24)	(± 6.69)	(± 6.21)	(± 7.05)
Slope std (degree)	6.26	2.64	2.51	3.36	5.59	2.23	9.41
	(± 5.87)	(± 1.44)	(± 1.82)	(± 2.03)	(± 4.83)	(± 3.59)	(± 4.95)
TPI	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(± 0.00)	(± 0.00)	(± 0.00)	(± 0.00)	(± 0.00)	(± 0.00)	(± 0.00)
TPI std	0.08	0.03	0.03	0.04	0.07	0.03	0.11
	(± 0.11)	(± 0.02)	(± 0.02)	(± 0.02)	(± 0.08)	(± 0.06)	(± 0.07)
TRI	0.37	0.12	0.12	0.17	0.30	0.13	0.50
	(± 0.51)	(± 0.07)	(± 0.08)	(± 0.11)	(± 0.36)	(± 0.27)	(± 0.32)
TRI std	0.25	0.12	0.12	0.11	0.25	0.11	0.34
	(± 0.29)	(± 0.04)	(± 0.05)	(± 0.05)	(± 0.25)	(± 0.13)	(± 0.23)
Hydrological predictors (*n*=8)							
Distance to lakes/ponds	1061.33	891.34	959.40	751.43	907.16	380.55	1122.57
(meter)	(± 891.30)	(± 639.17)	(± 689.27)	(± 625.72)	(± 899.68)	(± 832.20)	(± 720.07)
Distance to ocean	2232.58	3135.47	2743.36	1188.76	6391.62	2384.46	3362.42
(meter)	(± 2481.19)	(± 2346.66)	(± 2274.72)	(± 995.08)	(± 774.73)	(± 2111.65)	(± 2402.42)
Distance to rivers	672.25	695.67	902.77	690.73	260.13	778.68	327.55
(meter)	(± 909.94)	(± 711.47)	(± 1009.47)	(± 681.52)	(± 305.85)	(± 753.20)	(± 537.71)
Distance to snowbanks	440.03	407.74	426.85	313.57	209.75	632.34	0.00
(meter)	(± 415.41)	(± 375.68)	(± 455.42)	(± 299.35)	(± 178.18)	(± 550.87)	(± 0.00)
NDWI	-0.03	-0.13	-0.26	-0.32	-0.46	0.32	0.06
	(± 0.04)	(± 0.05)	(± 0.07)	(± 0.04)	(± 0.04)	(± 0.24)	(± 0.05)
NDWI std	0.05	0.06	0.07	0.07	0.08	0.14	0.03
	(± 0.02)	(± 0.01)	(± 0.02)	(± 0.02)	(± 0.03)	(± 0.06)	(± 0.02)
TWI	4.21	4.84	4.99	4.59	4.41	5.42	3.69
	(± 0.89)	(± 0.46)	(± 0.62)	(± 0.71)	(± 0.78)	(± 0.99)	(± 0.59)
TWI std	2.85	2.81	2.82	2.84	3.19	2.51	3.10
	(± 0.46)	(± 0.32)	(± 0.39)	(± 0.38)	(± 0.39)	(± 0.56)	(± 0.38)

