The influences of land surface properties on soil thermal regimes in the Low Arctic of northwestern Siberia

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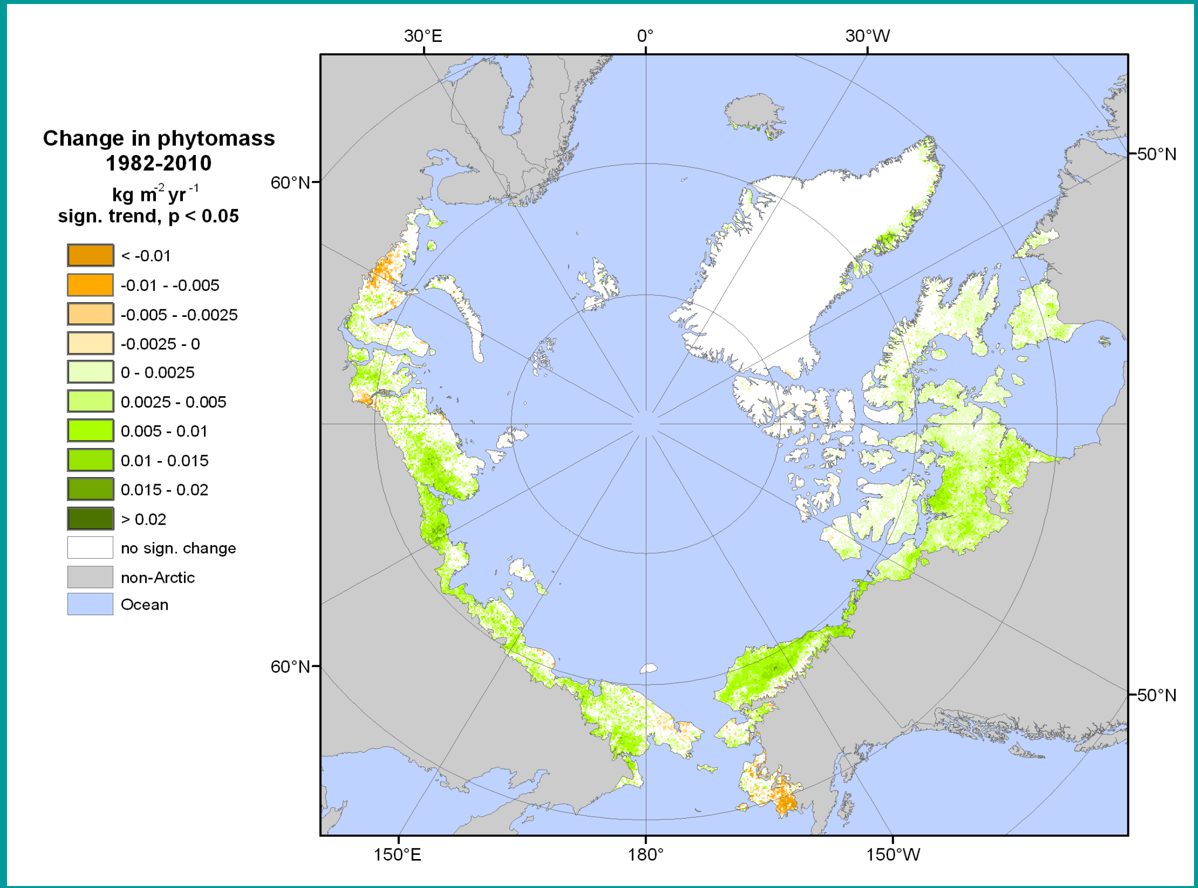
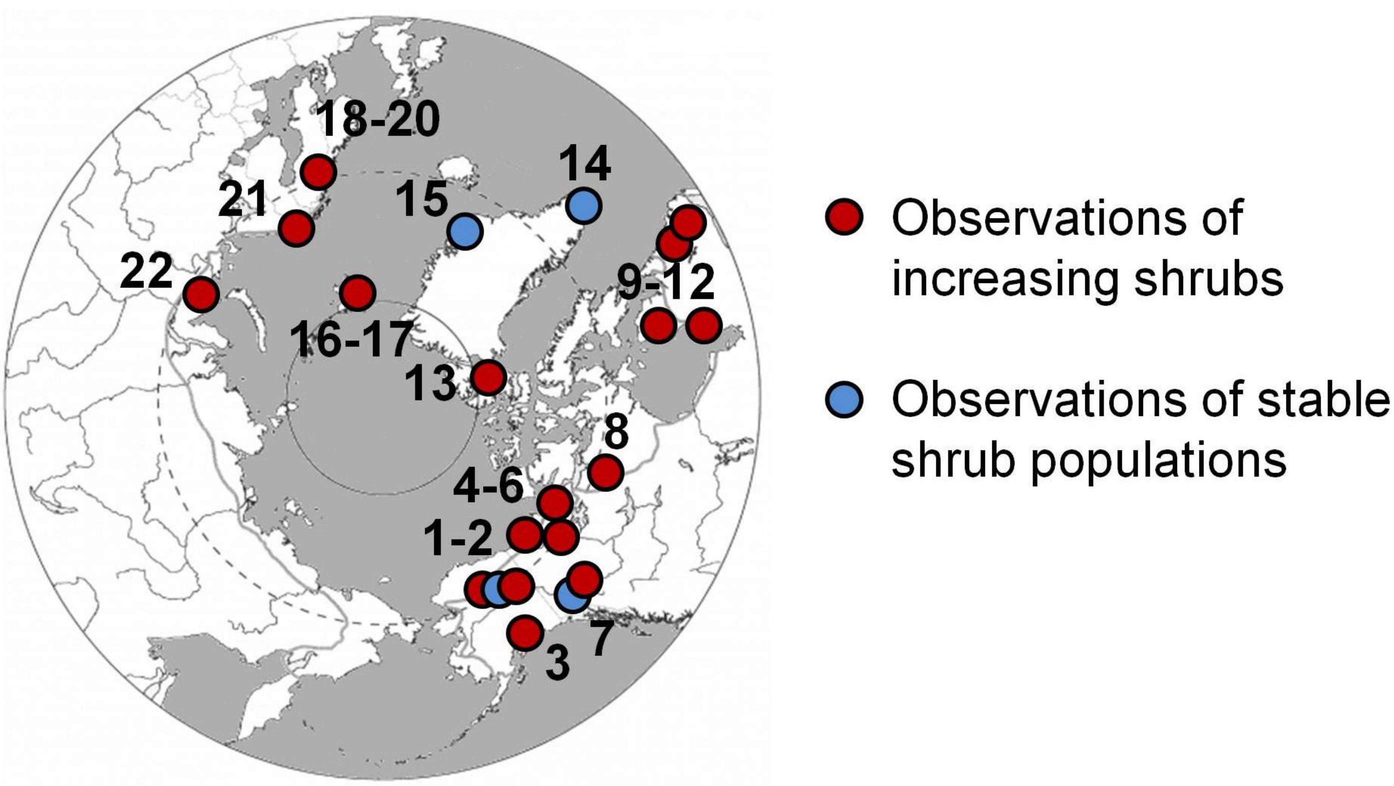
Arctic "Greening"



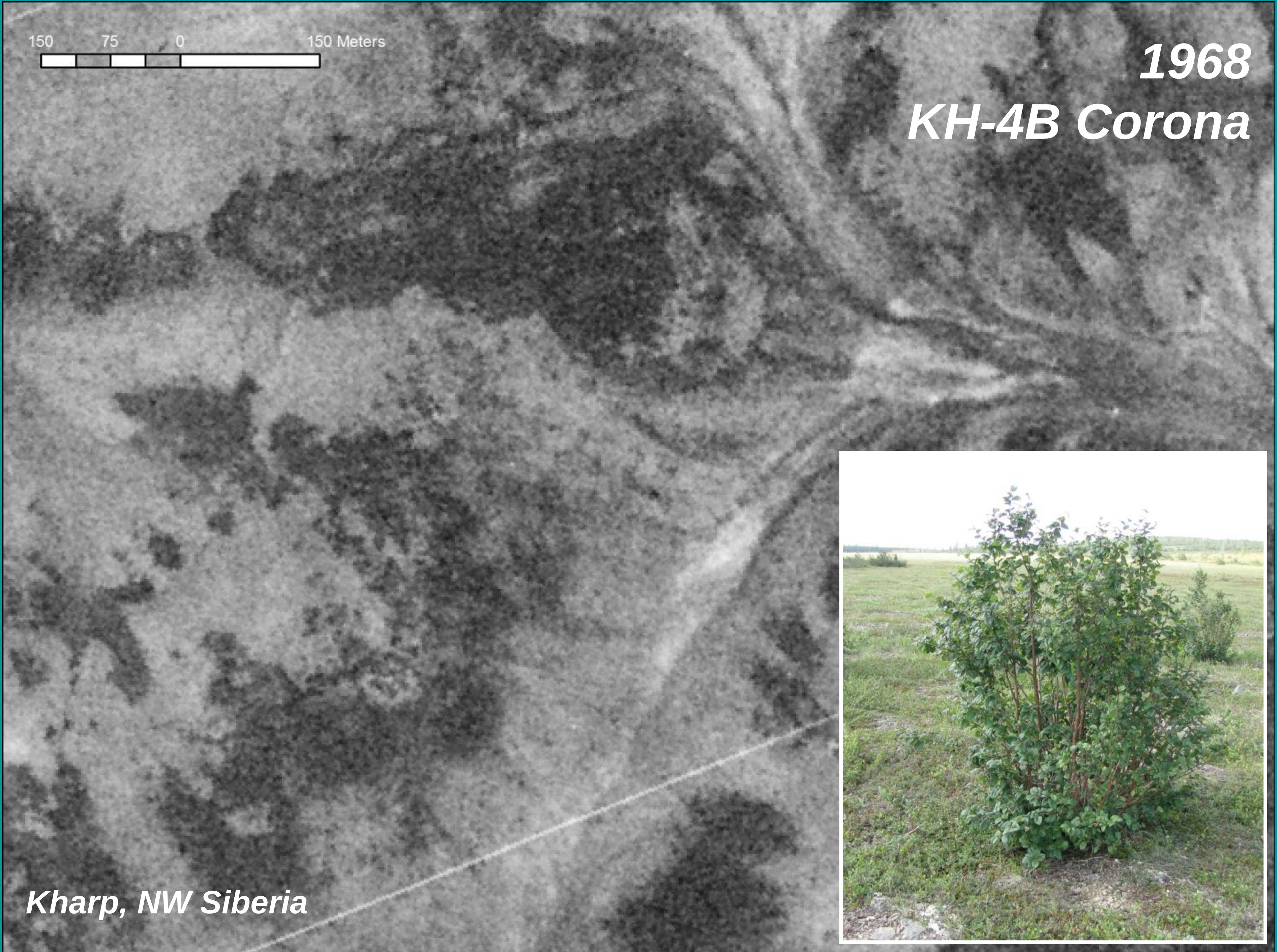
Bioclimate Subzone	Area (km²)	1982	SD	2010	SD	Change in mean biomass (g m⁻²)	Rate of change (g m⁻² y⁻¹)	1982	2010	Change	% change	Rate of change (% y⁻¹)
Greenland Ice Cap	1,795,920	83.8	14.0	84.4	18.0	0.6	0.02	0.15	0.15	0.0011	0.70	0.025
A	208,964	98.3	39.2	100.3	53.4	2.0	0.07	0.02	0.02	0.0004	2.05	0.073
B	530,780	142.7	100.9	151.8	118.4	9.1	0.33	0.08	0.08	0.0048	6.39	0.228
C	1,380,760	199.6	116.6	241.2	148.7	41.6	1.49	0.28	0.33	0.0575	20.85	0.745
D	1,708,430	319.8	145.6	401.5	195.2	81.7	2.92	0.55	0.69	0.1396	25.56	0.913
E	2,027,020	467.5	142.5	563.6	153.1	96.1	3.43	0.95	1.14	0.1948	20.55	0.734

