GEHO

GLOBAL ECOSYSTEM HEALTH OBSERVATORY

Metsien kaukokartoitus kasvintuhoojien seurannassa

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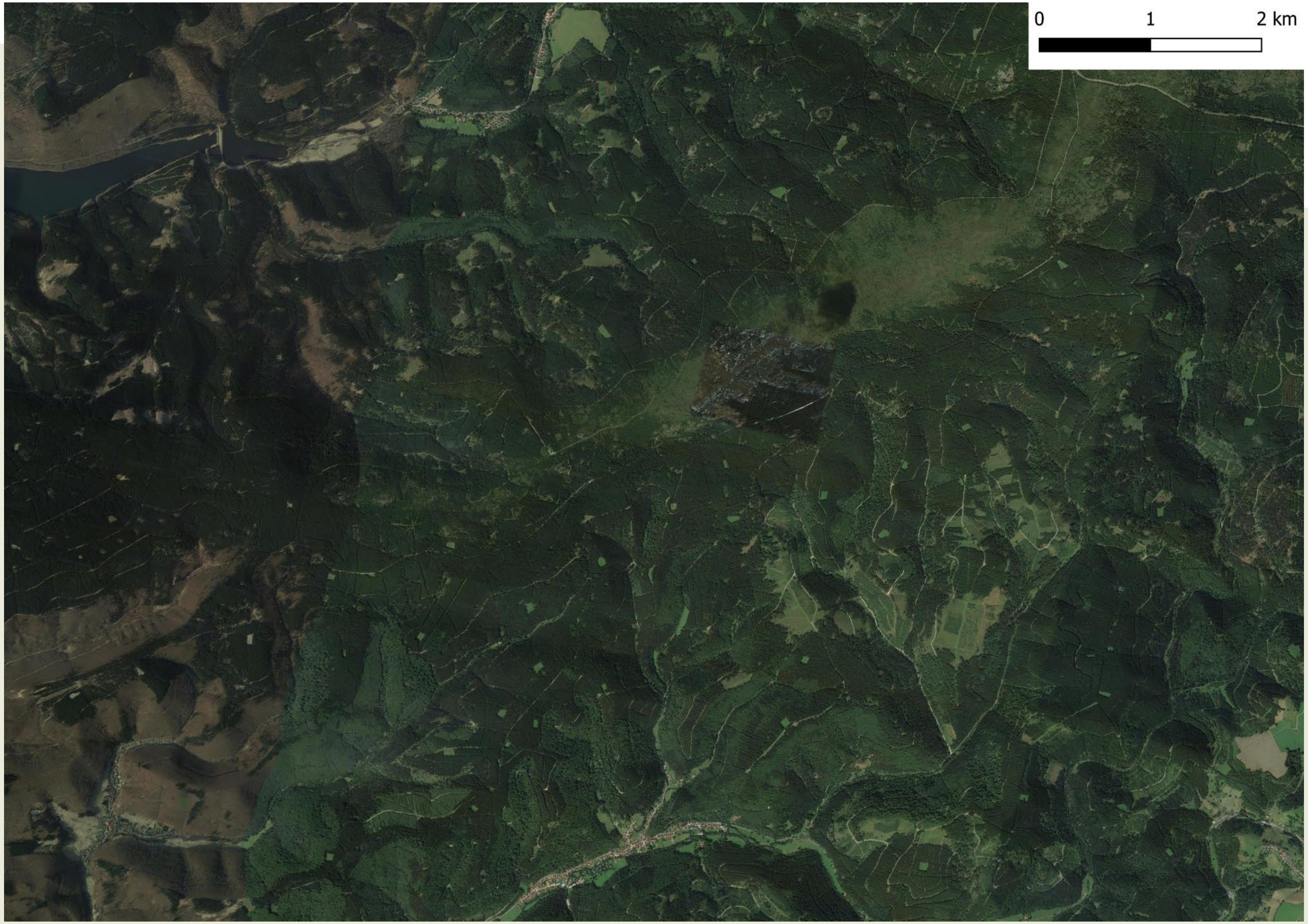
Helsingin yliopisto

