11– Tree health and mortality mapping

- Relevanceof tree mortality mapping
- Towards of global tree mortality mapping
- The platform deadtrees.earth
- Recent findings



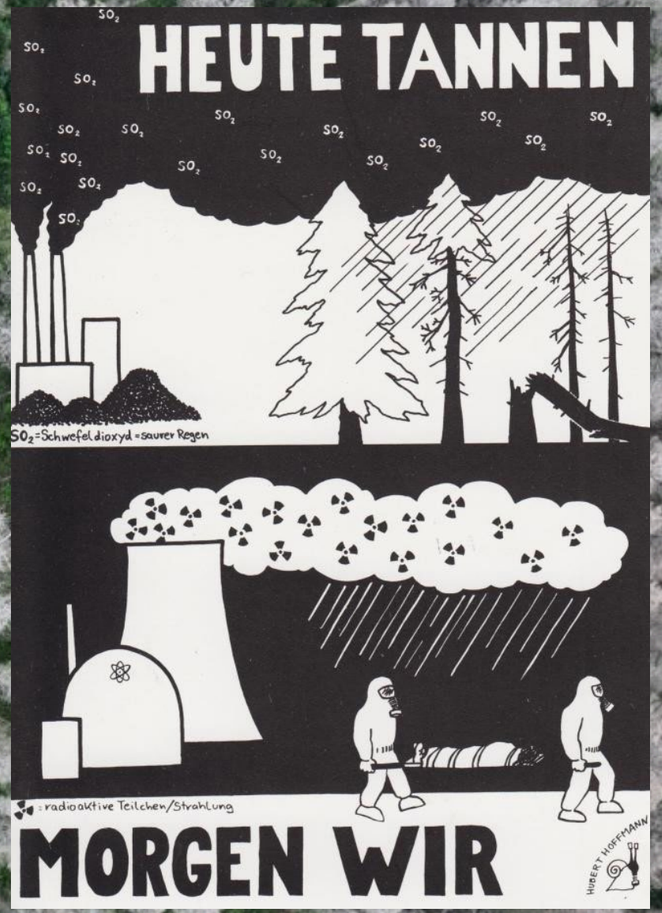
Chair of Sensor-based Geoinformatics (geosense)
www.geosense.uni-freiburg.de

Relevance of tree mortality mapping

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

Relevance of tree mortality mapping

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



Relevance of tree mortality mapping

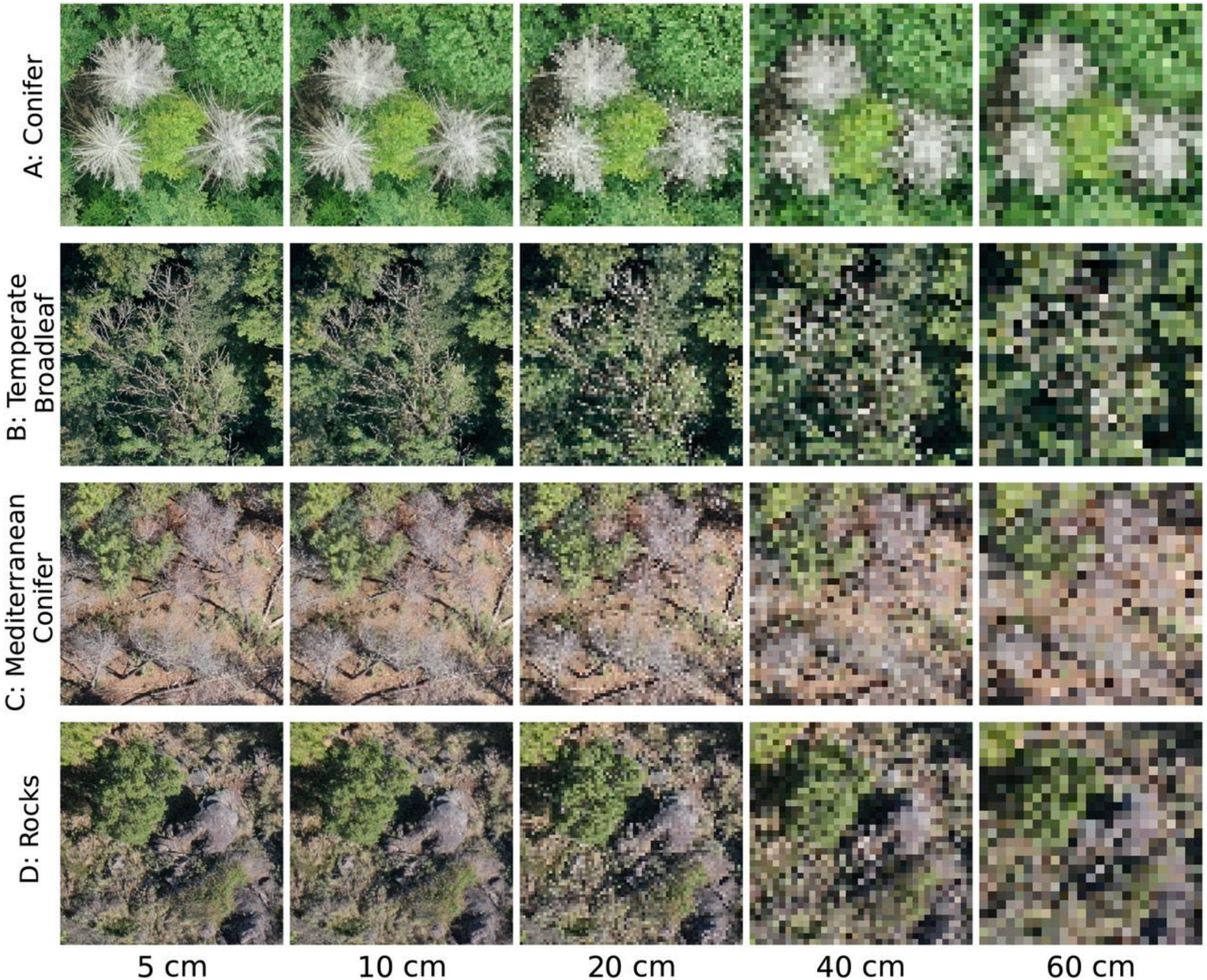
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

- Large-scale assessment of tree mortality only possible with remote sensing (satellites, airplanes, ….)
- Translating remote sensing signals into tree mortality patterns requires „training data“ (supervised learning)
- Inventory data could be a valuable resource. However, forestry is known to be a conservative/restrictive field, where institutions and companies do not or cannot share inventory data
- What to use instead of inventory data?

Relevance of tree mortality mapping

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

- Aerial imagery is a promising, widely available resource to detect dead trees (at least in the vegetation season).
- The spatial resolution can be of cardial importance.
- Drones enable to create aerial imagery with unprecendeed resolution.
- Automatization is key.



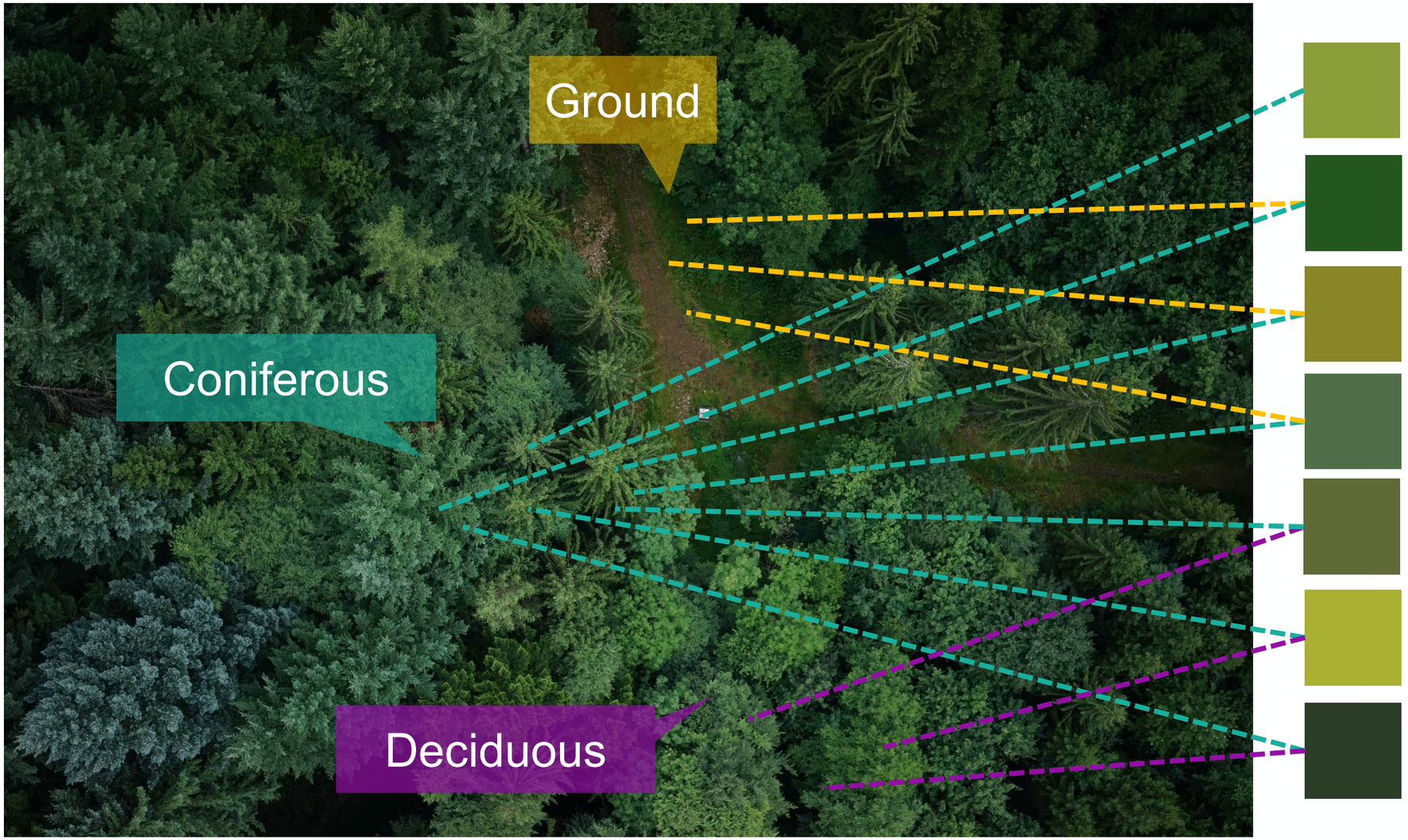
Mosig et al. 2024

Recap pattern recognition

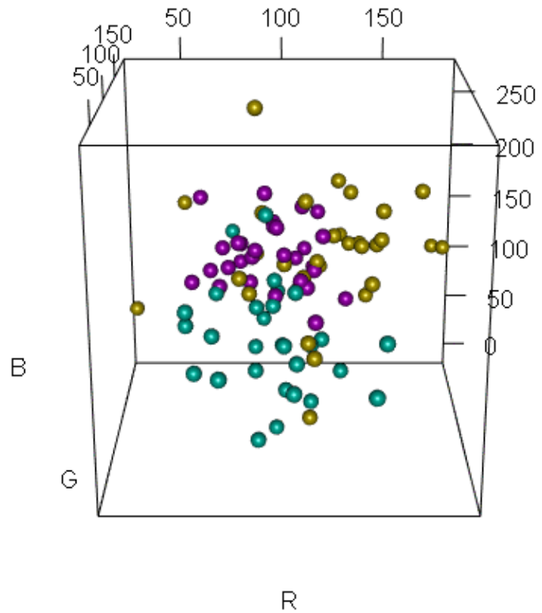
Recap pattern recognition

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

RGB Drone image



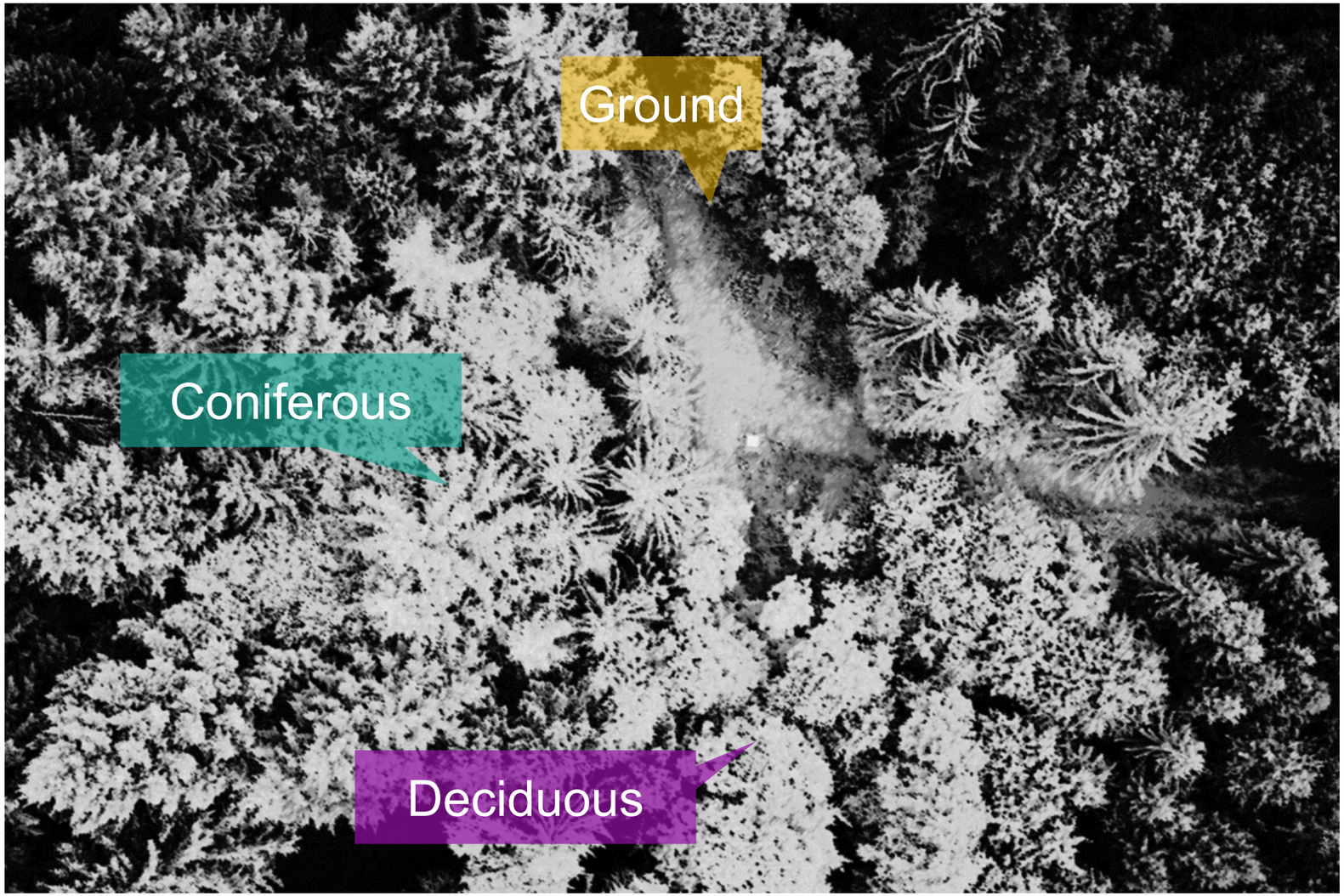
RGB color space:



Conifer
Deciduous
Ground

Recap pattern recognition

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



Texturmetriken

- Entropy
- Variance
- Mean
- Homogenity
- etc…

input

3_0	3_1	2_2	1	0
0_2	0_2	1_0	3	1
3_0	1_1	2_2	2	3
2	0	0	2	2
2	0	0	0	1

output

12.0	12.0	17.0
10.0	17.0	19.0
9.0	6.0	14.0

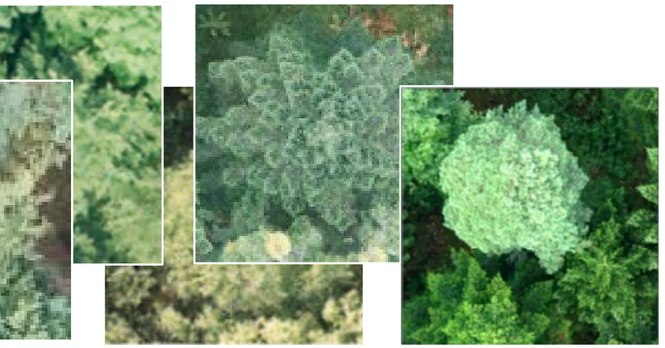
Haralick, R. M., & Shanmugam, K. (1973). Textural features for image classification. *IEEE Transactions on systems, man, and cybernetics*, (6), 610-621.

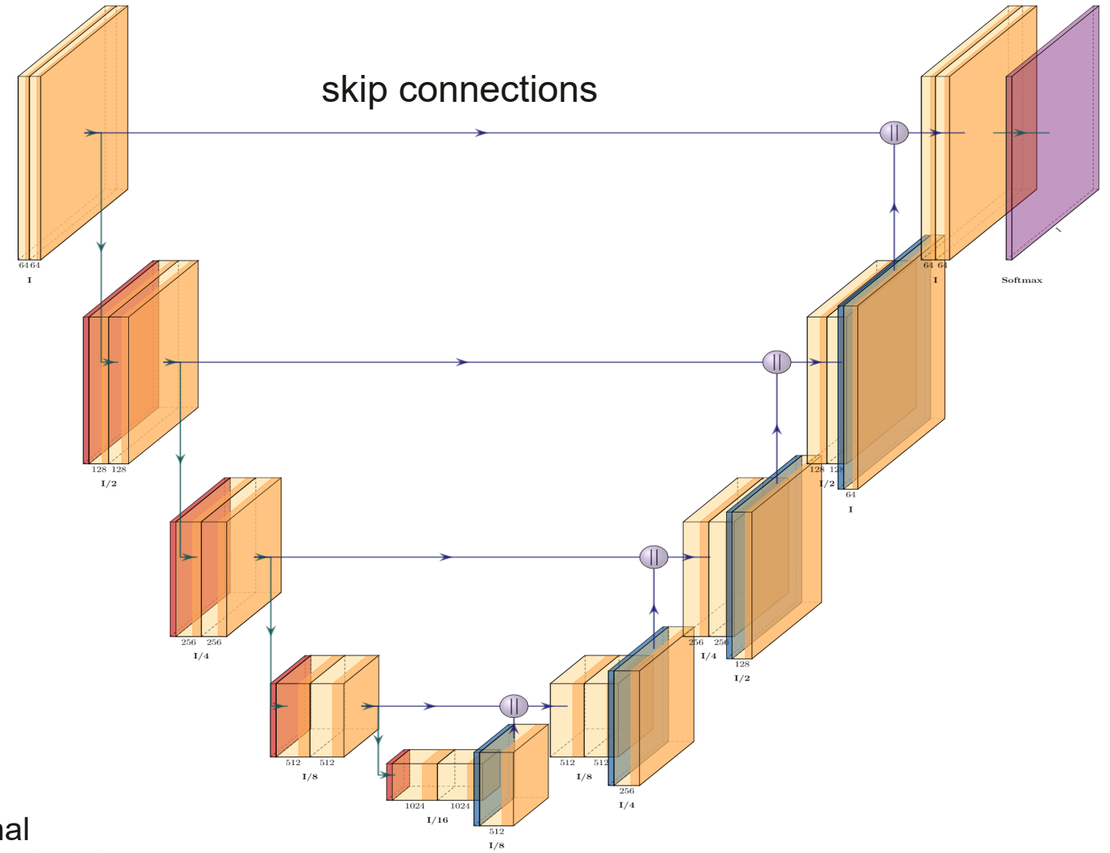
Recap pattern recognition

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

Image Segmentation with Convolutional Neural Networks (CNN, Unet)

Predictors (x, image data)





Output: Segmentierung

https://github.com/HarisIqbal88/PlotNeuralNet

Kattenborn et al. 2022; Review on Convolutional Neural Networks for vegetation remote sensing, ISPRS.

