images: Vecteezy: K. Rafalia; sm wizzard

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European Environment Agency

esa

Second conference on Earth Observation for Monitoring, Reporting and Verification of Carbon Removals

Copenhagen, 7-10 October 2025

Remote sensing based forest biomass assessment for the European bioenergy sector

Authors:

Deutscher, Janik; Gallaun, Heinz; Puhm, Martin; Bernsteiner, Felix; Viehweger, Jonas; Bastrup-Birk, Annemarie; Zeug, Gunter; Bielski, Conrad; Kouacou, Koimé; Vogler, Sebastian

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Motivation

- EU Renewable Energy Directive sets an overall binding target of at least 42.5% renewable energy in the EU's energy mix by 2030.
- To ensure Europe’s energy security, the energy transition – shifting from fossil fuels to renewables – is no longer just an environmental goal but a geopolitical necessity.
- Forest biomass is a key component of Europe’s energy transition.

image: Vecteezy: sm wizzard

JRC Report, 2021:
The use of woody biomass for energy production in the EU

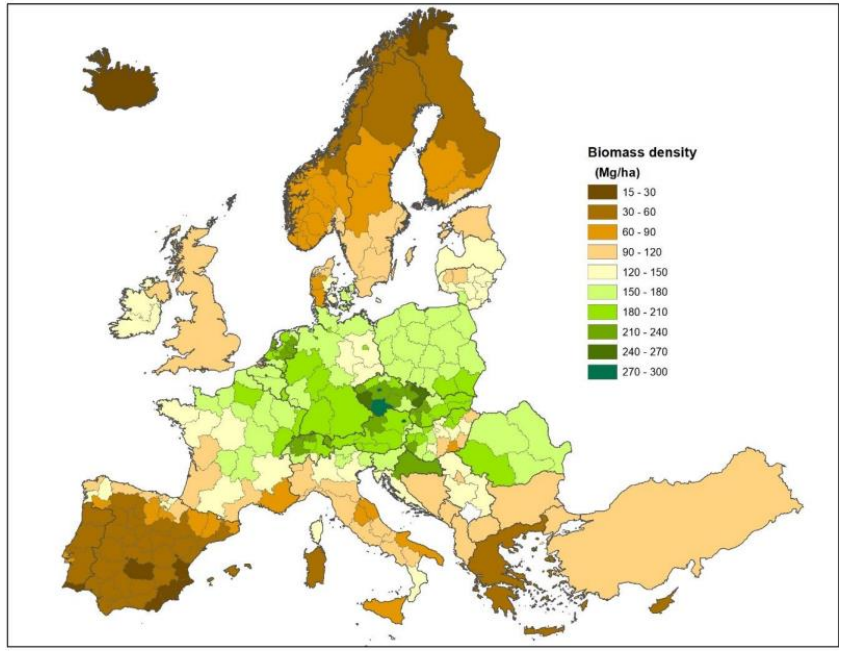

Figure 24. Map of the reference biomass statistics for the year 2010, expressed as biomass density of the forest area (Unit: megagrams per hectare, equivalent to tonnes per hectare).

Motivation

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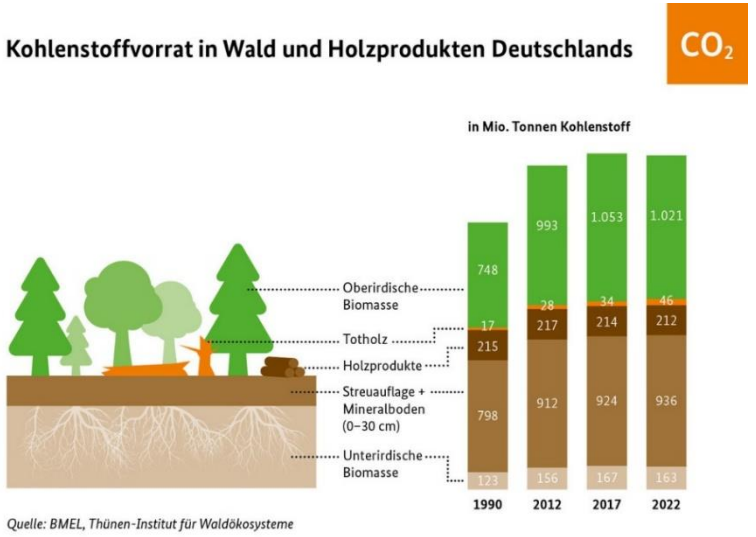
- Forest biomass is a key component of Europe’s energy transition.
- Use of forest biomass for bioenergy must be sustainable and ensure forests ecosystem functions **-> damaged wood / residues**
- **Goal**: support regional planning of biomass use (power plants) with **spatially explicit information**

National German Forest Inventory

carbon sink or carbon source?



