KI in der Forst- und Holzwirtschaft – Hype oder Game-Changer?

KI im Waldmonitoring

Prof. Dr. Teja Kattenborn
Professur für Sensorgestützte Geoinformatik (geosense)
www.geosense.uni-freiburg.de

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1. **KI und Computer Vision** in der Fernerkundung
2. **Waldinventur** mit KI + Drohnen + 3D-LiDAR
3. **Waldzustandserhebung** mit KI + Drohnen + Erdbeobachtungssatelliten

Professur für Sensorgestützte Geoinformatik (geosense)

Überblick

- KI, Data Science, Geoinformatik, Remote Sensing, Vegetationsmonitoring
- 8 Laufende Forschungsprojekte zu Vegetationsmonitoring
- Das Team: Jung + bunt + talentiert + motiviert

Wissenswertes

- Deadtrees.earth (größtes Drohnendaten Archiv)
- Emmy Noether Gruppe PANOPS zum Globalen Biodiversitätsmonitoring
- Drohnen-Service Pool der Fakultät UNR
- DFG-Sonderforschungsbereich ECOSENSE zu Walddynamiken

Emmy Noether-Programm
DFG Deutsche Forschungsgemeinschaft

DFG
Deutsche Forschungsgemeinschaft

NFDI4Earth

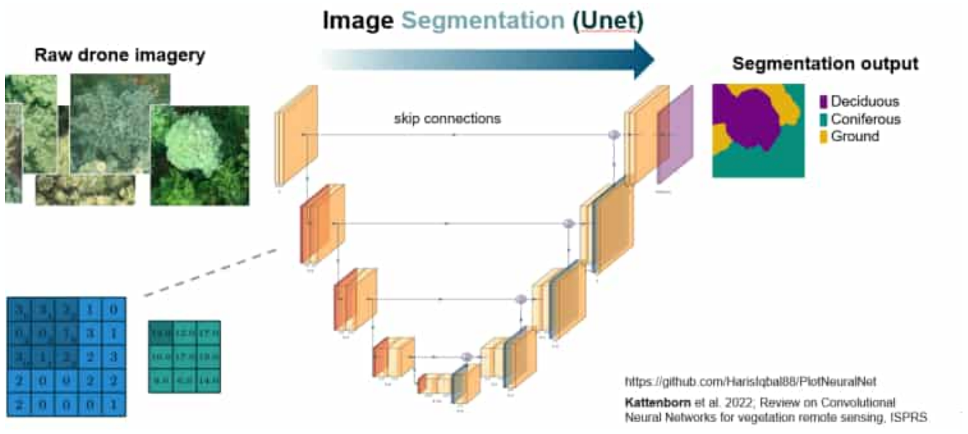
EVA MAYR-STIHL STIFTUNG

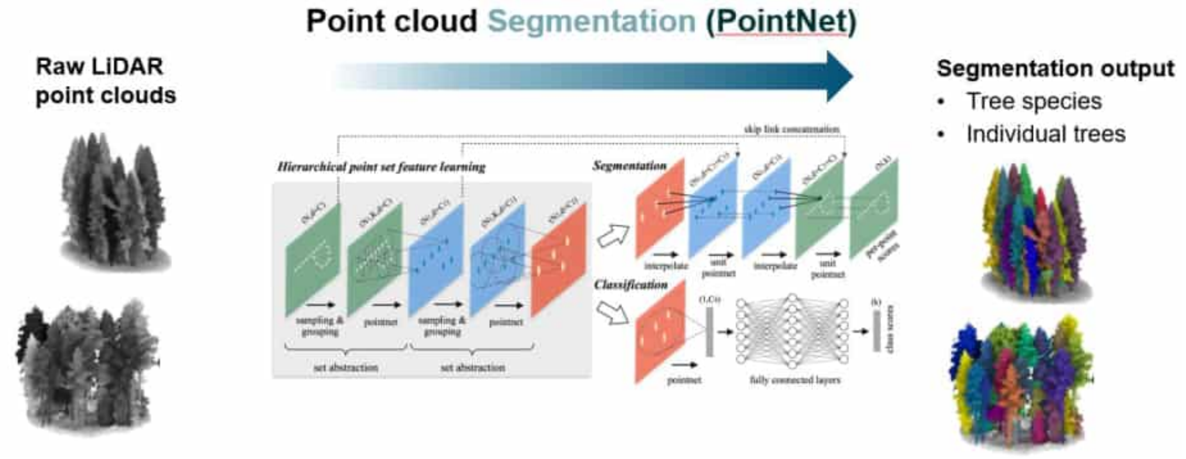
esa
European Space Agency

Baden-Württemberg
MINISTERIUM FÜR ERNÄHRUNG, LÄNDLICHEN RAUM UND VERBRAUCHERSCHUTZ

MARIE CURIE ACTIONS

KI und Computer Vision in der Fernerkundung





KI und Computer Vision in der Fernerkundung

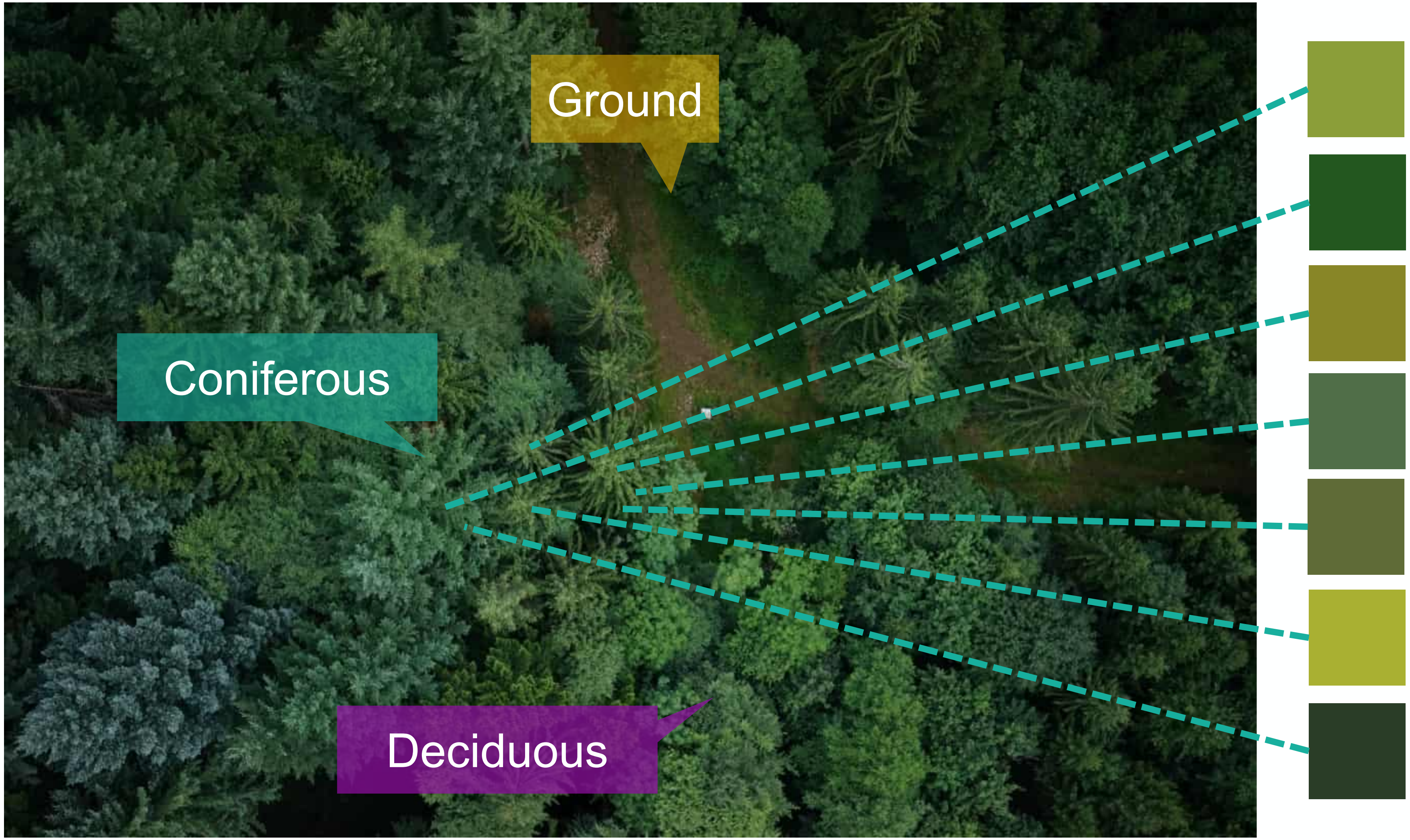
RGB Drone image

KI und Computer Vision in der Fernerkundung

RGB Drone image

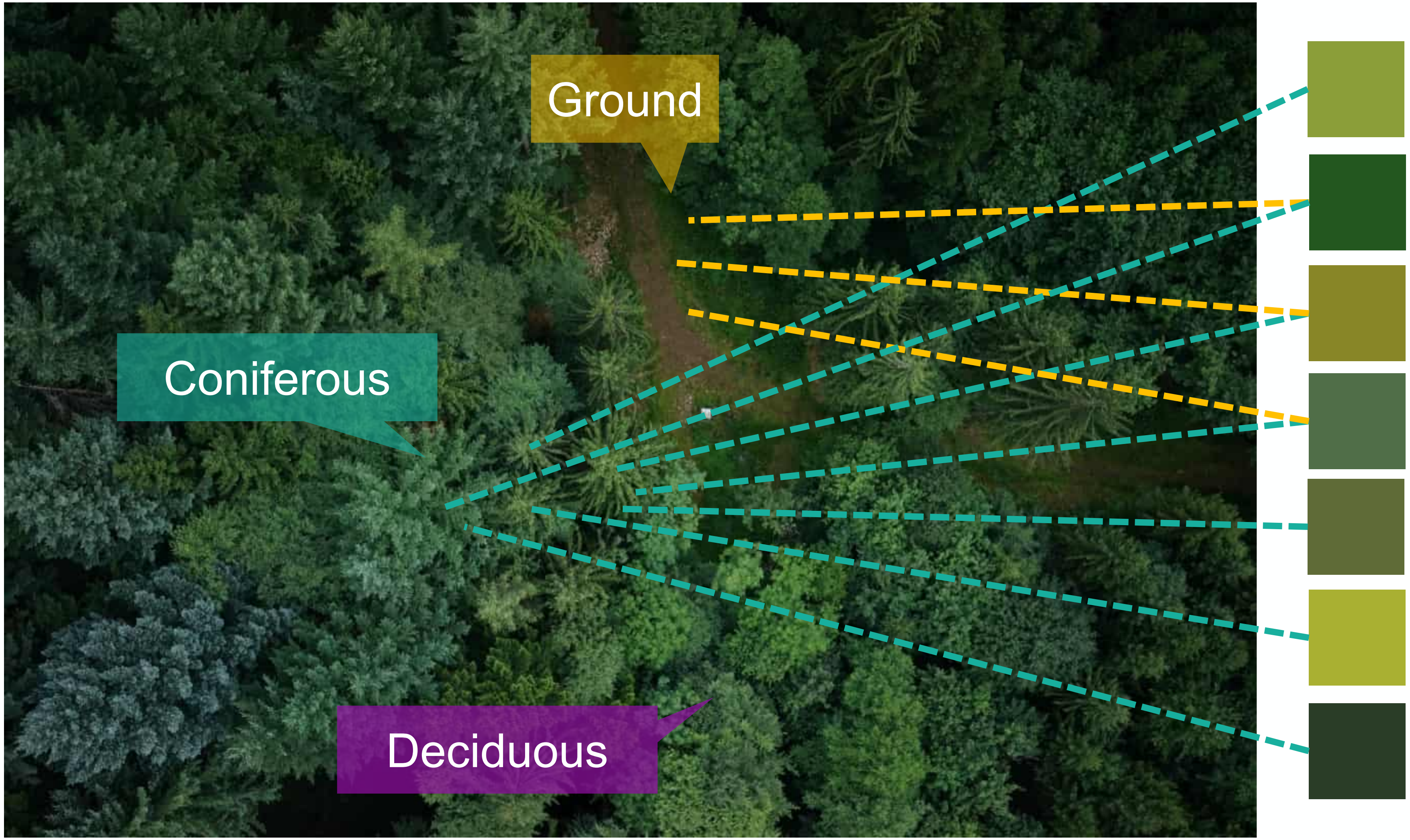
KI und Computer Vision in der Fernerkundung

RGB Drone image



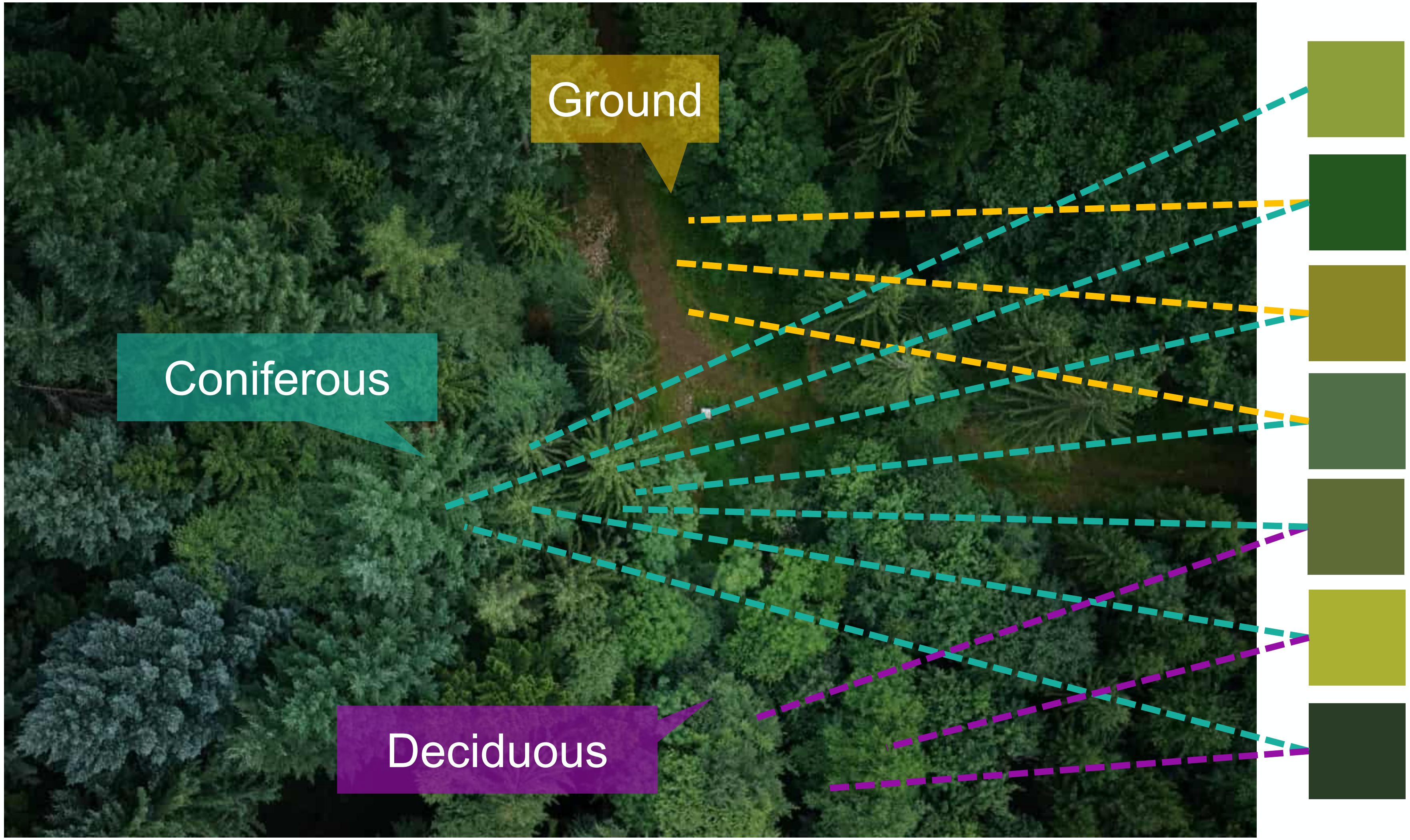
KI und Computer Vision in der Fernerkundung

RGB Drone image



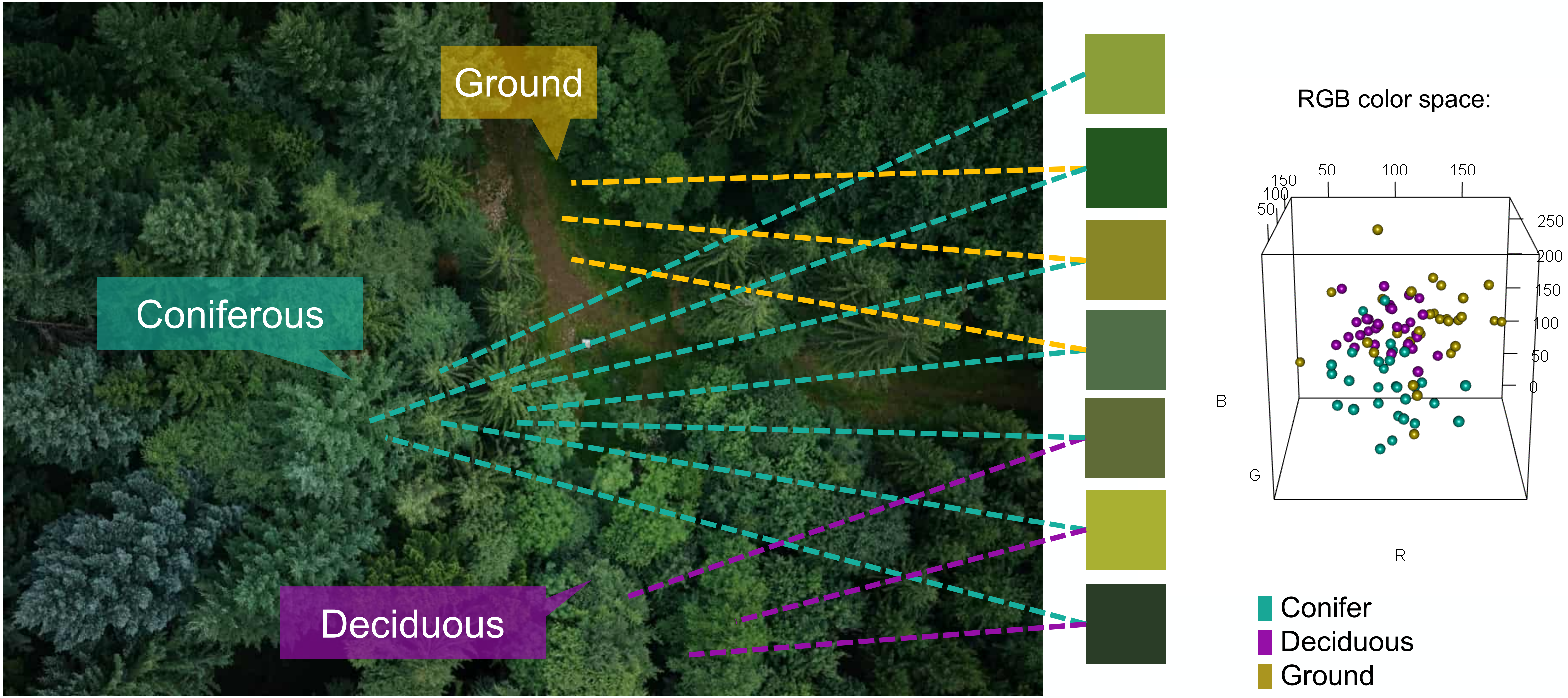
KI und Computer Vision in der Fernerkundung