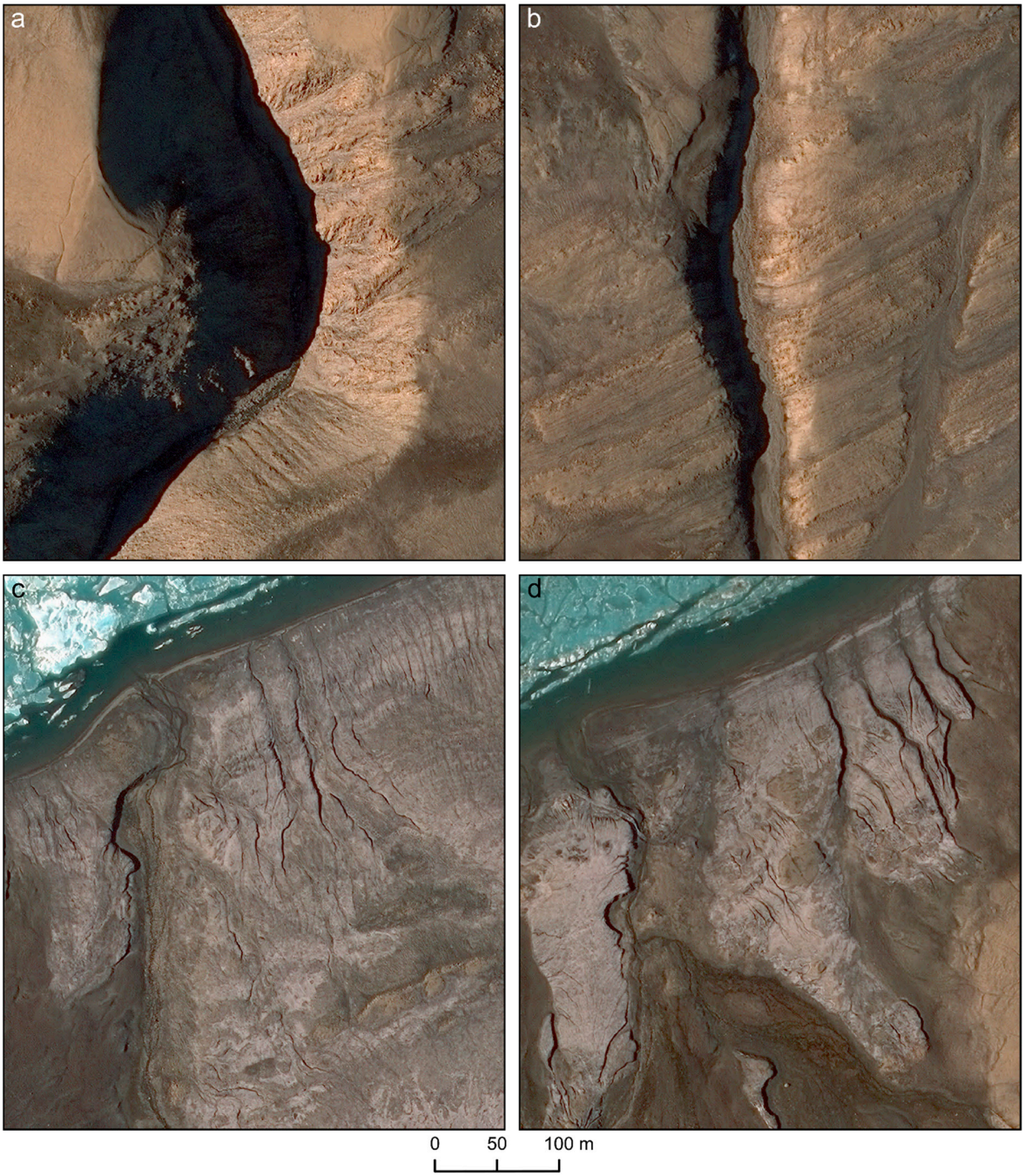

Figure S1. Top view of illuminated canyon slopes (light areas, **a** and **b**) and saline soils along the coast (pale gray areas, **c** and **d**). Reference points were added in these types of areas since they were confused with snow in preliminary classifications.