Proposed „EU Forest Monitoring Law“

- **Member States** shall collect the following forest data:
  - forest available and not available for wood supply;
  - growing stock volume;
  - net annual increment;
  - stand structure;
  - tree species composition and richness;
  - European forest type;
  - removals;
  - deadwood;
  - location of forest habitats in Natura 2000 sites;
  - abundance of common forest birds;
  - location of primary and old-growth forests;
  - protected forest areas;
  - production and trade of wood products;
  - **forest biomass for bioenergy**

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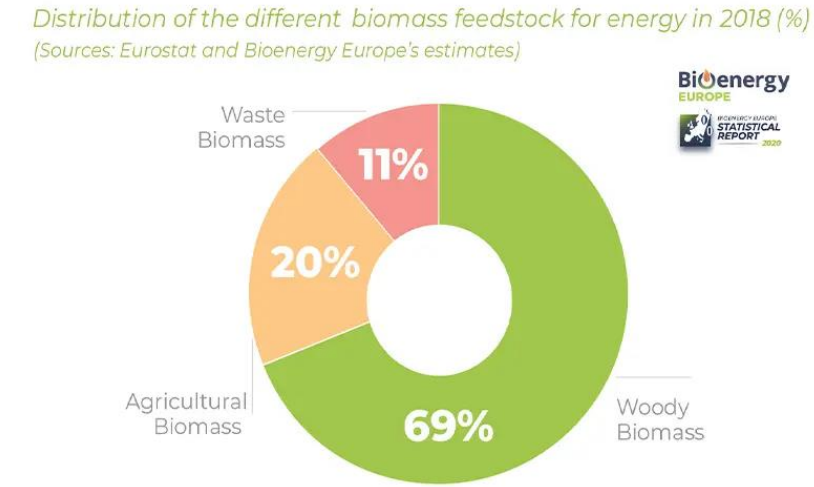
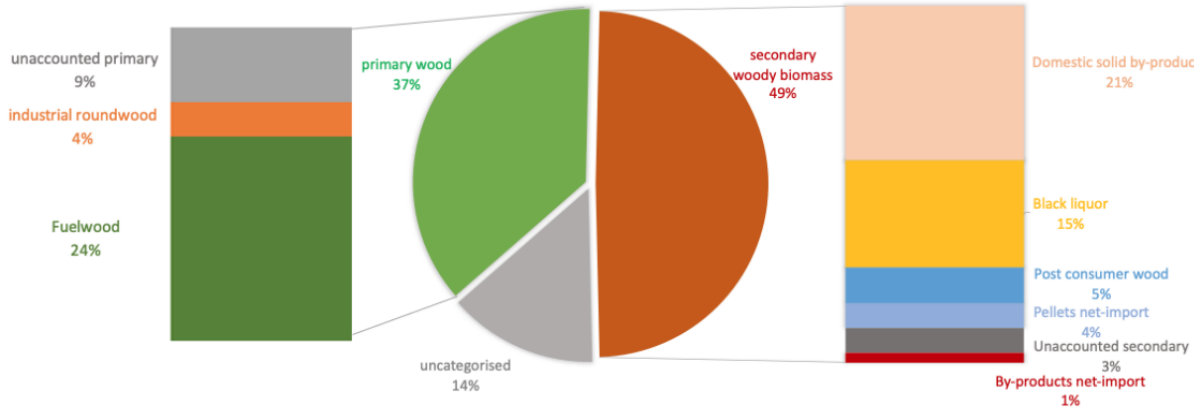


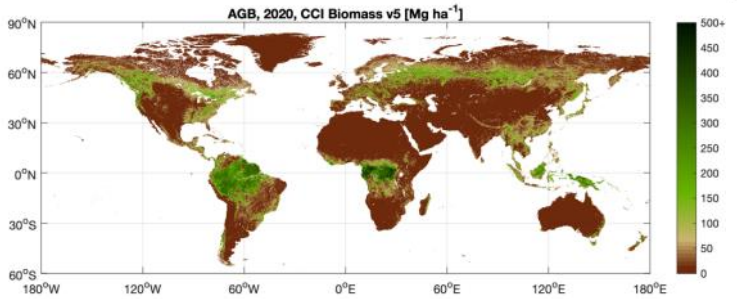


Origin of wood fibres used for bioenergy in the EU (2015)

