Supplementary Material

A new habitat map of the Lena Delta in Arctic Siberia based on field and remote sensing datasets

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Table S1: *Vegetation plots in the central Lena Delta, mainly on Kurungnakh and Samoylov islands (Dateset 1, 2: Shevtsova et al. 2021a, Shevtsova et al. 2021b).*

Vegetation Plot Code	N Latitude	E Longitude	Date	Landscape	Habitat
LD18-VP01	N 72.2920	E 126.1606	01.08.2018	Yedoma upland, wet sedge and moss-dominated tundra	**Polygonal tundra complex**
LD18-VP02	N 72.2911	E 126.1651	01.08.2018	Yedoma upland, wet sedge and moss-dominated tundra	**Polygonal tundra complex**
LD18-VP03	N 72.2839	E 126.1955	02.08.2018	tundra slope	**Dry tundra communities**
LD18-VP04	N 72.28179	E 126.1942	02.08.2018	terrace with shrub communities (> 30 cm height)	**Dry shrub communities**
LD18-VP05	N 72.3229	E 126.2553	03.08.2018	young drained lake basin, baydzherakhs and wet basin floor	**Dry grass to wet sedge communities**
LD18-VP06	N 72.3228	E 126.2583	03.08.2018	young drained lake basin, rim with shrub communities (> 50 cm height)	**Dry grass to wet sedge communities**
LD18-VP07	N 72.3243	E 126.2633	04.08.2018	Yedoma upland, wet sedge and moss-dominated tundra	**Polygonal tundra complex**
LD18-VP08	N 72.3265	E 126.2638	04.08.2018	Yedoma upland, wet sedge and moss-dominated tundra	**Polygonal tundra complex**
LD18-VP09	N 72.3057	E 126.2506	07.08.2018	alas floor, tussock	**Dry tundra communities**
LD18-VP10	N 72.3042	E 126.2511	07.08.2018	alas floor, tussock	**Dry tundra communities**
LD18-VP11	N 72.3330	E 126.281536	08.08.2018	thermo-erosional valley	**Dry grass to wet sedge communities**
LD18-VP13	N 72.3679	E 126.2573	10.08.2018	tussock on slope	**Dry tundra communities**
LD18-VP14	N 72.3657	E 126.2731	10.08.2018	Yedoma upland, wet sedge and moss-dominated tundra	**Polygonal tundra complex**
LD18-VP15	N 72.3794	E 126.3892	11.08.2018	polygonal tundra, Holocene terrace	**Polygonal tundra complex**

LD18-VP16	N 72.3728	E 126.4702	14.08.2018	floodplain, dry ridge with shrub communities	**Dry shrub communities**
LD18-VP17	N 72.3873	E 126.4791	15.08.2018	floodplain, *Salix*, Alder	**Moist *Equisetum* and shrubs**
LD18-VP18	N 72.3669	E 126.2550	16.08.2018	heterogenous plot (not used for training)	
LD18-VP19-	N 72.3623	E 126.2666	16.08.2018	heterogenous plot (not used for training)	**Dry grass to wet sedge communities**
LD18-VP20	N 72.3244	E 126.2731	18.08.2016	thermo-erosional valley slope	**Dry grass to wet sedge communities**
LD18-VP21	N 72.3750	E 126.4987	19.08.2018	polygonal tundra, Holocene terrace	**Polygonal tundra complex**
LD18-VP22	N 72.3269	E 126.0479	22.08.2018	degraded Yedoma on slope	**Polygonal tundra complex** (transition to tussock)
LD18-VP23	N 72.3260	E 126.0544	22.08.2018	degraded Yedoma on slope	**Polygonal tundra complex (**transition to tussock)
LD18-VP24	N 72.3292	E 126.0439	22.08.2018	steep valley slope with high shrub communities (>100 cm) heterogenous plot (not used for training)	**Dry shrub communities**
LD18-VP25	N 72.3283	E 126.0397	22.08.2018	terrace with shrub communities (>50 cm) heterogenous plot (not used for training)	**Dry shrub communities**
LD18-VP26	N 72.3767	E 126.5038	24.08.2018	polygonal tundra, Holocene terrace	**Polygonal tundra complex**
LD18-VP27	N 72.3443	E 126.1907	25.08.2018	Yedoma upland, wet sedge and moss-dominated tundra	**Polygonal tundra complex**

Table S2: *Cross Reference table for 2018 expedition plots for vegetation and field spectrometry in the central Lena Delta.*

Landscape	Vegetation Plot [date of survey]	Spectrometry Plot [date of survey]
Polygonal tundra complex	VP01 [01.08.2018]	SP008 [09.08.2018]

Polygonal tundra complex	VP02 [01.08.2018]	SP009 [09.08.2018]
Polygonal tundra complex	VP07 [04.08.2018]	SP007 [08.08.2018]
Polygonal tundra complex	VP08 [04.08.2018]	SP026 [28.08.2018]
Polygonal tundra complex	VP14 [10.08.2018]	SP013 [10.08.2018]
dry tundra communities	VP03 [02.08.2018]	SP010 [09.08.2018] SP024 [27.08.2018]
dry tussock tundra	VP13 [10.08.2018]	SP015 [10.08.2018]
dry tussock tundra	VP09	SP003 [07.08.2018]
dry tussock tundra	VP10	SP004 [07.08.2018]
Dry grass to wet sedge communities in young drained lake basin, baydzherakhs, wet basin floor	VP05 [03.08.2018]	SP005 [08.08.2018] SP027 [28.08.2018]
Dry grass to wet sedge communities in young drained lake basin, rim with shrub communities (>50 cm height)	VP06 [03.08.2018]	SP006 [08.08.2019]
terrace with dry shrub communities (>30 cm height)	VP04 [02.08.2018]	SP011 [09.08.2018] SP022 [27.08.2018]
Dry grass to wet sedge communities on disturbed slope	VP19 [16.08.2018]	SP014 [10.08.2018]
floodplain, dry ridge with dry shrub communities	VP16 [14.08.2018]	SP019 [26.08.2018]
floodplain, **Moist *Equisetum* and shrubs**	VP17 [15.08.2018]	SP018 [26.08.2018]
floodplain, low shrub communities	NaN	SP002 [06.08.2018]
floodplain, sand	NaN	SP001 [06.08.2018]