RGB Drone image



KI und Computer Vision in der Fernerkundung

RGB Drone image



KI und Computer Vision in der Fernerkundung

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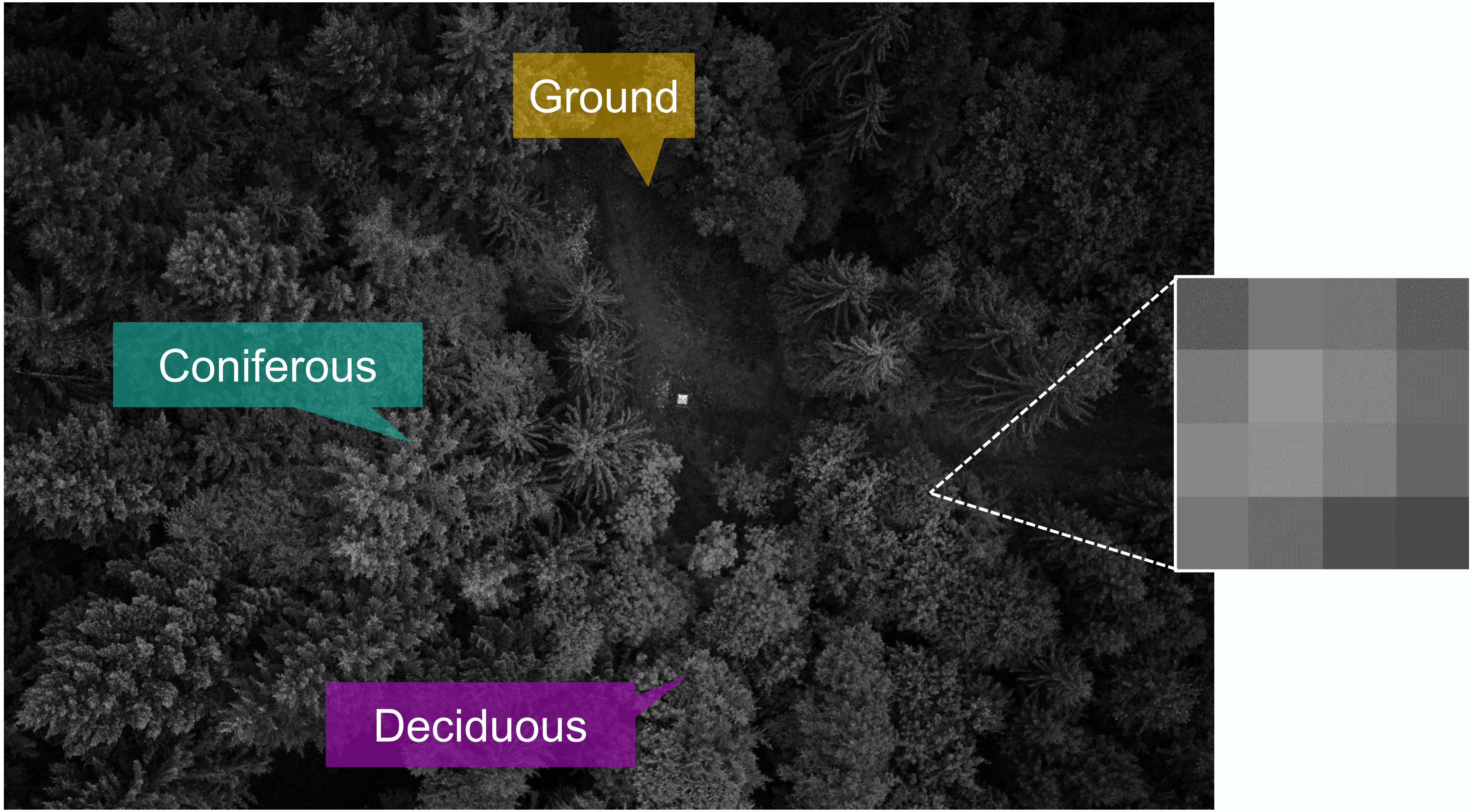


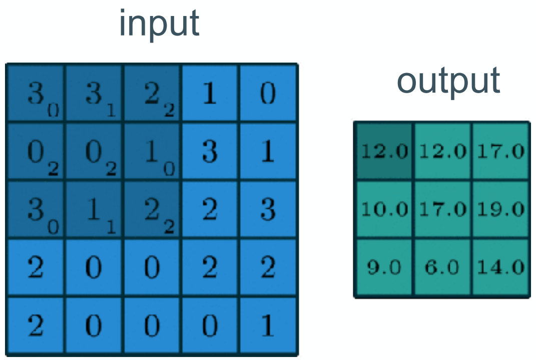
089	110	105	075
112	175	125	097
125	167	155	102
131	103	069	052

4 x 4 pixel matrix

KI und Computer Vision in der Fernerkundung

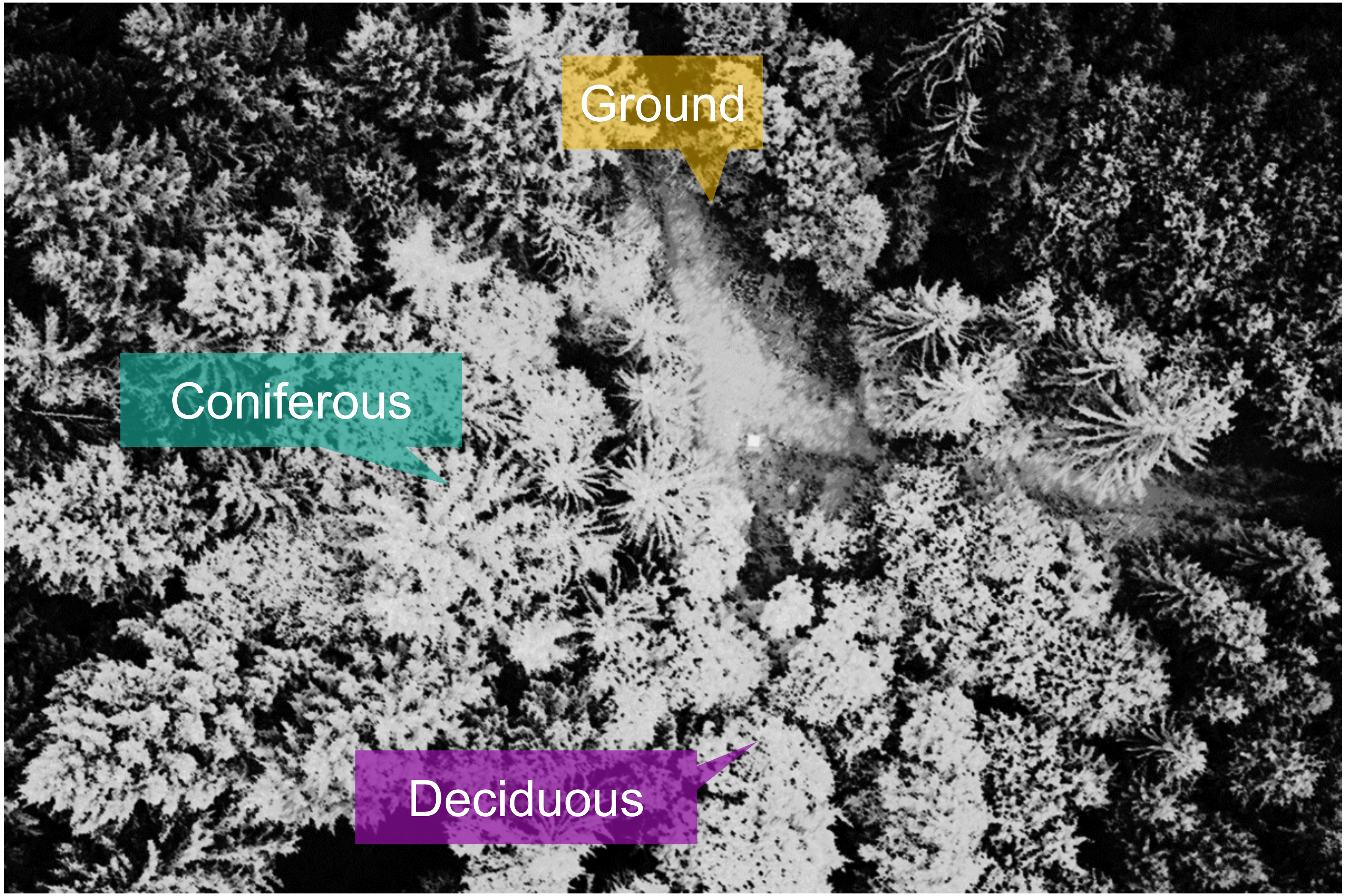
Texture Metrics

- Entropy
- Variance
- Mean
- Homogenity
- etc…



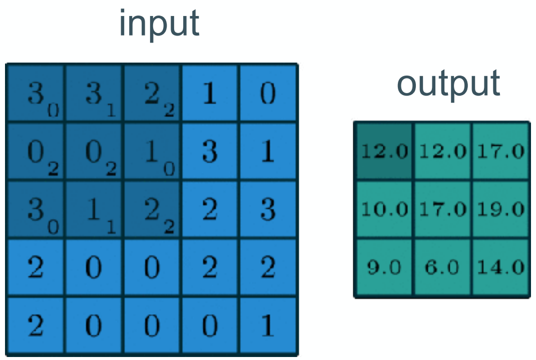
Haralick, R. M., & Shanmugam, K. (1973). Textural features for image classification. *IEEE Transactions on systems, man, and cybernetics*, (6), 610-621.

KI und Computer Vision in der Fernerkundung



Texturmetriken

- Entropy
- Variance
- Mean
- Homogenity
- etc…

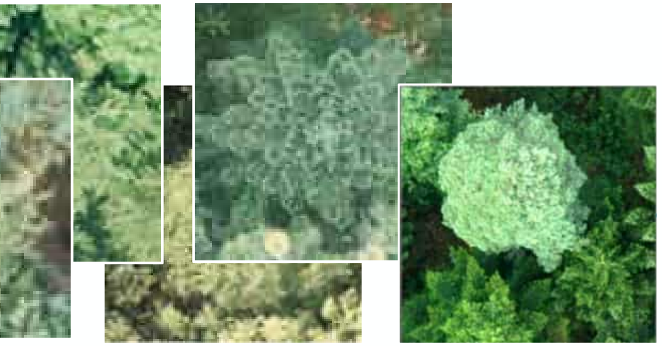


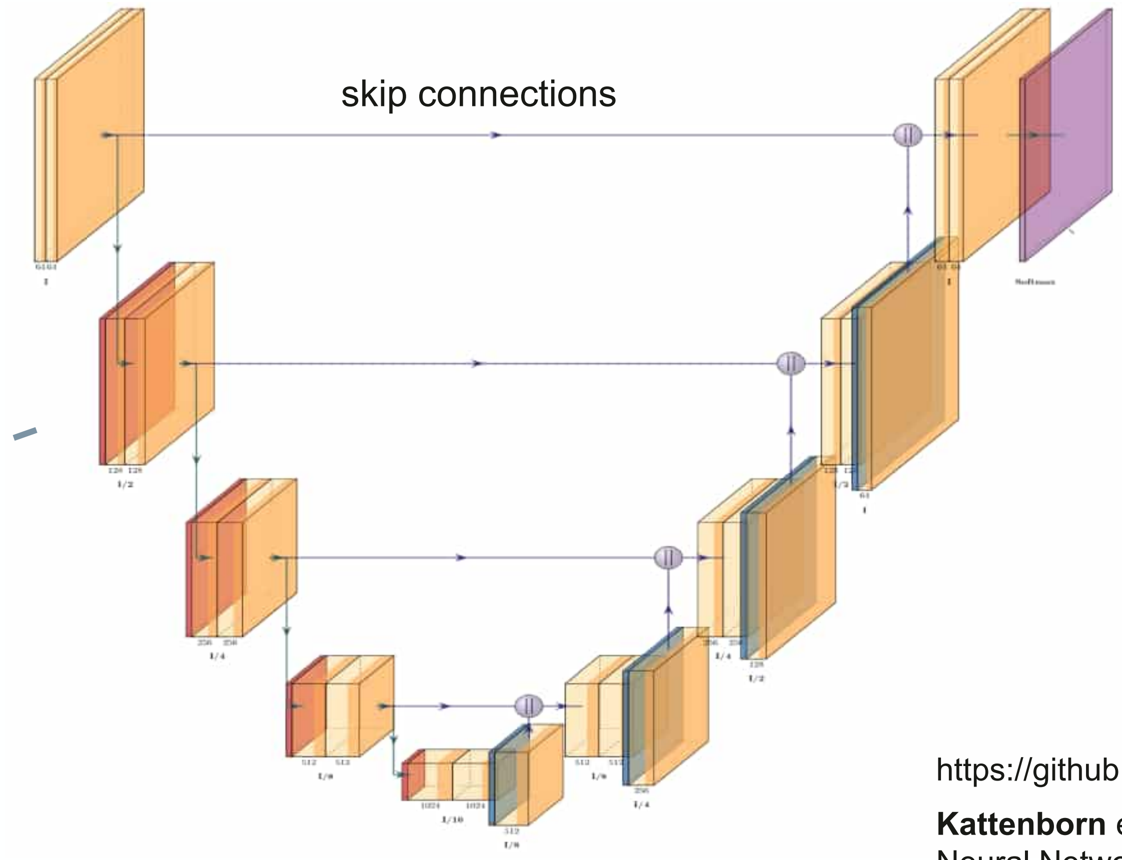
Haralick, R. M., & Shanmugam, K. (1973). Textural features for image classification. *IEEE Transactions on systems, man, and cybernetics*, (6), 610-621.

KI und Computer Vision in der Fernerkundung

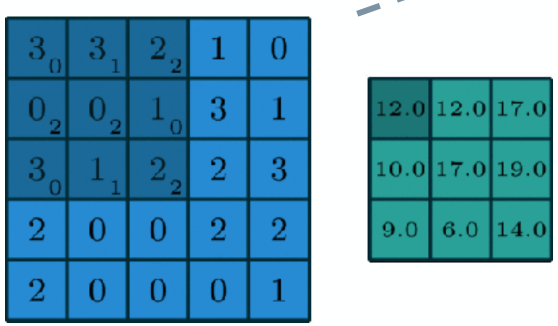
Image Segmentation (Unet)

Raw drone imagery





Segmentation output



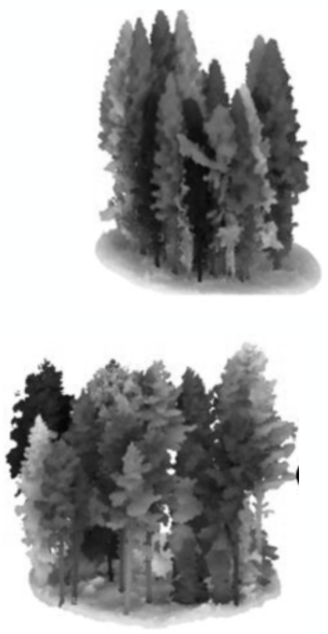
https://github.com/HarisIqbal88/PlotNeuralNet

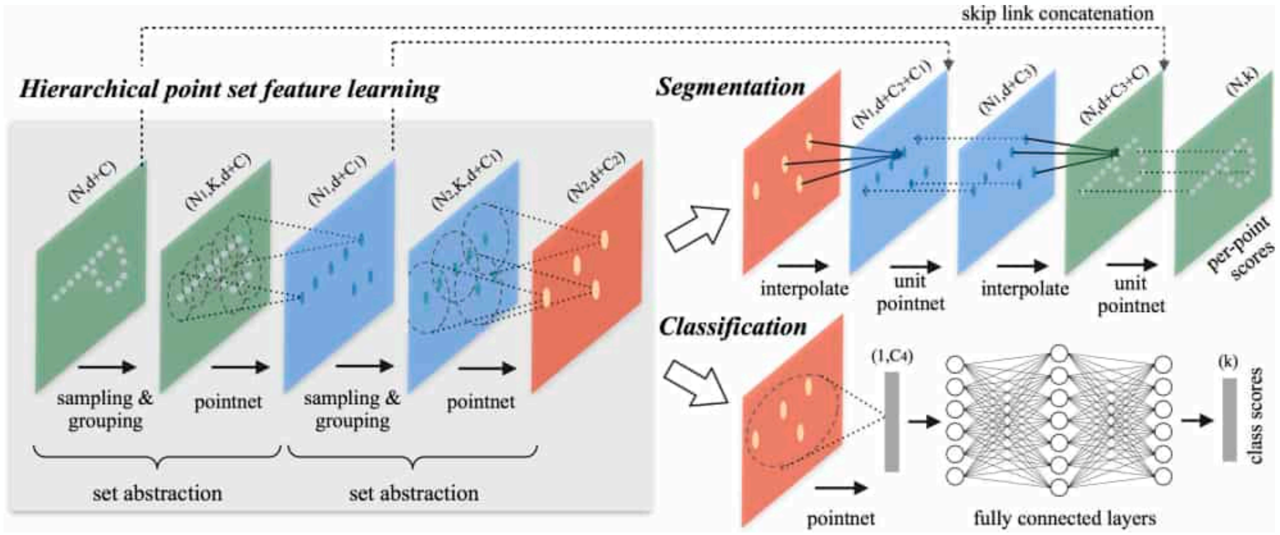
Kattenborn et al. 2022; Review on Convolutional Neural Networks for vegetation remote sensing, ISPRS.

