

ASSESSING RECENT FOREST STRUCTURE DYNAMICS IN GERMANY (2017-2022) BASED ON GEDI, SENTINEL-1 AND SENTINEL-2

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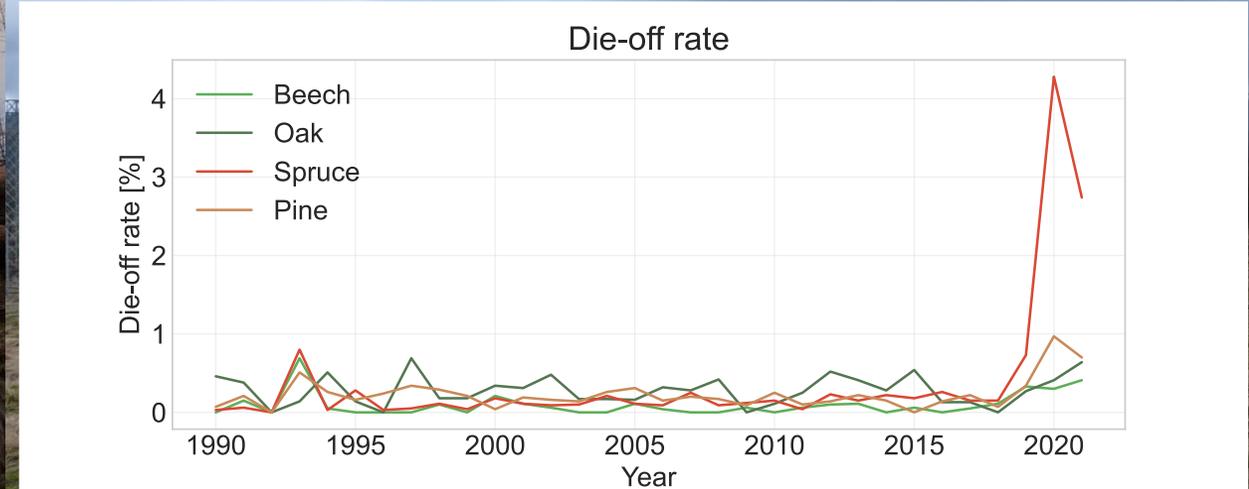
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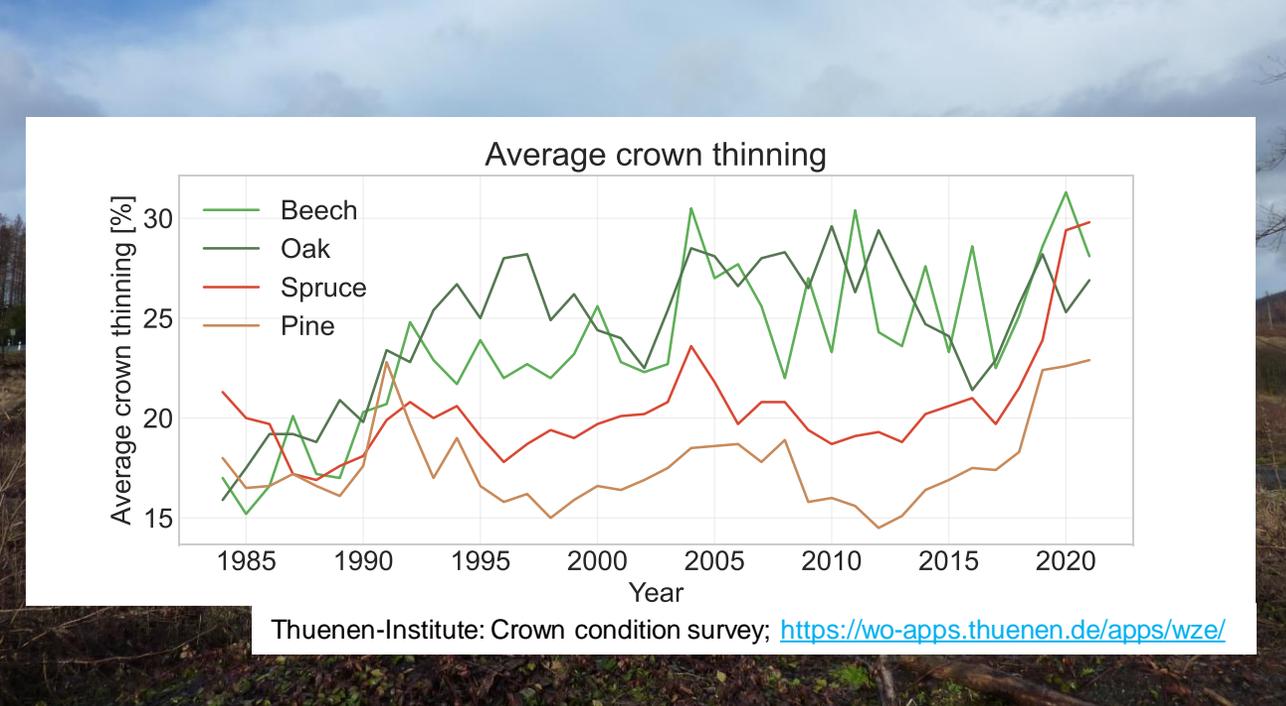




RECENT FOREST CONDITIONS IN GERMANY



Thuenen-Institute: Crown condition survey; <https://wo-apps.thuenen.de/apps/wze/>



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Fotos: P. Kacic



REMOTELY SENSED MONITORING OF FOREST CANOPY COVER LOSS

2018



10 km

Thonfeld et al. 2022

2021

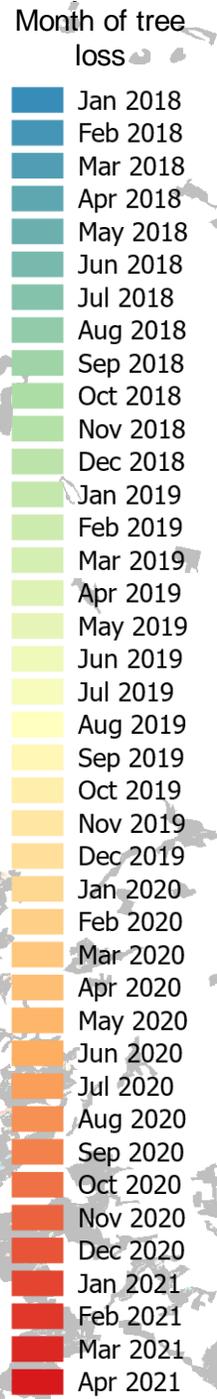


10 km

Thonfeld et al. 2022

2021

Forest canopy cover loss of **5 010 km²**
(01/2018 to 04/2021)
→ About **5 %** of the total forest area
in **Germany**