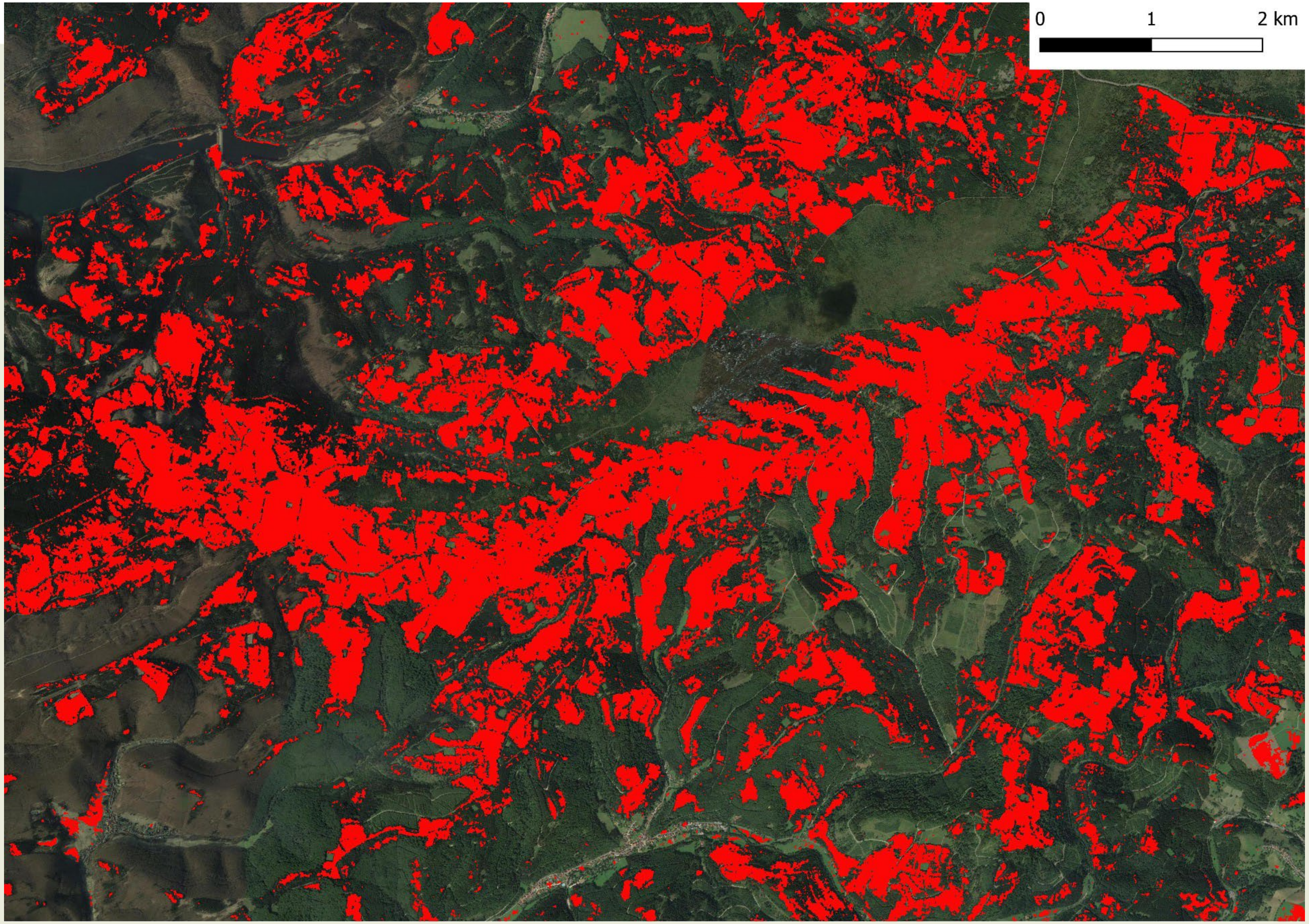
DRYTREE

Funded by the European Union

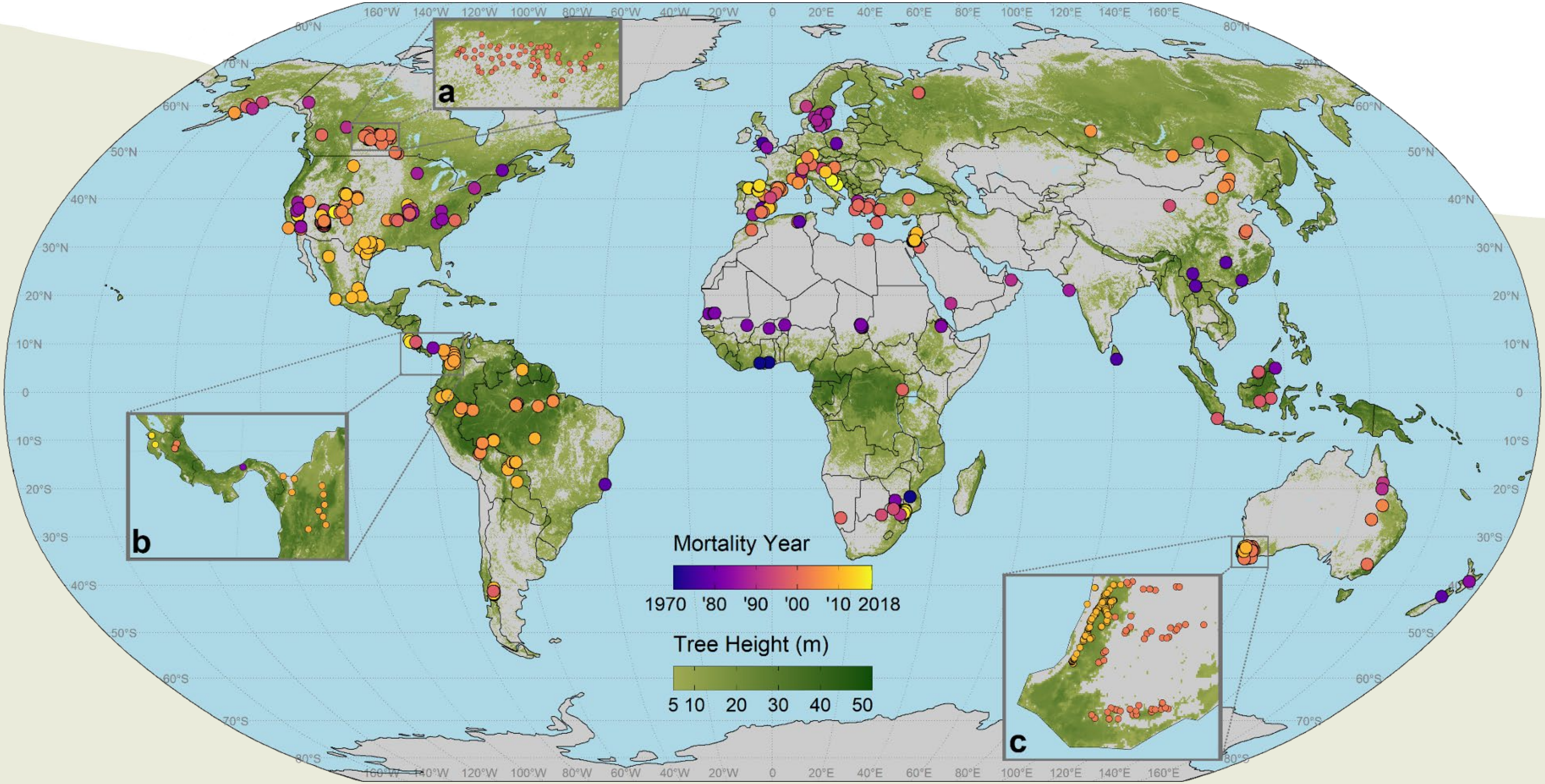
erc European Research Council
Established by the European Commission





0
1
2 km



Most spruce forest lost


a
b
c
Mortality Year
1970 '80 '90 '00 '10 2018
Tree Height (m)
5 10 20 30 40 50

Forest disturbances are increasing – what now?

1. We need systematic and frequent assessment of forest disturbances
   - Remote sensing (wall-to-wall) + field plot based monitoring system
   - Where, when and what kind of trees are dying?
2. We need adaptive forest management that is based on accurate data
   - Mitigation of damages + pre-emptive attempts by increasing resilience

Lack of understanding of future trajectories of tree mortality

WHERE, WHEN, WHAT

Lack of information on tree mortality at tree-level

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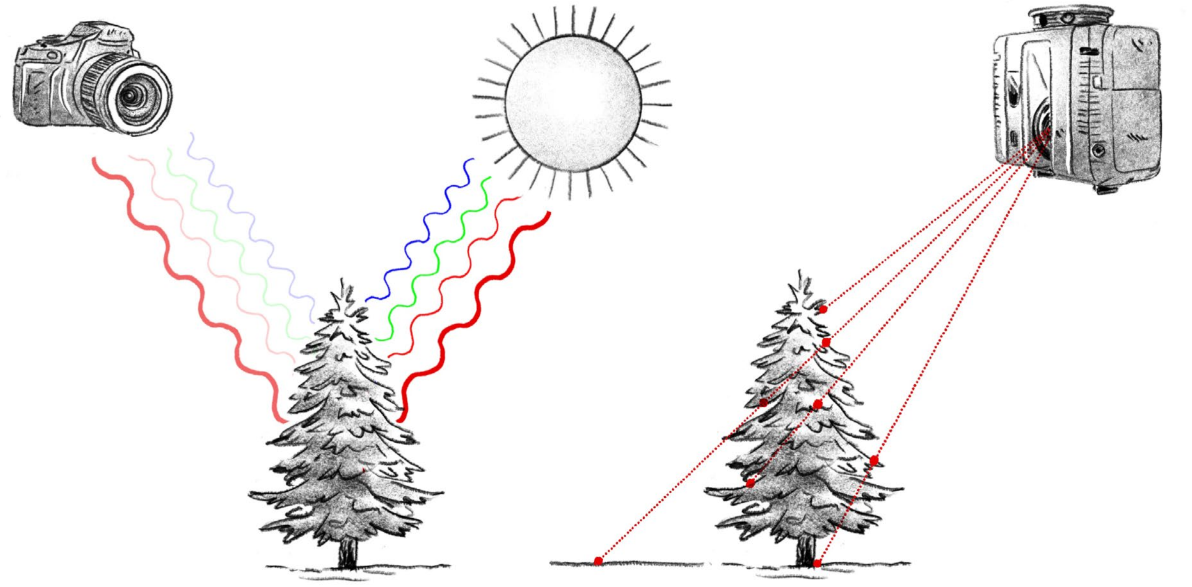
WHY

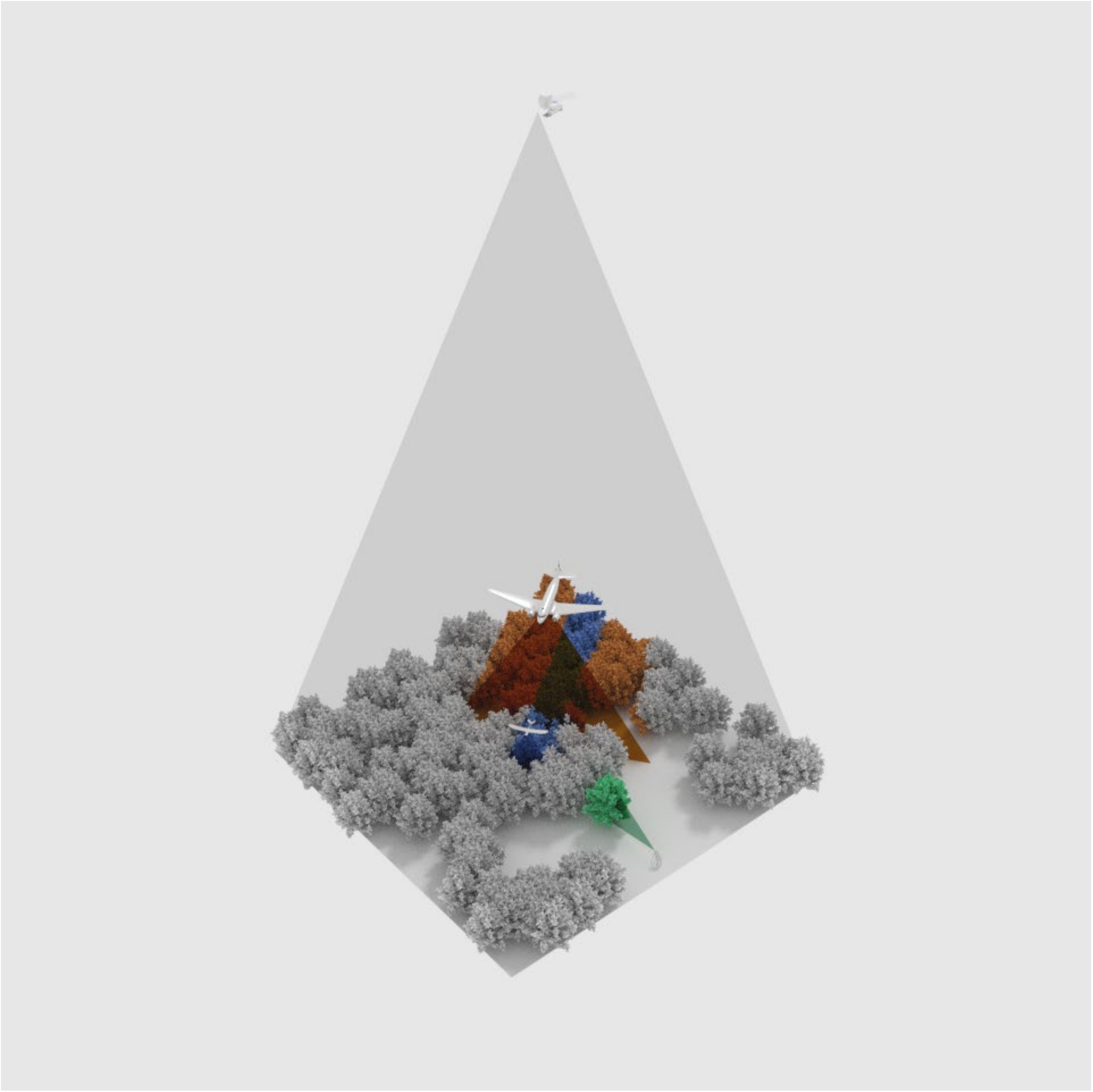
Lack of knowledge of **tree mortality drivers and environmental thresholds**

