Monitoring Biodiversity through Remote Sensing - *the Story of European Aspen*

Photo: *Sarita Keski-Saari*

Pekka Hurskainen

Finnish Environment Institute SYKE

Earth Observation for European Sustainable Forest Management Webinar, 24.9.2020

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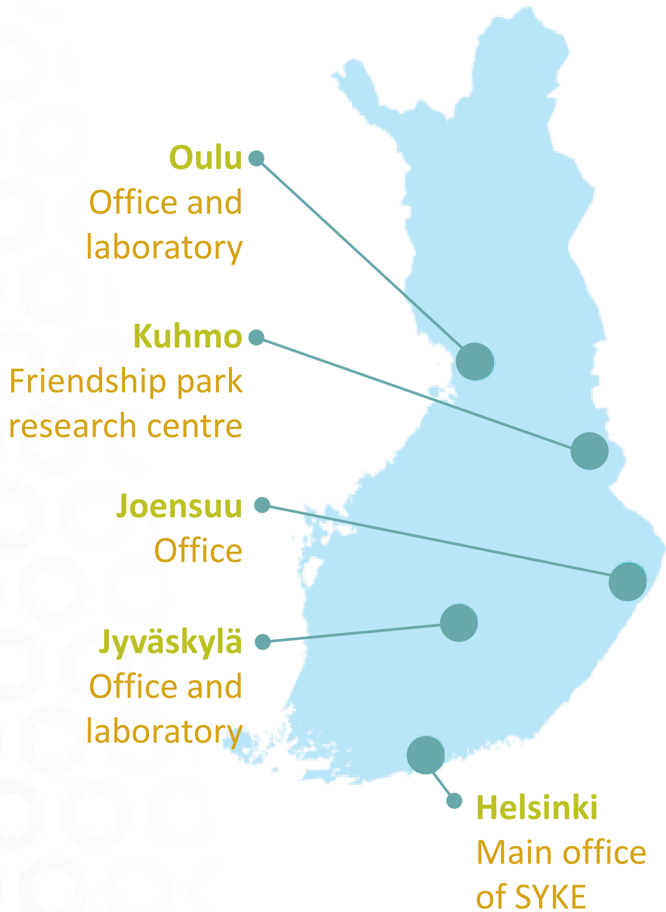
- SYKE is a multidisciplinary research and expert institute under the auspices of the Ministry of the Environment.



Environmental information

Consumption and production

Water

Ecosystem services

Climate change

Sea

Built environment

Urbanisation

Circular economy

600+ staff members

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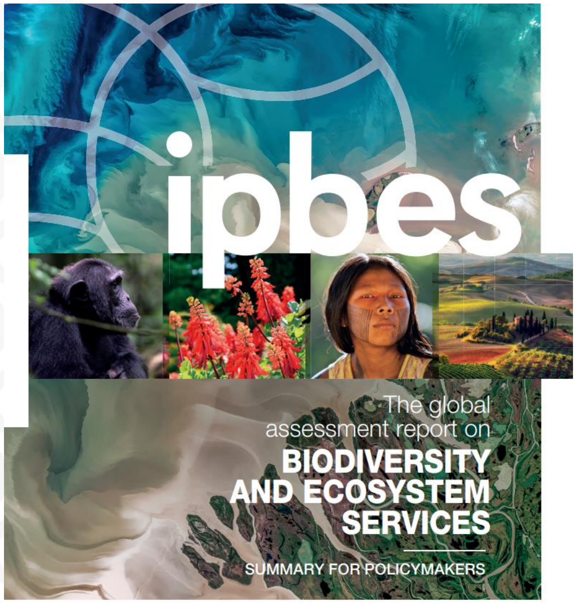
Prologue: We are facing a global biodiversity crisis

https://ipbes.net/global-assessment



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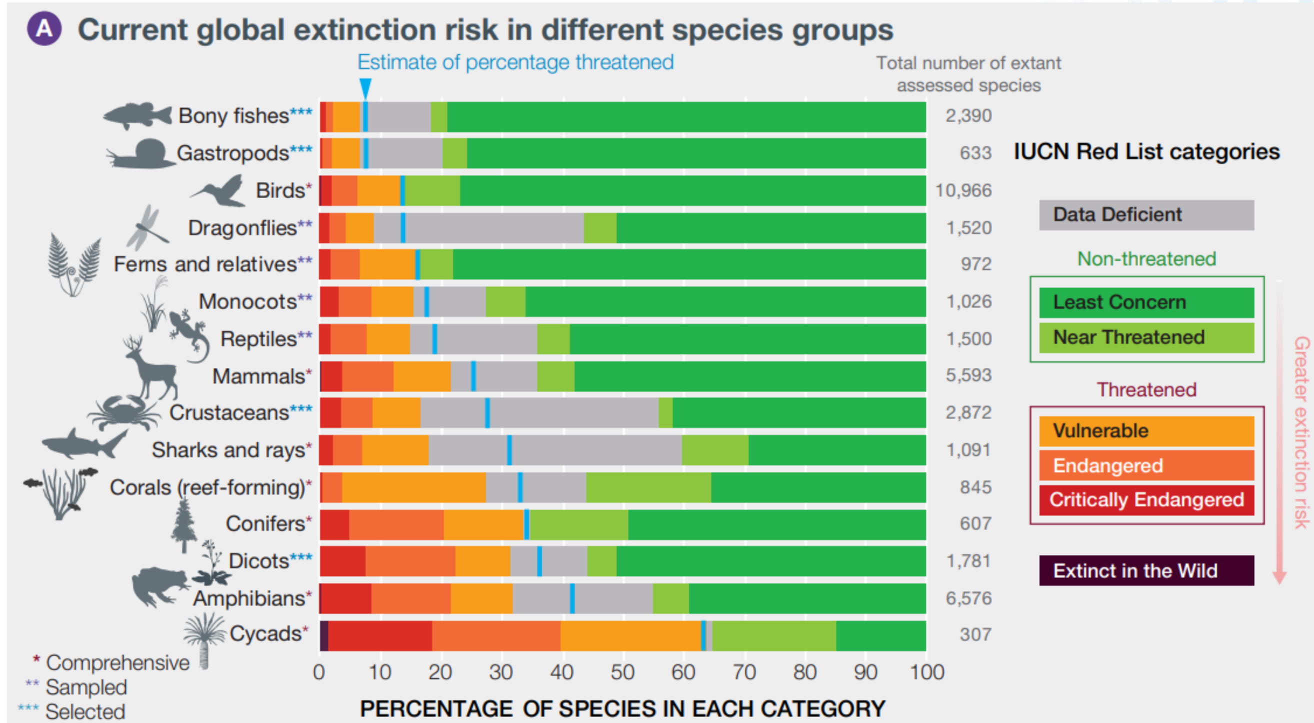