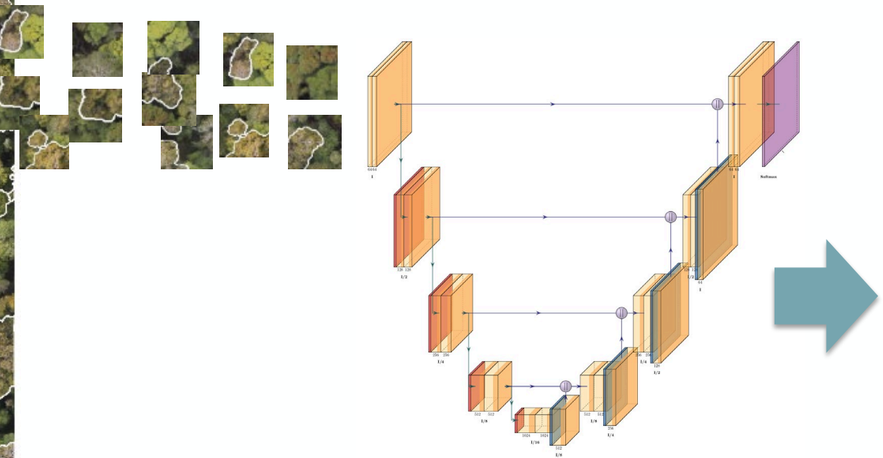
Recap pattern recognition

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

CNN Training
(Training phase with reference data)

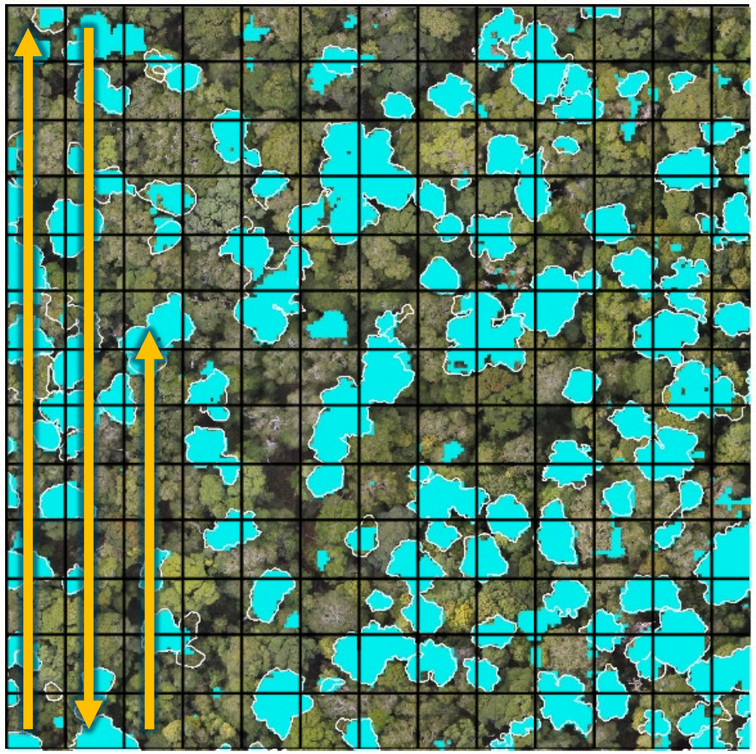
Drone Orthomosaic
2 cm Resolution
> 56 Mio Pixel

Visual
Interpretation



Trained
Convolutional Neural Network
(Segmentation, UNet)

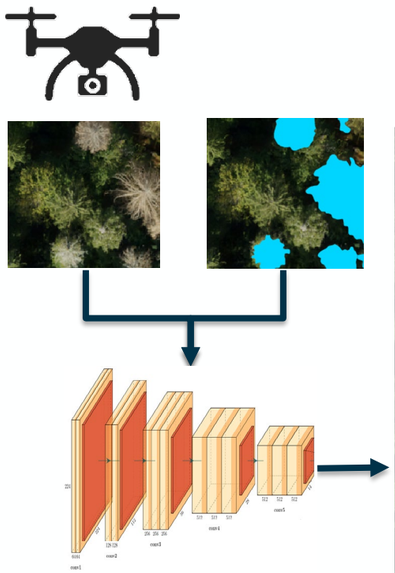
CNN Inference
(Application to new data)

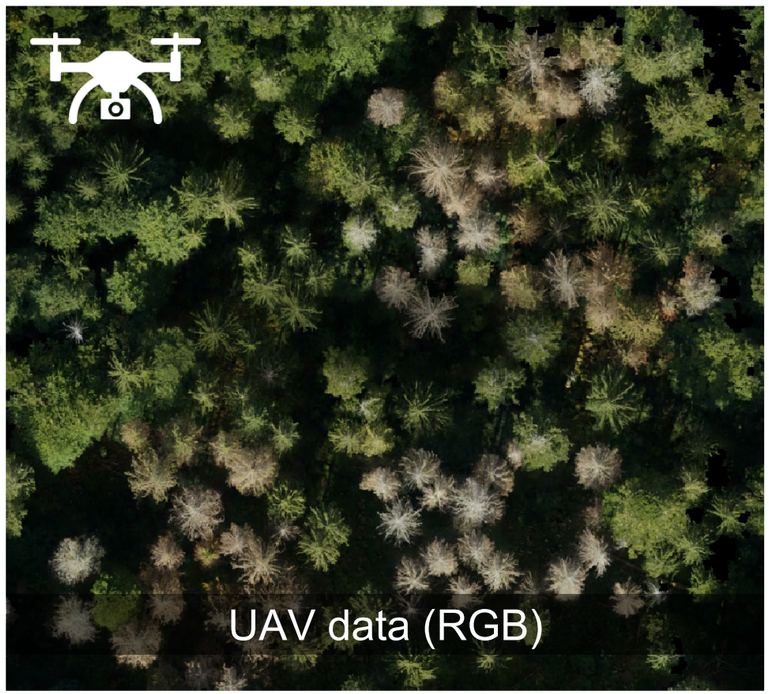


Towards of global tree mortality mapping

Towards of global tree mortality mapping

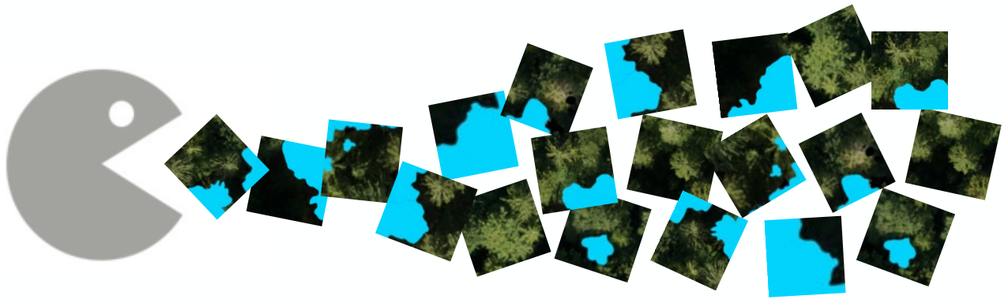
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

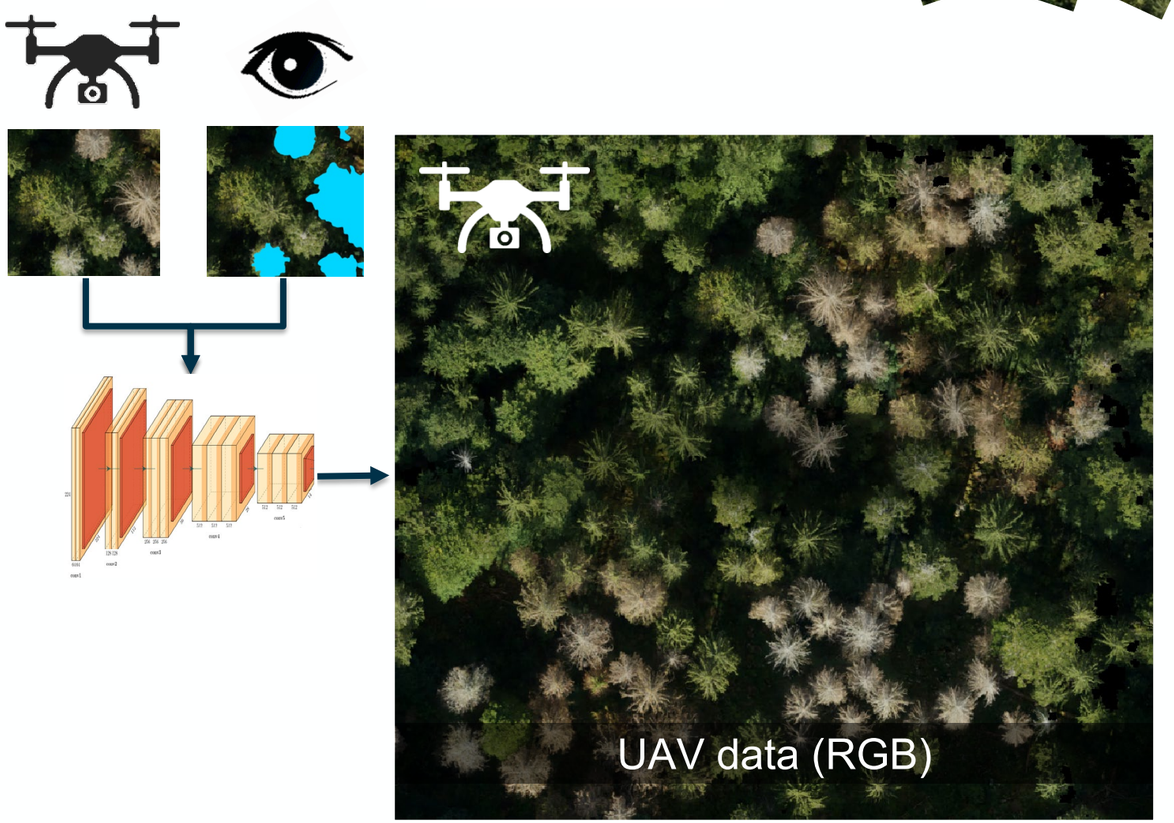




Towards of global tree mortality mapping

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

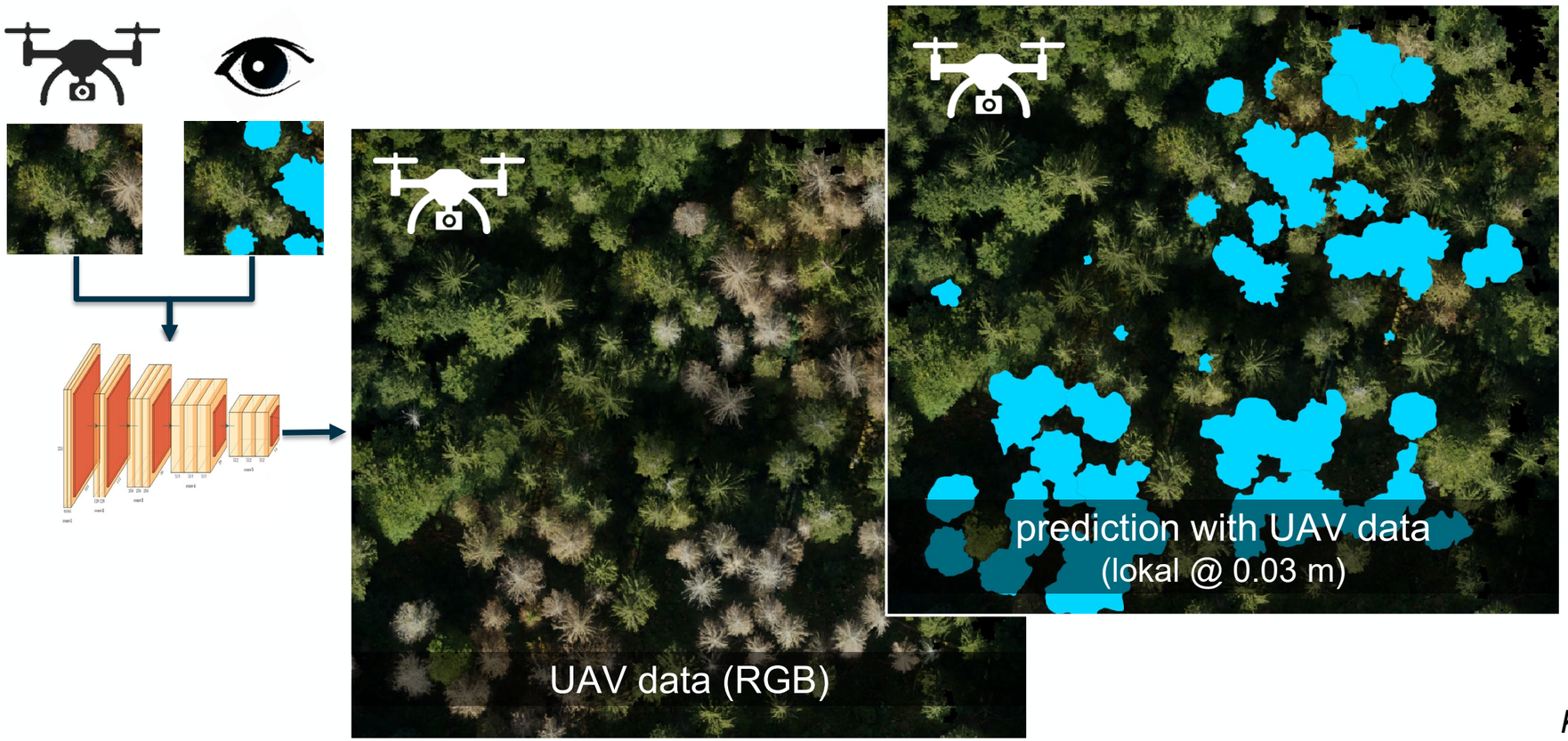




Kattenborn et al. (2019) Scientific reports
Schiefer et al. (2023) ISPRS Open

Towards of global tree mortality mapping

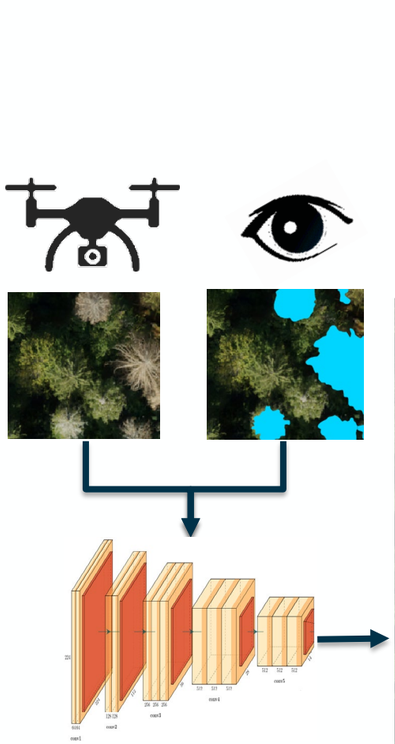
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

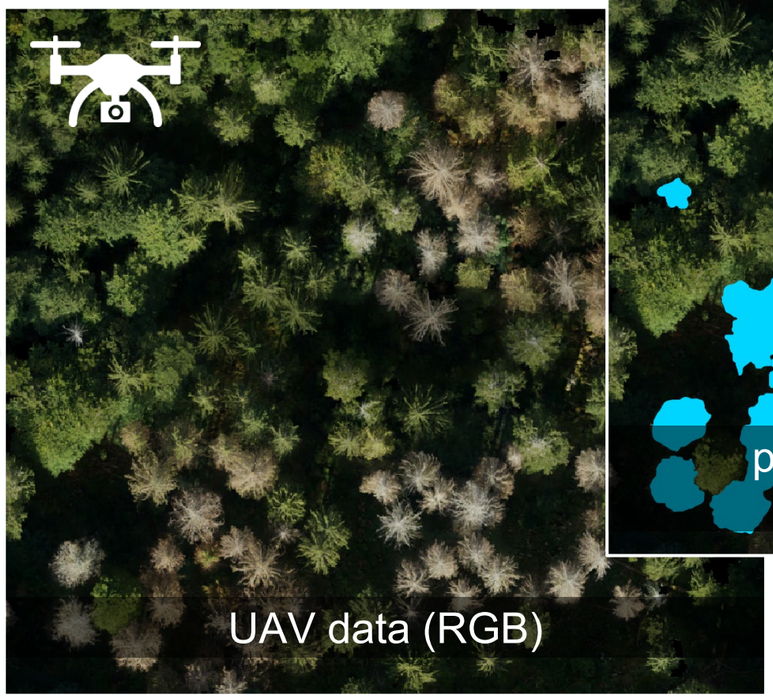


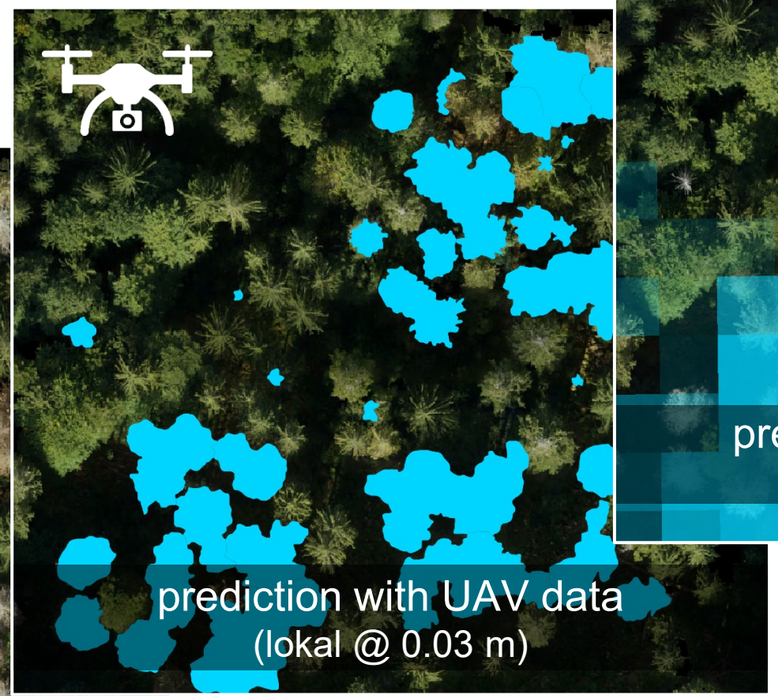
Kattenborn et al. (2019) Scientific reports
Schiefer et al. (2023) ISPRS Open

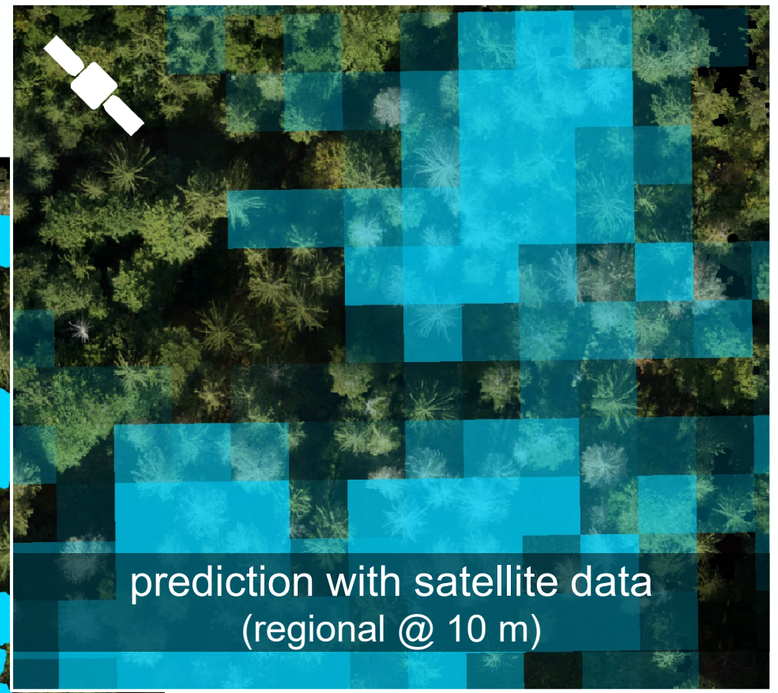
Towards of global tree mortality mapping

