IGARSS-2021, Session: TU4.O-14: Biodiversity and Vulnerable Ecosystems

FEO

Finnish Ecosystem Observatory (FEO) – operationalizing remote sensing analyses for threatened habitats and biodiversity monitoring

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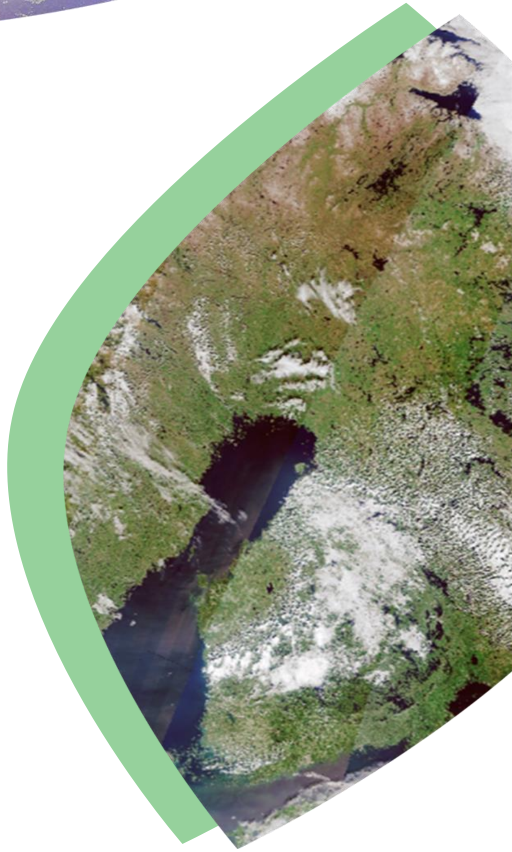

What FEO?

- Finnish Ecosystem Observatory (FEO) is a national research and development project with a budget of 6 M€ for 4 years (2020-2024) funded by the MoE of Finland and SYKE
- In close collaboration with GEO BON, Europa BON and EU Biodiversity Partnership
- Cross-cutting themes: BIODIVERSITY (e.g. habitats and species) and ECOSYSTEM PROCESSES (e.g. carbon and nutrient cycling)
- Special focus on:

1. **Management of data interoperability;**
2. **Modernizing of BD monitoring methods (e.g. *in situ*, EO & AI);**
3. **Integration of knowledge and decision-making at various scales**

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2. Introduction: A need for harmonized biodiversity and ecosystem monitoring systems

- Biodiversity (BD) crisis, ecosystem degradation, and climate change
- Changes in nature and ecosystem condition are happening fast – novel monitoring methods are needed to track the changes and to provide knowledge for decision-making processes
- Long-term BD monitoring is crucial but resources have been limited and decreasing over last decade
- Integration of remote sensing, *in situ*, and modelling data can provide new insights in the BD and ecosystem monitoring