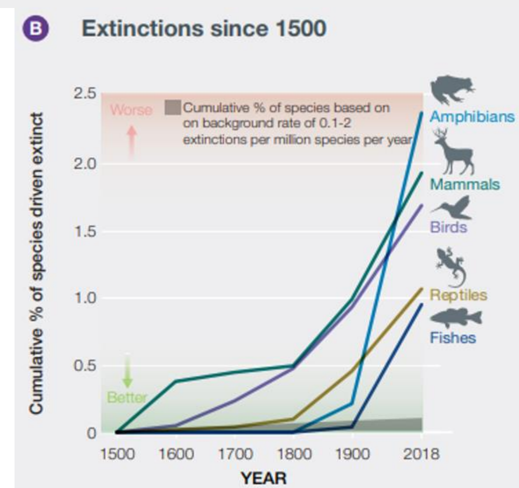

ipbes
Science and Policy for People and Nature
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

Key message #1: Nature and its vital contributions to people, which together embody biodiversity and ecosystem functions and services, are deteriorating worldwide.

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Global Biodiversity Crisis also in Finland


VIEWS ON ENVIRONMENTAL POLICY I **SYKE POLICY BRIEF** I 28.3.2019

Our natural capital is shrinking – the trend can be turned

Functioning ecosystems are a foundation for human well-being and sustainable economy. Biodiversity contributes to the resilience and adaptiveness of ecosystems.

The latest research shows that Finland's biodiversity continues to degrade: 12% of species and 48% of habitat types are threatened.[1, 2] Biodiversity loss is a global phenomenon, much like climate change, threatening the conditions for life globally. However, it is possible to use ecosystems and natural resources sustainably and thereby safeguard human well-being. We need targeted solutions to support the fight against biodiversity loss and climate change.

The natural environment is degrading at a fast pace. Human activity has already resulted in the loss of 34% of global biodiversity, and the deterioration continues.[3]

Stopping the loss of biodiversity requires urgent and widespread action. Action should be taken by all, including governments and municipalities as well as companies, landowners and private citizens.

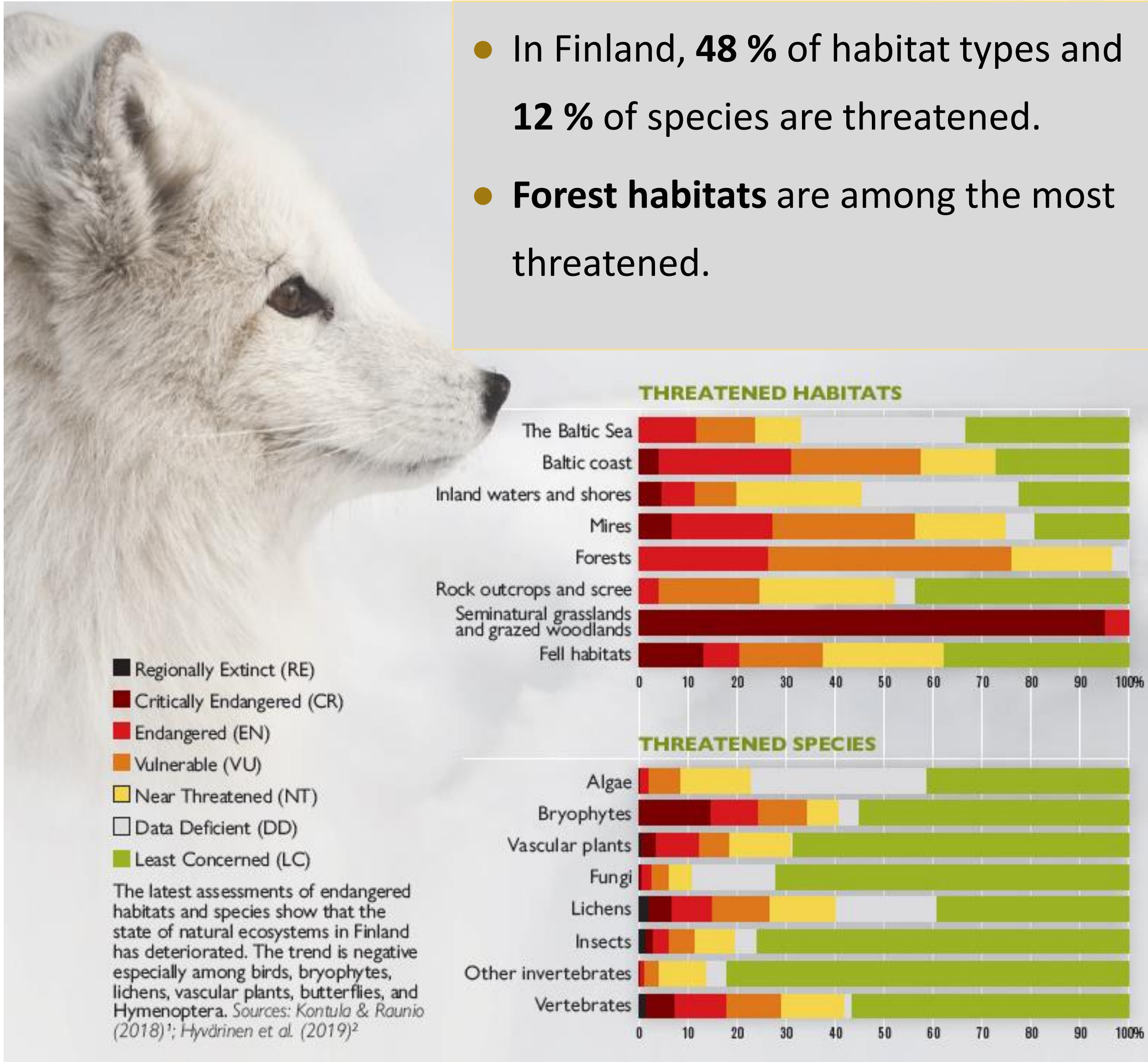
The solutions need to build on up-to-date information and mobilise effective practices. The economy must be based on sustainable use of natural resources.