Aboveground biomass increases since 1982, particularly strong in the mid- to Low-Arctic (20-26%) Epstein et al. (2012).

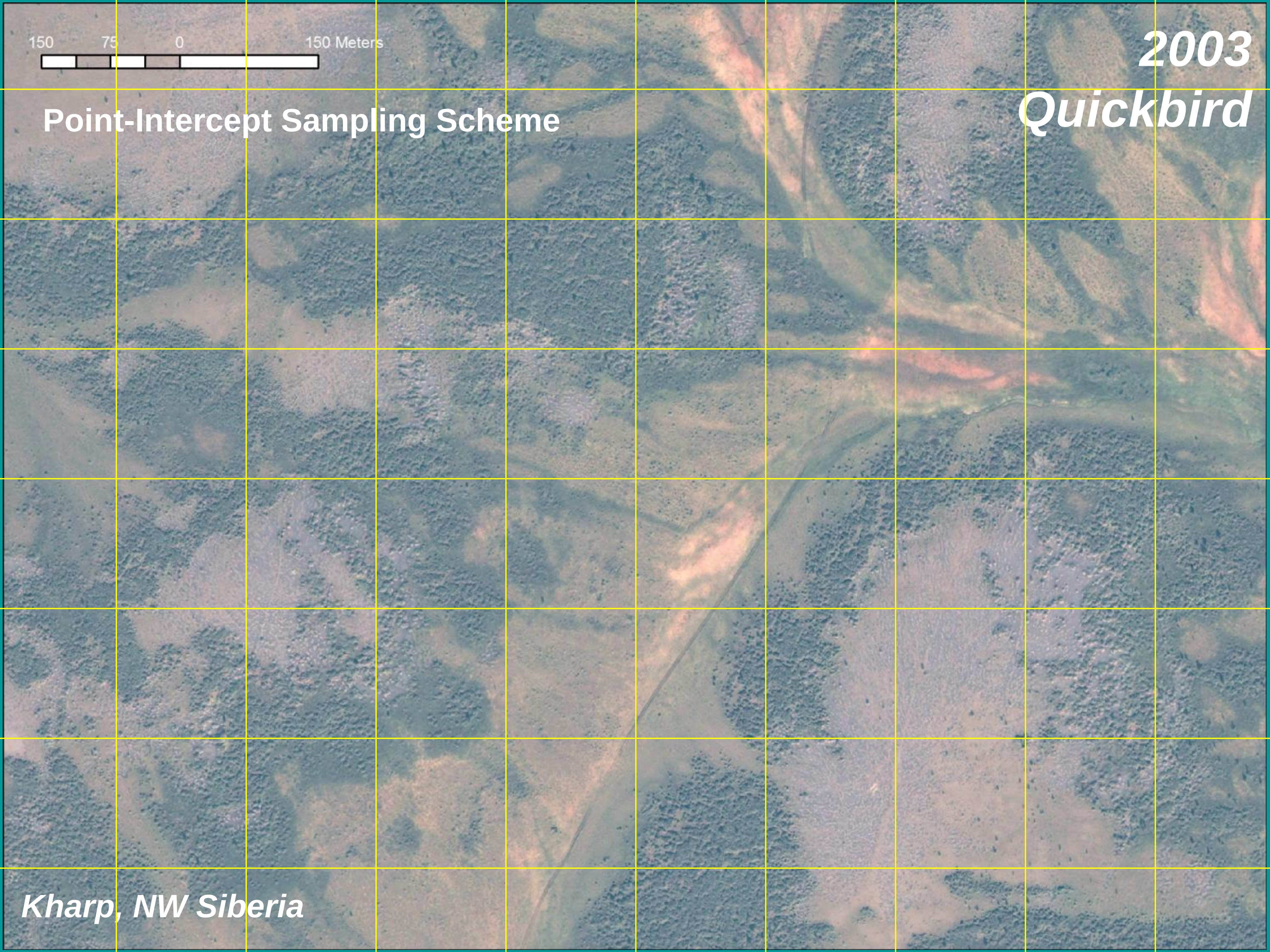
Studies of shrub expansion

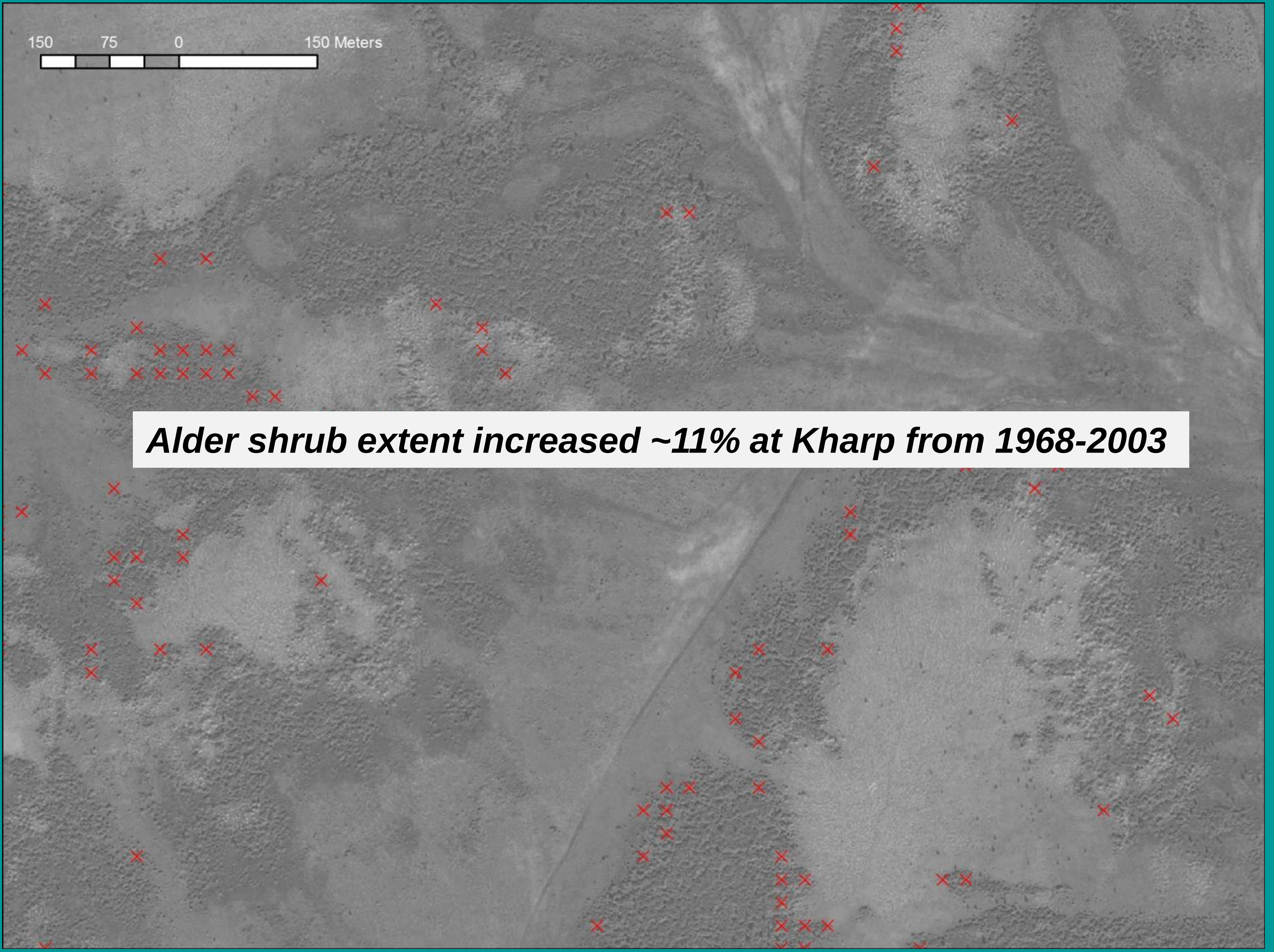


Myers-Smith *et al.* 2011, ERL

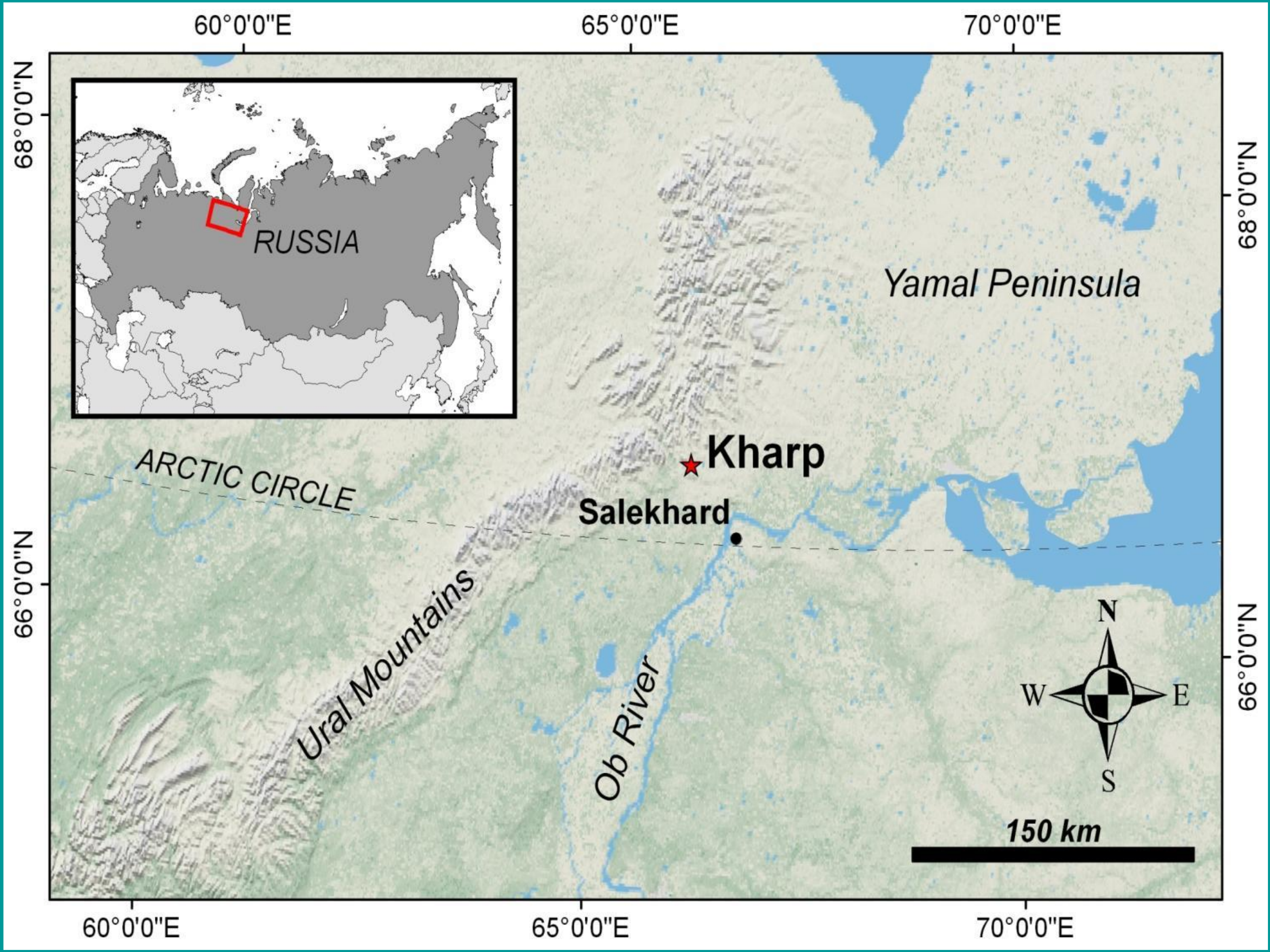

150
75
0
150 Meters
1968
KH-4B Corona
Kharp, NW Siberia


150
75
0
150 Meters
2003
Quickbird
Kharp, NW Siberia


150
75
0
150 Meters
Point-Intercept Sampling Scheme