Photo: Ari-Pekka Auvinen, SYKE

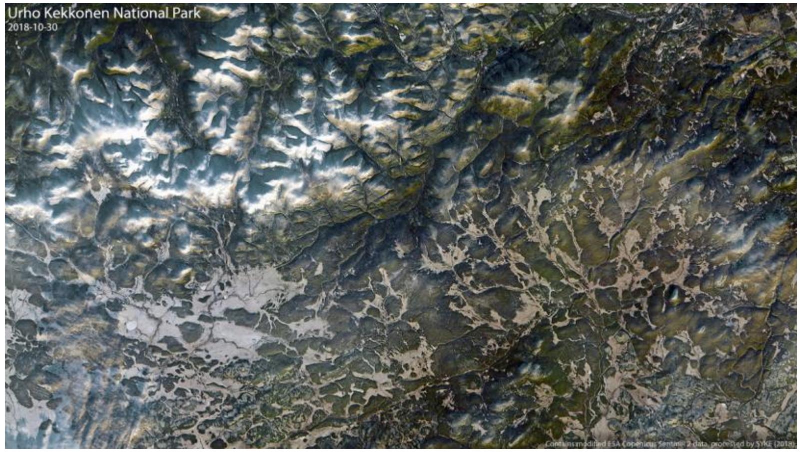

Photo: ESA/Copernicus, SYKE

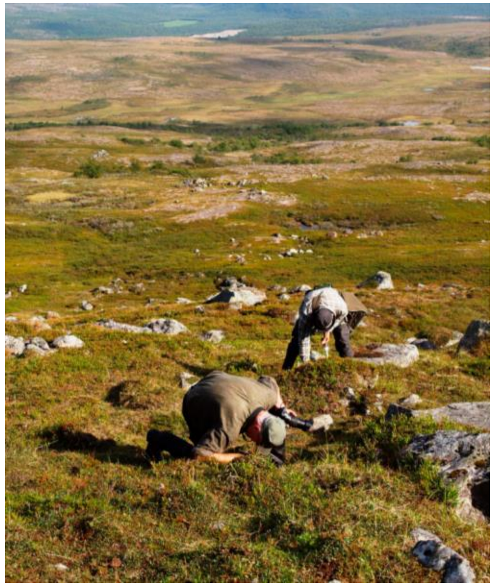

Photo: Kimmo Syrjänen, SYKE

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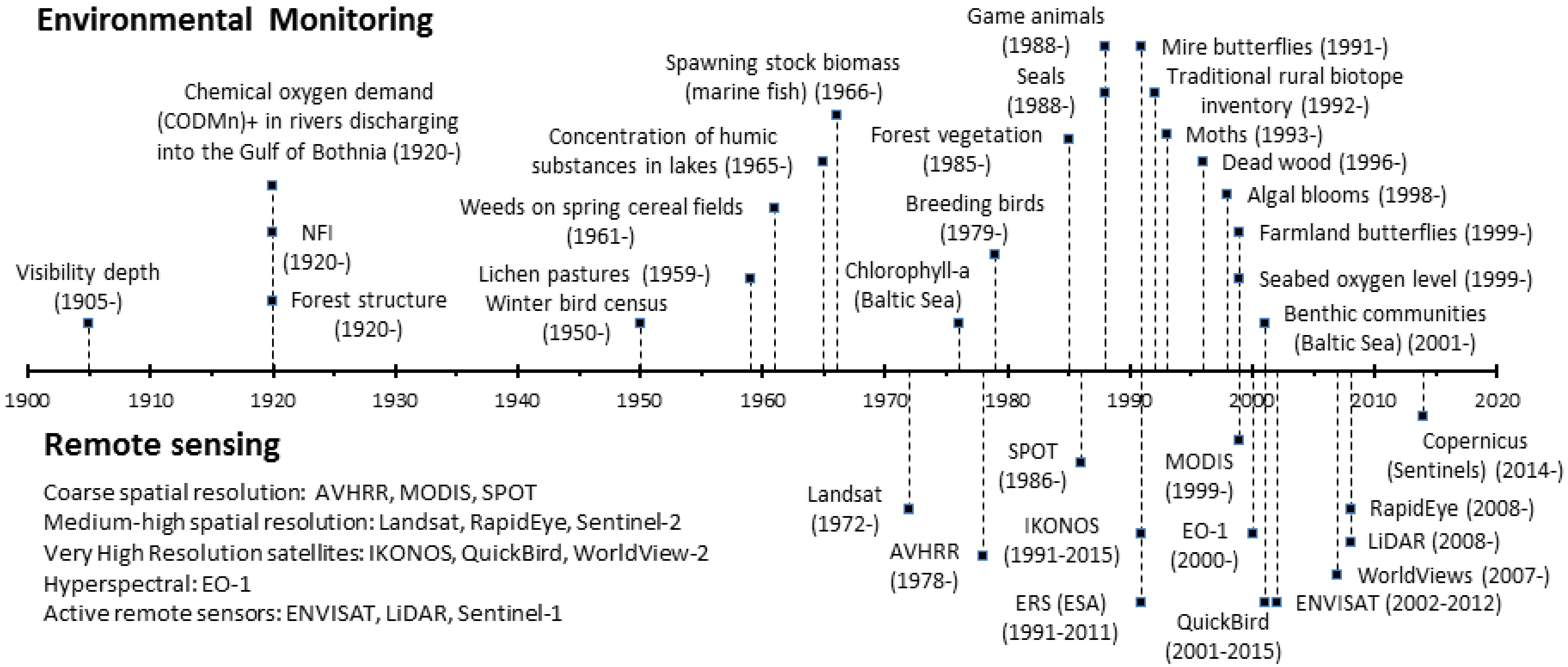


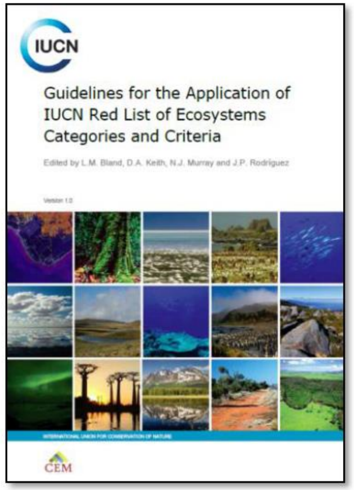
”Long-term ecosystem monitoring is crucial to understand and measure changes in nature. We need integration of in-situ observations and remote sensing, and models.”

