MAPPING THREATENED SNOWBED AND SNOW PATCH HABITATS IN NORTHERN FINLAND USING LANDSAT DATA

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SNOWBED AND SNOW PATCH HABITATS

SNOWBEDS

Snow melts by the end of the summer

Vascular plant species, bryophytes, lichens, and algae

Total area and quality estimated to decline

NEAR-THREATENED

SNOW PATCHES

Permanent snow throughout the year

Bare ground and rock beneath

Snow algae and snow fungi

ENDANGERED

Snowbed habitat characteristics

- short growing season
- water saturation
- infertile thin soils
- plants able to subnivean growth


Photo: Soili Jussila


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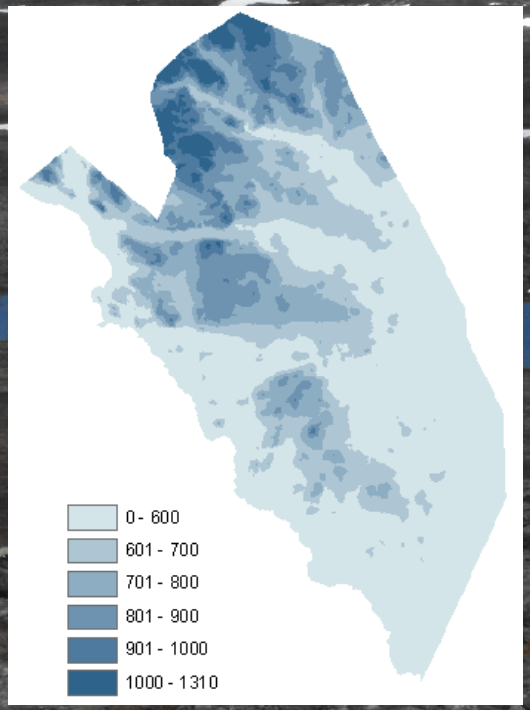
STUDY REGION IN ENONTEKIÖ LAPLAND, NORTHWESTERN FINLAND

