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Suomen ympäristökeskus
Finlands miljöcentral
Finnish Environment Institute

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Remote sensing the habitats of Northern Lapland

Kilpisjärvi

5th of September 2024

Anna Tammilehto

Metsähallitus, National Parks Finland

Photo: Anna Tammilehto


Photo: Anna Tammilehto

The project in short

- Project duration: 2020-2023
- Partners: Metsähallitus National Parks Finland and Finnish Environment Institute
- Annual budget: 310 000 €
- Funding: Ministry of the Environment and Finnish Environment Institute
- The project report – published 2/2024 (in Finnish)

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Photo: Saku Anttila

Henkilöstö

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- **Maastotiimi**
  - 2020: Laura Puikkonen ja Inka Kuusisto + Arto ja Anna
  - 2021: Aleksi Pudas ja Terhi Hultamo + Arto ja Anna
  - 2022: Saana Mattanen ja Terhi Hultamo + Arto ja Anna
  - Mukana olleet myös Saara Tynys ja Pauliina Kulmala

Background and aims

- Habitat data from the northernmost Finland is old (most red areas in the map)
  - Nature conservation areas (state and private), wilderness areas, Natura 2000- areas
  - Collected in LUOTI-project in 1996-2000
  - 20 % field observations and 80 % mapped using aerial photographs
  - Data is needed and used e.g. in Habitat´s directive reporting, assessment of threatened habitat types, land use planning
- Need for updating the data is urgent
  - Geographically vast area; 2,8 million hectares
  - Pressures on land use
  - Monitoring environmental change

  -> Earth observation/remote sensing

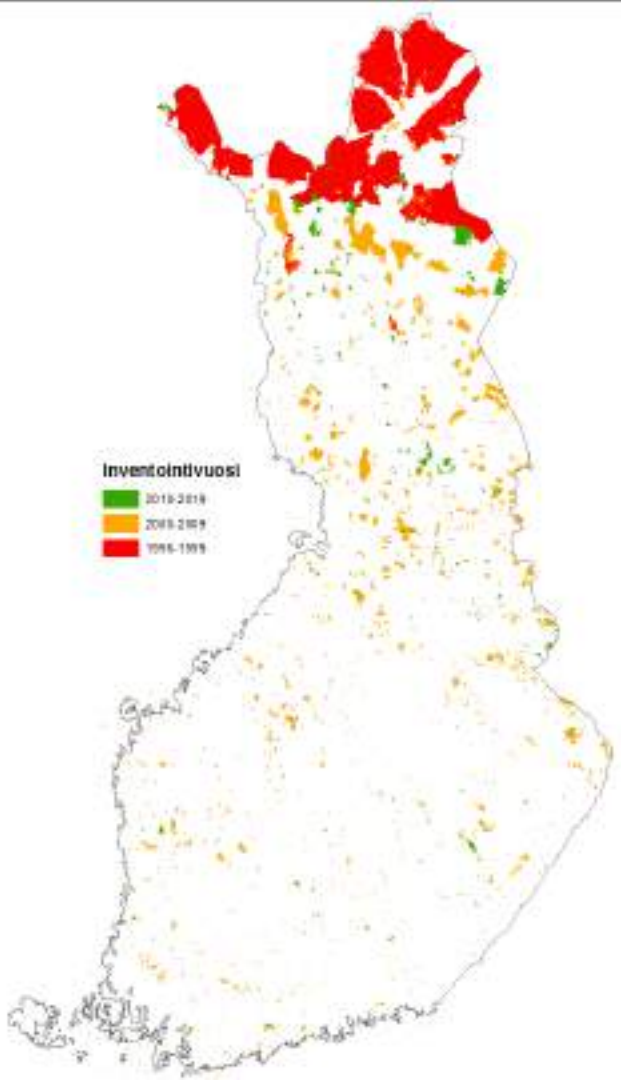


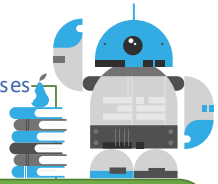

Photo: Laura Puikkonen/MH

Objectives

I. Habitats Directive habitat type (Annex I) (minimum level)
   - And representativity (when possible)

II. Habitat type defined by vegetation (more detailed inventory class)

Work flow



The amount of field data increases

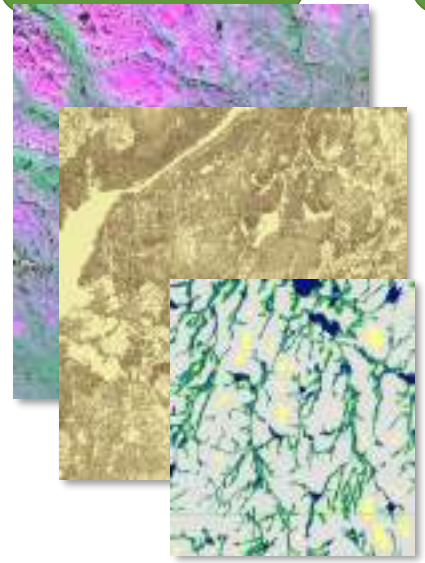
Compilation and processing of remote sensing data and map data

Field data collection

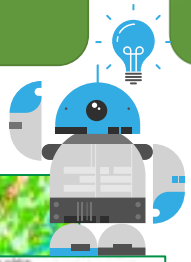
Machine learning using a subset of field data "training data" i.e. model building

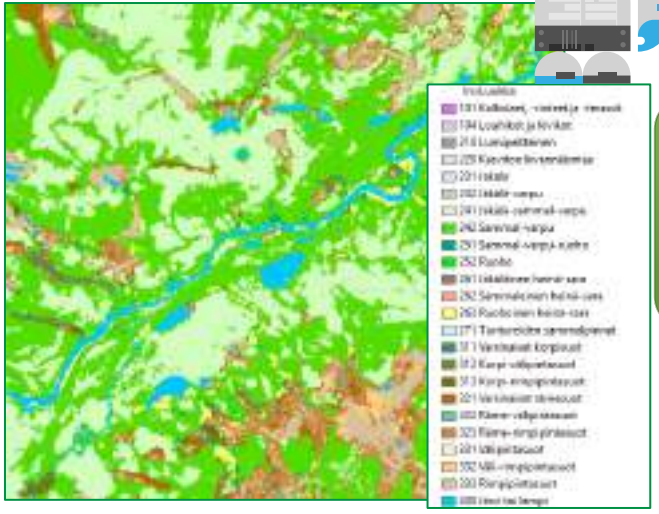
Model validation using another subset of field data

Model application i.e. identifying habitat types using remote sensing data



Which field parametres are the best?
Which remote sensing data to use?