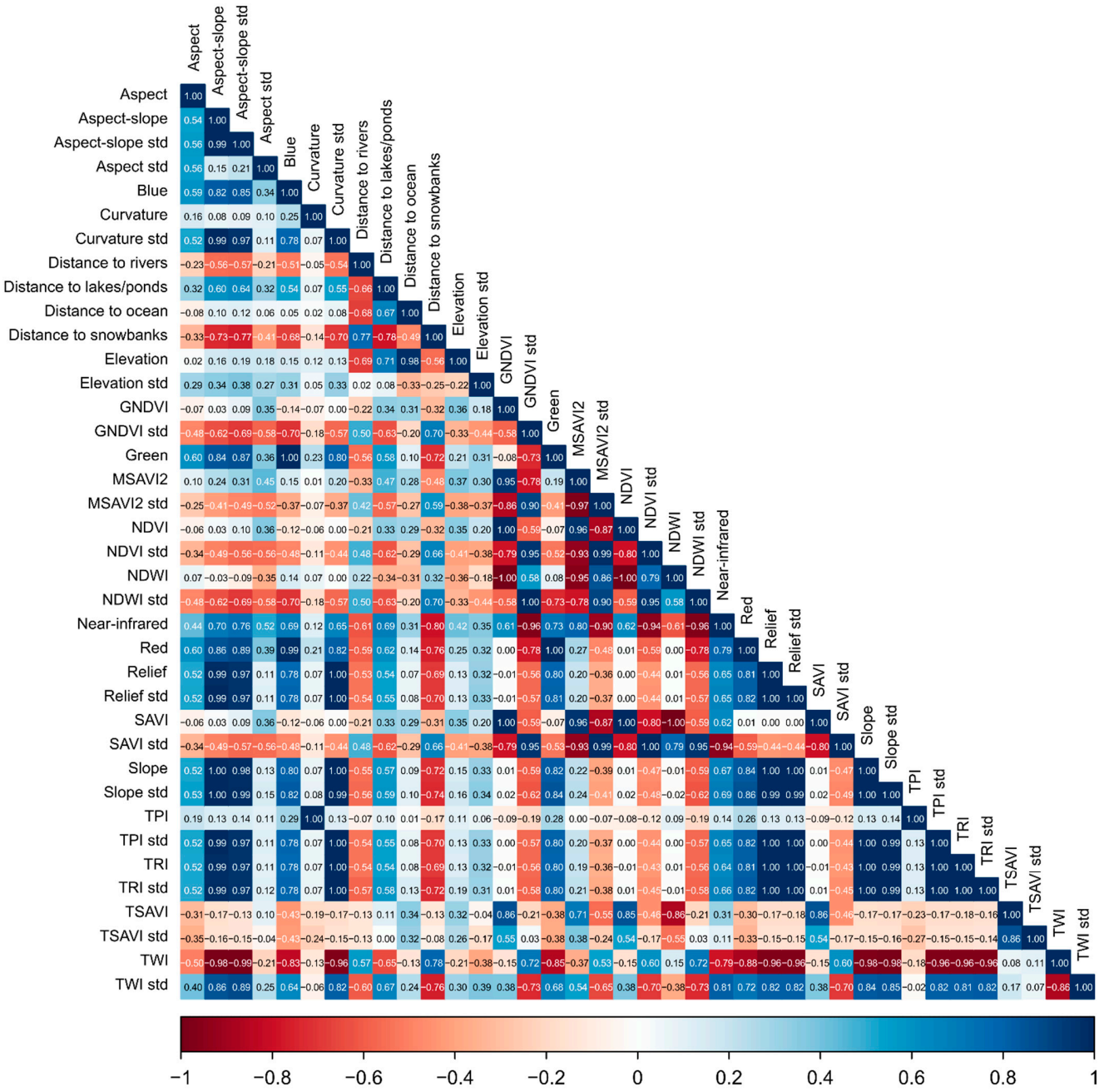

Figure S2. Color-coded correlogram outlining the Pearson correlation coefficients (r) between all 38 predictors used in the study.