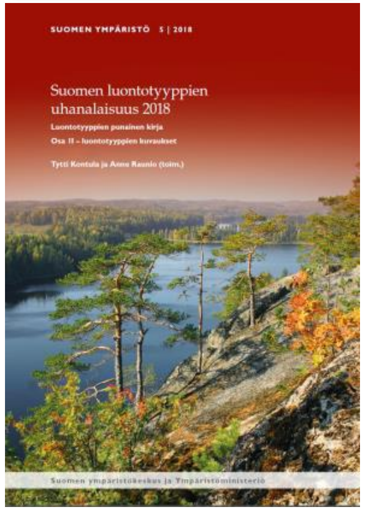
Vihervaara et al. 2017: How Essential Biodiversity Variables and remote sensing can help national biodiversity monitoring. *Global Ecology and Conservation* 10: 43-59

Data is needed

- CBD reporting (every 4 yrs)
- EU
  - Habitats and Birds Directives (every 6 yrs)
  - Water Framework Directive
  - Marine Strategy Directive
  - Net Emission Ceilings Directive
- Eurostat / UN SEEA-EEA
  - Ecosystem accounting
- National legislation: e.g. Nature Conservation Act
- The Red Lists of Species and Habitats (every 10 yrs)

➢ **FEO aims at demonstrating use cases such as i) national BD indicators, ii) Habitat Directive reporting, iii) C neutral land-use, iv) BD data for municipalities, and v) ecosystem accounting**





https://iucnrle.org/resources/key-documents/

Source: SYKE Policy Brief 2019

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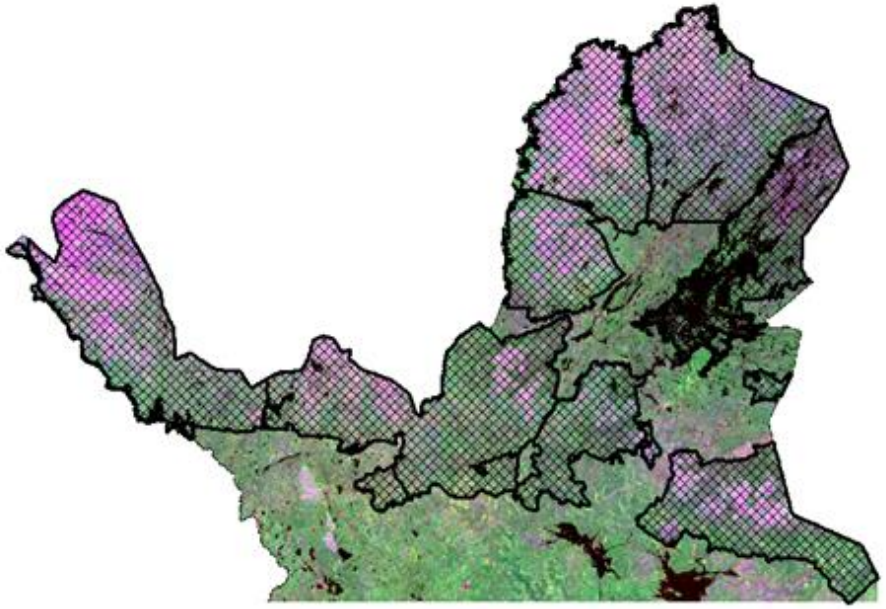
3. Case 1: Remote sensing aided mapping of habitats in northern Finland (Lapland)

- Objectives
  - Update of spatial db describing habitats in protected areas in northern Finland. This includes
    - Geometry
    - Attributes (habitat/vegetation type, etc.)
    - Development of monitoring system for future updates
- Customer
  - Metsähallitus (Forest service) responsible for management of state owned protected areas, wildernss areas, hiking areas, ..
- Project
  - Target area 30 000 km2 (figure)
  - Duration 2020-2022
- Data will be used
  - Maintenance and restoration of conservation values of threatened habitats
  - Detection of changes and pressures (turism, reindeer grazing, climate change)
  - Land use planning
  - Reporting oblications
  - Management and use of protected areas
  - ...