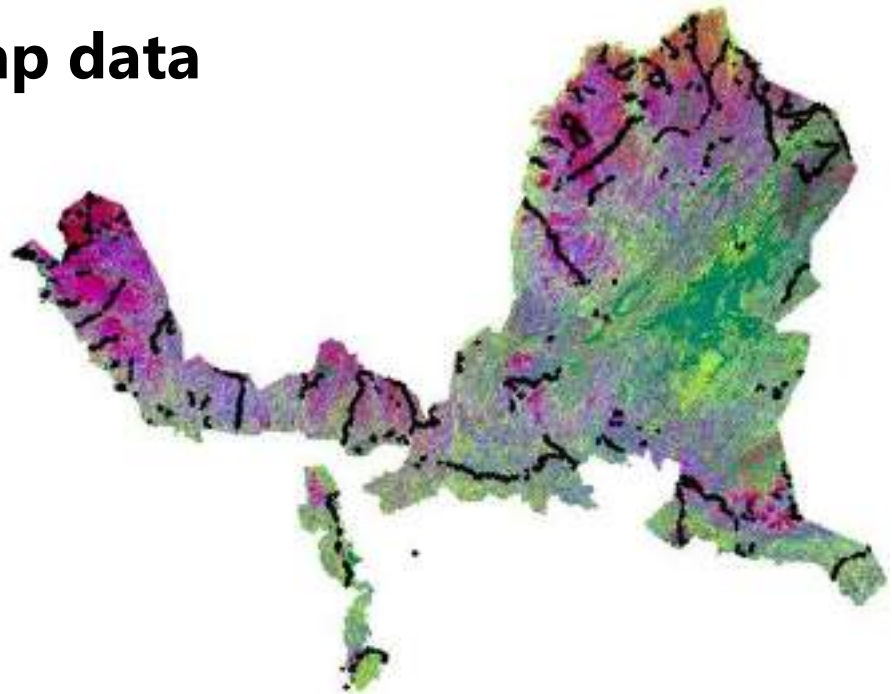




Updated habitat data

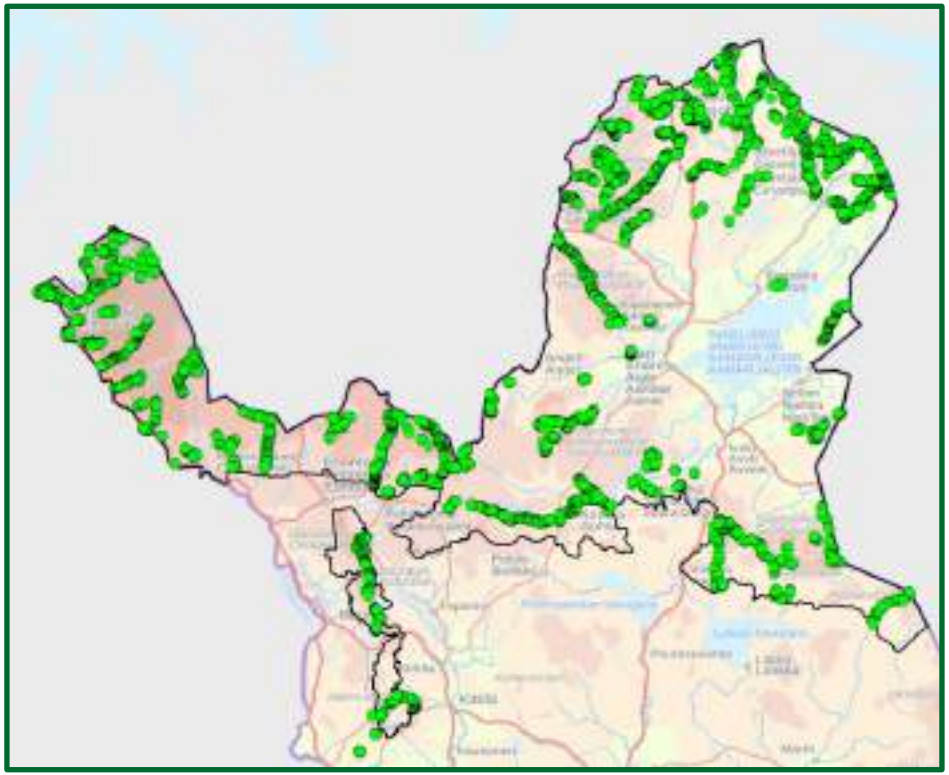
Input remote sensing and map data

- Satellite data
  - Sentinel 2, Sentinel 1, VHR images (Copernicus)
- Airborne data
  - Lidar
  - OrtoPhotos
- Map data
  - Topographic database (National Land Survey)
  - Map masks: e.g. delineation of fjell habitats
  - Other: land use and land cover (HR Corine by Syke)

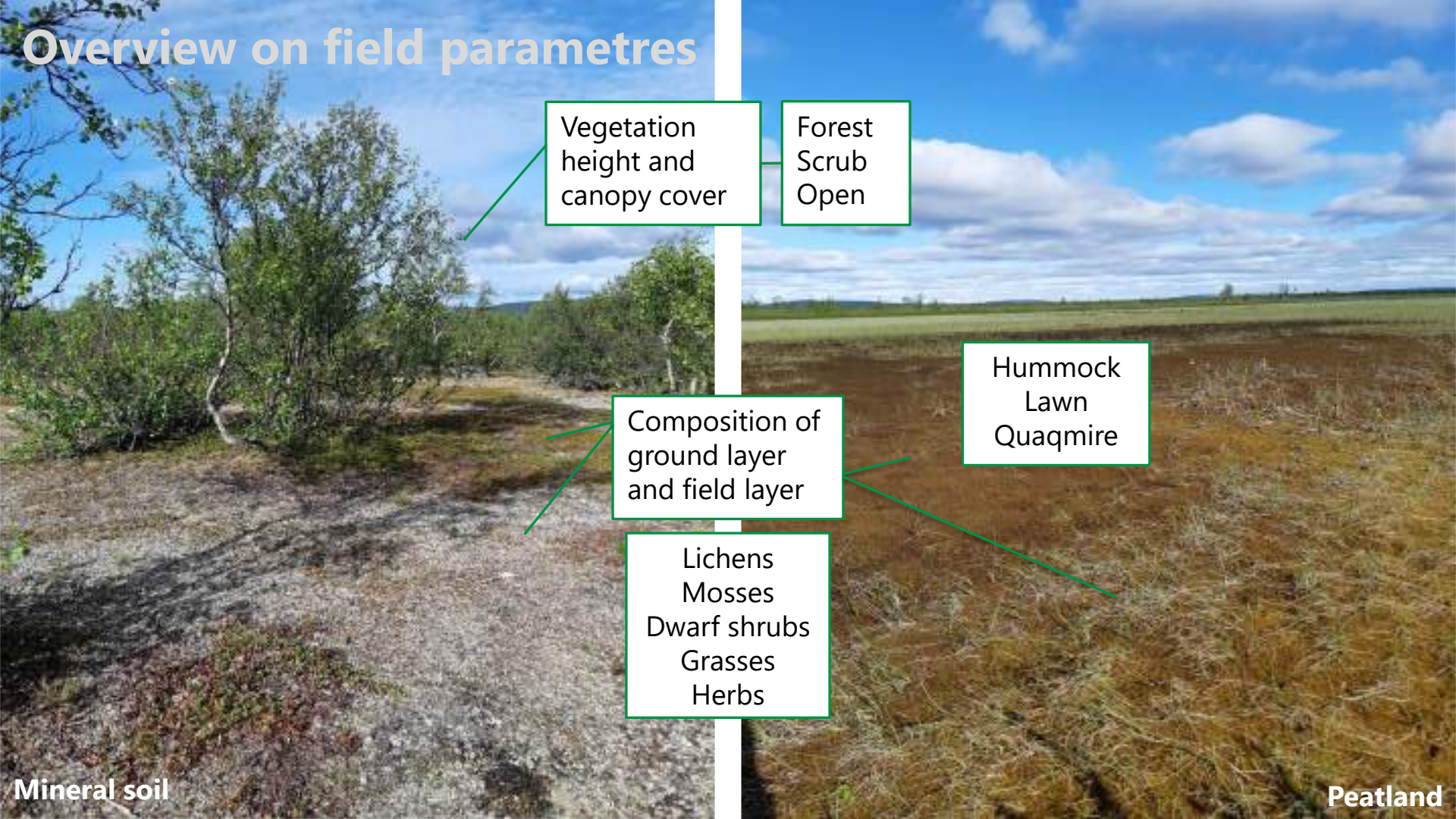


Field data collection

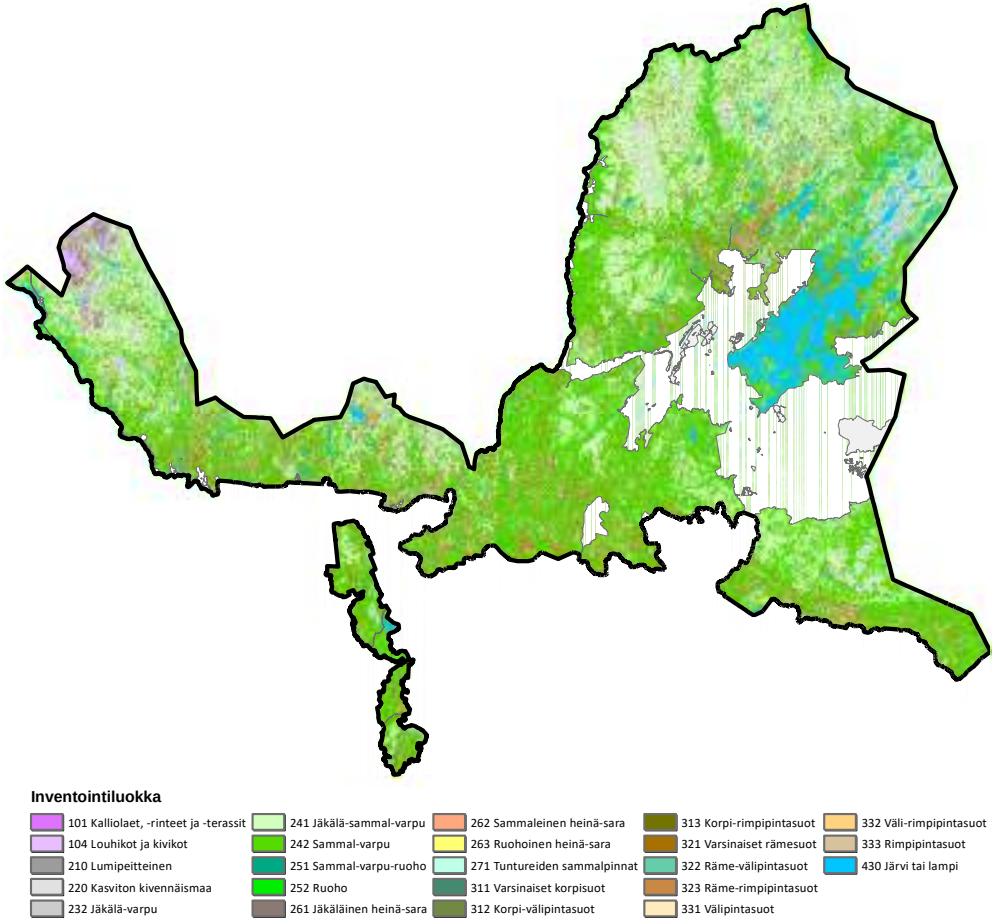
- 4500 field data points (2020-2022)
- Field data (habitat data) collected from predefined and random (interesting) spots (Ø 20 m) to cover all habitat types + special sites