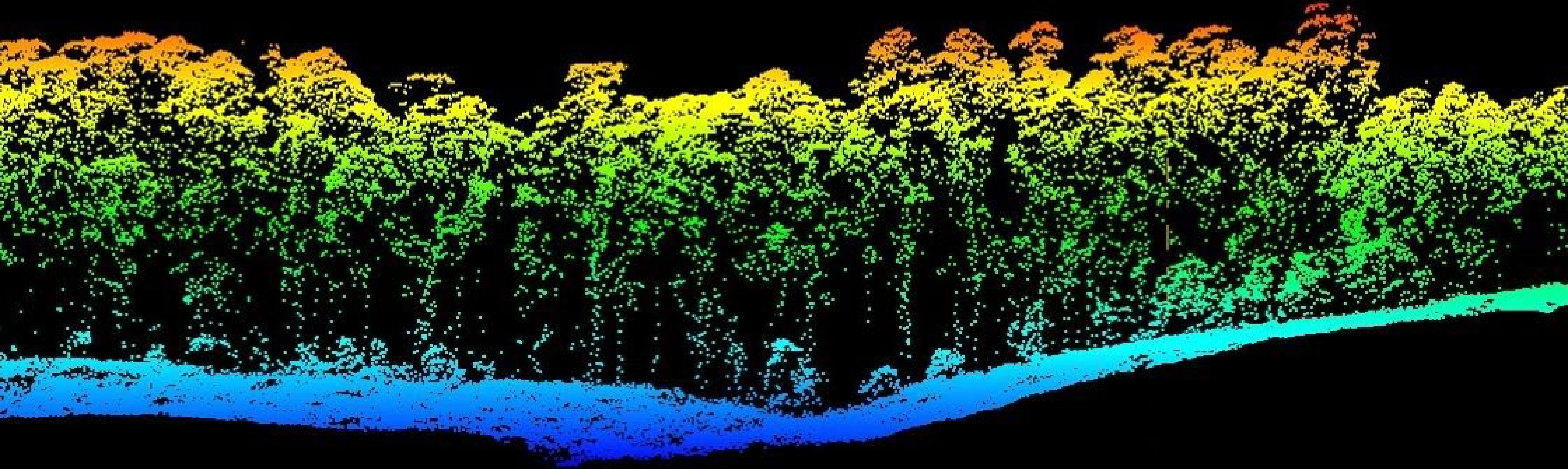
Physiological principles for tree and plant health monitoring

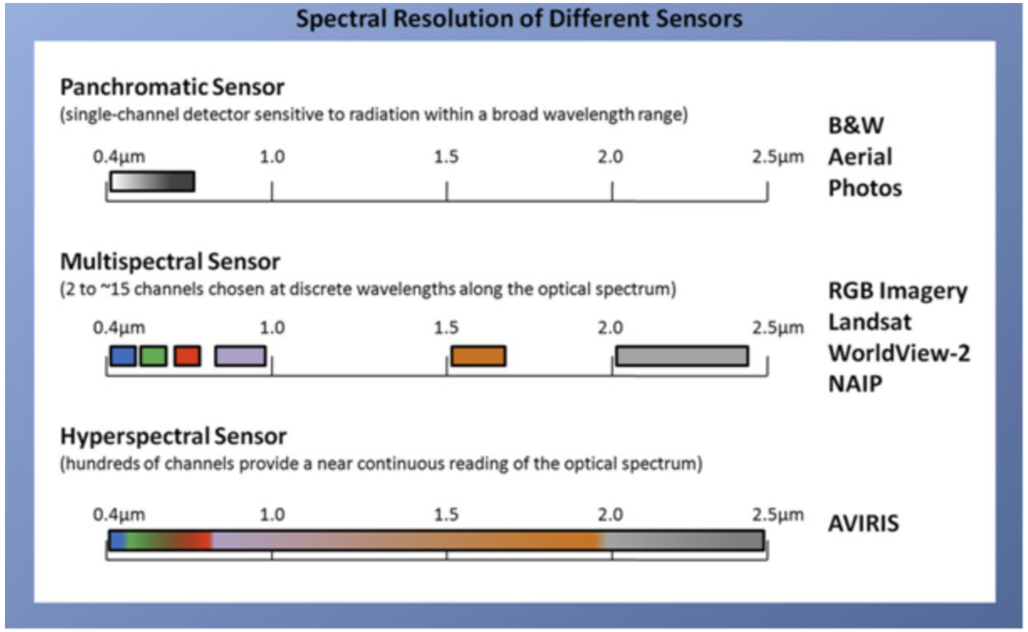
What happens to trees or plants when they are stressed?

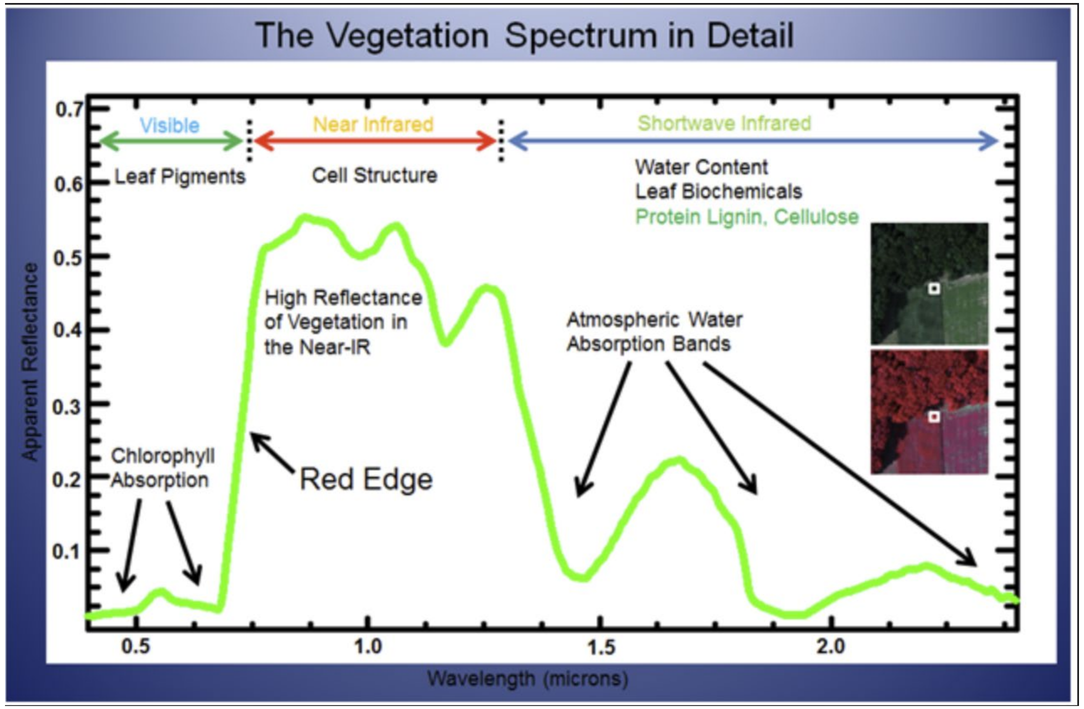
- Stomatal closure
- Reduced photosynthetic activity
- Reduced growth
- Reduced leaf area (defoliation)
- Reduced leaf water content
- Discoloration of leaves