Table S3: *Habitat classes of the central delta and 2nd terrace.*

Habitat class	photo
moist Equisetum and shrubs on floodplain, Samoylov Island (photo AWI 2018)	
dry shrub communities on lower terrace on Kurungnakh Island, flooded during spring flood (photo AWI 2018)	

moist to wet sedge communities in thermo-erosional valley on Kurungnakh Island (photo AWI 2018)	
wet sedge communities on floodplain, Samoylov Island (photo AWI 2019)	

polygonal tundra up to 10% surface water on Pleistocene Yedoma terrace, Kurungnakh Island (photo AWI 2018)	
polygonal tundra up to 20% surface water on Holocene fluvial terrace, Island in the central delta (photo AWI 2019)	

polygonal tundra up to 50% surface water on Holocene fluvial terrace, Samoylov Island (photo AWI 2019)	
dry grass to wet sedge communities in young drained lake basin on Kurungnakh Island (photo AWI 2018)	

sparsely vegetated areas on floodplain, Samoylov Island (photo AWI 2019)	
dry tundra tussock type on drained slopes of Kurungnakh Island (photo AWI 2018)	
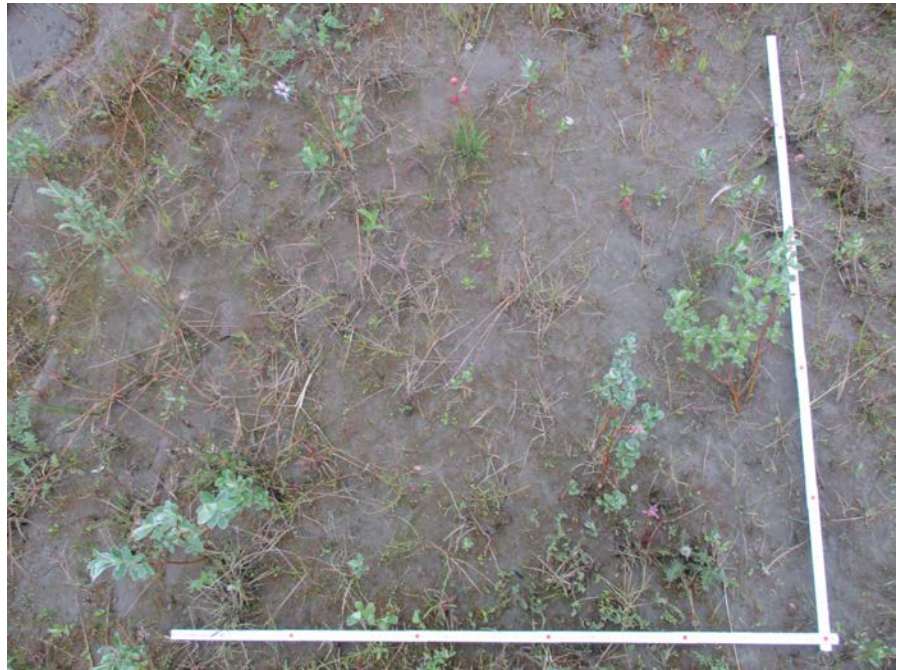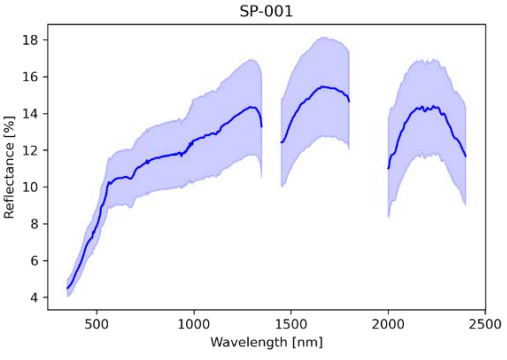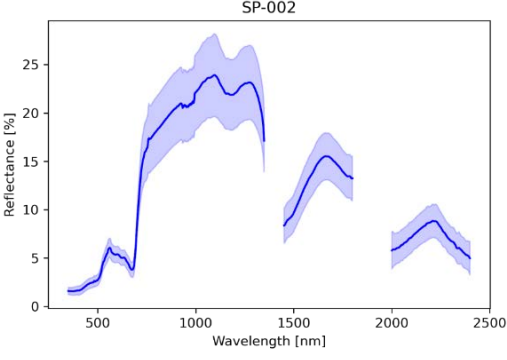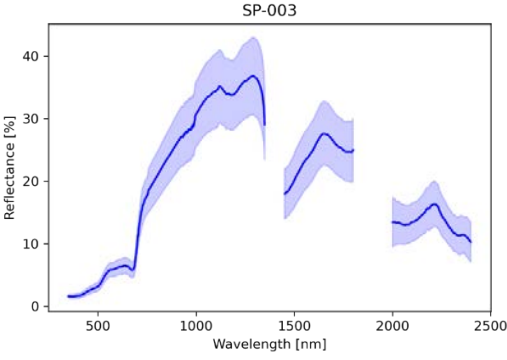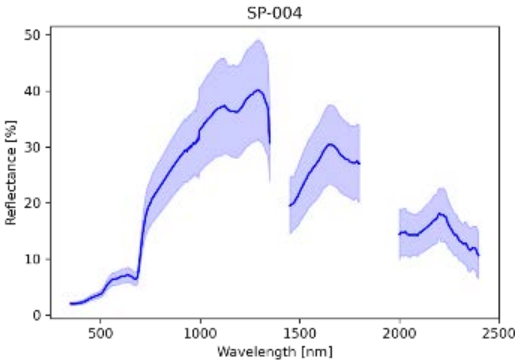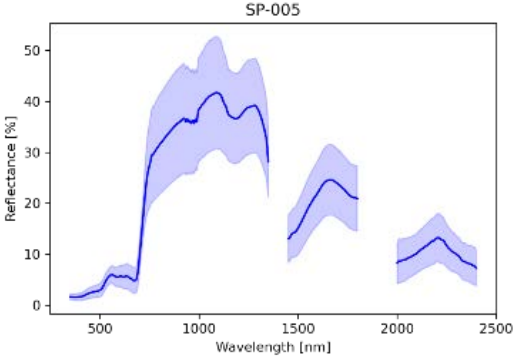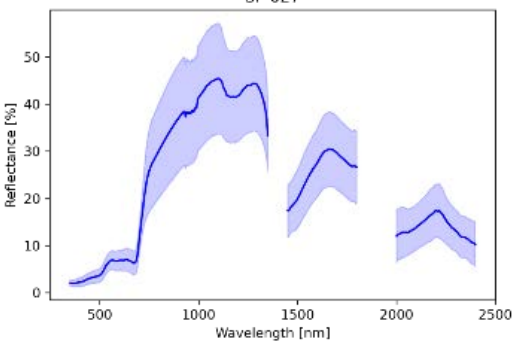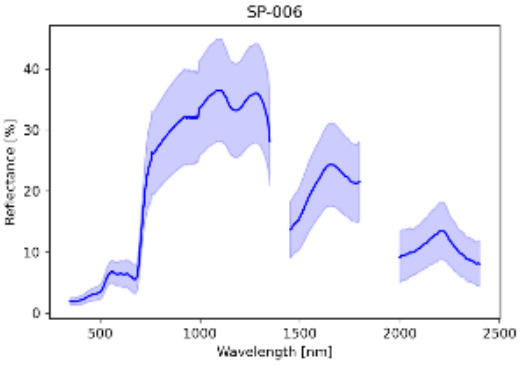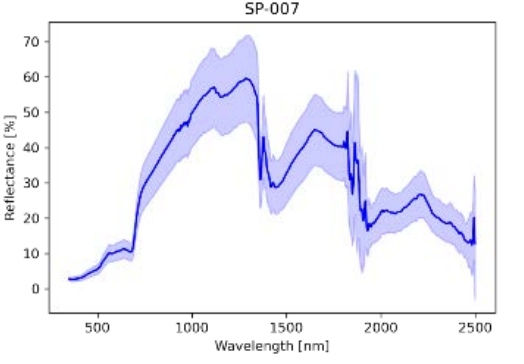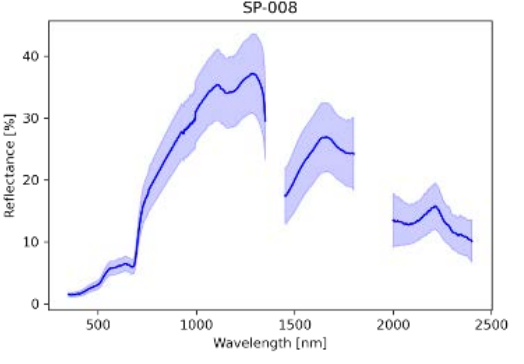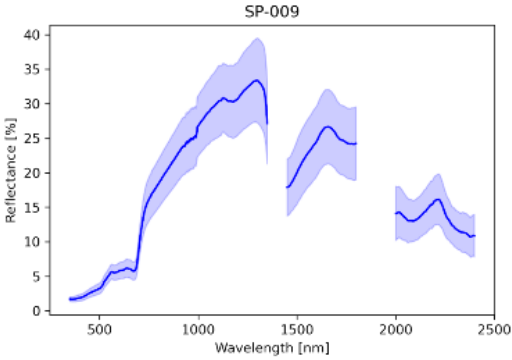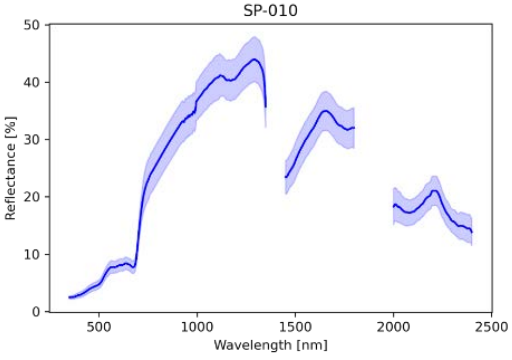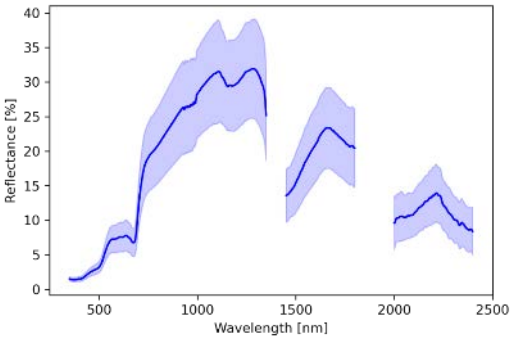
barren / sand on floodplain, Samoylov Island (photo AWI 2018)	
dwarf shrub - herb communities on the 2nd delta terrace plateau (sandy Pleistocene fluvial and aeolic complex) in Schneider et al. 2009, Figure 2d, dry moss-, sedge-, and dwarf shrub-dominated tundra (class DMSD); photo AWI)	