3177 km^2

Mean altitude 627 m, max. 1324 m



Treeless alpine tundra and subarctic birch forests up to ca 600 m

SNOWBEDS AND SNOW PATCHES = LATE SUMMER SNOW COVERED AREA

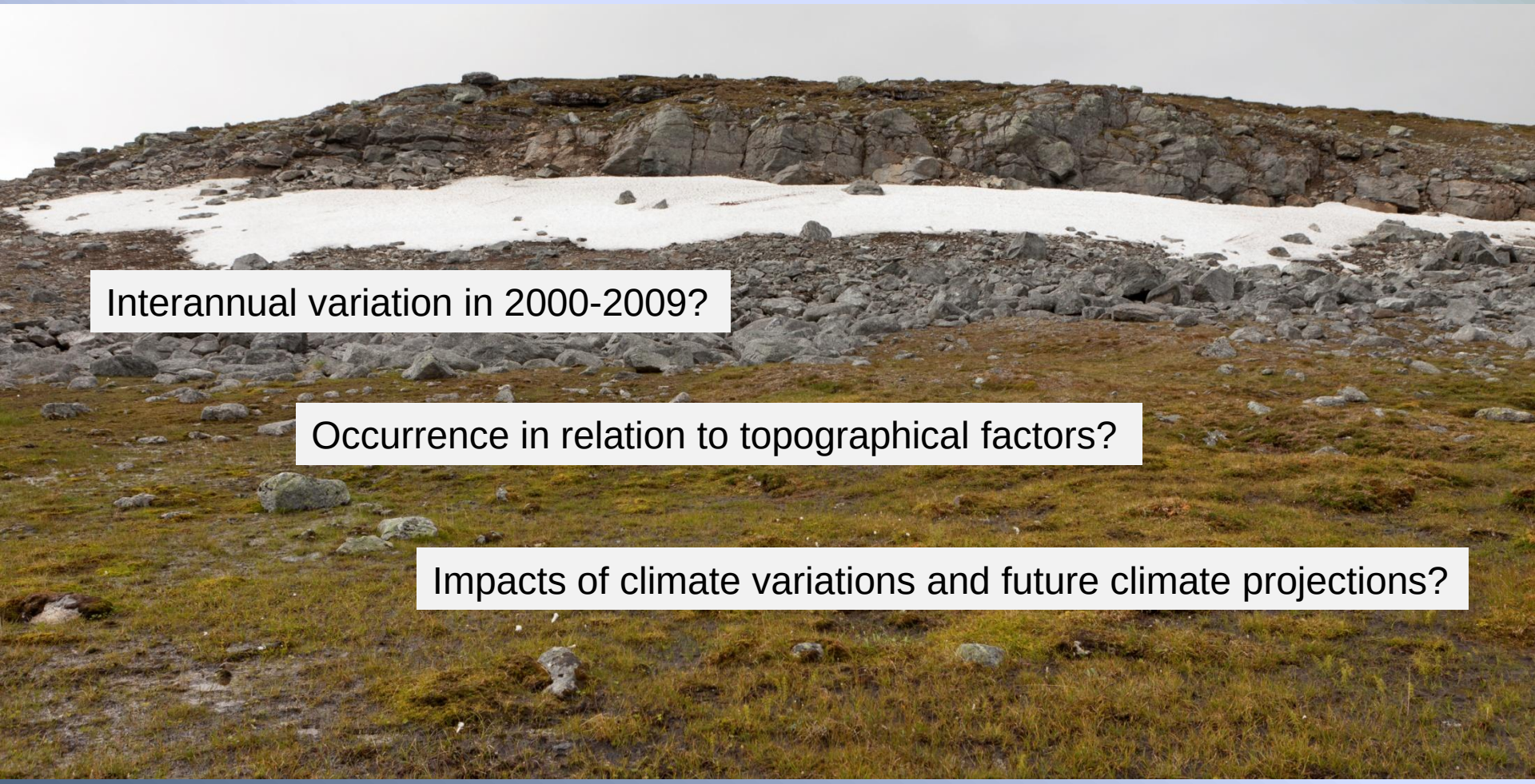
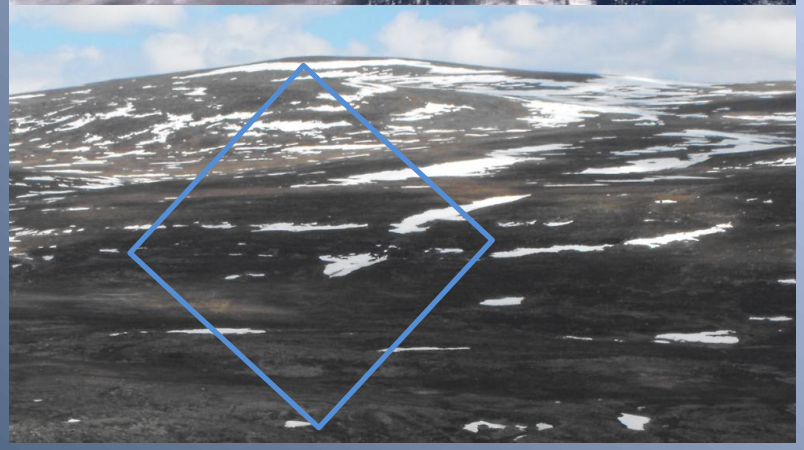
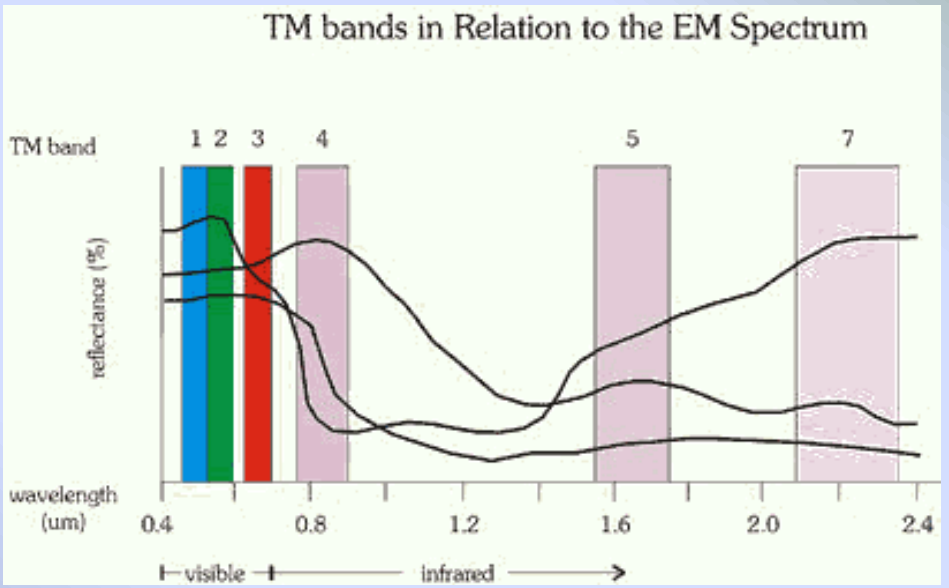


Photo: Soili Jussila

LANDSAT TM AND ETM+ DATA

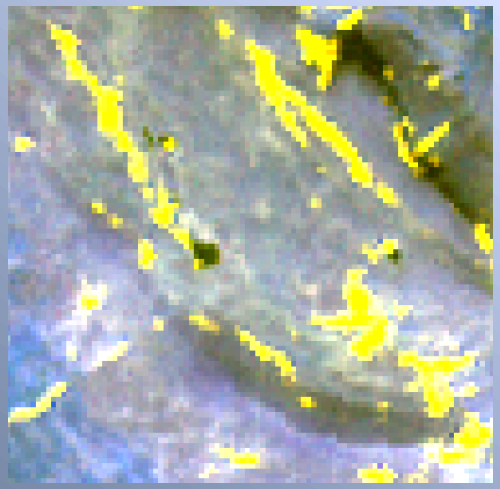


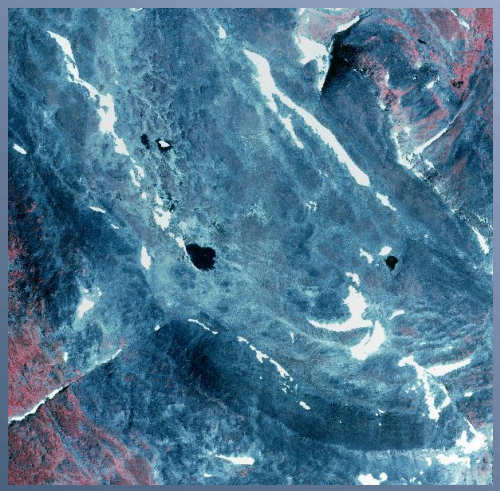


ETM+ TECHNICAL SPECIFICATIONS

Sensor type: opto-mechanical
Spatial Resolution: 30 m (60 m - thermal, 15-m pan)
Spectral Range: 0.45 - 12.5 μm
Number of Bands: 8
Temporal Resolution: 16 days
Image Size: 183 km X 170 km
Swath: 183 km
Programmable: yes