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de





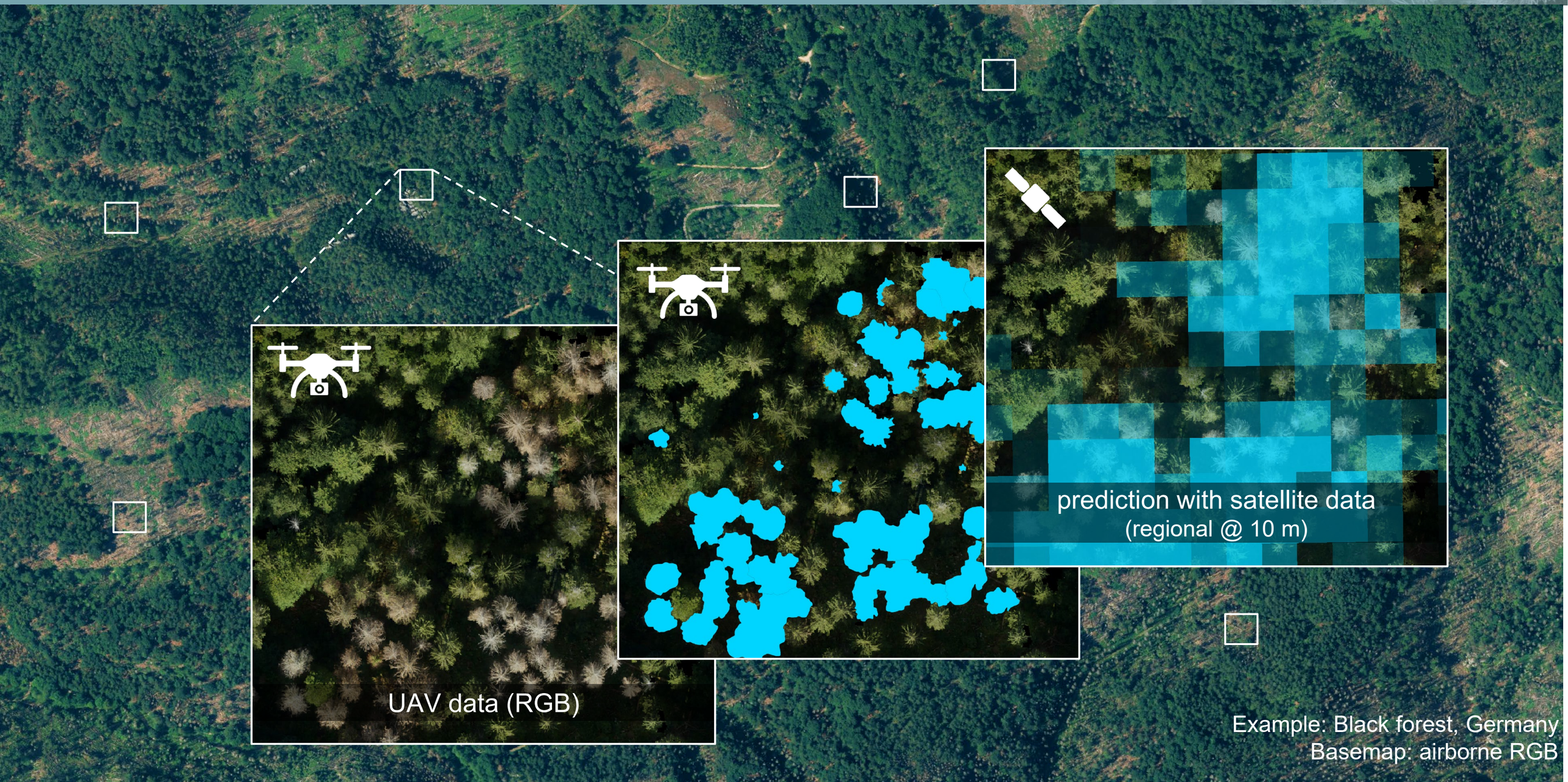




Schiefer et al. (2023) ISPRS Open

Towards of global tree mortality mapping

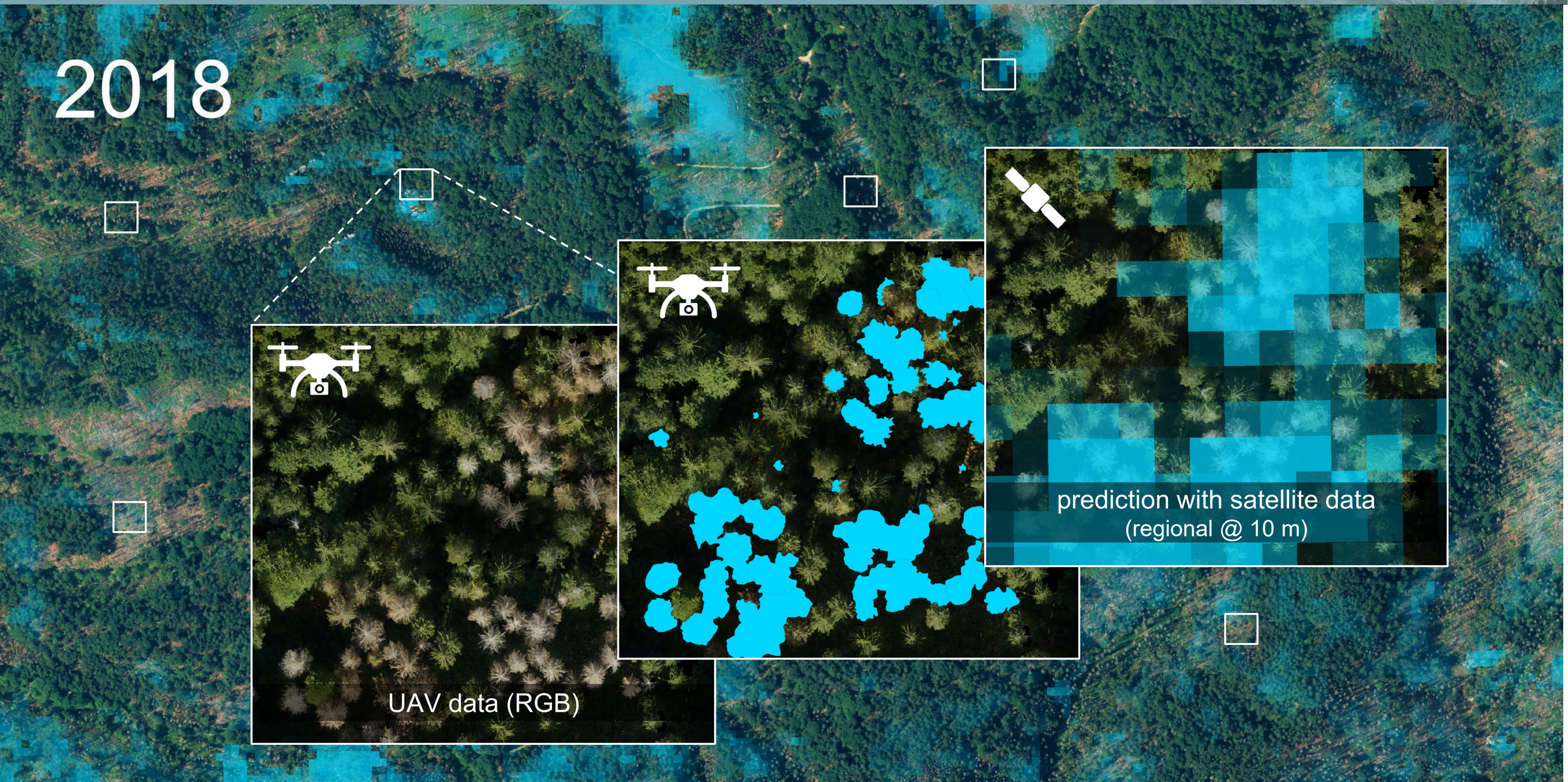
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



Example: Black forest, Germany
Basemap: airborne RGB

Towards of global tree mortality mapping

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



Towards of global tree mortality mapping

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

Standing dead wood

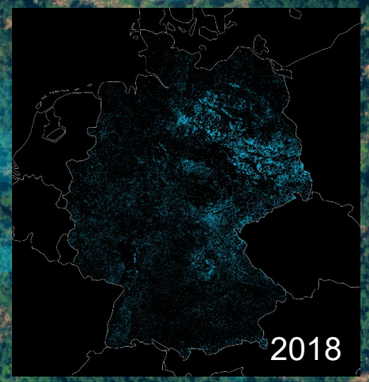
0% cover 100%

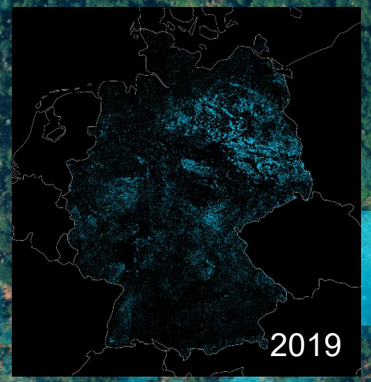
- Schiefer et al. 2023
- Annual product
- 2018-2023
- 10 m resolution
- National coverage (Germany)

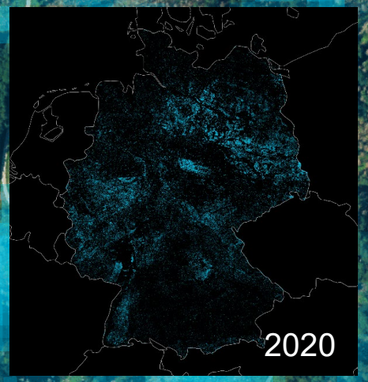
Towards of global tree mortality mapping

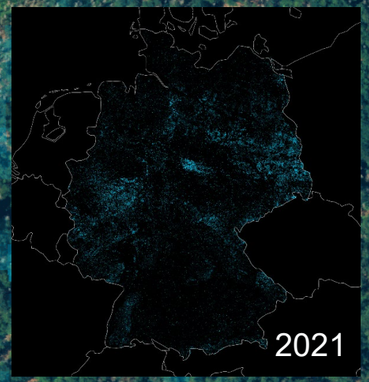
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

2018









Standing dead wood

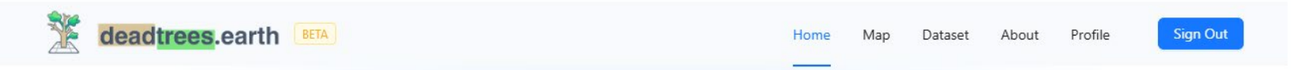
0% cover 100%

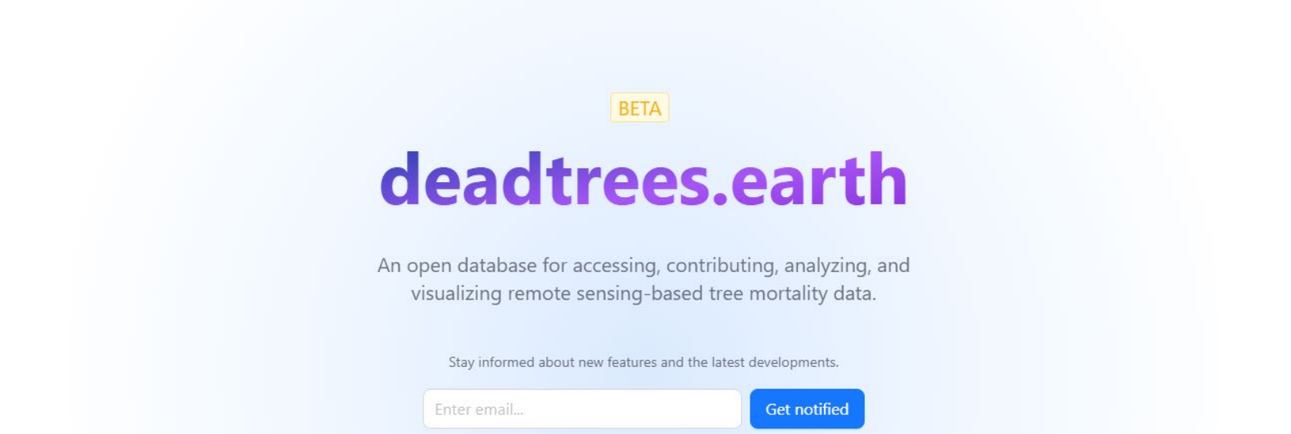
- Schiefer et al. 2023
- Annual product
- 2018-2023
- 10 m resolution
- National coverage (Germany)

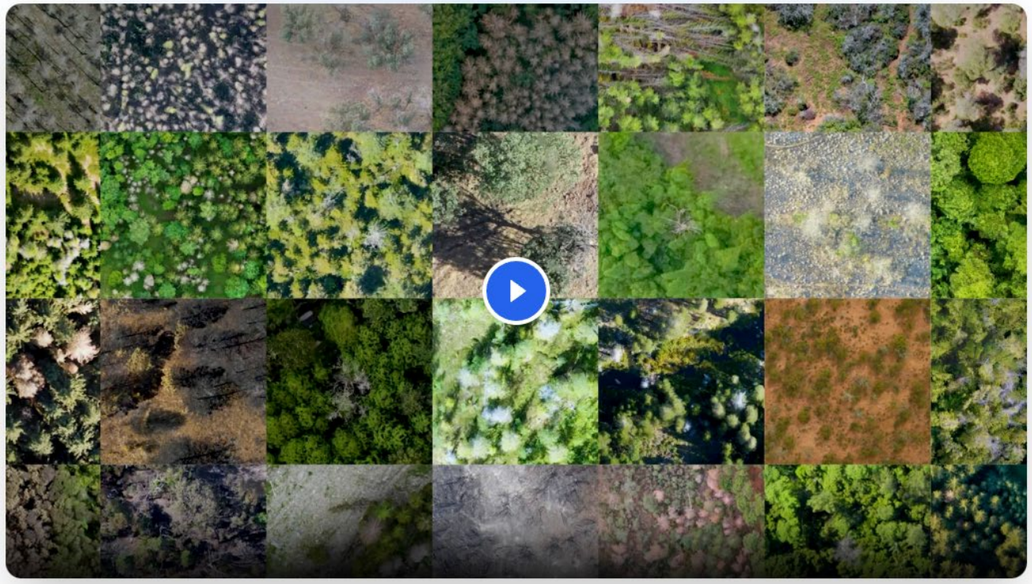
The platform deadtrees.earth

The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de







OUR SERVICES TO THE COMMUNITY

Revealing tree mortality patterns

By integrating Earth observation, machine learning, and ground-based data sources, this initiative aims to bridge the existing gaps in understanding global tree mortality dynamics, fostering a comprehensive and accessible resource for researchers and stakeholders alike.

Open access community effort

Upload and download your aerial imagery with optional delineations of standing deadwood. Every contributor will be credited and invited to collaborate.

Automatic dead tree detection

Automatic detection (semantic segmentation) of dead trees in uploaded aerial imagery through a generic detection computer vision model.

Large-scale tree mortality map

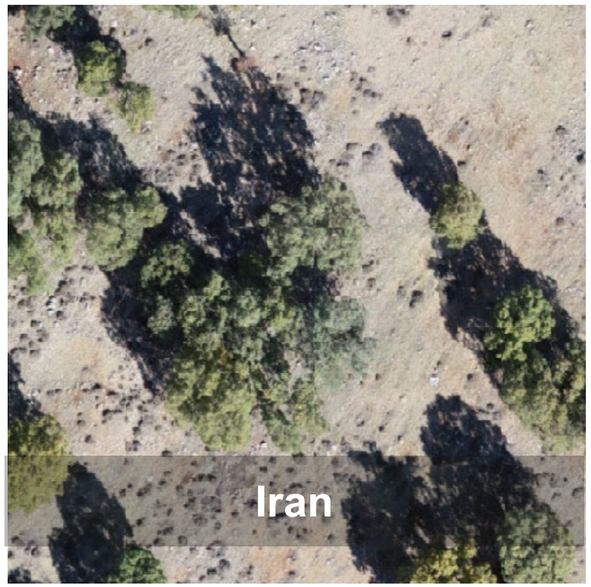
Embedded visualization and download of extensive spatiotemporal tree mortality products derived from extrapolating standing deadwood using Earth observation data.

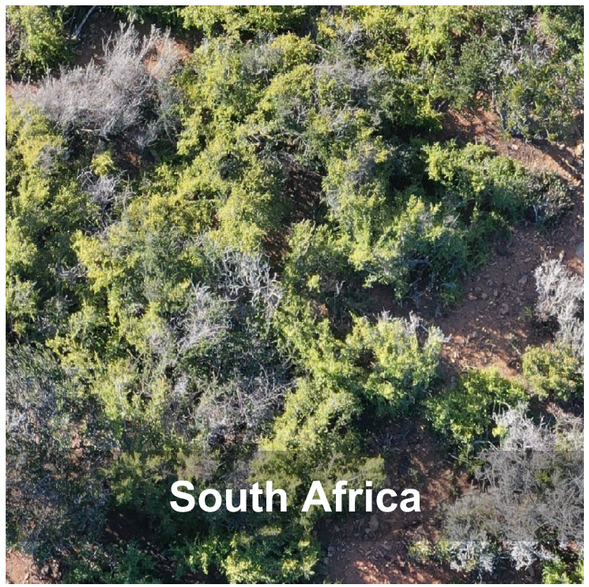
Analysis ready training data

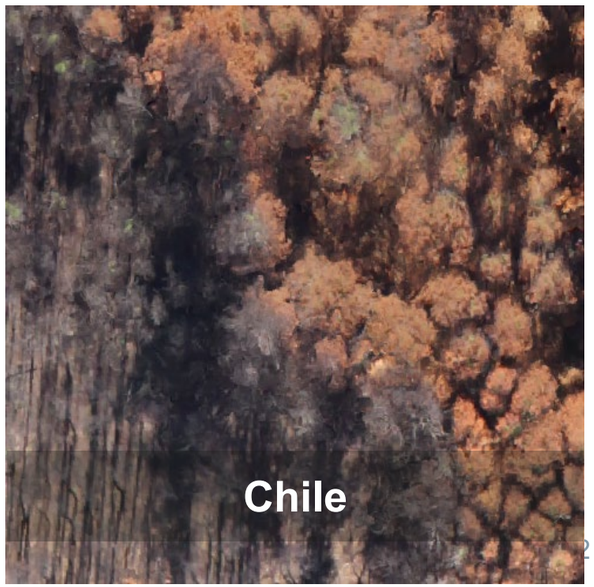
High-resolution aerial imagery of forests worldwide together with delineated standing deadwood which can be used for training your own AI models.