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3. Case 1: Remote sensing aided mapping of habitats in northern Finland (Lapland)

Input data

- Field observations
  - About 2000 sample plots measured summer 2020
  - New set of plots will be measured summer 2021, 2022
- Remote sensing data sets
  - Satellite images
    - Mosaics of Sentinel 1 backscattering coefficient (time series) and Sentinel 2 reflectances
    - Phenological features based time series of Sentinel 2 spectral indices
  - LiDar
    - Vegetation surface model
    - Tree crown coverage
    - Vertical structure of canopy
  - Aerial photographs
- GIS data
  - Topographic database
    - Digital elevation model and Soil type (peatlands)
  - National Forest Inventory

Visited and measured plots summer 2020 (green dots) and planned field routes for summer 2021 (black lines)

3. Case 1: Remote sensing aided mapping of habitats in northern Finland (Lapland)

Methods

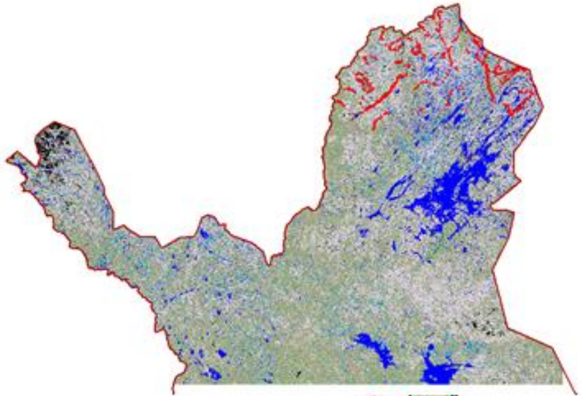
- Segmentation
- Machine learning tools (RF, NN)

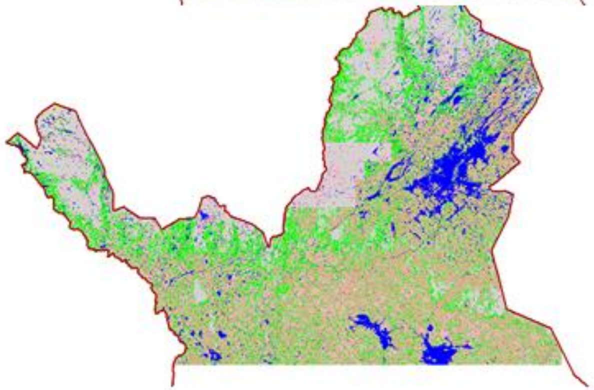
Preliminary results

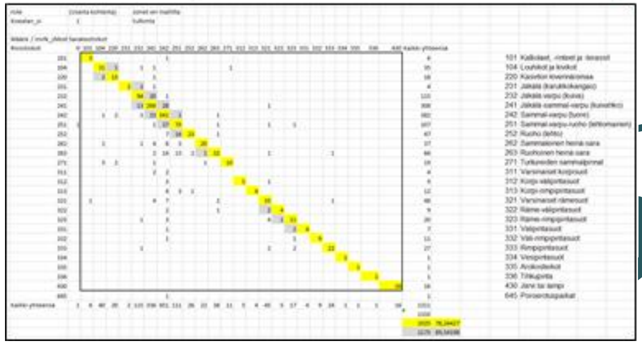
- Optimised network for field visits
- Geometry based on Sentinel 2, Lidar and GIS data
- Estimates for target variables (pixel- and segmentvise)
    - Inventointiluokka
    - Natura2000 type
    - Uncertainty surfaces for target variables
    - Accuracy estimates (error matrix)

Next

- Inclusion of new features and field data into models







4. Case 2: Remote sensing hydrological condition of aapa mires

- A priority habitat type in the EU Habitats Directive
- Mosaics of seasonally and permanently wet and drier surfaces, with respective species assemblages

- Land-use, especially ditching, affects mire hydrology → Drying causes degradation of ecological conditions
- Climate change may also affect mire hydrology in the future

Photo: Kaisu Aapala

- **Satellite-based remote sensing enables monitoring and understanding changes in hydrology of these ecosystems, and identifying vulnerable and drought-sensitive sites**