MAPPING LATE SUMMER SNOW COVERED AREA





SATELLITE DATA

Landsat ETM+: 27 July 2000
Landsat TM: 30 July 2004, 27 July 2006, 4 August 2009

SNOW EXTRACTION

Normalized Difference Snow Index
I NDSI = (band 2 – band 5)/(band 2 + band 5)

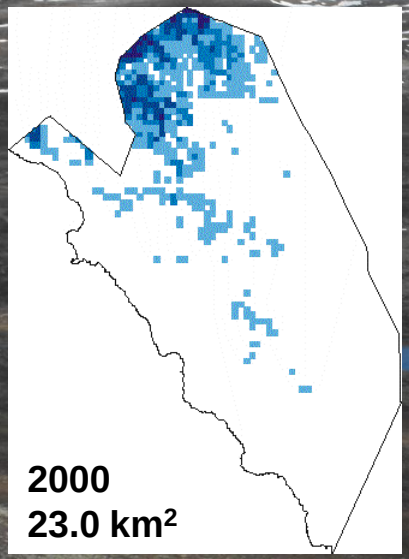
II Unsupervised classification to remove water bodies

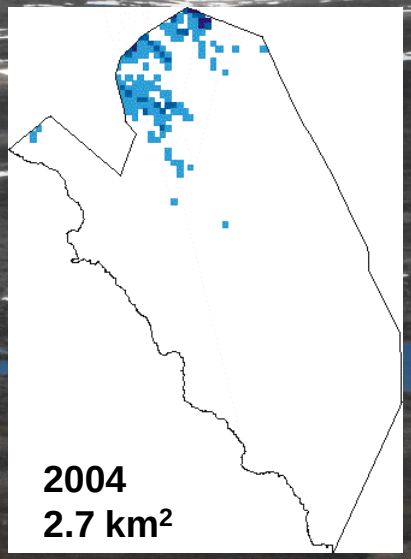
ACCURACY ASSESSMENT

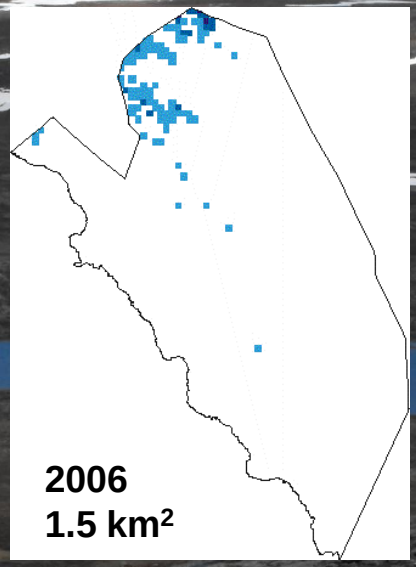
Landsat ETM+ 27 July 2000 and aerial photographs 25 July 2000

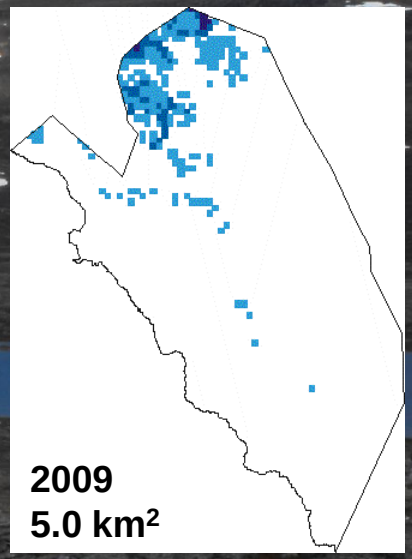
Overall classification accuracy = 95.2%.
Error of commission: snow = 6.3%, other land cover = 3.2%
Error of omission: snow = 3.3%, other land cover = 6.2%