The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

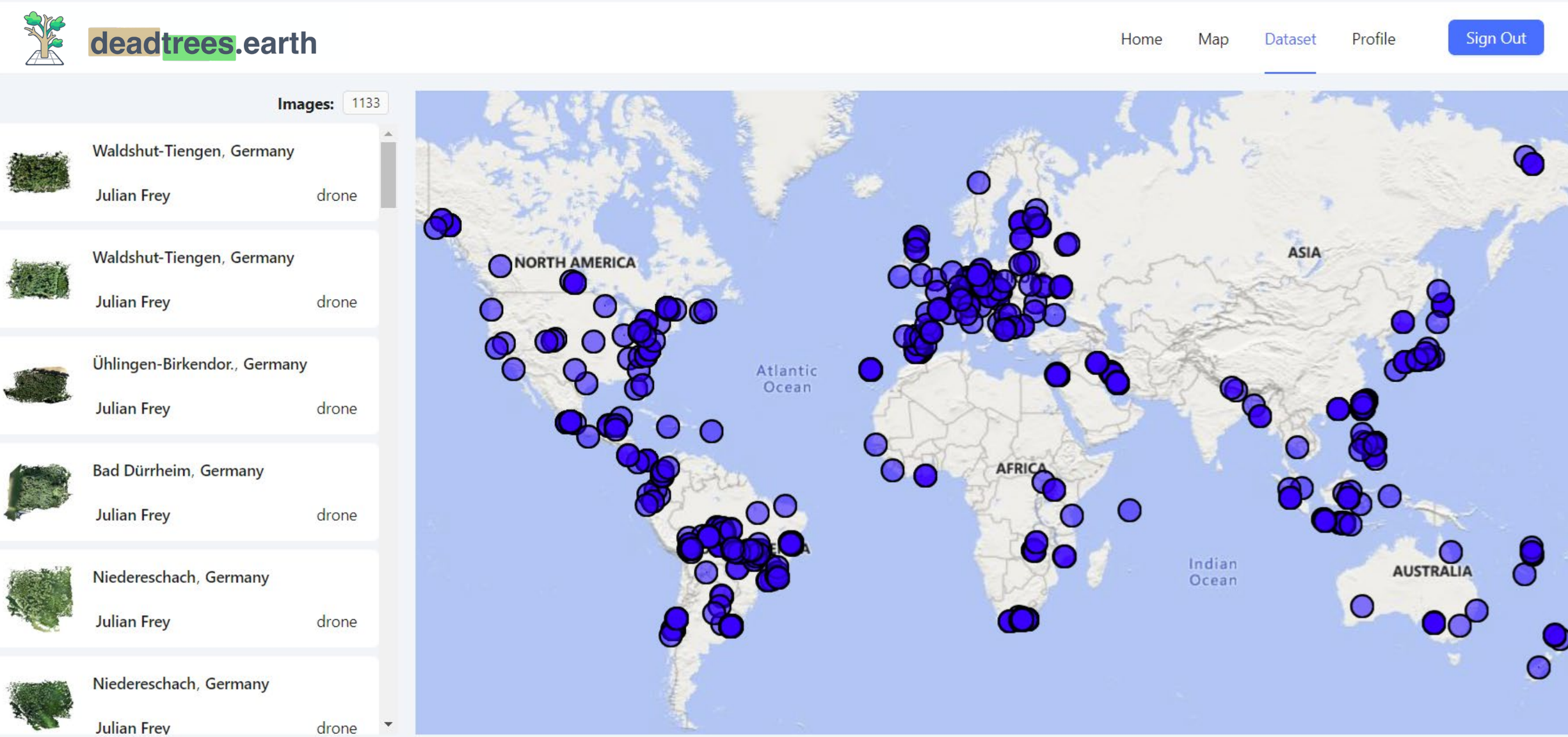






The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

deadtrees.earth

Home | Map | Dataset | Profile | Sign Out

Ühlingen-Birkendorf, Germany

Author: Julian Frey

Acquisition Date: October 4, 2019

License: CC BY

Platform: drone

File Size: 602 MB

Spectral Properties : RGB

Label Source: visual_interpretation

Label Type: semantic_segmentation

Label Quality: 3

Download Ortho & Labels

The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

deadtrees.earth

Home | Map | Dataset | Profile | Sign Out

Ühlingen-Birkendorf, Germany

Author: Julian Frey

Acquisition Date: October 4, 2019

License: CC BY

Platform: drone

File Size: 602 MB

Spectral Properties : RGB

Label Source: visual_interpretation

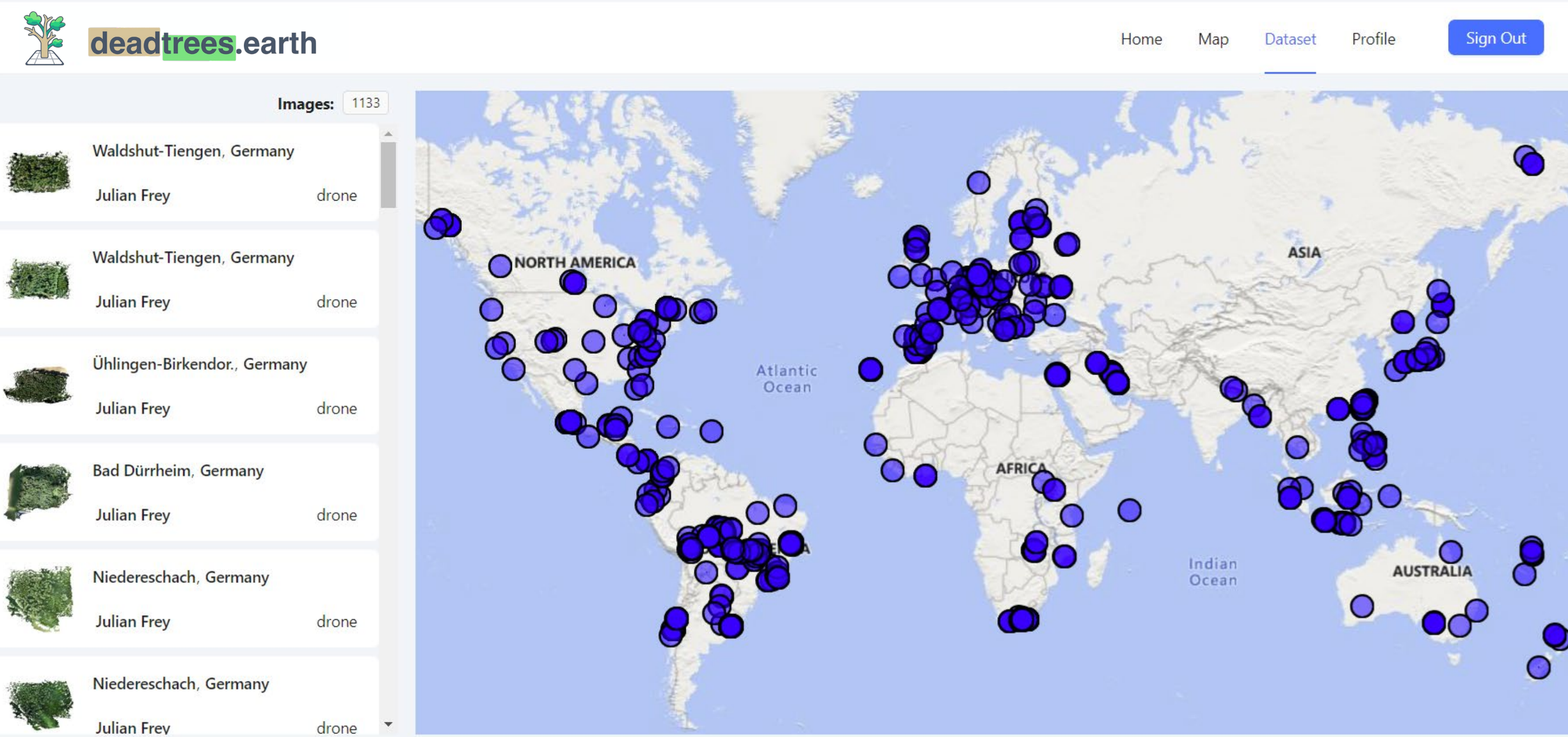
Label Type: semantic_segmentation

Label Quality: 3

Download Ortho & Labels

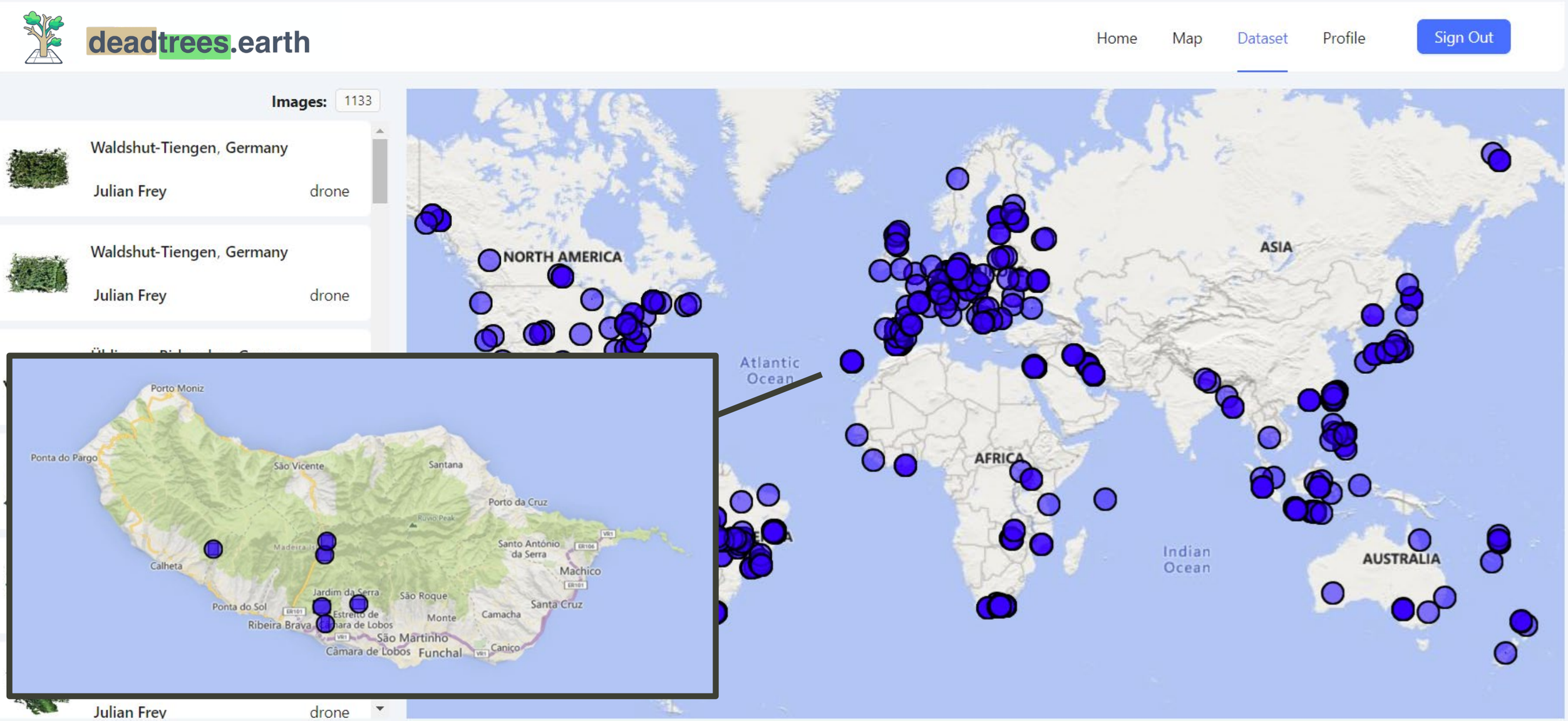
The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



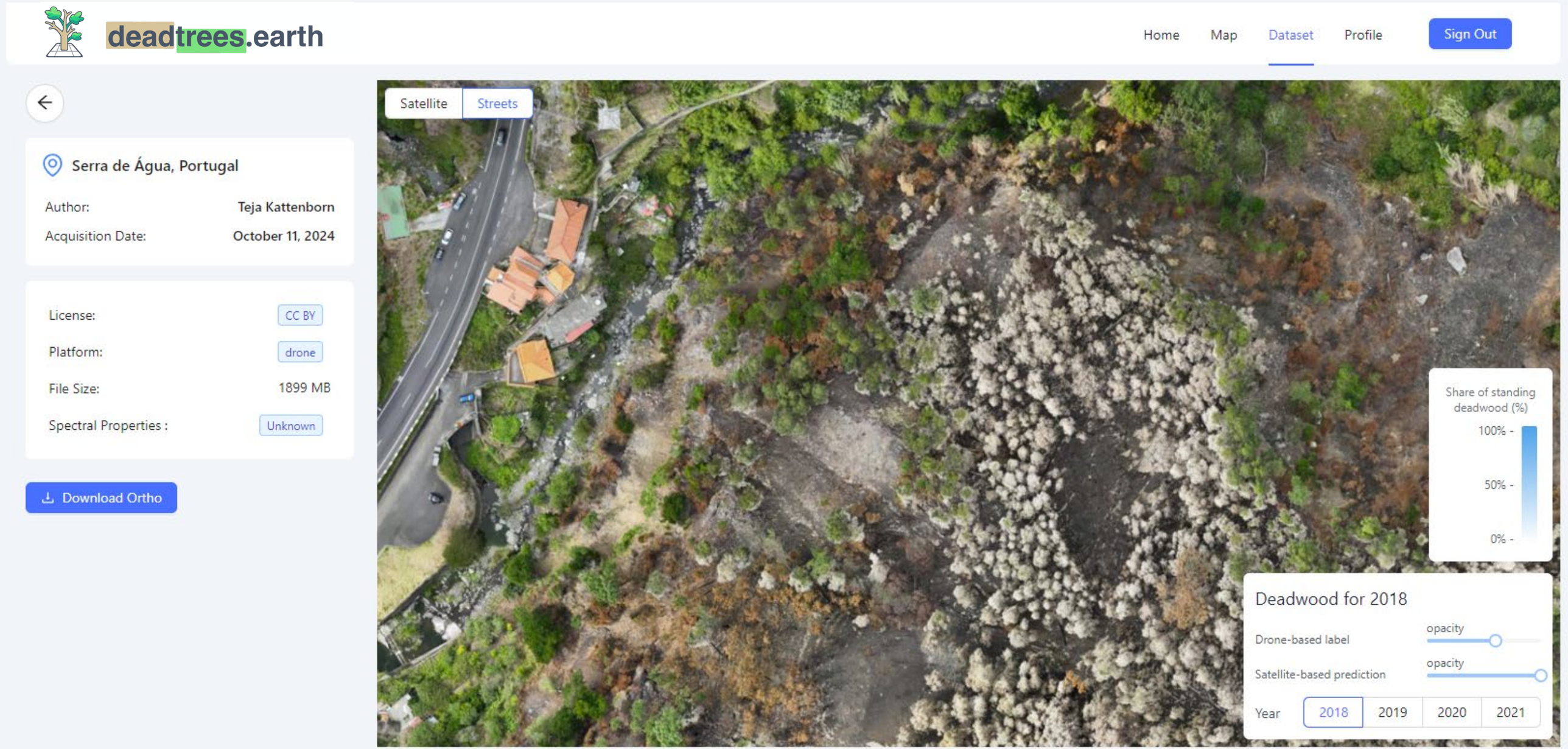
The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

deadtrees.earth

Home Map Dataset Profile Sign Out

Campanário, Portugal

Author: Teja Kattenborn

Acquisition Date: October 10, 2024

License: CC BY

Platform: drone

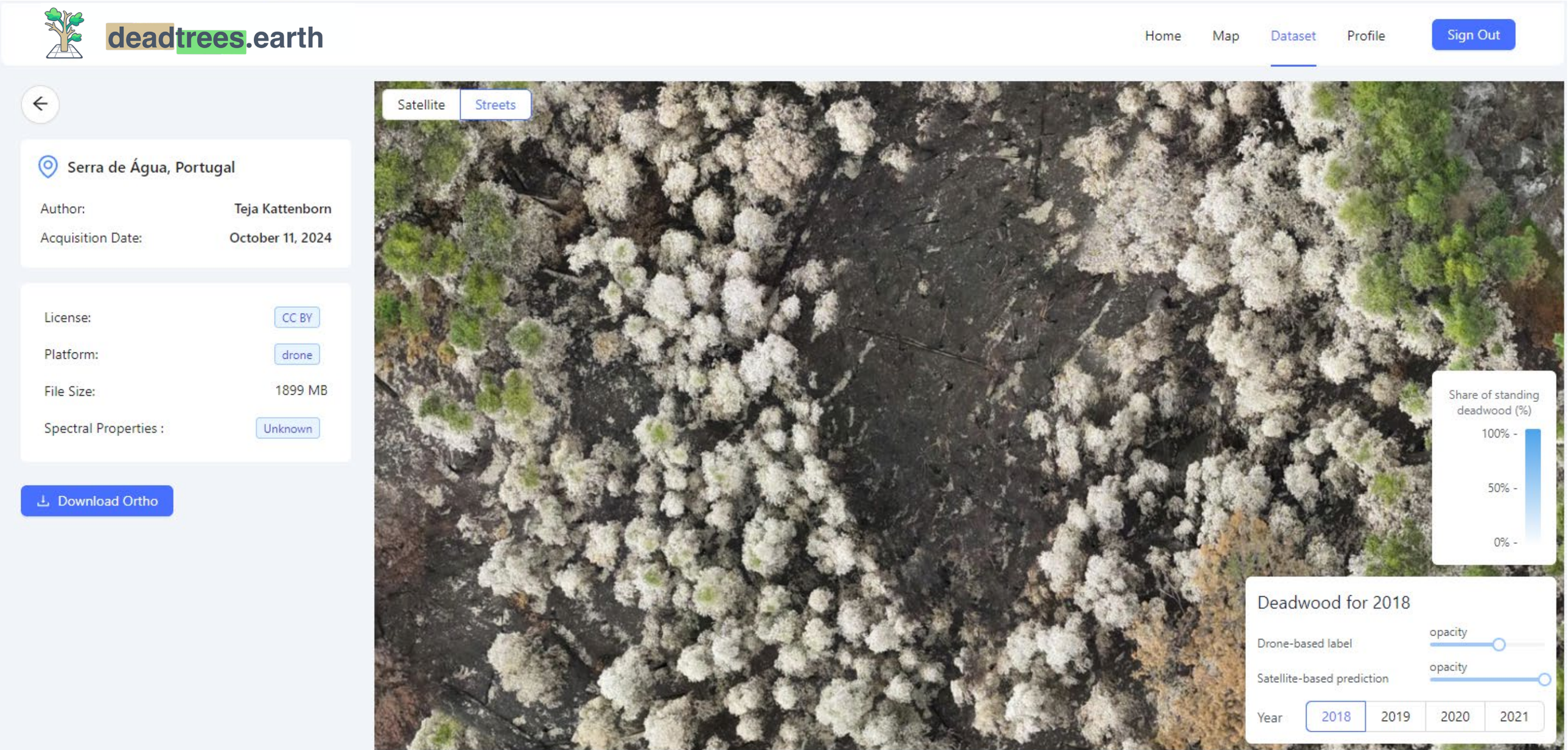
File Size: 3018 MB

Spectral Properties : Unknown

Download Ortho

The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

deadtrees.earth

Home Map Dataset Profile Sign Out

Profile

teja.kattenborn@geosense.uni-freiburg.de

Upload is available!