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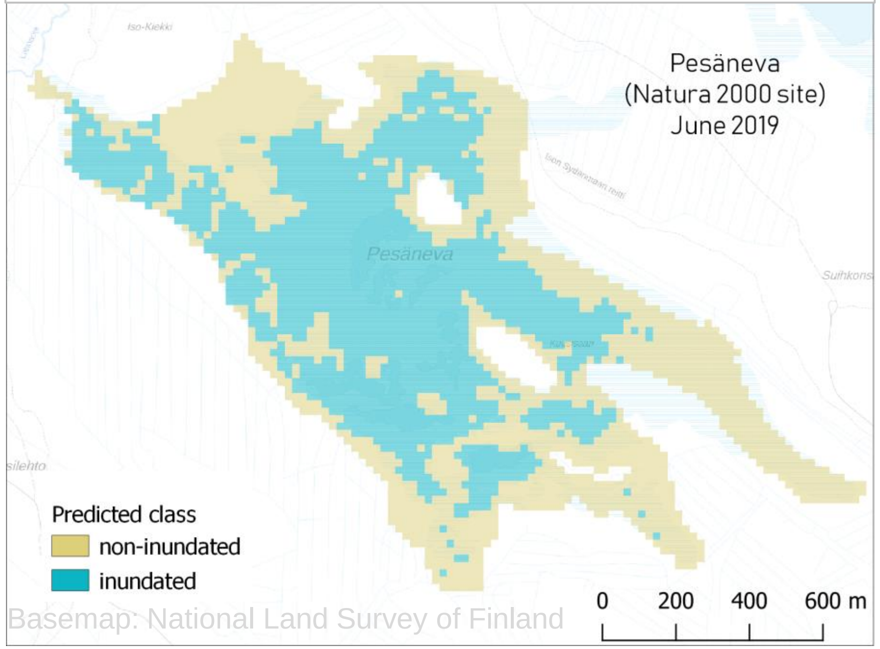
Aerial image, June 2019

Classification from Sentinel 2



Aims

To test the use of the Sentinel 2 satellites in monitoring seasonal and interannual hydrological changes in aapa mires

1. Test and develop methods for mapping spatiotemporal patterns of inundation:
    - Supervised classification of inundated/ non-inundated pixels
    - Moisture indices
    - Shortwave infrared bands

Reference data based on aerial images:

- 1761 classified 20m pixels located in 16 example mire sites
- Represent spectrally different subclasses of inundated and non-inundated surfaces, visually interpreted from aerial images

2. Upscale RS methods for the whole aapa mire zone of northern Finland

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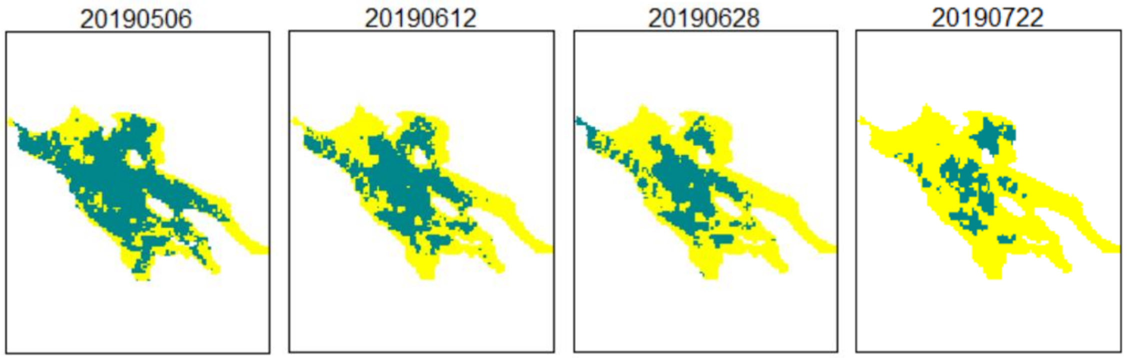

Key findings

- Developed classification models show good accuracy (OA 95-97%) in reference data.
- Moisture indices such as NDMI seem to perform poorly. Single shortwave infrared bands are more reliable in tracking seasonal changes in aapa mires.

→ Monitoring aapa mire hydrology and inundation extent is possible with S2 imagery, but many moisture and water indices are not suitable

➢ Next step: developing upscaling process of best methods with Sentinel Hub API. Extracting time series statistics from all aapa mires of northern Finland.

- Reference data based on aerial images enables spatially comprehensive approach but leaves uncertainties without supporting field reference.
- Uncertainties remain in applicability of models to variable types of mire habitats and all seasonal conditions.

