Photo: Tove Agnes Utsi

Nordic Centre of Excellence (NCoE)
funding mechanism coordinated by NordForsk

- Top-Level Research Initiative (TRI) 2009-
  - Established by the Nordic Prime Ministers
  - A major Nordic venture for climate, energy and the environment
- Top-level Research Initiative consists of six sub-programmes:
  - Effect studies and adaptation to climate change
  - Interaction between climate change and the cryosphere
  - Energy efficiency with nanotechnology
  - Integration of large-scale wind power
  - Sustainable bio-fuels
  - CO_2 - capture and storage

NCoE Tundra Partners

NCoE Tundra Team:
Lauri Oksanen, Pekka Niemelä, Lars Ericson, Bruce C. Forbes,
Jane Uhd Jepsen, Bernt Johansen, Erkki Korpimäki, Annamari Markkola, Tarja
Oksanen, Johan Olofsson, Jouni Pulliainen, Tove Aagnes Utsi, Rolf Anker Ims,
Juha Tuomi, Risto Virtanen, Annu Ruotsalainen, Sami Aikio, Mariska te Beest,
Martin Biuw, Anu Eskelinen, Tim Horstkotte, Katrine S. Hoset, Liisa Huttunen,
Sonja Kivinen, Elina Koivisto, Cécile B. Ménard, Lise Ruffino, Patrick Saccone,
Karita Saravesi, Judith Sitters, Mysore Tejesvi, Piippa Wäli, Saija Ahonen, Antti
Aikio, Juval Cohen, Dagmar Egelkraut, Nirmalee Hengodage, Karoliina Huusko,
Elina Kaarlejärvi, Maarit Kaukonen, Åsa Larsson Blind, Inkeri Markkula, Miia
Kauppinen, Tuija Pyykkönen, Maria Tuomi, Hélène Prouillet-Leplat, Piippa Wäli,
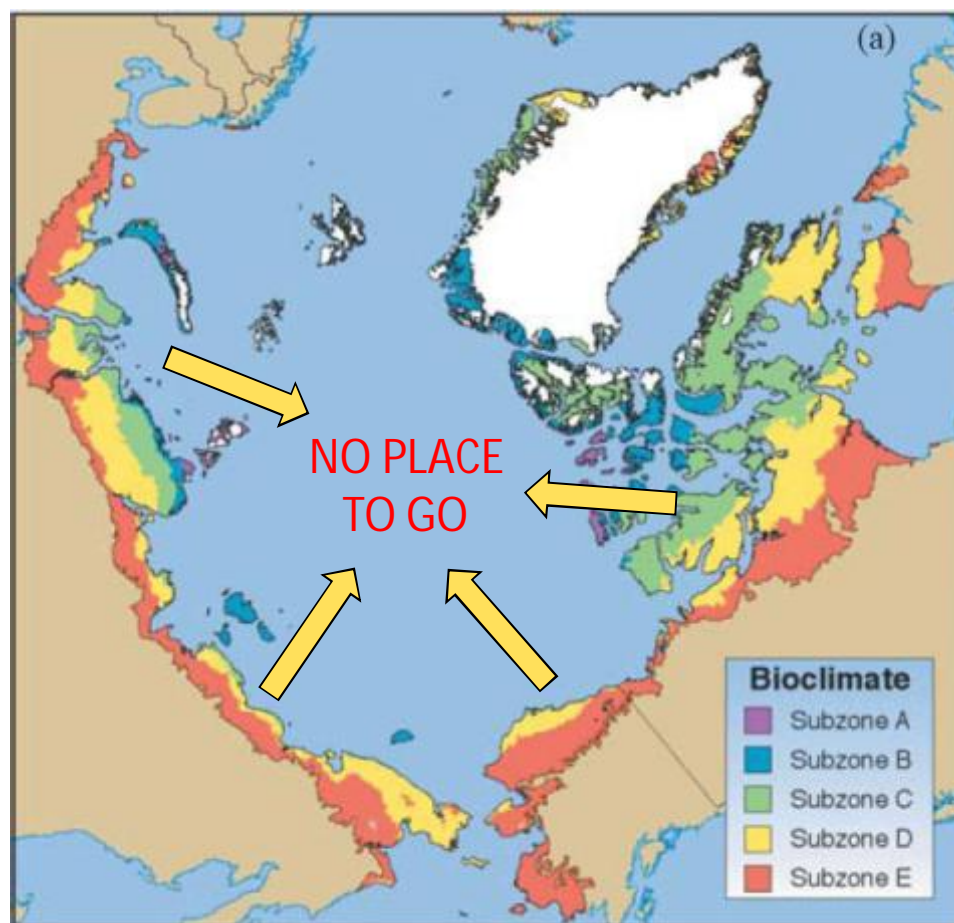Ole Petter L. Vindstad

www.ncoetundra.utu.fi

The circumpolar tundra ecosystem
...has no escape

NO PLACE TO GO

Circumpolar Arctic Vegetation Map (CAVM) with five subzones of tundra vegetation

Walker et al. *J. Veg Sci* 16, 2005

Bioclimate
- Subzone A
- Subzone B
- Subzone C
- Subzone D
- Subzone E

Shrubification: tundra is turning into shrubby 'forest'

Reflecting snow and ice cover decreases

(a) Northern Hemisphere Snow Cover Anomaly June 1967 - 2012
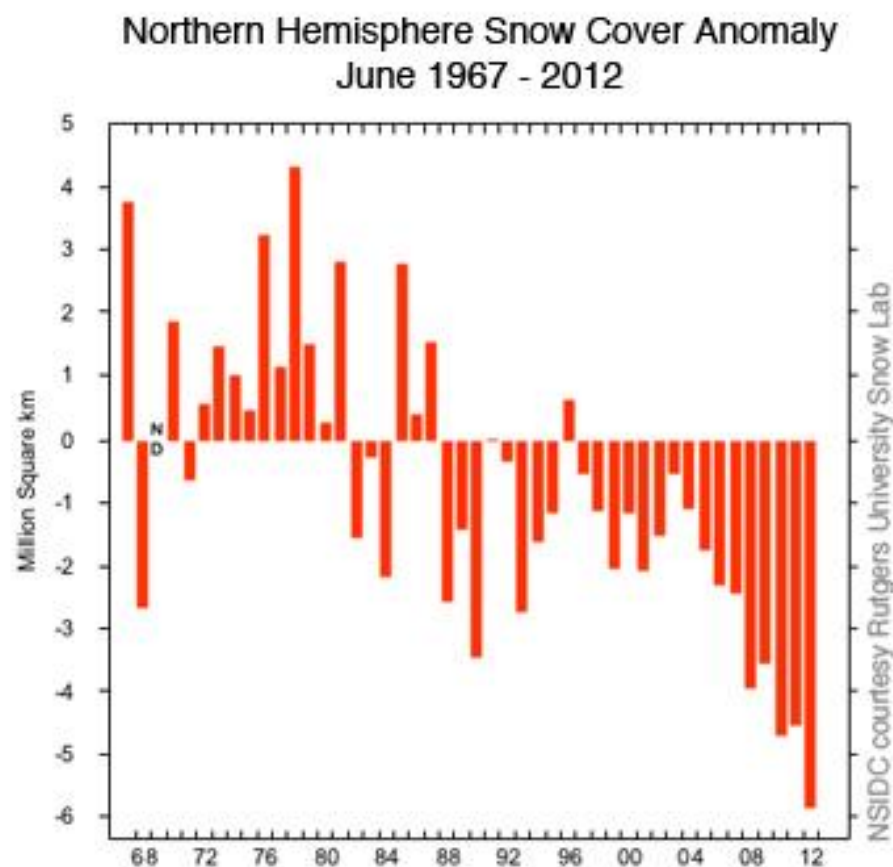
(b) Northern Hemisphere Snow Cover Anomaly June 2012
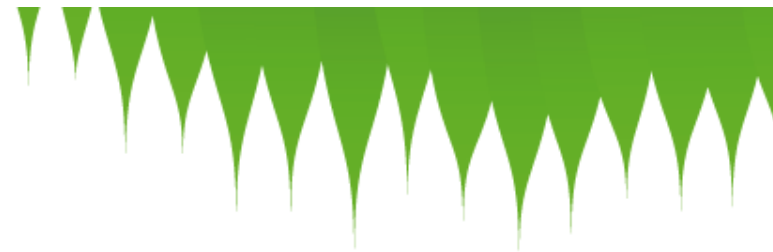
Percent difference from 1971 - 2000 average June snow cover extent
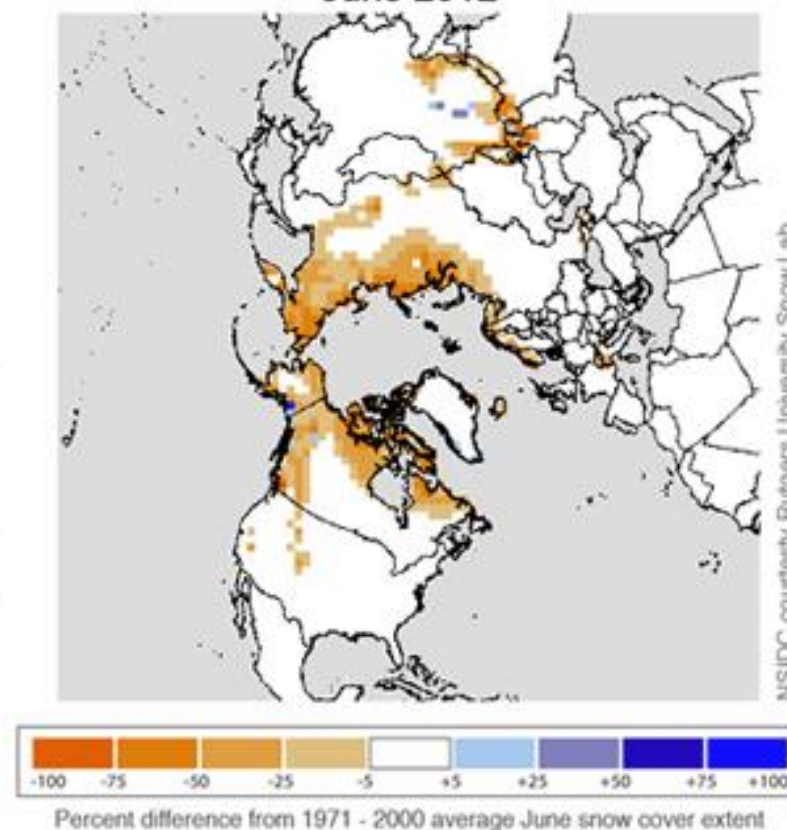
Shrubs protruding through the snow pack enhance the effect -> smaller reflection -> warmer planet