Overview on field parametres



Results



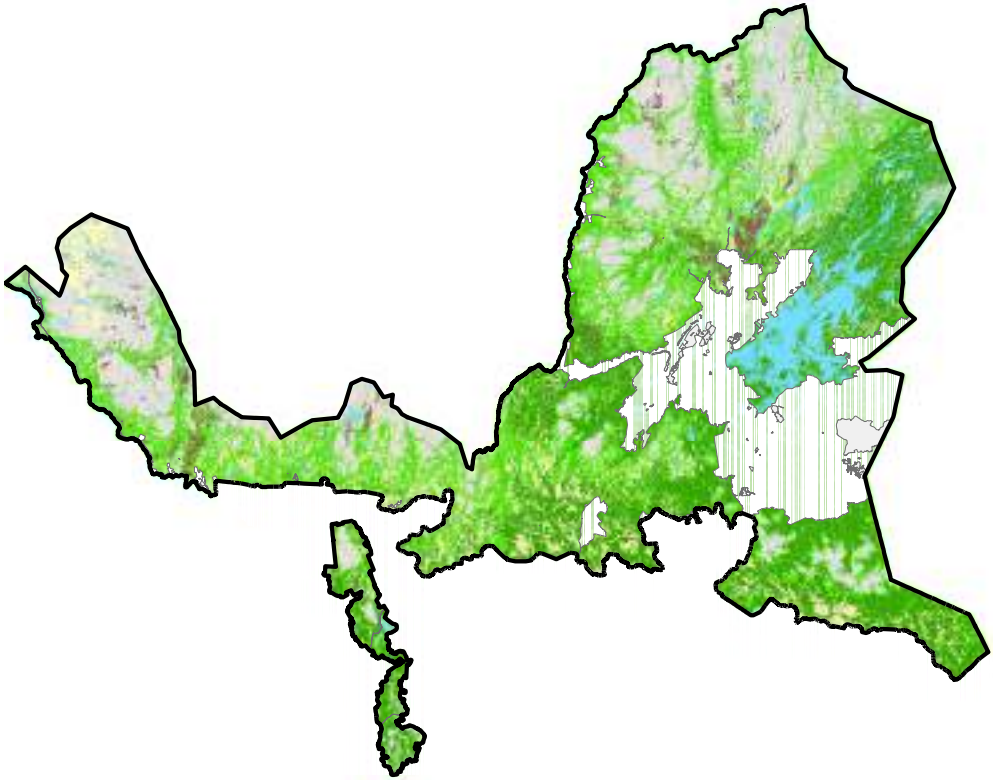
Inventory class

- 82 % of land areas inventory class resolved with more than 80 % accuracy


Photo: Terhi Hultamo/MH

Producing an inventory class with remote sensing is the most accurate in the following:

- 101 Rocks
- 104 Boulder fields
- 241 Lichen-moss-dwarf shrubs
- 242 Moss-dwarf shrubs
- 251 Moss-dwarf shrubs-herbs
- 271 Mossy surfaces of fells
- 331 Intermediate surface fen
- 333 Quaqmire fens
- 430 Lakes and ponds



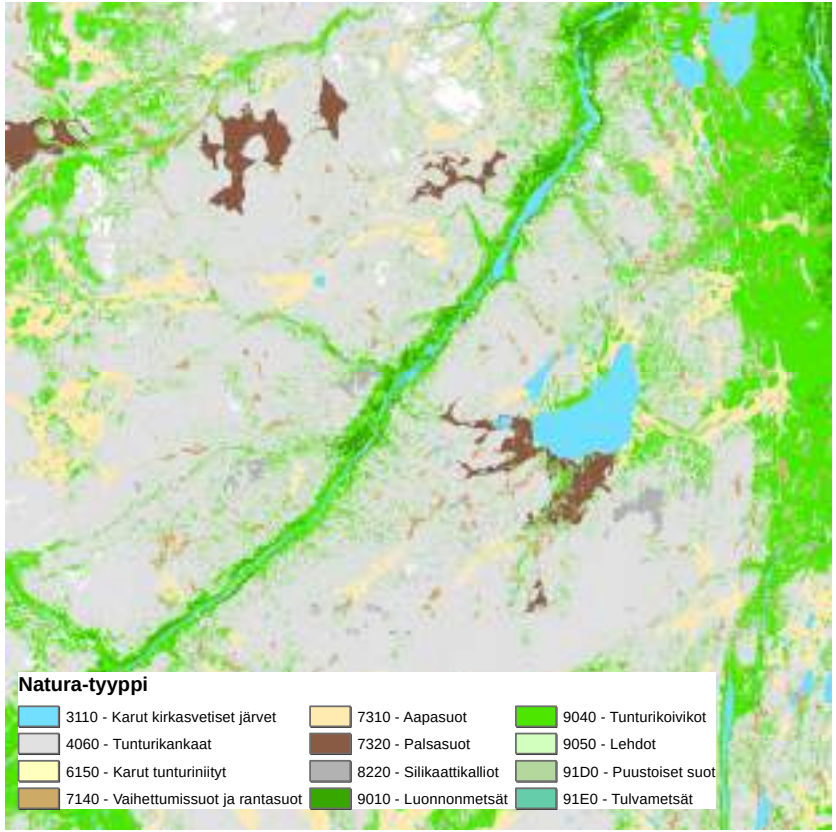
Annex I habitats

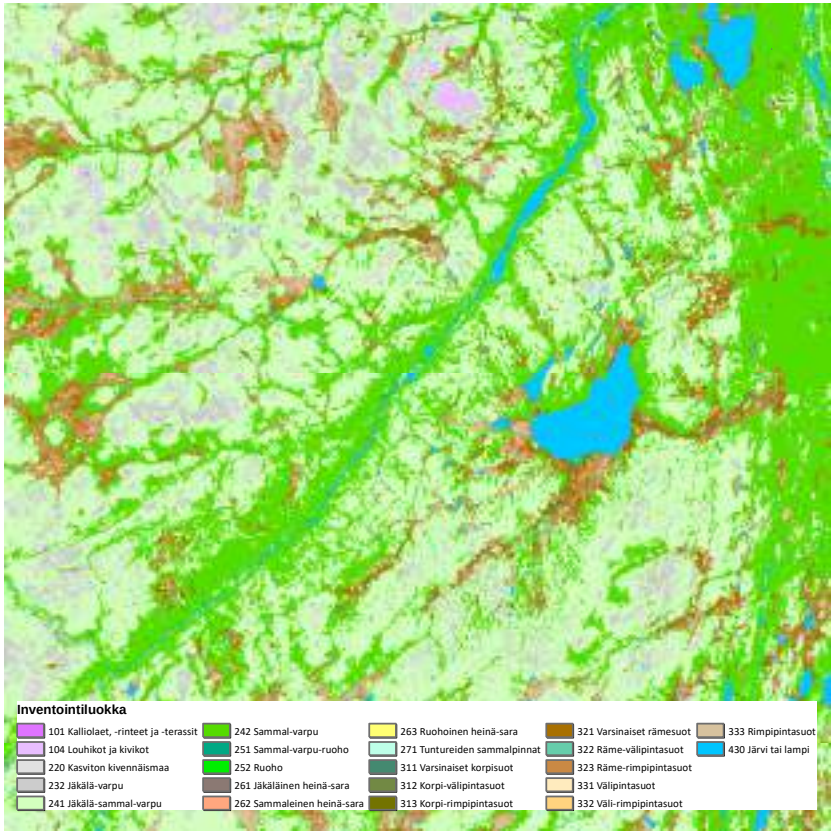
- F1-score weighted = 0,86 (Ø 15 m)
  - Expert system


Photo: Saana Mattanen/MH

Producing the Annex I habitat type with remote sensing is the most accurate in the following:

- 3110 Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae) (Note: can include some Natural dystrophic lakes and ponds)
- 4060 Alpine and boreal heaths
- 6510 Siliceous alpine and boreal grasslands
- 9010 Western taiga
  - Can be distinguished from 9040
  - Can not be reliably distinguished from managed conifer forests
- 9040 Nordic subalpine/subarctic forests with Betula pubescens ssp. czerepanovii


Natura-tyyppi
3110 - Karut kirkasvetiset järvet
4060 - Tunturikankaat
6150 - Karut tunturiniityt
7140 - Vaihettumissuot ja rantasuot
7310 - Aapasuot
7320 - Palsasuot
8220 - Silikaattikalliot
9010 - Luonnonmetsät
9040 - Tunturikoivikot
9050 - Lehdot
91D0 - Puustoiset suot
91E0 - Tulvametsät