2003
Quickbird
Kharp, NW Siberia



Alder shrub extent increased ~11% at Kharp from 1968-2003



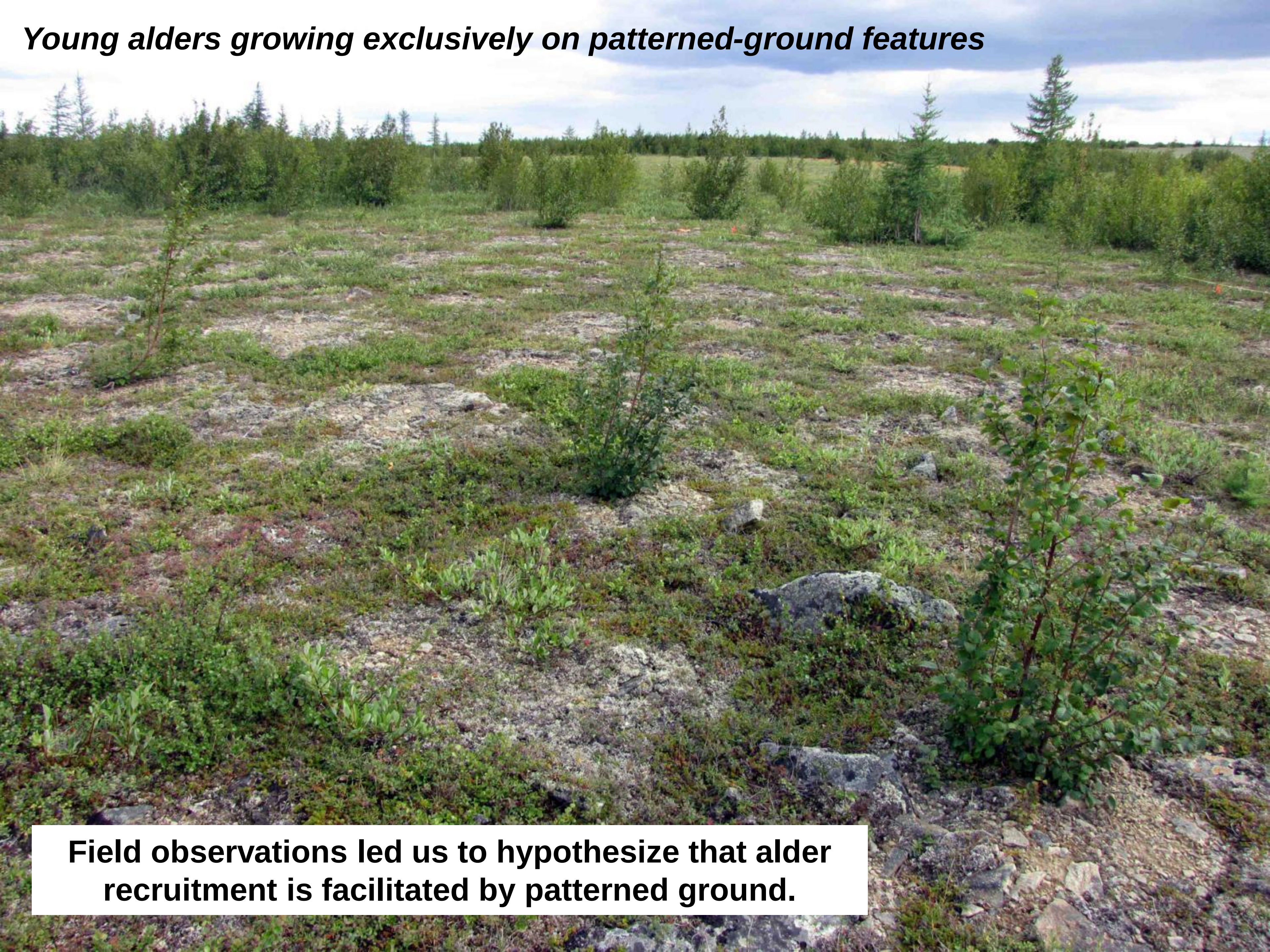
60°0'0"E
65°0'0"E
70°0'0"E
68°0'0"N
66°0'0"N
RUSSIA
Yamal Peninsula
Kharp
ARCTIC CIRCLE
Salekhard
Ural Mountains
Ob River
N
W
E
S
150 km

We can get there… all we need is one of these things.

(photo H. Epstein)

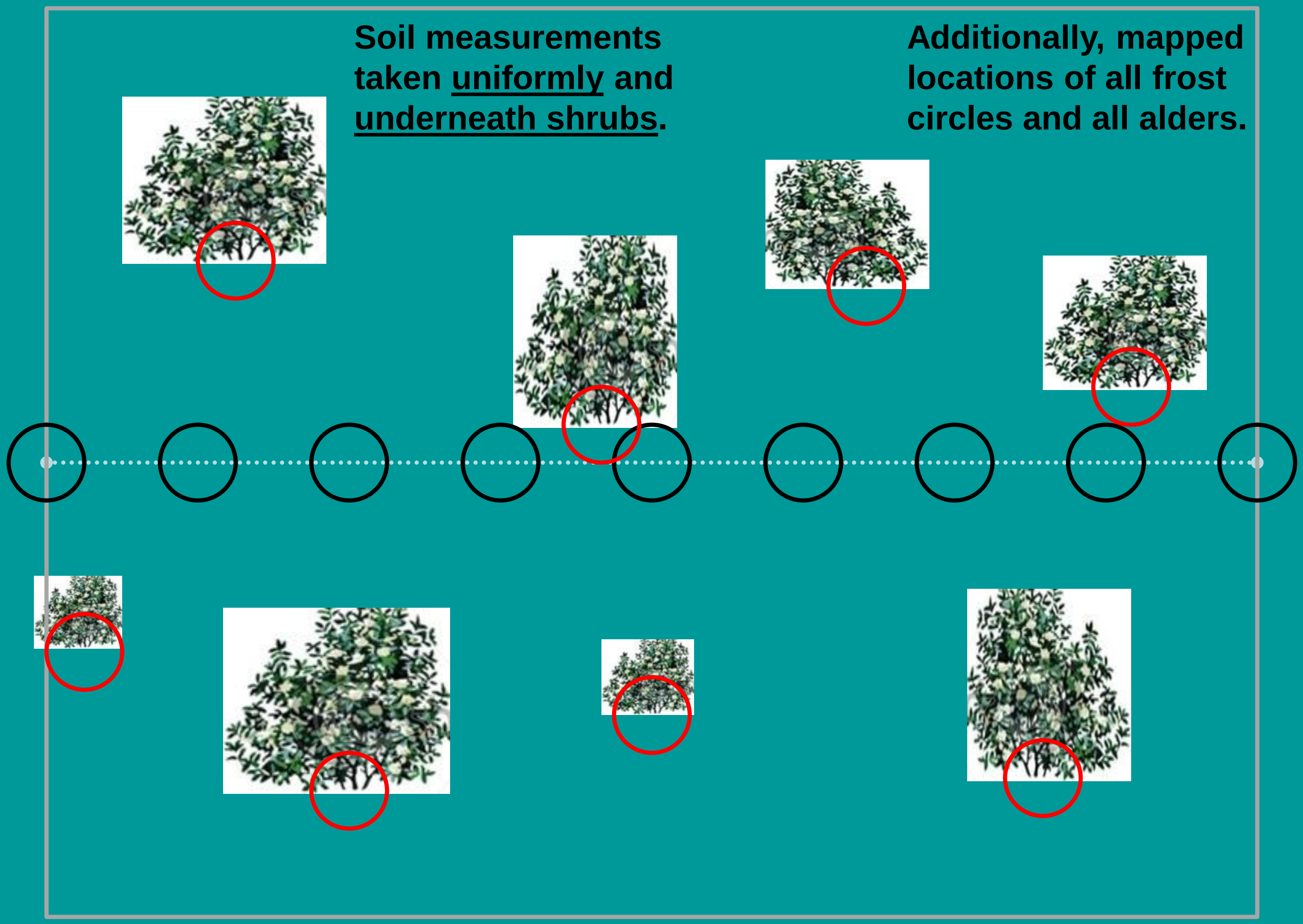
Patterned ground features (frost circles), Kharp