10 km

Thonfeld et al. 2022

MULTI-TEMPORAL ANALYSIS OF FOREST STRUCTURE DYNAMICS

Forest Structure Characterization in Germany – Methodology



Article

Forest Structure Characterization in Germany: Novel Products and Analysis Based on GEDI, Sentinel-1 and Sentinel-2 Data

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Abstract: Monitoring forest conditions is an essential task in the context of global climate change to preserve biodiversity, protect carbon sinks and foster future forest resilience. Severe impacts of heatwaves and droughts triggering cascading effects such as insect infestation are challenging the semi-natural forests in Germany. As a consequence of repeated drought years since 2018, large-scale canopy cover loss has occurred calling for an improved disturbance monitoring and assessment of forest structure conditions. The present study demonstrates the potential of complementary remote sensing sensors to generate wall-to-wall products of forest structure for Germany. The combination of high spatial and temporal resolution imagery from Sentinel-1 (Synthetic Aperture Radar, SAR) and Sentinel-2 (multispectral) with novel samples on forest structure from the Global Ecosystem Dynamics Investigation (GEDI, LiDAR, Light detection and ranging) enables the analysis of forest structure dynamics. Modeling the three-dimensional structure of forests from GEDI samples in machine learning models reveals the recent changes in German forests due to disturbances (e.g., canopy cover degradation, salvage logging). This first consistent data set on forest structure for Germany from 2017 to 2022 provides information of forest canopy height, forest canopy cover and forest biomass and allows estimating recent forest conditions at 10 m spatial resolution. The wall-to-wall maps of the forest structure support a better understanding of post-disturbance forest structure and forest resilience.

Keywords: forest; forest structure Germany; canopy height; Global Ecosystem Dynamics Investigation; GEDI; Sentinel-1; Sentinel-2; random forest regression



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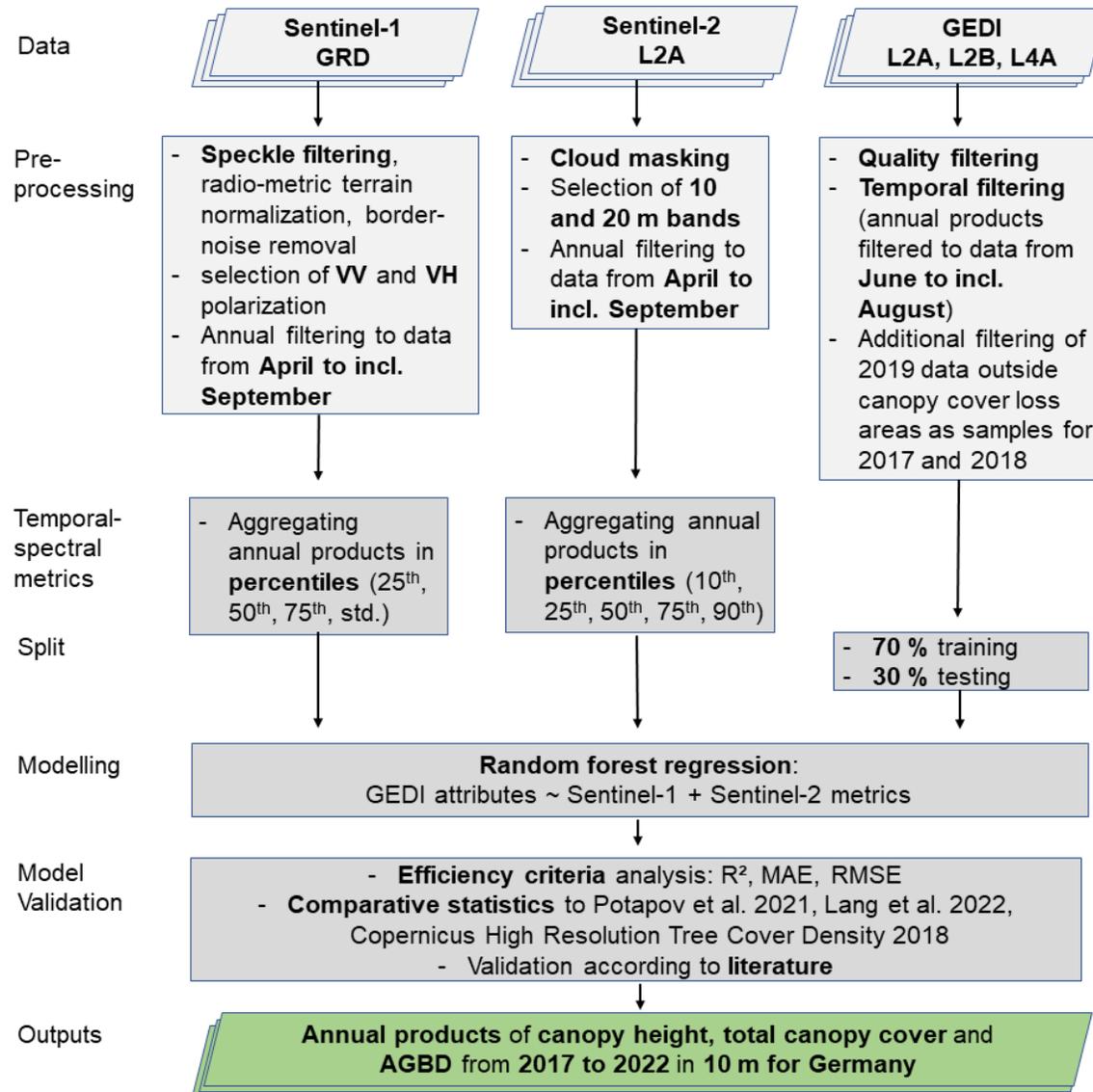
Combination of complementary sensors:



<https://daac-news.ornl.gov/content/moving-version-2-gedi-data-products>, <https://www.esa.int/eologos/>

Quantitative assessment of forest canopy height, total canopy cover, AGBD from 2017 to 2022 in 10 m spatial resolution

Forest Structure Characterization in Germany – Methodology



Combination of **complementary sensors:**



<https://daac-news.ornl.gov/content/moving-version-2-gedi-data-products>, <https://www.esa.int/eologos/>