SPATIAL DISTRIBUTION OF LATE SUMMER SNOW COVERED AREA





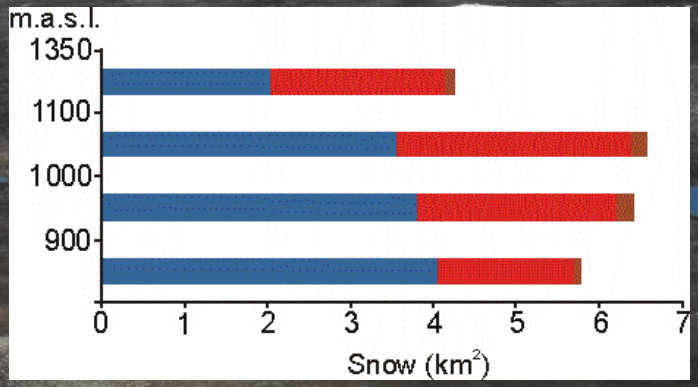




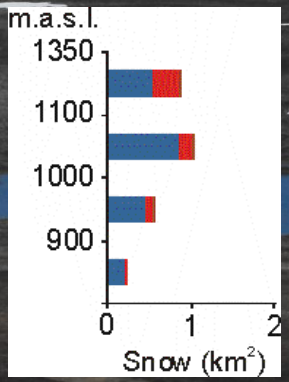
SPATIAL DISTRIBUTION OF LATE SUMMER SNOW COVERED AREA

in relation to altitude and aspect at 30 m resolution

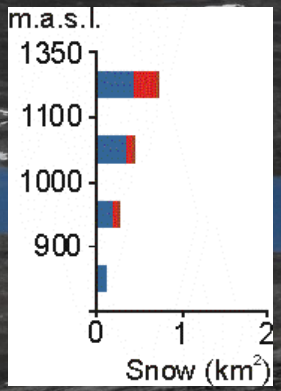
2000



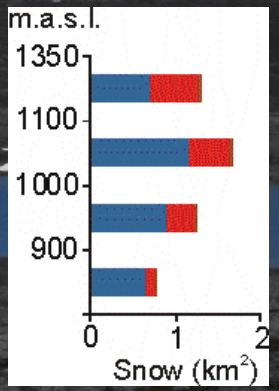
2004



2006



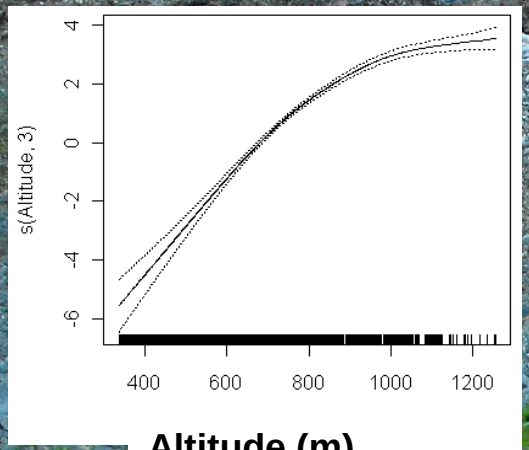
2009



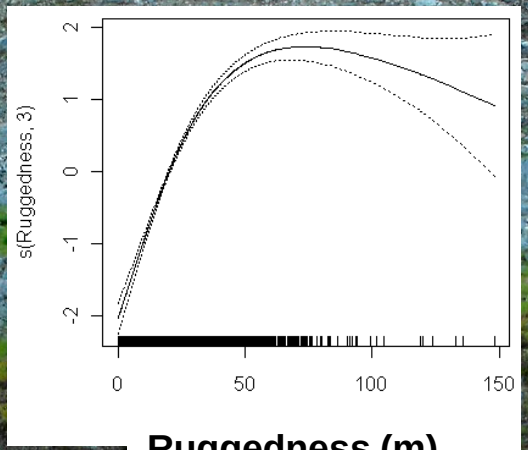
FACTORS EXPLAINING THE OCCURRENCE OF LATE SUMMER SNOW

A generalized additive model (GAM) for the number of snow years (0 – 4 years)

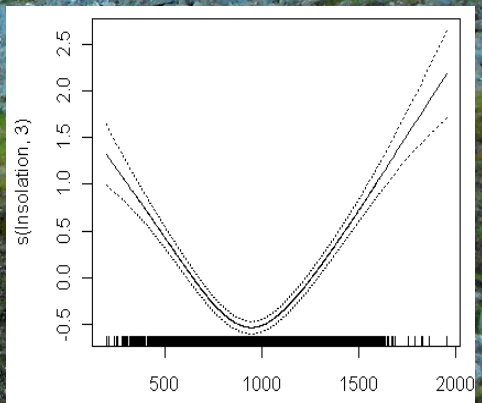
Total model explained 72.7% of the variation



Altitude (m)
- **Univariate: 66.5%**



Ruggedness (m)
- **Univariate: 27.2%**



Insolation (kWh/m^2)
- **Univariate: 8.3%**

Aspect
- **Univariate: 2.5%**

RECENT CLIMATE VARIATIONS AND PROJECTIONS

I Recent climate variations

Climate data for 1995–2009
10 km resolution grid data (Finnish Meteorological Institute)

II Climate change projections

ENSEMBLES (Ensembles-Based Predictions of Climate Changes and Their Impacts)