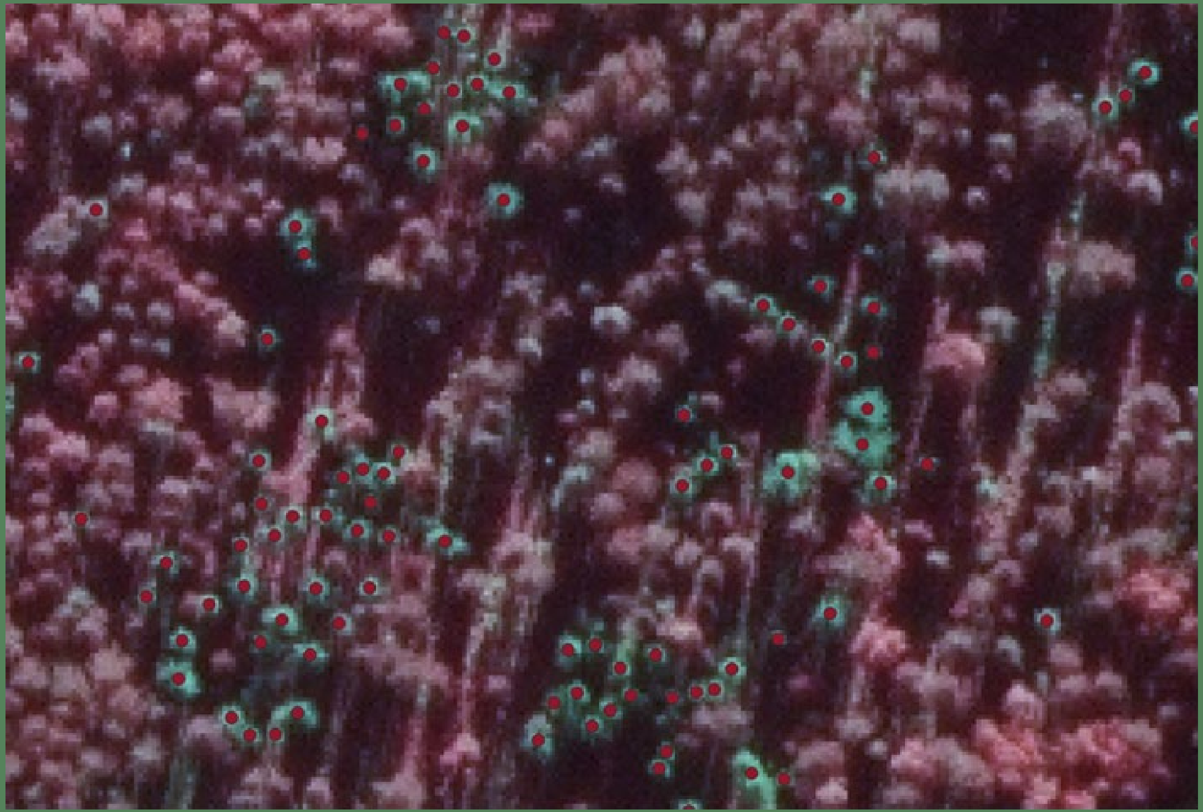



Spectral Resolution of Different Sensors
Panchromatic Sensor
(single-channel detector sensitive to radiation within a broad wavelength range)
0.4µm
1.0
1.5
2.0
2.5µm
B&W
Aerial
Photos
Multispectral Sensor
(2 to ~15 channels chosen at discrete wavelengths along the optical spectrum)
0.4µm
1.0
1.5
2.0
2.5µm
RGB Imagery
Landsat
WorldView-2
NAIP
Hyperspectral Sensor
(hundreds of channels provide a near continuous reading of the optical spectrum)
0.4µm
1.0
1.5
2.0
2.5µm
AVIRIS


The Vegetation Spectrum in Detail
Visible
Near Infrared
Shortwave Infrared
Leaf Pigments
Cell Structure
Water Content
Leaf Biochemicals
Protein Lignin, Cellulose
High Reflectance
of Vegetation in
the Near-IR
Atmospheric Water
Absorption Bands
Chlorophyll
Absorption
Red Edge
Apparent Reflectance
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.5
1.0
1.5
2.0
Wavelength (microns)

Tree mortality mapping system at individual tree level

- Based on openly available high-resolution imagery (< 1 m spatial resolution)
  - Enables resolving individual tree canopies
  - Over 60% of dead tree observations in Finland as isolated trees
- Aerial imagery is collected every 2-3 years in many countries
- Deep learning models enable automated data processing for large-scale application



Proof of concept

- We aimed to investigate changes in forest canopy mortality in SE Finland during 2017-2023 using aerial imagery
- 1) Has forest canopy mortality increased in Southern Finland between 2017, 2020 and 2023?
- 2) In what types of forests has canopy mortality occurred, and have these changed over time?

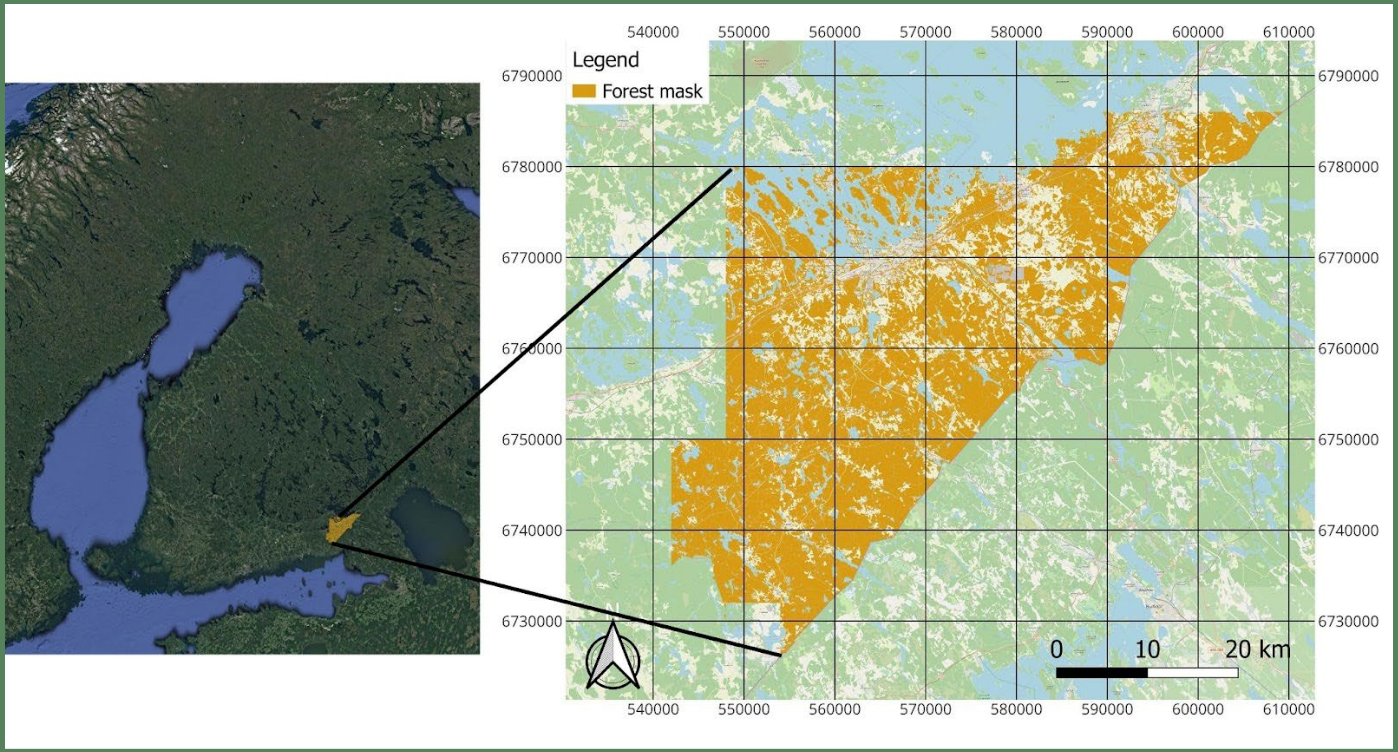
ELSEVIER
Forest Ecology and Management
Volume 565, 1 August 2024, 122020

Significant increase in forest canopy mortality in boreal forests in Southeast Finland

S. Junttila [a], M. Blomqvist [a b], V. Laukkanen [c], E. Heinaro [a], A. Polvivaara [a], H. O'Sullivan [b], T. Yrttimaa [a], M. Vastaranta [a], H. Peltola [a]