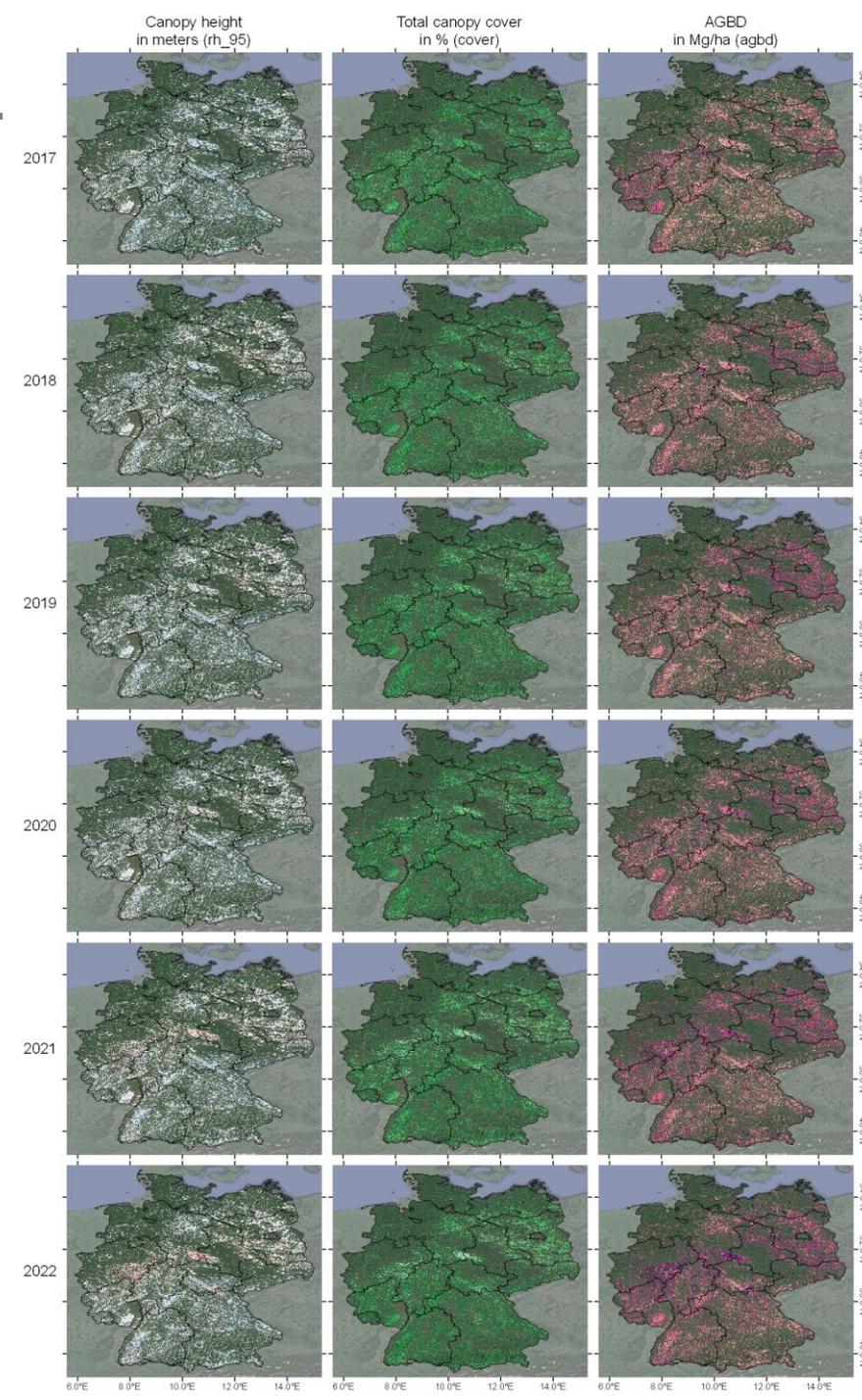
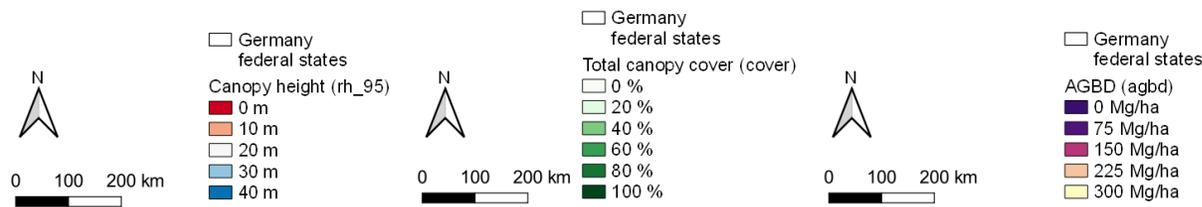
Quantitative assessment of forest canopy height, total canopy cover, AGBD from 2017 to 2022 in 10 m spatial resolution

Forest Structure Characterization in Germany – Model Accuracy

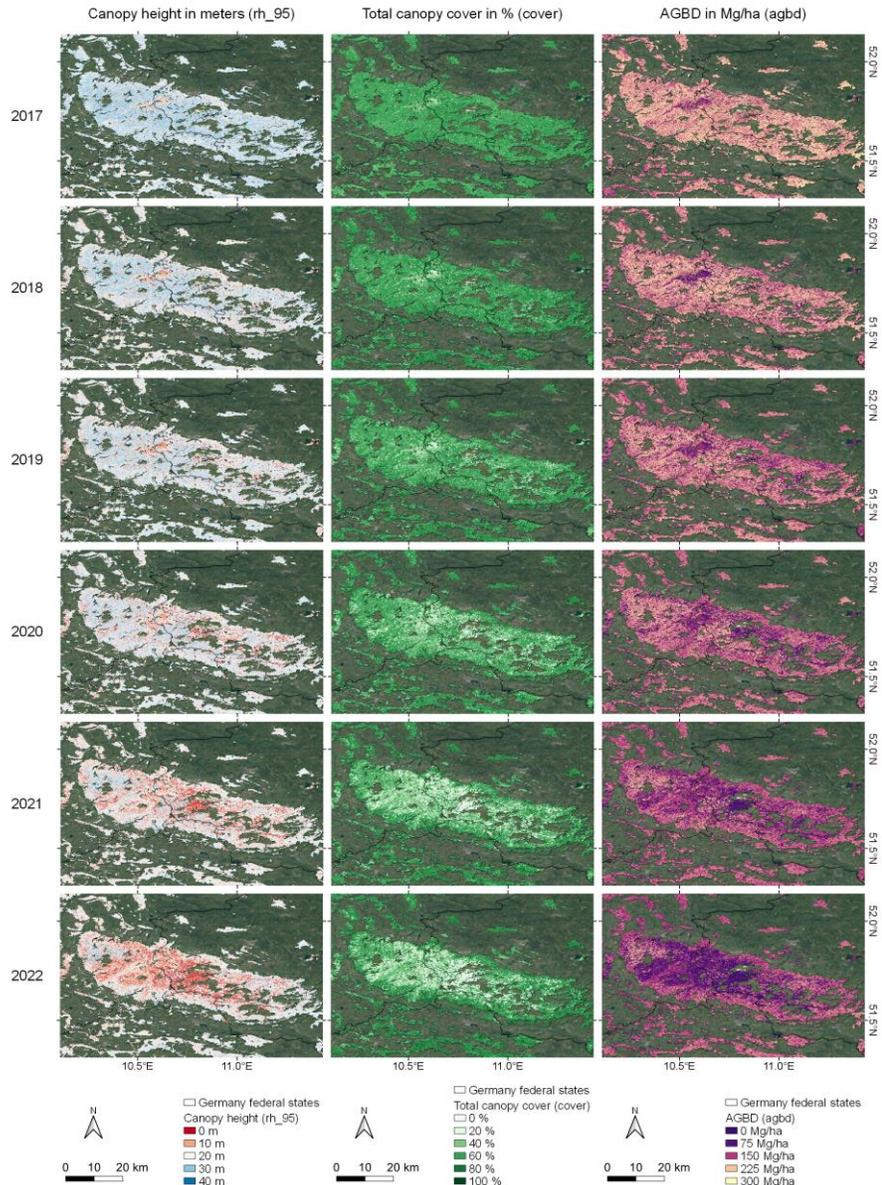
Mean Statistics of all years:

R^2 =coefficient of determination, MAE=Mean Absolute Error

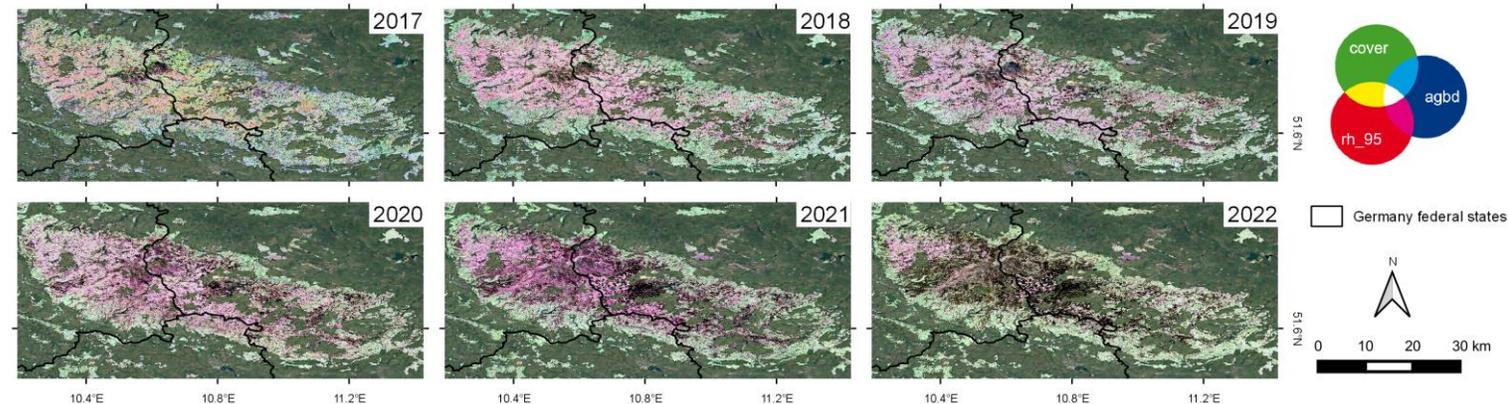
Canopy height:	64.6 % (R^2)	4.4 m (MAE)
Total canopy cover:	67.0 % (R^2)	12.5 % (MAE)
AGBD:	58.8 % (R^2)	41.0 Mg/ha (MAE)



Forest Structure Characterization in Germany – Results Harz region



- **Major losses** in all attributes of forest structure since 2017
- Disturbance hotspots are **spruce mono-cultures**
- **Asynchronous temporal dynamics** in forest structure decline
 - **Canopy cover loss** followed by **reduction in canopy height** → drought-affected stands → **salvage-logging**



Forest Structure Characterization in Germany – Windthrow in Hesse (January 2018)



Classification of **three disturbance classes** according to data from Copernicus EMS



SUMMARY & OUTLOOK

Summary and Outlook

- **Recent forest structure dynamics** can be accurately characterized by fusion products of GEDI, Sentinel-1 and Sentinel-2

→ **Declining forest structure** in the context of recent multiple **drought** years

- Different **post-disturbance structures** after a windthrow-event can be identified

→ **Standing deadwood** as an important structure promoting biodiversity



Next steps:

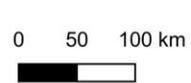
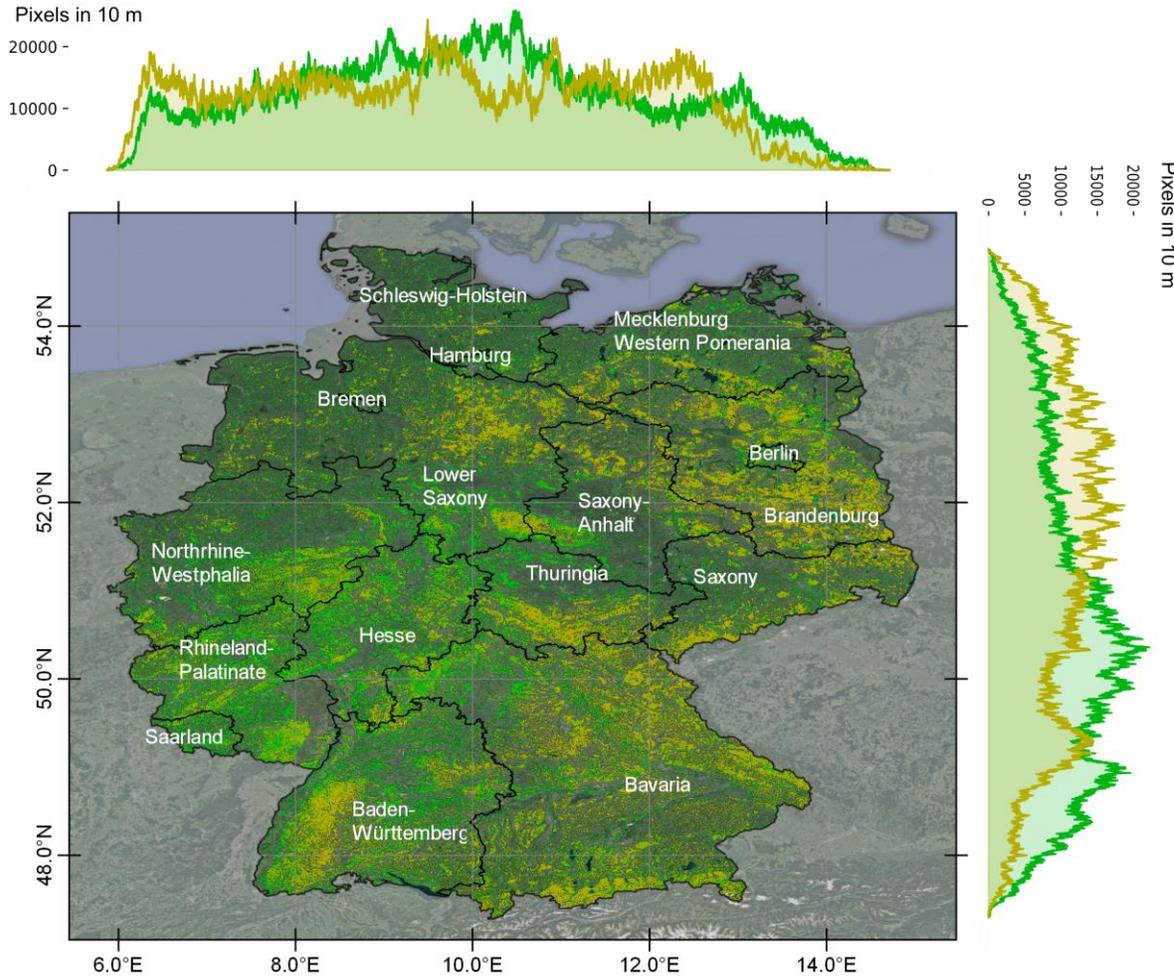
- **Validation** based on ALS data
- **Post-disturbance characterization** of different structures:
 - windthrow, fire, clear-cut, standing deadwood