- 11-model means
- 25 km resolution

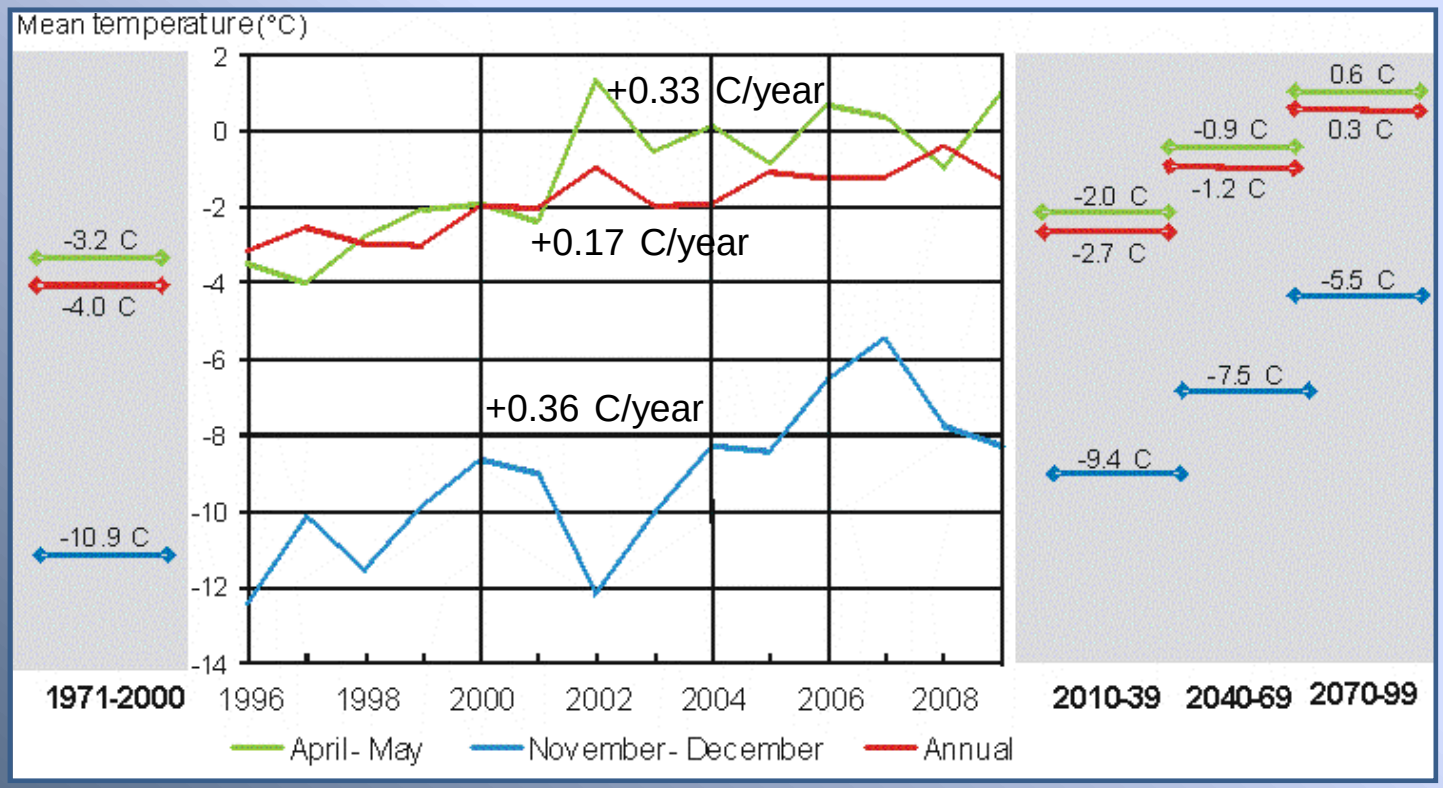
Räisänen J and Eklund J 2012. 21st century changes in snow climate in Northern Europe: a high-resolution view from ENSEMBLES regional climate models. *Climate Dynamics* 38, 2575-91

PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects) project

- 7-model means
- 50 km resolution

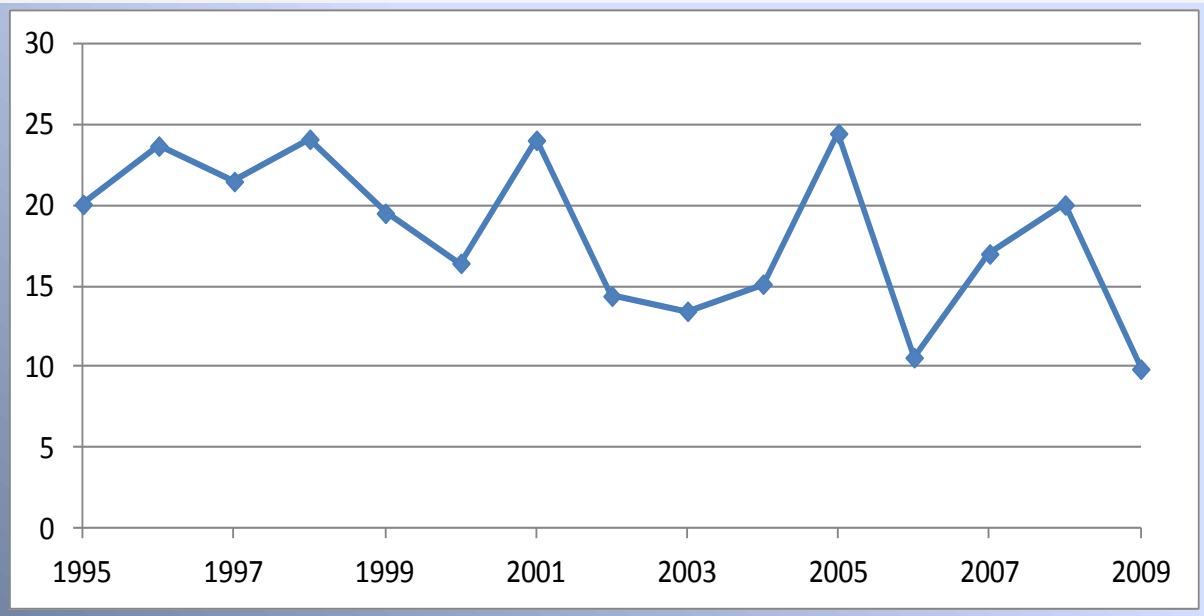
Jylhä K, Fronzek S, Tuomenvirta H, Carter TR & Ruosteenoja K (2008). Changes in frost, snow and Baltic sea ice by the end of the twenty-first century based on climate model projections for Europe. *Climatic Change* 86, 441–462.