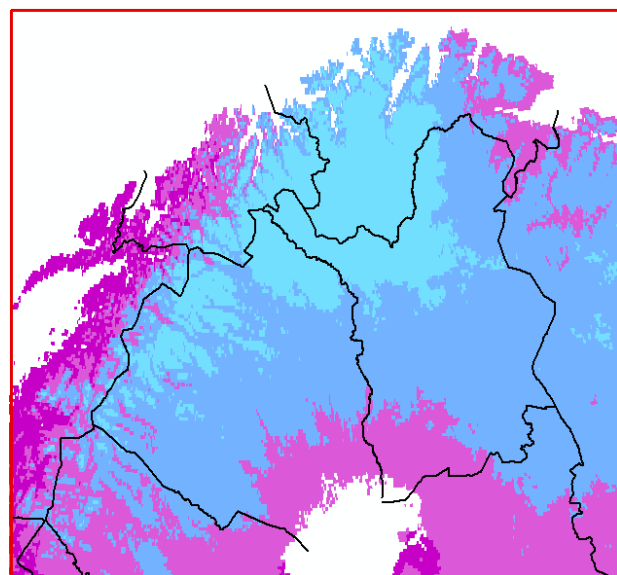# Mean annual temperature in Fennoscandia

Today   2050   2070
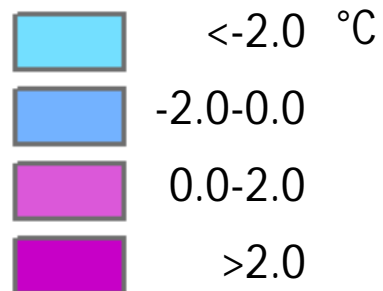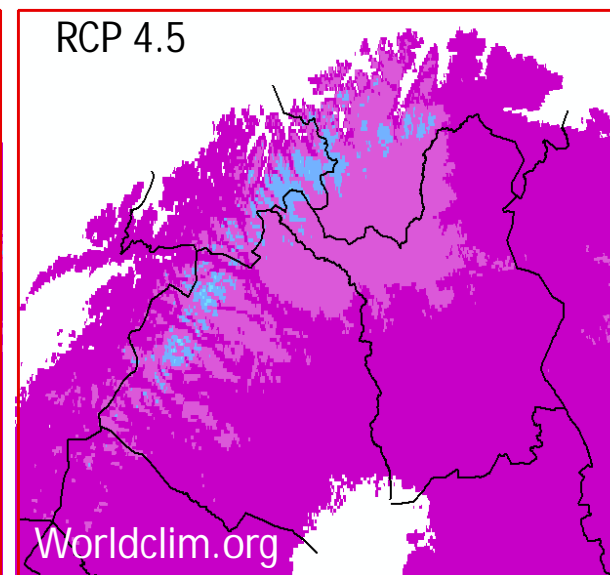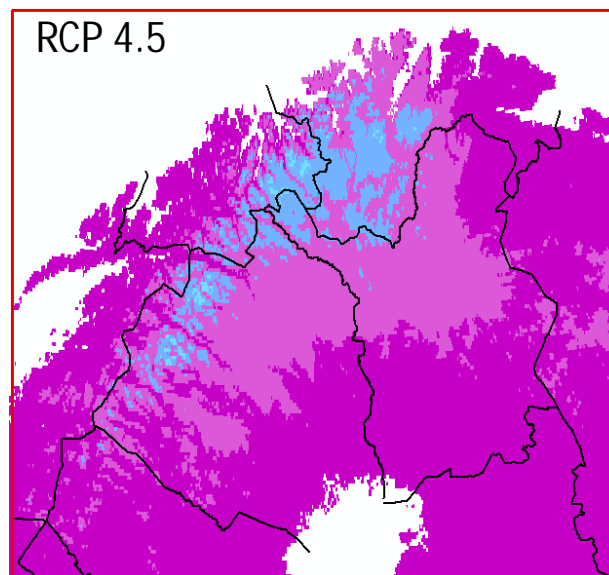
NCoE Tundra rationale

...we wish to learn how reindeer husbandry can be optimally applied to prevent climate-driven woodland expansion and additional warming

...and support the adaptation of the indigenous Sámi culture to the warming climate

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Top-level Research Initiative

snow

CO_2

CH_4

Climate

adaptation

predation

albedo
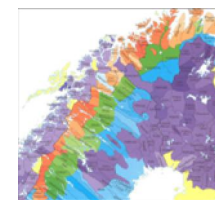
administration

sámi culture

From information to knowledge

min T

moth damage

Food Webs

rodent herbivory

vegetation

biodiversity

trees

shrubs

rare plants

lichens

soil properties

reindeer management

reindeer herbivory

Turun yliopisto
University of Turku
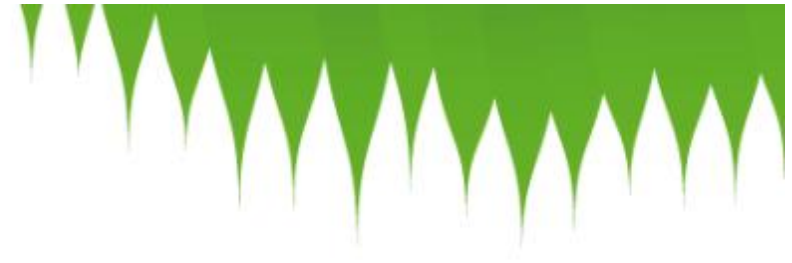
Tundra structure
8 work packages in 3 realms:

Abiotic changes
(temperature, snow, freeze-thaw cycles ...)

Biotic changes
(vole dynamics, moth dynamics, birch forest structure & function, food webs...)

Sámi culture and reindeer herding practices
(ecology, economy, politics,...)
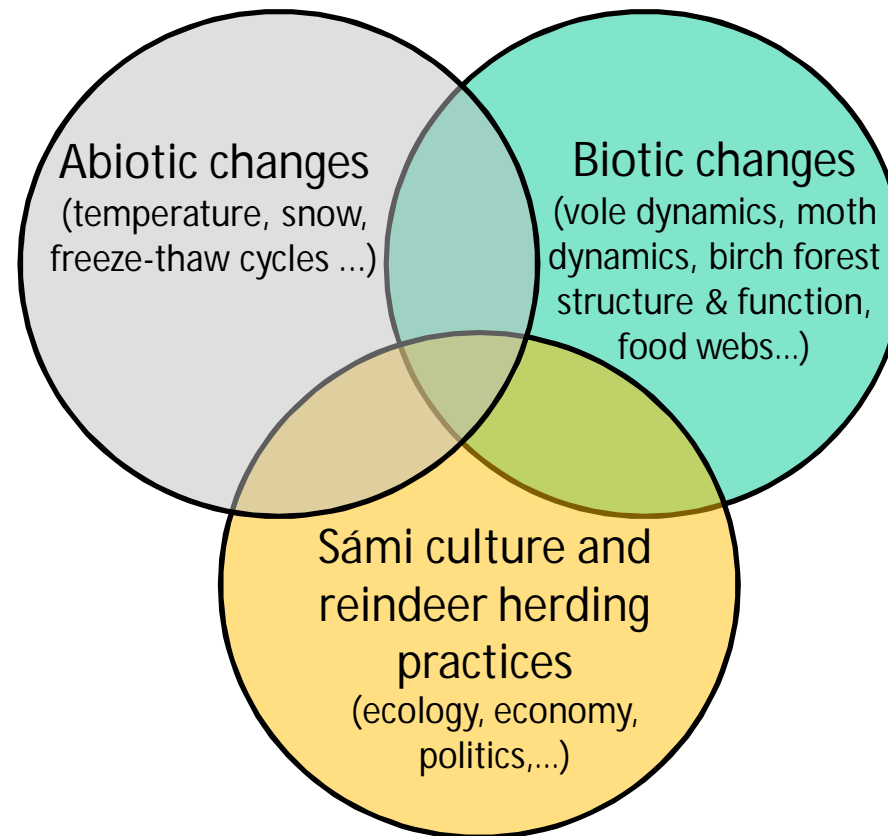
A quick tour to some
NCoE Tundra highlights