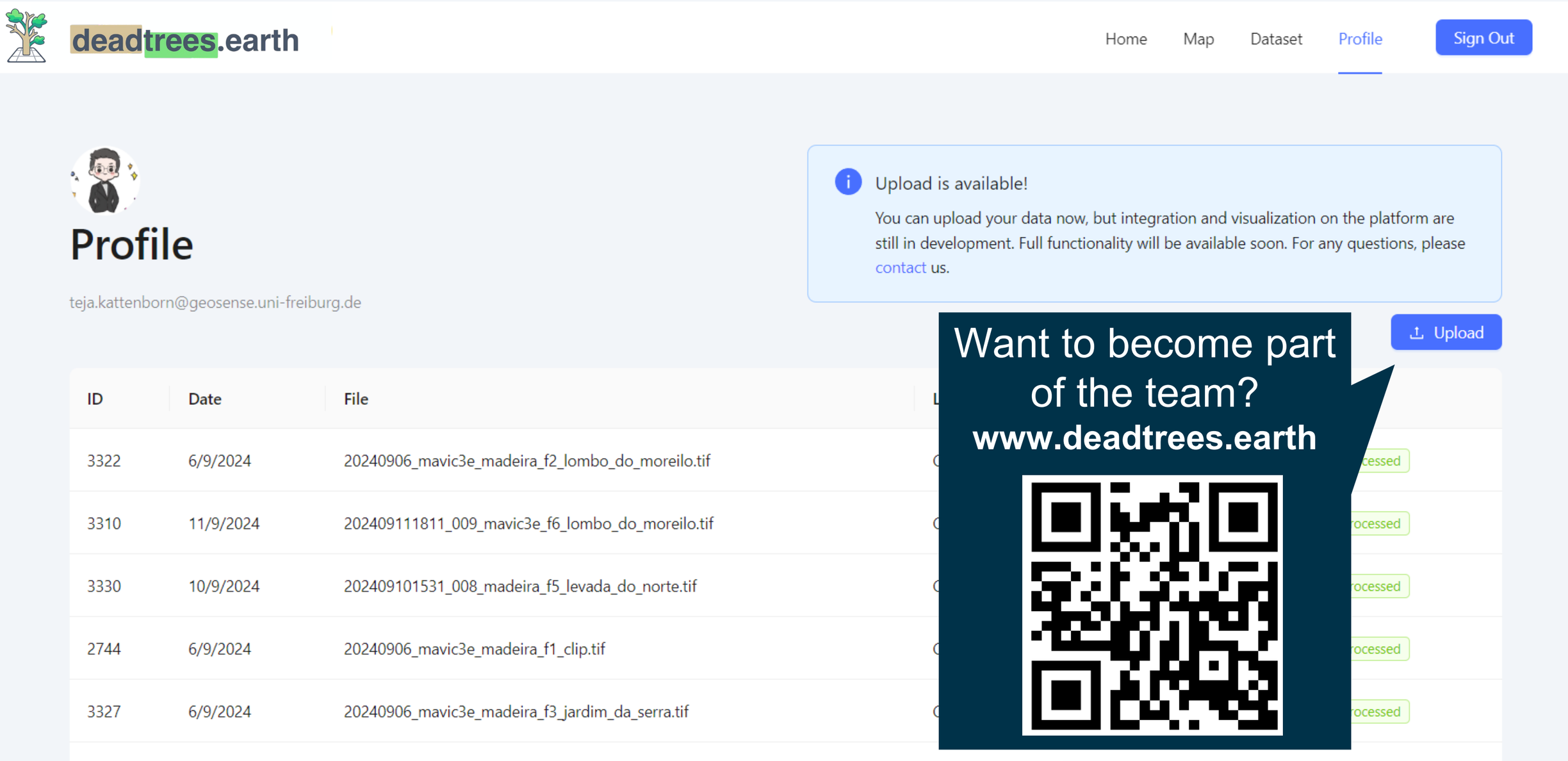
You can upload your data now, but integration and visualization on the platform are still in development. Full functionality will be available soon. For any questions, please contact us.

Upload

ID	Date	File	License	Platform	Map	Status
3322	6/9/2024	20240906_mavic3e_madeira_f2_lombo_do_moreilo.tif	CC BY	drone		processed
3310	11/9/2024	202409111811_009_mavic3e_f6_lombo_do_moreilo.tif	CC BY	drone		processed
3330	10/9/2024	202409101531_008_madeira_f5_levada_do_norte.tif	CC BY	drone		processed
2744	6/9/2024	20240906_mavic3e_madeira_f1_clip.tif	CC BY	drone		processed
3327	6/9/2024	20240906_mavic3e_madeira_f3_jardim_da_serra.tif	CC BY	drone		processed

The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

deadtrees.earth

Profile

teja.kattenborn@geosense.uni-freiburg.de

Upload

You can u
still in de
contact u

Drone or airborne orthomosaic

- Simple RGB imagery, <= 10 cm resolution.
- Any forest or biome type

Optionally: **Reference data on dead trees**

- e.g. polygons or points
- Canopies or individual trees

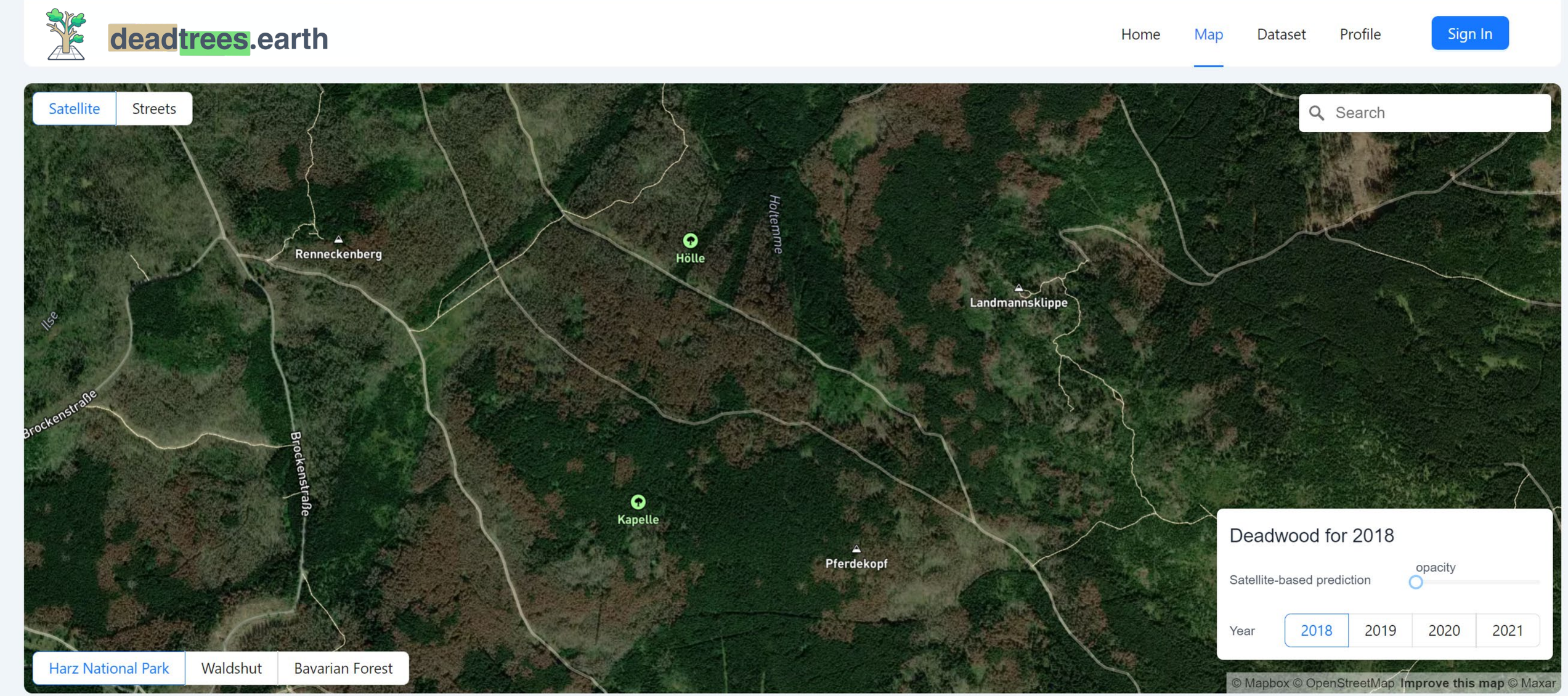
Upload

ID	Date	File	L
3322	6/9/2024	20240906_mavic3e_madeira_f2_lombo_do_moreilo.tif	C
3310	11/9/2024	202409111811_009_mavic3e_f6_lombo_do_moreilo.tif	C
3330	10/9/2024	202409101531_008_madeira_f5_levada_do_norte.tif	C
2744	6/9/2024	20240906_mavic3e_madeira_f1_clip.tif	C
3327	6/9/2024	20240906_mavic3e_madeira_f3_jardim_da_serra.tif	C

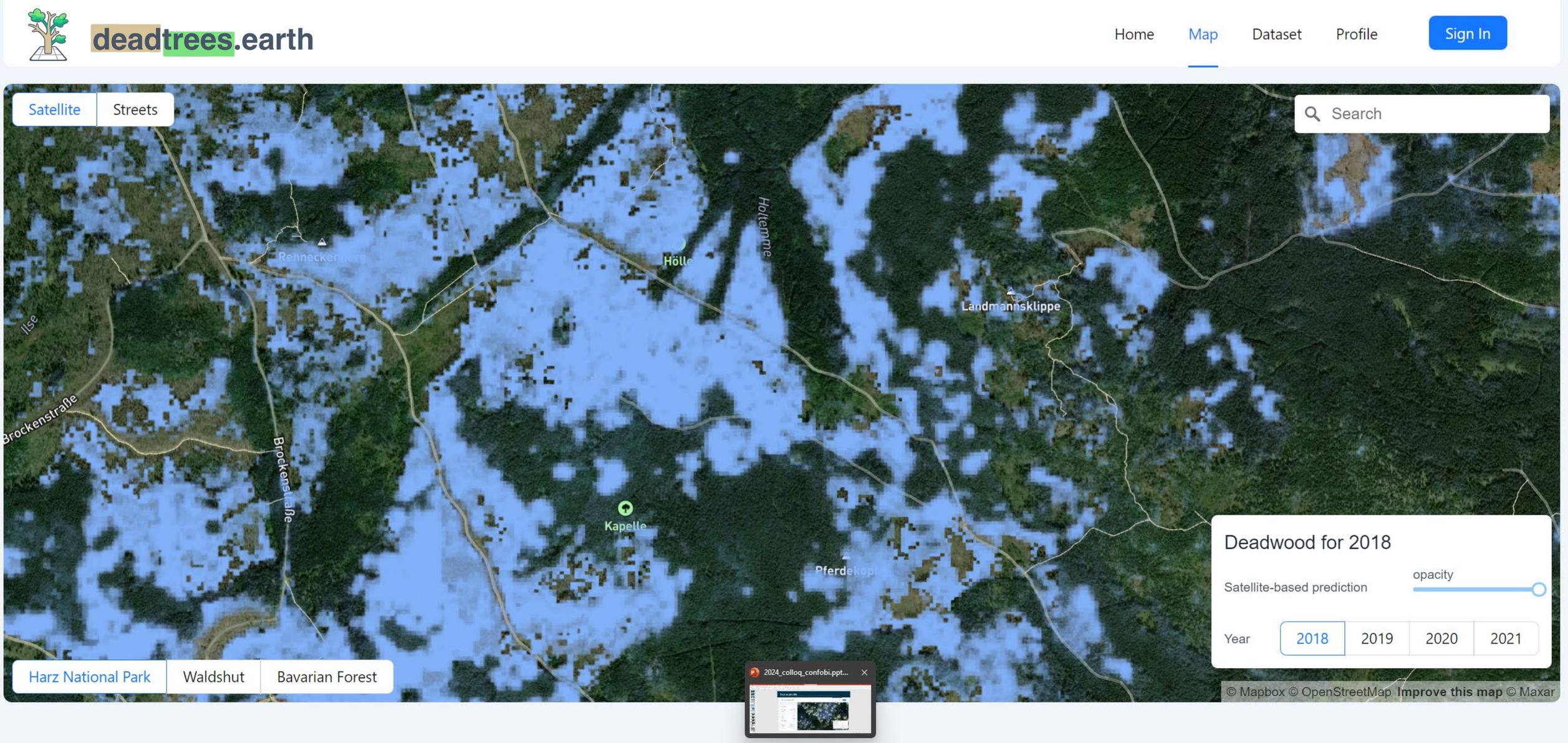
cessed
rocessed
rocessed
rocessed
rocessed

Want to become part of the team?
www.deadtrees.earth

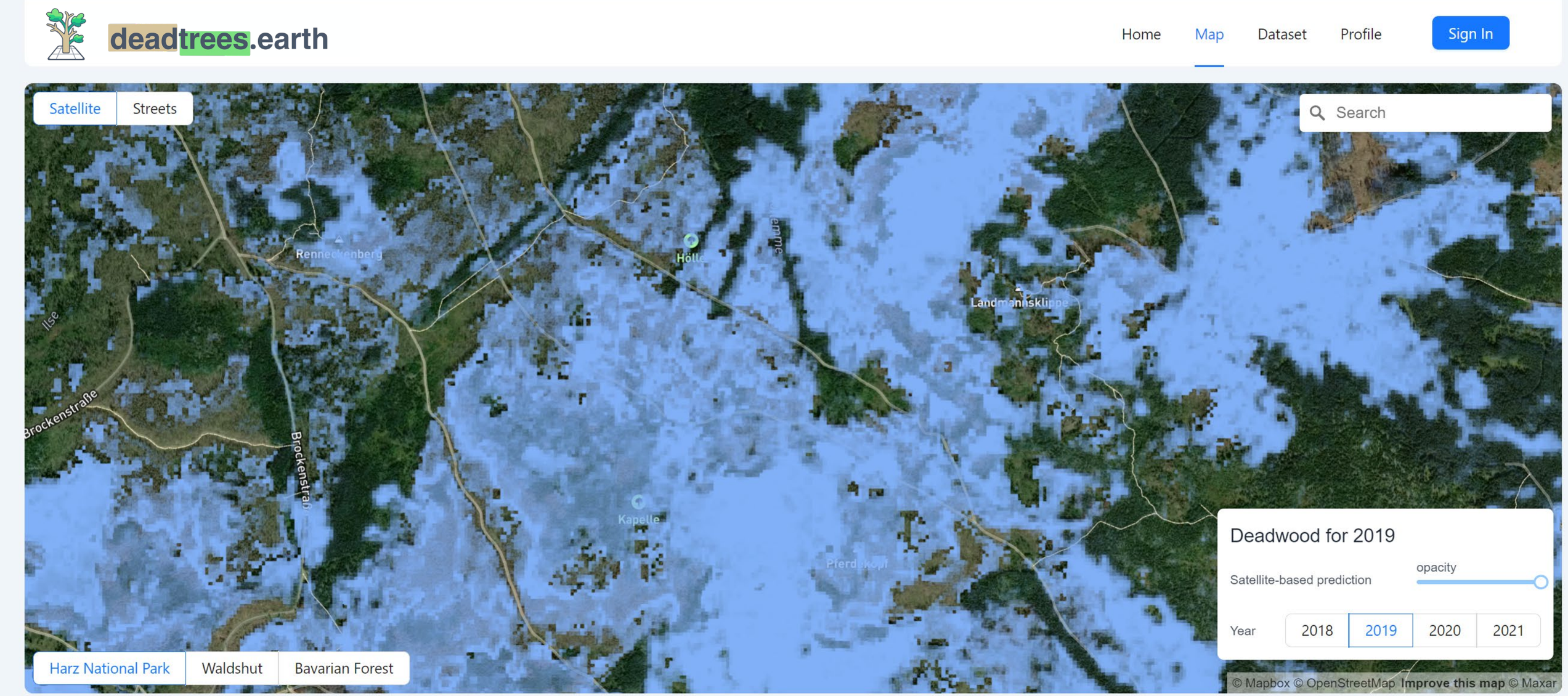
The platform deadtrees.earth



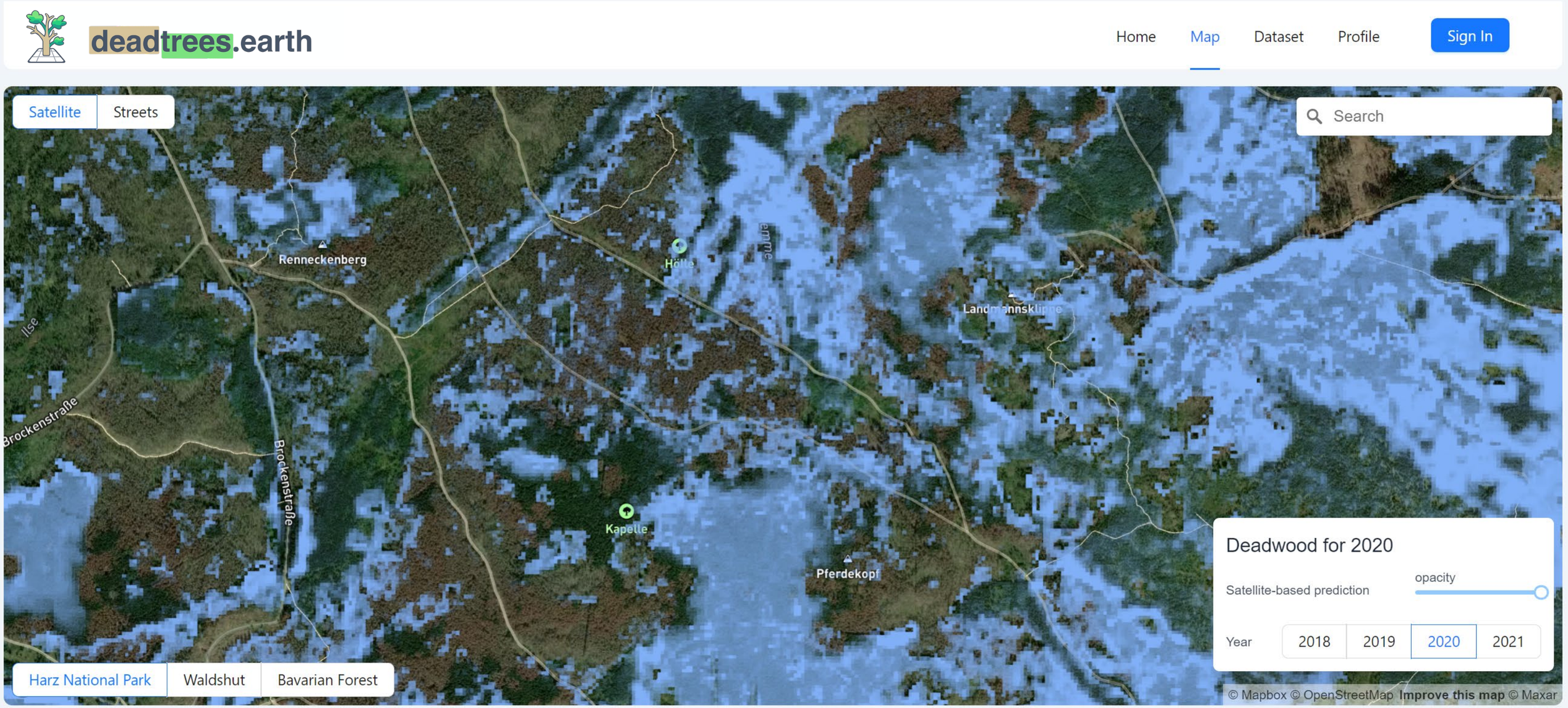
The platform deadtrees.earth



The platform deadtrees.earth

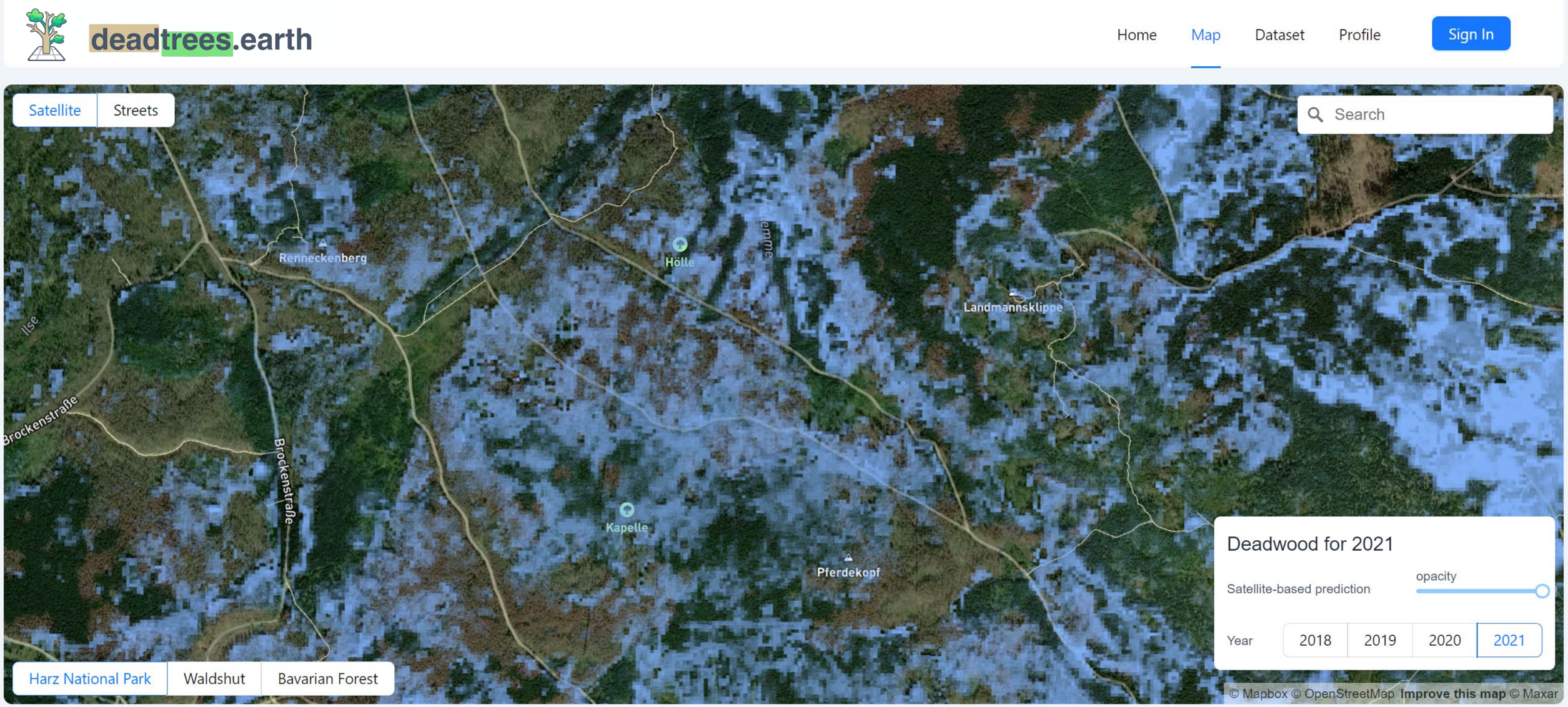


The platform deadtrees.earth



The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



The platform deadtrees.earth

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

- A **dynamic & open database** for monitoring tree mortality worldwide
- Integrating drone, airborne and satellite data
- Road map:
  - **Q3 2024: upload & download functionality** for aerial imagery and mortality reference data
  - **Q4 2024: Automated segmentation** of dead tree crowns in drone and airborne data
  - **Q1 2025:** Towards **Global satellite-based products** on tree mortality data
  - **Q2 2025: AI-ready datasets** (e.g. for PyTorch)
  - **Q3 2025:** Towards **Attribution** of tree mortality
  - **Q4 2025:** Towards **Forecasting** of tree mortality