APPENDIX

Forests in Germany

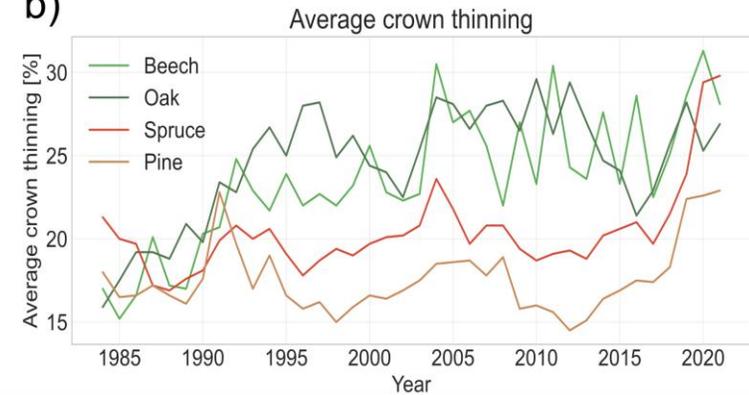
a)



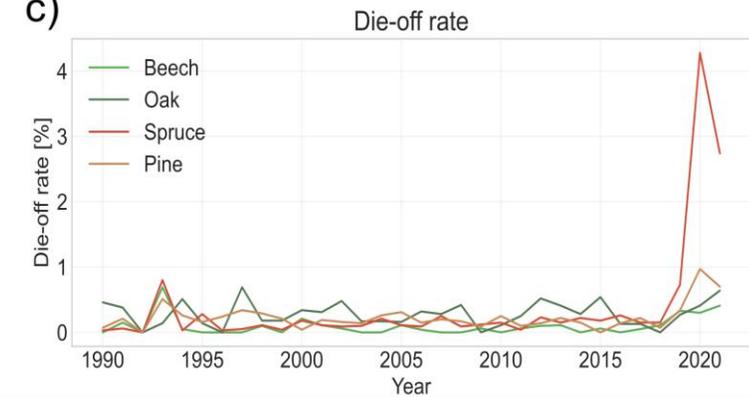
Background: Google Satellite imagery with federal states of Germany.

Copernicus HRL DLT
■ Deciduous Forest
■ Coniferous Forest

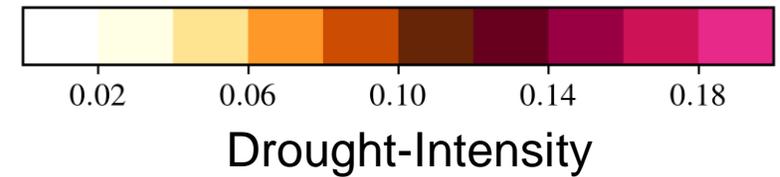
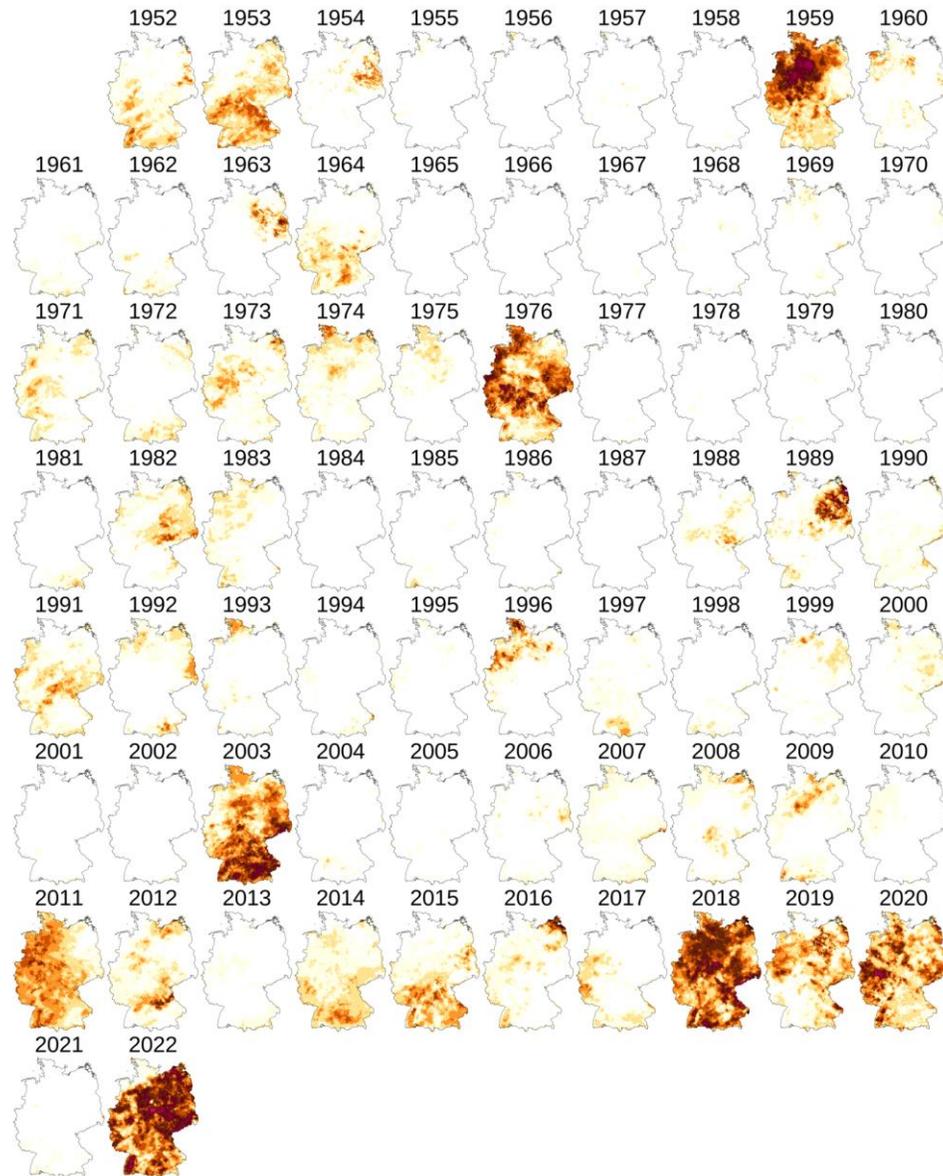
b)



