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

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MOTIVATION

- **Forests cover** about **30 %** of **Germany** and are often characterized by **age-class structures**.

- **Monitoring forest structure informs forest management** in order to **improve biodiversity** and enhance the **resilience** towards disturbance events.

AIM

Assess multi-annual forest structure dynamics in the context of **increasing disturbances in Germany** based on **GEDI** (Global Ecosystem Dynamics Investigation), **Sentinel-1** and **Sentinel-2** data.

METHODS - WORKFLOW

Machine learning regression modeling of **GEDI samples** (footprint information on canopy height, total canopy cover, above-ground biomass density) based on **Sentinel-1** and **Sentinel-2 temporal-spectral metrics**.
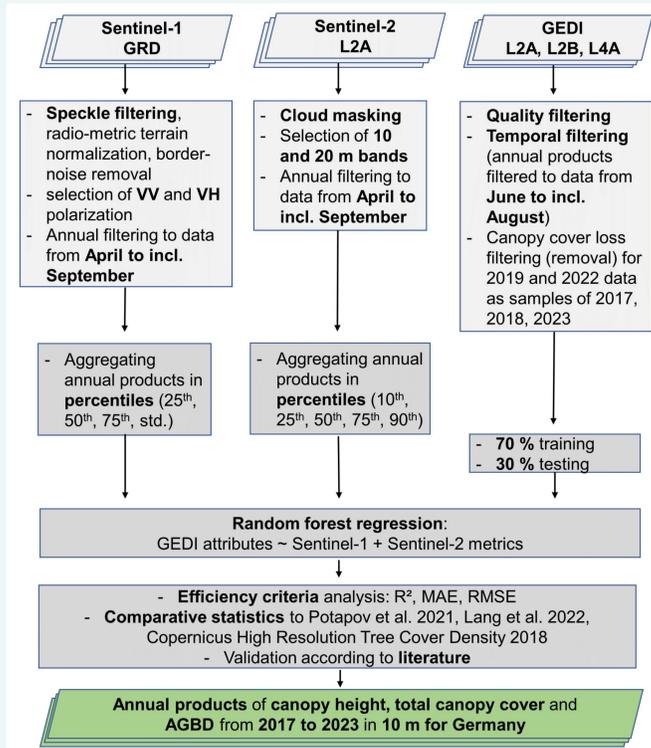

Fig. 1: **Workflow chart** of **machine learning regression modeling** of **GEDI samples** based on **Sentinel-1** and **Sentinel-2 temporal-spectral metrics**.

RESULTS – MODEL ACCURACY

Evaluation of **model accuracy** based on **independent GEDI samples** (70/30 split).
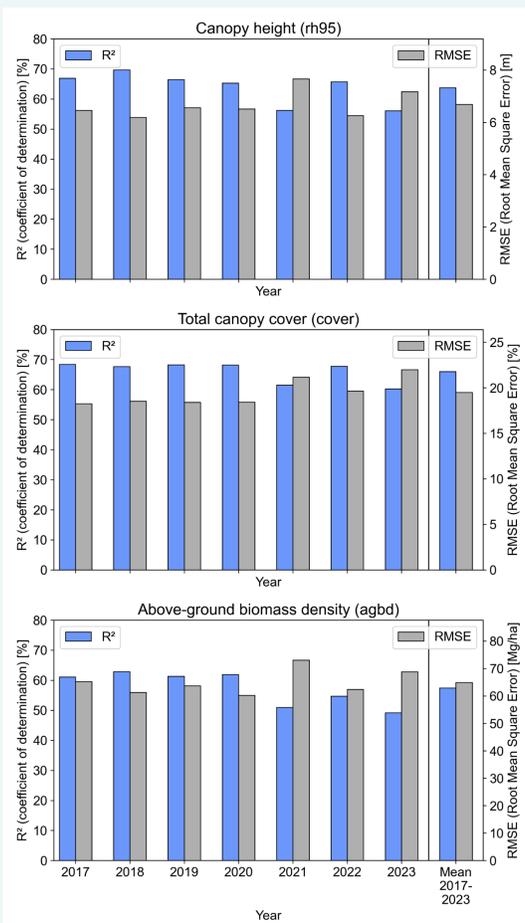

Fig. 2: **Evaluation** of **model accuracy** based on **independent GEDI samples** (70/30 split). The **mean model accuracy per attribute** is shown on the **right side**.