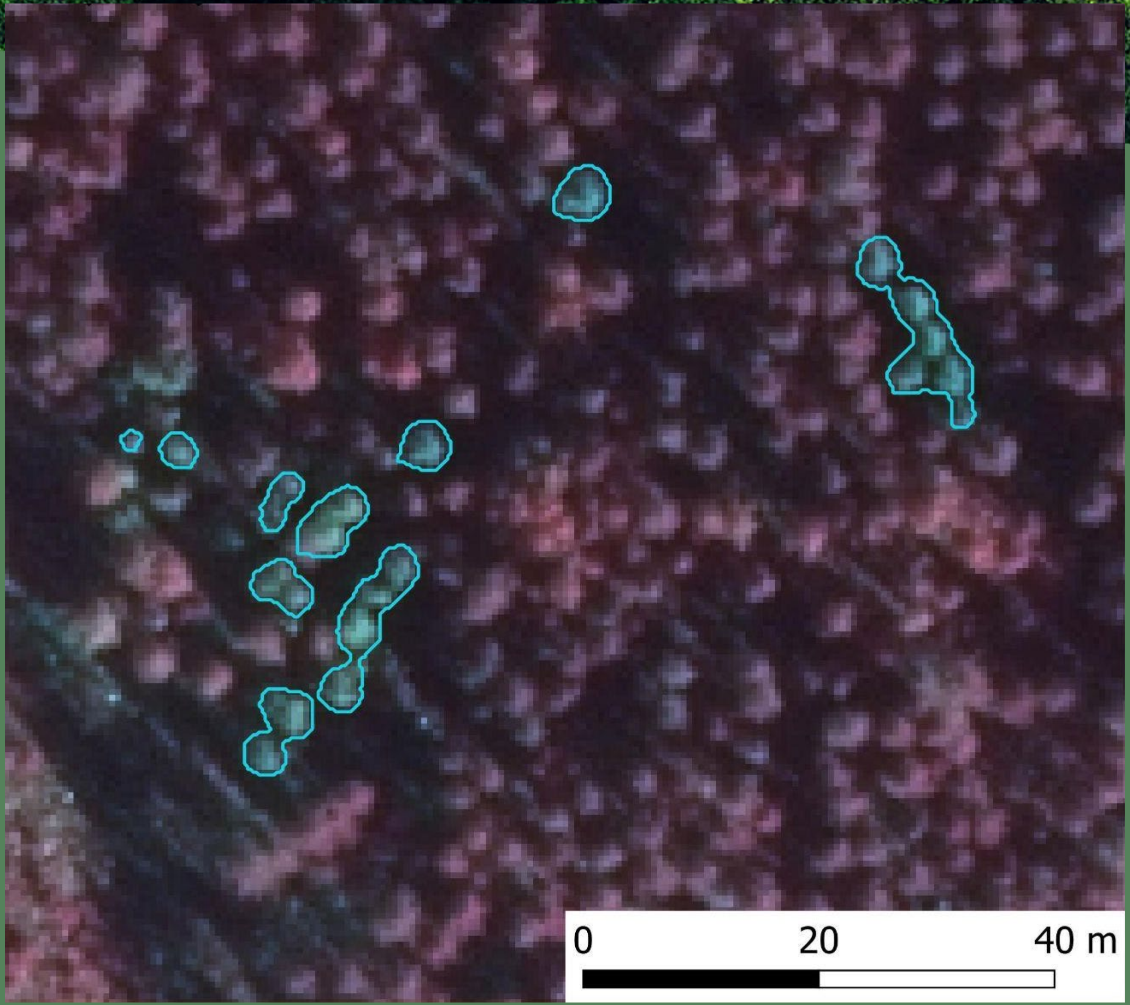
Study area and data

- 117 000 ha of boreal forest in SE Finland
- Intensively managed
- Aerial imagery for 2017, 2020, and 2023 (0.5 m resolution)
- Open forest resource data (16 m x 16 m grid)



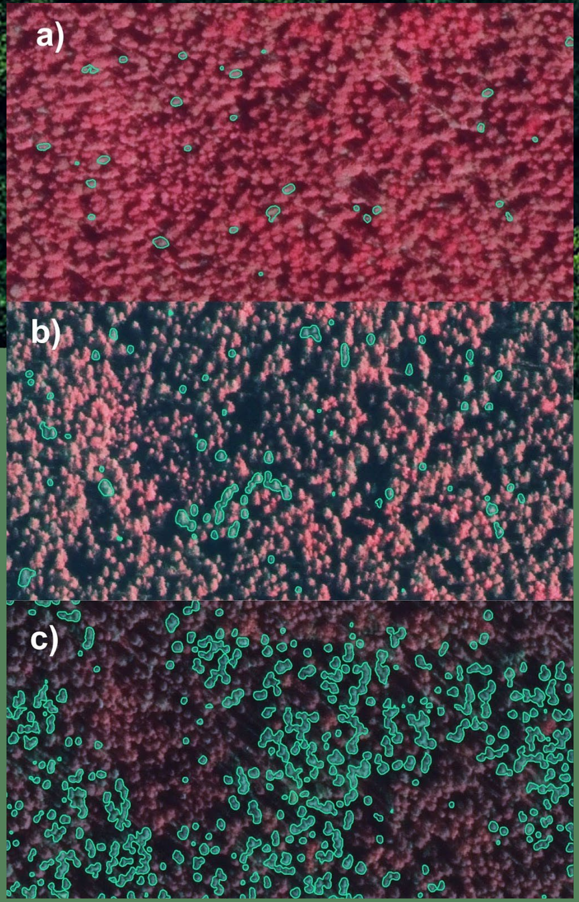
Computer vision – a game changer in remote sensing analysis

- We developed a computer vision model to enable image interpretation similar to human capability
- A high-speed image interpreter: Our model prediction runs at a pace of approximately 100 ha/s

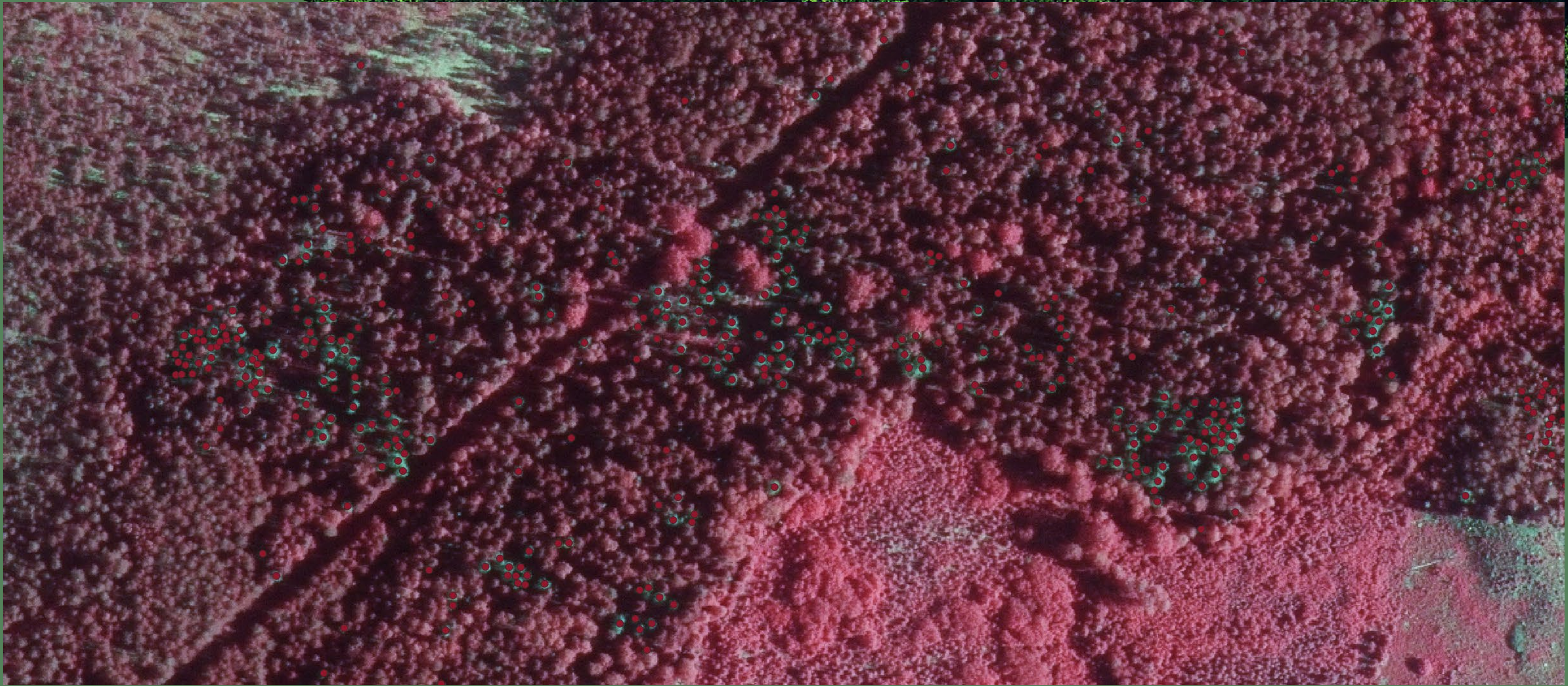


Dead tree detection algorithm

- U-Net based algorithm trained on 32 000 manually labelled trees
- Independent validation based on random 42 one-hectare squares
- Consistent performance of the algorithm over different years (F1-scores 0.86-0.93)



Year	Total trees	Intersection over union	True positives	False positives	False negatives (misses)	Precision	Recall	F1
2017	145	0.634	130	26	15	0.83	0.9	0.86
2020	208	0.619	180	20	28	0.9	0.87	0.88
2023	1137	0.671	1269	63	120	0.95	0.91	0.93