deadtrees.earth

teja.kattenborn@geosense.ui-freiburg.de

The platform deadtrees.earth

Alastair Potts (Nelson Mandela University)
Allan Buras (Technical University of Munich)
Andreas Uhl (Forest Research Institute (FVA))
Anna Göritz (University of Freiburg)
Annett Frick (Luftbild Umwelt Planung GmbH (LUP))
Annette Menzel (Technical University of Munich)
Antonia Ludwig (Leipzig University)
Arko Lucieer (University of Tasmania)
Arlena Brosinsky (Potsdam University)
Ben Sparrow (TERN/The University of Adelaide)
Ben Weinstein (University of Florida)
Benjamin Stöckigt (Luftbild Umwelt Planung GmbH (LUP))
Carl Gosper (Western Australian Department of Biodiversity, Conservation and Attractions)
Chris Reudenbach (Universität Marburg)
Christian Mestre Runge (Universität Marburg)
Christian Rossi (Swiss National Park)
Christoph Dreiser (Nationalpark Schwarzwald)
Clemens Mosig (Leipzig University, Center for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI))
Daniel Moreno-Fernández (Universidad de Alcalá, Institute of Forest Sciences (INIA-CSIC))
David Hedding (University of South Africa)
David Montero (Leipzig University, German Center for Integrative Biodiversity Resarch (iDiv))
Djamil Al-Halbouni (Leipzig University)
Elham Shafeian (University of Saskatchewan)
Emily Lines (University of Cambridge)
Erik Carrieri (University of Turin)
Etienne Laliberté (Université de Montréal)
Fabian Fassnacht (Freie Universität Berlin)
Fabio Meloni (University of Turin)
Felix Schiefer (Karlsruhe Institute of Technology (KIT))
Helene C. Muller-Landau (Smithsonian Tropical Research Institute)
Henrik Hartmann (Julius Kühn-Institut)
Hooman Latifi (K. N. Toosi University of Technology)
Jacob Schladebach (Alfred Wegener Institute)
Jakobus Möhring (Leipzig University)
Jan Altman (Institute of Botany of the Czech Academy of Sciences)
Jan Hempel (Leipzig University)
Jana Eichel (Utrecht University)
Janusch Jehle (University of Freiburg)
Jesse M. Kalwij (Karlsruhe Institute of Technology (KIT), University of Johannesburg)
Josefine Umlauft (Center for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI))
Joseph Hupy (Purdue University)
Julian Frey (University of Freiburg)
Katarzyna Zielewska-Büttner (Forest Research Institute (FVA))
Katherine Zdunic (Western Australian Department of Biodiversity, Conservation and Attractions)
KC Cushman (Oak Ridge National Laboratory)
Kirill Korznikov (Institute of Botany of the Czech Academy of Sciences)
Konrad Greinwald (University of Freiburg)
Lars Oppgenoorth (Universität Marburg)
Laura Sotomayor (University of Tasmania)
Linyuan Li (Beijing Forestry University)
Marco Heurich (Bavarian Forest National Park, Inland Norway University of Applied Science, University of Freiburg)
Marie-Therese Schmehl (Potsdam University)
Martin Denter (University of Freiburg)
Marziye Ghasemi (K. N. Toosi University of Technology)
Matt Stenson (Commonwealth Scientific and Industrial Research Organisation)
Matteo Garbarino (University of Turin)
Matthew Allen (University of Cambridge)
Matthias Gassilloud (University of Freiburg)
Melvin Hernández (Smithsonian Tropical Research Institute)
Michael Maroschek (Technical University of Munich, Nationalpark Berchtesgaden)
Michael Scherer-Lorenzen (University of Freiburg)
Michele Volpi (ETH Zurich and EPFL)
Miguel Mahecha (Leipzig University)
Milton García (Smithsonian Tropical Research Institute)
Mirela Beloiu Schwenke (ETH Zurich)
Mirko Mälicke (Karlsruhe Institute of Technology (KIT), hydrocode GmbH, Karlsruhe, Germany)
Myriam Cloutier (Université de Montréal)
Nadine Rühr (Karlsruhe Institute of Technology (KIT))
Nicolás Vargas-Ramírez (Universidad Nacional Autónoma de México | National Autonomous University of Mexico)
Oscar Pérez-Priego (University of Cordoba)
Paloma Ruiz-Benito (Universidad de Alcalá)
Paul Neumeier (Leipzig University)
Peter Hajek (University of Freiburg)
Pratima Khatri-Chhetri (University of Washington)
Qin Ma (Nanjing Normal University)
Rupert Seidl (Technical University of Munich, Nationalpark Berchtesgaden)
Samuel Wiesmann (Swiss National Park)
Samuli Junttila (University of Eastern Finland)
Selina Ganz (Forest Research Institute (FVA))
Selina Schwarz (Karlsruhe Institute of Technology (KIT))
Stefan Kruse (Alfred Wegener Institute)
Stéphanie Horion (University of Copenhagen)
Stuart Grieve (Queen Mary University of London, Queen Mary University of London)
Suzanne Prober (Commonwealth Scientific and Industrial Research Organisation)
Tabea Olszewski (Bavarian Forest National Park)
Teja Kattenborn (University of Freiburg)
Tommaso Jucker (University of Bristol)
Ulrike Märkel (Hochschule für Forstwirtschaft Rottenburg)
Vicente Vásquez (University of Florida)
Vincent von Dosky (unique land use GmbH)
Yan Cheng (University of Copenhagen)
Yanjun Su (State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences)

deadtrees.earth

teja.kattenborn@geosense.ui-freiburg.de

Recent findings

Recent findings

JOURNAL ARTICLE

Large-scale remote sensing reveals that tree mortality in Germany appears to be greater than previously expected

Felix Schiefer ✉, Sebastian Schmidtlein, Henrik Hartmann, Florian Schnabel, Teja Kattenborn

Forestry: An International Journal of Forest Research, cpae062,
https://doi.org/10.1093/forestry/cpae062
Published: 21 December 2024 **Article history** ▾

Abstract

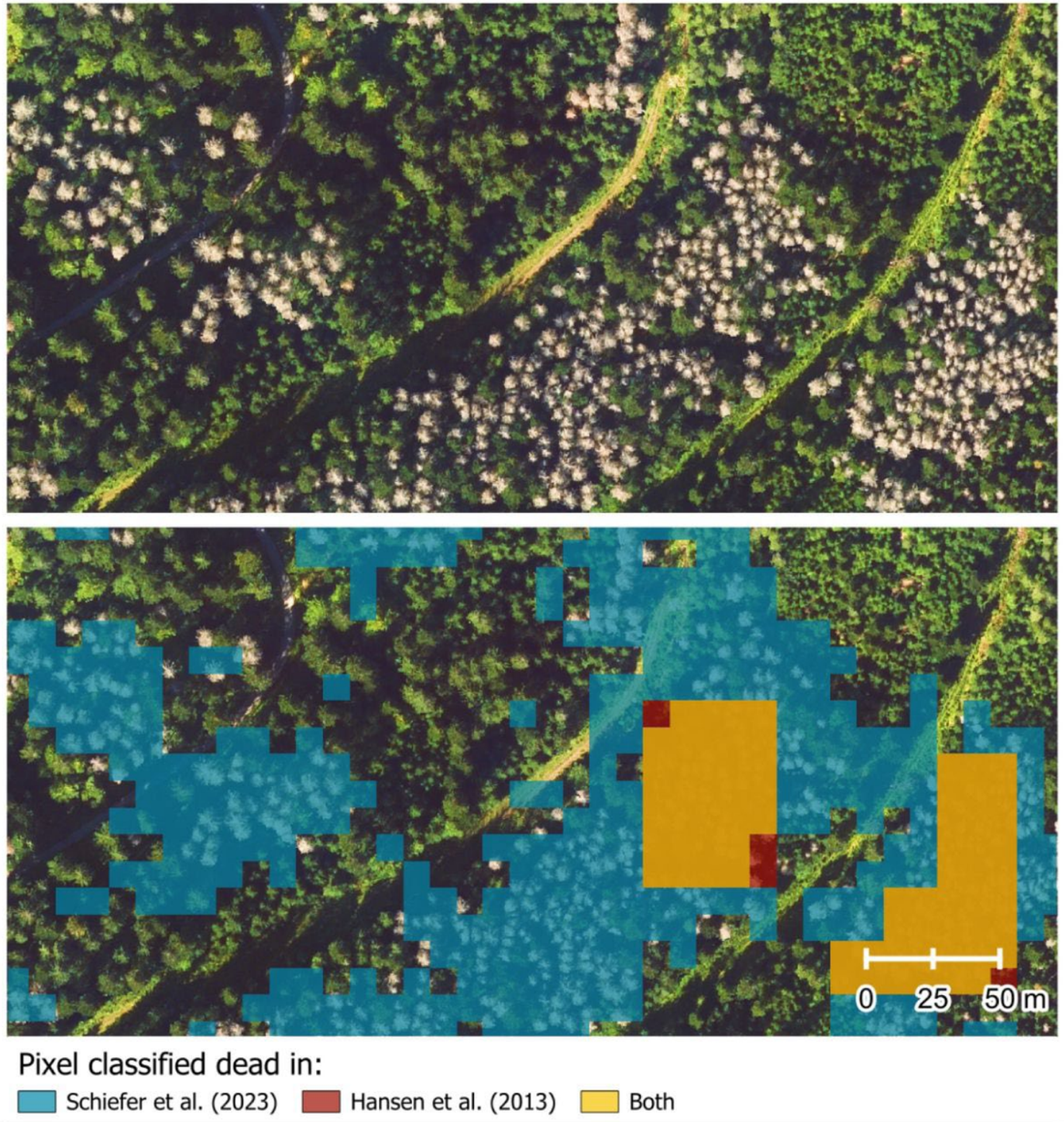
Global warming poses a major threat to forests and events of increased tree mortality are observed globally. Studying tree mortality often relies on local-level observations of dieback while large-scale analyses are lacking. Satellite remote sensing provides the spatial coverage and sufficiently high temporal and spatial resolution needed to investigate tree mortality at landscape-scale. However, adequate reference data for training satellite-based models are scarce. In this study, we employed the first maps of standing deadwood in Germany for the years 2018–2022 with 10 m spatial resolution that were created by using tree mortality observations spotted in hundreds of drone images as the reference. We use these maps to study spatial and temporal patterns of tree mortality in Germany and analyse their biotic and abiotic

- According to satellite-based assessments, tree mortality in Germany underestimated
- Tree mortality assessed across main tree species

- Main drivers revealed
  - Consecutive droughts
  - Early frost

Recent findings

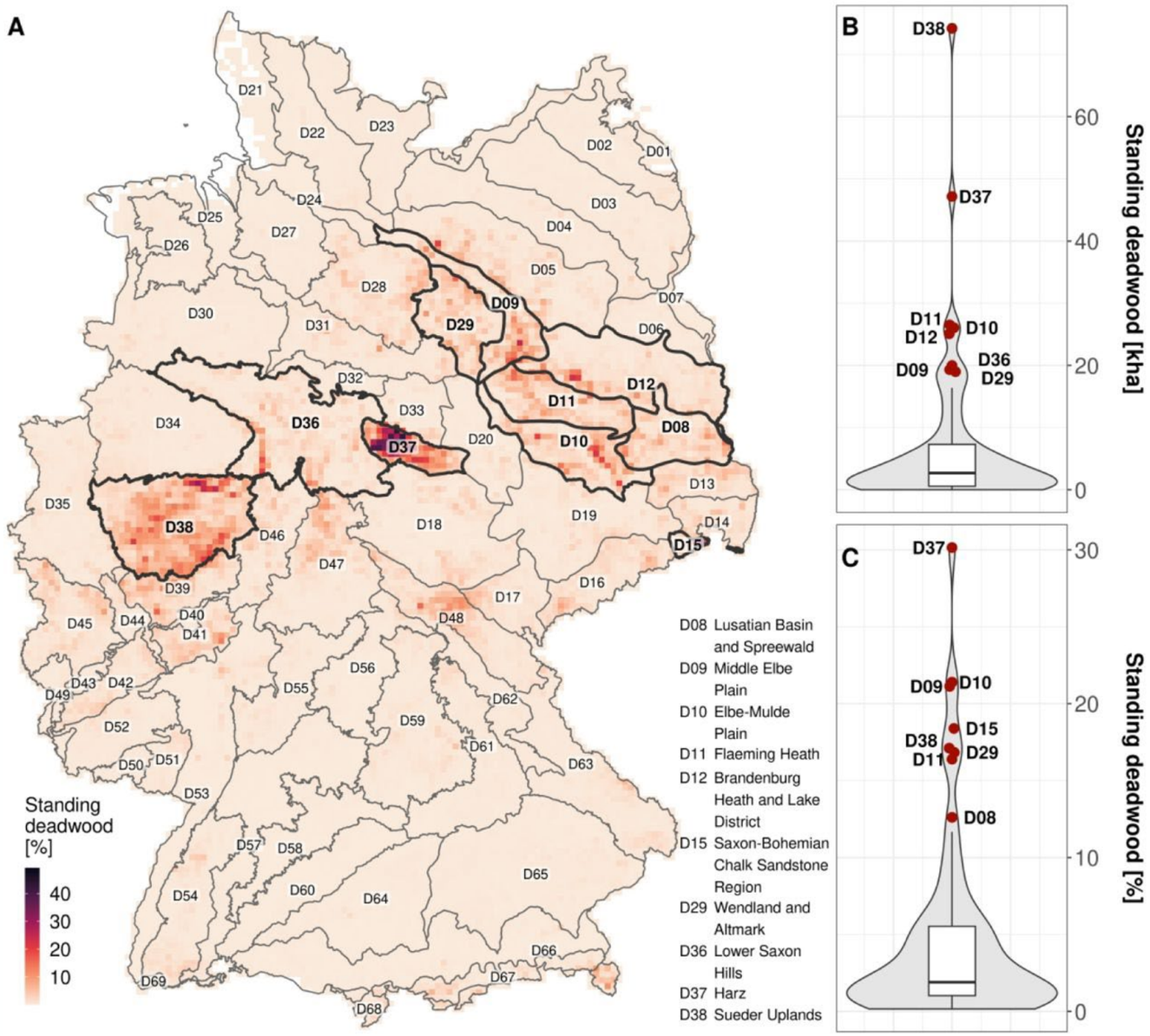
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



- Previous remote sensing products (e.g. Global Forest Watch) are not sensitive to tree mortality patterns, as they are
  - Often not stand-replacing
  - Scattered (not always clear patches)

Recent findings

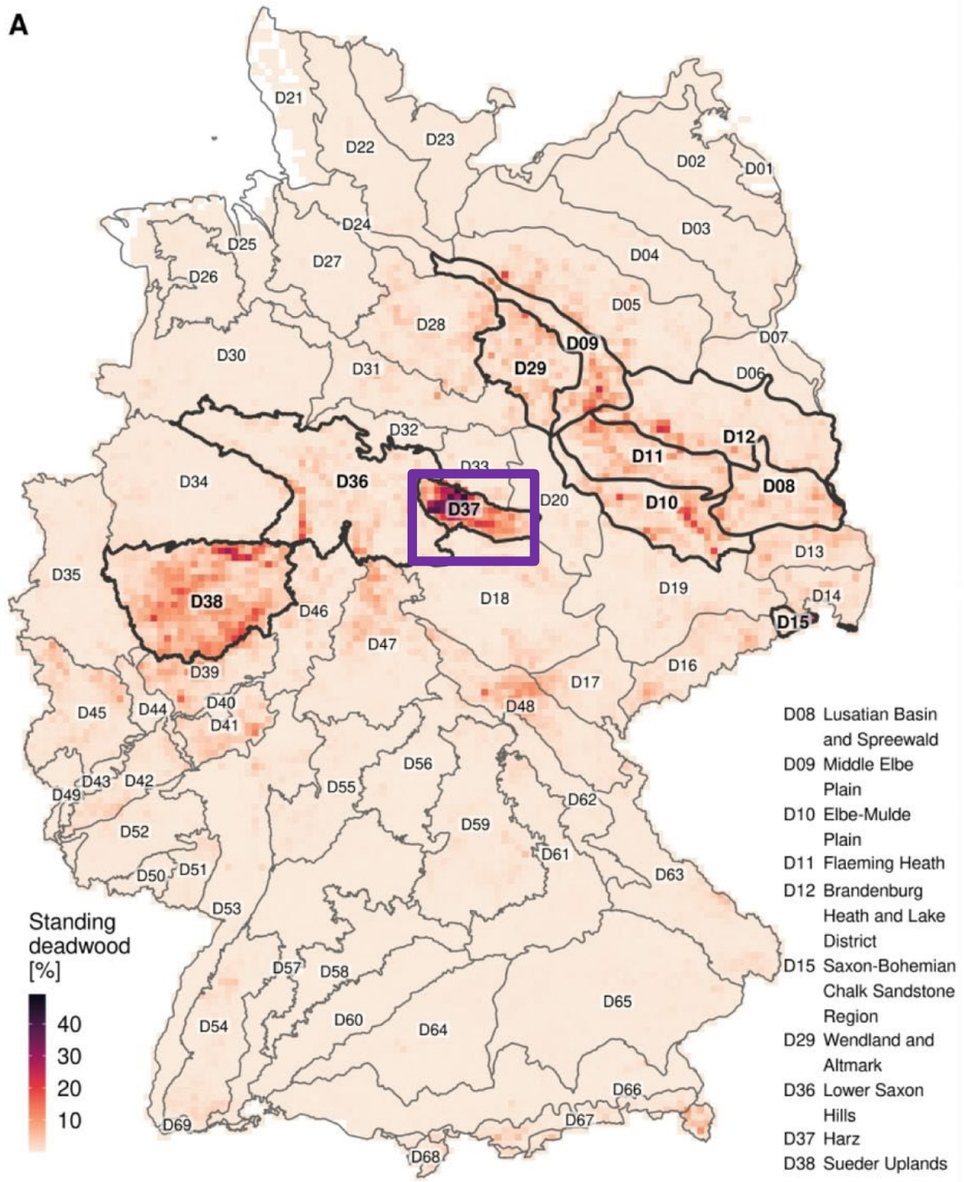
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