Table S4: *LD18 spectrometry plots and their mean surface reflectance (Dataset 3, Runge et al. 2022). The mean surface reflectance is depicted in dark blue, the standard deviation in light blue, and n states the number of randomly scattered measurements within a spectrometry plot (30 m2).*

LD18 spectrometry	Surface reflectance plot	Field photo
SP-001 floodplain, sand	n = 194 	
SP-002 floodplain, low shrubs	n = 206 	
SP-003 Drained Lake Basin floor, tussock	n = 89 	

SP-004 Drained Lake Basin floor, tussock	n =56 	
SP-005 / SP-027 young drained lake, Baydzherakhs and wet basin floor SP-005: 2018-08-08 SP-027: 2018-08-28	n = 106 n = 126 	

SP-006 young drained lake, rim with shrub communities (> 50 cm height)	n = 106 	
SP-007 Yedoma upland, wet sedge and moss-dominated tundra	n = 106 	
SP-008 Yedoma upland, wet sedge and moss-dominated tundra	n = 107 	

SP-009 Yedoma upland, wet sedge and moss-dominated tundra	n = 109 	
SP-010 / SP-024 tundra slope south-facing SP-010: 2018-08-09 SP-024: 2018-08-27	n = 111 n = 108 	

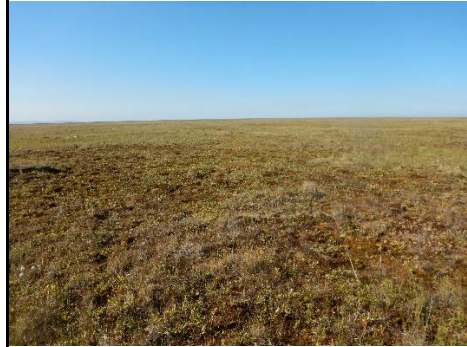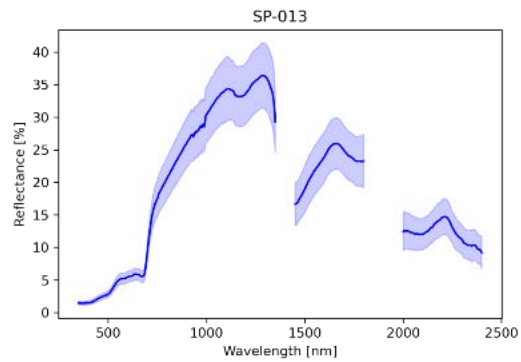|		
SP-011 / SP-022 terrace with shrub communities (> 30 cm height) SP-011: 2018-08-09 SP-022: 2018-08-27	n = 108 n = 110 	
SP-012 terrace, wet (~ 20 cm)	n = 73 	
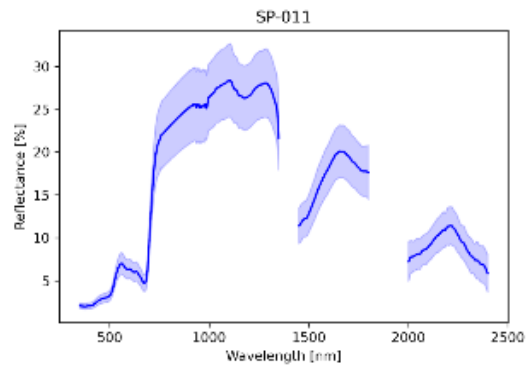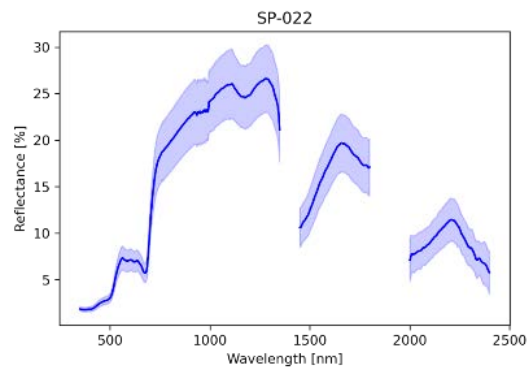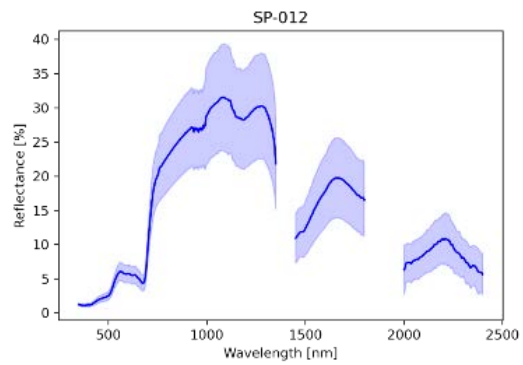
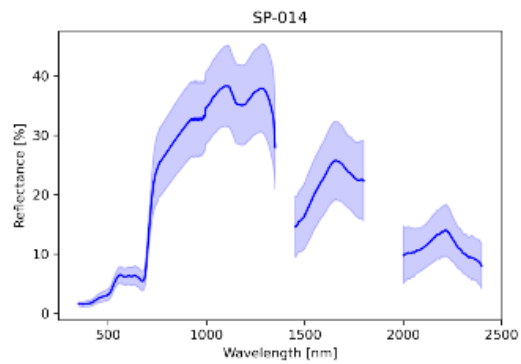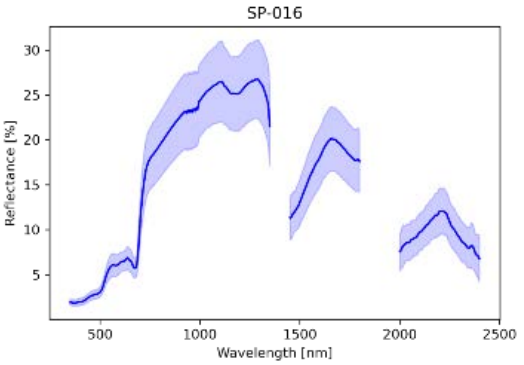|		
SP-013 Yedoma upland, wet sedge and moss-dominated tundra	n = 106 	
SP-014 disturbed slope, grasses and shrubs	n = 120 	
SP-015 tussock on slope, southwest-facing	n = 106 	
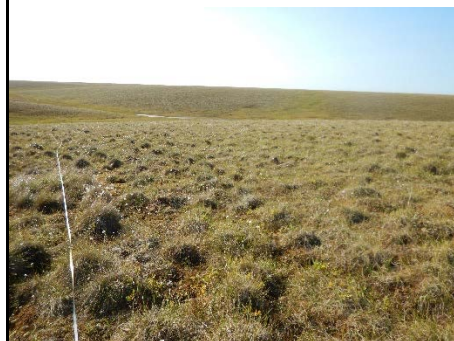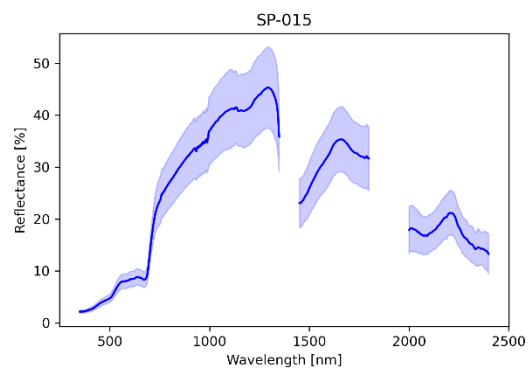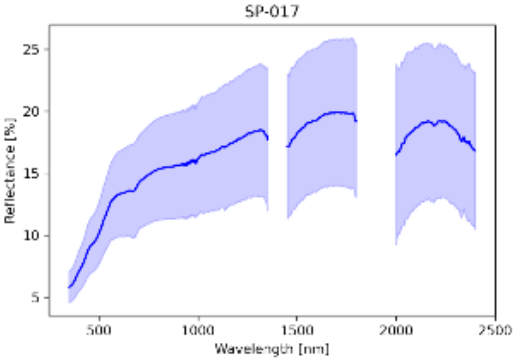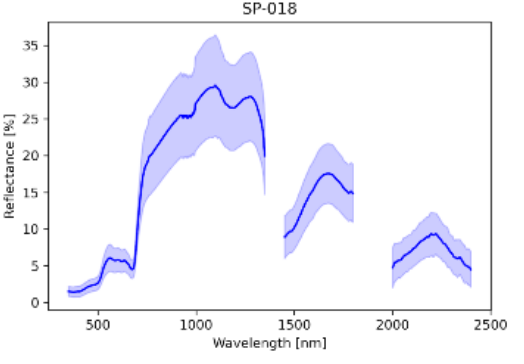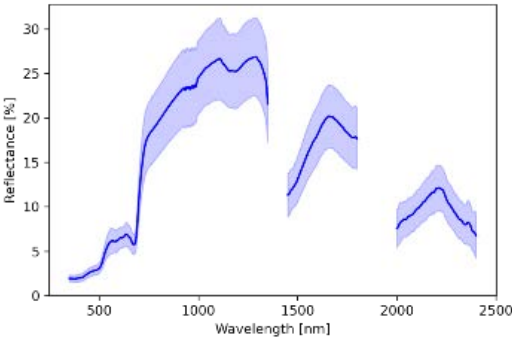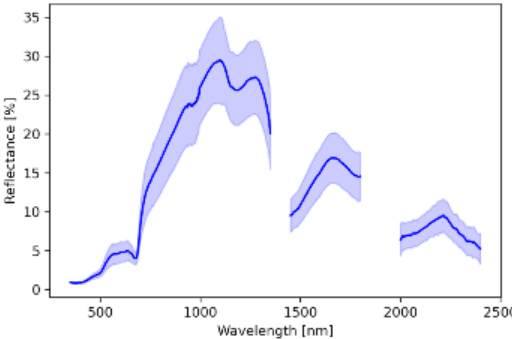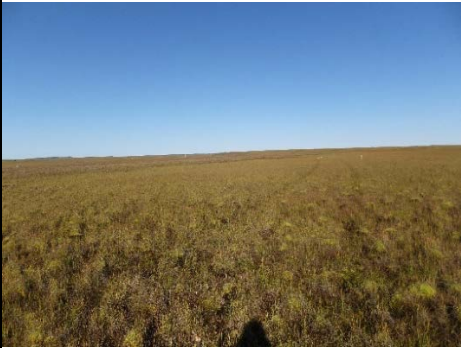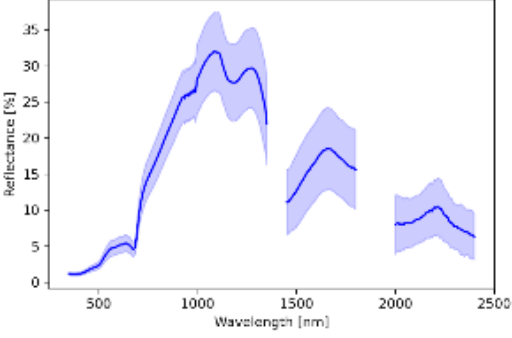
SP-016 floodplain, Salix and mosses	n = 116 	
SP-017 floodplain, sand	n = 50 	
SP-018 floodplain, moist, Salix, Alder	n = 106 	