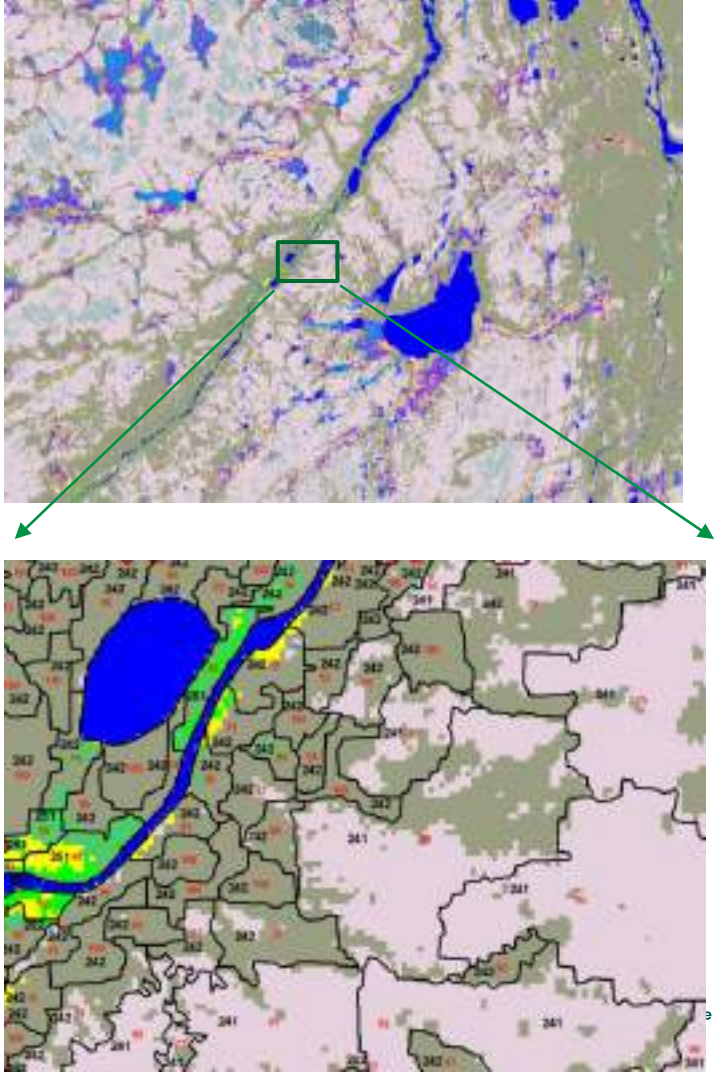

Inventointiluokka
101 Kalliolaet, -rinteet ja -terassit
104 Louhikot ja kivikot
220 Kasviton kivennäismaa
232 Jäkälä-varpu
241 Jäkälä-sammal-varpu
242 Sammal-varpu
251 Sammal-varpu-ruoho
252 Ruoho
261 Jäkäläinen heinä-sara
262 Sammaleinen heinä-sara
263 Ruohoinen heinä-sara
271 Tuntureiden sammalpinnat
311 Varsinaiset korpisuot
312 Korpi-välipintasuot
313 Korpi-rimpipintasuot
321 Varsinaiset rämesuot
322 Räme-välipintasuot
323 Räme-rimpipintasuot
331 Välipintasuot
332 Väli-rimpipintasuot
333 Rimpipintasuot
430 Järvi tai lampi

Accuracy of Outputs - summary

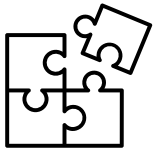
Target variables	Thematic coverage: No of classes: field /output	Overall accuracy	F1-score - Average	F1-score-weighted	n	Observations
Natura2000	64 % (14/22)	0,87	0,79	0,86	3522	• ML not succesfull > expert system • Only part of classes included • Also classes with low accuarcy
Inventory class	70 % (21/30)	0,80	0,70	0,79	630	• Only part of classes included • Accuracy in peatlands lower • Also classes with low accuarcy
Dominant tree species	100 % (8/8)	0,91	0,78	0,90	317	• Postprocessing effective • Tree lines, fells, etc..
Forest cover	100 % (3/3)	0,90	-	-	3671	• Accuracy of Lidar very OK • Low vegetation / big rocks problematic
Lichens (status)	40 % (2/5)	0,92	0,88	-	341	• Rocky soils problematic

Main outputs

- **Thematic maps**
  - Classification output (Annex I, inventory class)
  - 10*10 m raster
- **Geometry for habitat information**
  - Polygons
    - Why: End users use traditionally vector data
    - Derived using segmentation (ERDAS Imagine FLS)
    - About 1 300 000 polygons in the project area
  - Attributes
    - All information
    - Target classes and their proportion
      - 3 most common class in the polygon
  - Will be stored in a GIS-database (Parks & Wildlife Finland) and shared as open data

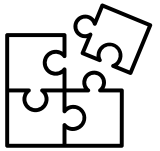


Conclusions 1/2



- Remote sensing is suitable for large-scale habitat types (groups) such as alpine and boreal heaths, mountain birch forests and meadows
  - For example, the resolution of the Sentinel 2 satellite is 10 m
  - Field data is still needed, especially for small-scale habitats and otherwise more special/rare habitats, such as the most nutrient-rich habitats, as well as training and validation data for modeling
  - Which characteristics describe the state of the habitat? Can they be remotely mapped?
    - With fell nature types, e.g.
      - The state of the terrestrial lichens- can be remotely mapped
      - the regenerative capacity of mountain birch- developing, can be remotely mapped
      - Elevation of the pine - requires information about individual trees
      - Possible scrub encroachment - requires development work
- With remote sensing, it is possible to produce data on areas that require a field check-> more efficient targeting of field inventories (e.g. herb rich forests)

Conclusions 2/2



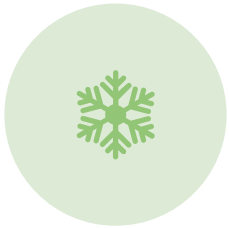
- There must be enough training data for the model, i.e. field data per habitat type, and it must be of high quality
  - In addition to model training, field data is needed in model validation, i.e. in assessing the reliability of the model
  - Field data should cover the internal variation of the habitat type, but on the other hand, the individual data spots used in model training should be as homogeneous as possible
  - Inventory class produced in raster format -> data can be generated for the polygon, e.g. from the three most common inventory classes -> at least with large patterns, habitat type information can be produced that is even more accurate than field mapping (the previous method)
  - Modelling the habitat types requires the use of masks (e.g. peatland, mineral soil, rocky areas)

Habitats

ALPINE AND BOREAL HEATHS

MOUNTAIN BIRCH FORESTS

PALSA MIRES



SNOW BEDS


Kuva: Inka Kuusisto/MH

Alpine and boreal heaths

- Alpine and boreal heaths (oroarctic zone)
  - Treeles or nearly treeless
  - Dwarf hrub dominated

Alpine and boreal heaths (Lichen-dwarf shrubs)

Kuva: Saana Mattanen/MH

Alpine and boreal heaths (Lichen-moss-dwarf shrubs)

Alpine and boreal heaths (moss-dwarf shrubs)

Kuva: Inka Kuusisto/MH

Alpine and boreal heaths (Moss-dwarf shrubs-herbs)

Ecological state of reindeer lichen grounds		Reindeer lichen (living part)			
		coverage (%)	length (mm)	biomass (kg/ha)	production (kg/ha/year)
Intensively worn out	1	< 15	< 15	< 100	< 25
Slowly regenerating	2	15–30	15–25	100–500	25–80
Well-regenerating	3	30–45	25–40	500–1,500	80–130
Maximum-stage productivity	4	45–60	40–55	1,500–3,500	130–150
No grazing		60–70	55–70	3,500–6,000	150–130
Climax stage	5	> 70	> 70	> 6,000	< 25

Kuva: Inka Kuusisto/MH

Alpine and boreal heaths

- State of ground lichens
  - Field assessment (length & coverage) based on classification produced by Natural Resources Institute Finland
  - 5 classes
    - Affects representativity of lichen dominated heaths if ground lichens intensively worn out or slowly regerating