S Y K E FINNISH ENVIRONMENT INSTITUTE | SYKE.FI | ENVIRONMENT.FI

SYKE Policy Brief 28 March 2019

https://issuu.com/suomenymparistokeskus/docs/syke-pb_biodiversity_03-2019_150

- In Finland, **48 %** of habitat types and **12 %** of species are threatened.
- **Forest habitats** are among the most threatened.



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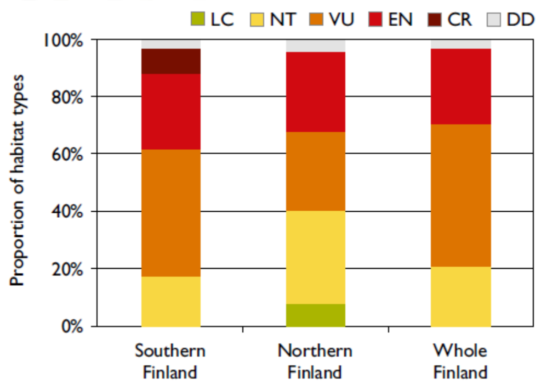
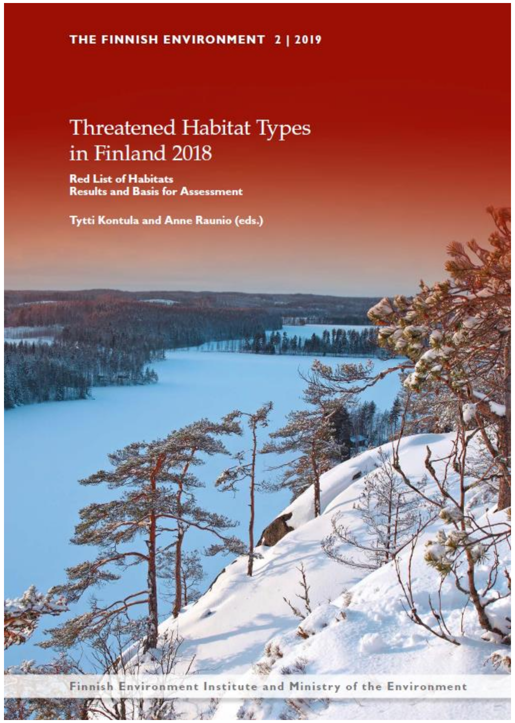
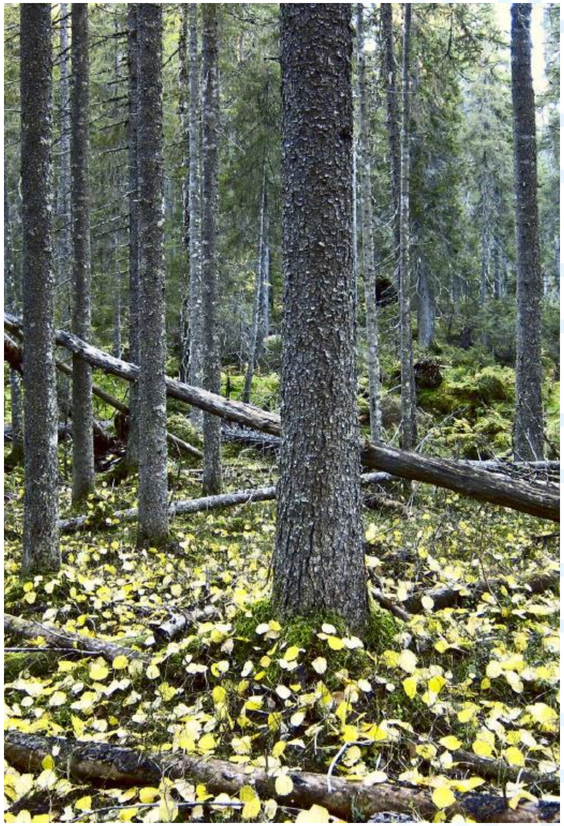
Finland’s threatened forest habitats

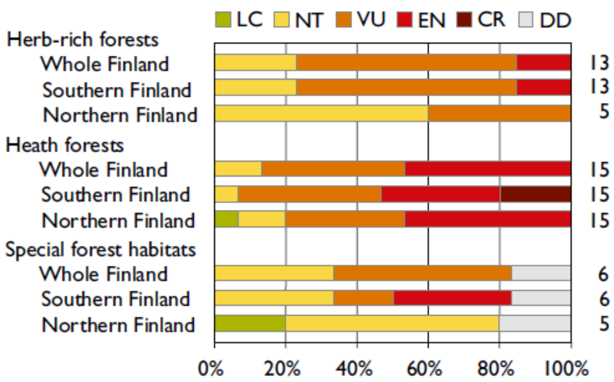
- Red List of Habitats, 2018: Nationwide, 34 forest habitat types were assessed. Of these:
  - **76 % threatened** (VU / EN / CR)
  - **21 % near-threatened** (NT)