KI und Computer Vision in der Fernerkundung

Point cloud Segmentation (PointNet)

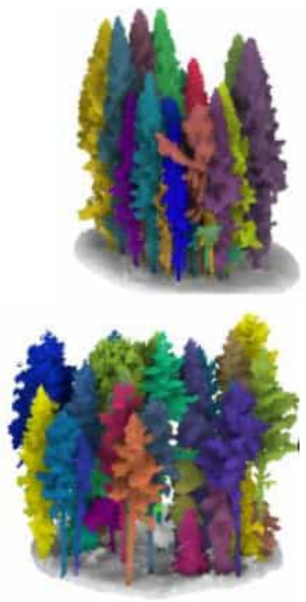
Raw LiDAR point clouds





Segmentation output

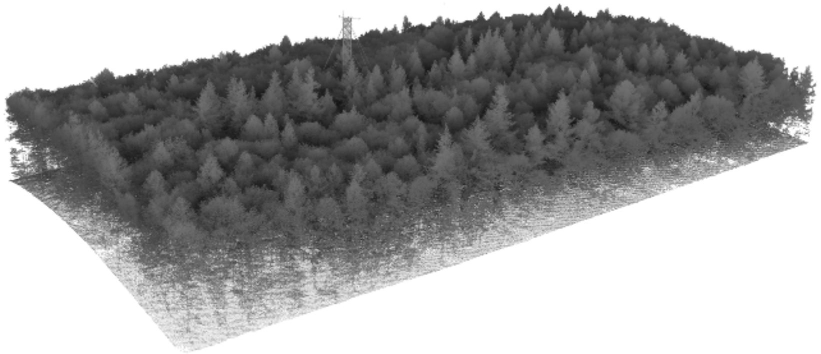
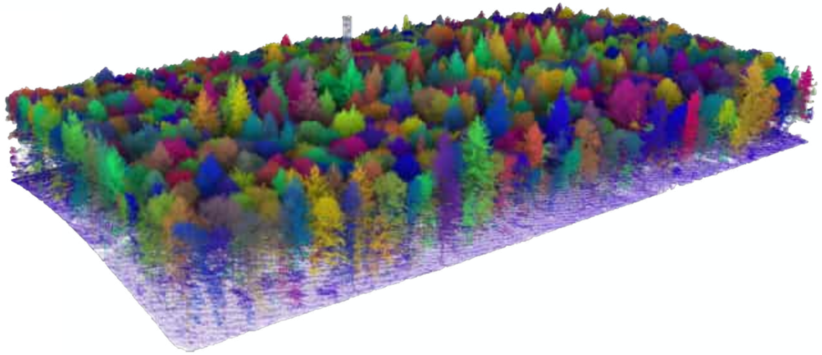
- Tree species
- Individual trees



https://stanford.edu/~rqi/pointnet2/

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

Waldinventur mit KI + Drohnen + 3D LiDAR

Waldinventur mit KI + Drohnen + 3D LiDAR

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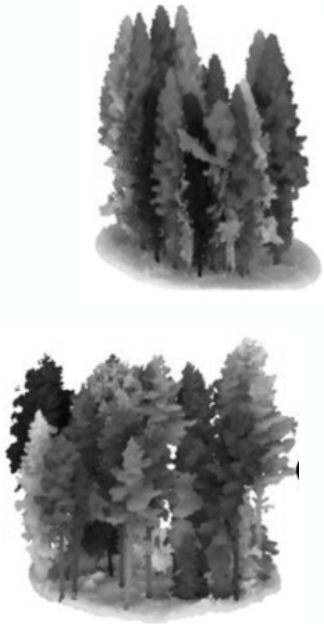

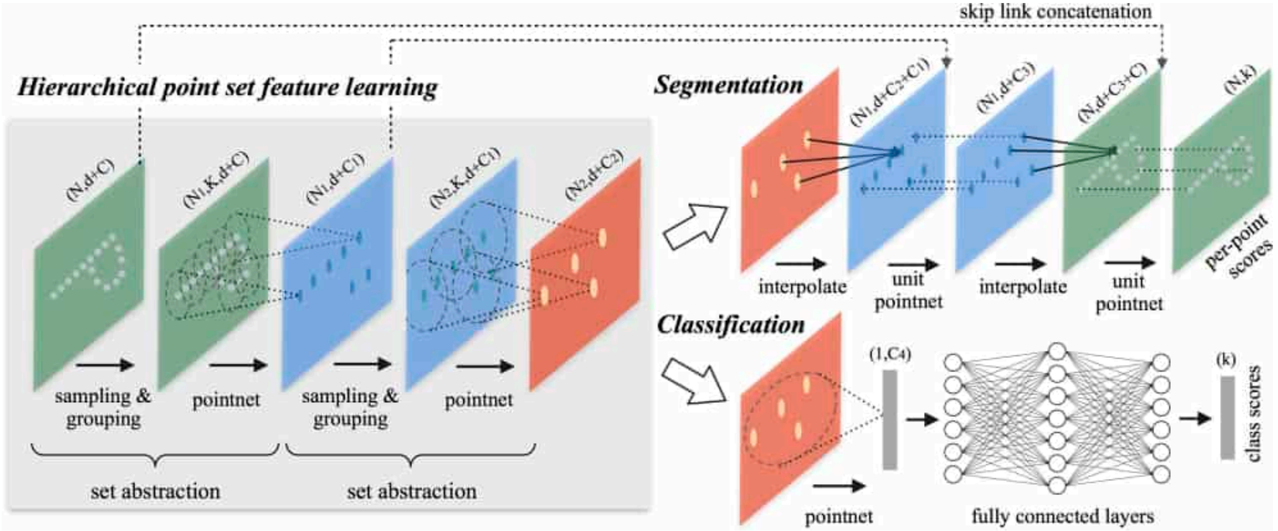

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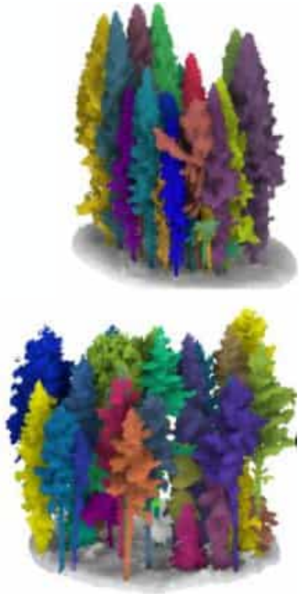

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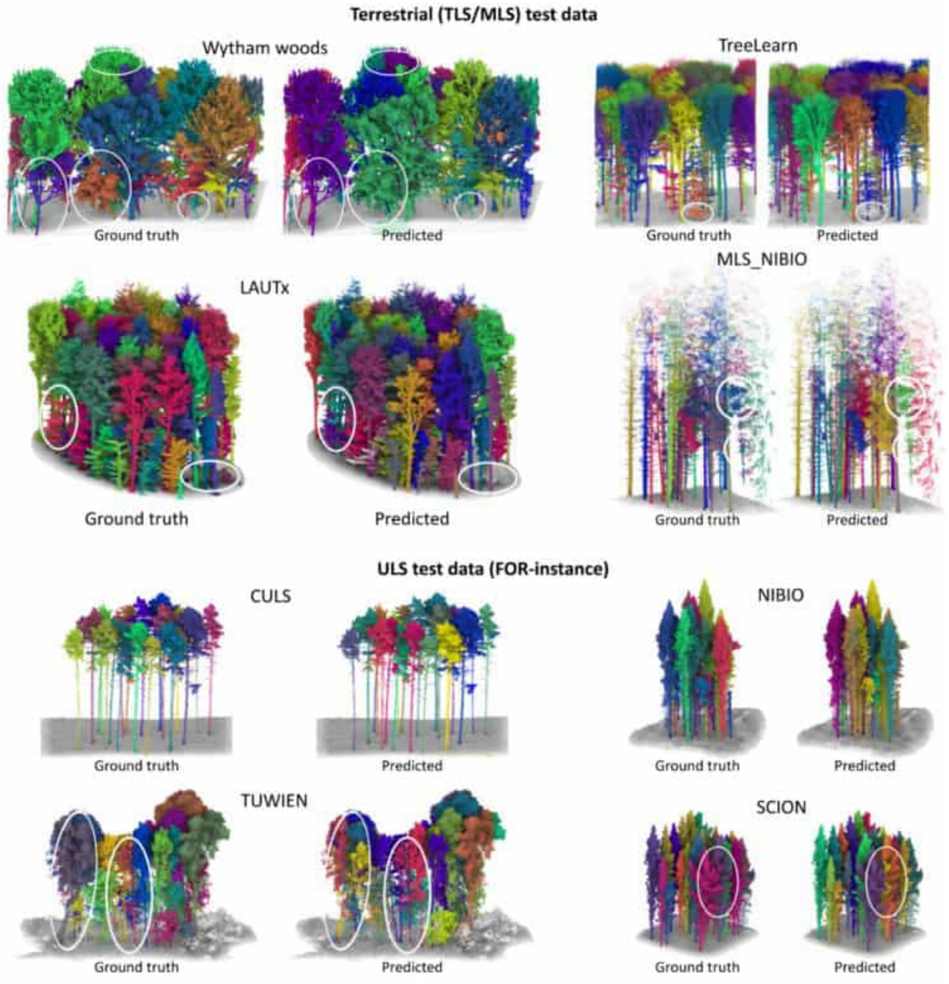
Kattenborn et al. 2022; Review on Convolutional Neural Networks for vegetation remote sensing, ISPRS.

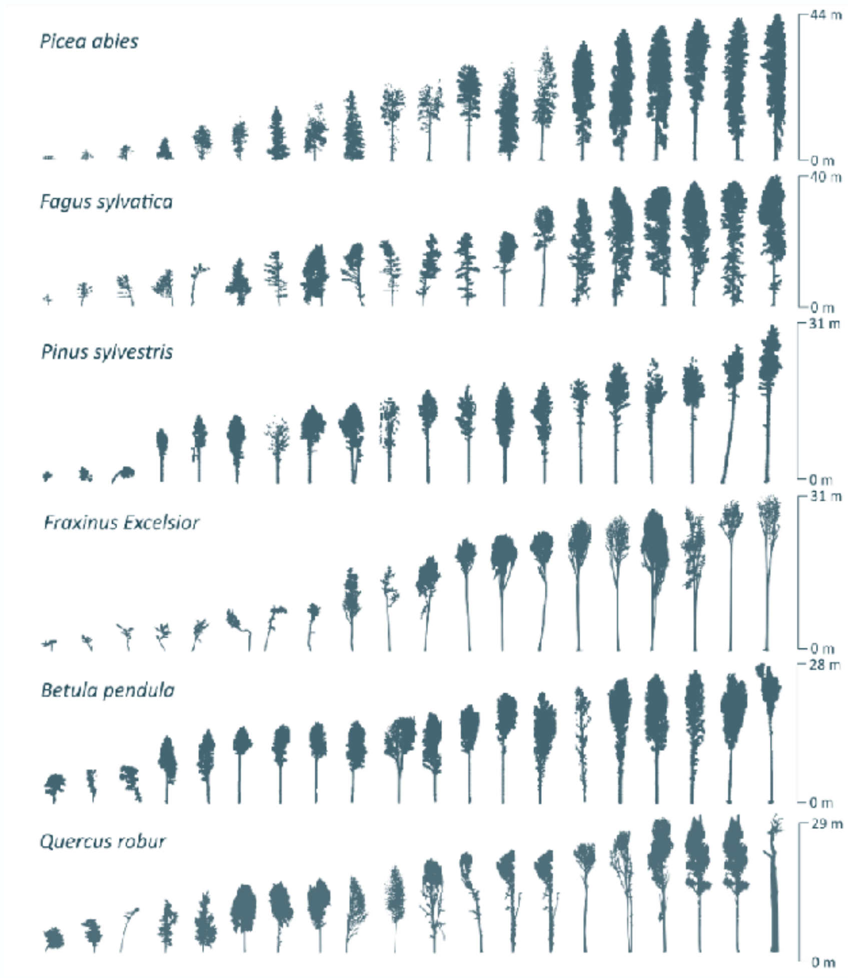
Waldinventur mit KI + Drohnen + 3D LiDAR

Trainingsdaten Einzelbaumerkennung



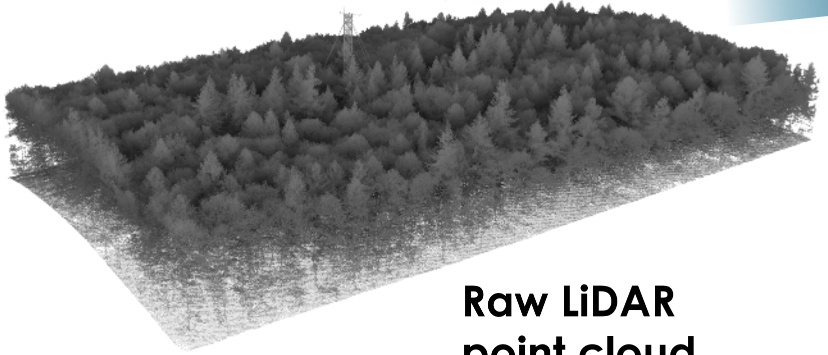
Wielgosz et al. 2024, https://doi.org/10.1016/j.rse.2024.114367

Trainingsdaten Baumartenarten



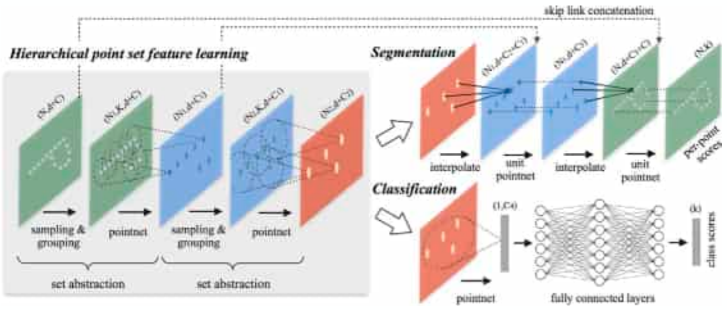
Frey et al. 2024, https://github.com/JulFrey/DetailView
Puliti et al. 2024, https://doi.org/10.48550/arXiv.2408.06507

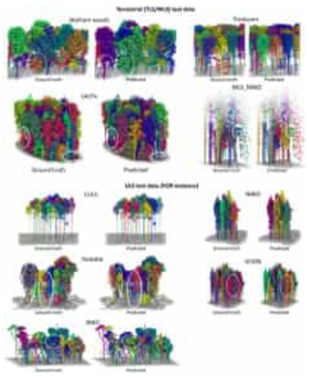
Waldinventur mit KI + Drohnen + 3D LiDAR

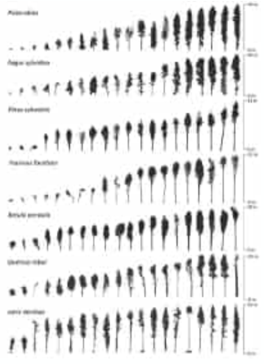


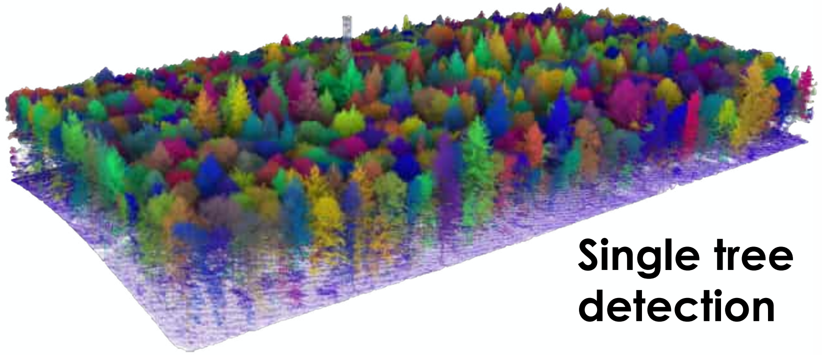
Raw LiDAR point cloud

Point cloud Segmentation (PointNet)

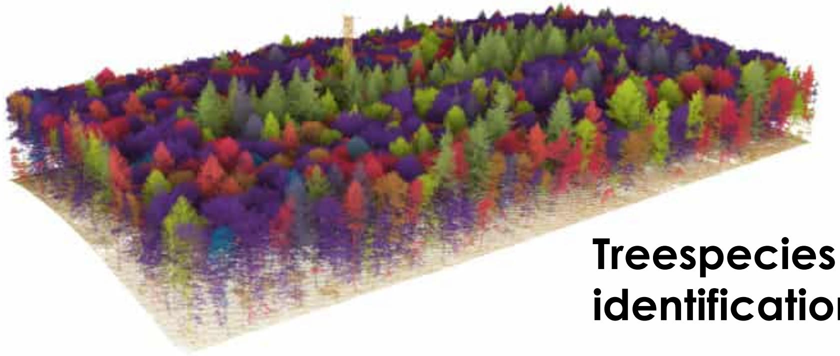








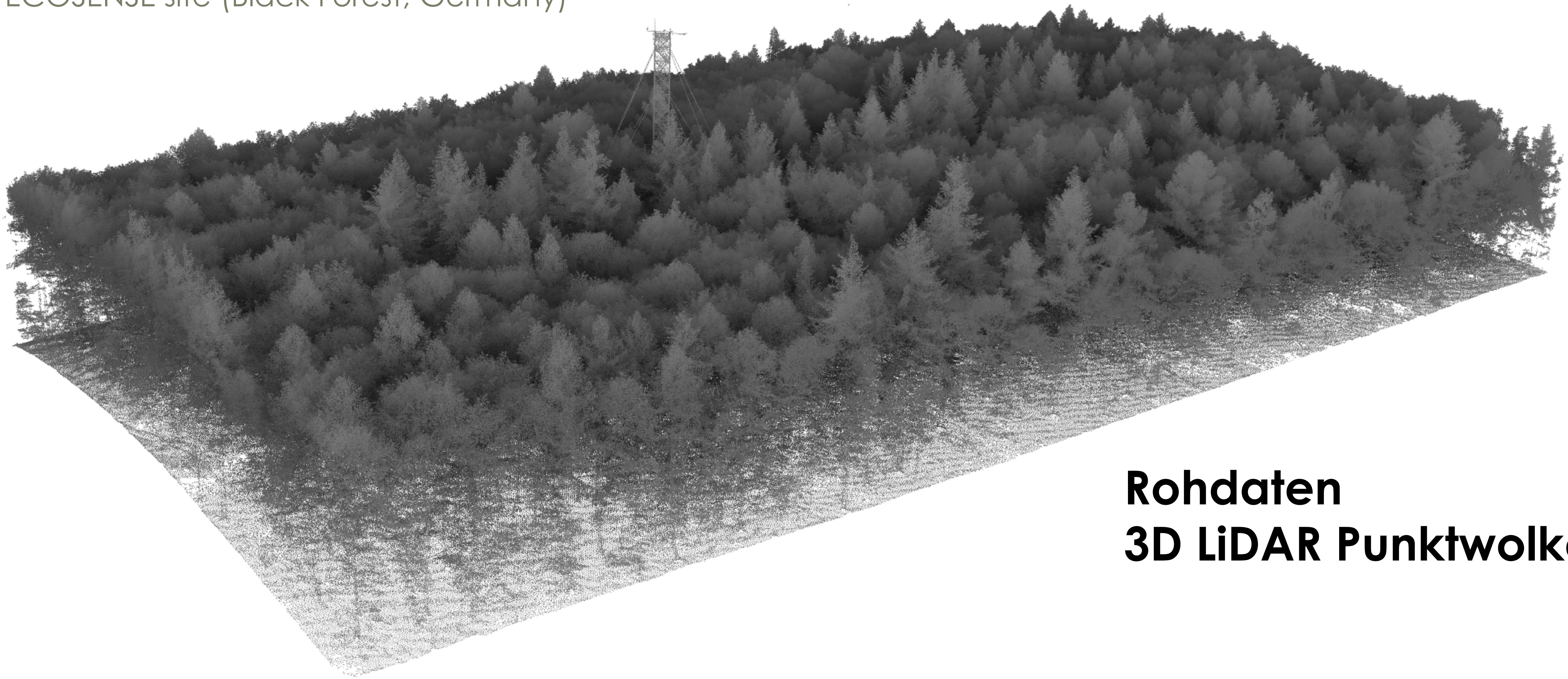
Single tree detection



Treespecies identification

Waldinventur mit KI + Drohnen + 3D LiDAR

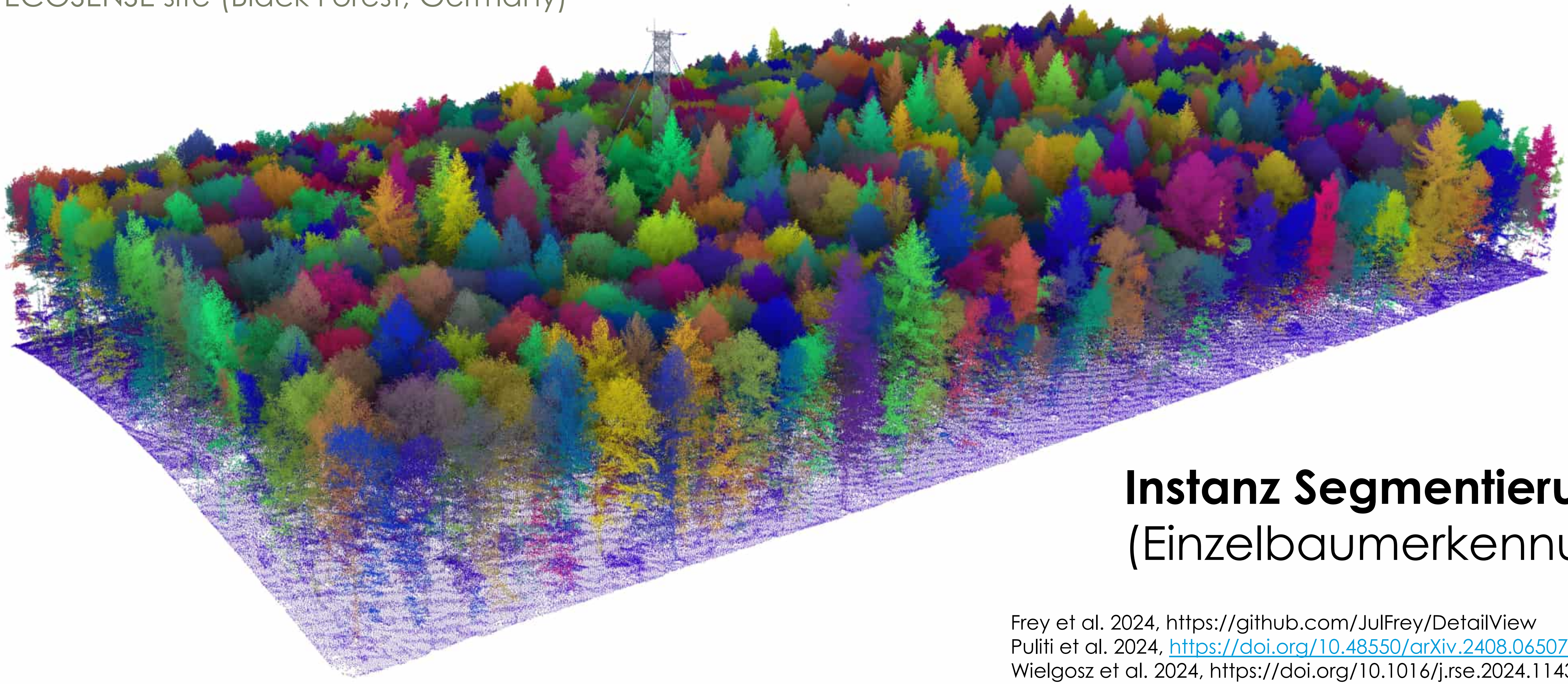
ECOSENSE site (Black Forest, Germany)