Intensively worn out lichen grounds

Kuva: Saana Mattanen/MH


Well-regenerating lichen grounds
Kuva: Terhi Hultamo/MH

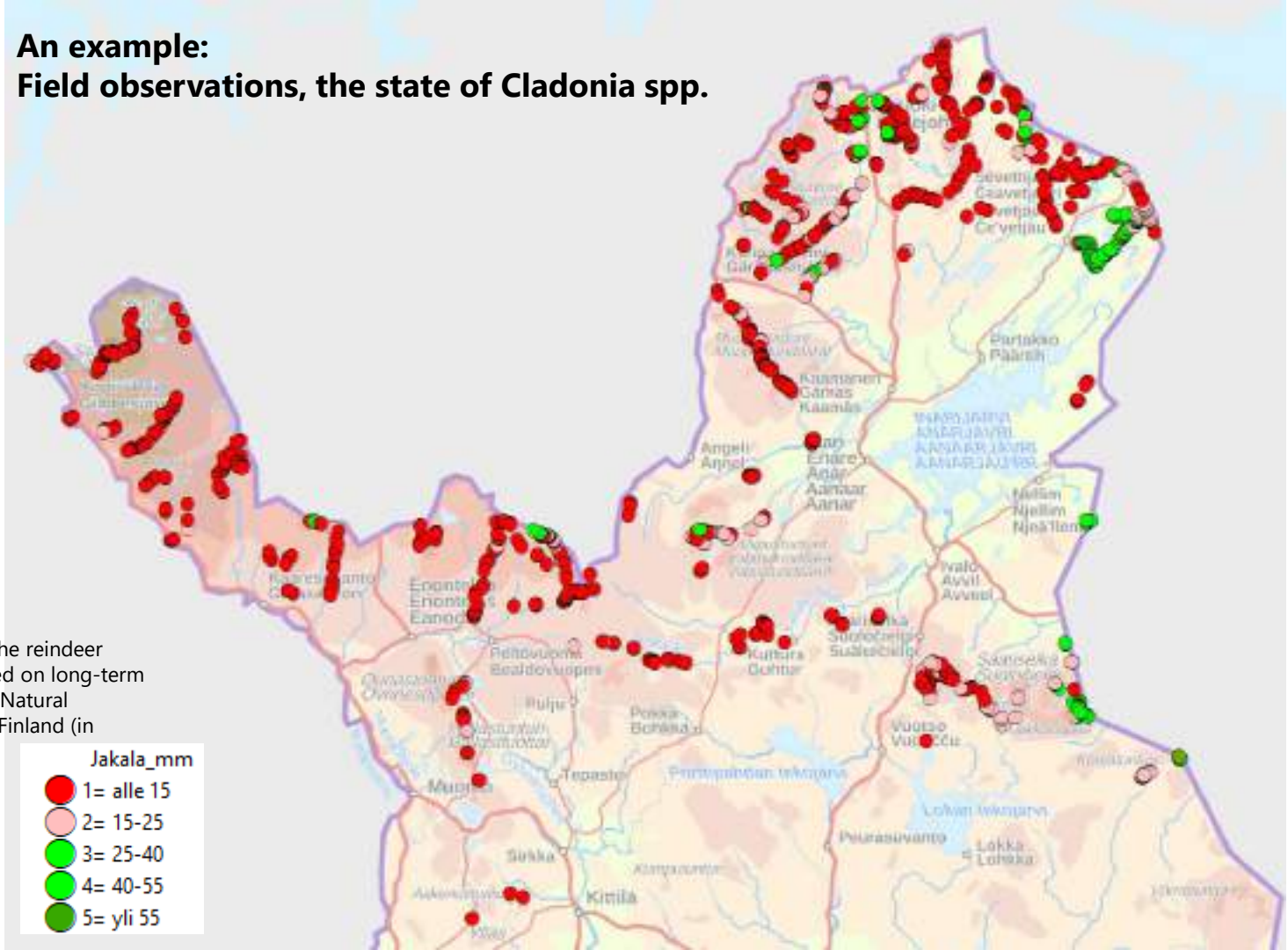
No grazing


Kuva: Laura Puikkonen/MH

Alpine and boreal heaths

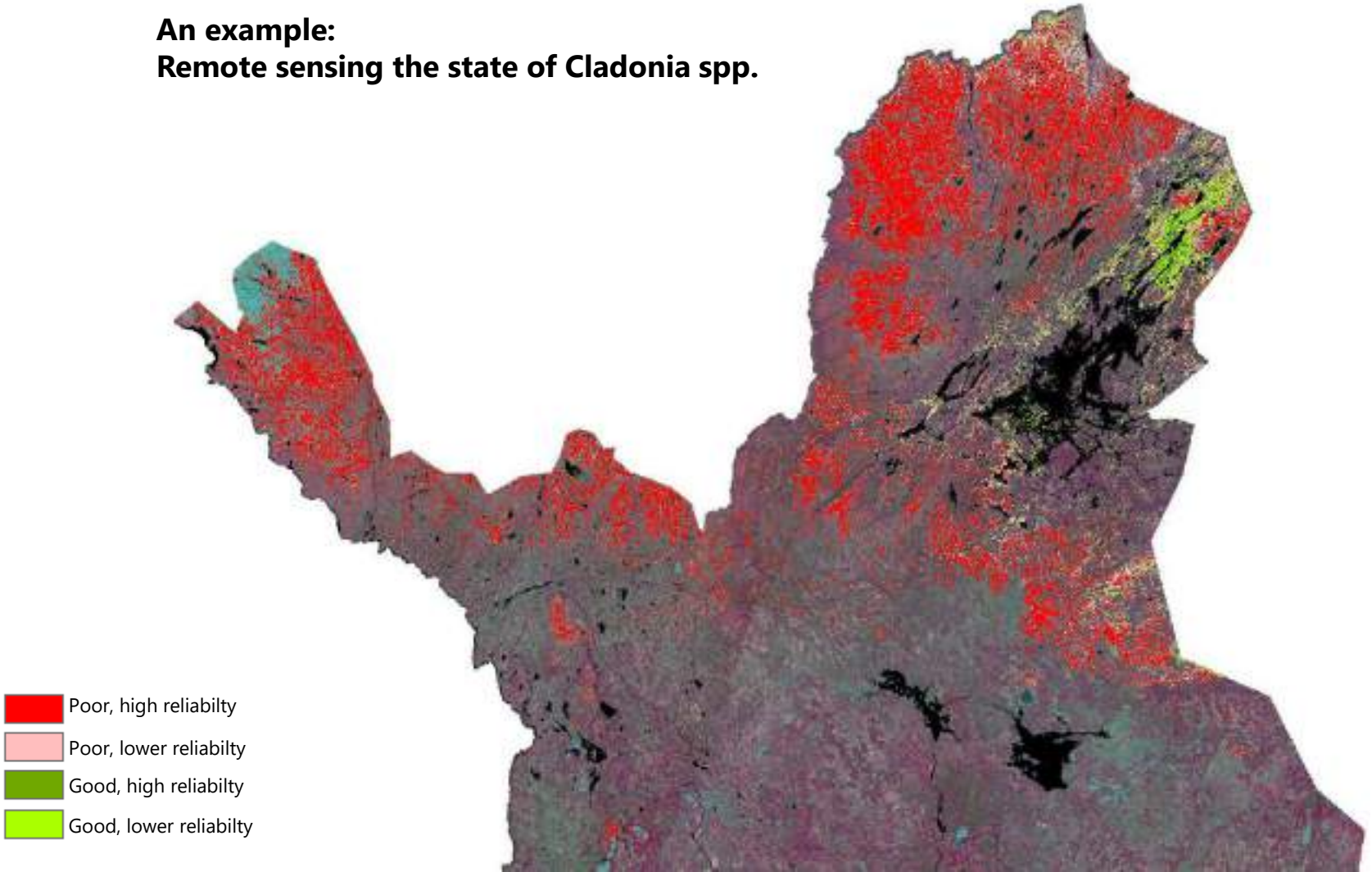
- Lichen grounds in Northern Lapland are mostly intensively worn out or slowly regerating
- Well-regenerating and non grazed lichen grounds are found only in Vätsäri wilderness area and some border zones
- The most significant factor affecting the state of lichen grounds is intensive reindeer grazing pressure

An example:
Field observations, the state of Cladonia spp.



Ecological state of the reindeer lichen grounds based on long-term monitoring data by Natural Resources Institute Finland (in Pääkkö et al. 2018)

An example:
Remote sensing the state of Cladonia spp.



Nordic subalpine/subarctic forests with Betula pubescens ssp. Czerepanovii = Mountain birch forests

- Oroboreal forests on mineral soil dominated by mountain birch
  - Tree height > 2 m
  - Canopy cover > 10 %
    - Of which min. 70 % is mountain birch
- Several types from dry, lichen-rich to moist, herb-rich


Kuva: Anna Tammilehto/MH

Mountain birch forests

- Representativity
  - Regeneration of mountain birch
    - Number of basal sprouts and seedlings (4 classes: well, moderately, poorly and non regenerating)
  - State of lichen grounds in lichen-rich mountain birch forests
  - Damages caused by moths