SP-019 floodplain, dry ridge with shrub communities	n = 106 	
SP-020 Drained Lake Basin floor, mosses, wet	n = 106 	
SP-021 Drained Lake Basin floor, polygonal network	n = 113 	

SP-023 in between slopes, wet depression	n = 118 	
SP-025 terrace, wet	n = 106 	
SP-026 Yedoma upland, wet sedge and moss-dominated tundra	n = 108 	
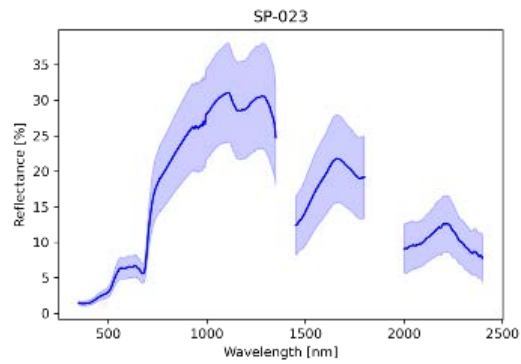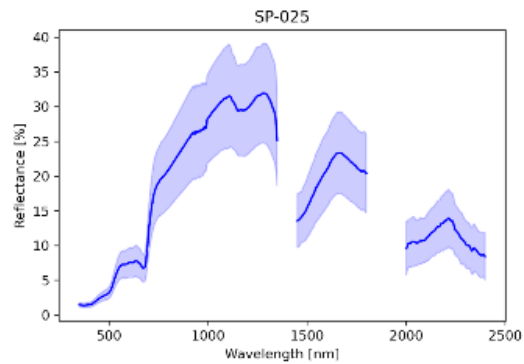
SP-028	n = 109	
floodplain, sand		
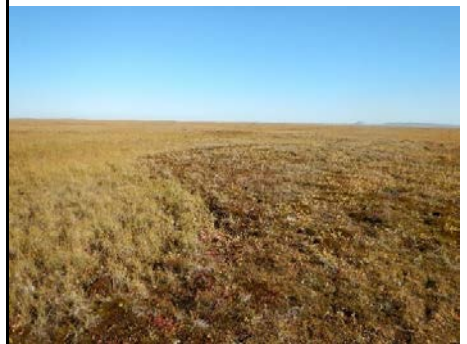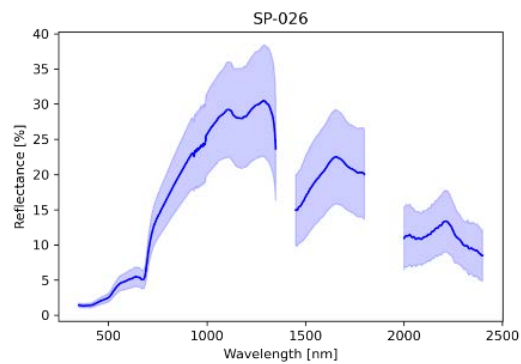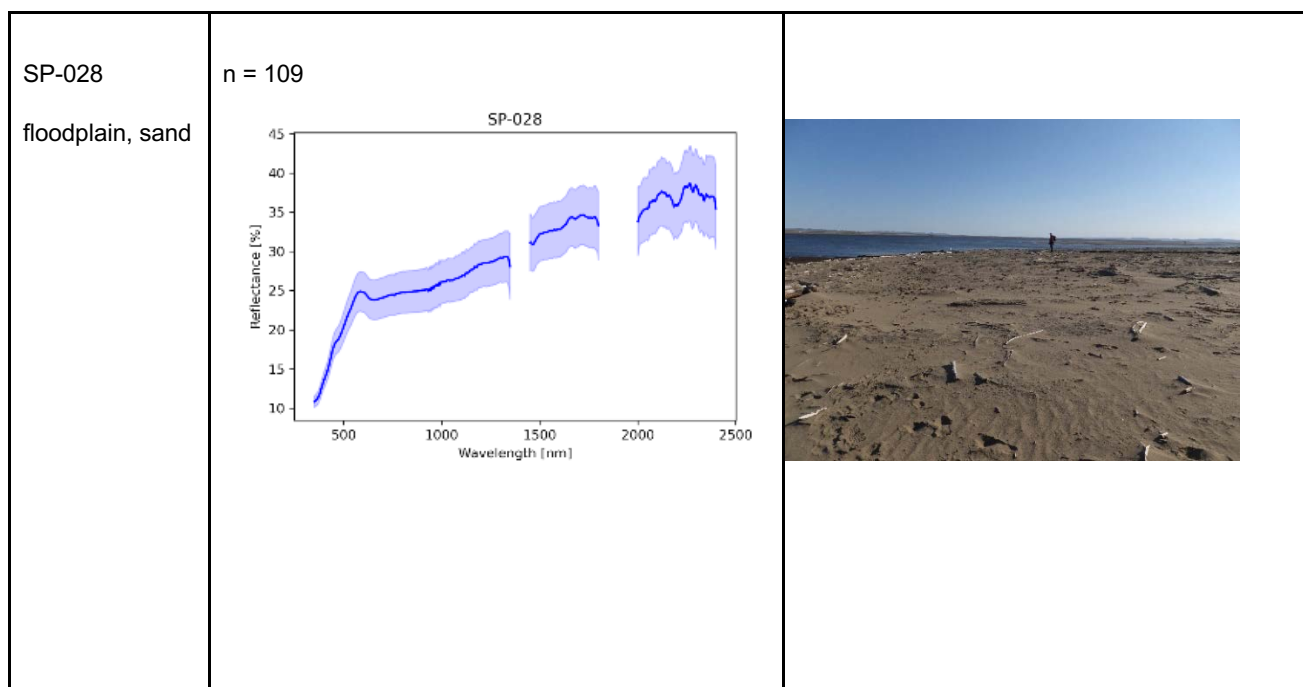
Table S5: Accuracy and precision results of the cross validation.