Young alders growing exclusively on patterned-ground features

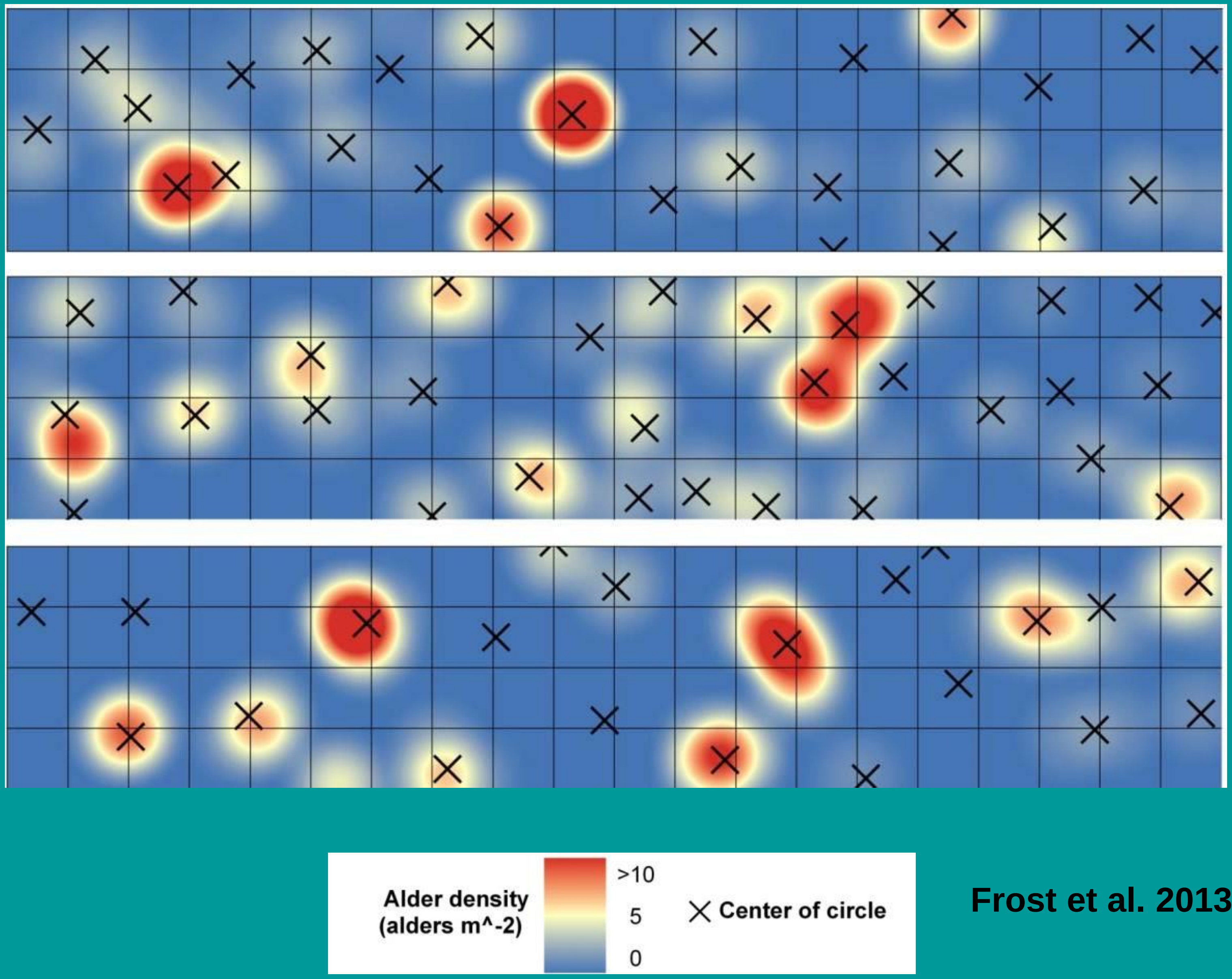


Field observations led us to hypothesize that alder recruitment is facilitated by patterned ground.

Soil sampling transects

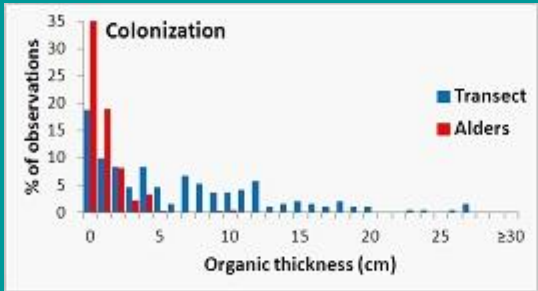


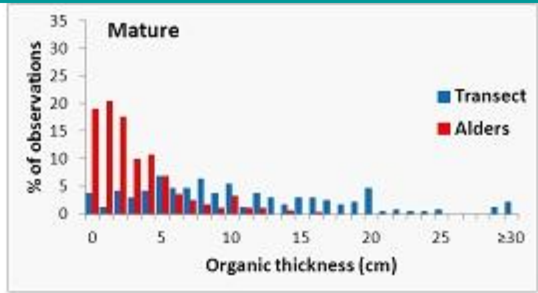
Alders almost exclusively on non-sorted circles

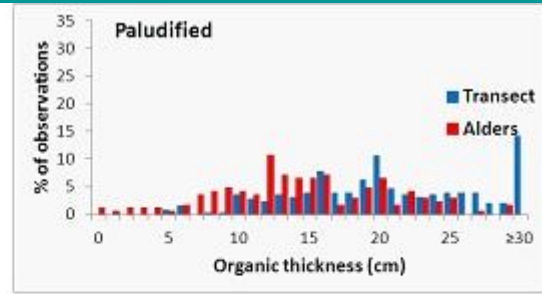


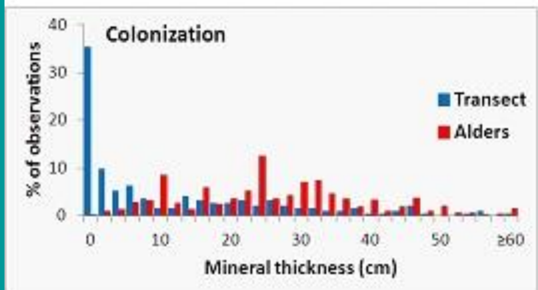
Frost et al. 2013 (ERL)

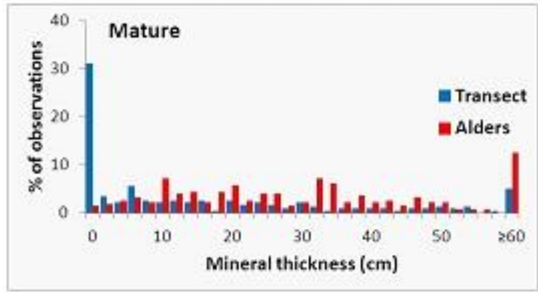
Alder Colonization | **Mature Alder** | **Paludified Alder Stand**