Mountain birch forest, well regenerating

Photo: Anna Tammilehto/MH

Mountain birch forest, not regenerating

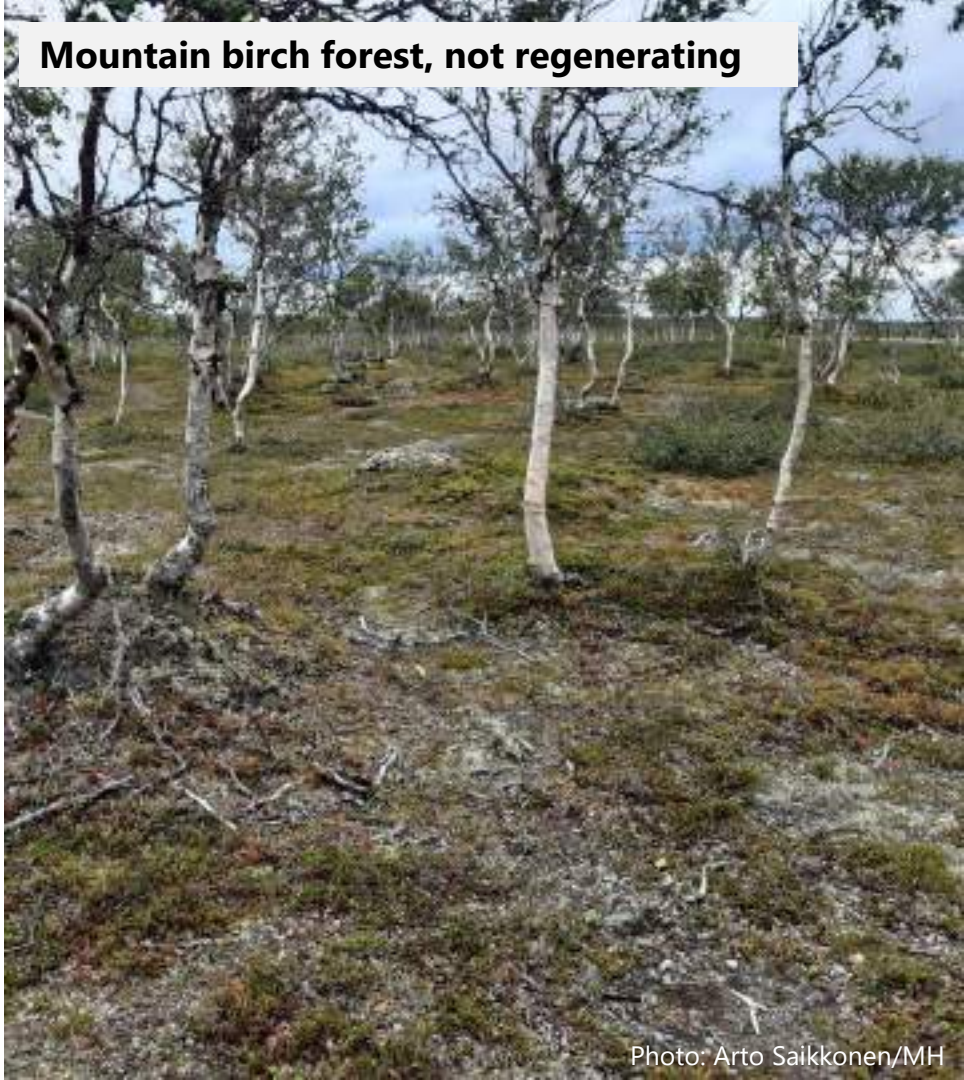
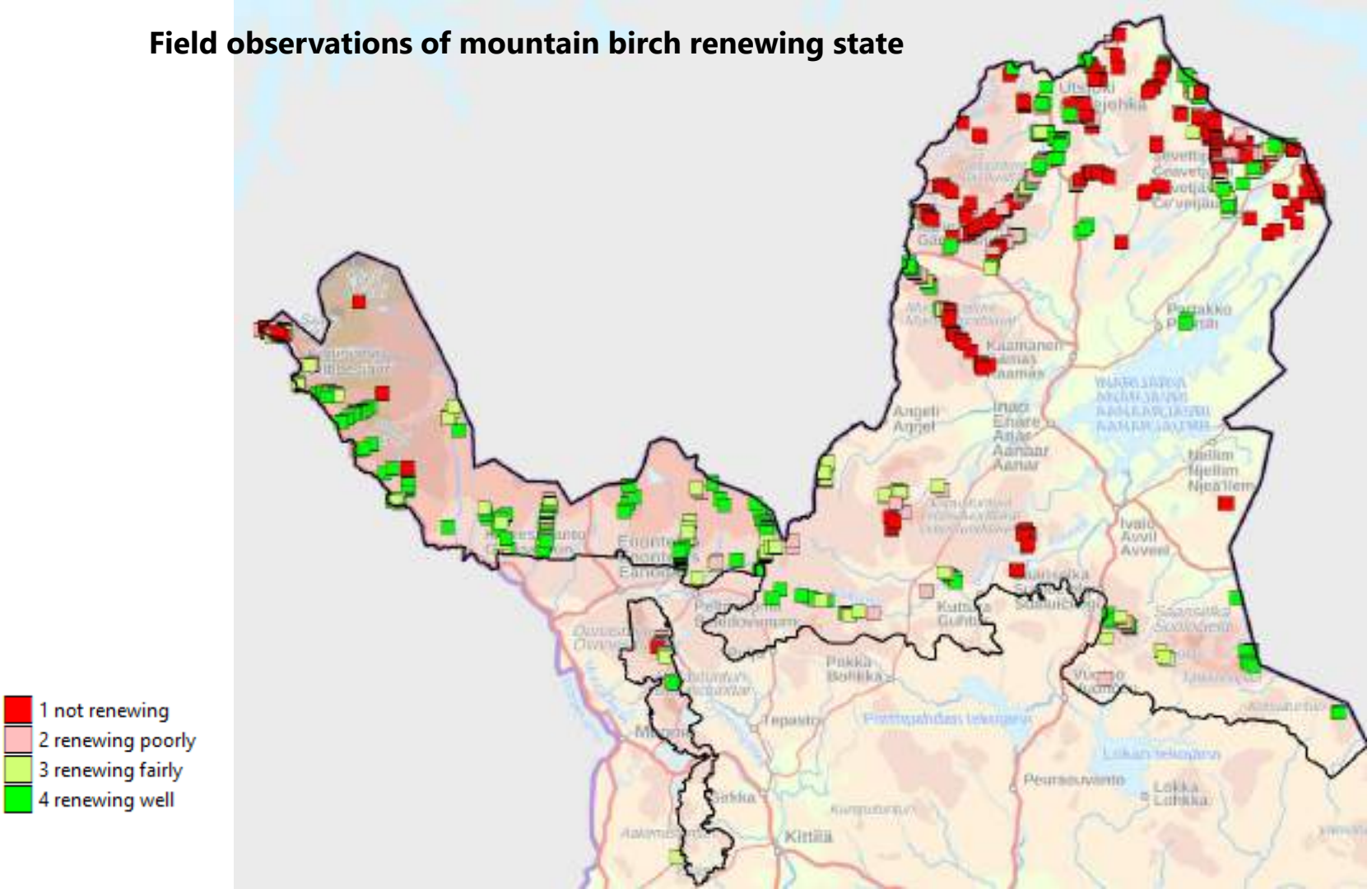