  - **Heath forests[1] in Southern Finland** most threatened







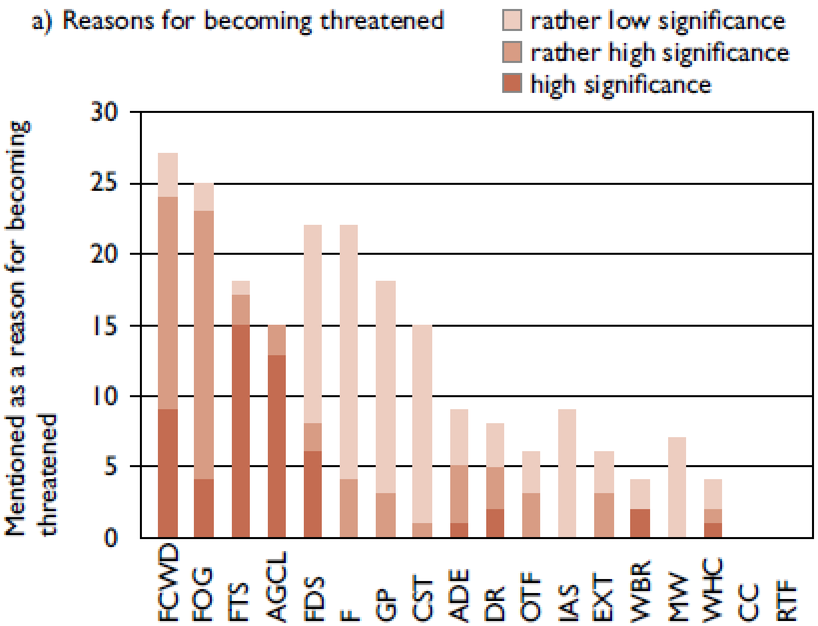
https://helda.helsinki.fi/handle/10138/308426

1 By heath forests we mean ‘taiga’ forests growing on podsolic soils (the prevailing forests in the boreal zone), as opposed to herb-rich forests which have black soil or peatland forests growing on peat. ‘Herb-rich heath forests’ is the most fertile forest site type of heath forests.

Why have forest habitats become threatened?

- Most common reasons:
1. Reduction in coarse woody debris (deadwood) (FCWD)
2. Reduction in old-growth forests and individual old trees (FOG)
3. Changes in tree species composition (FTS)
- Less common:
4. Clearing for agriculture (AGCL)
5. Reduction in natural large-scale disturbances and lack of natural succession (FDS)
6. Mechanical soil manipulation (F)
7. Mammal herbivory on deciduous tree saplings (GP)
8. Construction (CST)

etc.



Photograph by Riku Lumiaro, SYKE

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Why is it important to monitor biodiversity?

- Biodiversity crisis, weakening ecosystems, loss of habitats, climate change – all have common drivers
- Environmental change is faster than ever before – traditional monitoring methods and networks cannot meet the information demand
- Fortunately, also technology has developed fast and it its becoming mature enough to be utilized more efficiently (e.g. interoperable, open analysis-ready EO data, data cubes, cloud computing, deep learning, citizen science…)
- Up-to date information is needed to support decision making and to follow up progress to achieve policy targets and goals

Source: SYKE

Source: ESA/ P. Carril

The story of European aspen (*Populus tremula* L.)

- Keystone species for biodiversity and many ecosystem services in boreal forests
- Big aspen (both <u>living</u> and <u>dead</u> ones) host hundreds of species of fauna, flora and fungi, several of them red-listed
- Information of their occurrence, abundance and distribution is important for sustainable forestry and conservation
- *Species distribution* is one of the Essential Biodiversity Variable (EBV) candidates[1] proposed by GEO BON
- However, current stand-level forest inventory system focuses on economically significant tree species – ecologically important deciduous trees other than birch are pooled into one class
- Aspens are found as single scattered trees and/or clusters —rarely in homogeneous stands — challenge for mapping!

[1] https://geobon.org/ebvs/what-are-ebvs/

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RS techniques in tree species mapping

Kivinen et al. (2020)