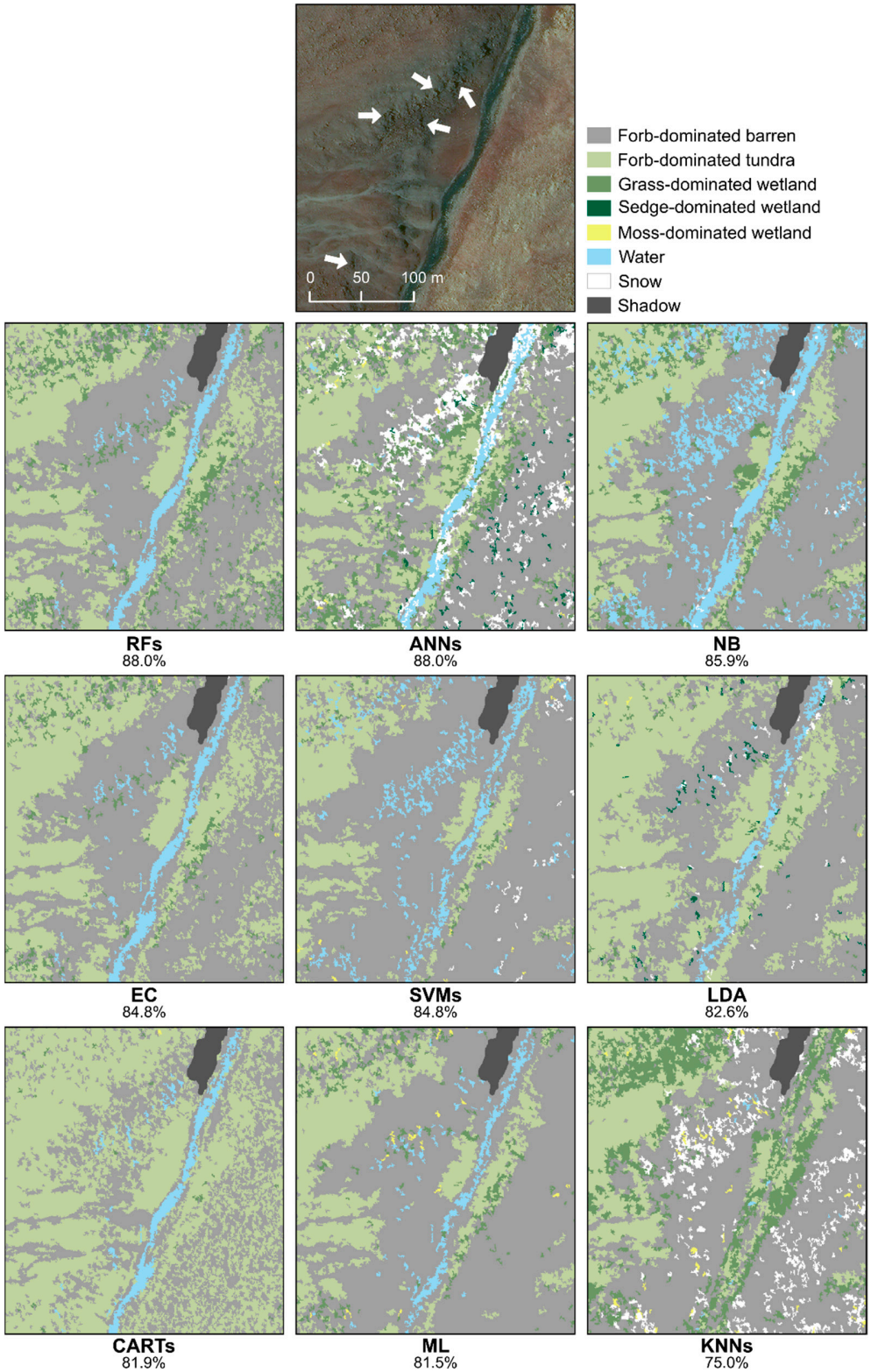

Figure S3. False colour infrared (near-infrared, red and green bands) satellite imagery (top panel) and classified sub-areas (9 lower panels) within Alert to illustrate that the shadow produced by the rocks (examples pointed by arrows in the top panel) has been classified as water, grass-dominated wetland, snow or sedge-dominated wetland by RFs (random forests), ANNs (artificial neural networks), NB (naive Bayes), EC (ensemble classifier), SVMs (support vector machines), LDA (linear discriminant analysis), CARTs (classification and regression trees), ML (maximum likelihood), and KNNs (K-nearest neighbors). Percentages indicate overall accuracy of the classifiers, which was derived from the confusion matrices.