JRC Report, 2021: The use of woody biomass for energy production in the EU

Existing Forest Biomass Data in Europe

- ESA CCI Biomass: global 100m AGB product



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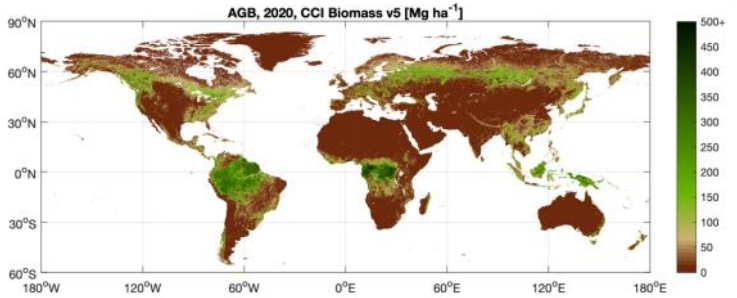

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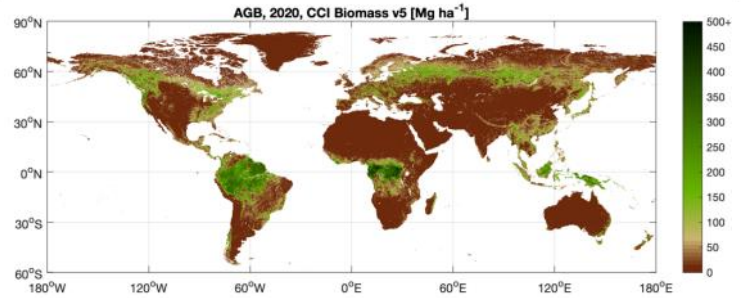