Rohdaten
3D LiDAR Punktwolke

Waldinventur mit KI + Drohnen + 3D LiDAR

ECOSENSE site (Black Forest, Germany)

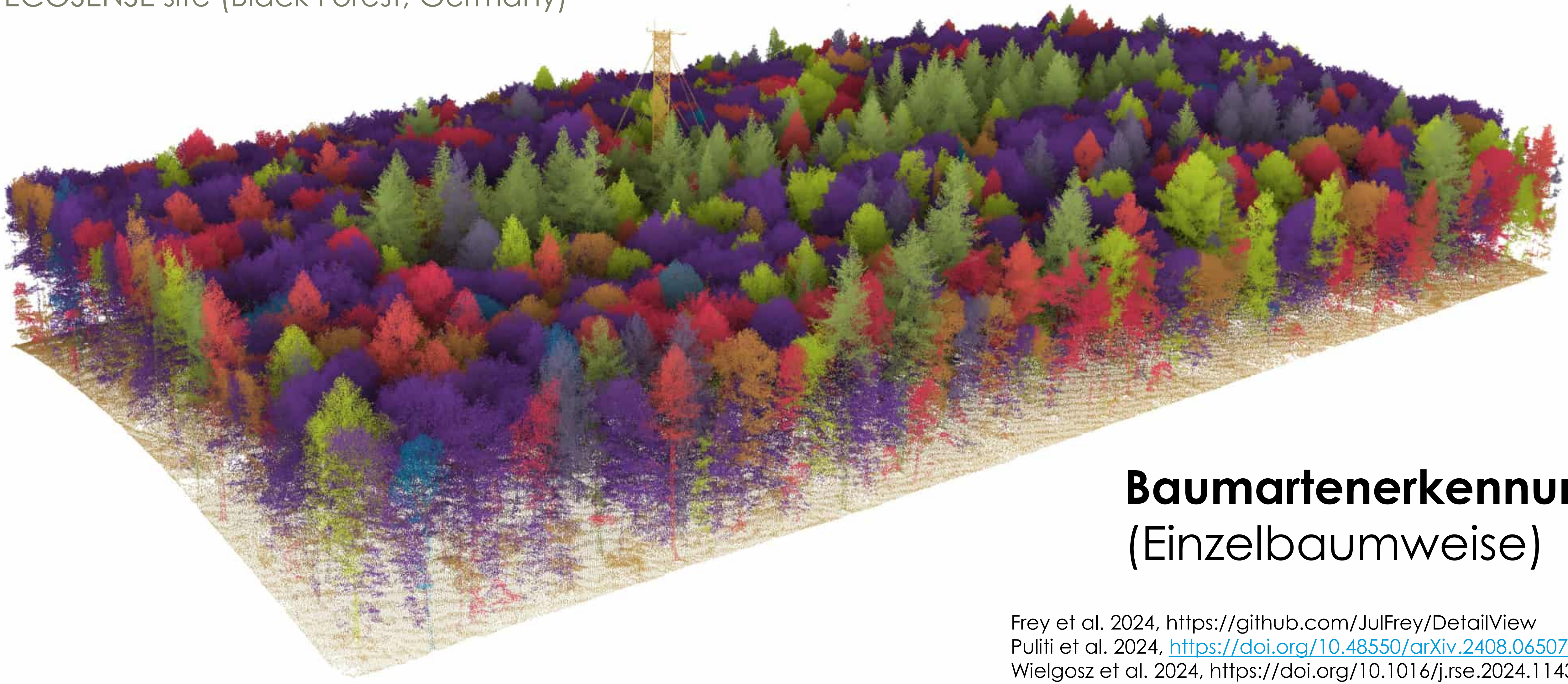


Instanz Segmentierun
(Einzelbaumerkennu

Frey et al. 2024, https://github.com/JulFrey/DetailView
Puliti et al. 2024, https://doi.org/10.48550/arXiv.2408.06507
Wielgosz et al. 2024, https://doi.org/10.1016/j.rse.2024.11436

Waldinventur mit KI + Drohnen + 3D LiDAR

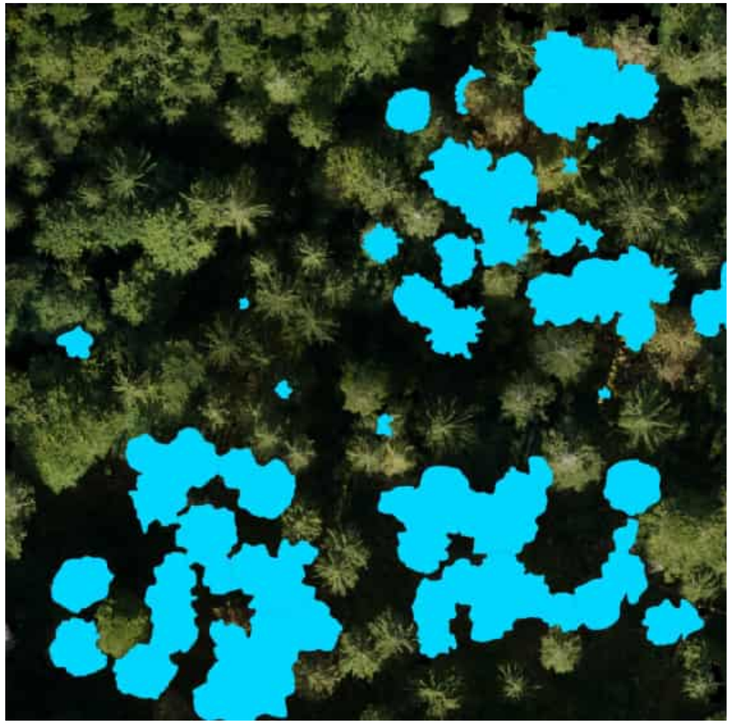
ECOSENSE site (Black Forest, Germany)



Baumartenerkennun
(Einzelbaumweise)

Frey et al. 2024, https://github.com/JulFrey/DetailView
Puliti et al. 2024, https://doi.org/10.48550/arXiv.2408.06507
Wielgosz et al. 2024, https://doi.org/10.1016/j.rse.2024.11436

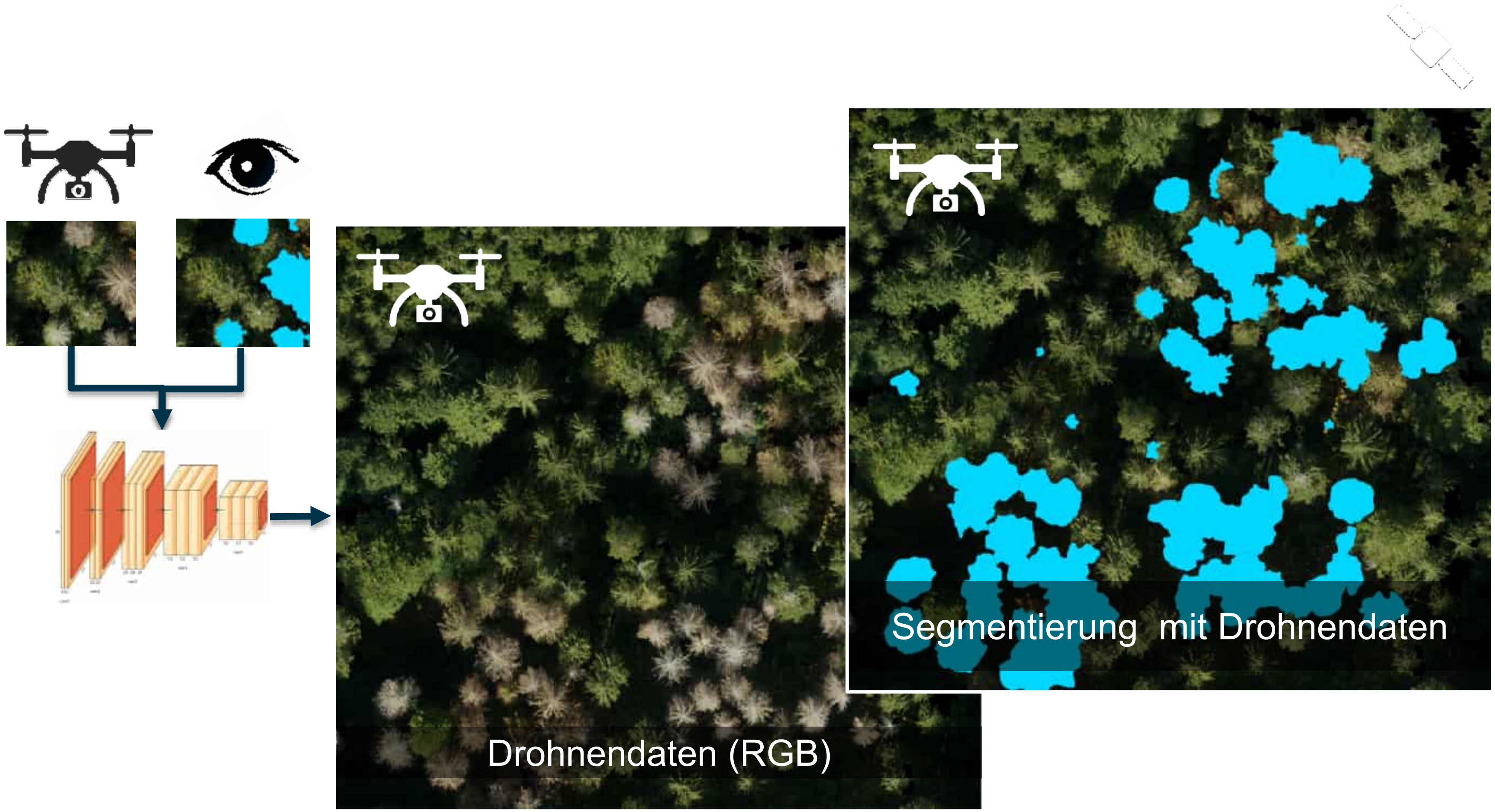
Waldzustandserhebung mit KI + Drohnen + Satelliten



Waldzustandserhebung mit KI + Drohnen + Satelliten

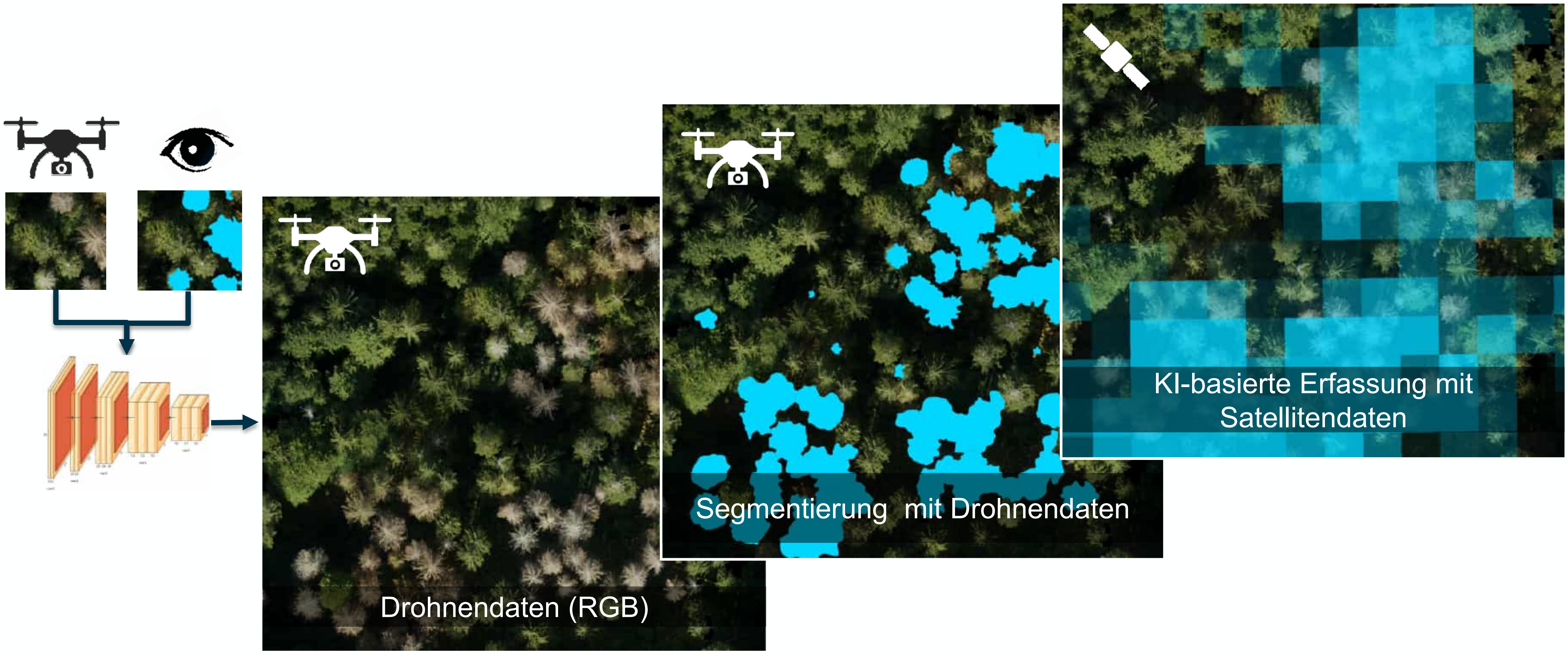
Waldzustandserhebung mit KI + Drohnen + Satelliten