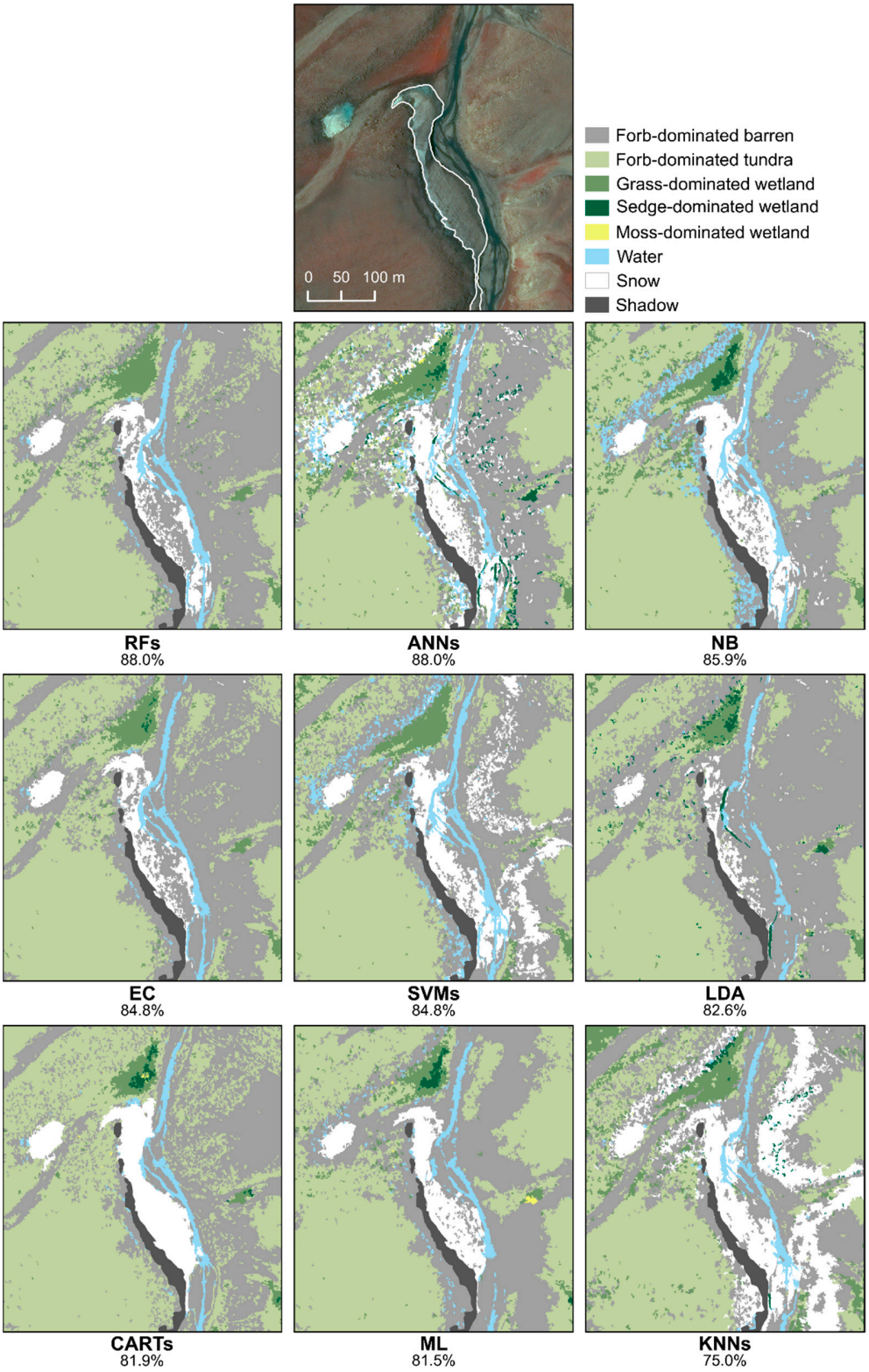

Figure S4. False colour infrared satellite imagery (top panel) and classified sub-areas (9 lower panels) within Alert to illustrate that the snow covered by till and gravel (outlined by a white line in the top panel) have been incorrectly classified as forb-dominated barren by all classifiers, except classification and regression trees (CARTs). RFs (random forests), ANNs (artificial neural networks), NB (naive Bayes), EC (ensemble classifier), SVMs (support vector machines), LDA (linear discriminant analysis), ML (maximum likelihood), and KNNs (K-nearest neighbors). Percentages indicate overall accuracy of the classifiers, which was derived from the confusion matrices.

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