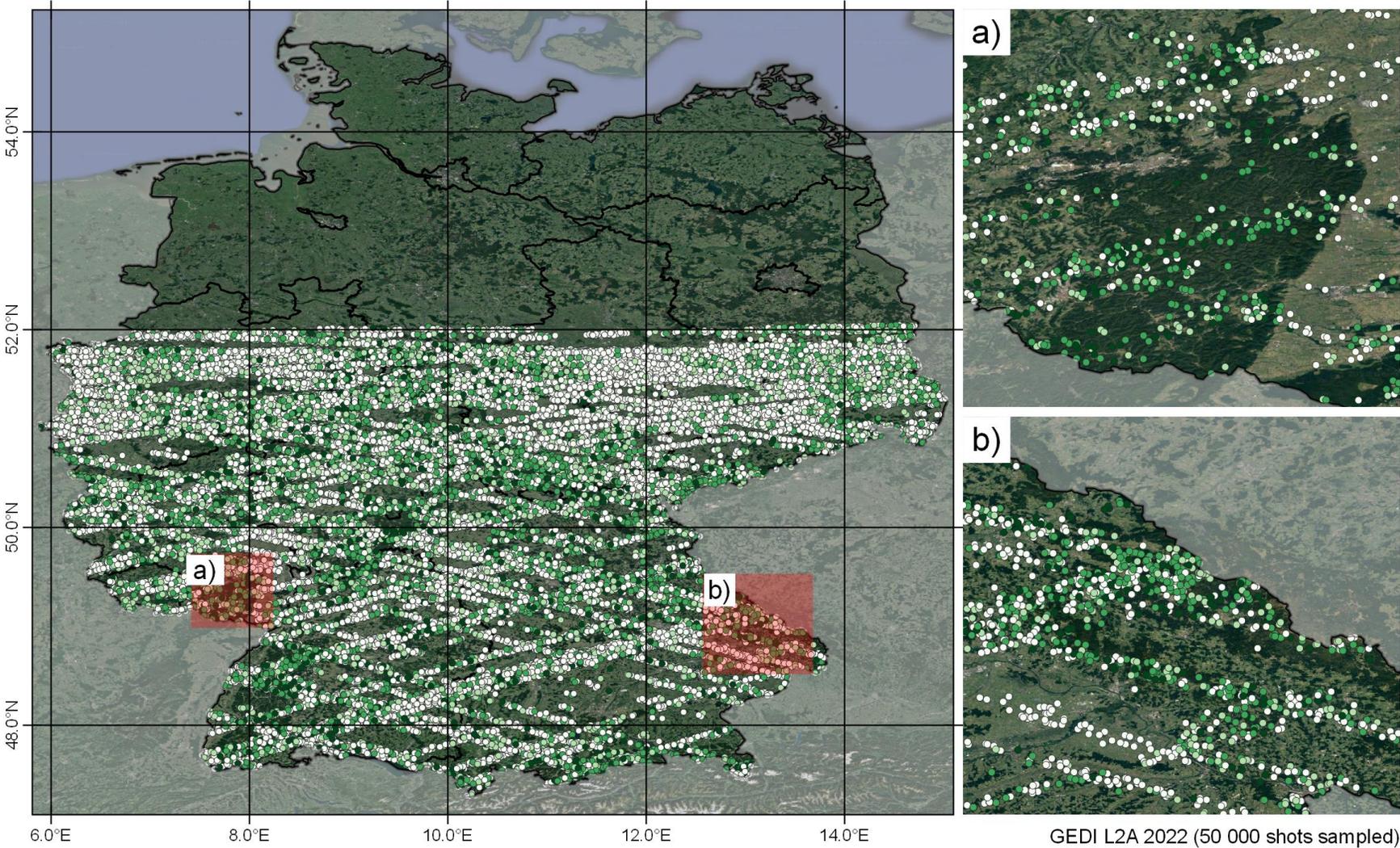
c)



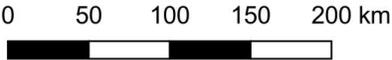
Drought-Intensity in Germany (UFZ Drought-Monitor)



GEDI Data for Germany



Background: Google Earth Satellite Imagery with Germany federal states boundary in EPSG:4326.

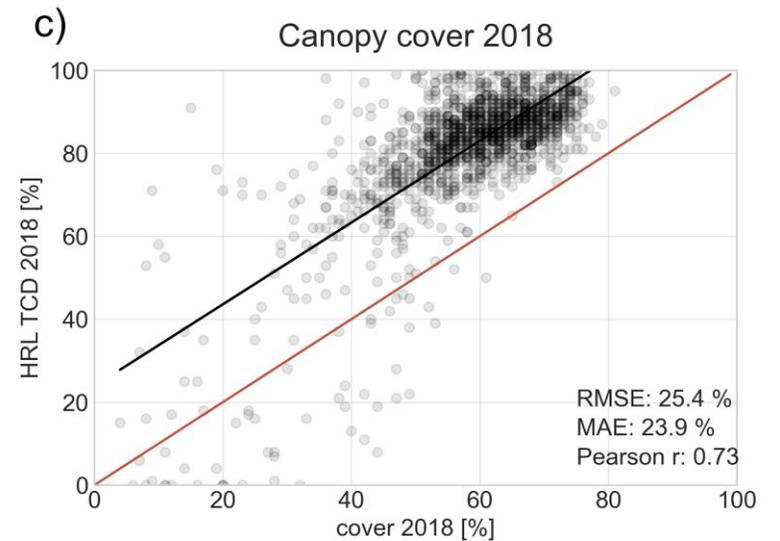
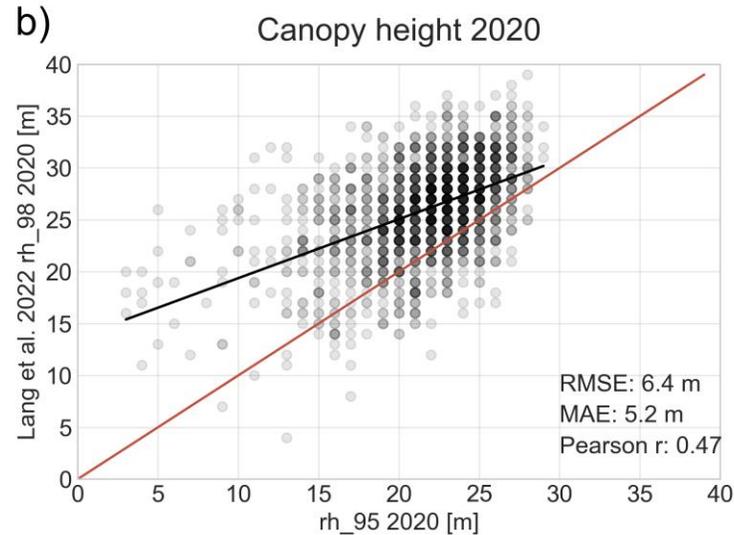
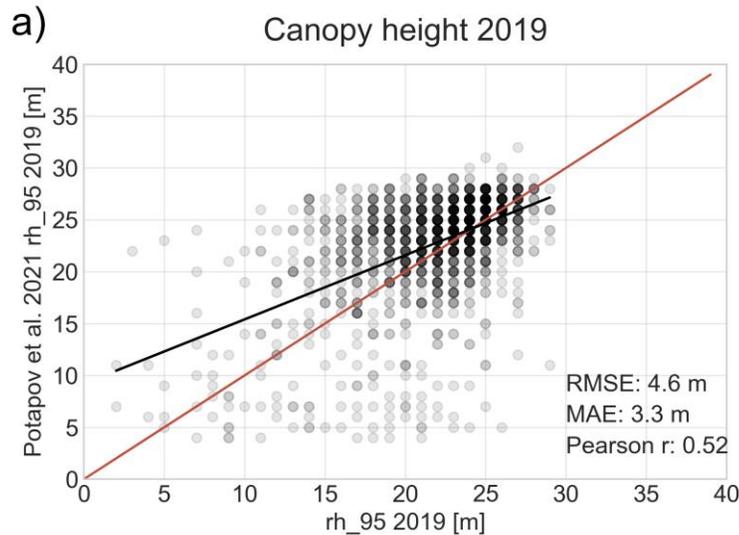