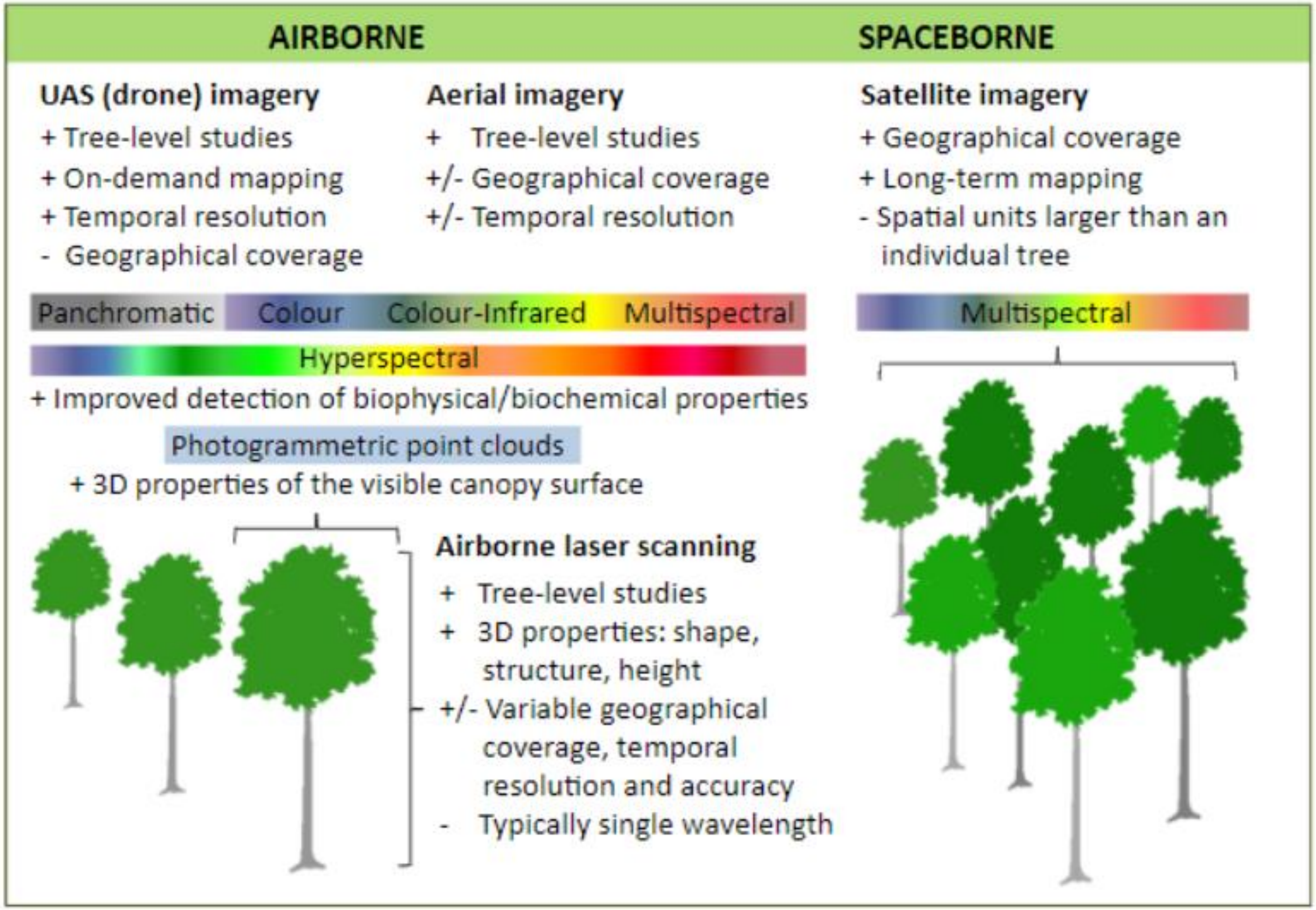

Fig. 4. Advances and drawbacks of different remote sensing techniques in tree-species mapping.

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A recent study on aspen detection

remote sensing

MDPI

Article

Detecting European Aspen (*Populus tremula* L.) in Boreal Forests Using Airborne Hyperspectral and Airborne Laser Scanning Data

Arto Viinikka [1,*], Pekka Hurskainen [1,2], Sarita Keski-Saari [3,4], Sonja Kivinen [1,3], Topi Tanhuanpää [3,5], Janne Mäyrä [1], Laura Poikolainen [3], Petteri Vihervaara [1] and Timo Kumpula [3]

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- **Overall objective**: tree-level discrimination of aspen from other common tree species (pine, spruce, birch) in the boreal forest landscape utilizing high-resolution airborne hyperspectral and airborne laser scanning data.
  1. Compare the performance of hyperspectral data features (spectral wavelengths (455-2500 nm), PCA, vegetation indices) in tree species classification using **machine learning** (SVM and RF) classifiers, and
  2. Find the **most important spectral features to discriminate aspen** from the other common tree species.

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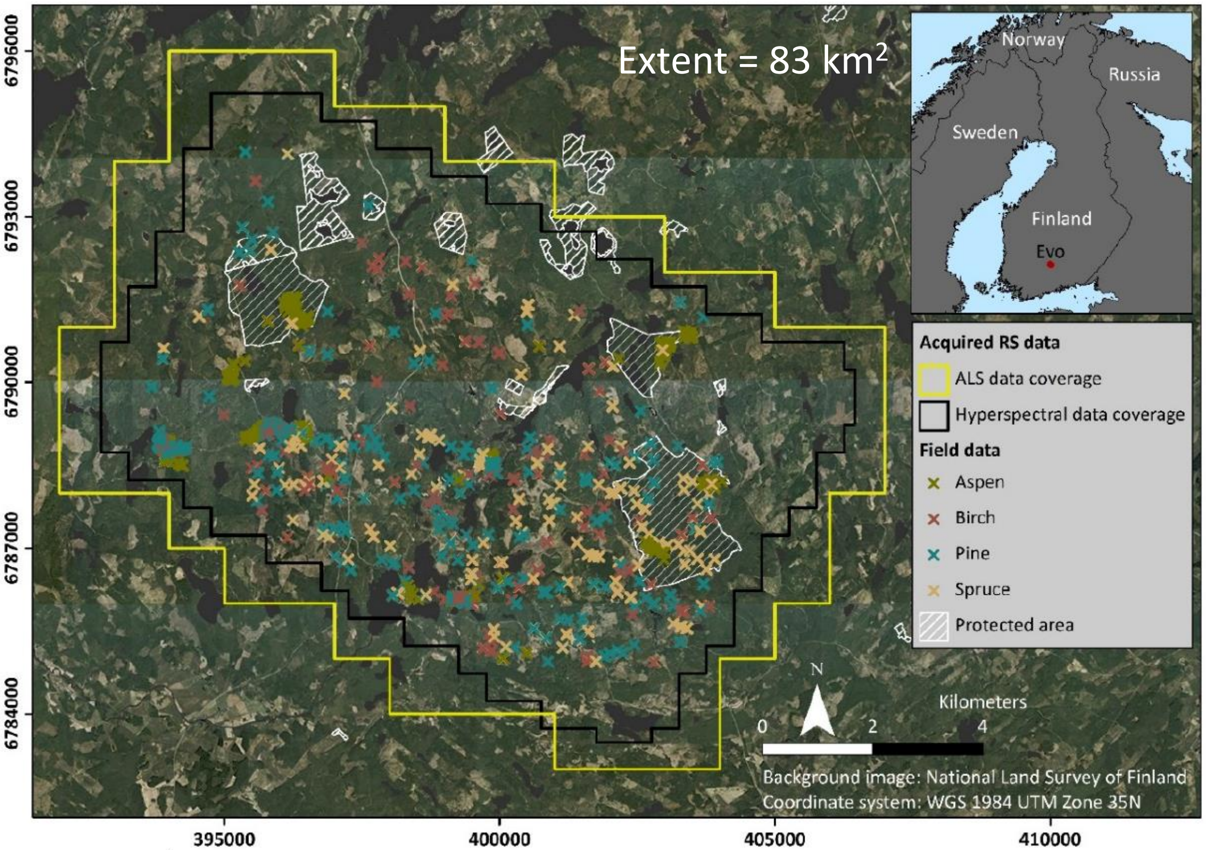
Study area and Data