Seamless cross-border vegetation/land cover map in 30 m resolution

Vegetation types in Northern Fennoscandia

Mountain vegetation and open lowland; 28.3% of the land area:

- Heath/Grass/Meadow/Dwarf shrub; 13.3%
- Lichen heath; 0.5%
- Heather ridge; 2.2%
- Bedrock/Boulder; 2.9%
- Snow patch vegetation; 7.9%
- Glacier/Snow; 2.4%

- Forest/Mire; 70.3% of the land area

Mapping based on 64 Landsat TM/ETM+ images from 1994-2006
Extensive field checks of the reliability & representativeness

norut
NORTHERN RESEARCH INSTITUTE
TROMSØ
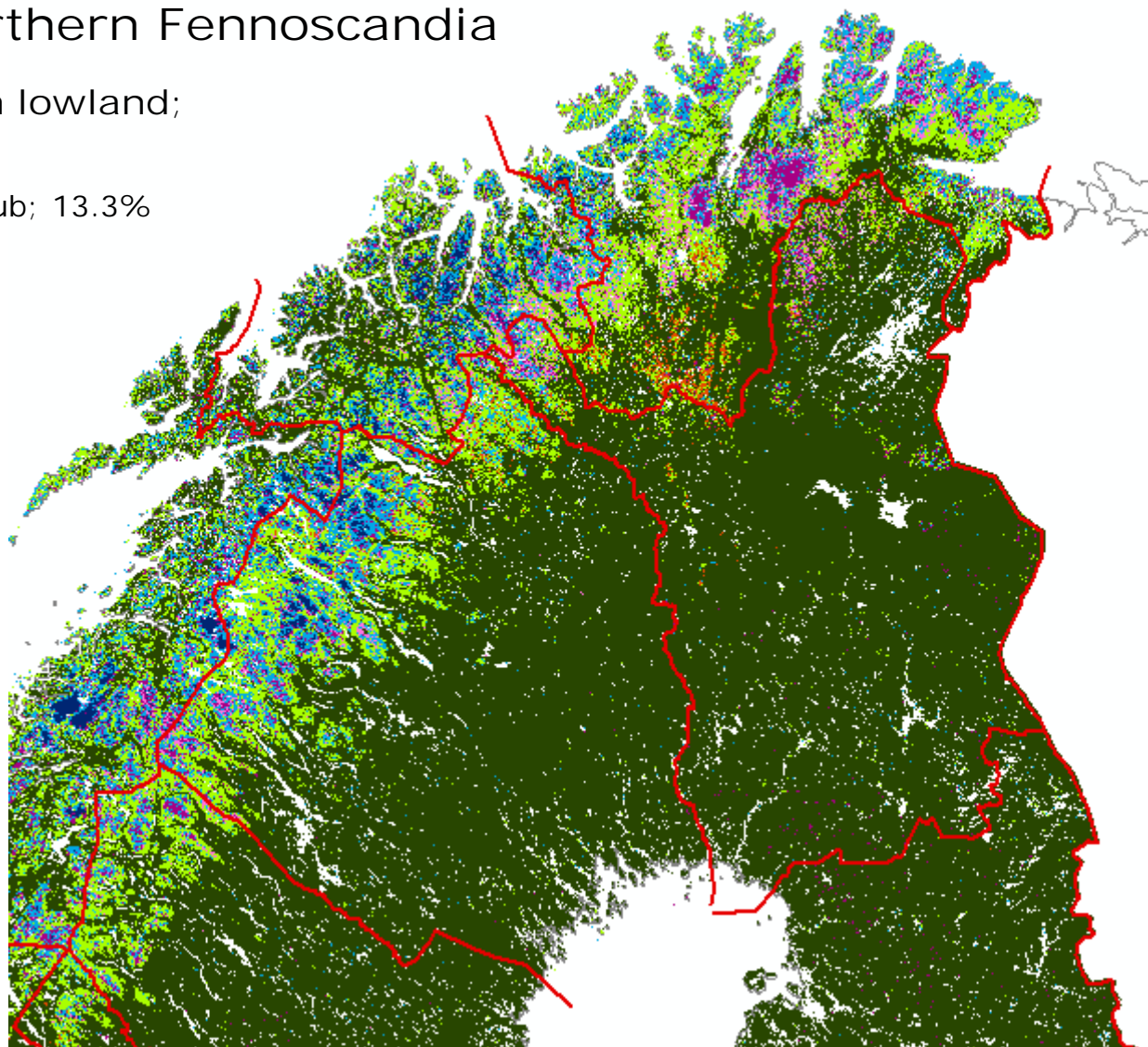
Comparison of vegetation and climate

10.5°C — 10.0°C — 9.5°C

Today
~ 75% tundra
~ 85% tundra
approx. pine limit

10.5°C — 10.0°C — 9.5°C

2070 RCP4.5

By 2070, tundra has practically vanished
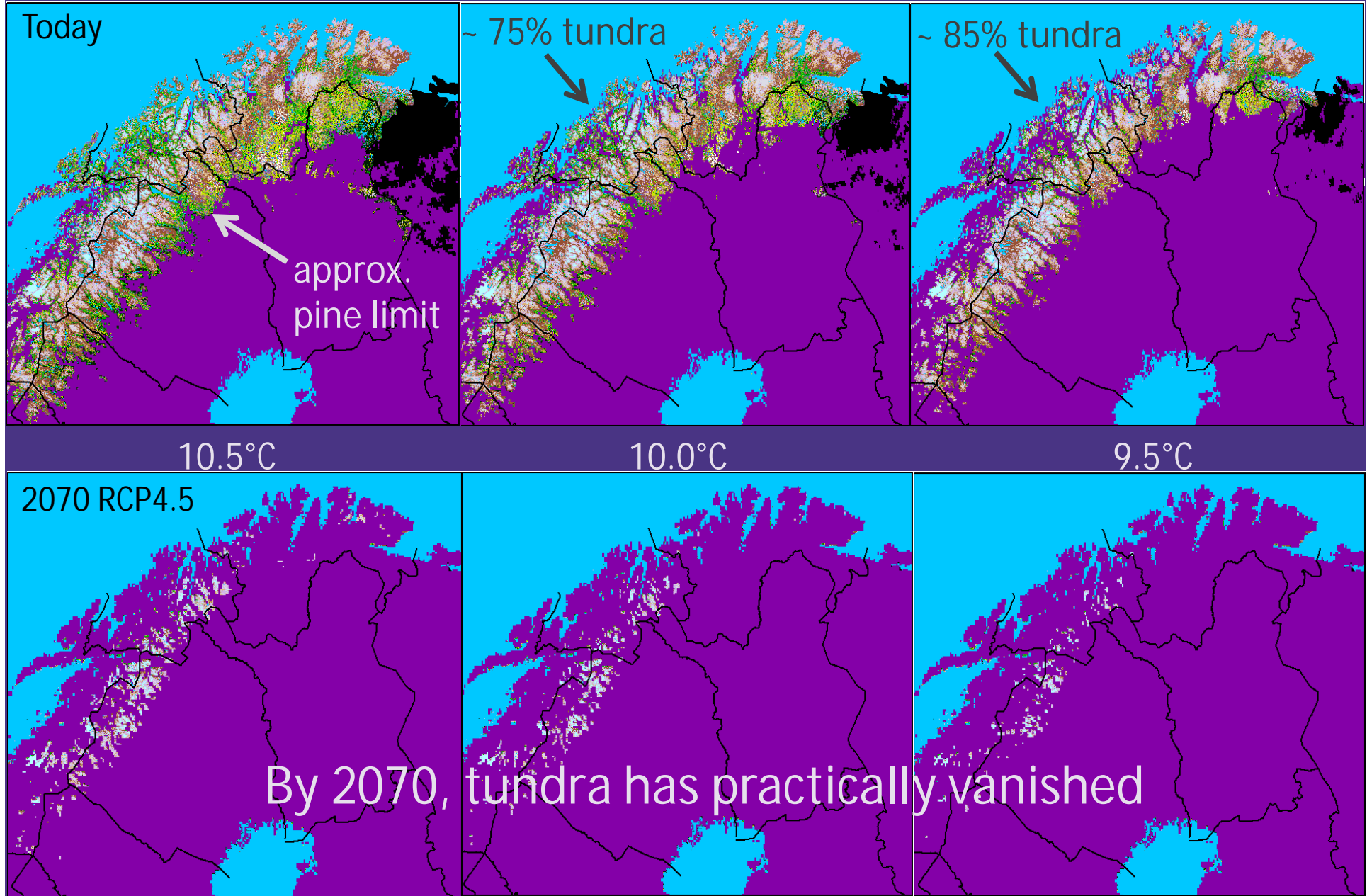
Herbivory by moth