Waldzustandserhebung mit KI + Drohnen + Satelliten



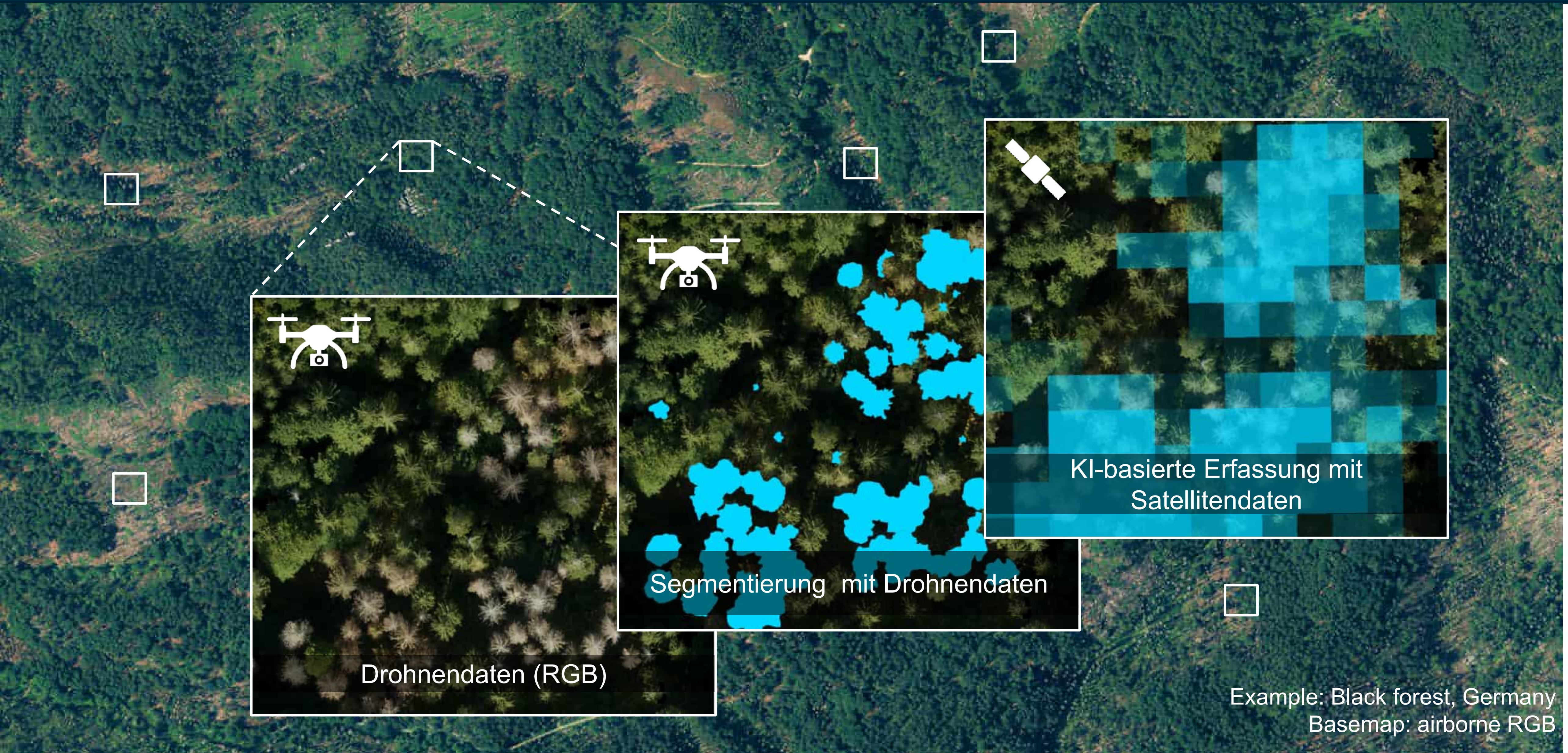
Schiefer et al. (2023) ISPRS Open

Waldzustandserhebung mit KI + Drohnen + Satelliten

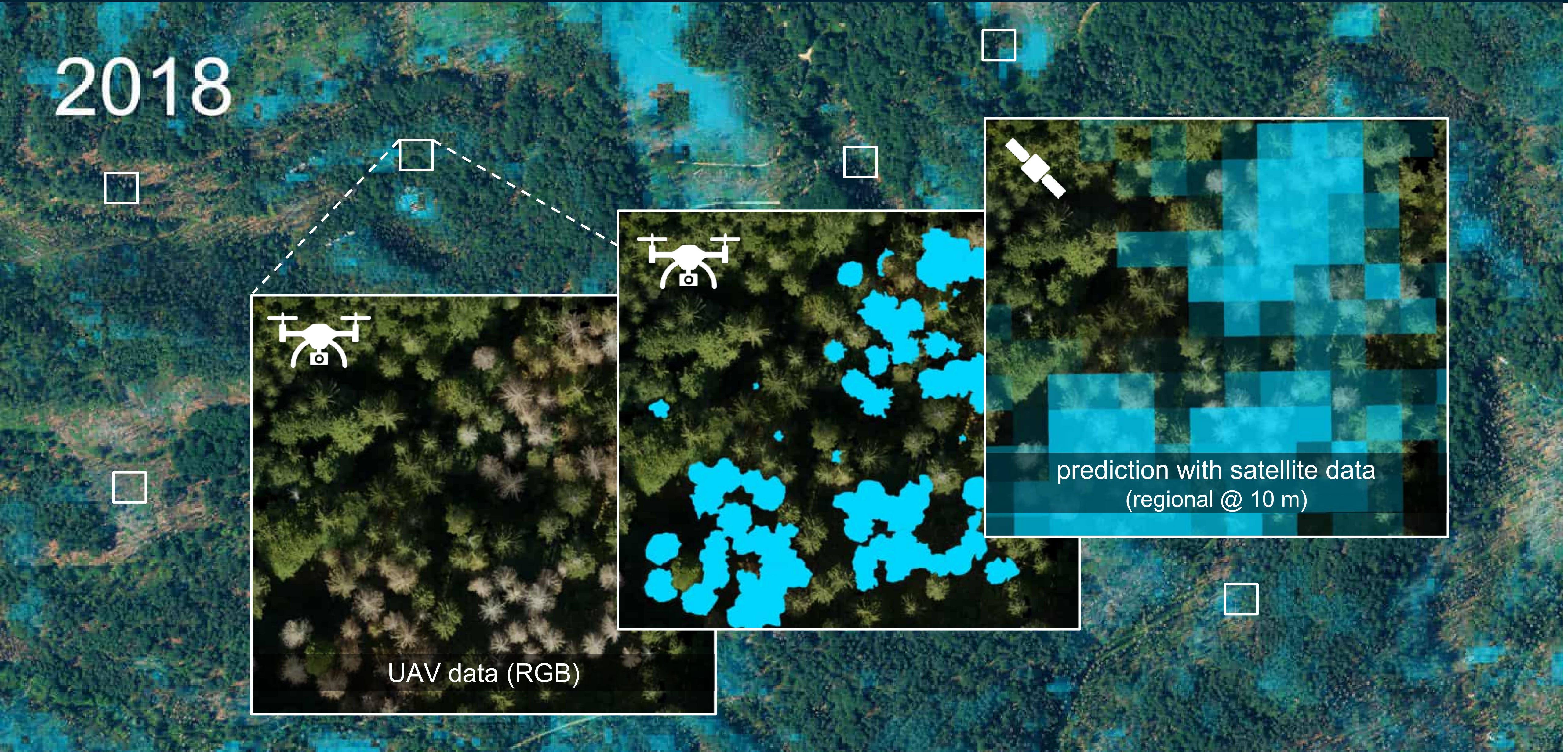


Schiefer et al. (2023) ISPRS Open

Waldzustandserhebung mit KI + Drohnen + Satelliten



Waldzustandserhebung mit KI + Drohnen + Satelliten



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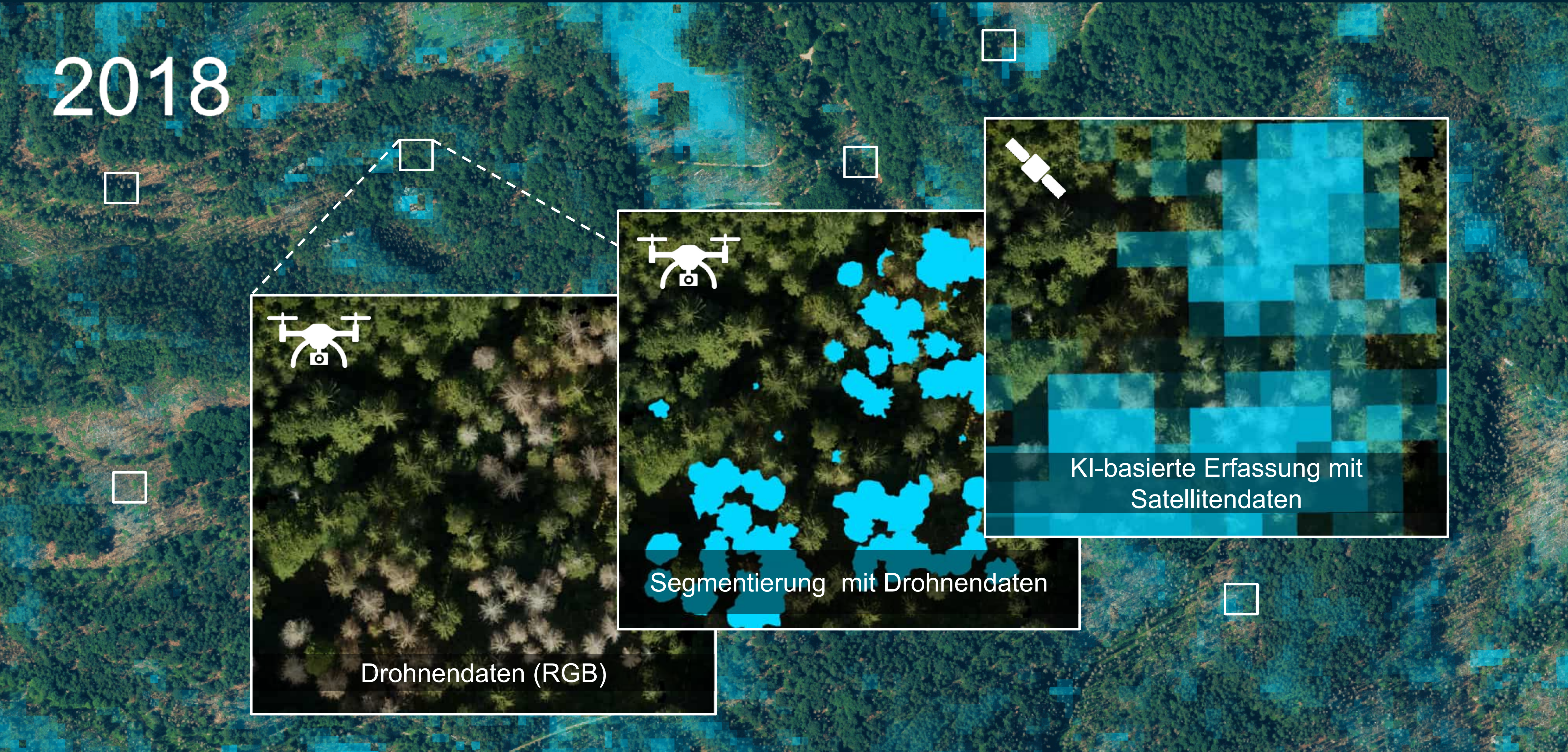
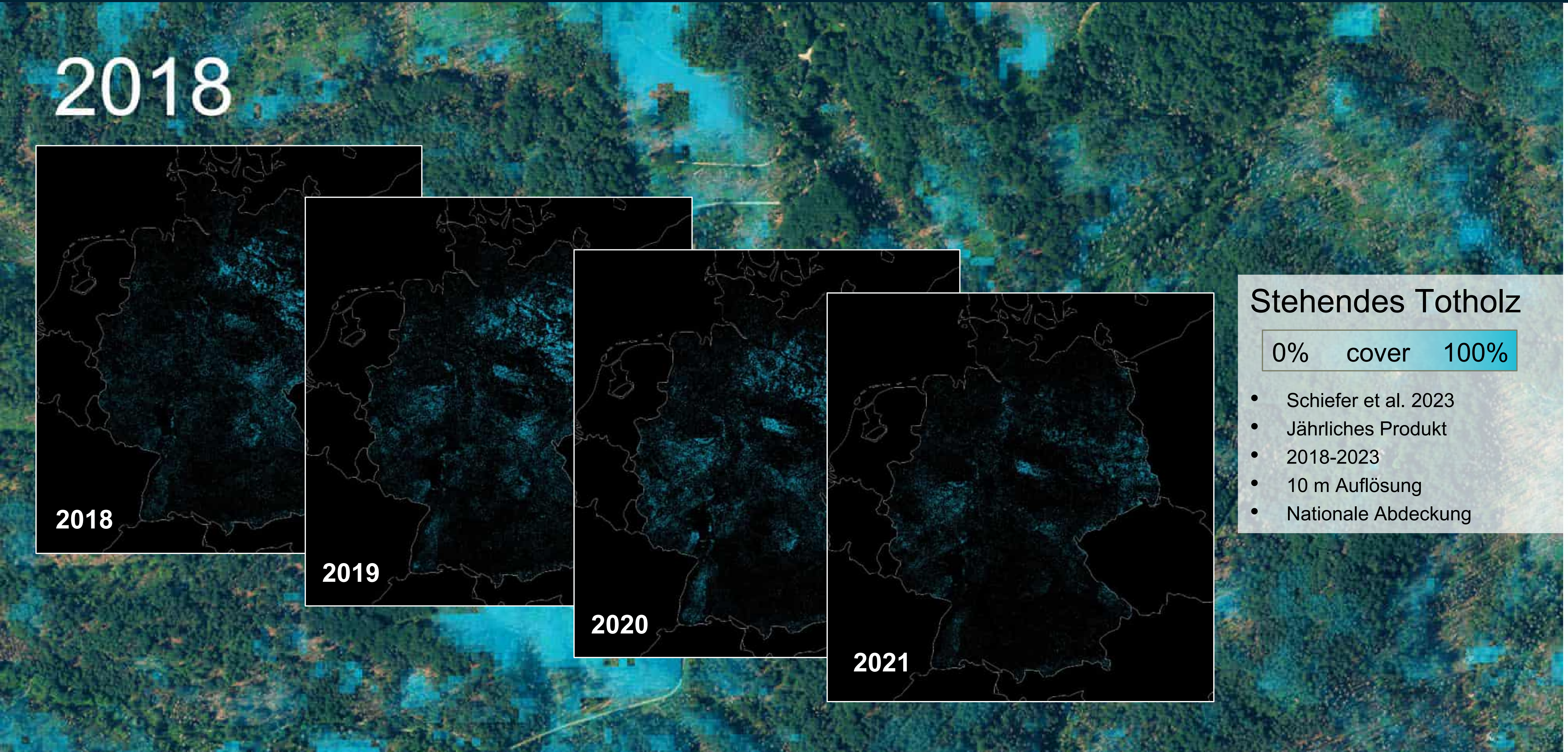


Waldzustandserhebung mit KI + Drohnen + Satelliten



Stehendes Totholz

0% cover 100%

- Schiefer et al. 2023
- Jährliches Produkt
- 2018-2023
- 10 m Auflösung
- Nationale Abdeckung

Waldzustandserhebung mit KI + Drohnen + Satelliten

OXFORD

Institute of Chartered Foresters

Forestry: An International Journal of Forest Research, 2024, 1–15

https://doi.org/10.1093/forestry/cpae062

Original Article

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

Felix Schiefer [1,*], Sebastian Schmidtlein [1], Henrik Hartmann [2,3,4], Florian Schnabel [5], Teja Kattenborn [6]

[1]Institute of Geography and Geoecology, Karlsruhe Institute of Technology, Kaiserstr. 12, 76131 Karlsruhe, Baden-Württemberg, Germany
[2]Institute for Forest Protection, Julius Kühn-Institute - Federal Research Center for Cultivated Plants, Erwin-Baur-Str. 27, 06484 Quedlinburg, Sachsen-Anhalt, Germany
[3]Faculty of Forest Sciences and Forest Ecology, Georg-August-University Göttingen, Büsgenweg 5, 37077 Göttingen, Niedersachsen, Germany
[4]Max Planck Institute for Biogeochemistry, Hans-Knöll-Str. 10, 07745 Jena, Thüringen, Germany
[5]Chair of Silviculture, Faculty of Environment and Natural Resources, University of Freiburg, Stefan-Meier-Str. 76, 79104 Freiburg, Baden-Württemberg, Germany
[6]Chair of Sensor-based Geoinformatics, Faculty of Environment and Natural Resources, University of Freiburg, Tennenbacher Str. 4, 79116 Freiburg, Baden-Württemberg, Germany

*Corresponding author. Institute of Geography and Geoecology, Karlsruhe Institute of Technology, Kaiserstr. 12, 76131 Karlsruhe, Baden-Württemberg, Germany. E-mail: felix.schiefer@kit.edu

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 environmental drivers using random forest regression. In 2019, the second consecutive hotter drought year in a row, standing deadwood increased steeply to 334 ± 189 kilohectar (kha) which corresponds to 2.5 ± 1.4% of the total forested area in Germany. *Picea abies*, *Pinus sylvestris*, and *Fagus sylvatica* showed highest shares of standing deadwood. During 2018–2021 978 ± 529 kha (7.9 ± 4.4%) of standing dead trees accumulated. The higher mortality estimates that we report compared to other surveys (such as the ground-based forest condition survey) can be partially attributed to the fact that remote sensing captures mortality from a bird's eye perspective and that the high spatial detail (10 m) in this study also captures scattered occurrences of tree mortality. Atmospheric drought (i.e. climatic water balance and vapor pressure deficit) and temperature extremes (i.e. number of hot days and frosts after vegetation onset) were the most important predictors of tree mortality. We found increased tree mortality for smaller and younger stands and on less productive sites. Monospecific stands were generally not more affected by mortality than average, but only when interactions with damaging insects (e.g. bark beetles) occurred. Because excess tree mortality rates threaten many forests across the globe, similar analyses of tree mortality are warranted and technically feasible at the global scale. We encourage the international scientific community to share and compile local data on deadwood occurrences (see example: www.deadtrees.earth) as such a collaborative effort is required to help understand mortality events on a global scale.