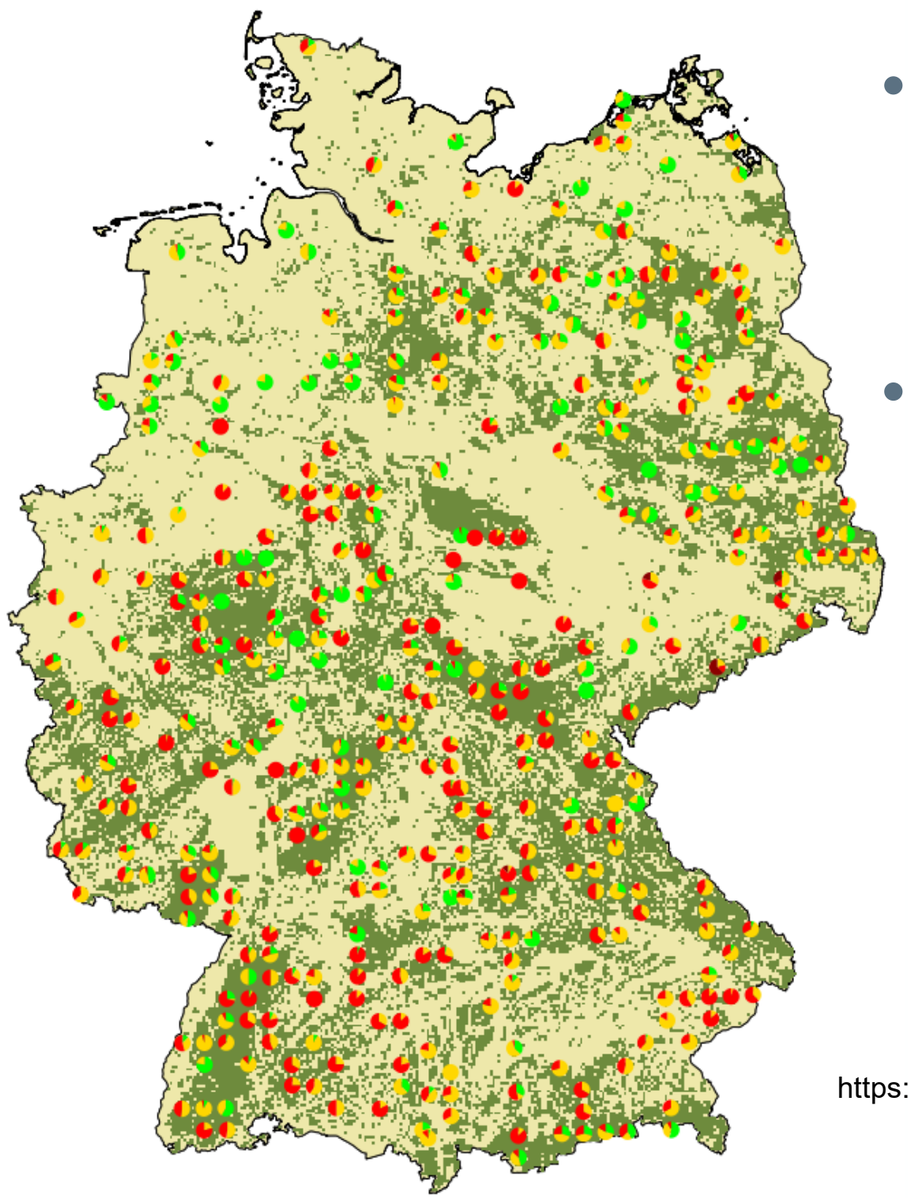


- Tree mortality differs in space
- Hotspots of tree mortality
  - Harz mountains
  - Sueder Uplands
  - Elbe-Mulde Plain

Recent findings

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



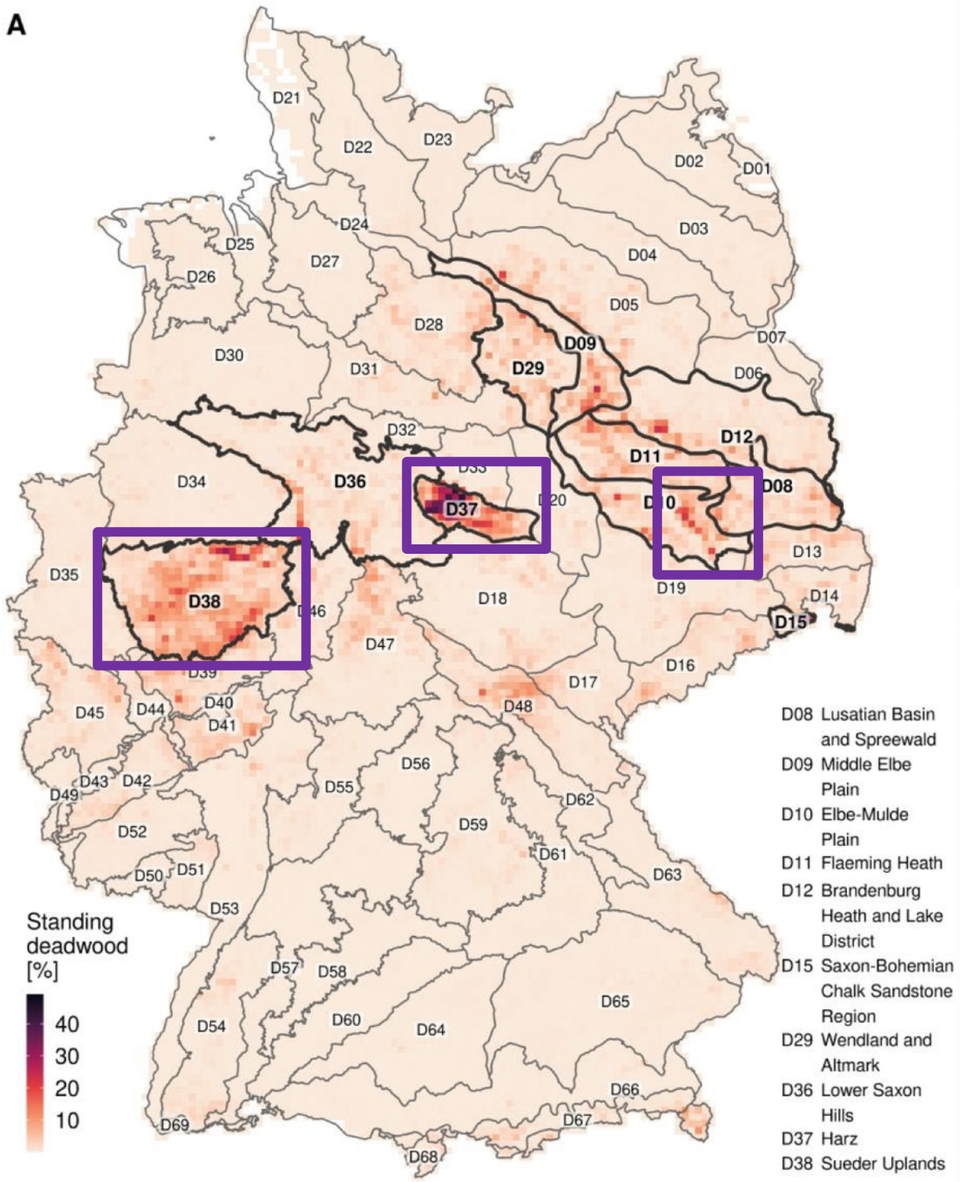


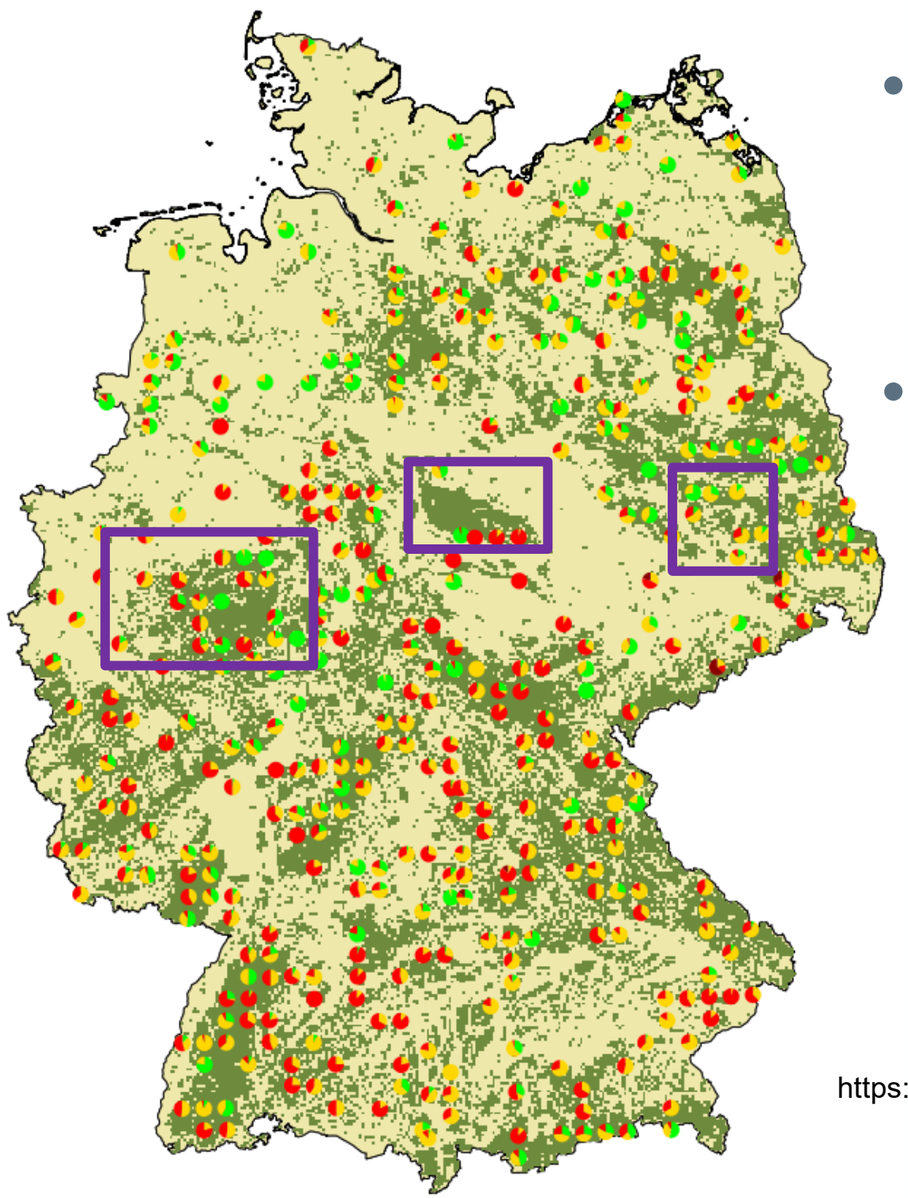
- Forest condition survey does often not cover hot spots
- Therefore, Forest condition survey can largely underestimate forest mortality

https://wo-apps.thuenen.de/apps/wze_maps/

Recent findings

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



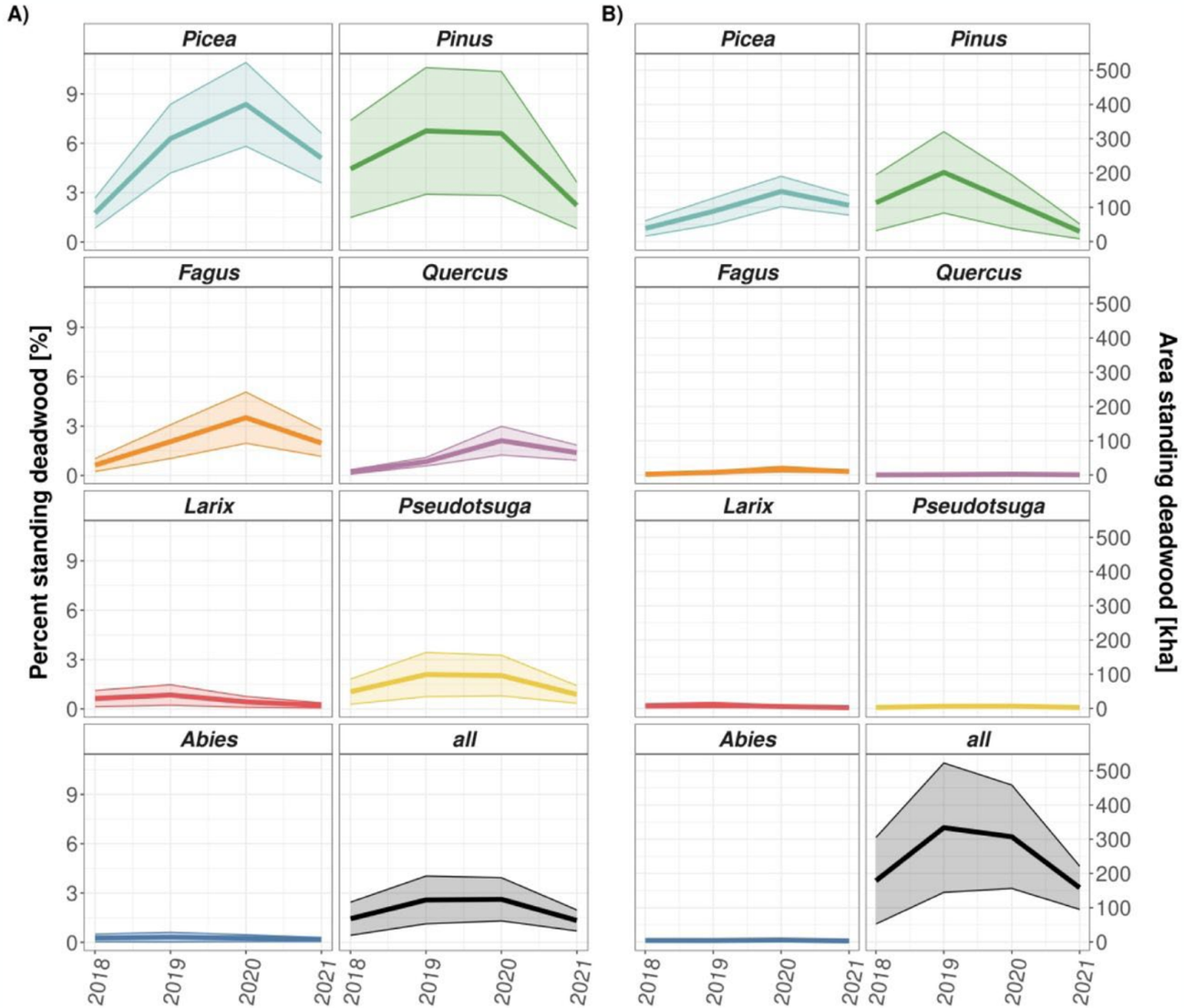


- Forest condition survey does often not cover hot spots
- Therefore, Forest condition survey can largely underestimate forest mortality

https://wo-apps.thuenen.de/apps/wze_maps/

Recent findings

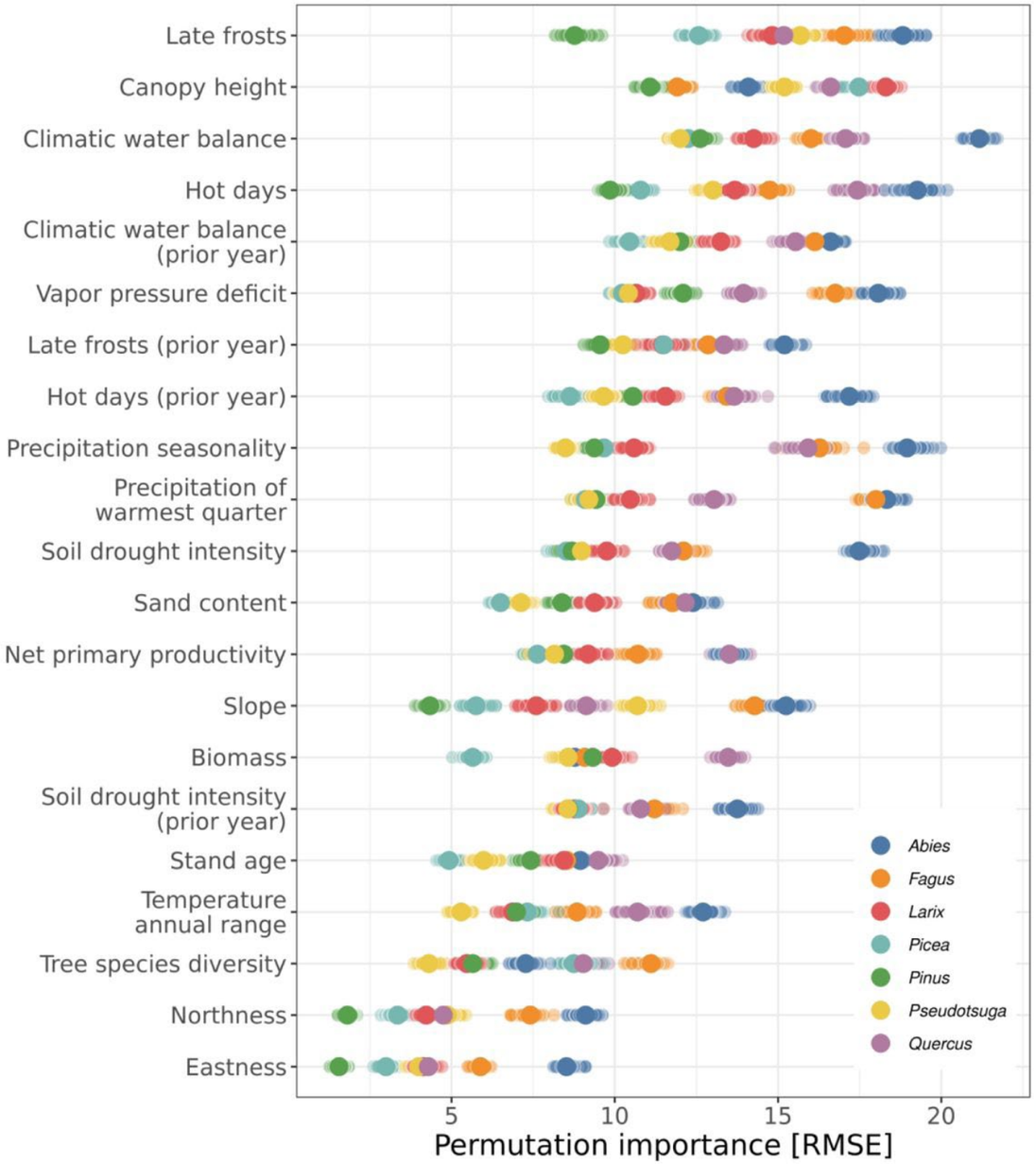
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



- Tree mortality differs strongly accross species
- Imprint of total share of tree species (tree species selection).