Photo: Roger Wasley

Birch forest damaged by moth in 1965-66 today;
no recovery, thanks to reindeer

Vast areas damaged by moth caterpillars

Egg survival over winter is temperature dependent: T below -36 °C kills the eggs

-> inversions, cold air drainage and snow thickness have local impact

Epirrita autumnata 1965–1966
Operophtera brumata 2005
Operophtera brumata 2006
Operophtera brumata 2008

m asl

640

2,8

© Katja Kosonen, MSc thesis 2014
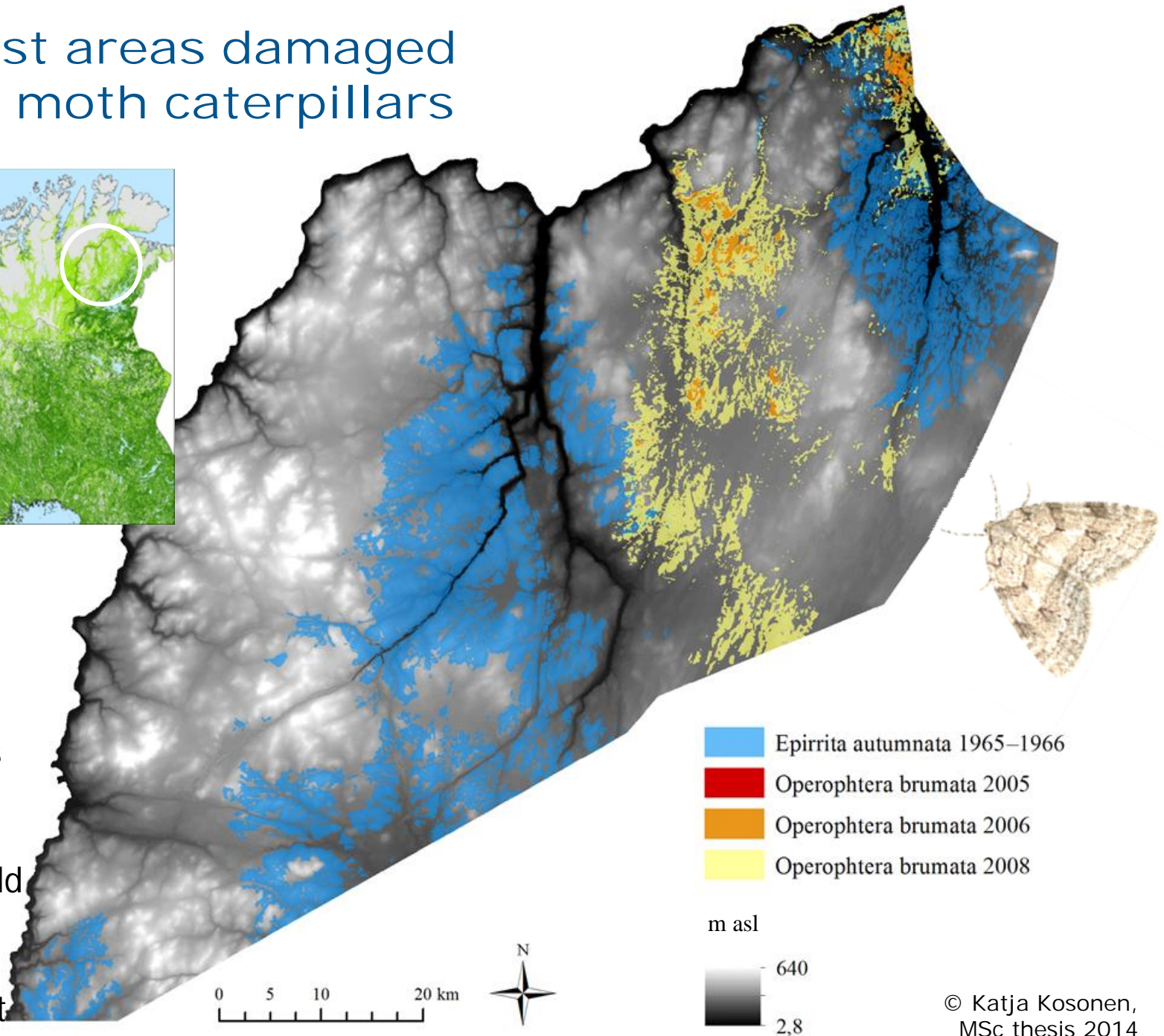
Arctic greening and the role of grazers to slow it down

Herbivores inhibit climate-driven shrub expansion on the tundra

JOHAN OLOFSSON*, LAURI OKSANEN†‡, TERRY CALLAGHAN§¶, PHILIP E. HULME‖, TARJA OKSANEN* and OTSO SUOMINEN†

REINDEER

LEMMING

VOLE

Reindeer grazing
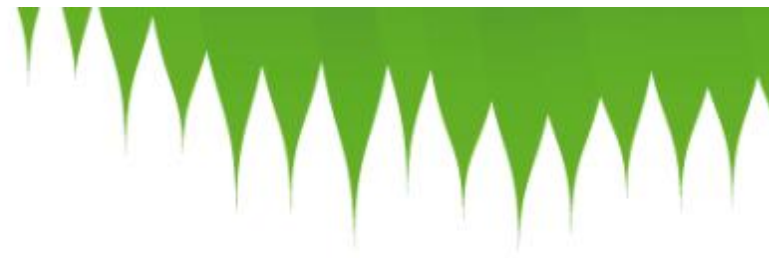
Reindeer husbandry system + NCoE TUNDRA field sites
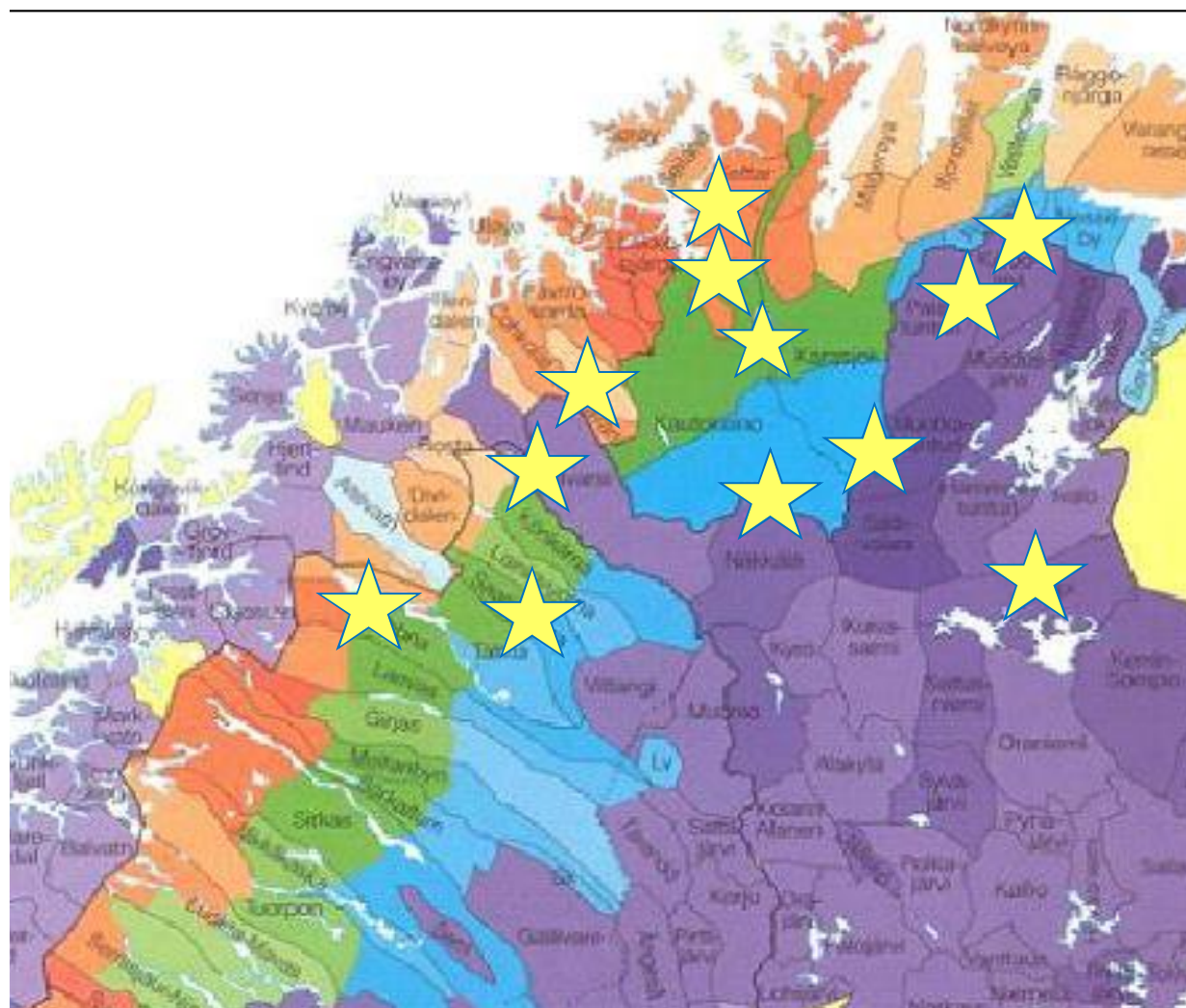
Similar average annual reindeer densities (2.5 /km²),
but different pasture rotation