Waldzustandserhebung mit KI + Drohnen + Satelliten

OXFORD

Institute of Chartered Foresters

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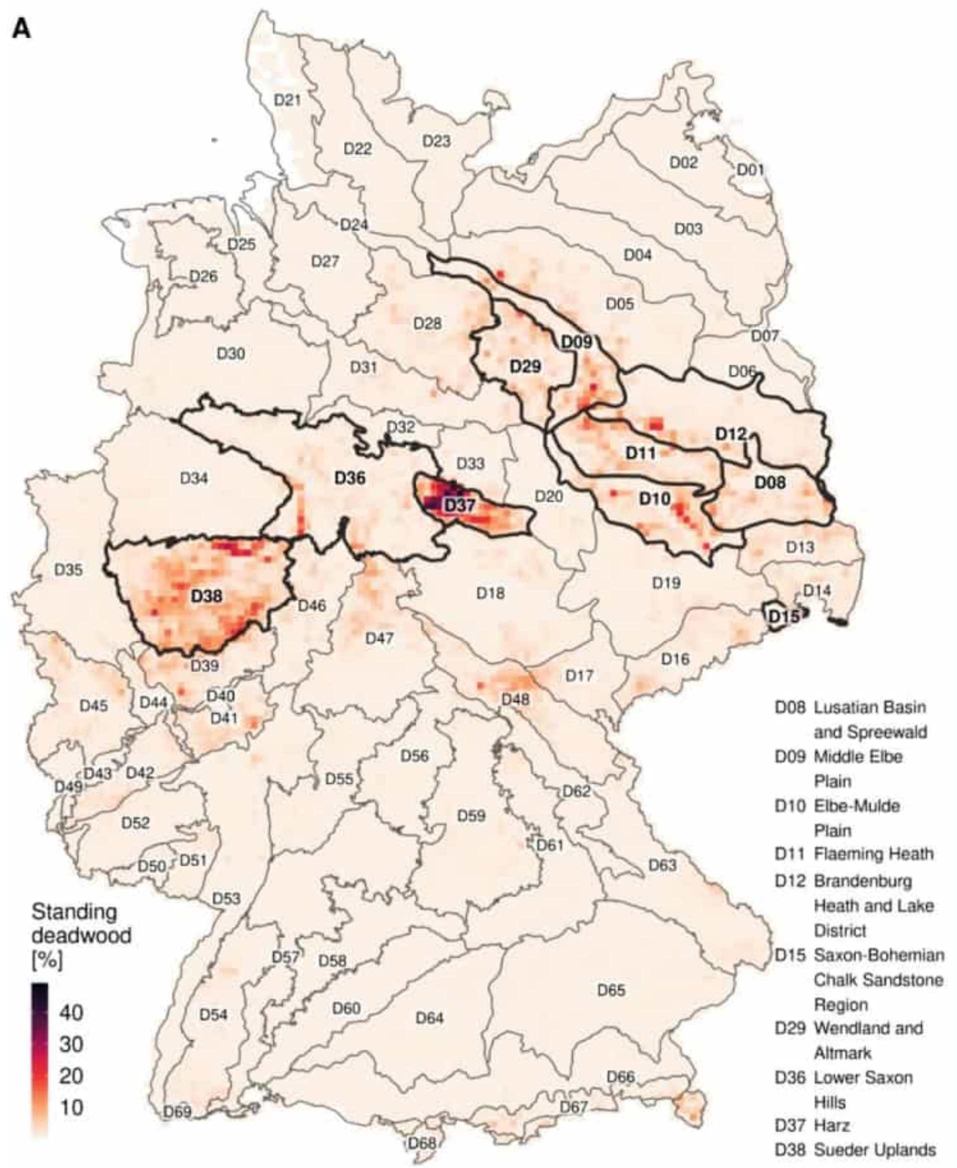
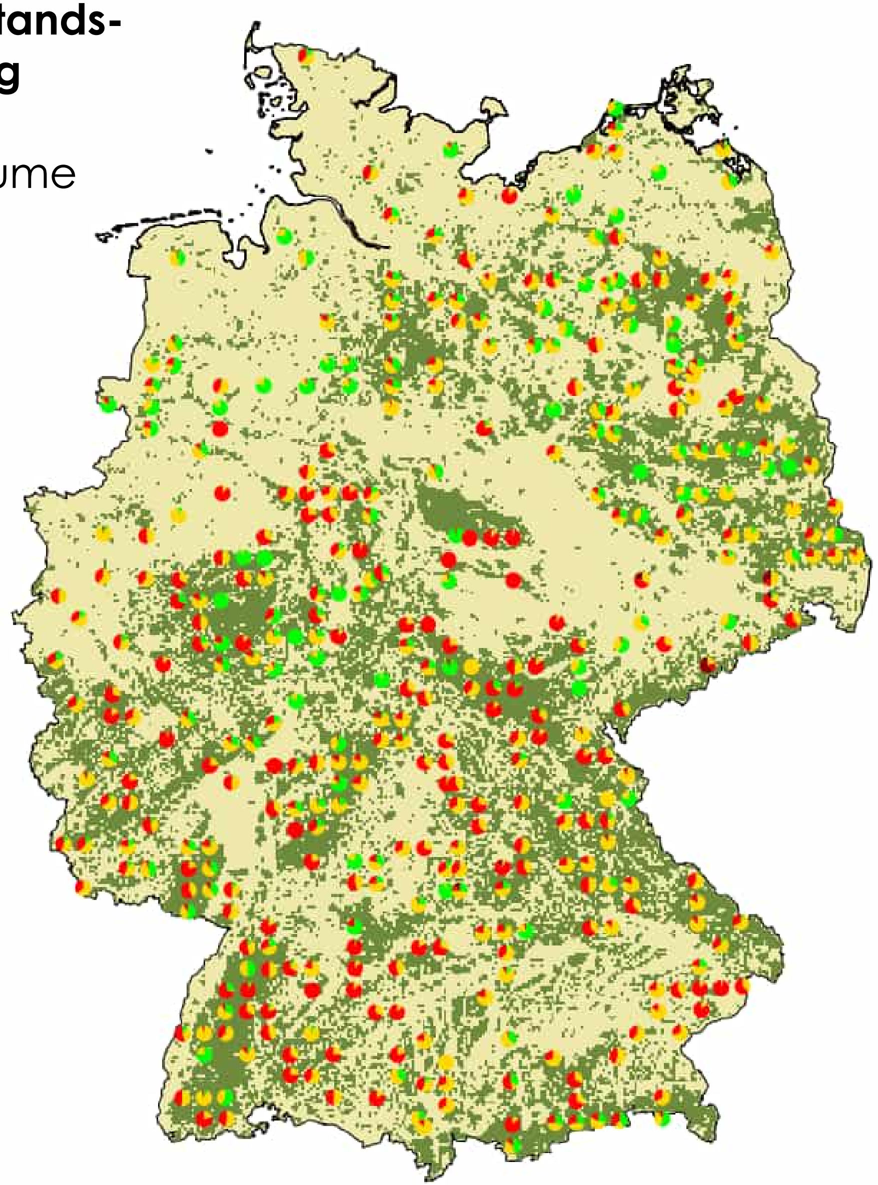
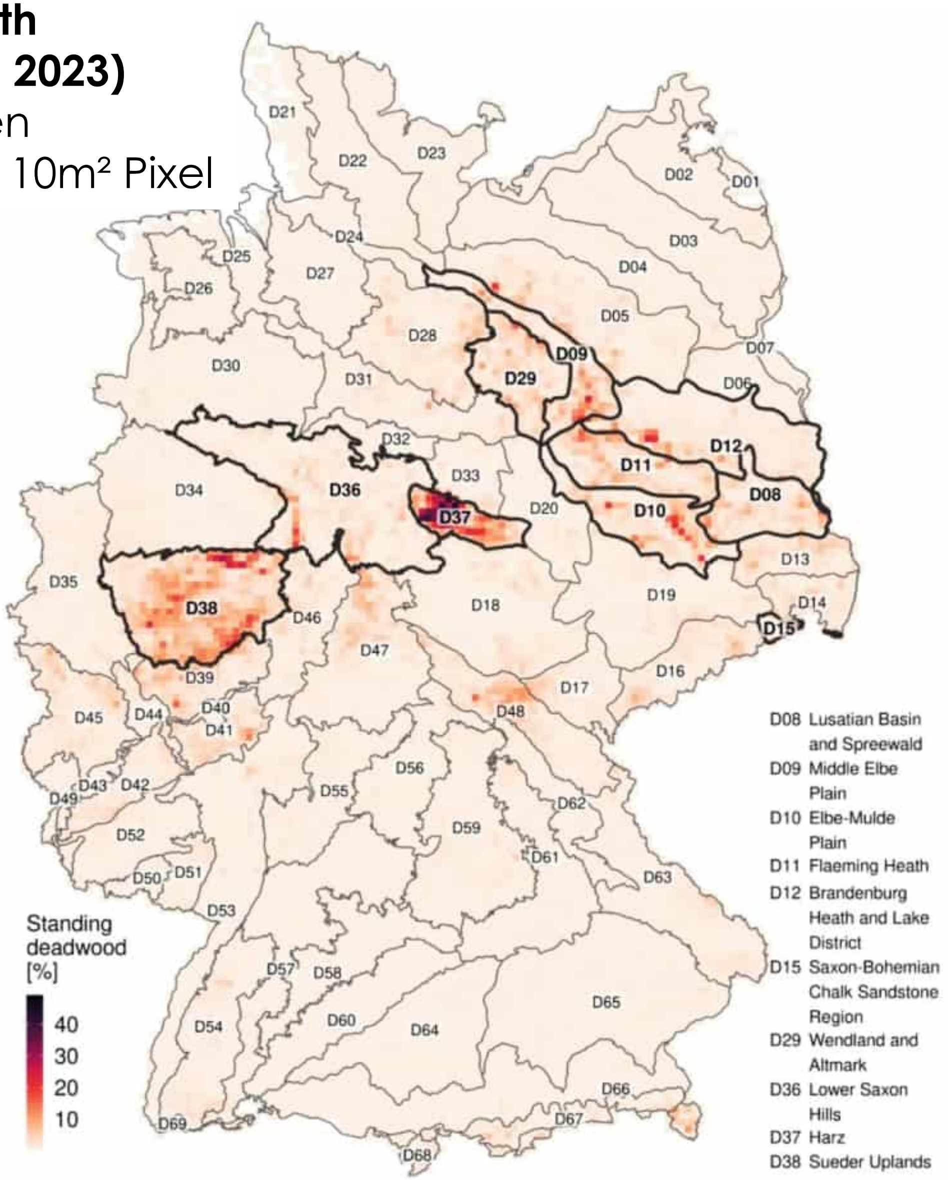


Waldzustandserhebung mit KI + Drohnen + Satelliten

**Waldzustands-
erfassung**
402 Plots
9688 Bäume

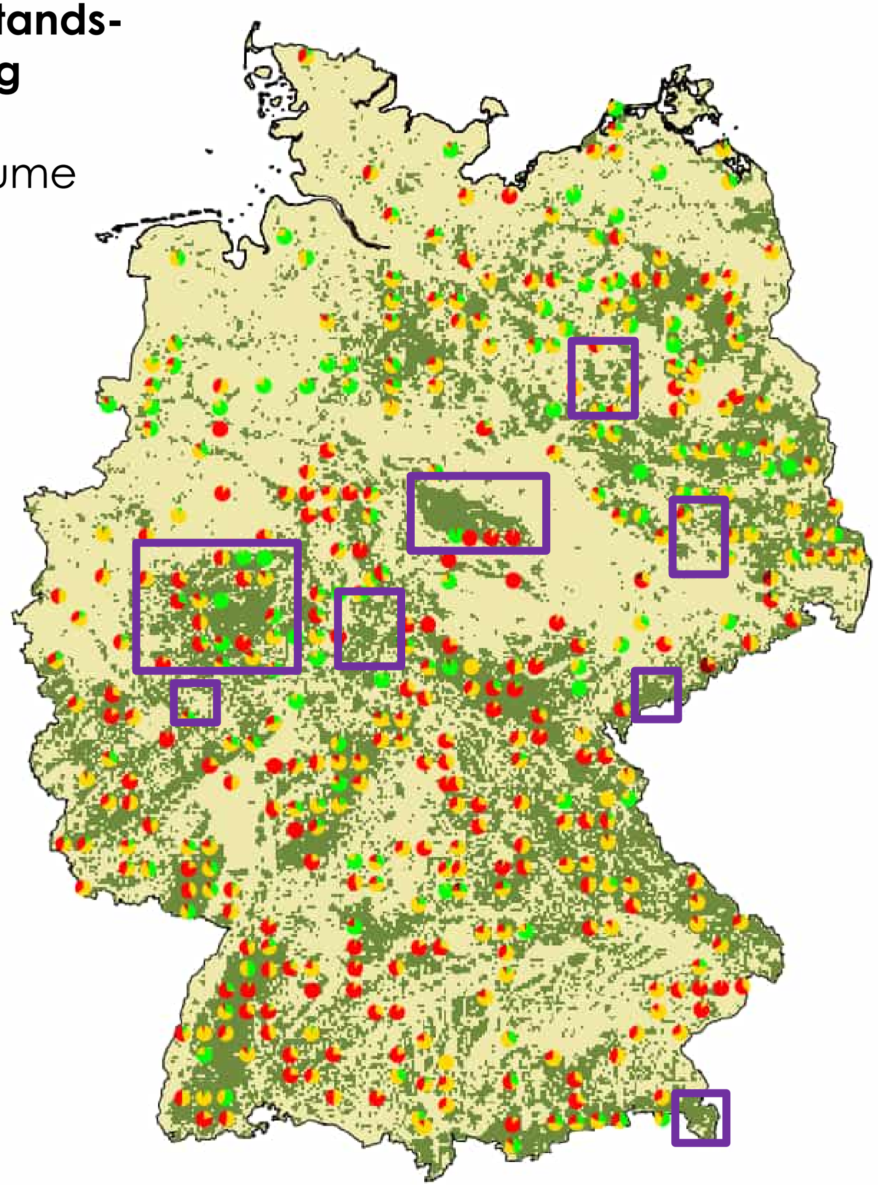


**Deadtrees.earth
(Schiefer et al. 2023)**
Flächendecken
1.14 Milliarden 10m² Pixel

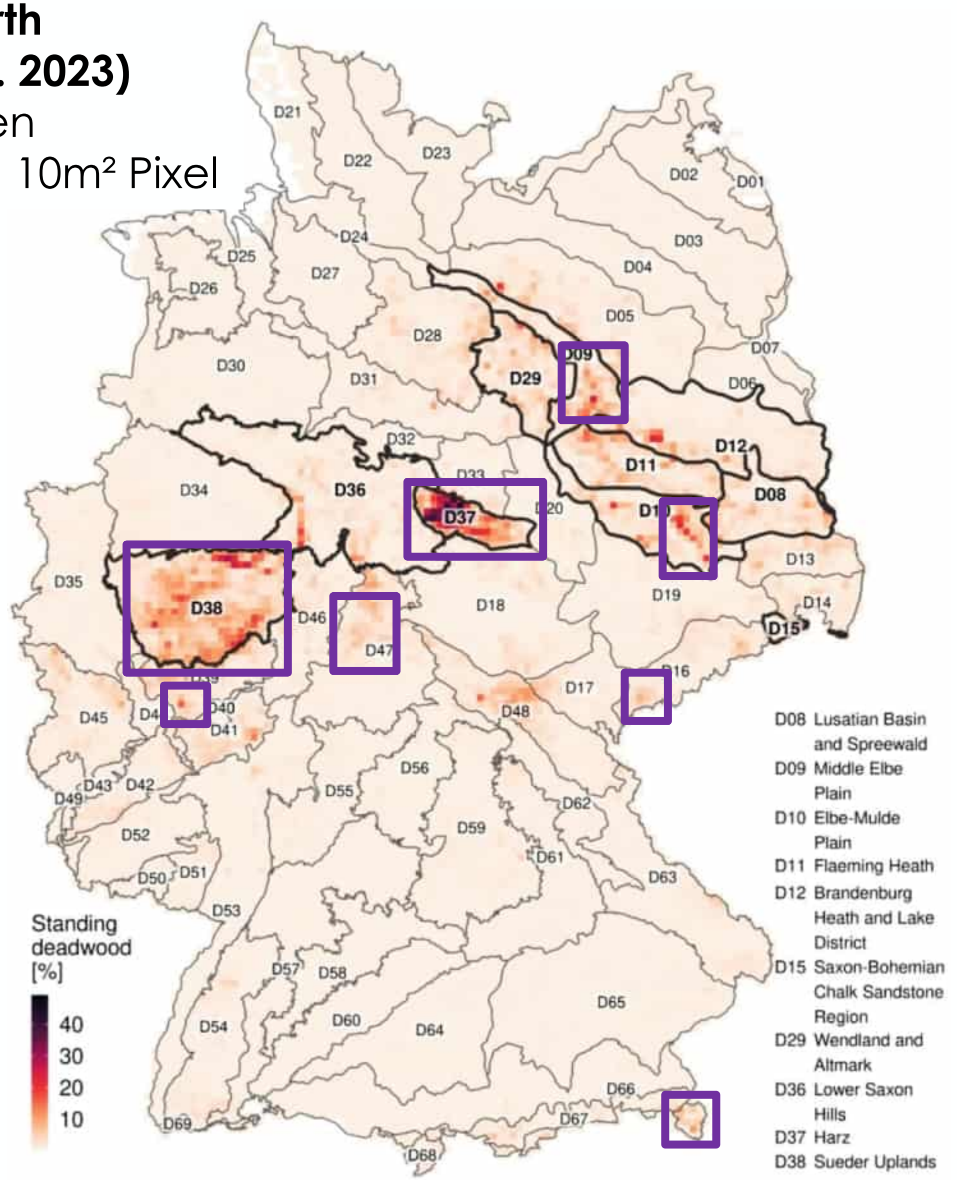


Waldzustandserhebung mit KI + Drohnen + Satelliten

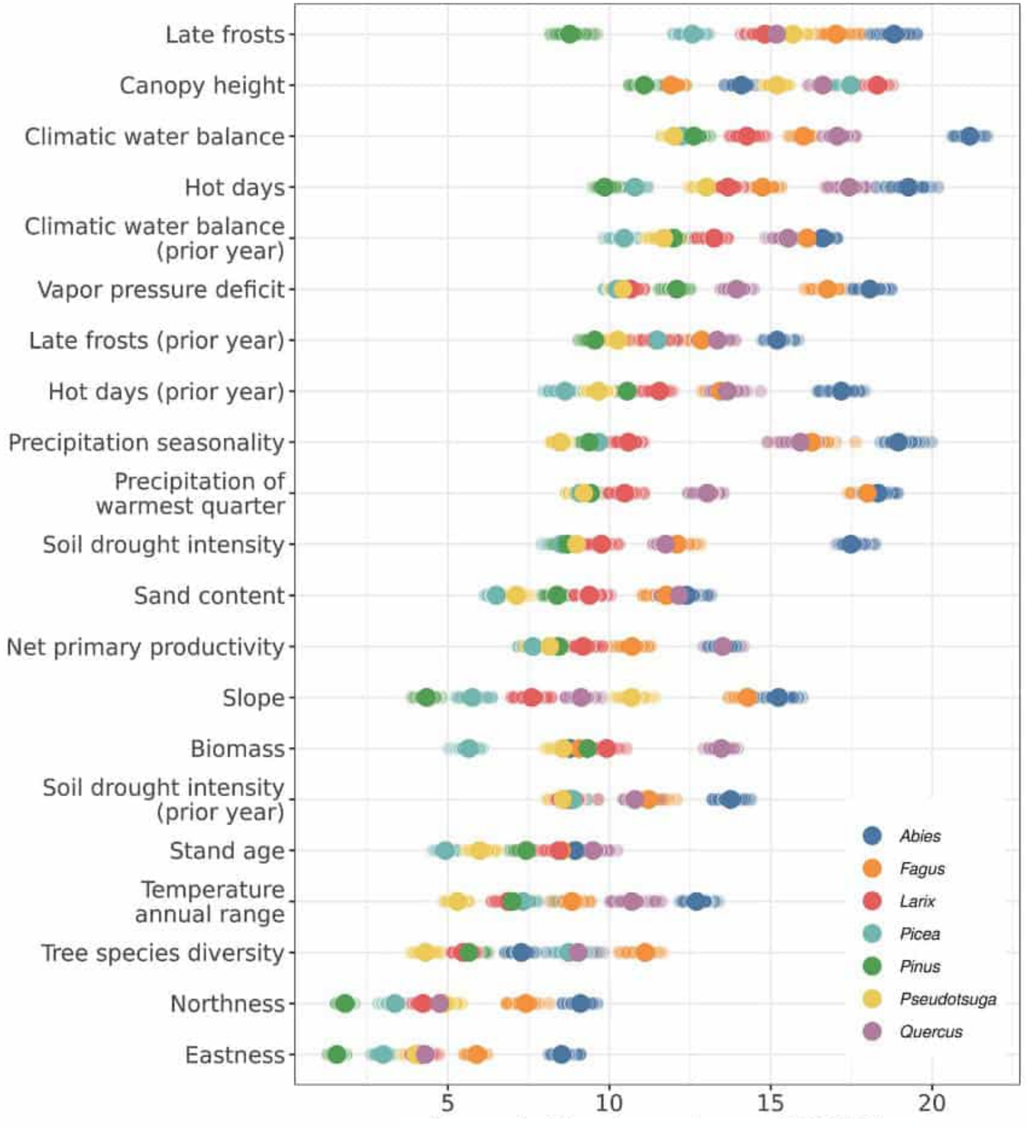
**Waldzustands-
erfassung**
402 Plots
9688 Bäume



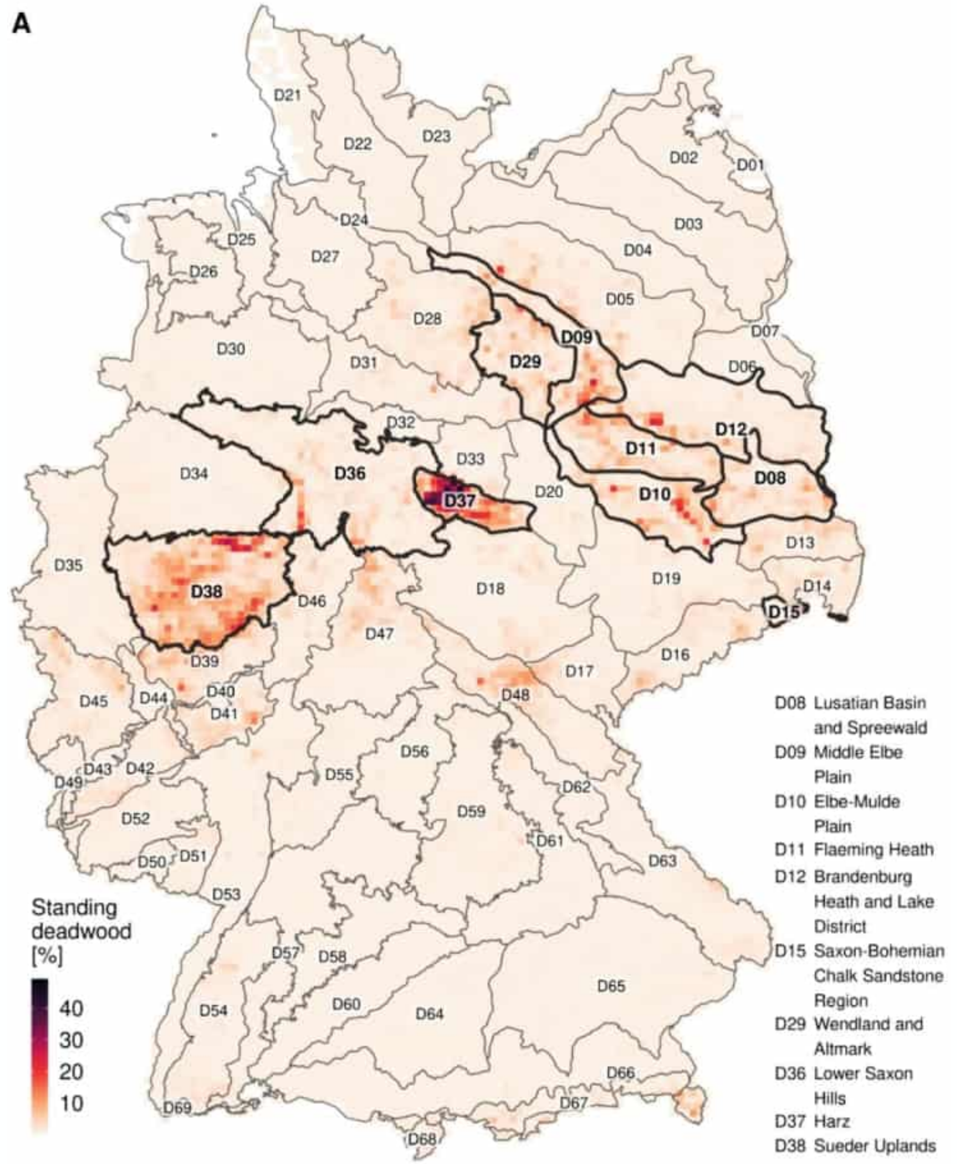
**Deadtrees.earth
(Schiefer et al. 2023)**
Flächendecken
1.14 Milliarden 10m² Pixel



Waldzustandserhebung mit KI + Drohnen + Satelliten



Variable importance [RMSE]



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An open database for accessing, contributing, analyzing, and visualizing remote sensing-based tree mortality data.