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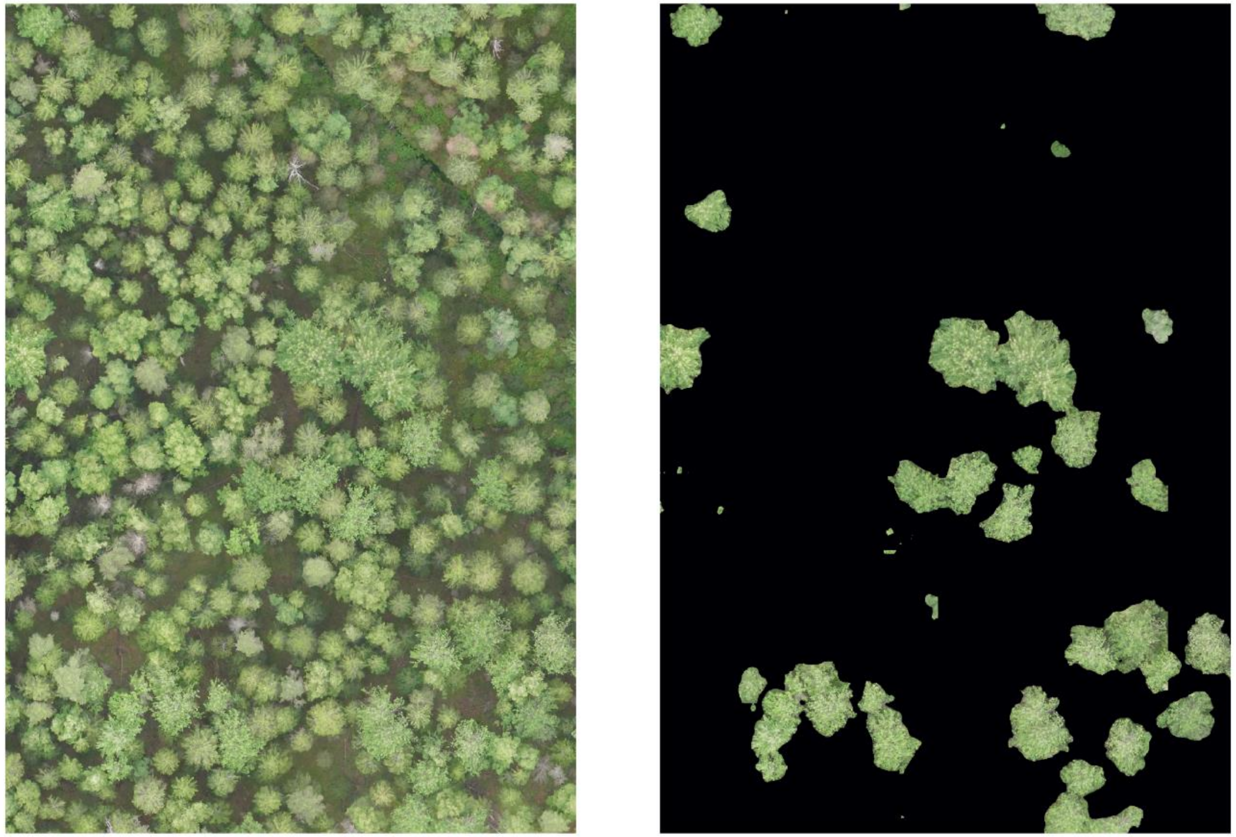
5. Case 3: Automated Aspen mapping for forest BD hotspots

- European aspen is a keystone species for the biodiversity of boreal forests, and spatially explicit data can be used to produce several biodiversity and ecosystem indicators
- However, as a deciduous species with minor economical value, aspen is either pooled together with other minor species or even omitted from forest resource inventories
- Detecting individual aspen from very high resolution UAV is nowadays fairly trivial, but due to limited area coverage it is not viable for operational use