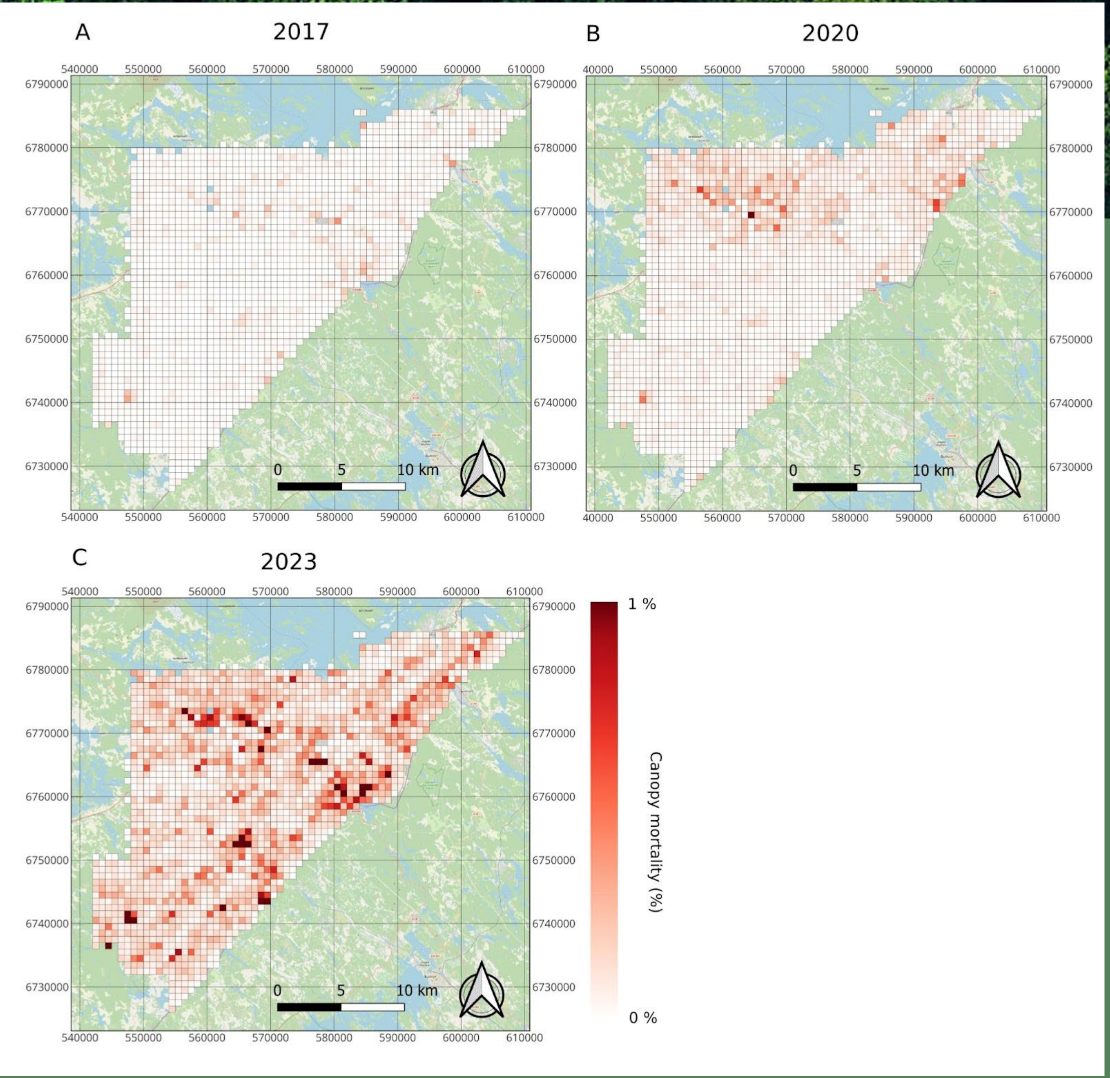
Change in forest canopy mortality in SE Finland 2017–2023

- A pronounced increase in forest canopy mortality during 2020-2023
- 10-fold increase in standing deadwood volume
- Area of forest canopy mortality increased by 788 %

Variable / year	2017	2020		2023	
		ha/m^3	% inc.	ha/m^3	% inc.
The total area of forest canopy mortality (ha)	23.4	61.2	162	207.8	788
The total volume of standing deadwood	5192	13866	167	52800	917
The mean volume of standing deadwood per forest hectare	0.04	0.12		0.45	

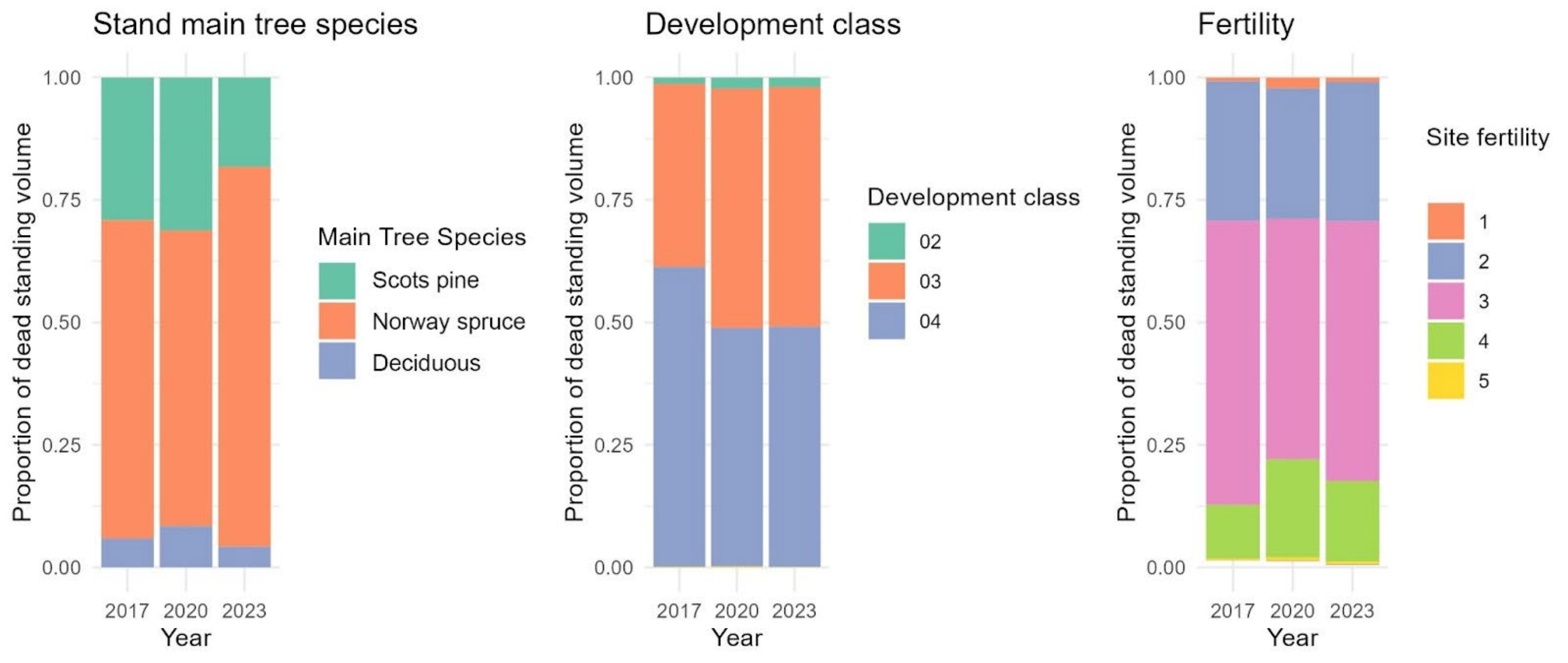
Change map

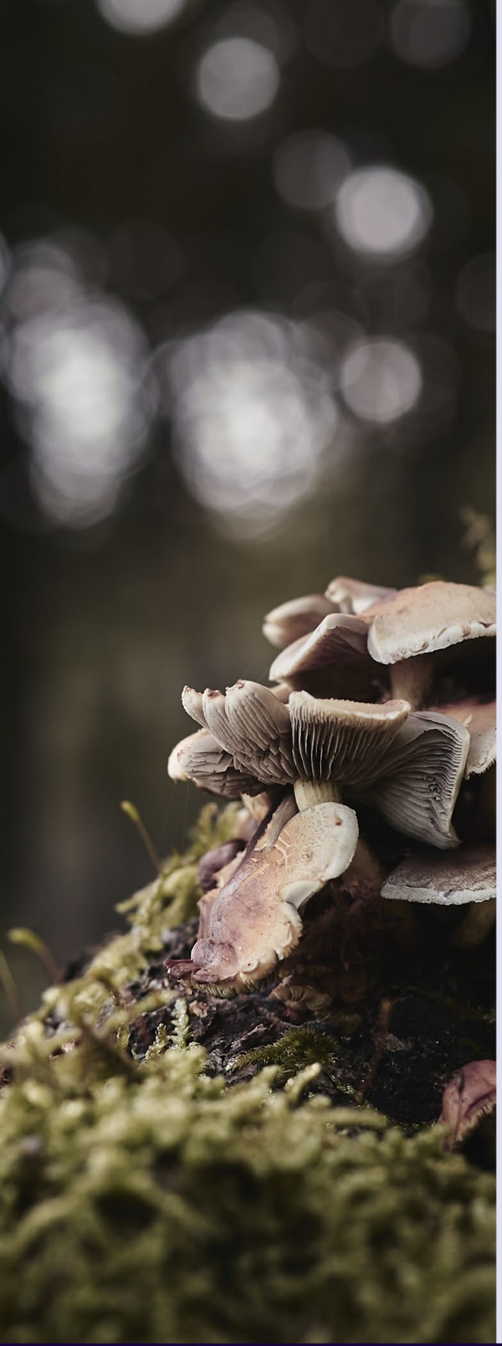
- Tree mortality increased fairly evenly over the study area