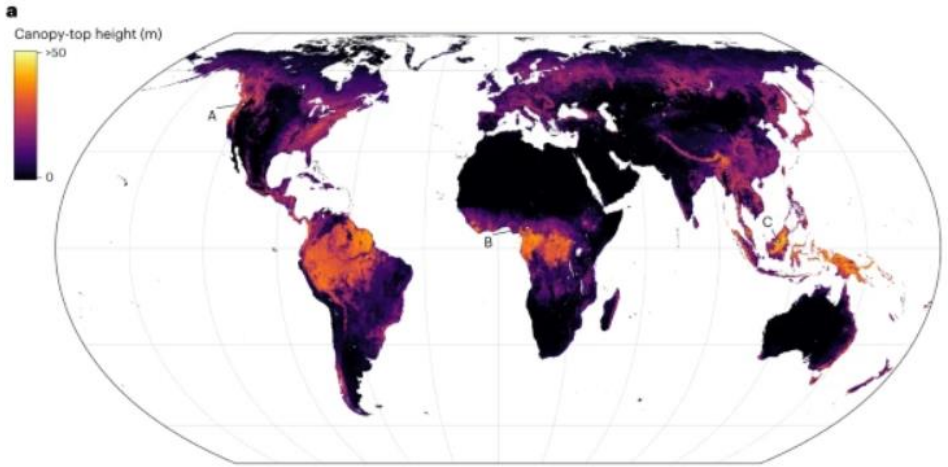

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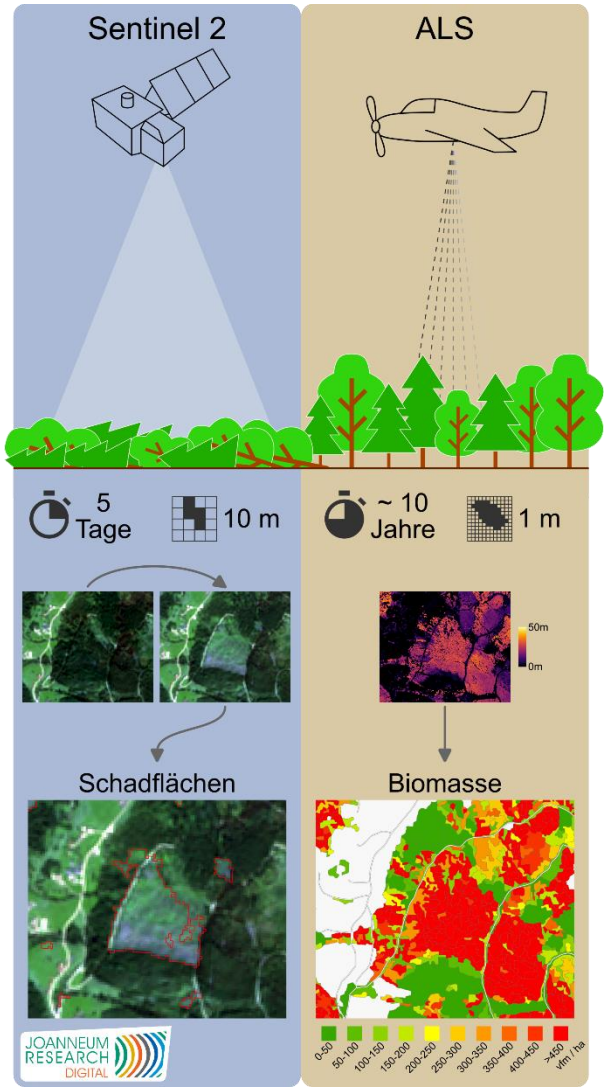
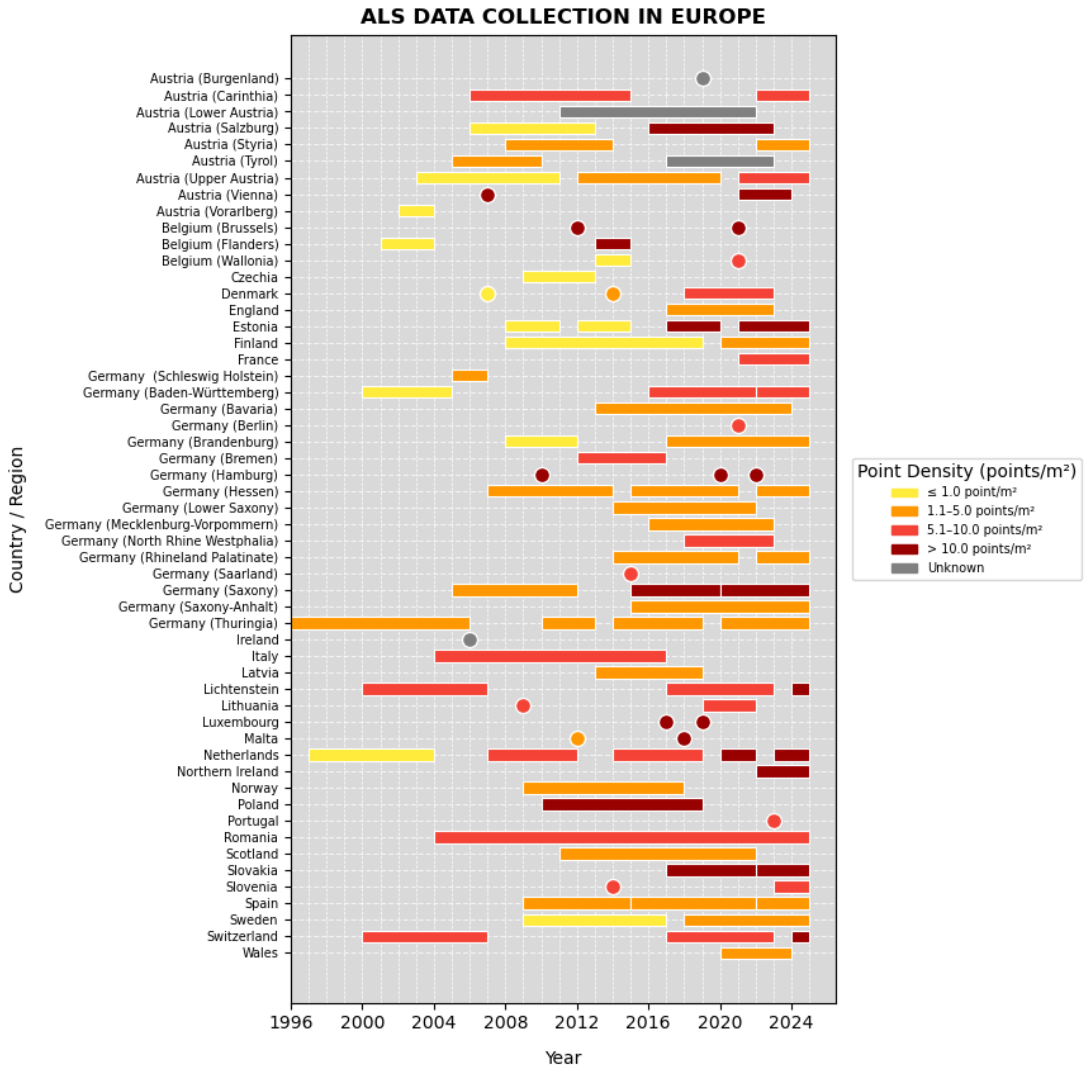
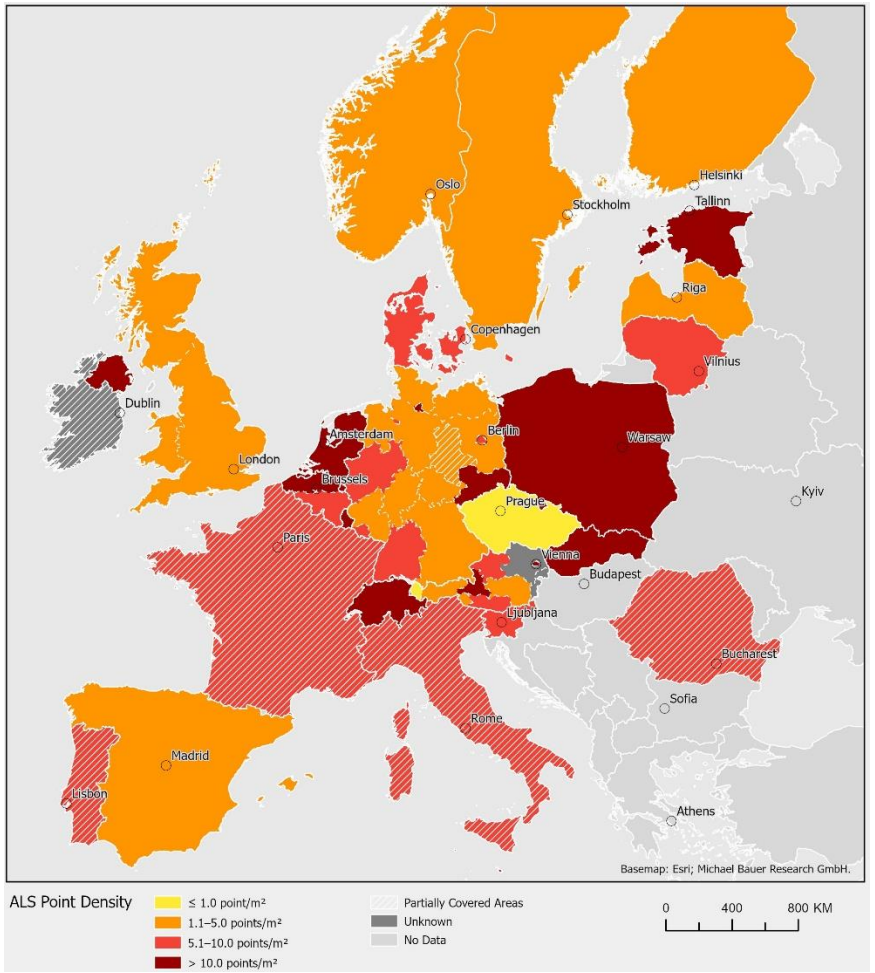
- Global Canopy Height models – such as Lang et al. 2023: fuses GEDI with Sentinel-2
- **National Airborne Laserscanning data (ALS) data combined with disturbance information and tree species information from Sentinel-2**