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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.

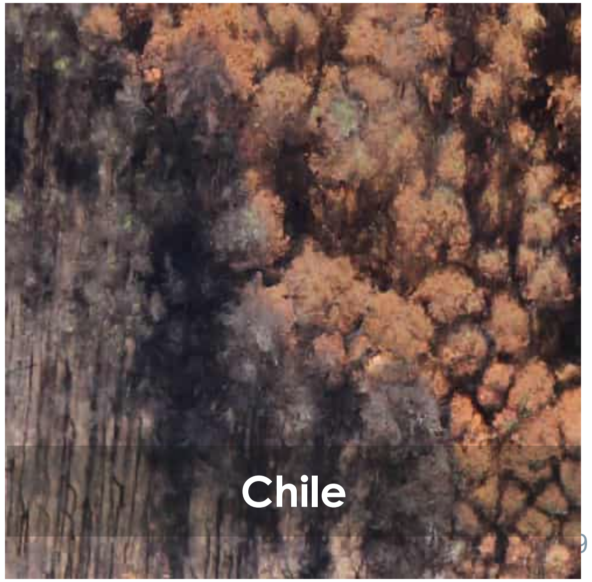
Large-scale tree mortality map

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.

Waldzustandserhebung mit KI + Drohnen + Satelliten



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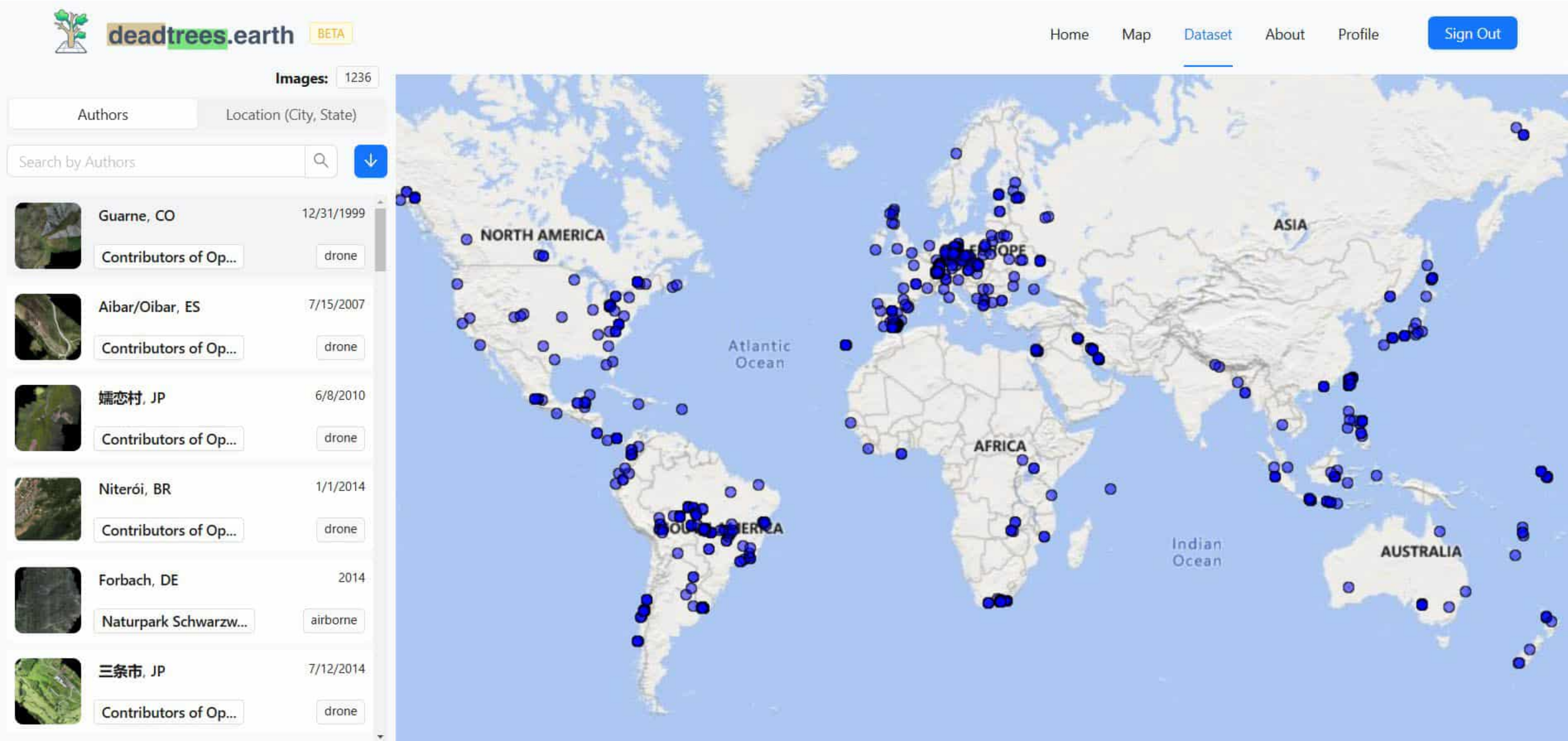

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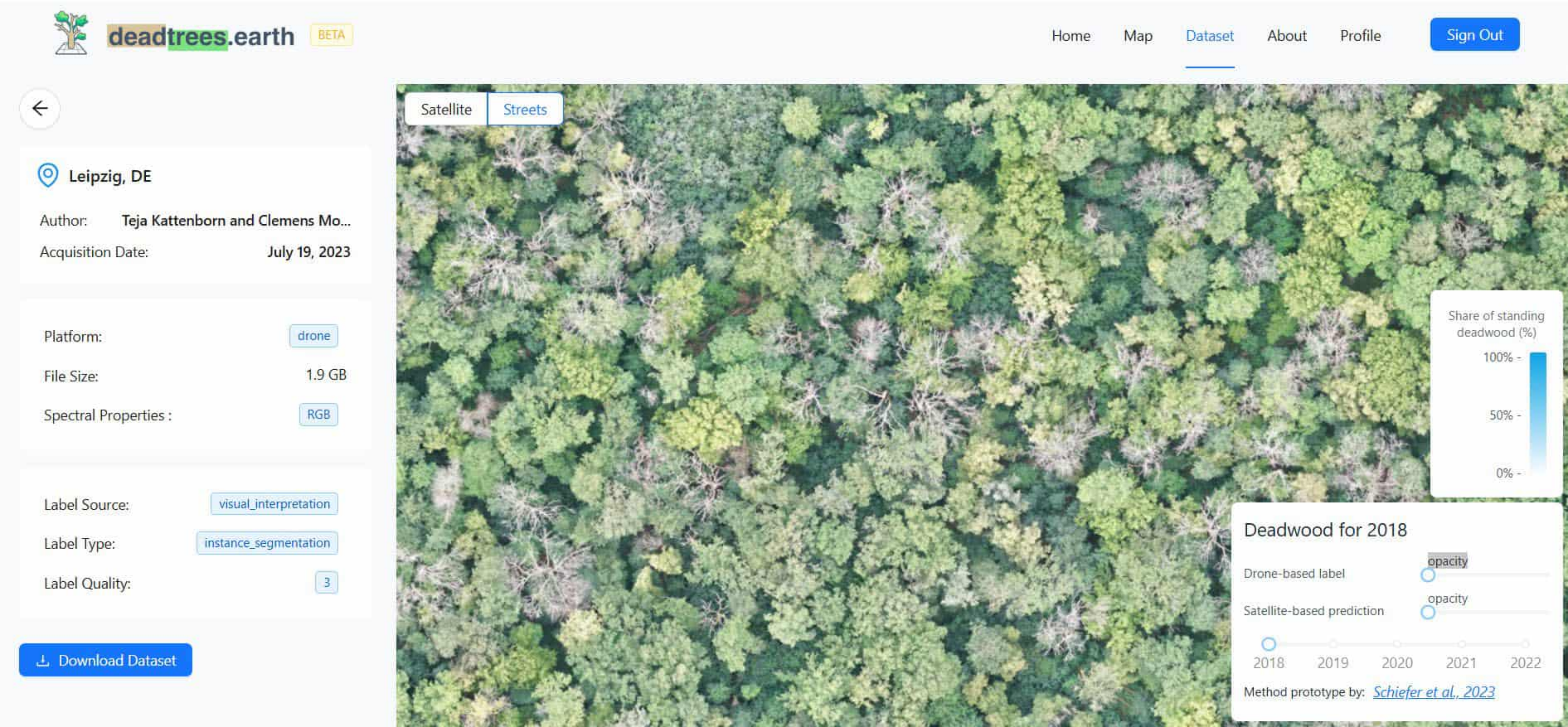

Waldzustandserhebung mit KI + Drohnen + Satelliten

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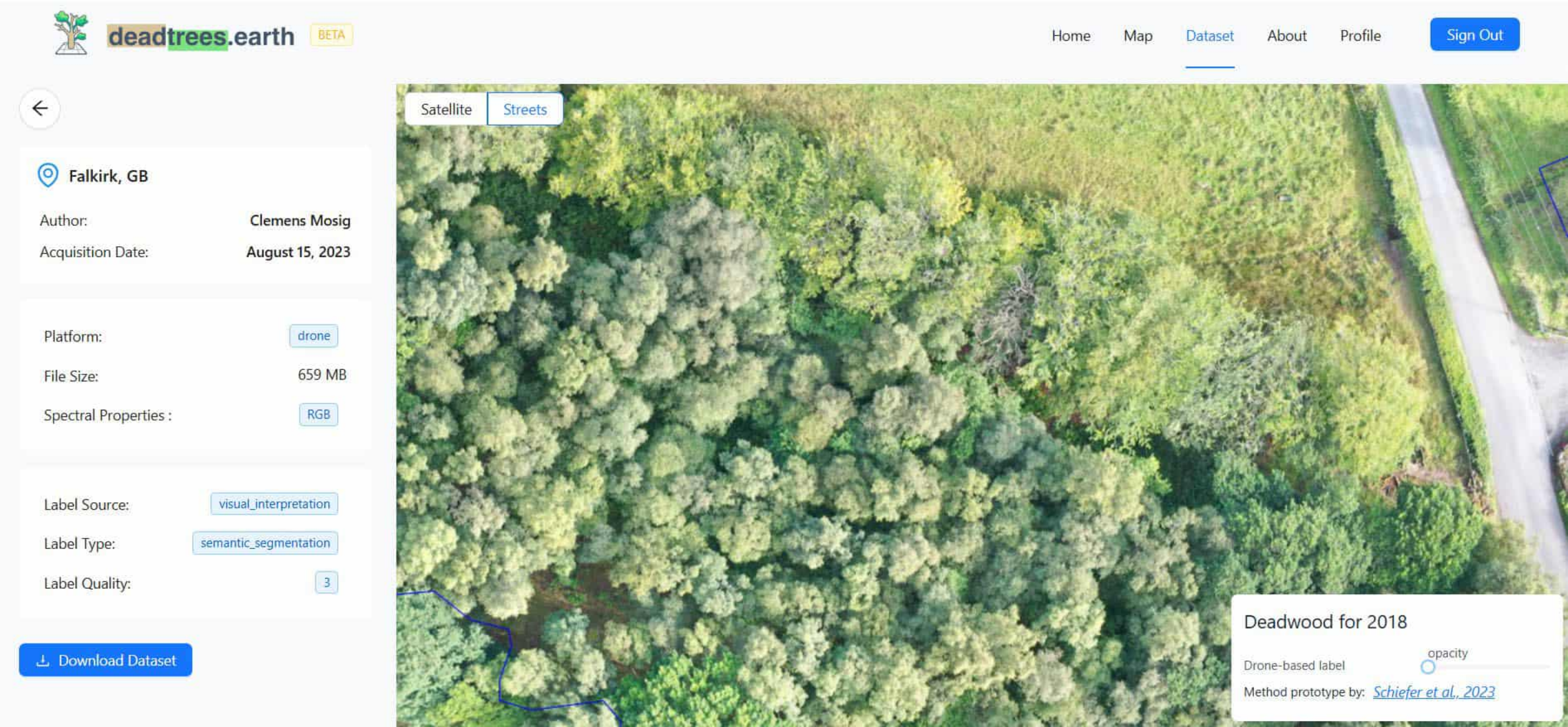

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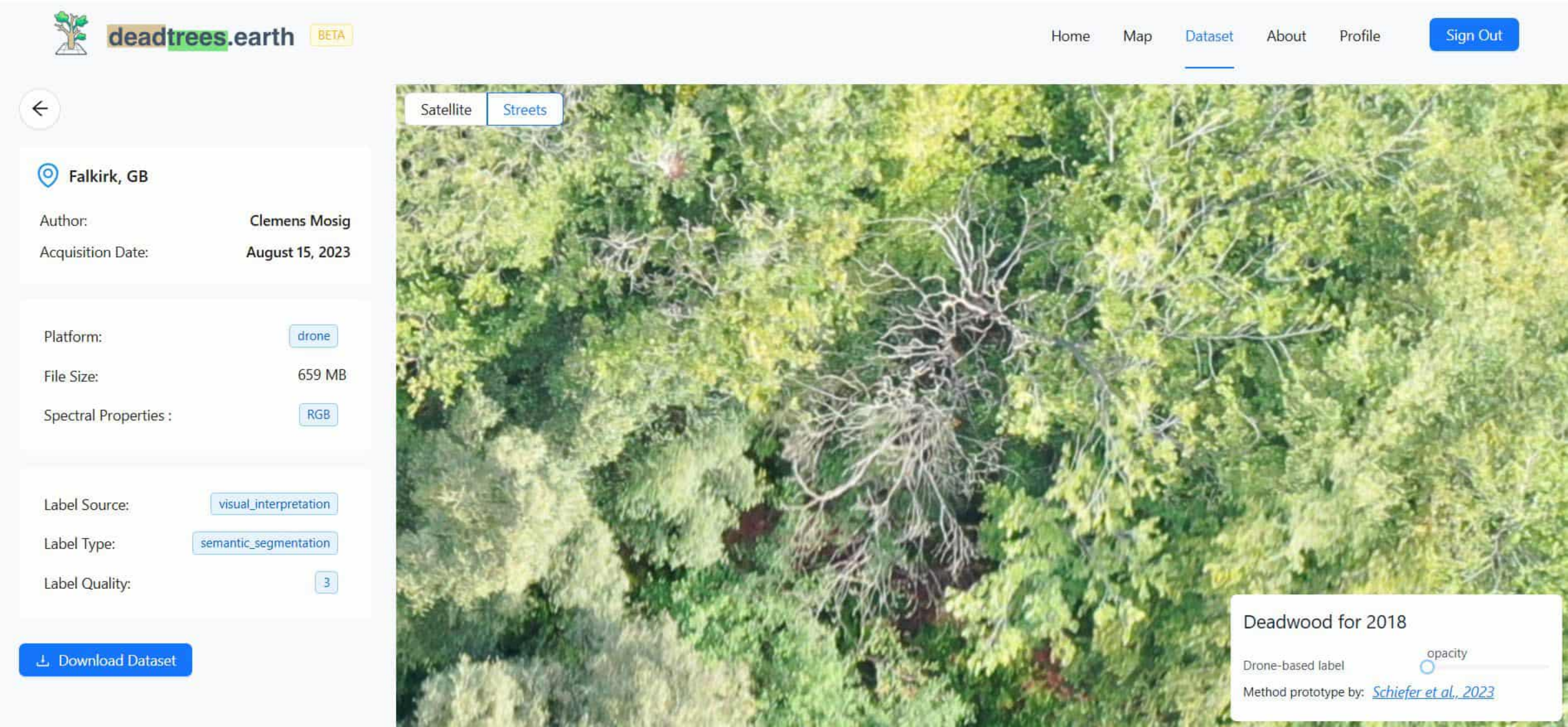

Waldzustandserhebung mit KI + Drohnen + Satelliten

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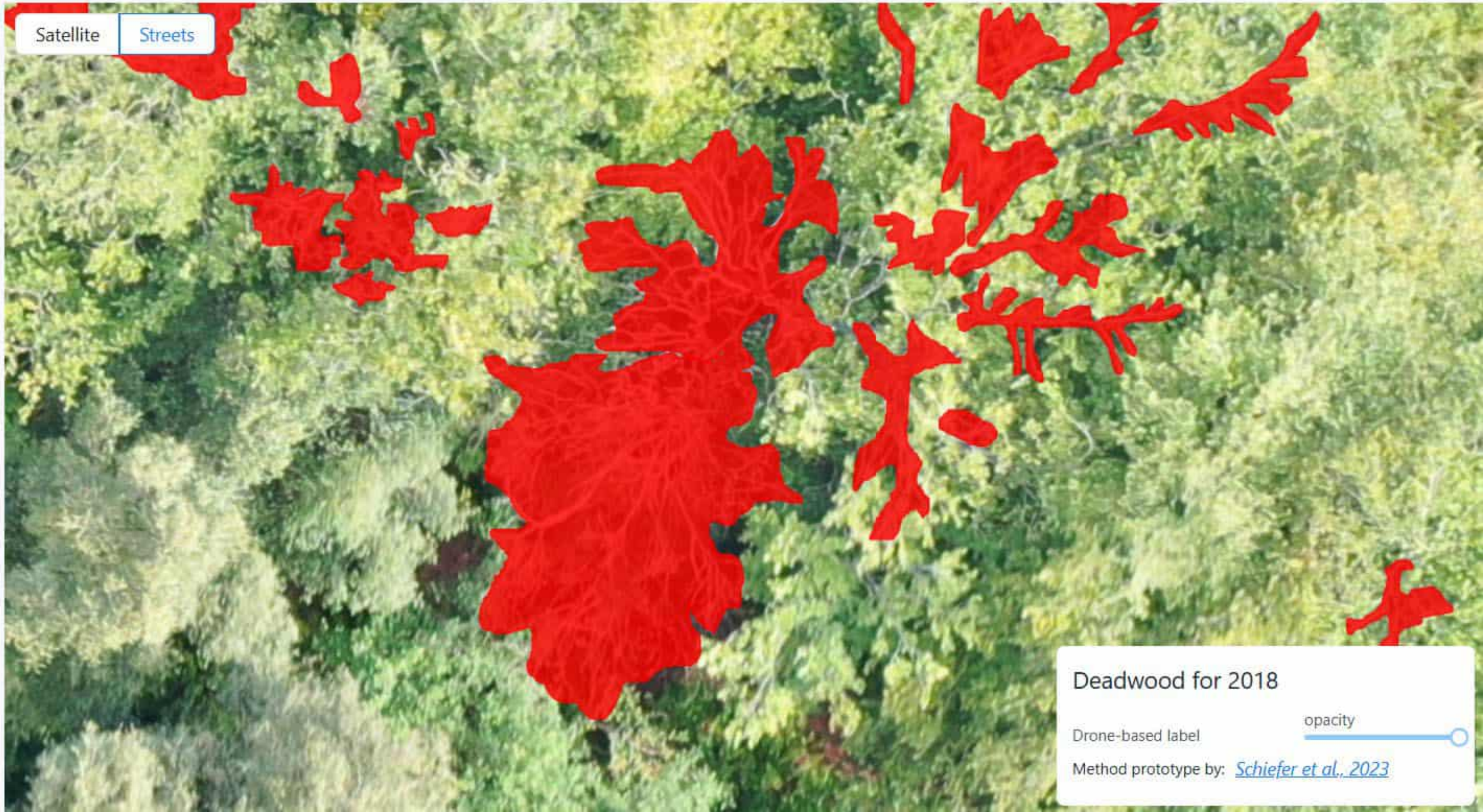
Falkirk, GB