What kind of forests suffered 2017–2023

- Increasing mortality in Norway spruce-dominated stands
- Increasing mortality in growing forests (50/50 mature and growing forests)
- Small increase in drier sites but mostly fertile forests (MT and OMT classes)



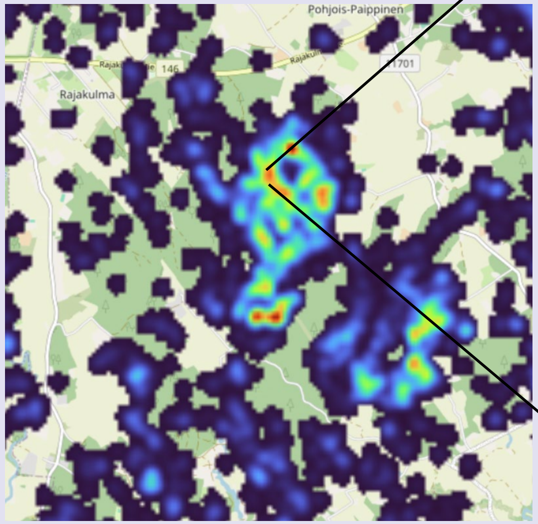


Lahopuurikkaiden alueiden tunnistaminen

Menetelmällä voidaan tunnistaa myös lahopuurikkaat metsäalueet, koska toimii myös vanhoilla ilmakuvilla

Vanhojen metsien inventointi

Monimuotoisten metsäalueiden tunnistaminen

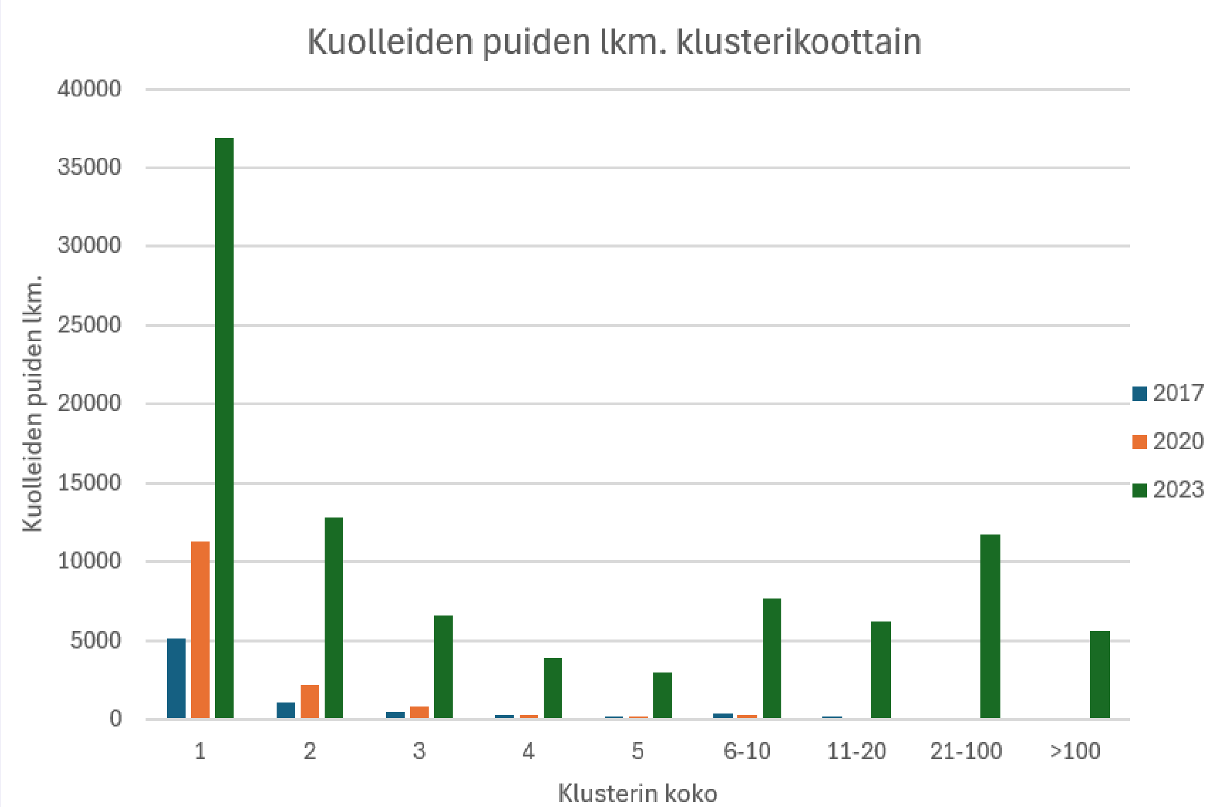


Miksi tarvitaan ilmakuvia tai muuta korkean resoluution aineistoa?

Jopa 90 % pystyyn kuolleista puista esiintyy 1-2 puun ryhmissä → näin pieniä muutoksia on hyvin haastava havaita luotettavasti avoimilla satelliittikuva-aineistoilla (esim. Sentinel-2, 10 m resoluutio)

Avoimilla satelliittikuva-aineistoilla tuho havaitaan vasta kun se on edennyt jo pitkälle

Varhaiseen havainnointiin tarvitaan aineisto, josta yksittäiset puut erottuvat



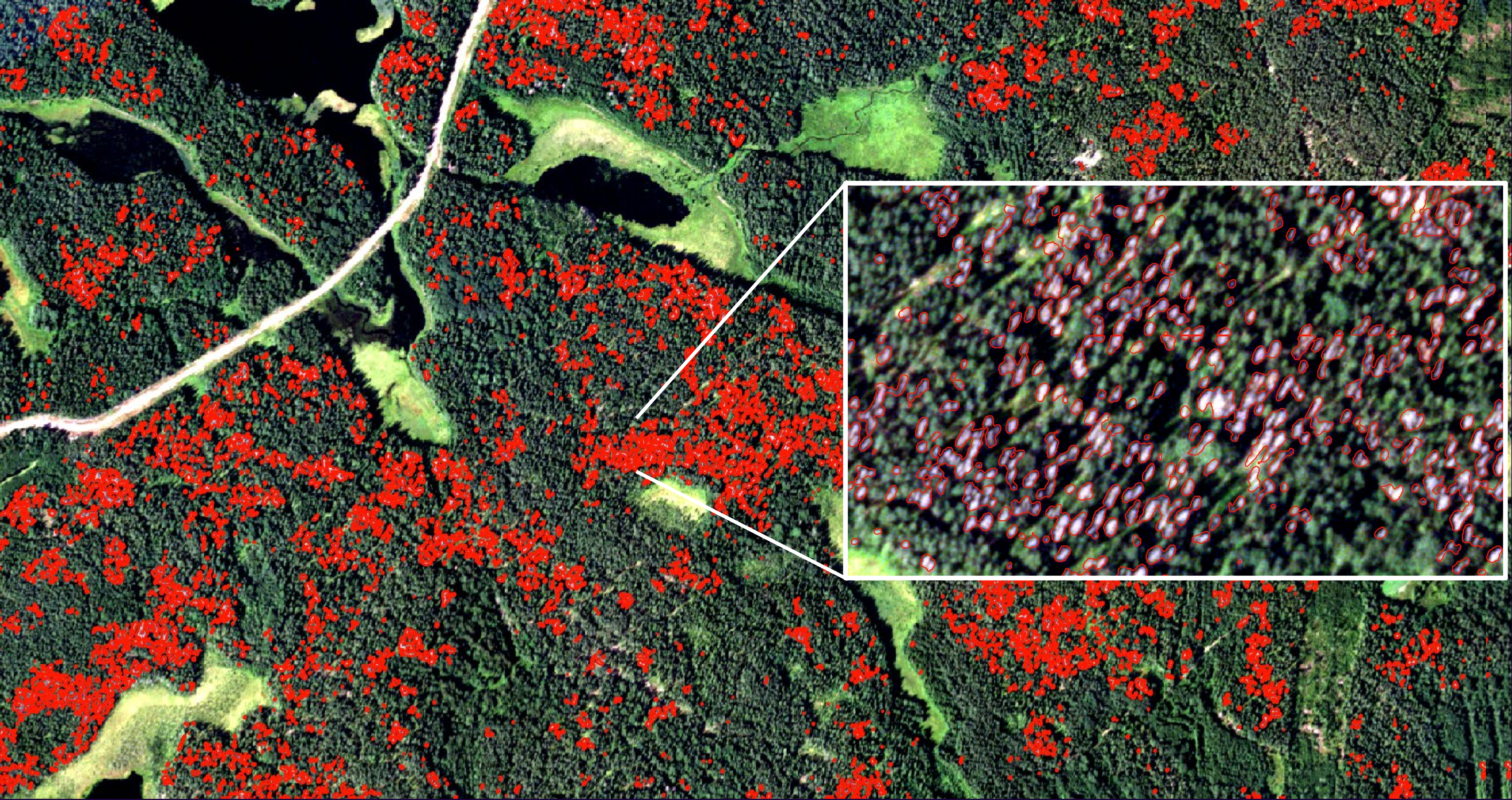
High-resolution satellite imagery for areas without aerial imagery