Photo: Arto Saikkonen/MH

Field observations of mountain birch renewing state



Mountain birch forest, renewing well

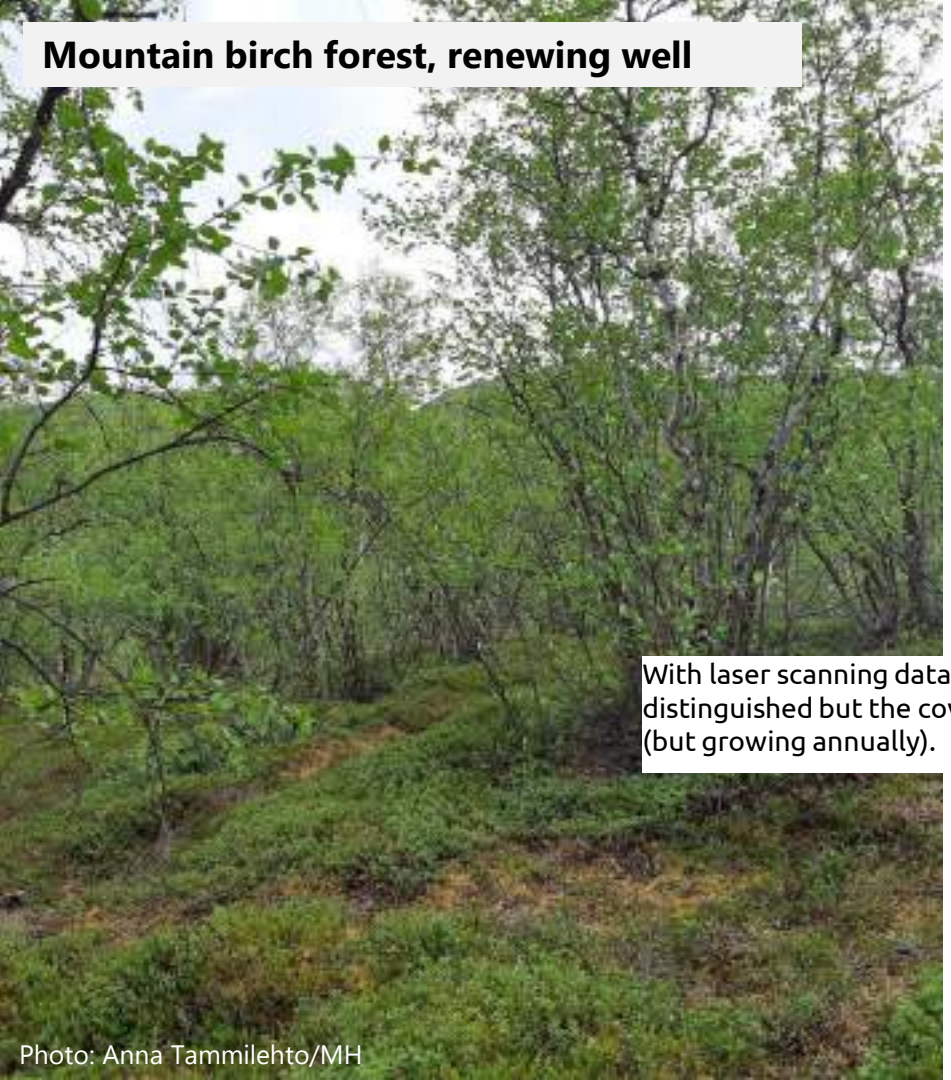


Photo: Anna Tammilehto/MH

Mountain birch forest, not renewing

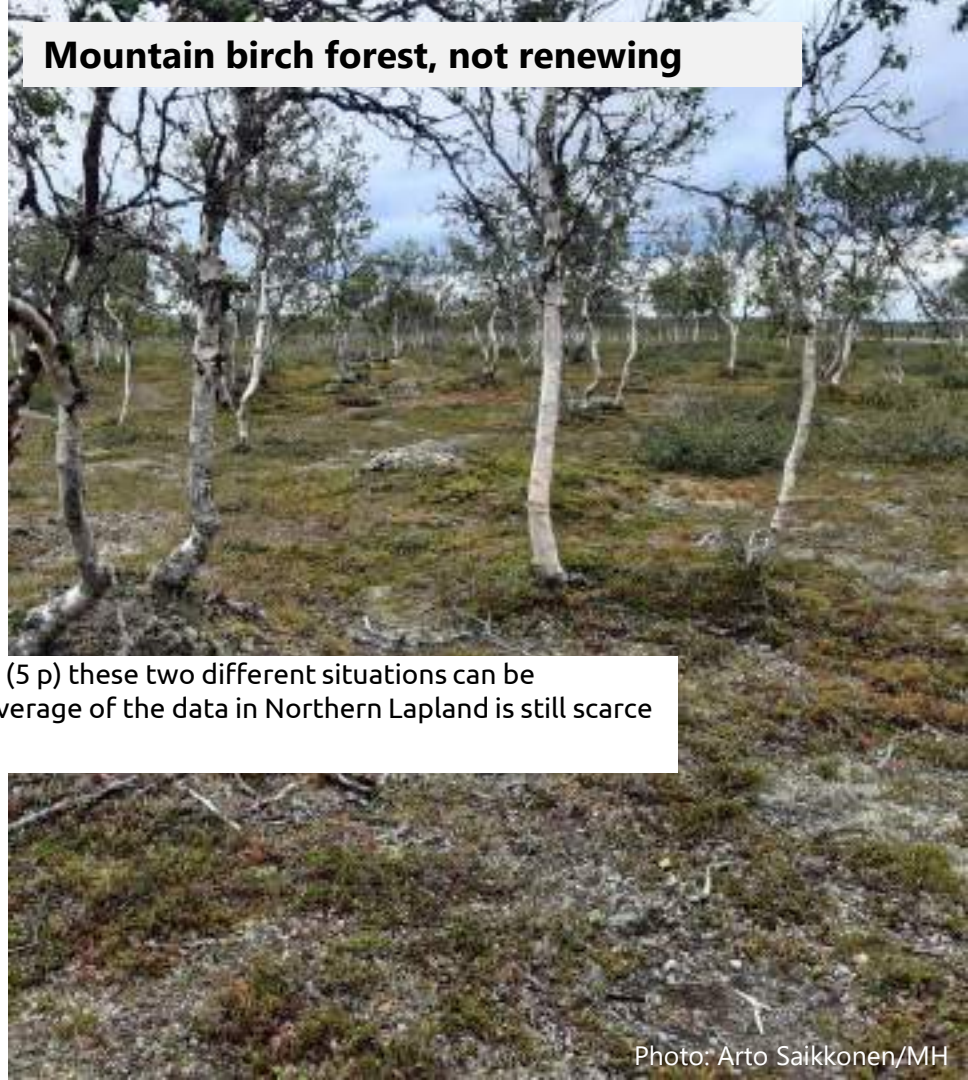


Photo: Arto Saikkonen/MH

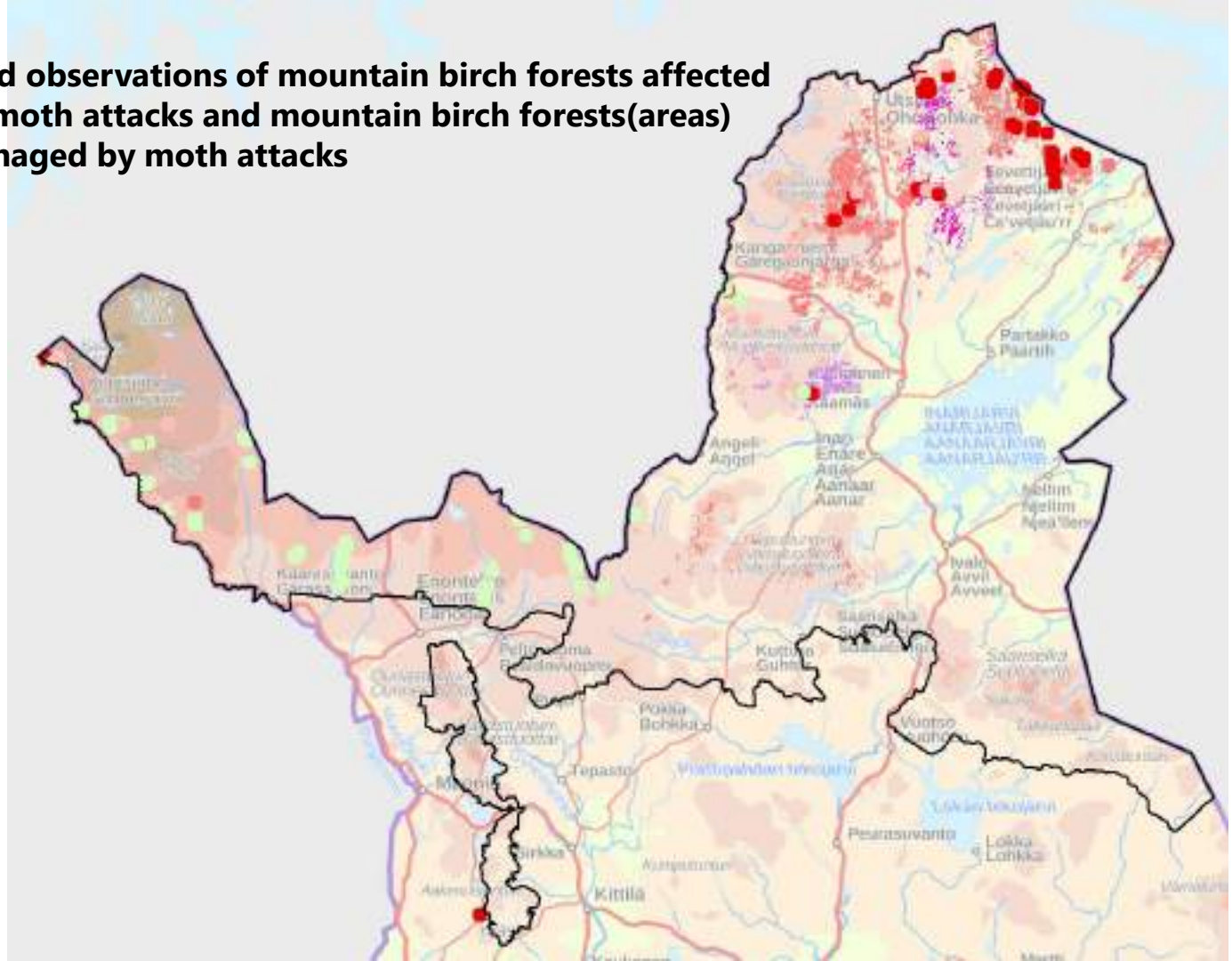
With laser scanning data (5 p) these two different situations can be distinguished but the coverage of the data in Northern Lapland is still scarce (but growing annually).


Kuva: Arto Saikkonen/MH

Mountain birch forests

- Damages caused by the moths
  - Autumnal moth and winter moth
    - During a mass outbreak larvae defoliate extensive areas
      - Expected to become more frequent event because of the climate change
    - Well regenerating mountain birch forest usually recovers from the moth outbreaks

Field observations of mountain birch forests affected by moth attacks and mountain birch forests(areas) damaged by moth attacks



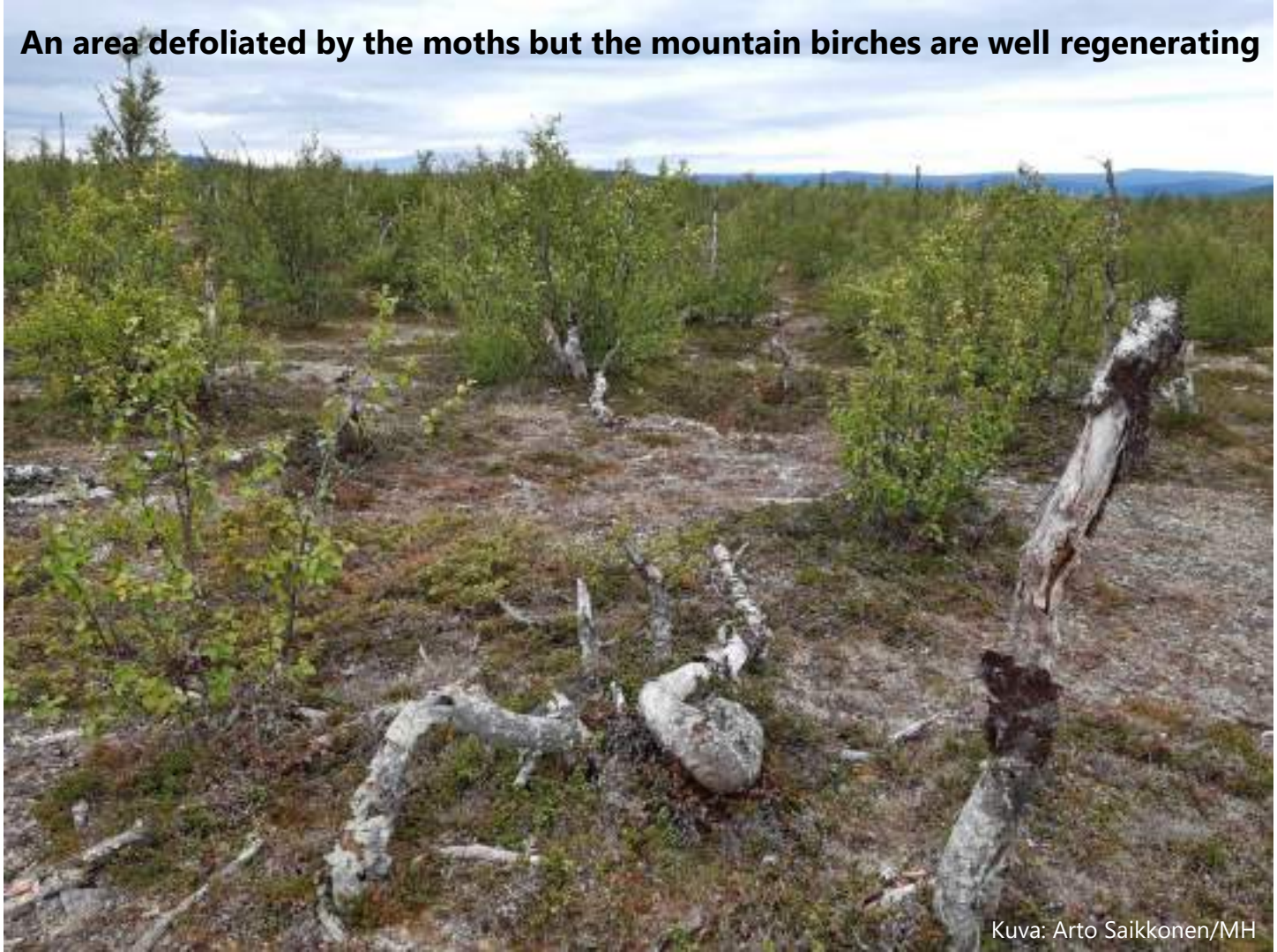
Percentage of mountain birches affected by moth attacks on field sites