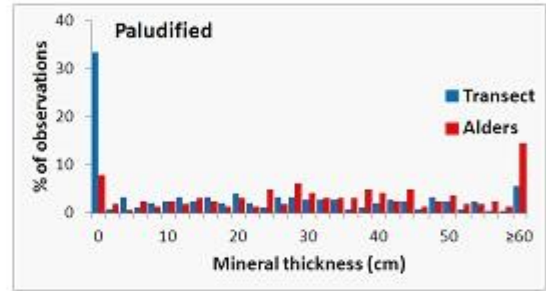










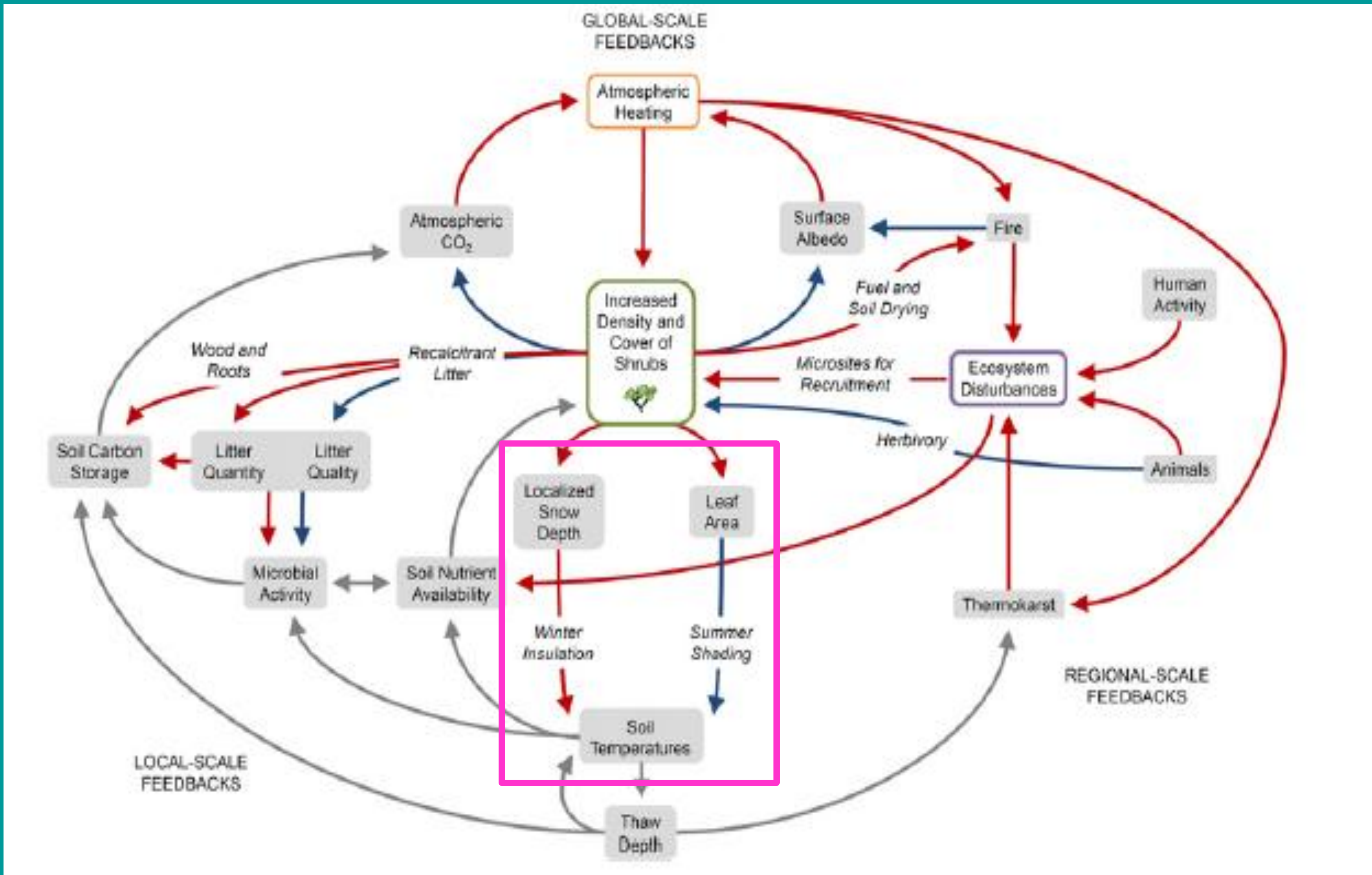


1) **Young alders found on microsites with shallow organic layer and deep mineral soils, typical of frost circles**
2) **Mature alders also found on microsites with shallow organic layer and deep mineral soils, suggesting legacy**
3) **Organic matter layer develops under alder as the system ages**

Implications of tall shrub expansion on arctic ecosystems

- **<u>Biological processes</u>**
  - **increased primary productivity**
  - **alterations to carbon cycling**
- **<u>Surface energy balance</u>**
  - **reduced surface albedo**
  - **feedbacks to local and regional climate**
- **<u>Hydrology</u>**
  - **winter snow trapping**
  - **increased summer evapotranspiration**
- **<u>Soil thermal regime</u>**
  - **changes to active layer dynamics and permafrost stability**
  - **additional effects on carbon cycling**
- **<u>Ecological communities</u>**
  - **reduced biodiversity**
  - **alterations to wildlife habitats**

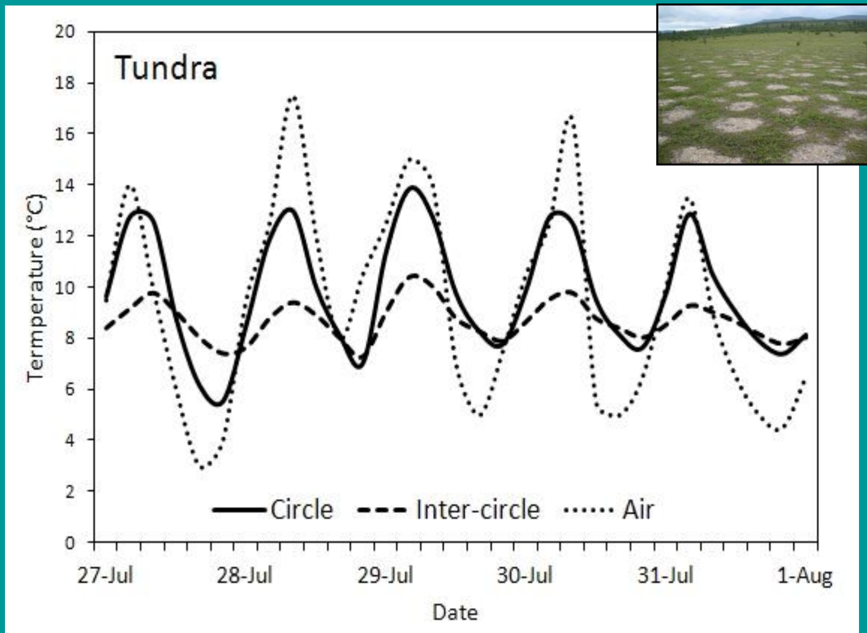
Conceptual model of shrub expansion effects

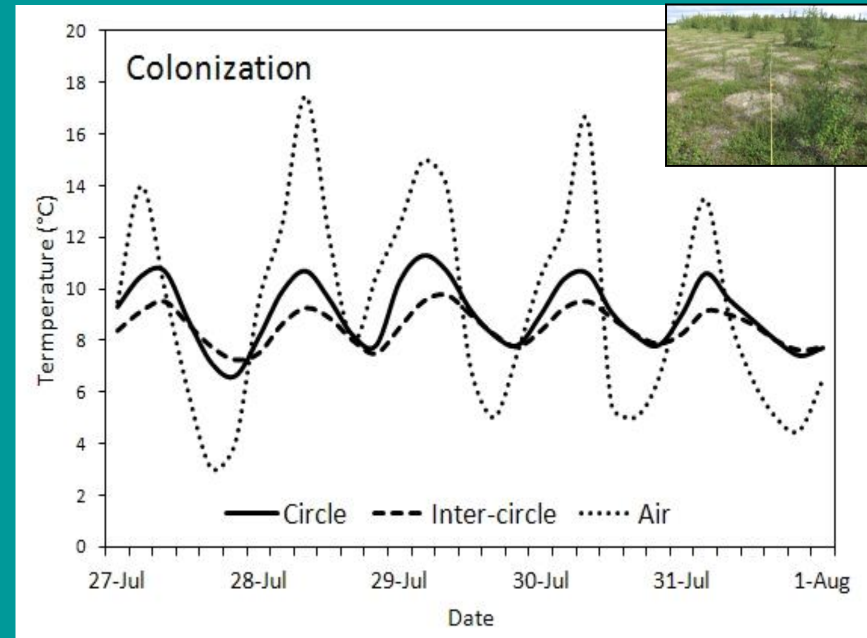


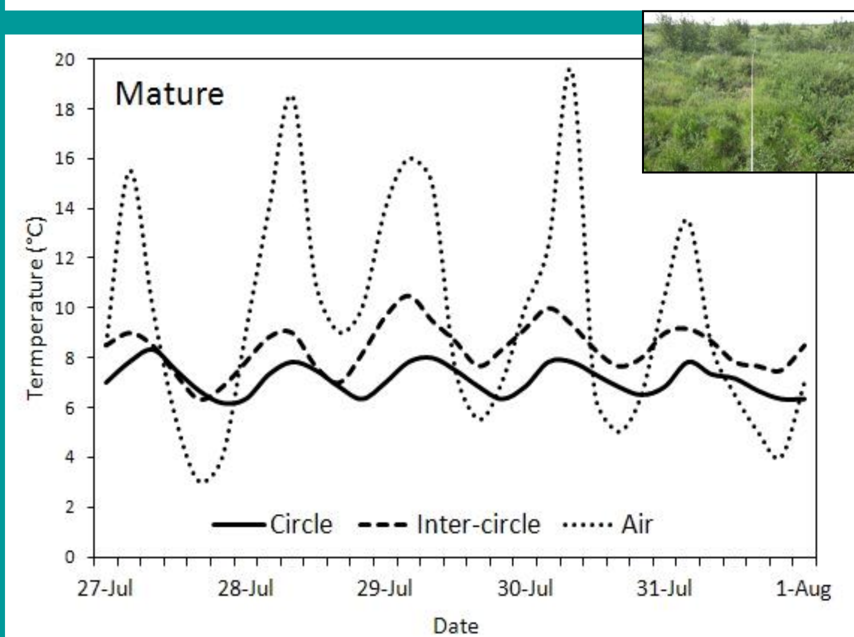
(Myers-Smith et al. 2011)

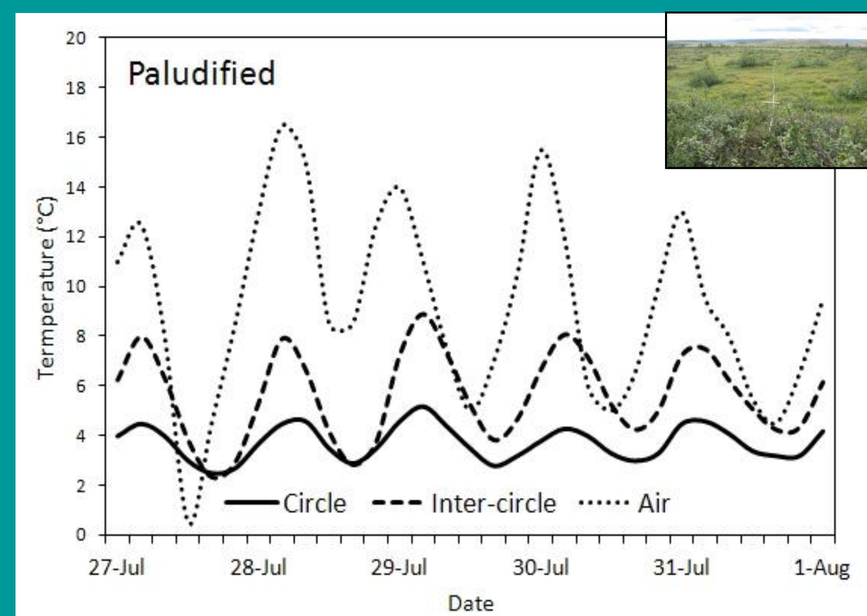
Summer soil temperature changes throughout shrubland succession

- ibutton dataloggers installed for one year (4 stages x 2 locations x 2 depths)