ALS Data Availability in Europe



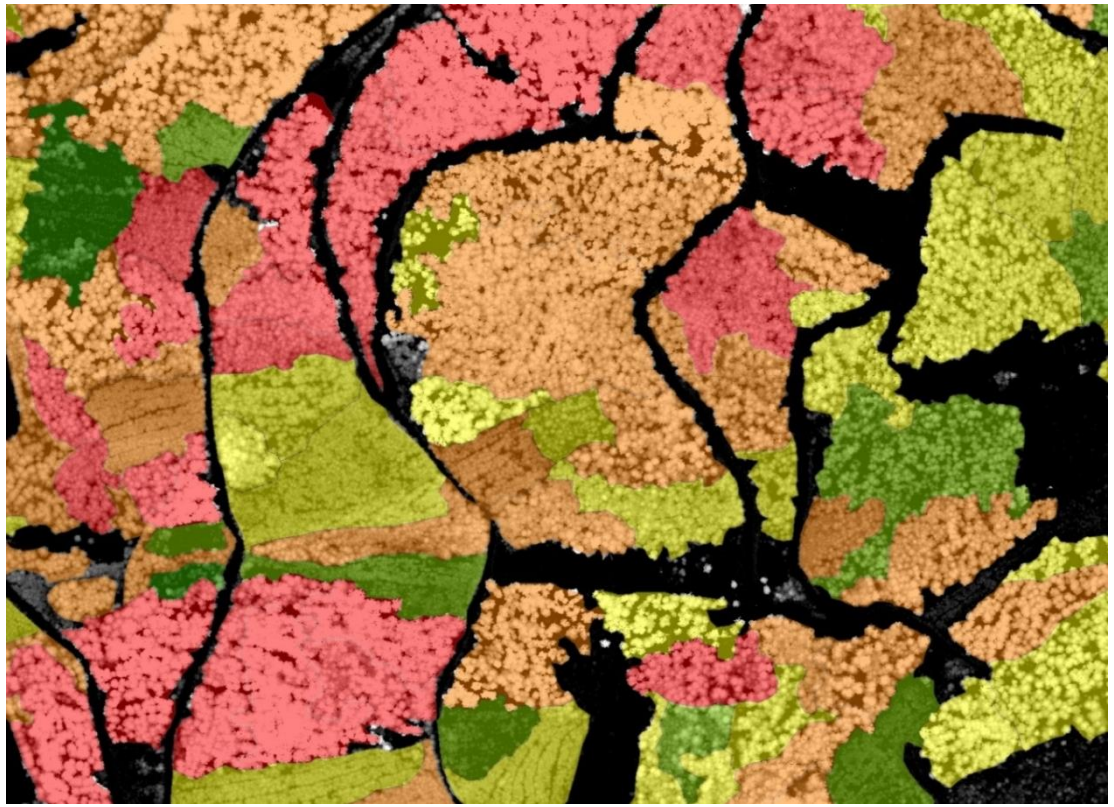


Vítězslav Moudrý et al. (2025)
Preprint: https://eartharxiv.org/repository/view/8160/