Class	Name	Accuracy	Precision	Correlation	Error rate	Samples
0	Moist Equisetum and Shrubs on Floodplain	0.999	0.987	0.990	0.001	4313
1	Dry Low Shrub Community	0.998	0.952	0.975	0.002	4314
2	Moist to Wet Sedge Complex	0.997	0.976	0.983	0.004	4315
3	Wet Sedge Complex	0.951	0.959	0.959	0.009	4316
4	PC_50%: Wet Polygon Complex	0.988	0.950	0.941	0.012	4317
5	PC_20%: Moist Polygon Complex	0.986	0.938	0.934	0.014	4318
6	Dry Grass to Wet Sedge Complex	0.981	0.949	0.949	0.010	4319
7	'Sparsely Vegetated Areas'	1.000	0.997	0.997	0.001	4320
8	Dry Tundra Communities	0.979	0.966	0.966	0.007	4321

| 9 | PC_10%: Dry Polygon Complex | 0.996 | 0.984 | 0.981 | 0.004 | 4322 |

Table S6: *Cross match of the vegetation/habitat classes from the three different Lena Delta classification products discussed in the main text (Schneider et al. 2009, Bartsch et al. 2019, Lisovski et al. 2022).*

| Authors	Schneider et al 2009	Lisovski et al 2022	Bartsch et al. 2019
Product name		Lena Delta habitat map	ESA GlobPermafrost Land Cover (selected regions)
sensor	Landsat 7 (30 m)	Sentinel-2 (10 m res.)	Sentinel-1, Sentinel-2 (20 m)
time	Summer 2000/2001	Peak summer 2016	2015 -2018
low disturbance regime land cover classes	Wet sedge and moss dominated tundra WT	Polygonal tundra complex up to 50 % water PC 50	Disturbed, including forest fire scars, seasonally inundated areas and landslide scars
	Moist grass and moss-dominated tundra MT	Polygonal tundra complex up to 20 % water PC 20	Sparse vegetation (without shrubs), mostly sandy soil; flood plains, recent landslides, also within fire scars
		Polygonal tundra complex up to 10 % water PC 10	Graminoid, prostrate dwarf shrub, patterned ground, partially bare Dry cryptogamic-crust
	Dry moss- sedge and dwarf shrub dominated tundra DMSD	Dwarf shrub - herb communities DSHH	Dry cryptogamic-crust
	Dry tussock tundra DT	Dry (tussock) tundra DT	Dry to moist prostrate to erect dwarf shrub tundra 'grassland' Moist to wet graminoid prostrate to erect dwarf shrub tundra 'grassland' Graminoid, prostrate dwarf shrub, patterned ground, partially bare 'grassland'
high disturbance regime land cover classes	Moist to dry dwarf shrub dominated tundra MDD	Dry low shrub communities DLSH	Wet to waterlogged graminoid prostrate to low shrub tundra
		Moist Equisetum and shrub communities I MESH	
		Moist to wet sedge complex MWS	Floodplain, mostly fluvial
		Wet sedge complex WS	Wet to waterlogged graminoid prostrate to low shrub tundra
	Dry grass-dominated trundra DG	Dry grass- to wet sedge complexes with low shrub communities D	Moist to wet graminoid prostrate to erect dwarf shrub tundra
very high disturbance	Mainly non-vegetated areas (NV)	Sparsely vegetated Barren, sand	Disturbed, including forest fire scars, seasonally inundated areas and landslide scars
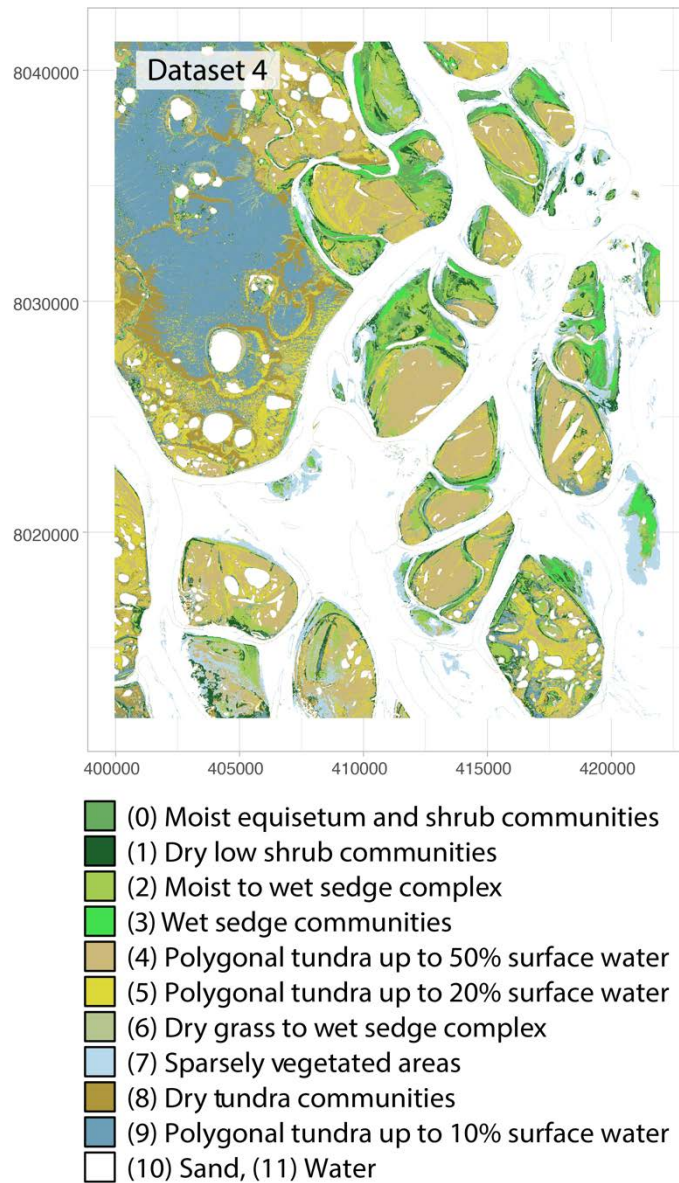
Figure S1: Supervised habitat classification of the central Lena Delta based on a cloud-free S-2 August 2018 acquisition (Dataset 4). Numbers in legend correspond to the labels in published Dataset 4 (Landgraf et al. 2022). Universe Transverse Mercator Z52 on WGS 84 projection.