RESULTS – GERMANY

- Assessment of **forest canopy height, total canopy cover, and above-ground biomass density** from **2017** to **2023** in **Germany** in **10 m spatial resolution**.
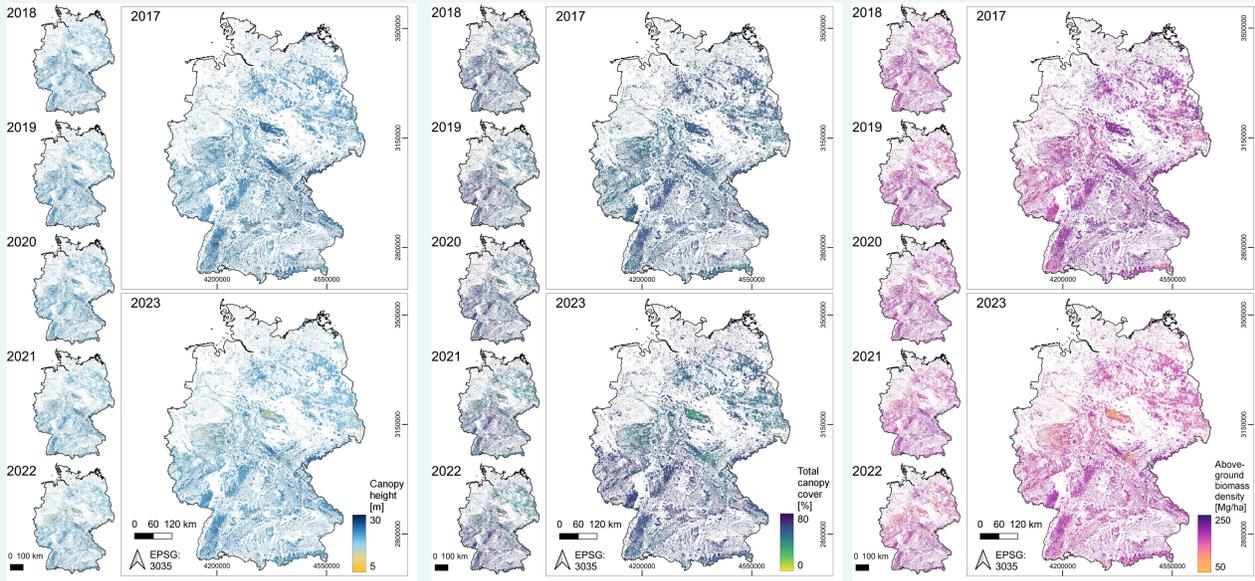
- Several **hotspots of forest structure change** are located in **Central Germany**, such as the **Harz forest** which is characterized by **strong losses for all attributes of forest structure**.

Fig. 3: **Forest structure characterization** from **2017** to **2023** in **Germany** as canopy height (left), **total canopy cover** (middle), and **above-ground biomass density** (right). One **hotspot of forest structure change dynamics** is the **Harz forest** (see figures below) in **Central Germany**.

RESULTS – HARZ FOREST (CENTRAL GERMANY)