- GEDI L2A 2022 (50 000 shots sampled)
- < 10 m
 - 10 - 20 m
 - 20 - 30 m
 - > 30 m

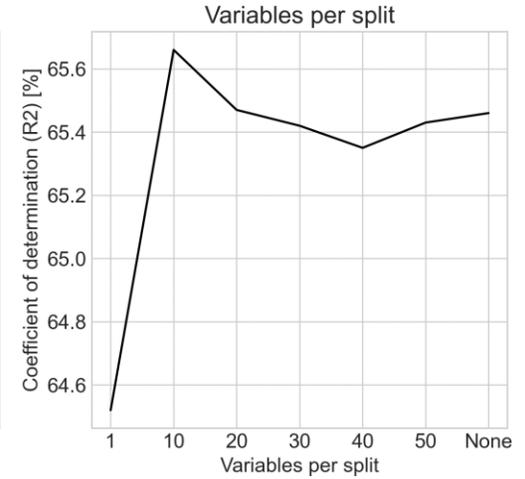
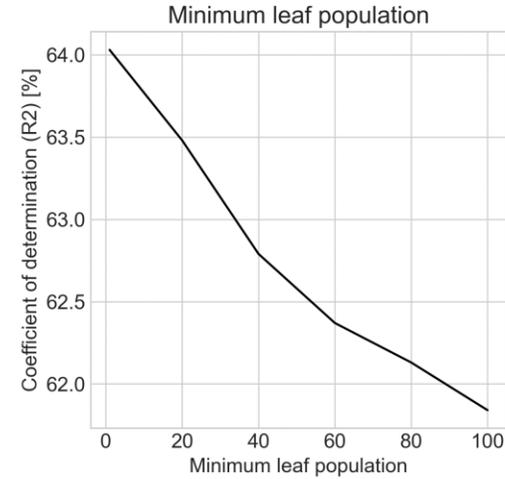
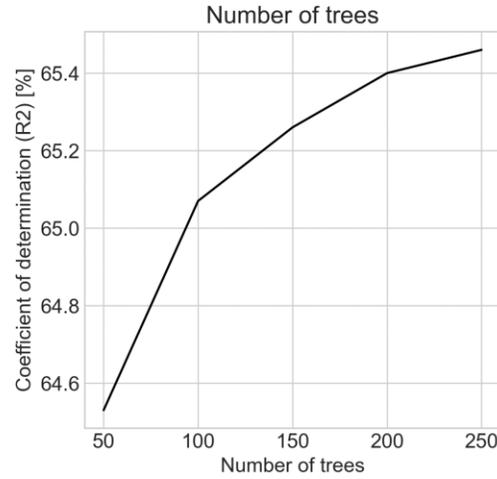
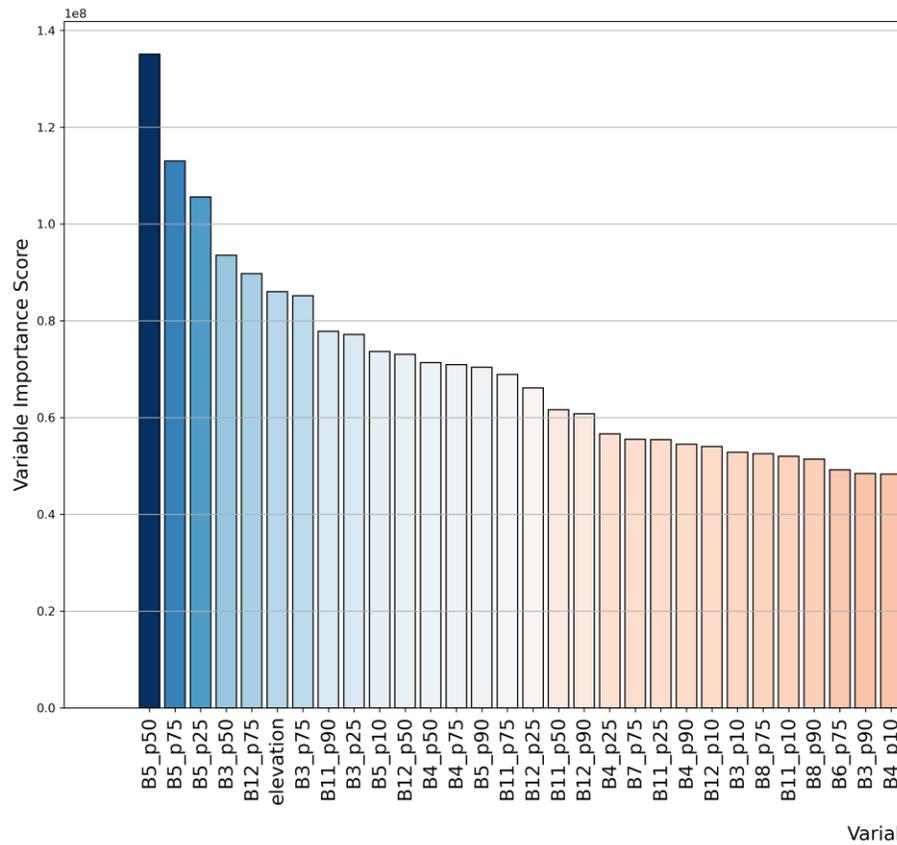
Comparison to other Products