Figure S2*: Spectral Evolution SR-2500 field-spectrometer measurement set-up in the Lena Delta, August 2018 (photos: M. Fuchs).*
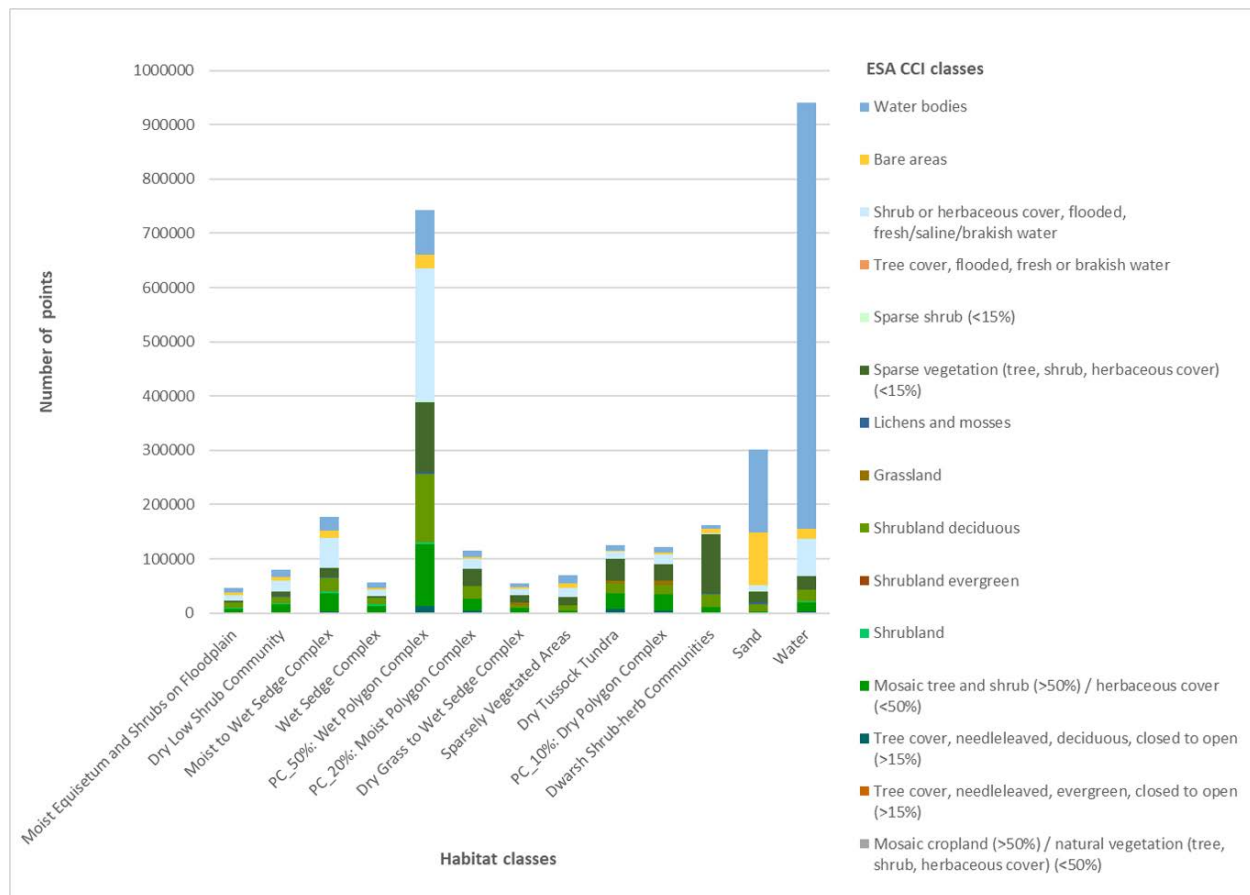
Figure S3*: Comparison between the habitat classification (Dataset 5) and ESA CCI Landcover classes based on 3 million sampled points, regularly distributed in the Lena Delta.*
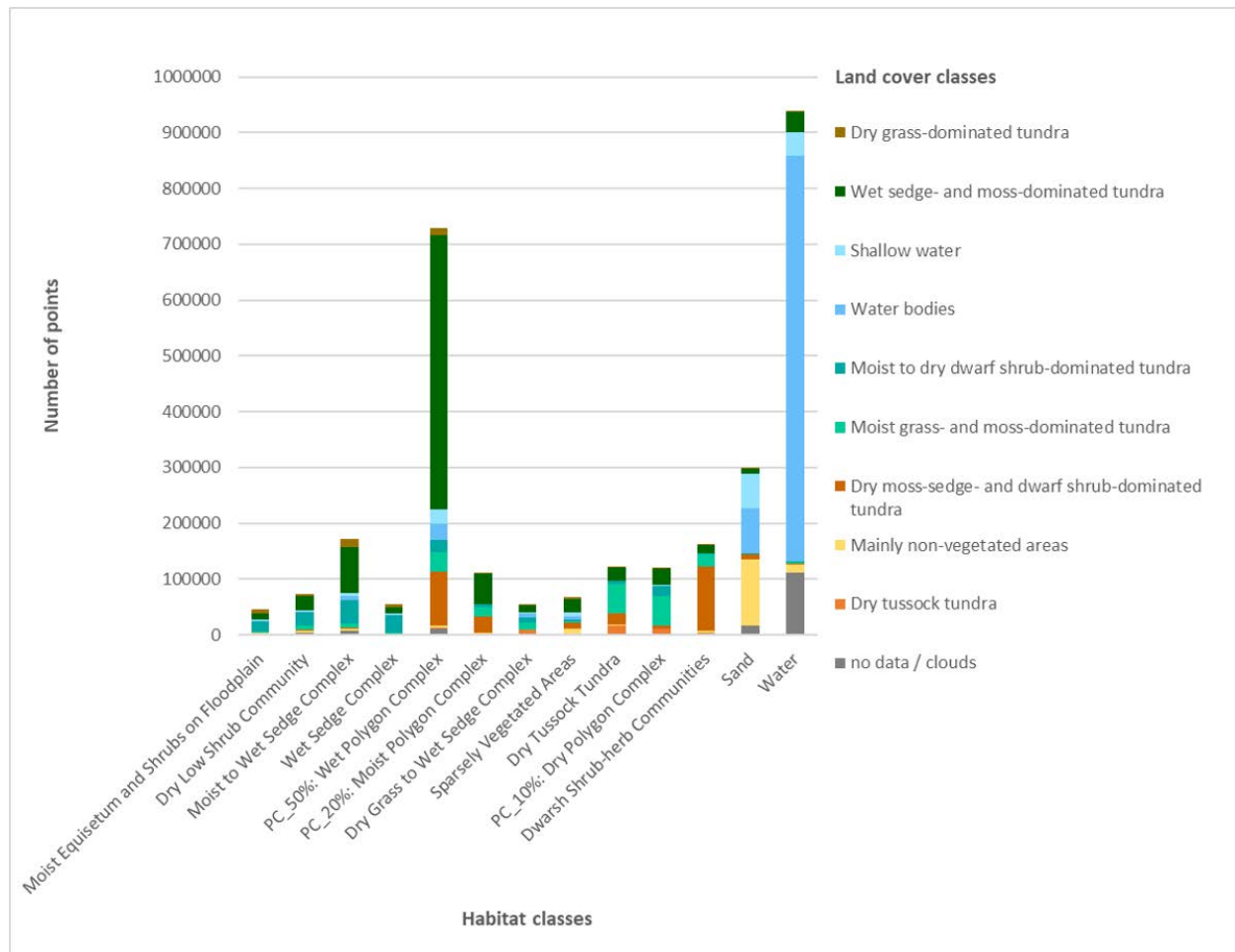