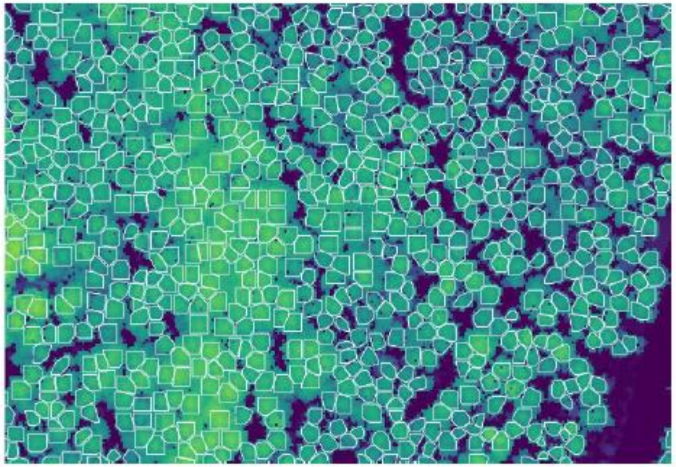


Table 1. Flight information and sensor parameters.

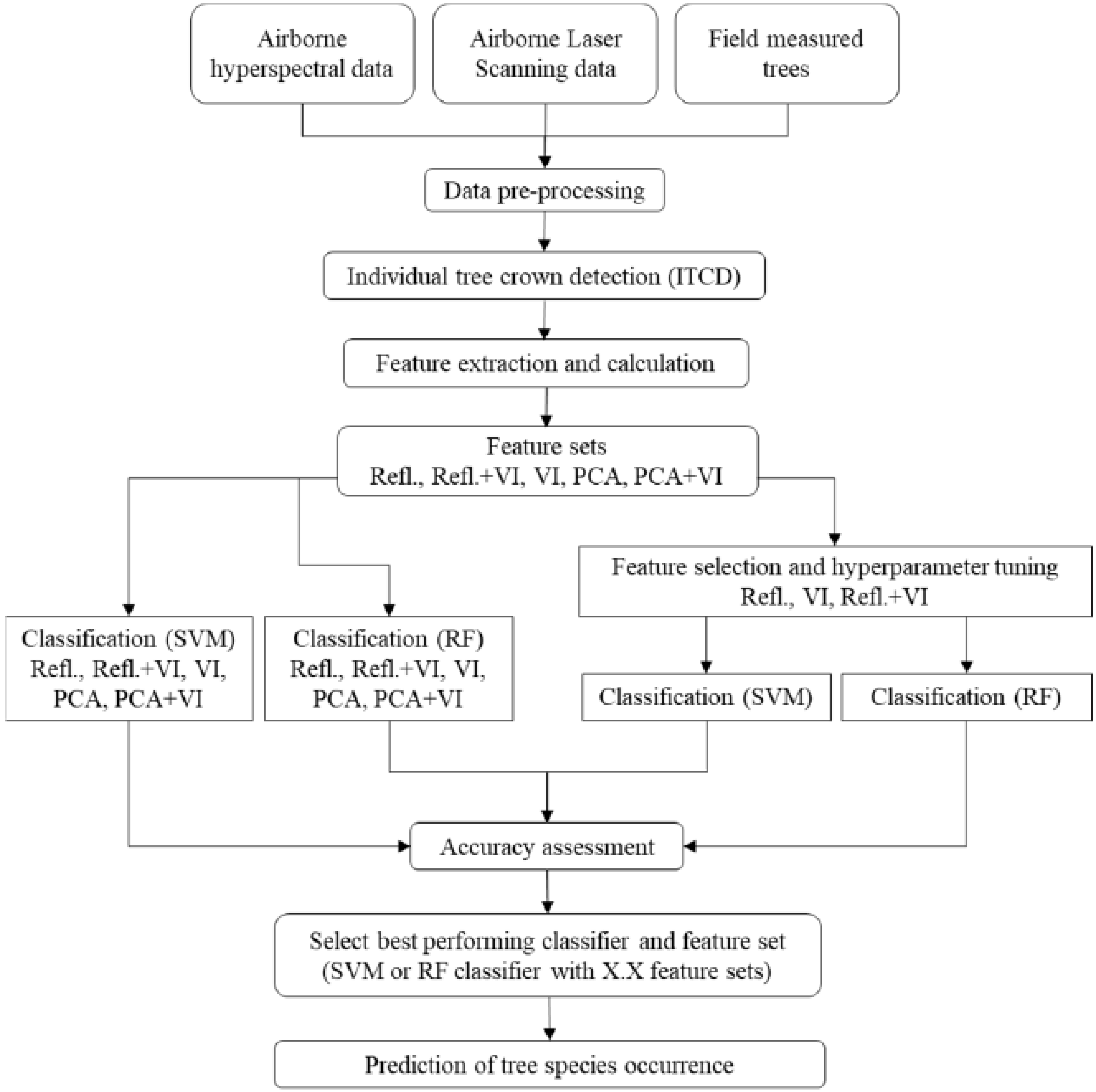
Time of Data Capture	2018.07.16 08:27–11:14
VNIR camera VNIR spectral range	HySpex 1800–SN00827 406–995 nm, 186 bands, bandwidth 3.26 nm
SWIR camera SWIR spectral range	HySpex 384me–SN3126 956–2525 nm, 288 bands, bandwidth 5.45 nm
LiDAR scanner Pulse density	Leica ALS70-HP–SN7204 10.2 p/m^2

Table 2. Abundance of tree species in field data. Data consisted of trees with diameter at breast height (DBH) of over 15 cm.