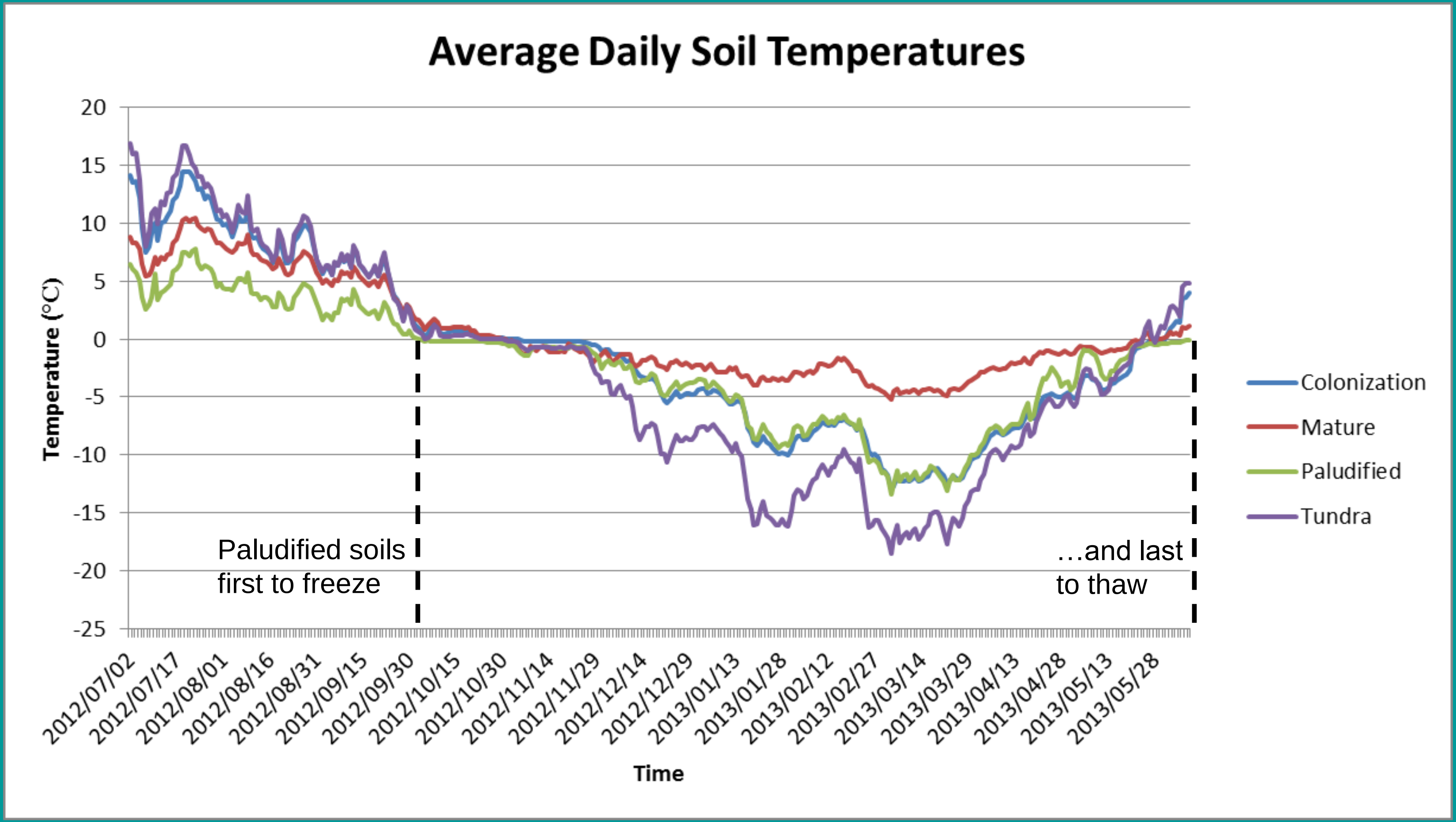








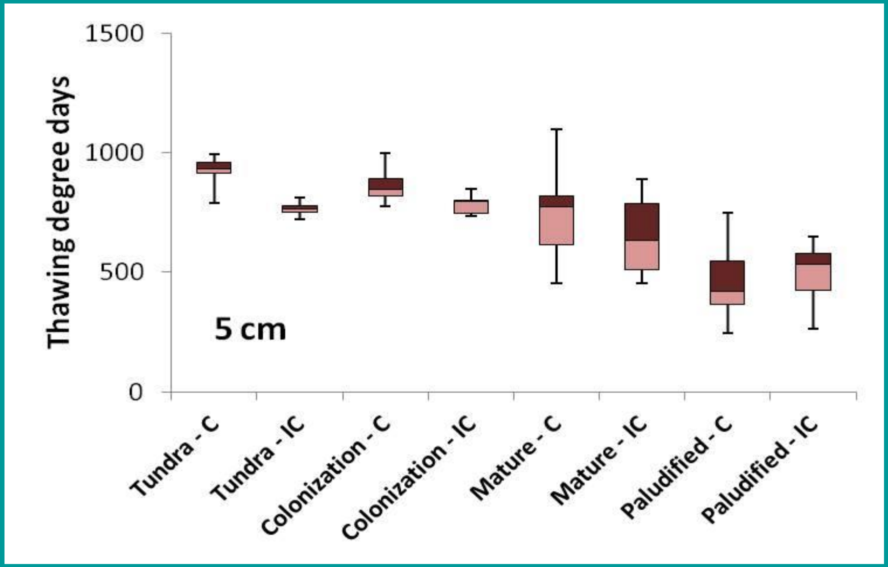
Mean daily soil temperatures (5 cm depth) under frost circles / alders



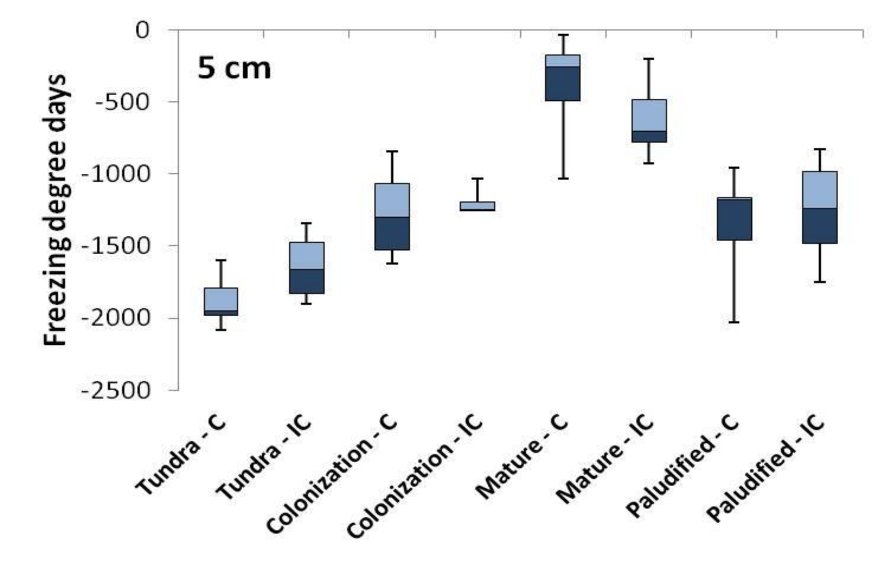
- Bare circles up to ~8 °C warmer than soils under mature alders in summer.
- Bare circles up to ~12 °C colder than soils under mature alders in winter.

Frost et al. (in prep.)

Thawing degree days increase throughout shrubland succession

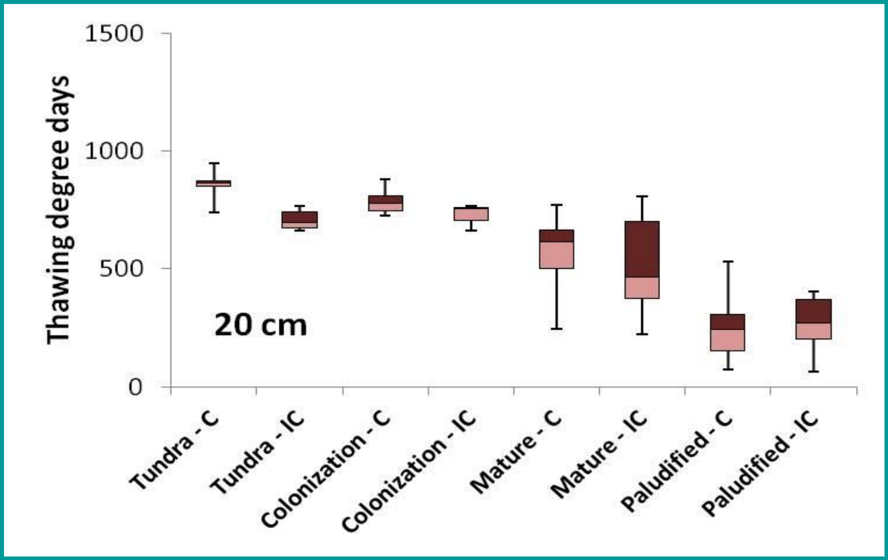


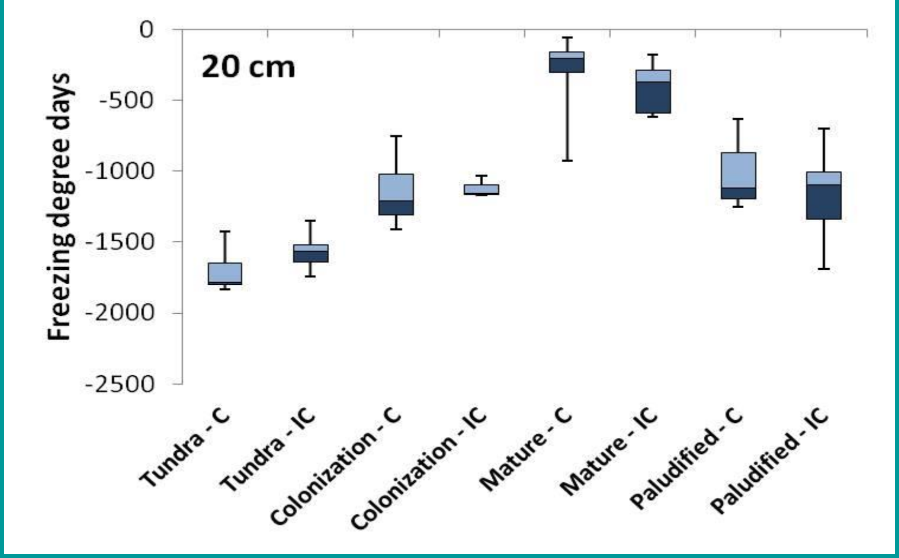
Freezing degree days decrease throughout shrubland succession