Figure S4: *Comparison between the habitat classification (Dataset 5) and the land cover classification from Schneider et al. (2009) based on 3 million sampled points, regularly distributed in the Lena Delta.*
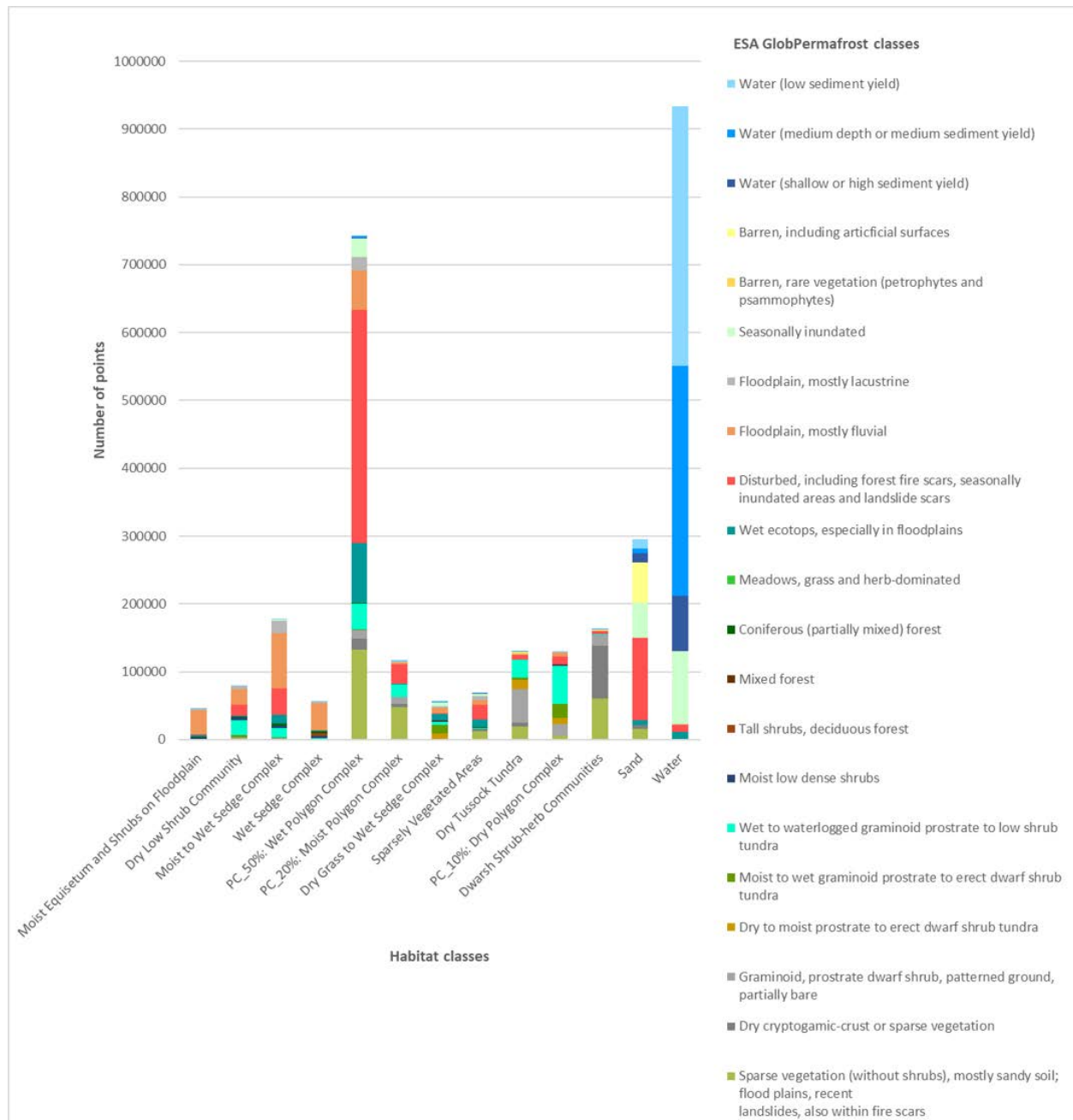
Figure S5: *Comparison between the habitat classification (Dataset 5) and the land cover classification from ESA GlobPermafrost (Bartsch et al. 2019) based on 3 million sampled points, regularly distributed in the Lena Delta.*