Segmented aspen canopies from UAV imagery with U-Net based CNN method

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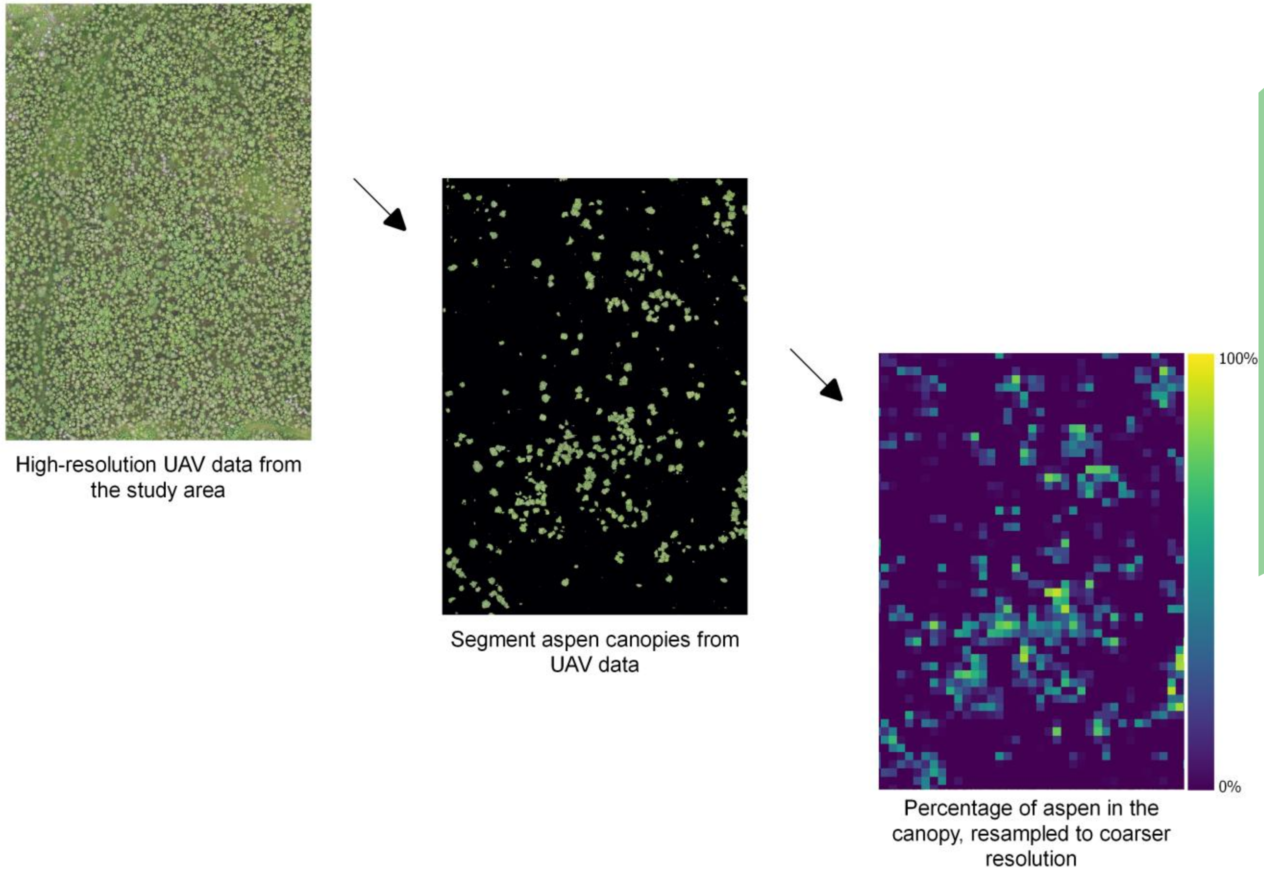
VHR data as an alternative for field sampling

- Operational nation-wide aspen detection requires accurate reference data in order to validate the methods used
- Traditional fieldwork is laborious, costly and matching field data to airborne imagery is often difficult
- As e.g. Kattenborn et al (2019) have proposed, UAVs are a viable alternative for reference data collection
- High resolution data can be used to produce accurate information in local scale, and then resampled to a coarser resolution, similar to e.g. Sentinel-2 imagery



An example workflow for utilizing UAV imagery as a field sampling method.