- a) Potapov et al. 2021: Landsat + GEDI rh_95 globally (2019)
- b) Lang et al. 2022: Sentinel-2 + GEDI rh_98 globally (2020)
- c) Copernicus HRL Tree Cover Density (2018)

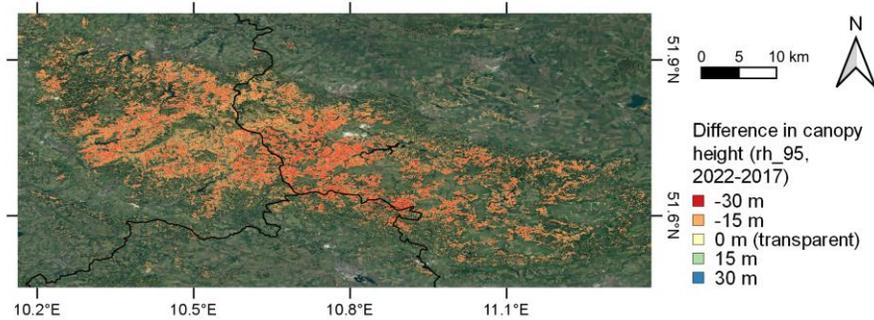


Model Sensitivity

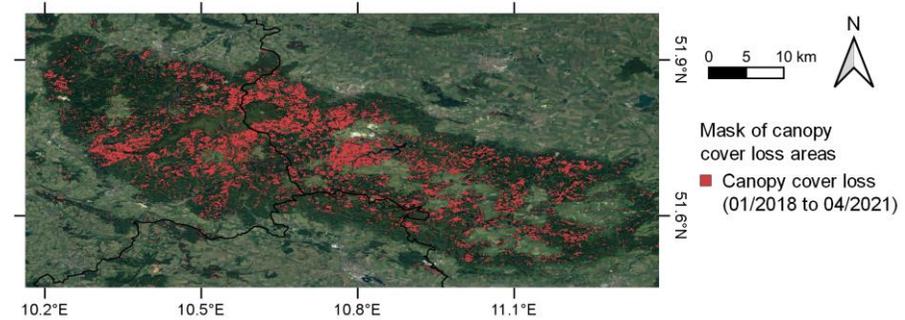


Forest Structure Dynamics in the Harz region

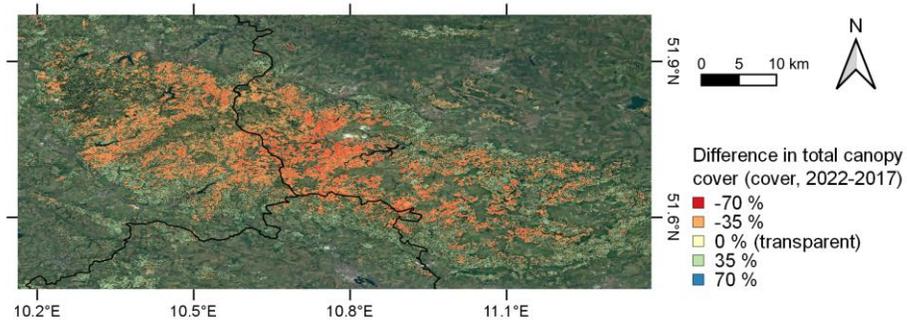
Difference in canopy height (rh_95, 2022-2017)



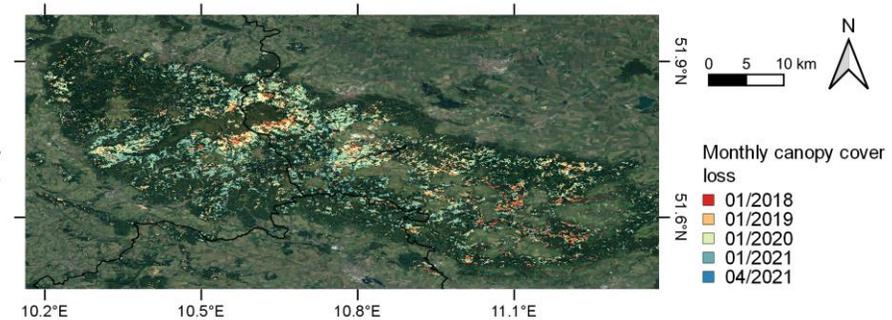
Canopy cover loss areas (Thonfeld et al. 2022)



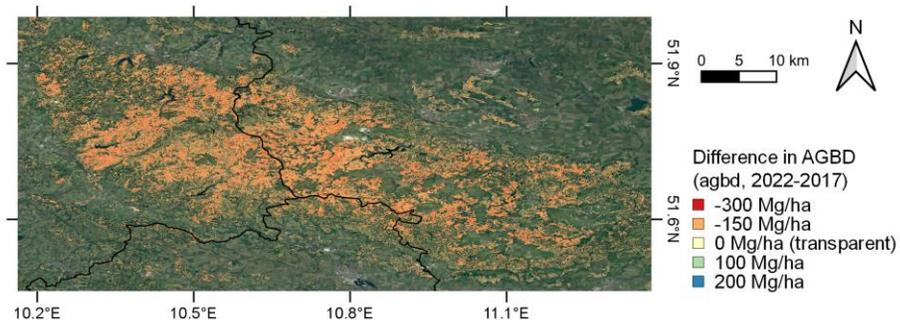
Difference in total canopy cover (cover, 2022-2017)



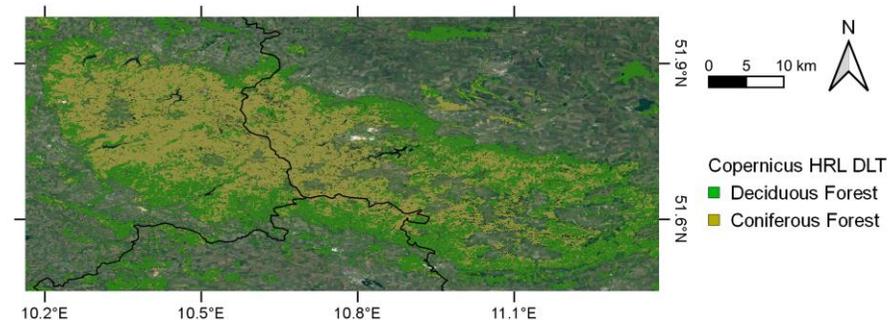
Monthly canopy cover loss areas (Thonfeld et al. 2022)



Difference in AGBD (agbd, 2022-2017)



Dominant Leaf Type (Copernicus HRL DLT)



National Statistics – canopy height



- a) Annual statistics for Germany
- b) Difference statistics per federal state between 2022 and 2017
- c) Annual statistics per federal state