Norway (winter pasture only)
ground layer lush with *Cladina*
lichen (pale colour)

Finland (year-round pasture)
lichen missing due to reindeer impact
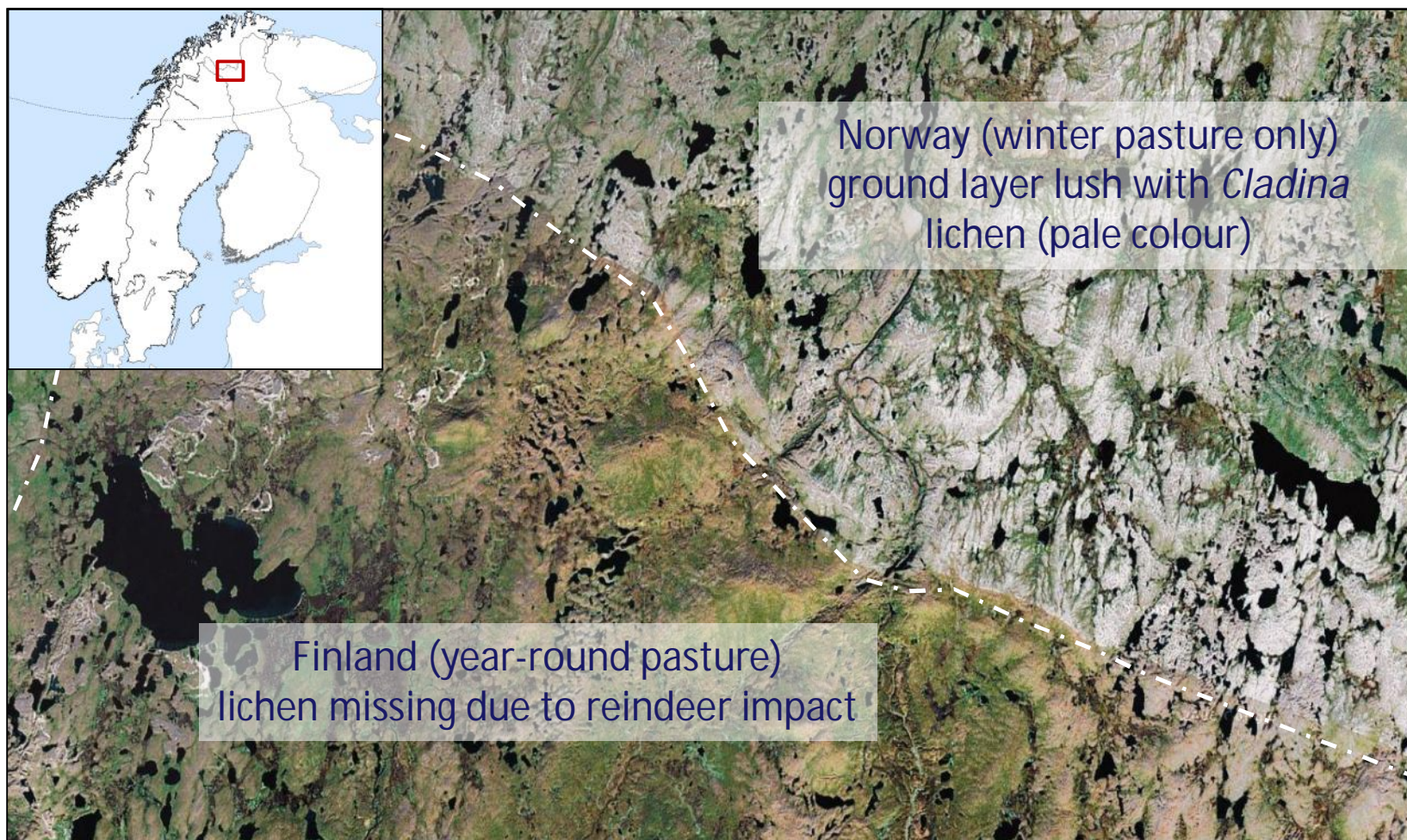
2 km

National border + reindeer fence

Norway, plenty of *Cladina* lichen on the ground (pale colour)

Finland, almost no *Cladina* lichen on the ground

Similar average annual reindeer densities (2.5 /km²),
but different pasture rotation

Finland; few *Betula* trees   Norway; dense *Betula* forest

National border +
reindeer fence
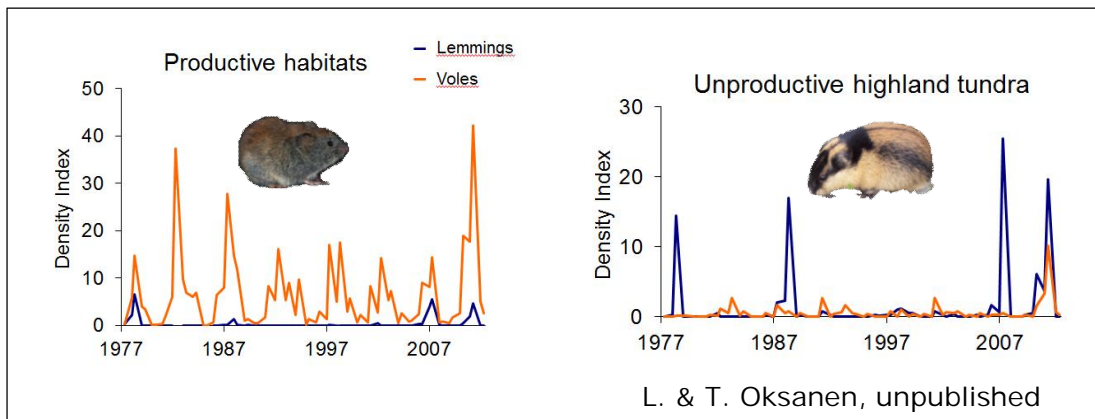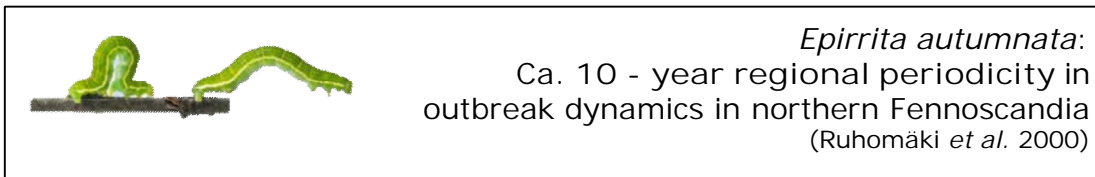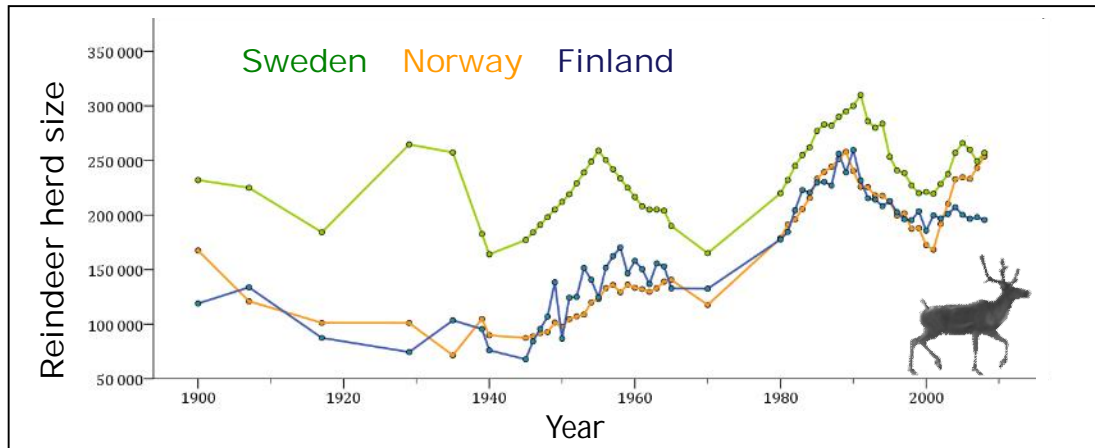
Magnitude of impacts at different spatial and temporal scales?