ALS Growing Stock Volume: Example Forest Atlas Styria

Growing stock volume estimates at stand level

Different models for different forest type and growth regions

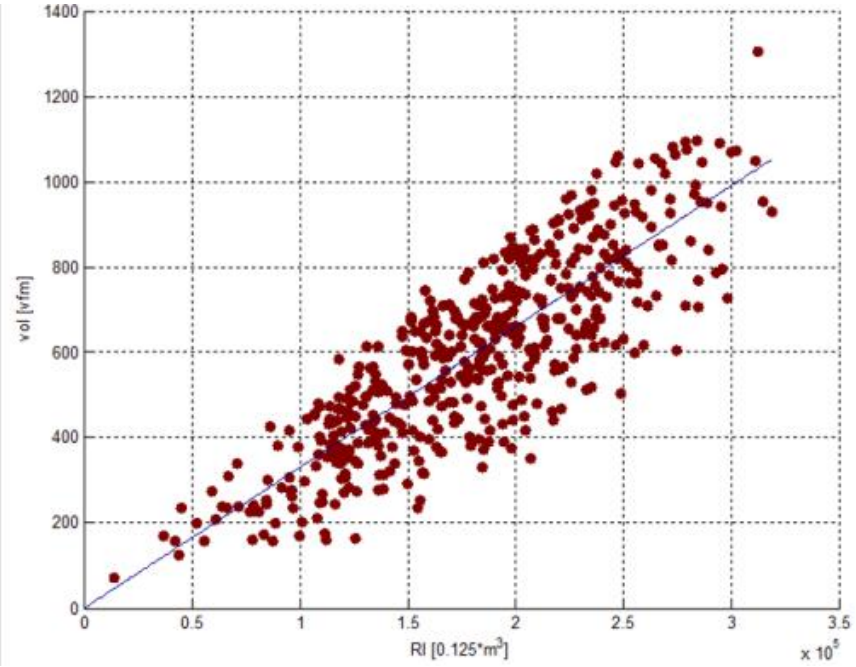


Linear regression model

- $y = a_0 x^{a1}$
- y....Timber Volume
- x....Canopy Space Integral

Correlation

- $R^2 = 0,78$



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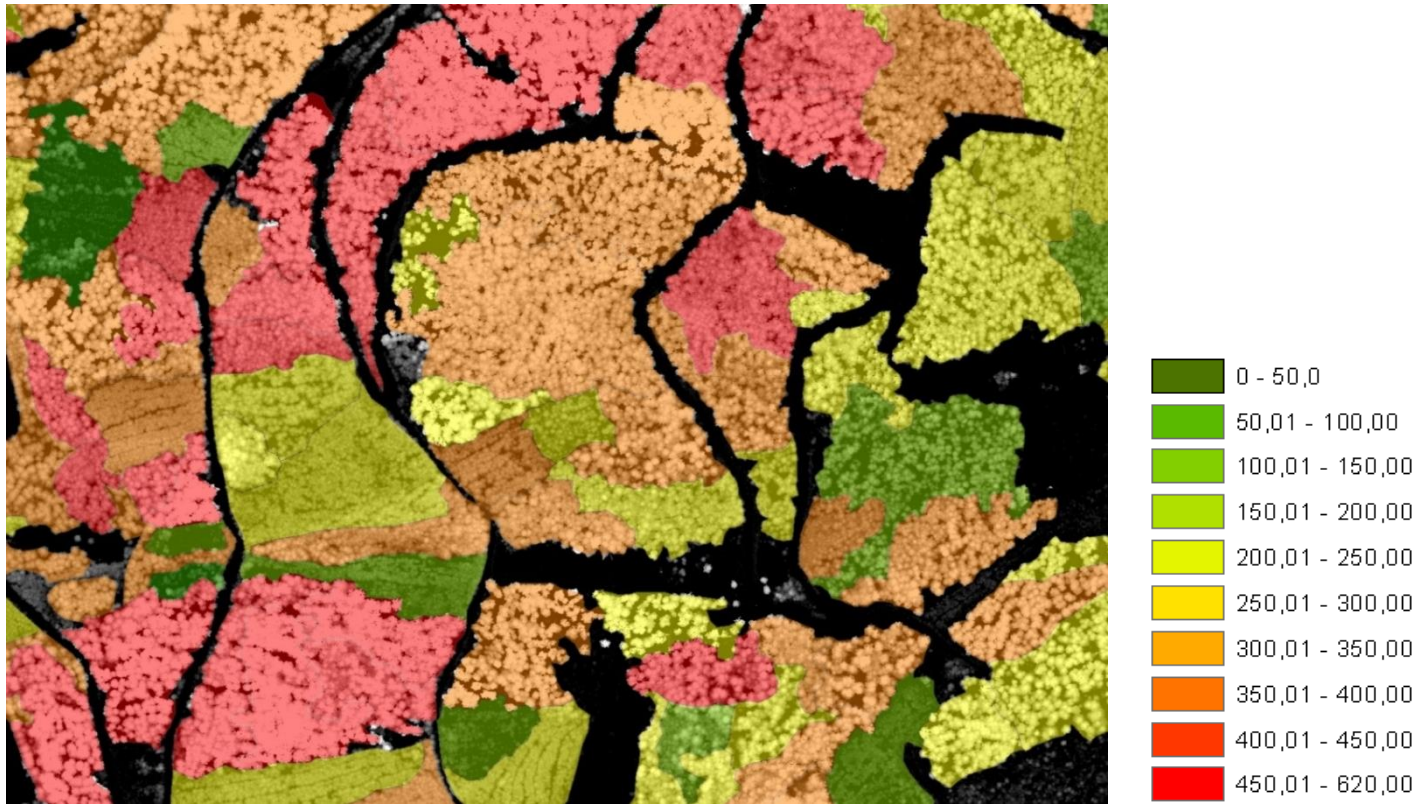
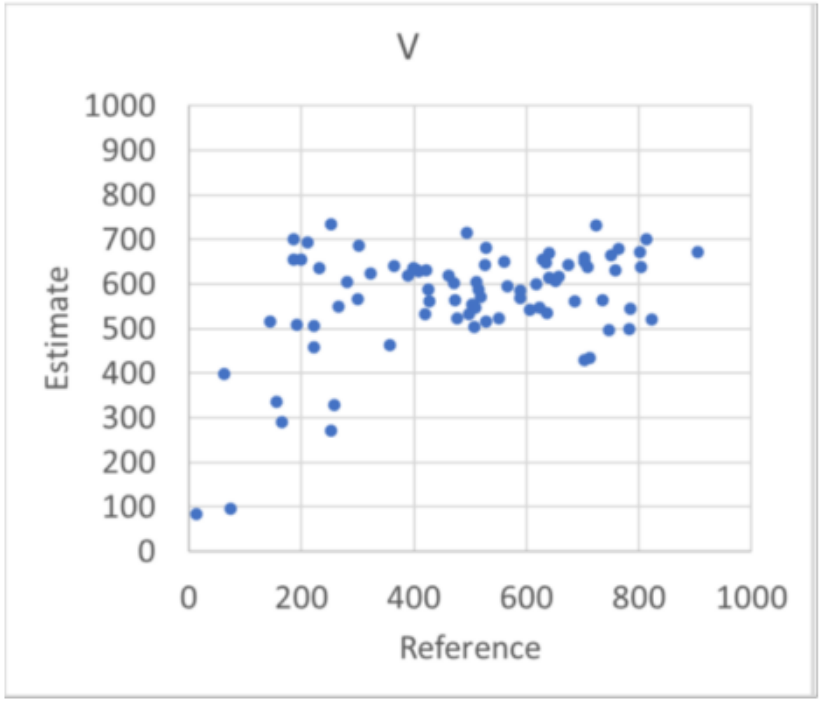