RECENT TEMPERATURE TRENDS AND FUTURE PROJECTIONS



TRENDS IN THE NUMBER OF FROST DAYS (Tmin < 0)

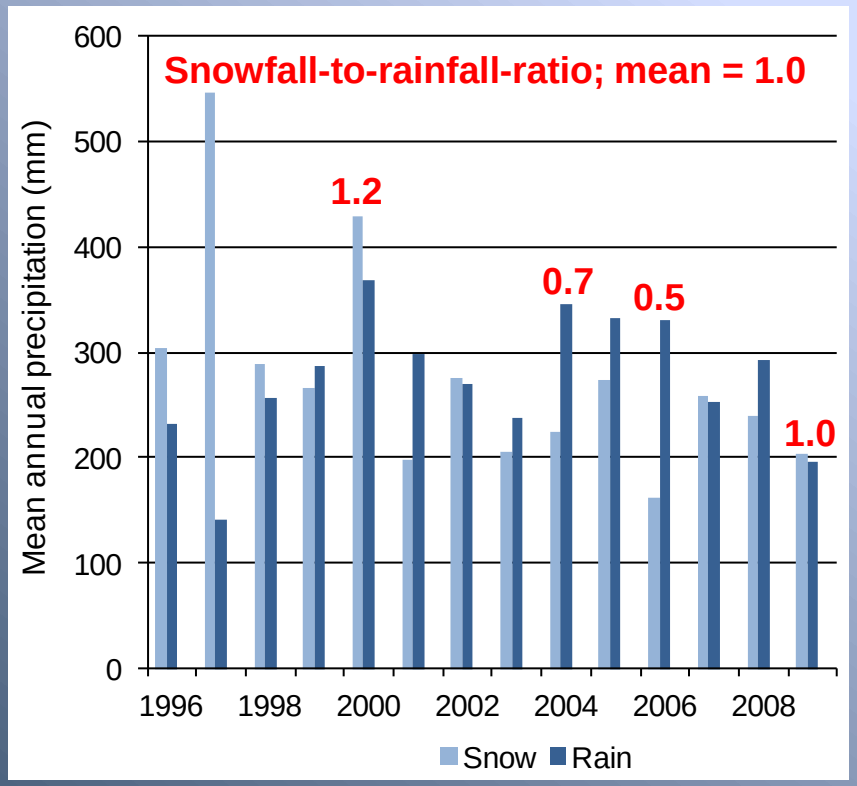
The number of frost days in May has declined by 0.6 days per year (P < 0.05)



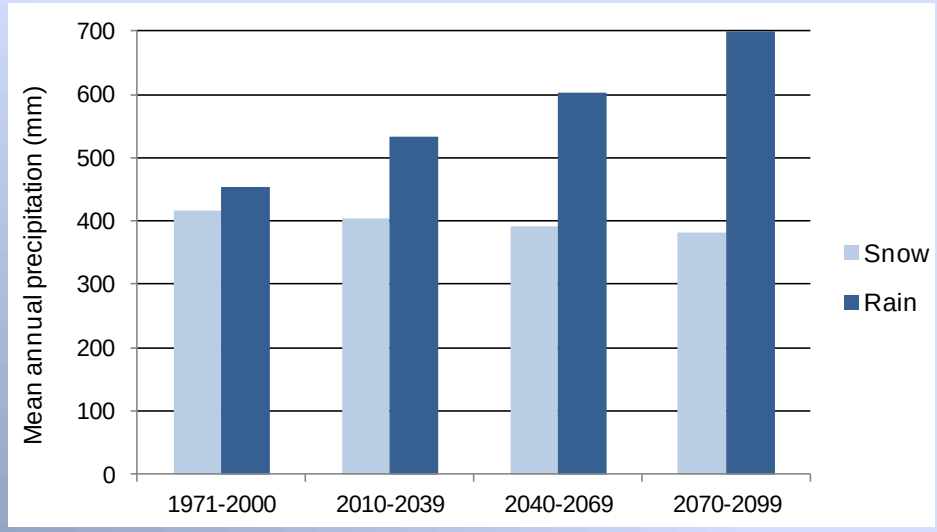
PRUDENCE SIMULATIONS:
Annual number of frost days: 240 in1961-1990 → 185 in 2071-2100

The greatest projected declines in May from 21.5 to 6.7 days and in October from 25.2 to 11.9 days.