Recent findings

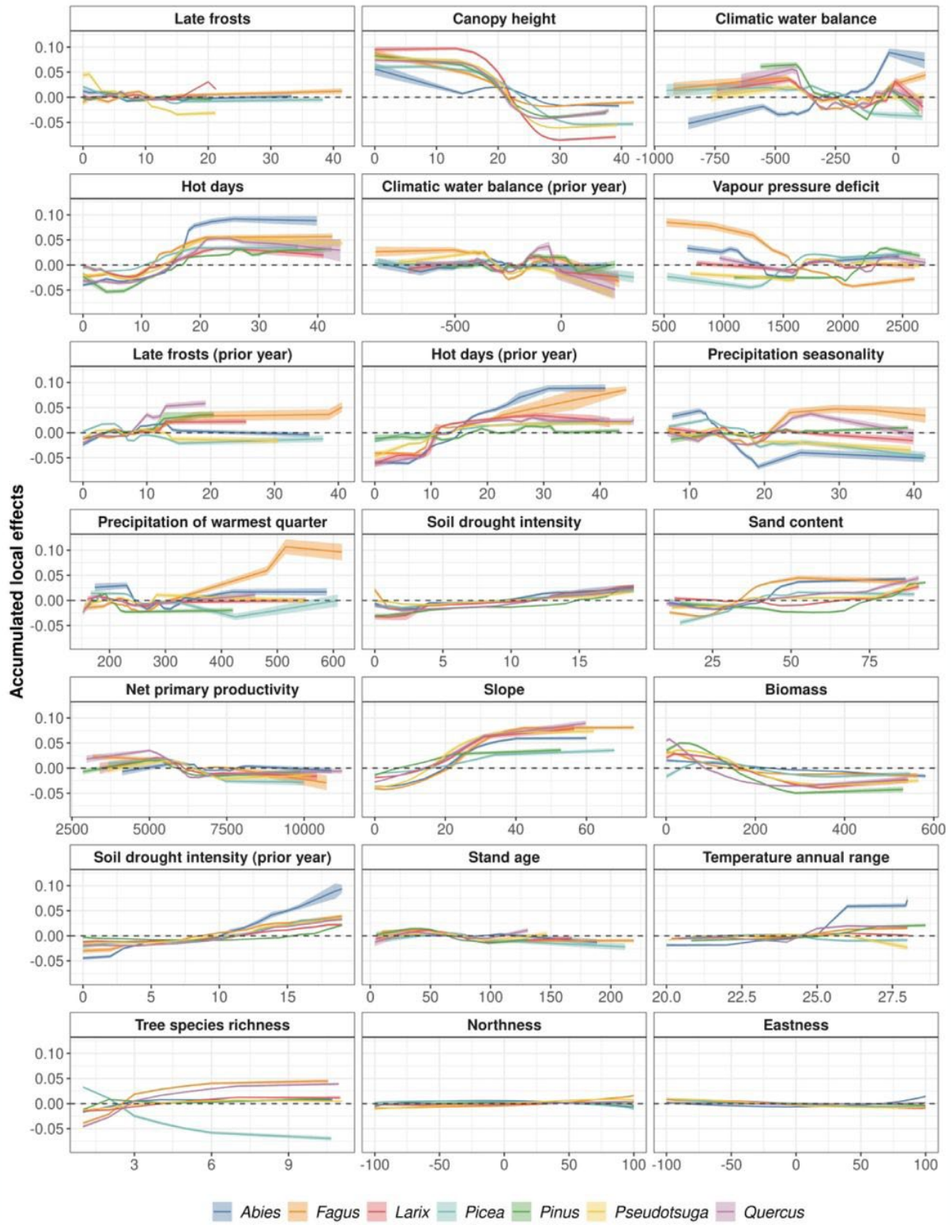
Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



- Drivers per tree species show varying effects
- Some drivers accumulate over multiple years (e.g. reoccurring droughts).
- Tree morality is an complex interplay of multiple drivers

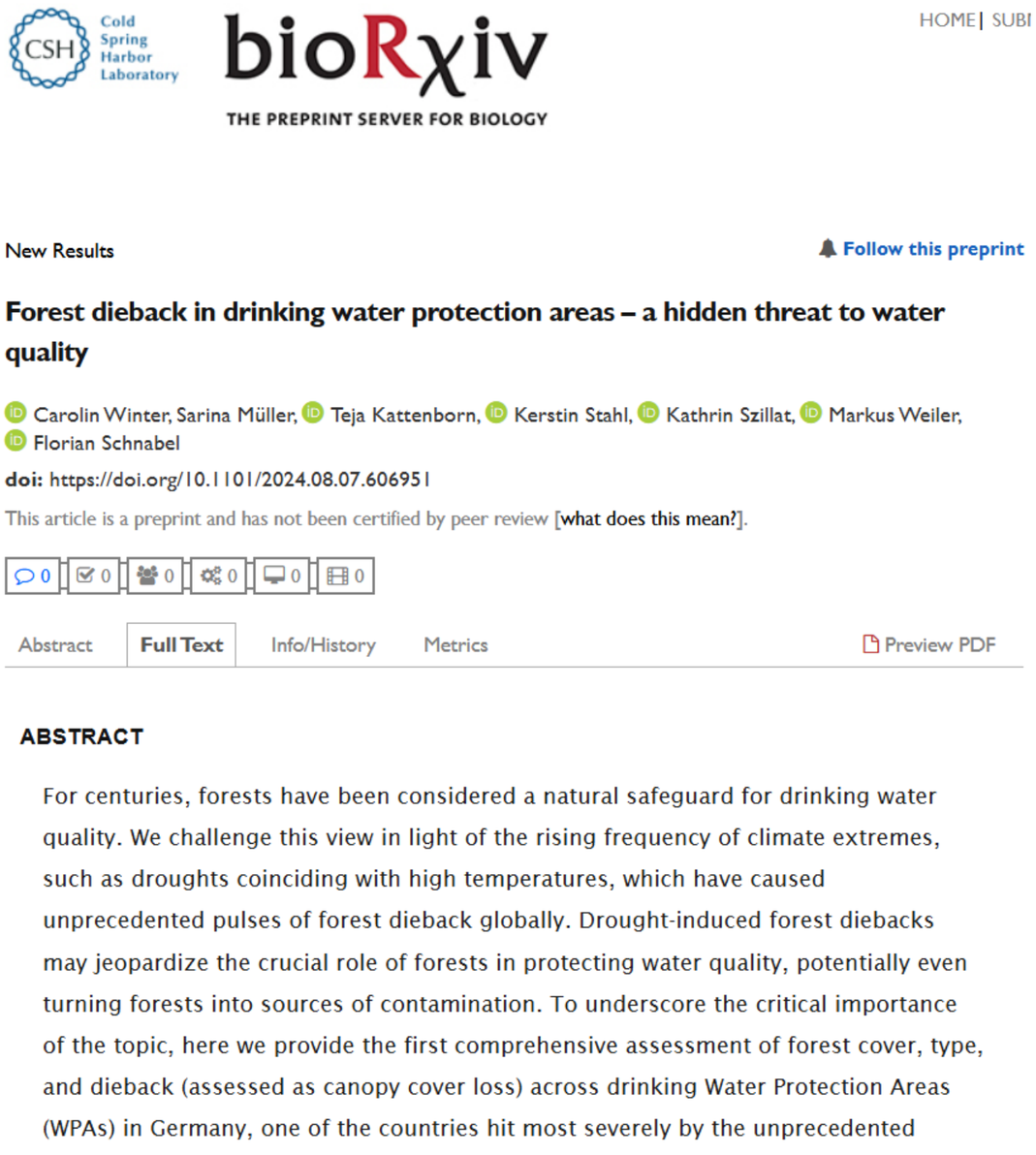
Recent findings

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



- Drivers per tree species show varying effects
- Some drivers accumulate over multiple years (e.g. reoccurring droughts).
- Tree morality is an complex interplay of multiple drivers

Recent findings



Cold Spring Harbor Laboratory

bioRxiv

THE PREPRINT SERVER FOR BIOLOGY

HOME | SUBI

New Results

Follow this preprint

Forest dieback in drinking water protection areas – a hidden threat to water quality

Carolin Winter, Sarina Müller, Teja Kattenborn, Kerstin Stahl, Kathrin Szillat, Markus Weiler, Florian Schnabel

doi: https://doi.org/10.1101/2024.08.07.606951

This article is a preprint and has not been certified by peer review [what does this mean?].

0 0 0 0 0 0

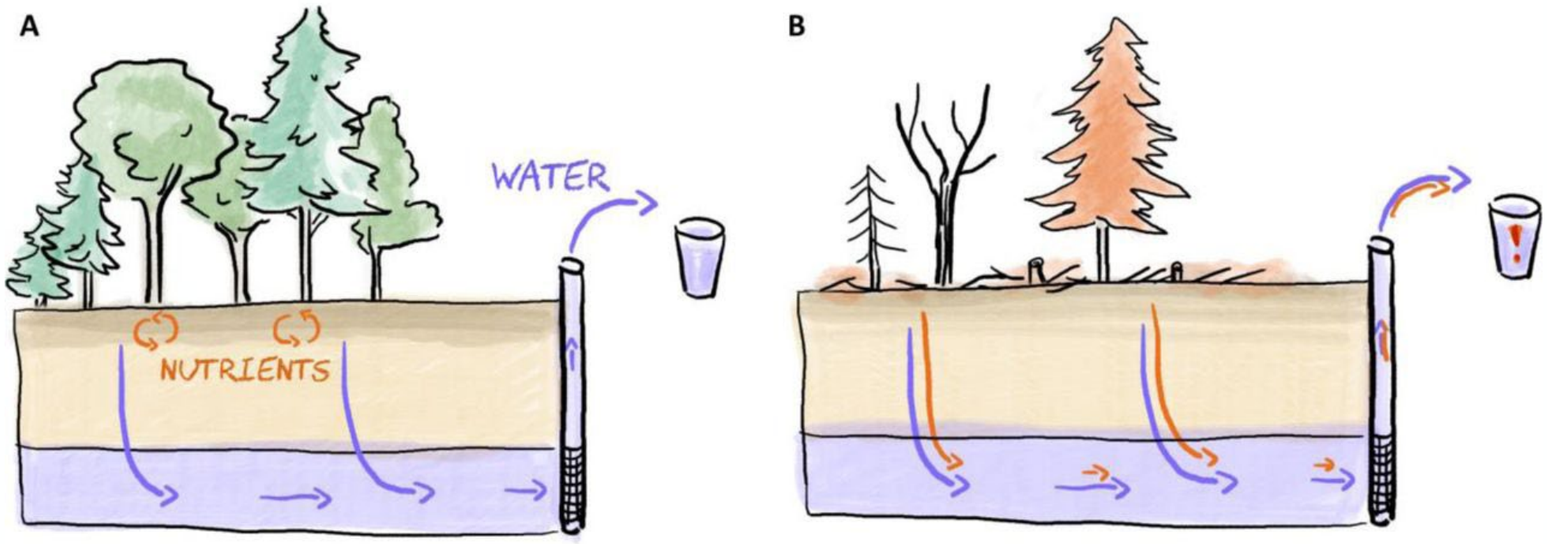
Abstract | Full Text | Info/History | Metrics | Preview PDF

ABSTRACT

For centuries, forests have been considered a natural safeguard for drinking water quality. We challenge this view in light of the rising frequency of climate extremes, such as droughts coinciding with high temperatures, which have caused unprecedented pulses of forest dieback globally. Drought-induced forest diebacks may jeopardize the crucial role of forests in protecting water quality, potentially even turning forests into sources of contamination. To underscore the critical importance of the topic, here we provide the first comprehensive assessment of forest cover, type, and dieback (assessed as canopy cover loss) across drinking Water Protection Areas (WPAs) in Germany, one of the countries hit most severely by the unprecedented

- Case study on NO3 concentrations in ground water after forest loss
- Focus on Germany
- Time frame: 2018-today

Recent findings

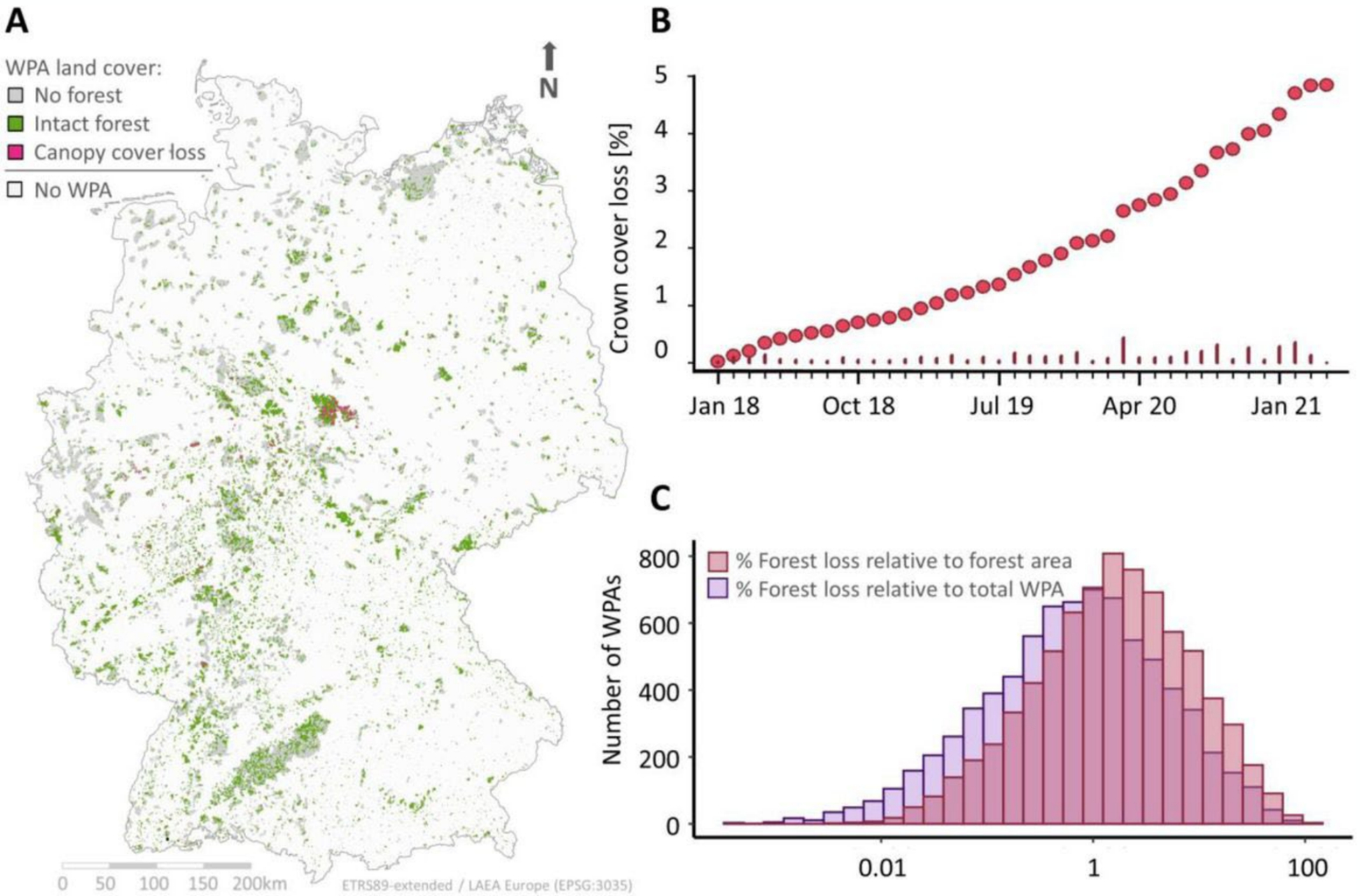


Schematic view on the role of forests as a safeguard of groundwater quality and related drinking water quality.

- Intact ecosystems do commonly not leach large amounts of NO3
- Disturbed ecosystems can leach large quantities of NO3 into the ground water

Recent findings

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de

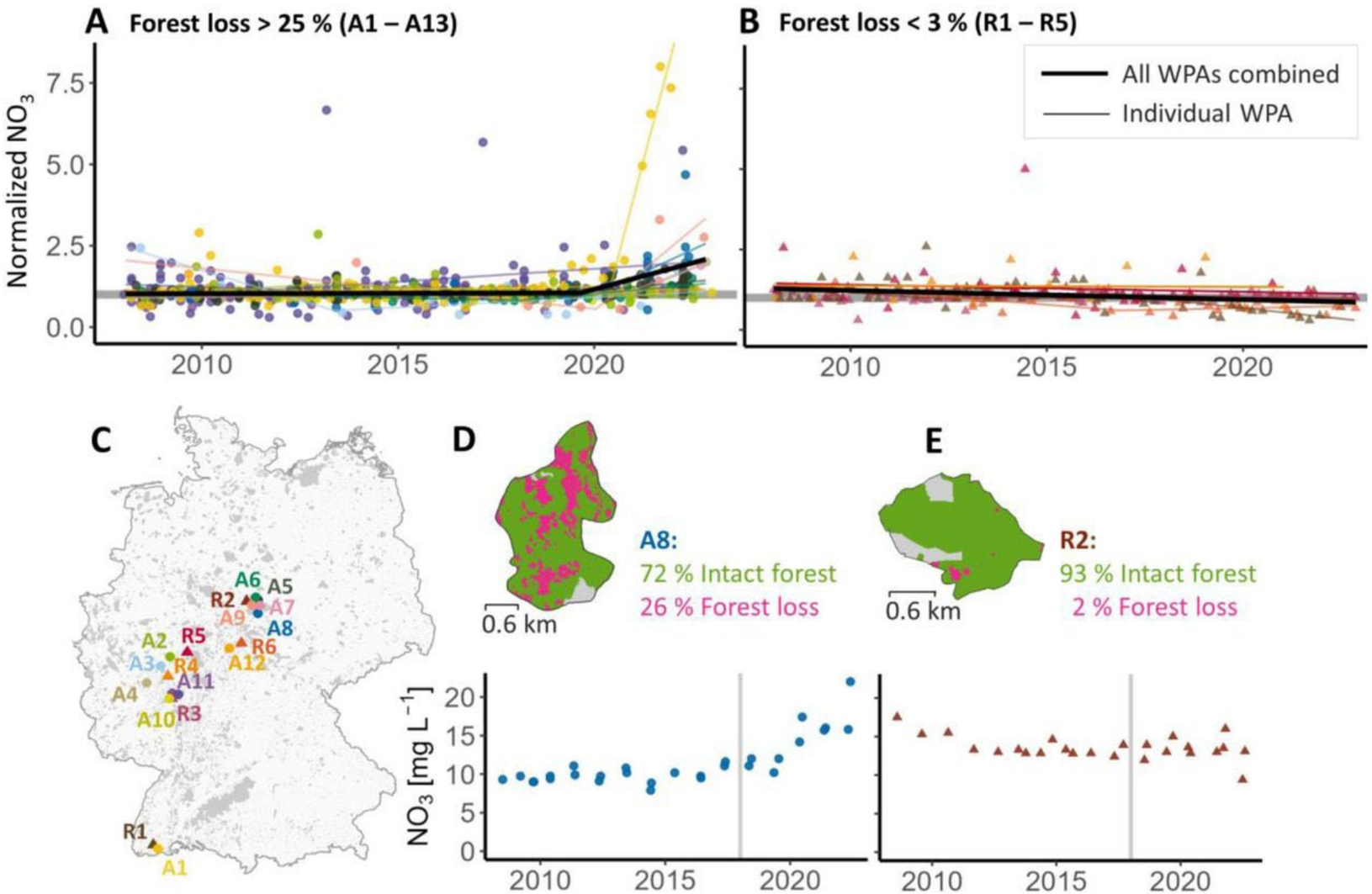


- Most water protection areas (WPA) are forested
- Crown cover loss increased in WPA since 2018

Canopy cover loss across German WPAs, with A) a map of intact forest and canopy cover loss between January 2018 and April 2020, B) the temporal resolution of canopy cover loss as absolute (lines) and cumulative (dots) percentage, and C) the percentage of canopy cover loss relative to the forested area of a WPA and relative to the entire area of the WPA.

Recent findings

Sensor-based Geoinformatics
University of Freiburg
geosense.uni-freiburg.de



- Increased NO3 in areas with forest loss > 25 %
- No increase in areas where forest loss < 3 %

Normalized groundwater nitrate concentrations between 2008 and 2022 in forested sites that were A) affected by <25% canopy cover loss or B) reference sites with <3% canopy cover loss. Thin colored lines depict the area-specific linear models with or without a breakpoint. Thick black lines depict the linear models across all sites with >25% or <3% canopy cover loss. Panel C) depicts a map with the locations of the canopy cover loss and reference sites. Panels D) and E) show two exemplary sites, one with substantial canopy cover loss and a significant increase in nitrate concentration after 2018 (D), and the other a reference site with marginal canopy cover loss and no significant breakpoint after 2018 (E).