- 3= 80-100
- 2= 50-80
- 1= 20-50
- 4= <20

Mountain birch forest after a moth attach, the birches are not regenerating

Photo Arto Saikkonen/MH

An area defoliated by the moths but the mountain birches are well regenerating



Kuva: Arto Saikkonen/MH


Kuva: Arto Saikkonen/MH

Mountain birch forests

- Mountain birches are generally well regenerating in the west (except for Malla and Saana) whereas in the east (especially Kaldoaivi, Paistunturi and Muotkatunturi wilderness areas) the birches regenerate poorly or not at all
  - Lichen-rich mountain birch forests are mostly intensively worn out
- The most signicant factors affecting the state of mountain birch forests are climate chance, intensive reindeer grazing and their combined effects


Kuva: Arto Saikkonen/MH

Palsa mires

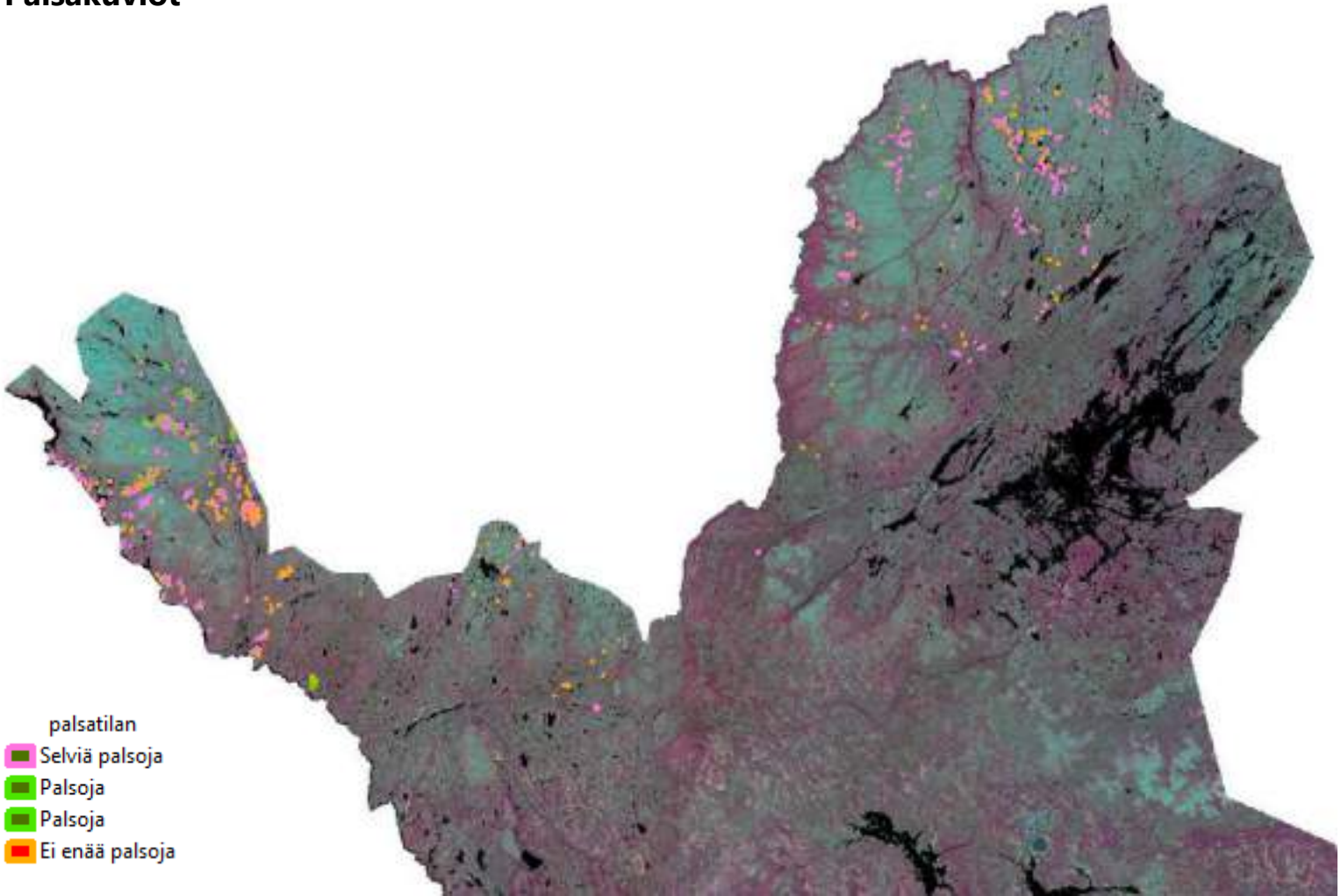
- The northernmost type of aapa mires
  - Contains frost cores = palsa peat mounds (permafrost)


Kuva: Anna Tammilehto/MH

Palsa mires

- State and distribution in the project area
  - Checking old GIS-data on palsa mires (910 targets)
    - Palsas detected on 597 targets
      - 485 clearly detected
      - 112 somewhat detected
    - No palsas detected in 313 targets

Palsakuviot




Kuva: Anna Tammilehto/MH

Palsa mires

- The southernmost known palsa mire Pippovuoma in Pallas-Ylläs National Park has disappeared
  - Palsa mire -> palsas thaw -> aapa mire


Kuva: Arto Saikkonen/MH

Palsa mires

- The most significant factor affecting the palsa mires is the rising temperature which thaws the palsas and prevents regeneration of new palsas
  - In addition, erosion due to off-road vehicle use and reindeer grazing deteriorates the palsas


Kuva: Anna Tammilehto/MH

Snow beds

- Free from snow late-June, mostly July-August
    - Shorter growing season and more moist than surroundings
        - Oligotrophic and eutrophic
    - Above the treeline, in the treeless fell zone
    - Organic layer thin or absent
- *Ranunculus glacialis* Glacier buttercup
    - The northernmost vascular plant
    - In Europe grows at higher altitudes than any other vascular plant


Kuva: Anna Tammilehto/MH

Snow beds

- Identification of areas where snow stays longer (Sentinel 2 – images, 2018-2021)
  - Normalized Difference Snow Index (NDSI) -> identification of snow covered areas
    - Two last weeks of June -> so called snow bed mask
      - Identification of snow beds in the area of snow bed mask
      - The following inventory classes are snow beds in the area of the snow bed mask
        - 261 lichen-rich grassland
        - 262 mossy grassland
        - 263 herb-rich grassland
        - 271 Mossy surfaces of fells


Kuva: Anna Tammilehto/MH

Snow beds

- Huttunen et al. 2023: Lumenviipymien kasvillisuusyhteisöjen ja lajiston seurannat uhanalaisuusarvioinnin tukena
  - LumenviipymäPUTTE – a collaboration project on snow beds


Kuva: Anna Tammilehto/MH

Snow beds

- Reasons for becoming threatened and threat factors
  - Climate change and reindeer grazing

https://www.metsa.fi/projekti/yla-lapin-kaukokartoitus/

https://feosuomi.fi/en/

Suomen ympäristökeskus
Finlands miljöcentral
Finnish Environment Institute

Ympäristöministeriö
Miljöministeriet
Ministry of the Environment

Final report (in Finnish), published 2/2024

Part 1 Material and Methods: https://julkaisut.metsa.fi/julkaisu/yla-lapin-luonnon-kaukokartoitus-projektin-loppuraportti-osa-1-aineistot-ja-menetelmat/

Part 2 Habitats: https://julkaisut.metsa.fi/julkaisu/yla-lapin-luonnon-kaukokartoitus-projektin-loppuraportti-osa-2-luontotyypit/

METSÄHALLITUS

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Thank you

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