References:

Bartsch, A., B. Widhalm, G. Pointner, K. Ermokhina, M. Leibman, and B. Heim. 2019. Landcover derived from Sentinel-1 and Sentinel-2 satellite data (2015-2018) for subarctic and arctic environments. PANGEA.

Landgraf, N., I. Shevtsova, B. Pflug, and B. Heim. 2022. Sentinel-2 derived central Lena Delta land cover classification. PANGAEA.

Lisovski, S., A. Runge, R. R. Okoth, I. Shevtsova, and B. Heim. 2022. Lena Delta Land Cover Classification (2018, Sentinel-2). PANGAEA.

Runge, A., M. Fuchs, I. Shevtsova, N. Landgraf, B. Heim, U. Herzschuh, and G. Grosse. 2022. Hyperspectral field spectrometry of Arctic vegetation units in the central Lena Delta. PANGAEA.

Schneider, J., G. Grosse, and D. Wagner. 2009. Land cover classification of tundra environments in the Arctic Lena Delta based on Landsat 7 ETM+ data and its application for upscaling of methane emissions. Remote Sensing of Environment **113**:380-391.

Shevtsova, I., B. Heim, A. Runge, M. Fuchs, J. Melchert, and U. Herzschuh. 2021a. Total above-ground biomass of 25 vegetation sites of central Lena Delta from 2018. PANGAEA.

Shevtsova, I., N. Laschinskiy, B. Heim, and U. Herzschuh. 2021b. Foliage projective cover of 26 vegetation sites of central Lena Delta from 2018. PANGAEA.