Epirrita autumnata:
Ca. 10 - year regional periodicity in outbreak dynamics in northern Fennoscandia
(Ruhomäki *et al.* 2000)

L. & T. Oksanen, unpublished

Ecological food webs and interactions alone are not the answer

⟹ Which drivers can be controlled?

Snow & albedo

Don Komarechka
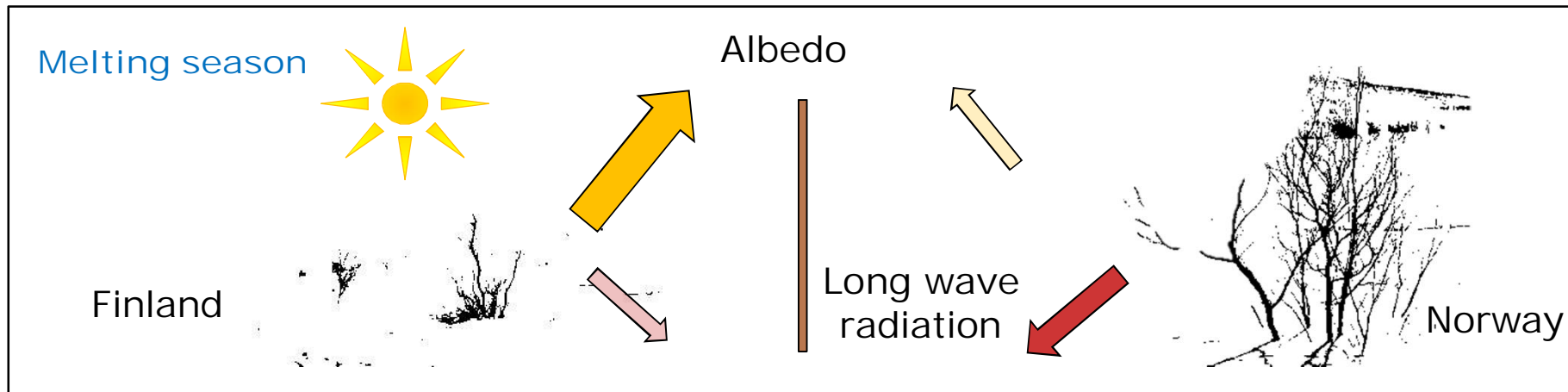
Due to different grazing practices, fractional snow cover is larger and albedo 5% higher on the Finnish side during melting period → lower solar absorption

Cohen *et al.* (2013), *Remote Sens. Environ.* 135
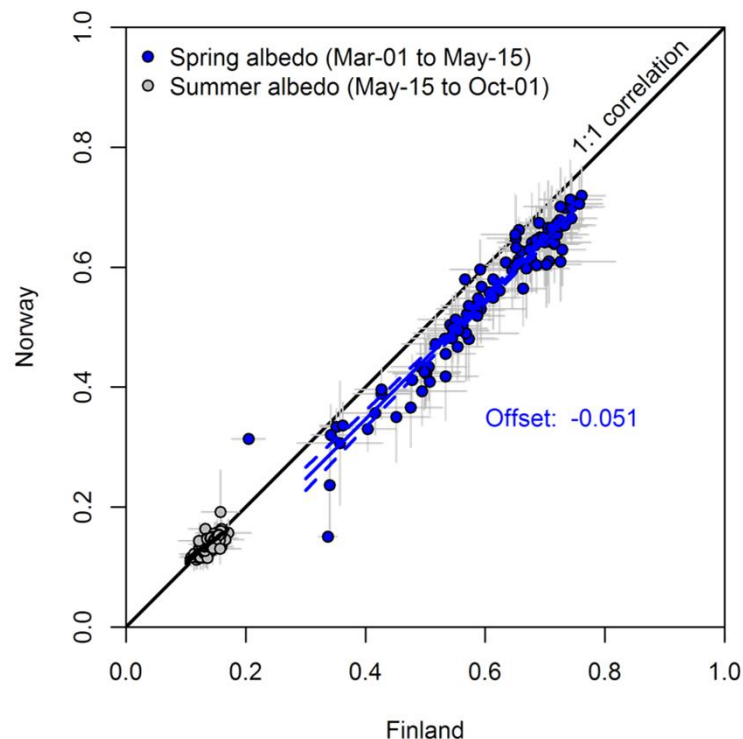
During March-May, the heat balance difference between Finland and Norway is so large that the extra heat produced on the Norwegian reference area (22 000 km²) is enough to melt one cubic kilometer of ice!
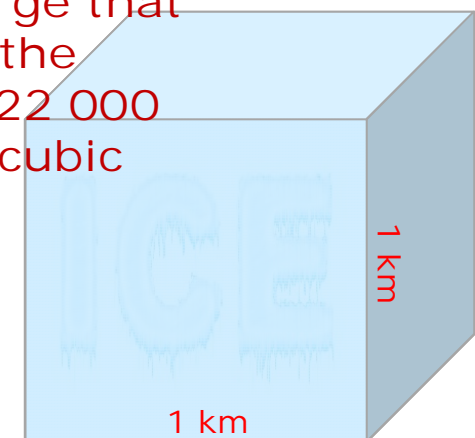
Socio-economy of reindeer herding
(work underway)

Photo: Camilla Sandström

Reindeer husbandry case studies

- 6 districts
- 2 in each country (Norway, Sweden & Finland)
- Stakeholder workshops during autumn-winter 2014-15
- Herders + academics
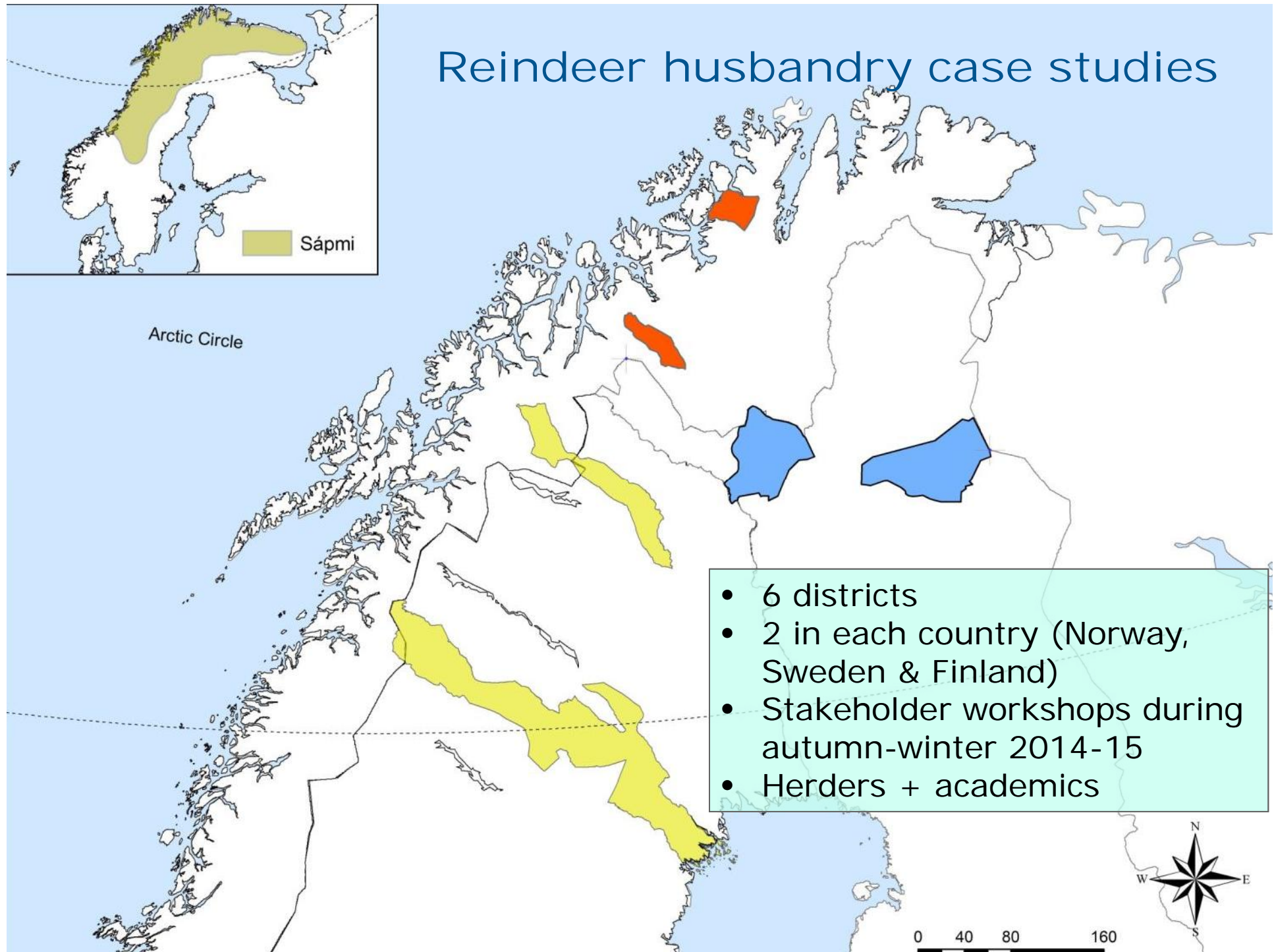
> "Social landscape: nature is a home—a community of biotic actors with whom to have social life... livelihoods are interwoven with conservation goals."
>
> (Heller & Hobbs 2014)

⟹ Landscape of multiple values, priorities and practices based on social heterogeneity

Can we adapt and implement existing grazing practices as management tool on large spatial scales?