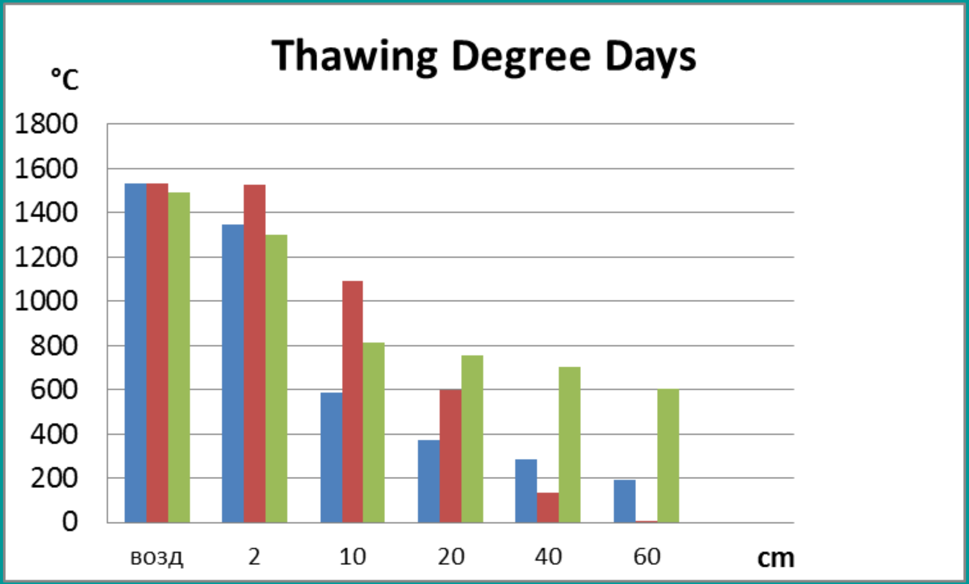
- **Increased organic layer depth**
- **Increased shading (LAI)**

- **Increased organic layer depth**
- **Increased snow trapping**

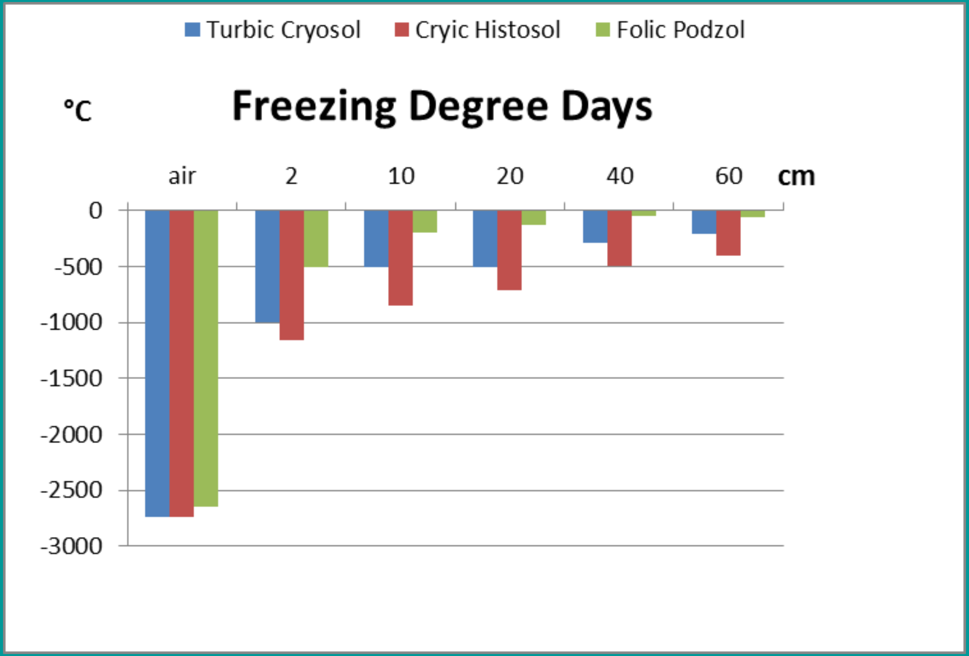




Forest (Podzol) vs. peatland (Histosol, Cryosol) soils at Nadym, Russia



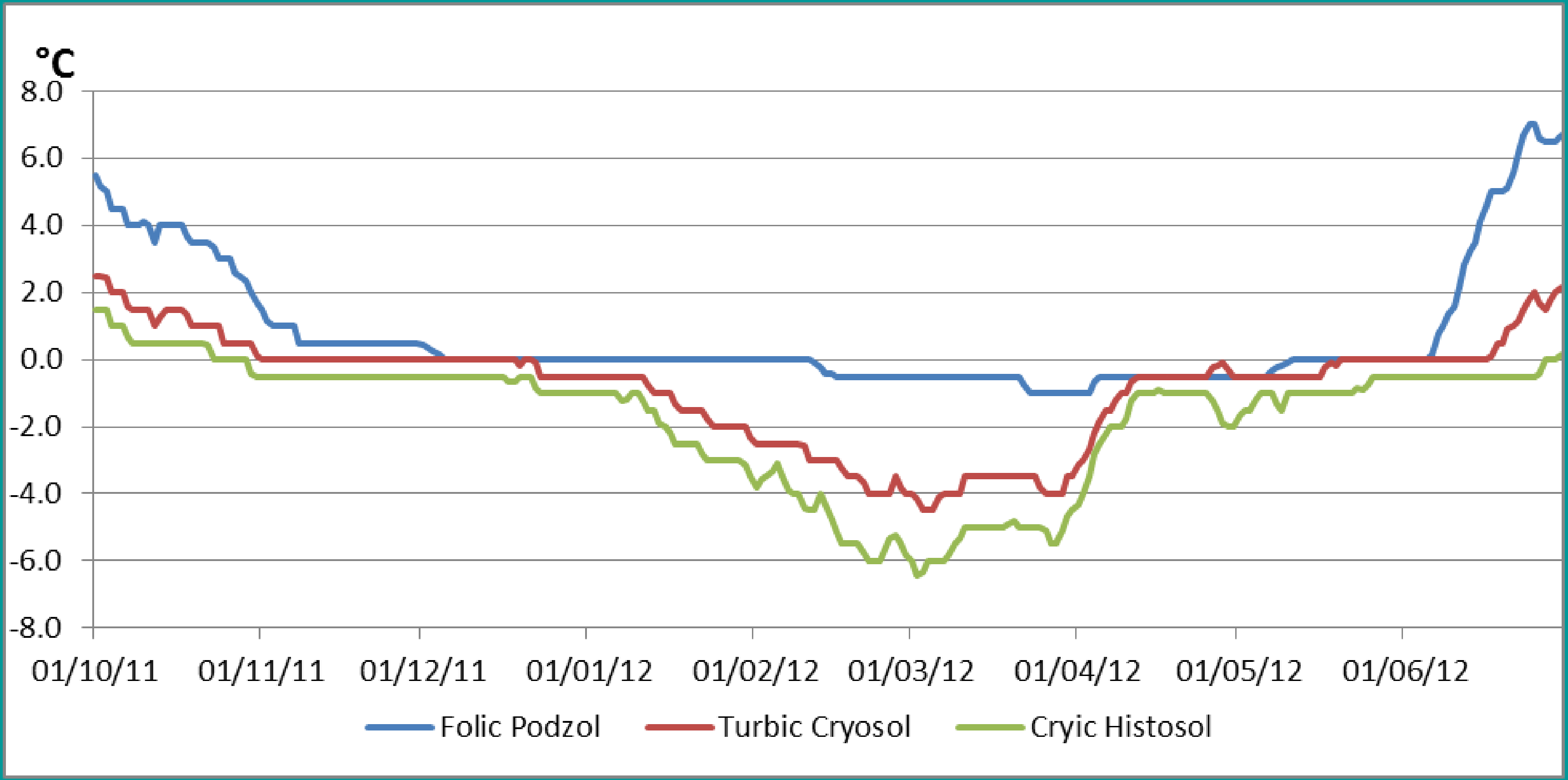
Depth Effect: forest soils cooler than peatland soils in summer to 10 cm depth, warmer at depths 20 cm and greater



Forest soils substantively warmer than peatland soils in winter across all depths

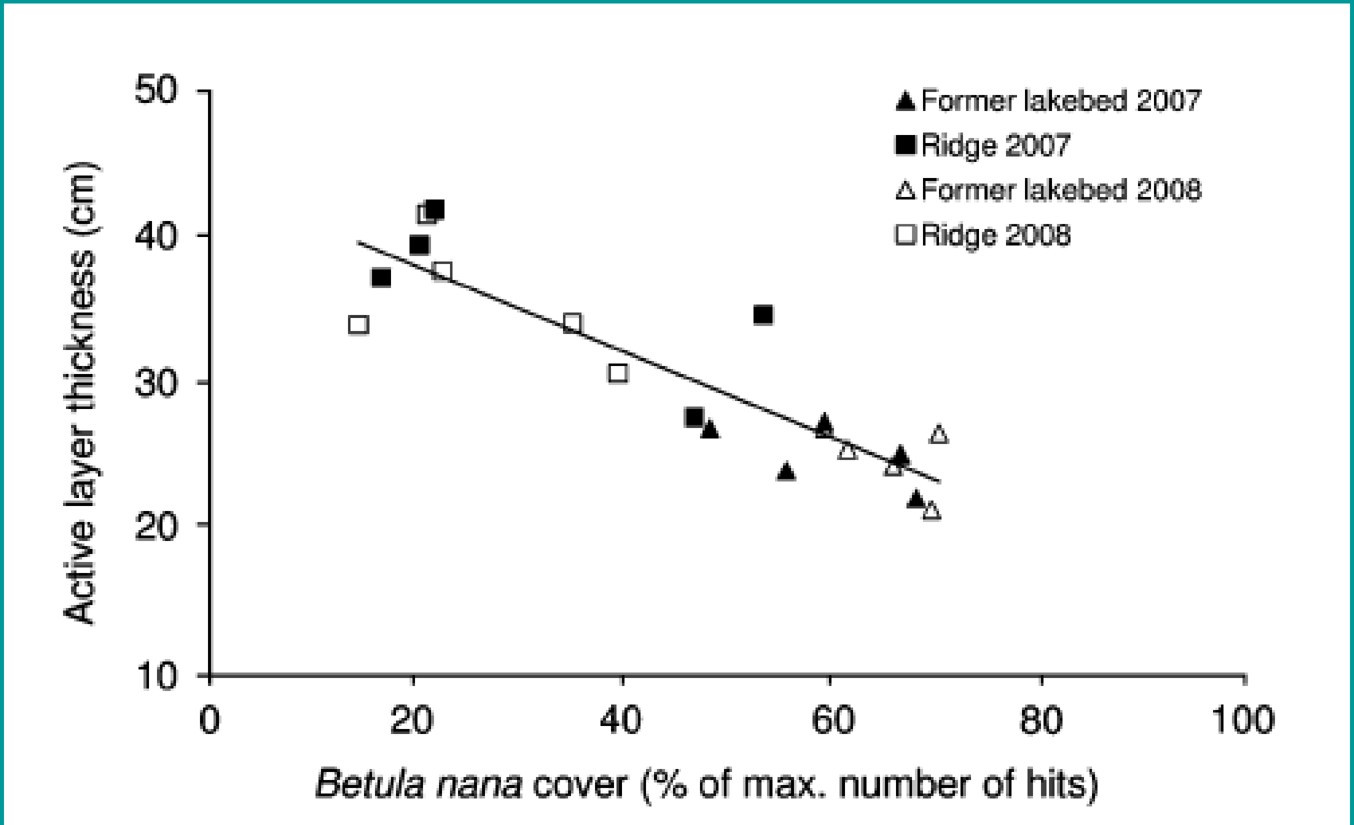
Matyshak et al. (in prep.)