PRECIPITATION AMOUNTS AND FUTURE PROJECTIONS



ENSEMBLES simulations



LIKELY IMPACTS OF WARMING CLIMATE

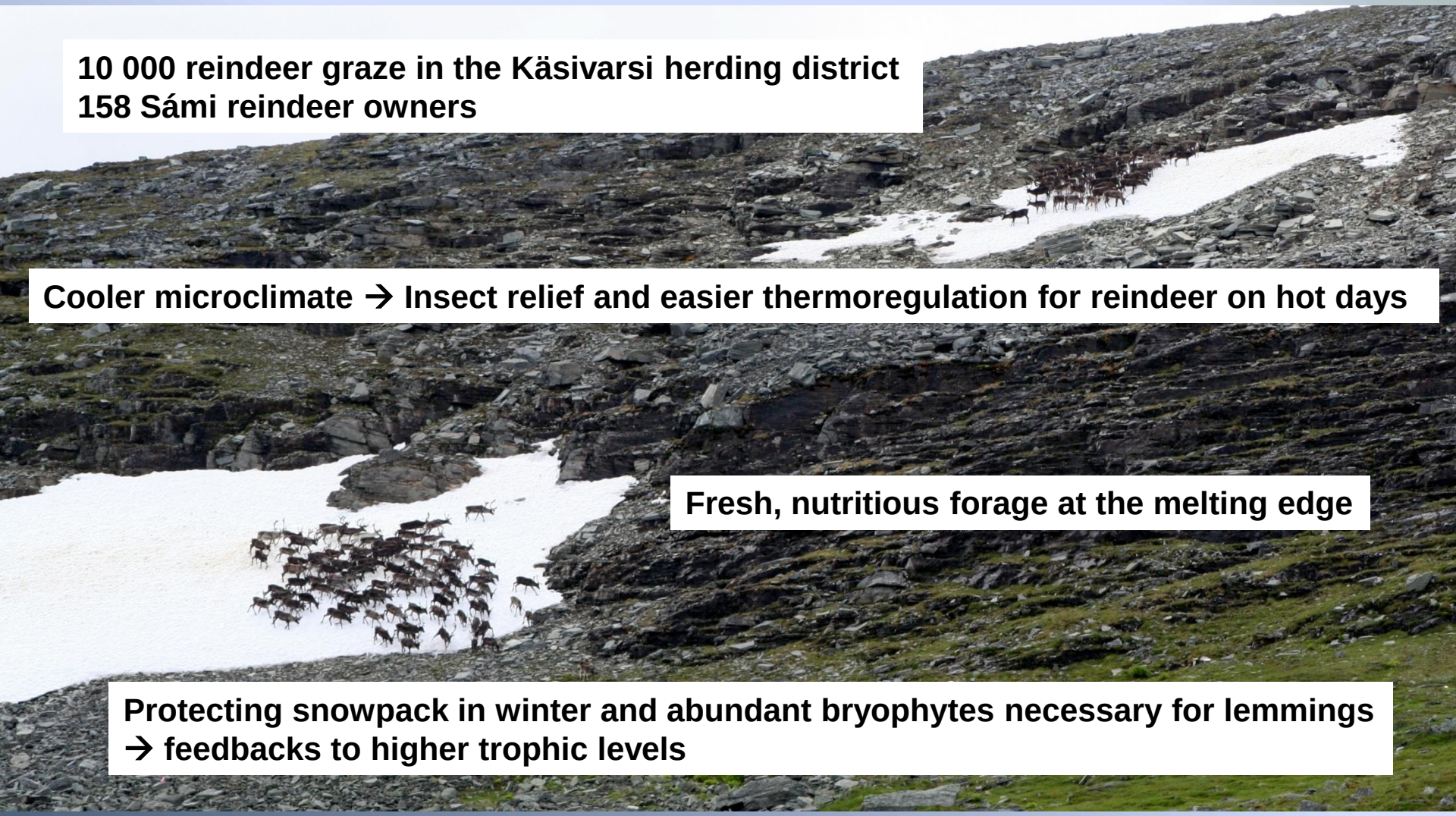
Earlier start of snow melt → Prolonged growing season

Changes in hydrology → Drier soils

Most harmful to the snowbed specialists → Diminishing diversity?

Photos: Soili Jussila

EFFECTS ON ECOSYSTEM SERVICES



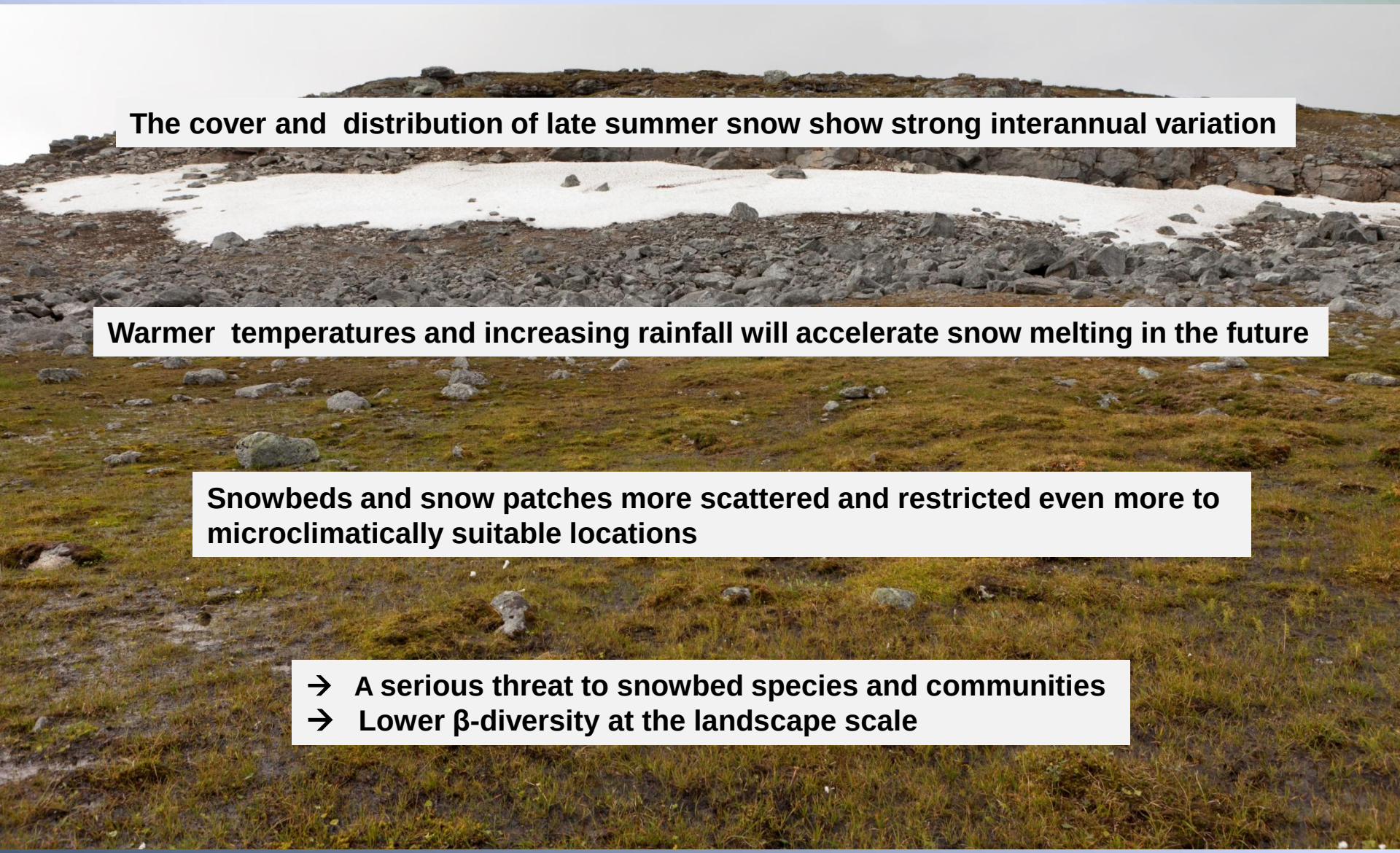
10 000 reindeer graze in the Käsivarsi herding district
158 Sámi reindeer owners