⟹ we need to understand actor behaviour

Photo: Philip Burgess

Decision-making in reindeer husbandry

Socio-administrative drivers

National — Regional — Local

Ecological drivers

Patch — Landscape — Region

EU regulations

Legislation of trans-border grazing

Mobility across landscapes / borders

Certification schemes

Land use legislation

Land use planning

Power distribution

Self-determination

Siida – decision making

Reindeer management

Availability / accessibility of grazing resources

Weather dynamics

Plant community composition

Density dependency of reindeer condition

Increasing hierarchical organization

Tundra synthesis in 2015

Abiotic changes
(temperature, snow, freeze-thaw cycles ...)

Biotic changes
(vole dynamics, moth dynamics, birch forest structure & function, food webs...)

Sámi culture and reindeer herding practices
(ecology, economy, politics,...)
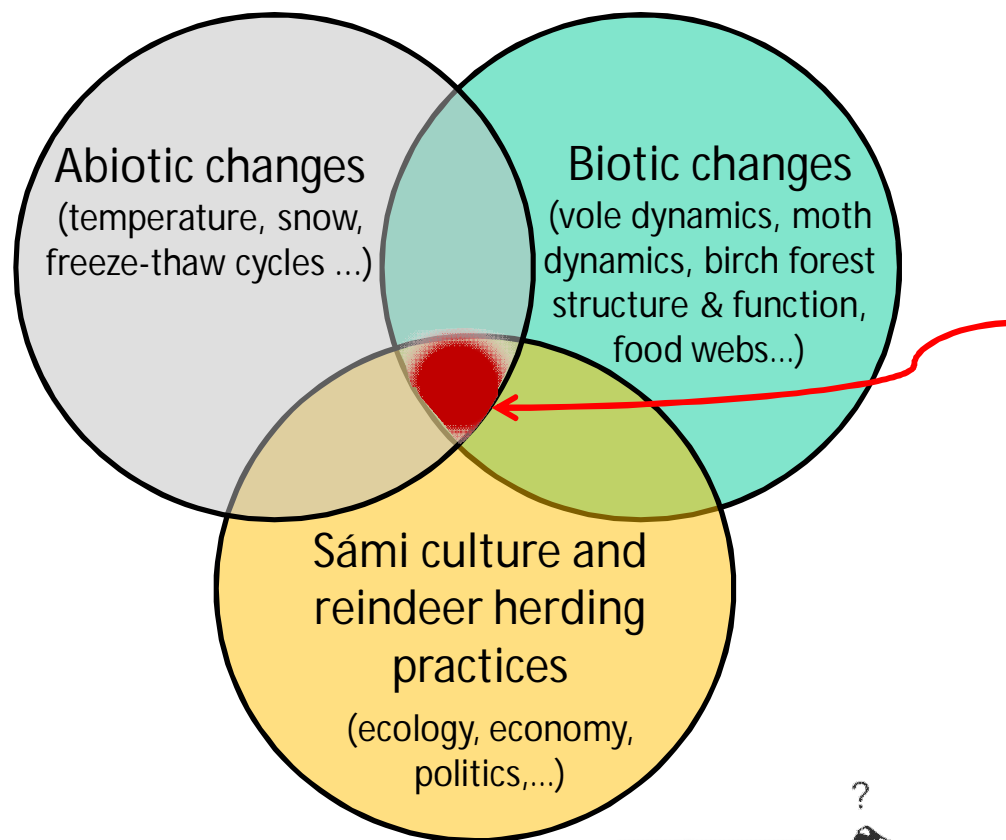
Integration and analysis of information from work packages

- GIS database building
- Include material from the reindeer workshops
- Model the entity with a systems model (????)
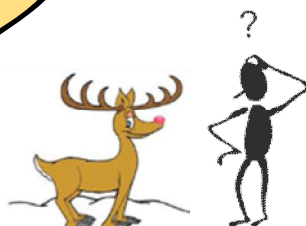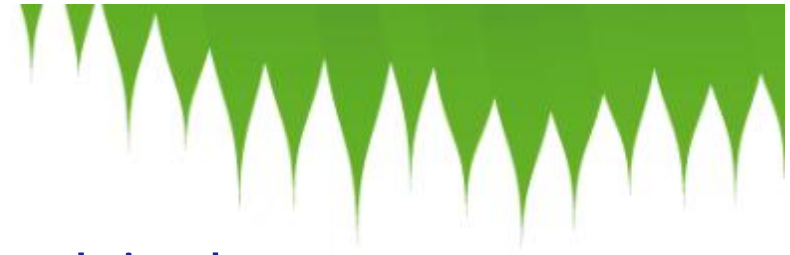- Narratives and Scenarios for decision makers

The co-evolving relationship between people and nature

Science *('the truth')* — Communication — Policy *('power')*

What are the *ecological consequences* of the decline in tundra habitat?

Does the decline in tundra habitat warrant a *change in policy*?
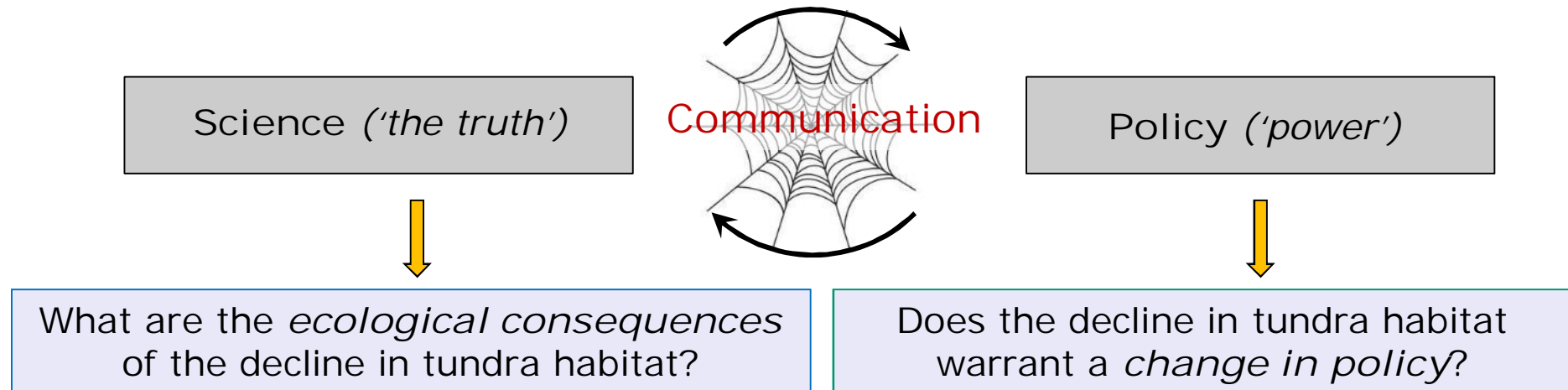
Co-production of knowledge by science and society needed for policy decisions

(Vogel et al., 2007)

Resilience of reindeer husbandry livelihood will require co-existence of:

Viable social-cultural-economic system

Critical ecosystem functions at variable spatio-temporal scales

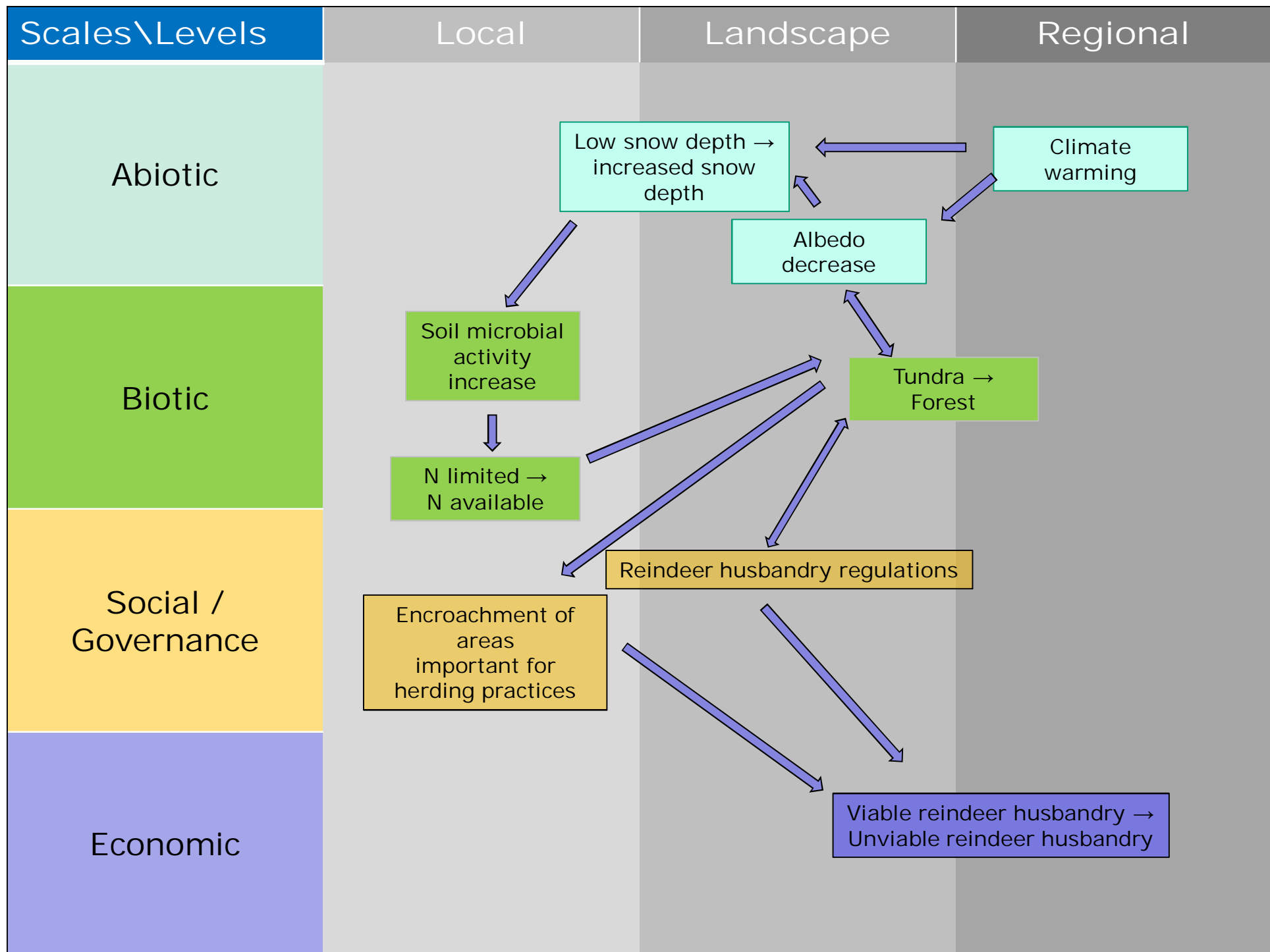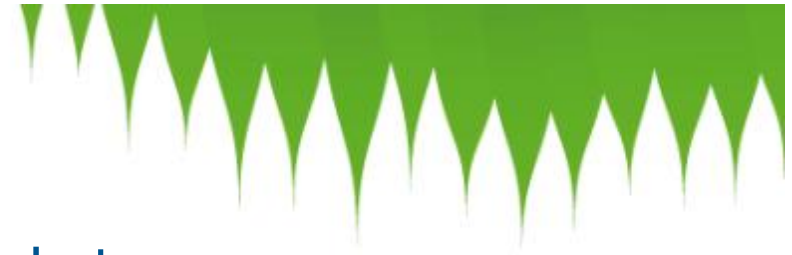| Scales\Levels	Local	Landscape	Regional
Abiotic		Low snow depth → increased snow depth	Climate warming
		Albedo decrease	
Biotic	Soil microbial activity increase	Tundra → Forest	
	N limited → N available		
Social / Governance	Encroachment of areas important for herding practices	Reindeer husbandry regulations	
Economic			Viable reindeer husbandry → Unviable reindeer husbandry

Conclusions to date

- **reindeer are able** to keep the forest down by eating seedlings
- dramatic **influence on albedo** -> **climate mitigation tool**
- **timing of grazing** is crucial - > **optimization of herding practices**
- however, we have **no control on natural herbivory** (moth, rodents), which has a strong influence on the ecosystem
- to **harmonize ecological and socio-economic** requirements, **co-designed scenarios** are necessary
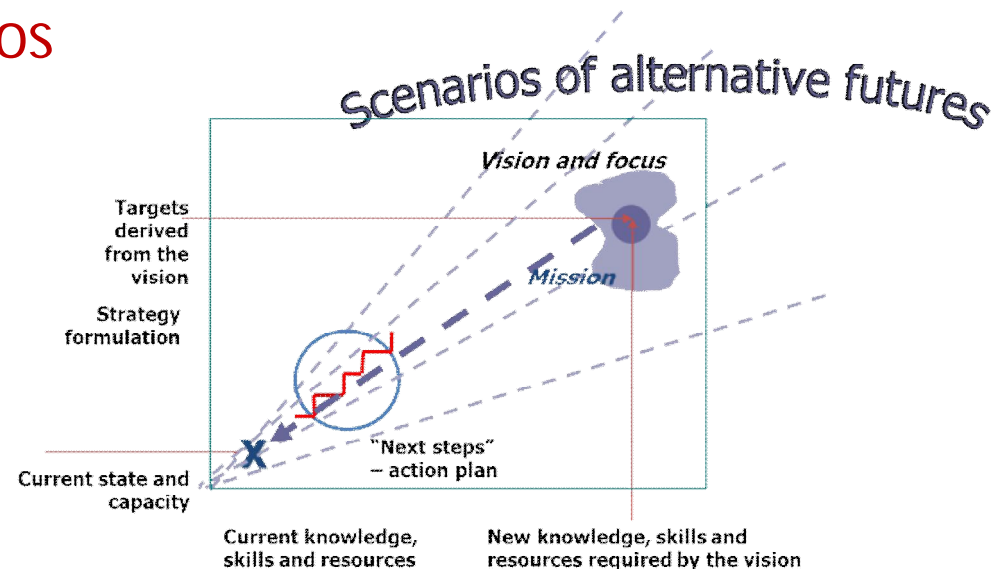
What next?

- Can this socio-cultural-economic-ecological system be modelled (at all)?
- If yes, what components, spatial entities, temporal framework, resolution etc. can be incorporated?
- Is it doable in collaboration with IIASA?
- If not, we will 'downgrade' the synthesis to qualitative narratives and scenarios
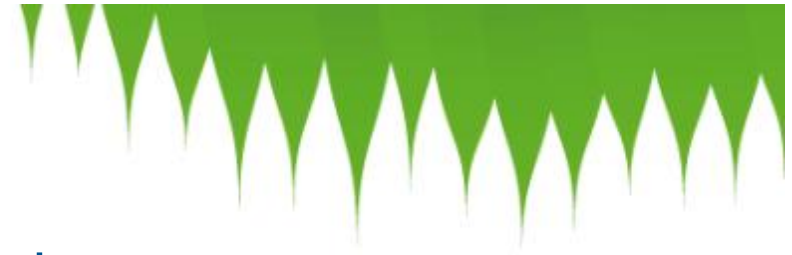
Our data include:

- DEM, Northern Fennoscandia, 25-50 m
- WorldClim climate data, Northern Fennoscandia, 30 arc seconds-2.5 minutes grid; current situation and projections for 2050 and 2070
- Temperature data from weather stations in Northern Fennoscandia; temporal coverage depends on the station
- Bedrock; covers parts of Northern Fennoscandia; resolution of data depends on the area of interest
- Vegetation map, Northern Fennoscandia; 30 classes, 100 m resolution
- Reindeer numbers per herding district 1950-2014 (Finland, Sweden, Norway)
- More detailed reindeer district data from Finland*
- Detailed temperature data from selected field sites

norden
Top-level Research Initiative

Turun yliopisto
University of Turku

*Reindeer district data

- Number of reindeer owners
- Highest allowed number of animals
- Number of animals not slaughtered in the annual round-up (='living animals')
- Number of slaughtered animals
- Number of working days / 'counted animals' (> 1 yr old 'living animals')
- Number of living a) calves, b) males, c) castrated males
- Number of slaughtered a) calves, b) males, c) castrated males
- Number of 'counted animals'
- Number of sold animals a) 'counted animals', b) calves
- Number of calves a) living, b) slaughered, c) total
- Calf %
- Purchase of 'living animals' a) 'counted animals', b) calves
- Work € / 'counted animal'
- Damages € / 'counted animal'
- Other € / 'counted animal'
- Expenses total € / 'counted animal'
- Net profit € / 'counted animal'
- Lost counted animals
- True 'living animals'