Author:	Clemens Mosig
Acquisition Date:	August 15, 2023

Platform:	drone
File Size:	659 MB
Spectral Properties :	RGB

Label Source:	visual_interpretation
Label Type:	semantic_segmentation
Label Quality:	3

Download Dataset



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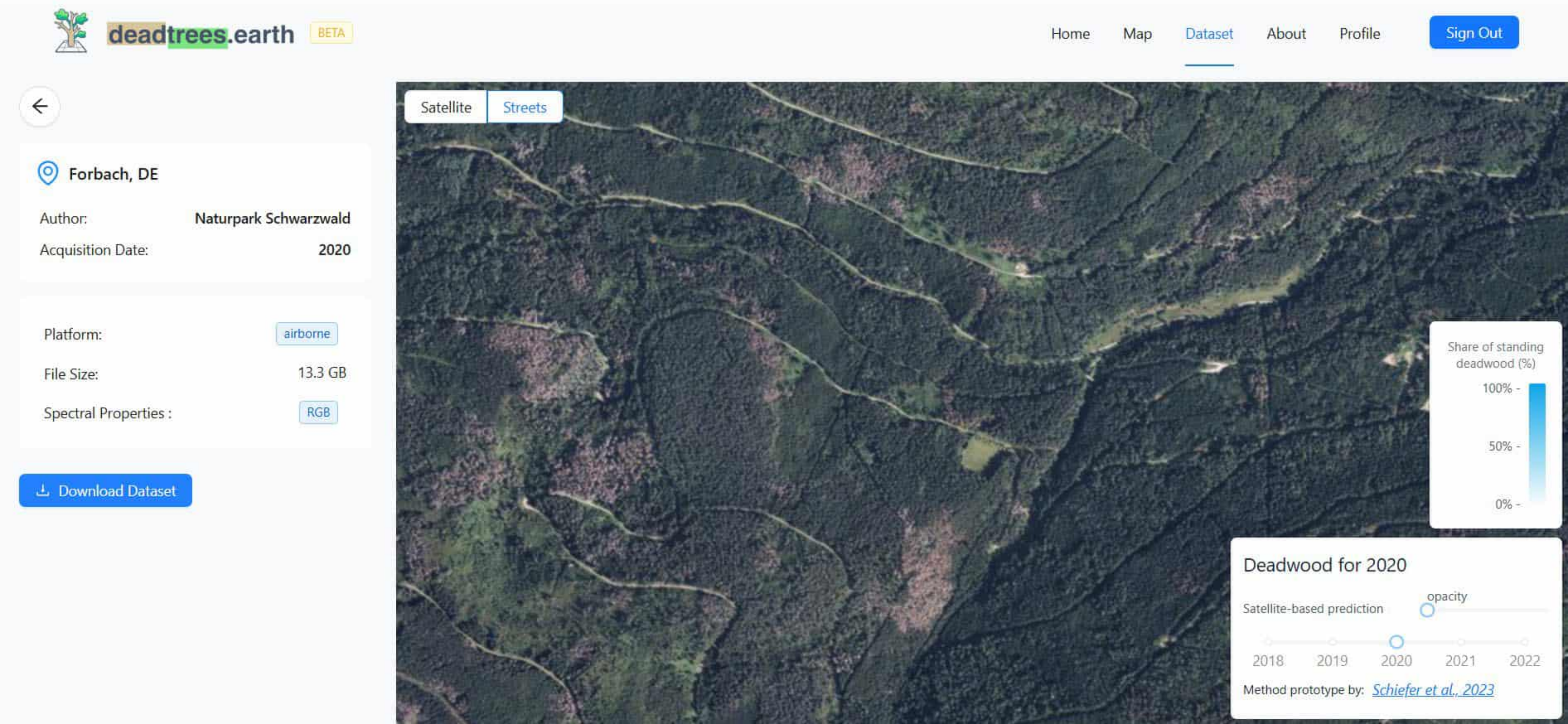

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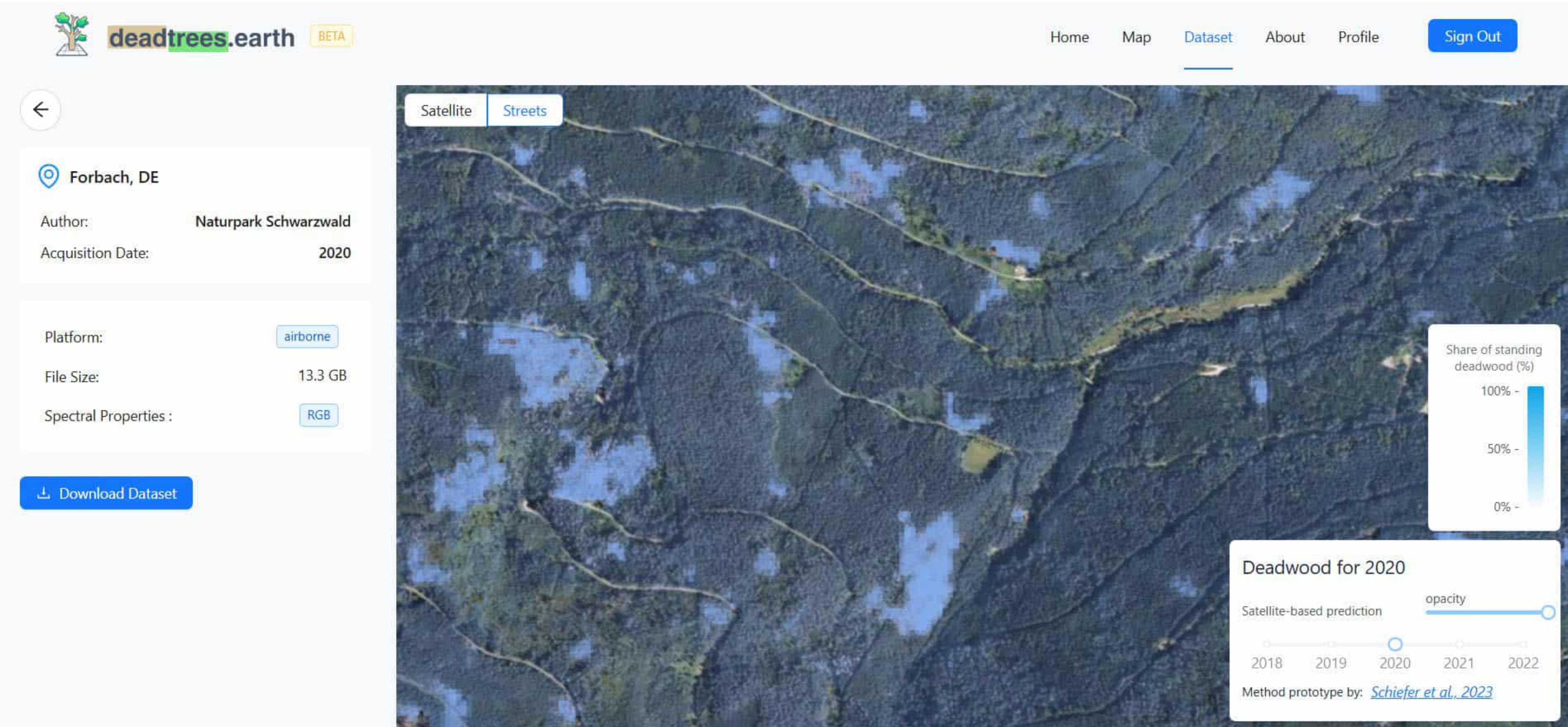

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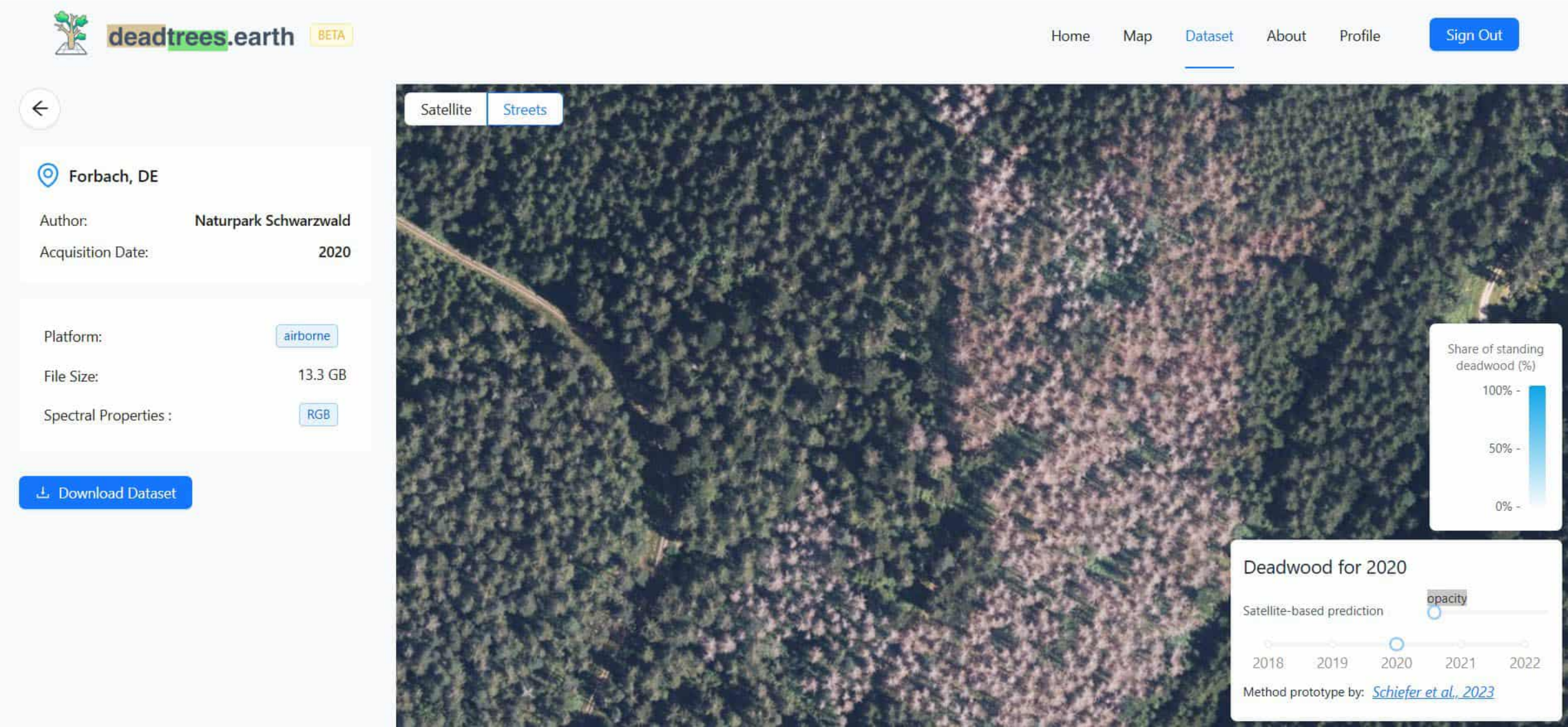

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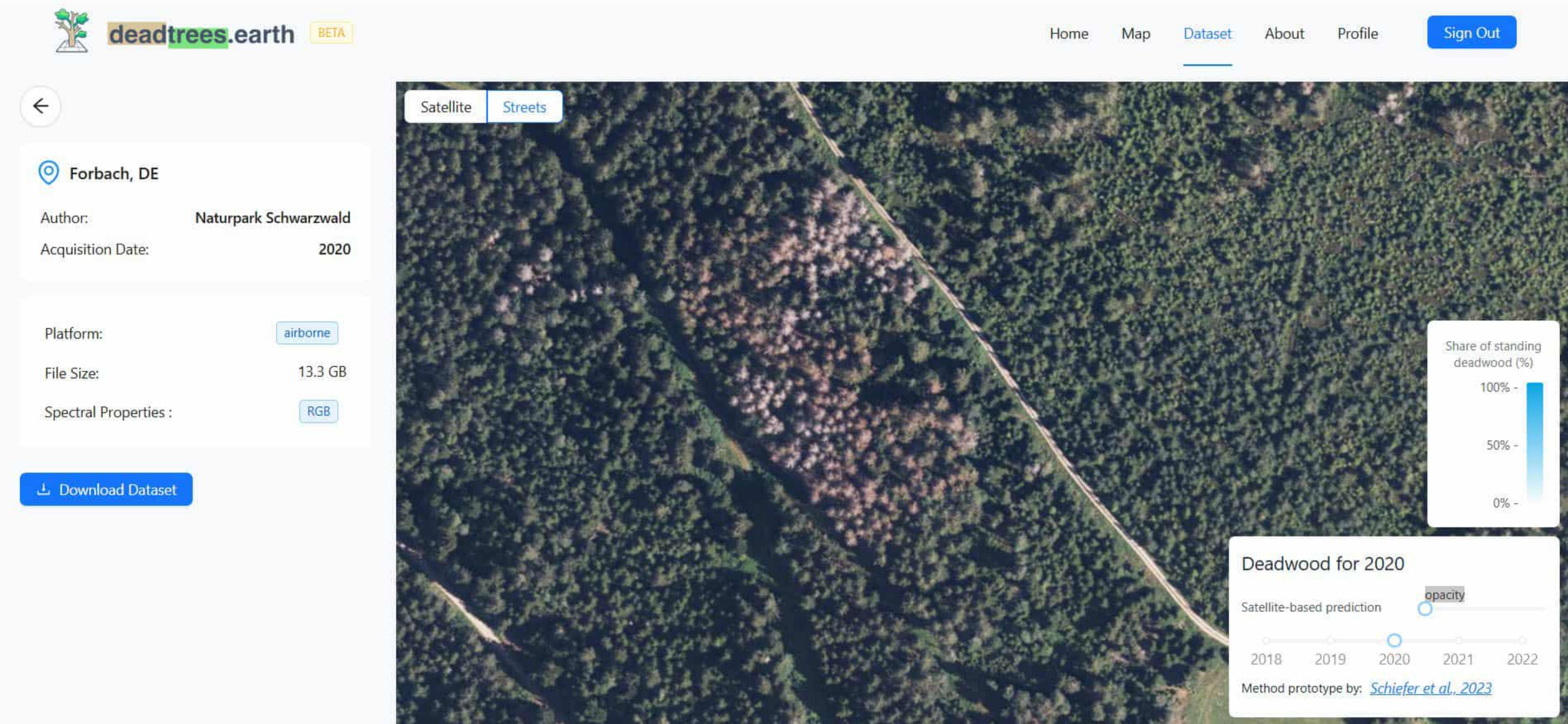

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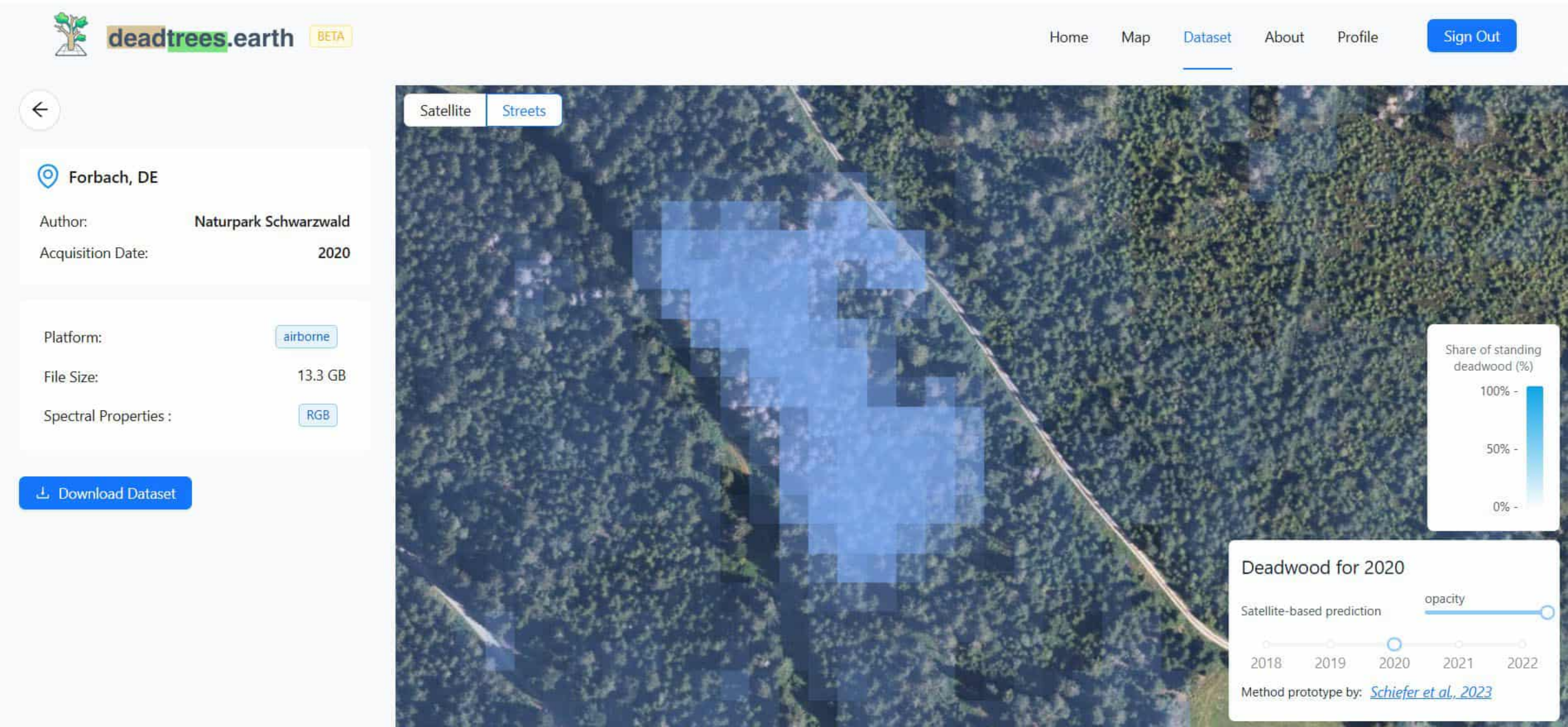

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