Species Name	Species Count	Species Percentage	Single Tree
Scots pine (*Pinus sylvestris* L.)	2570	38.9	688
Norway spruce (*Picea abies* (L.) *Karst*)	2045	31	495
***Birch* (*Betula* sp.) ***	1267	19.2	474
Aspen (*Populus tremula* L.)	717	10.9	599
All species	6599	100	2256

* Birch (*Betula* sp.) includes the species downy birch (*Betula pubescens* L.) and silver birch (*Betula pendula*).

Workflow



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Main findings (Viinikka et al. 2020)

- SVM outperformed RF, resulting in the highest overall accuracy (OA) of 84% in classifying the four most common tree species
- The highest classification accuracy (F1-score 0.92) for aspen was achieved using the linear SVM model with mean reflectance values combined with VI.
- If feature selection algorithm was applied, the same model was considerably simplified (from 500 to 290 features) with only 0.01 loss in F-score for aspen.
- The used feature set affected SVM performance little, but for RF, principal component analysis was the best

Table 4. Classification results for different tree species derived from the confusion matrix without feature selection with different feature sets. RF—random forest; SVM—support vector machine; VI—vegetation indices; PCA—principal component analysis.

Feature Set	F1-Score				Kappa	Overall Accuracy
	Aspen	Birch	Pine	Spruce		
Reflectance (SVM)	91%	82%	84%	78%	0.78	84%
Reflectance (RF)	72%	65%	74%	67%	0.59	70%
Reflectance + VI (SVM)	92%	80%	82%	75%	0.77	83%
Reflectance + VI (RF)	82%	72%	82%	76%	0.71	78%
VI (SVM)	89%	80%	83%	77%	0.76	82%
VI (RF)	82%	73%	81%	76%	0.70	78%
PCA (SVM)	91%	81%	82%	74%	0.76	82%
PCA (RF)	88%	78%	82%	75%	0.75	81%
PCA + VI (SVM)	90%	79%	83%	76%	0.76	82%
PCA + VI (RF)	88%	78%	81%	75%	0.74	81%

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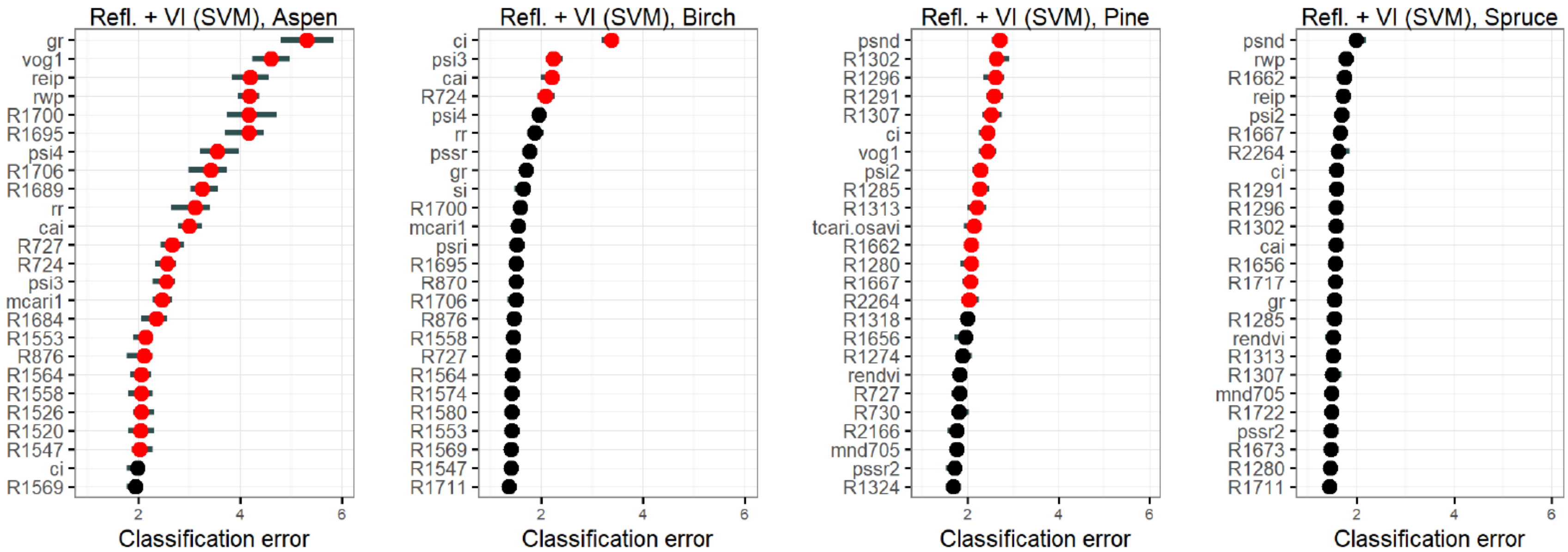
Main findings (Viinikka et al. 2020)

- We applied *permutation feature importance* to find out the most important features for tree species classification.
- The **most important VIs for aspen**: Green Ratio (GR), Vogelmann index 1 (VOG1), Red Edge Inflection Point (REIP), RedWell Position (RWP).
- The **most important wavelengths for aspen**: red edge range (724–727 nm) and shortwave infrared (1520–1564 nm and 1684–1706 nm).