Collected on a request basis

Deep learning approach for detecting standing dead trees from high-resolution satellite imagery

- RGB + Near-infrared bands
- 50 cm resolution

Can be used as sample plots for estimating tree mortality trends



Wall-to-wall tree-level mortality patterns

Spatial and temporal patterns of tree mortality

New database of 100s of millions of individual geolocated tree mortality events across different climate gradients

Wall-to-wall tree-level mortality patterns

- Finland: 30 000 000 dead trees
- Estonia: 3 900 000 dead trees

- California: 91 400 000 dead trees

Scattered tree death contributes to substantial forest loss in California

Yan Cheng, Stefan Oehmcke, Martin Brandt, Lisa Rosenthal, Adrian Das, Anton Vrieling, Sassan Saatchi, Fabien Wagner, Maurice Mugabowindekwe, Wim Verbruggen, Claus Beier & Stéphanie Horion

Nature Communications **15**, Article number: 641 (2024) | Cite this article

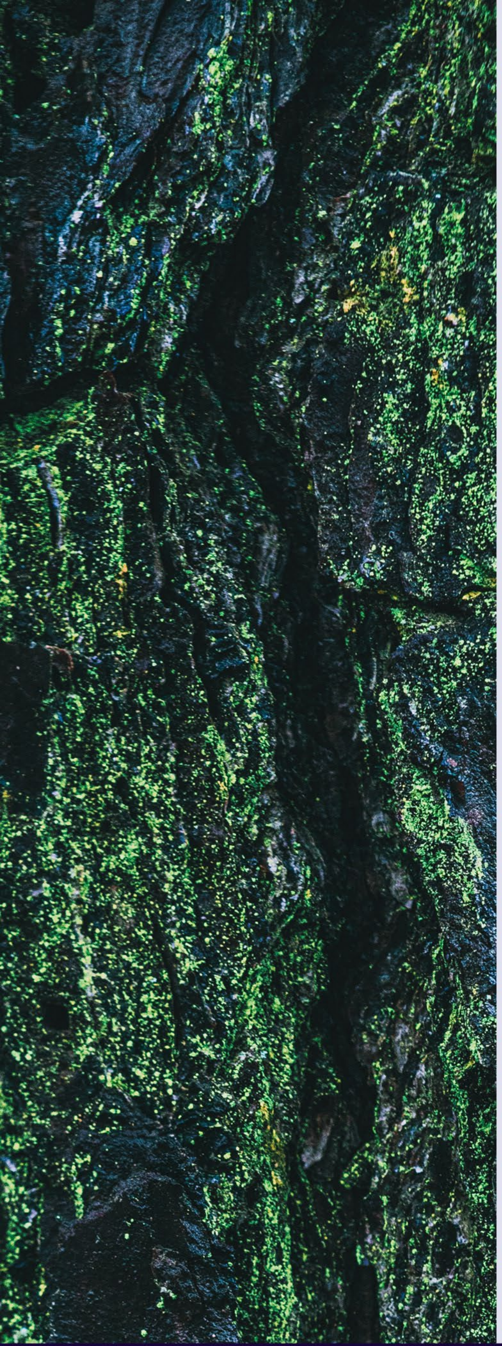
Diverse forests are your best insurance against climate warming

Diverse and complex ecosystems are more resilient (e.g., Jactel et al. 2005, Pautasso et al. 2005)

Diverse forests are more productive (support from over 20 studies)

Diverse forests are more stable against forest damages (McCann 2000, Ingham et al. 1985, Liiri et al. 2002)

But measuring biodiversity has been challenging to measure remotely



Urban Forestry & Urban Greening
Volume 104, February 2025, 128672

Original article

Quantifying the drivers of tree mortality: A case study from urban recreational boreal forest

Johanna Jääskeläinen [a], Samuli Junttila [a], Hannah O'Sullivan [b c], Yan Cheng [d], Stéphanie Horion [d], Mikko Vastaranta [a]

Climate resilience as a management objective

Intermediate disturbance hypothesis

- Intermediate disturbances lead to most diverse forest ecosystems
- Current management practices aim to avoid disturbances

Accurate data on tree mortality enables local risk modelling and adaptive management

- Identifying tree mortality risk factors (Jääskeläinen et al. 2025)
- E.g., ensuring water availability through lower forest density

From research to a start-up company

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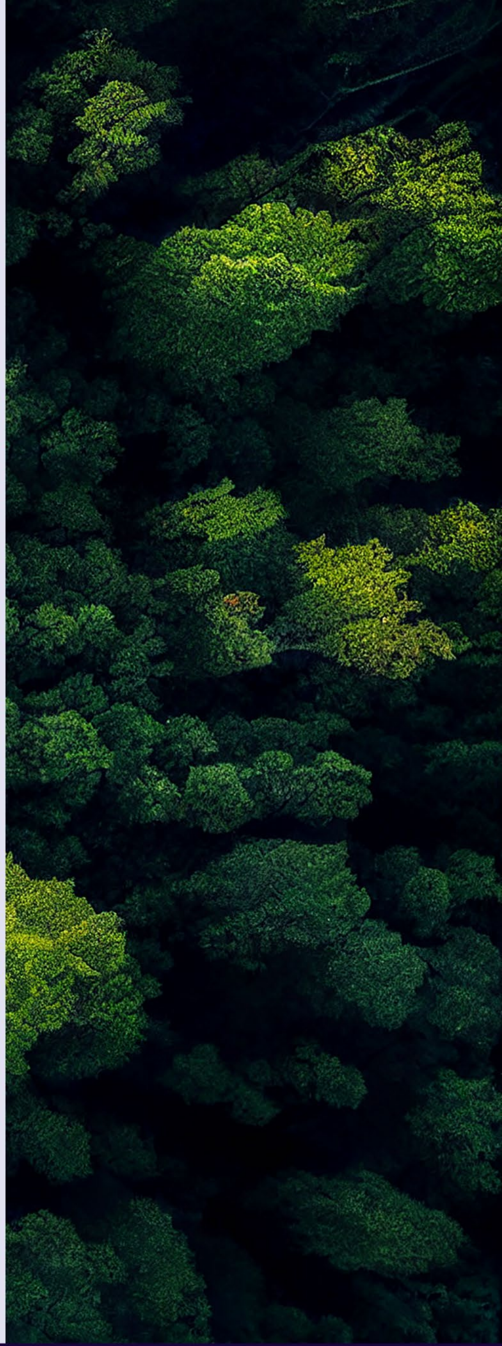
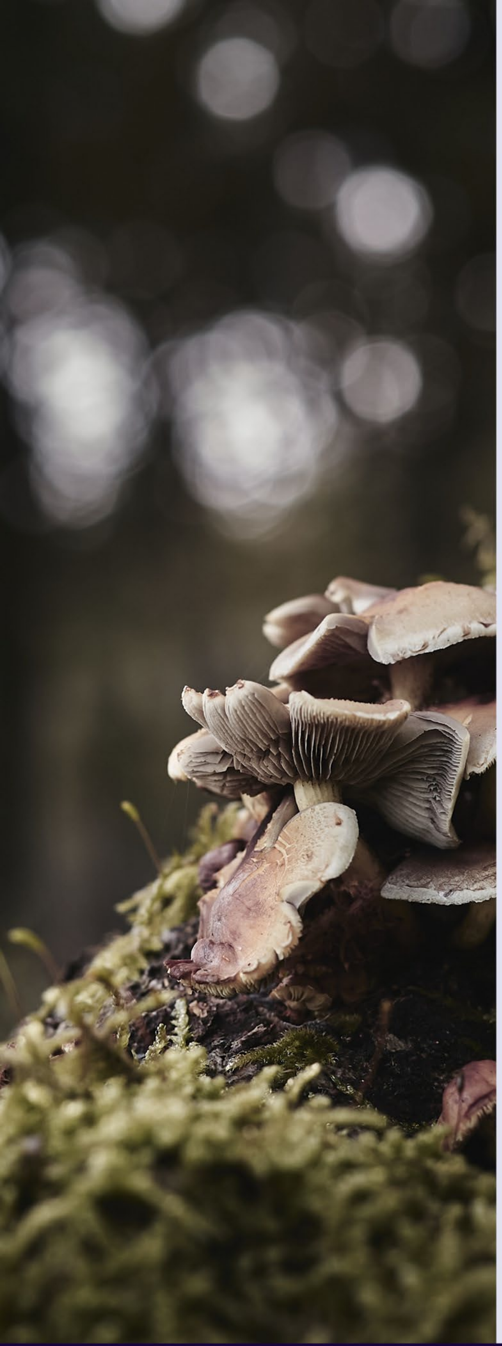
X

KOKO
FOREST





Key take-aways

We urgently need systematic forest disturbance monitoring – solutions exist for accurate monitoring

We have observed a worrying trend in forest canopy mortality in Southern Finland

Forest biodiversity should be increased to increase forest resilience

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