Seasonality of soil temperature at Nadym, Russia at 40 cm depth

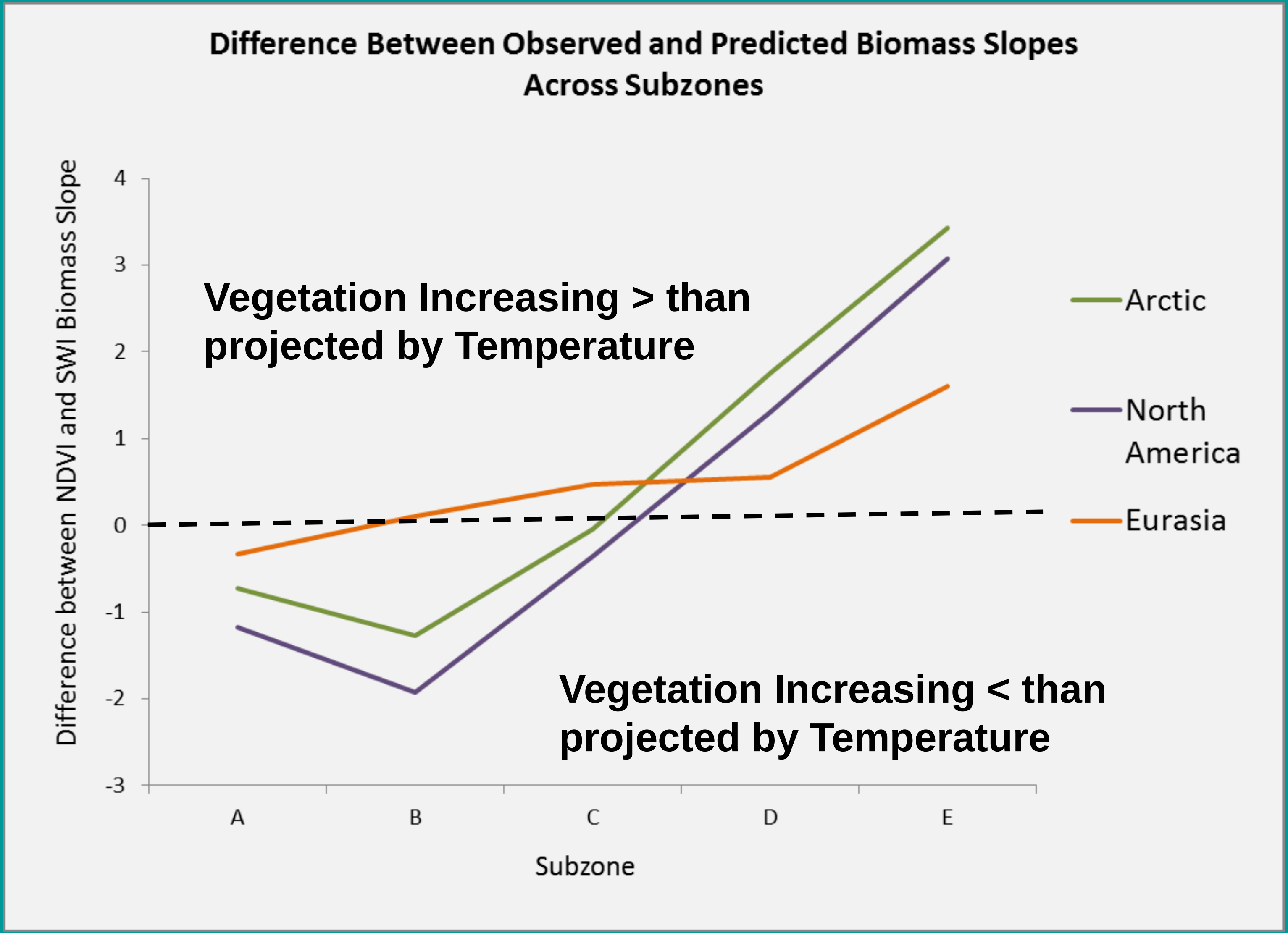


- **Forest soils remain warmer than peatland soils the entire year (at 40 cm), freeze latest, and thaw earliest**

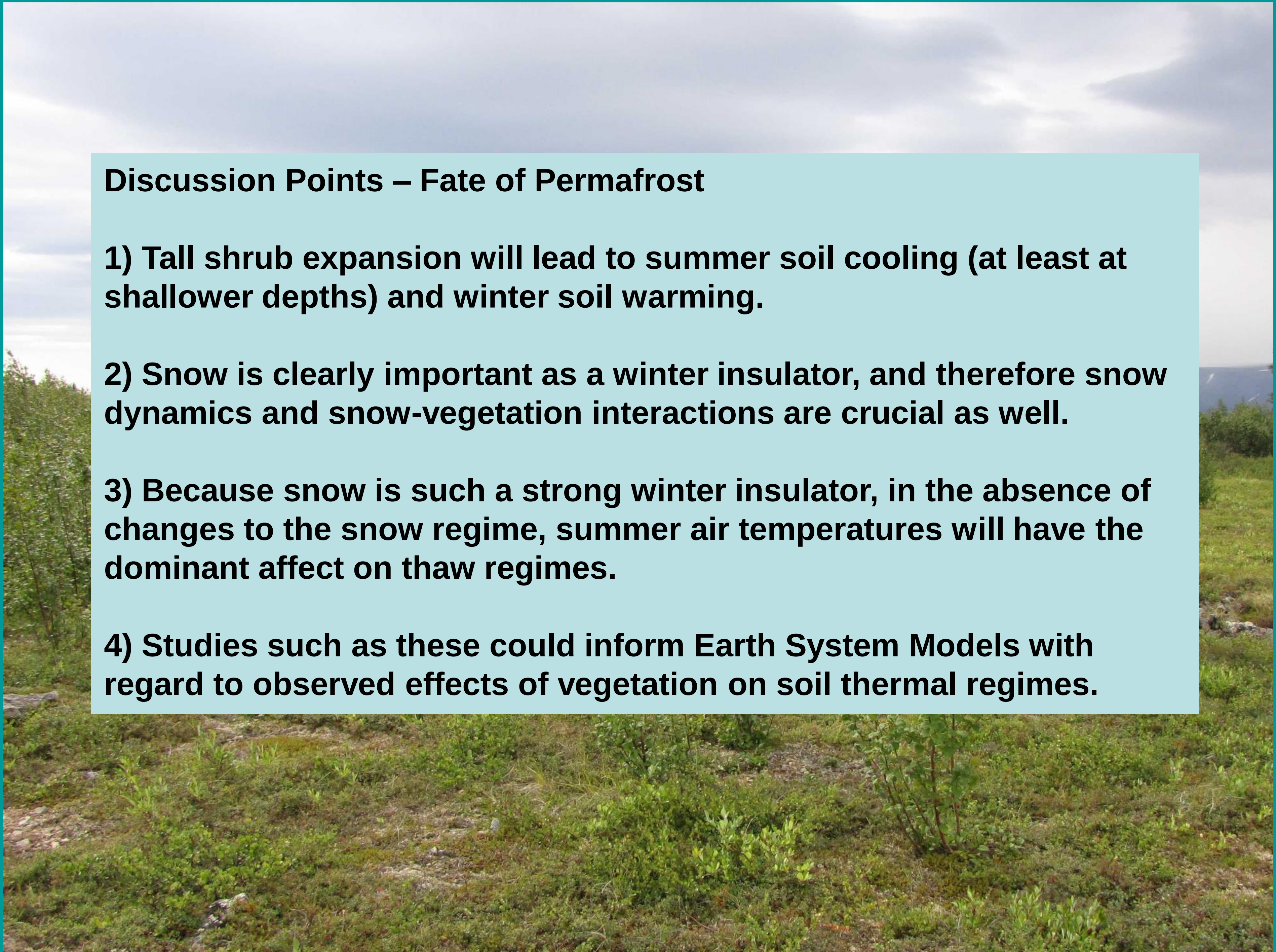
Cooler summer soils with increasing shrub cover leads to shallower active layers, potentially protecting permafrost under warmer climates (Blok et al. 2010)



Vegetation in the southern tundra (Mid- / Low Arctic) is increasing to a greater extent (biomass) than projected by temperature alone.



The interaction between this increasing vegetation and climate changes will determine the fate of permafrost.



Discussion Points – Fate of Permafrost

1) Tall shrub expansion will lead to summer soil cooling (at least at shallower depths) and winter soil warming.

2) Snow is clearly important as a winter insulator, and therefore snow dynamics and snow-vegetation interactions are crucial as well.

3) Because snow is such a strong winter insulator, in the absence of changes to the snow regime, summer air temperatures will have the dominant affect on thaw regimes.

4) Studies such as these could inform Earth System Models with regard to observed effects of vegetation on soil thermal regimes.

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