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Wall-to-wall mapping of aspen occurrence

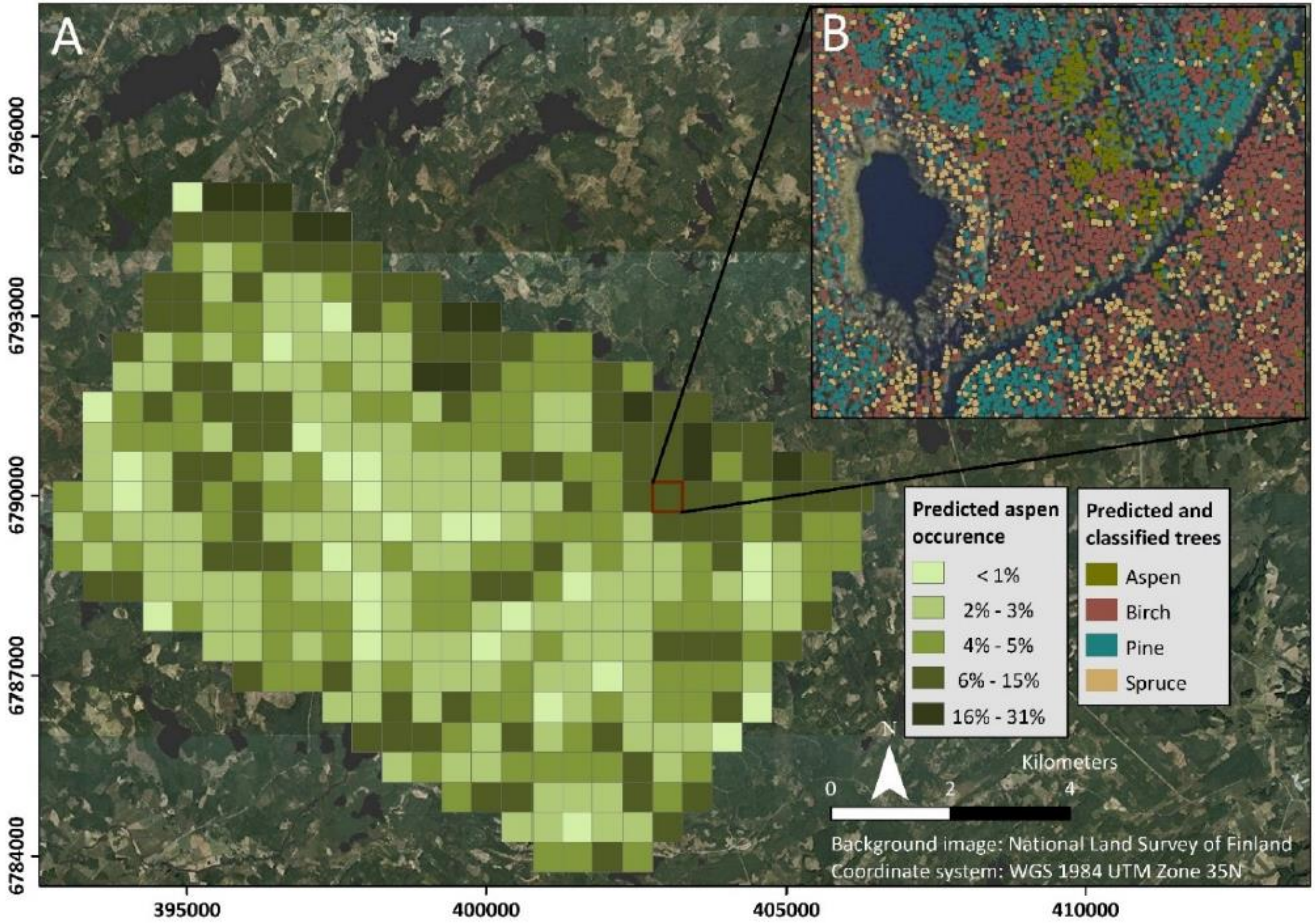

Figure 12. Percentage of the predicted aspen occurrence in 500 m grid based on the SVM model with reflectance and VI features (**A**). Illustration of the tree species segmentation and classification (**B**).

S

Paper currently under revision

Tree species classification from airborne hyperspectral and LiDAR data using 3D convolutional neural networks

Janne Mäyrä[a,*], Sarita Keski-Saari[b,c], Sonja Kivinen[a,c], Topi Tanhuanpää[c,d], Pekka Hurskainen[a,e], Peter Kullberg[a], Laura Poikolainen[c], Arto Viinikka[f], Sakari Tuominen[g], Timo Kumpula[c], Petteri Vihervaara[a]

- Continues from the findings of Viinikka et al. (2020), using the same data, the paper goes further to find out the possibilities of **deep learning**:
  1. How does **3D-CNN** perform in comparison with traditional machine learning methods (SVM, RF, GBM and ANN) in tree species classification?
  2. How accurately can the four common boreal tree species be recognized from hyperspectral data at tree level?

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Conclusions

- Our findings **increase spatial knowledge of boreal forest ecosystem composition** and provides a possibility of detecting ecologically important aspen regardless of its sparse and scattered occurrence.
- Tree-level species mapping requires high spatial and spectral resolution EO data and extensive field data. Linear SVM trained with vegetation indices and spectral reflectance values from the full spectrum performed best.

Challenges in tree species mapping at landscape-level

- From tree-level mapping to mapping of homogeneous stands, or area based estimates of species proportions
- Scarce occurrence of rare, ecologically important species. Random or systematic sampling methods inefficient.
- Need for extensive reference data set – NFI and Finnish Forest Centre plots are available, but not optimal for the task
- Our findings on important wavelengths for aspen mapping, and initial tests with upscaling using multispectral data are suggesting that the spectral resolution of Sentinel-2 is not enough → Potential of hyperspectral satellite data (e.g. PRISMA) will be tested.

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