Cooler microclimate → Insect relief and easier thermoregulation for reindeer on hot days

Fresh, nutritious forage at the melting edge

Protecting snowpack in winter and abundant bryophytes necessary for lemmings → feedbacks to higher trophic levels

CONCLUSIONS



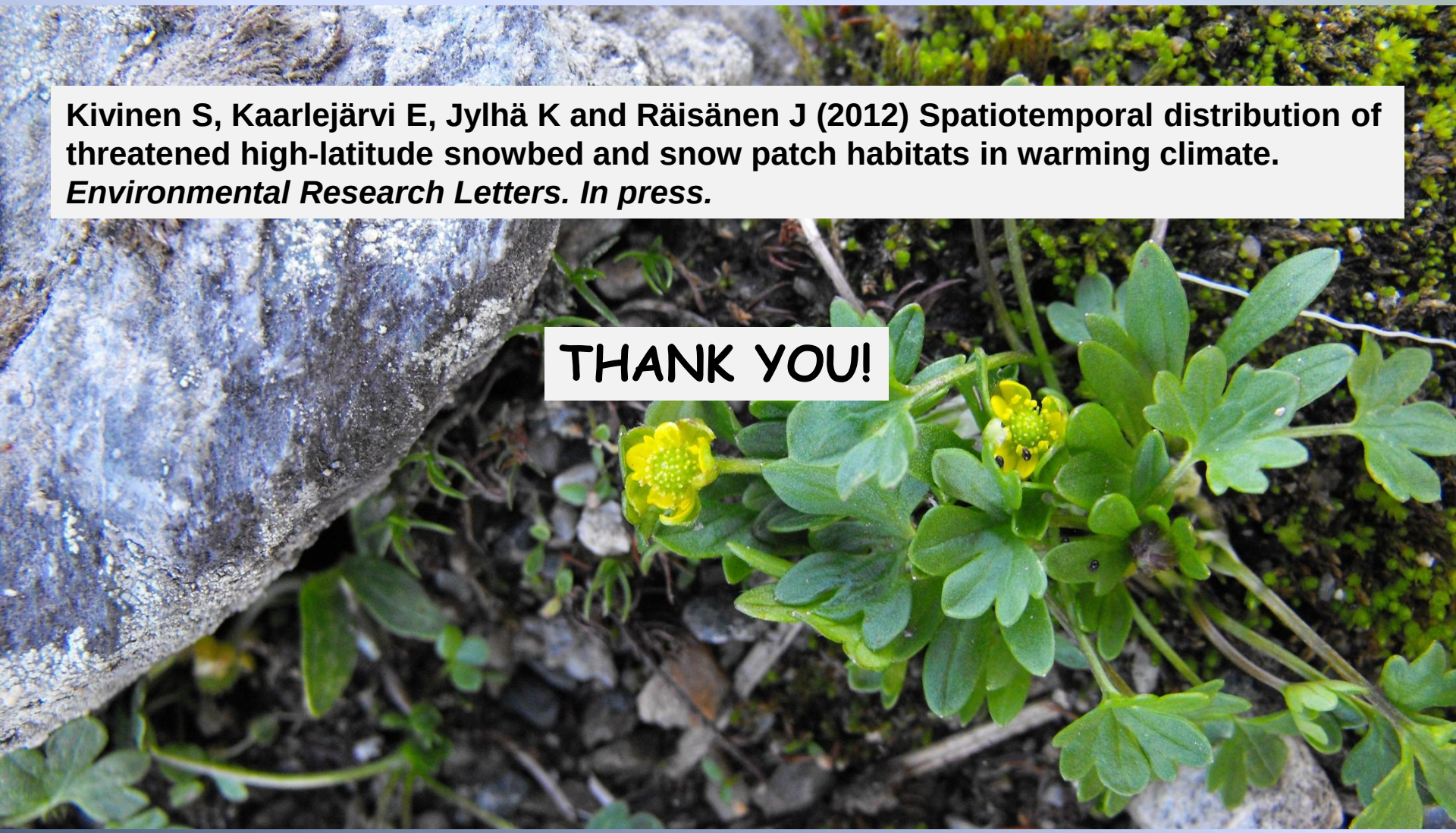
The cover and distribution of late summer snow show strong interannual variation

Warmer temperatures and increasing rainfall will accelerate snow melting in the future

Snowbeds and snow patches more scattered and restricted even more to microclimatically suitable locations

- → **A serious threat to snowbed species and communities**
- → **Lower β-diversity at the landscape scale**

Photo: Soili Jussila



Kivinen S, Kaarlejärvi E, Jylhä K and Räisänen J (2012) Spatiotemporal distribution of threatened high-latitude snowbed and snow patch habitats in warming climate. *Environmental Research Letters. In press.*

THANK YOU!