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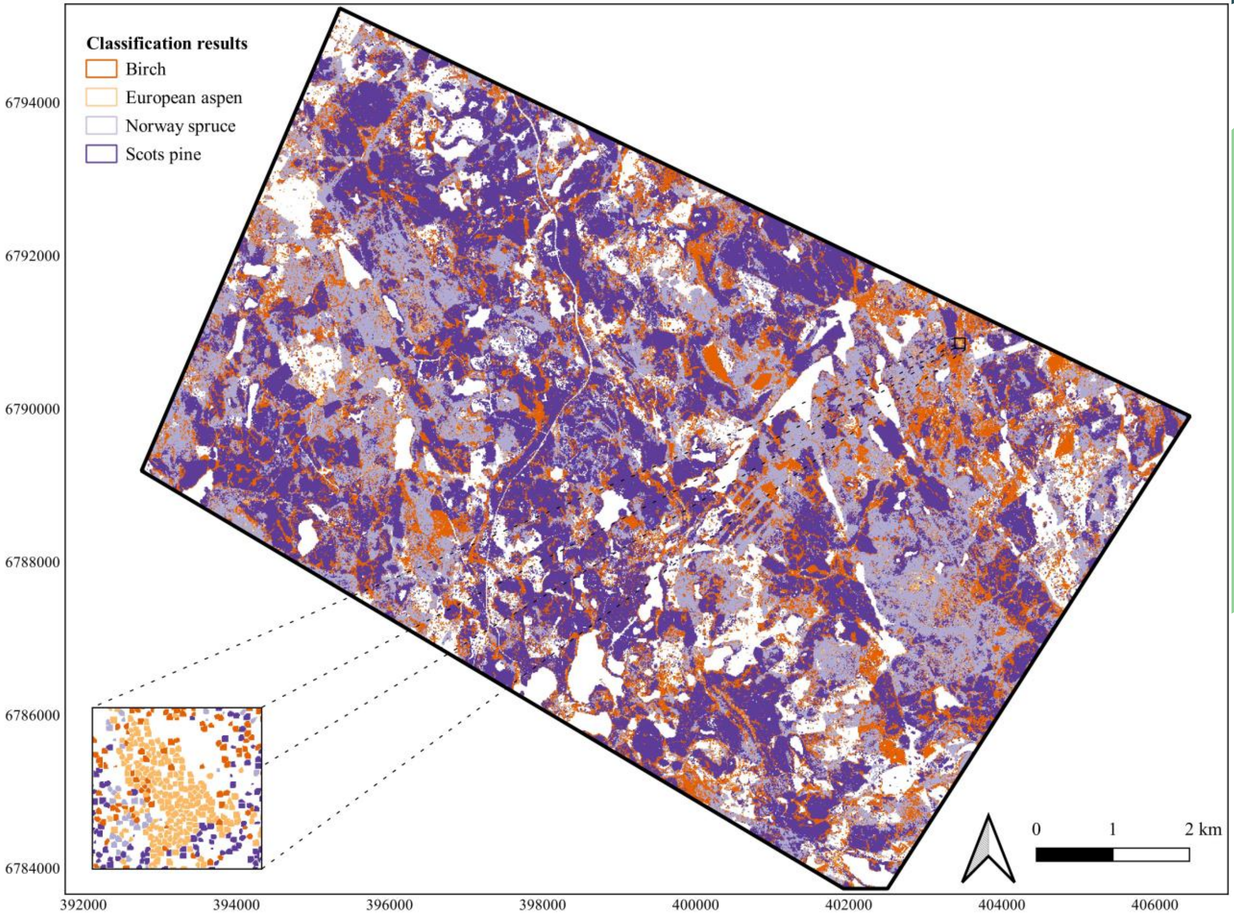
Utilizing hyperspectral data for aspen detection

- Aside from higher spatial resolution, higher spectral resolution enables distinguishing minor spectral differences between different species
- As a part of IBC-Carbon project, we have studied how well aspen can be classified at individual tree level using hyperspectral data in VNIR and SWIR ranges (Viinikka et al 2020, Mäyrä et al 2021)
- However, due to lack of available hyperspectral data, this is still only usable on local scale. This might change in the near future, after several hyperspectral satellite missions are launched



Predicted tree species map from Evo study area. Lower left highlights a detected aspen hotspot

6. Conclusion

- Great potential of remote sensing in BD mapping, in particular, habitat and ecosystem extent and condition mapping, but also in specific BD monitoring challenges such as Aspen mapping
- FEO aims to develop EO approaches into the operational data products which can be used for decision-making support
- There is a clear need to harmonize EO data processing and sharing capacities
- For the threatened habitat assessment in FEO, we have taken three-fold approach:
    1) to develop EO-derived information from the predefined areas such as existing habitat polygons;
    2) to utilize several EO data sources, field observation as training data and use computational methods to identify and classify habitats;
    3) to apply the Essential Biodiversity Variable (EBV) framework and identify EO-enabled EBV indicator information that can support national BD indicator development.
- In the future, a network of national and regional BD and ecosystem observation networks such as FEO could provide high-quality data and knowledge on a timely manner for various purposes that can support both research and the society at large.

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Thank you for your attention!

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