- **Small-scale changes before 2020** in the **Harz**.
- **Landscape-scale disturbances since 2020** for **previously high forests** with **dense canopy covers** being **rich in above-ground biomass density**.
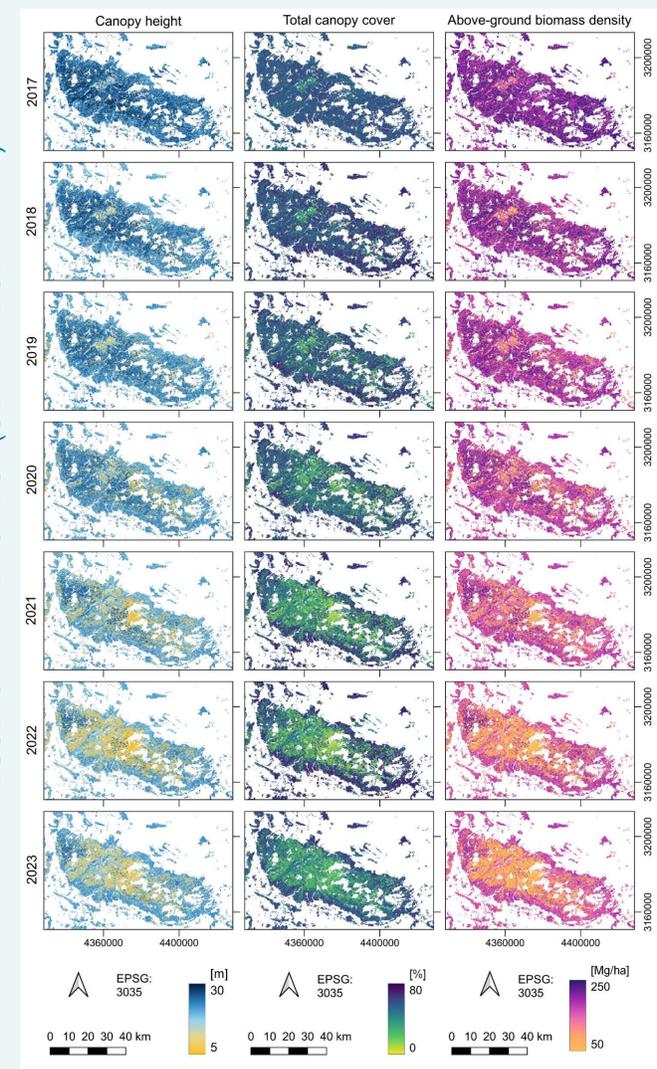
- **Former spruce plantations** (core area) are characterized by a **reduction in canopy height** of more than **20 m**, total canopy cover exceeding **50 %**, and above-ground biomass density of up to **200 Mg/ha**.
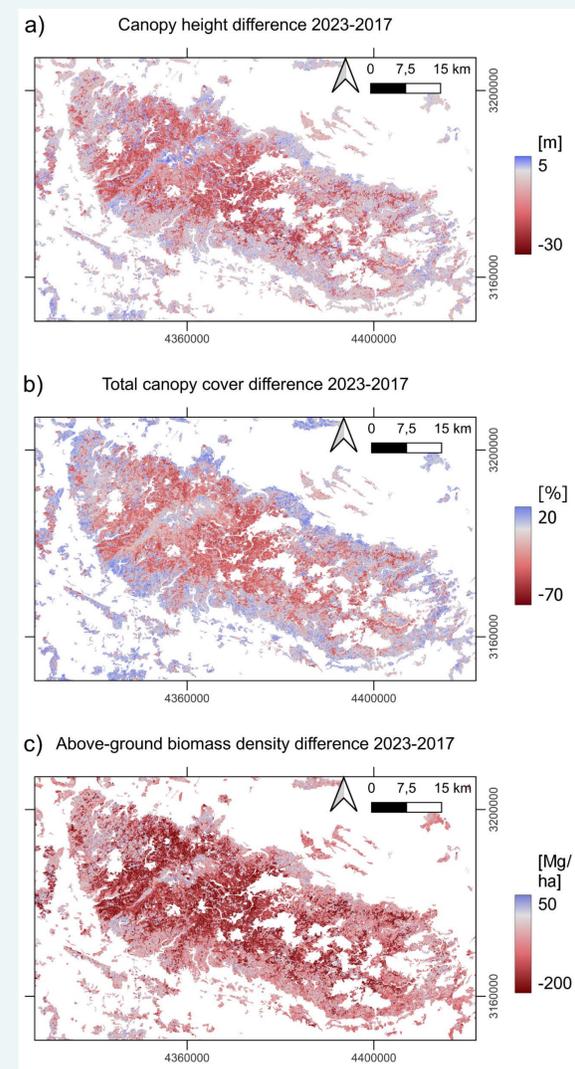

Fig. 4: **Multi-annual forest structure changes** from **2017** to **2023** for **canopy height** (left column), **total canopy cover** (middle column), and **above-ground biomass density** (right column). **Losses** for **all attributes** of forest structure specifically in **spruce plantations** of the Harz forest (central Germany).

Fig. 5: **Difference rasters** of **2023-2017** for **canopy height** (a), **total canopy cover** (b), and **above-ground biomass density** (c). **Strong changes in forest structure** are dominating in **spruce plantations** of the Harz forest in central Germany.

CONCLUSIONS

- Based on the **novel forest structure products for Germany**, **previously mapped areas of canopy cover loss** as response to repeated drought years can be **quantitatively characterized by canopy height, total canopy cover, as well as above-ground biomass density.**
- **Improved understanding of post-disturbance structures,** e.g. to **delineate stand-replacing and non-stand-replacing disturbances**.
- The **characterization of disturbance structures and undisturbed areas** enables the **assessment of potential future forest resilience** to **inform forest management**.

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