- Comparison with Sentinel based estimates show a clustering between 500 to 700m³/ha



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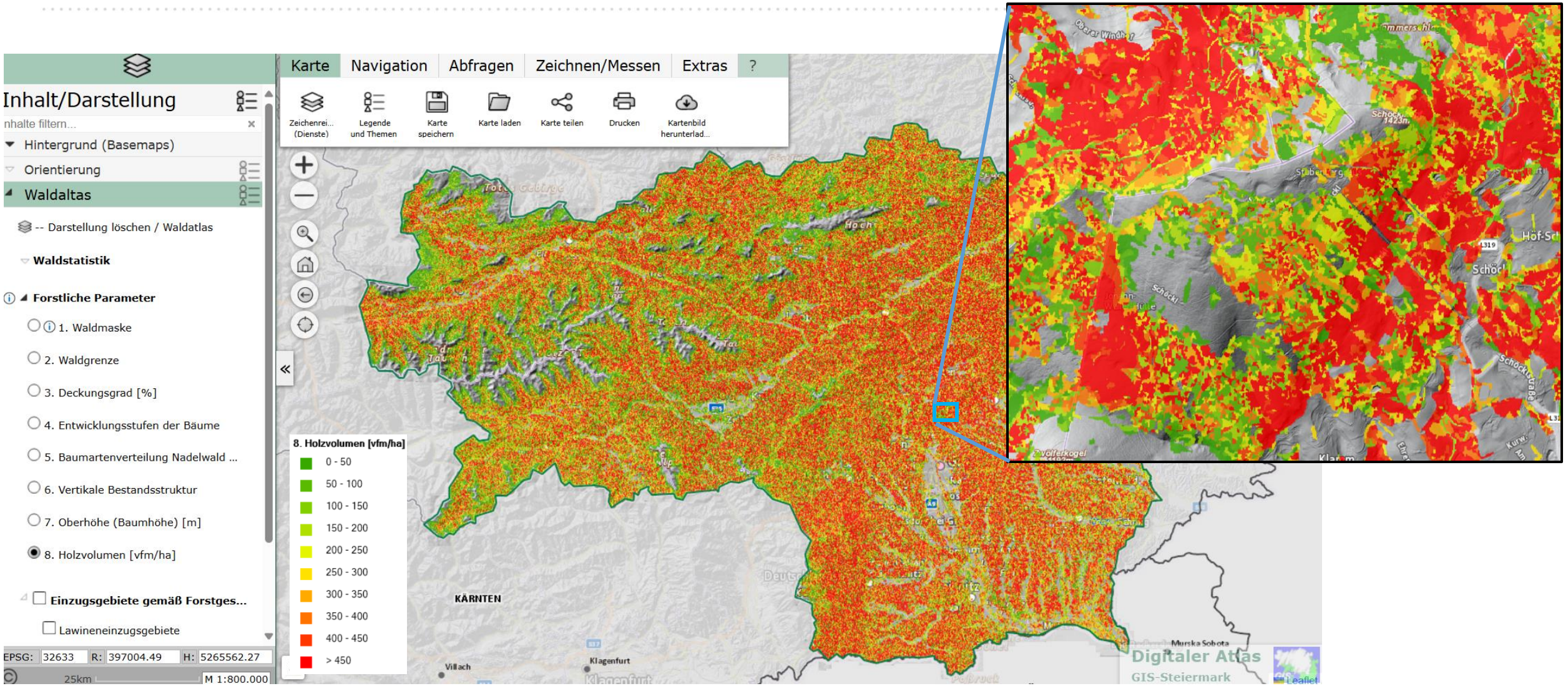
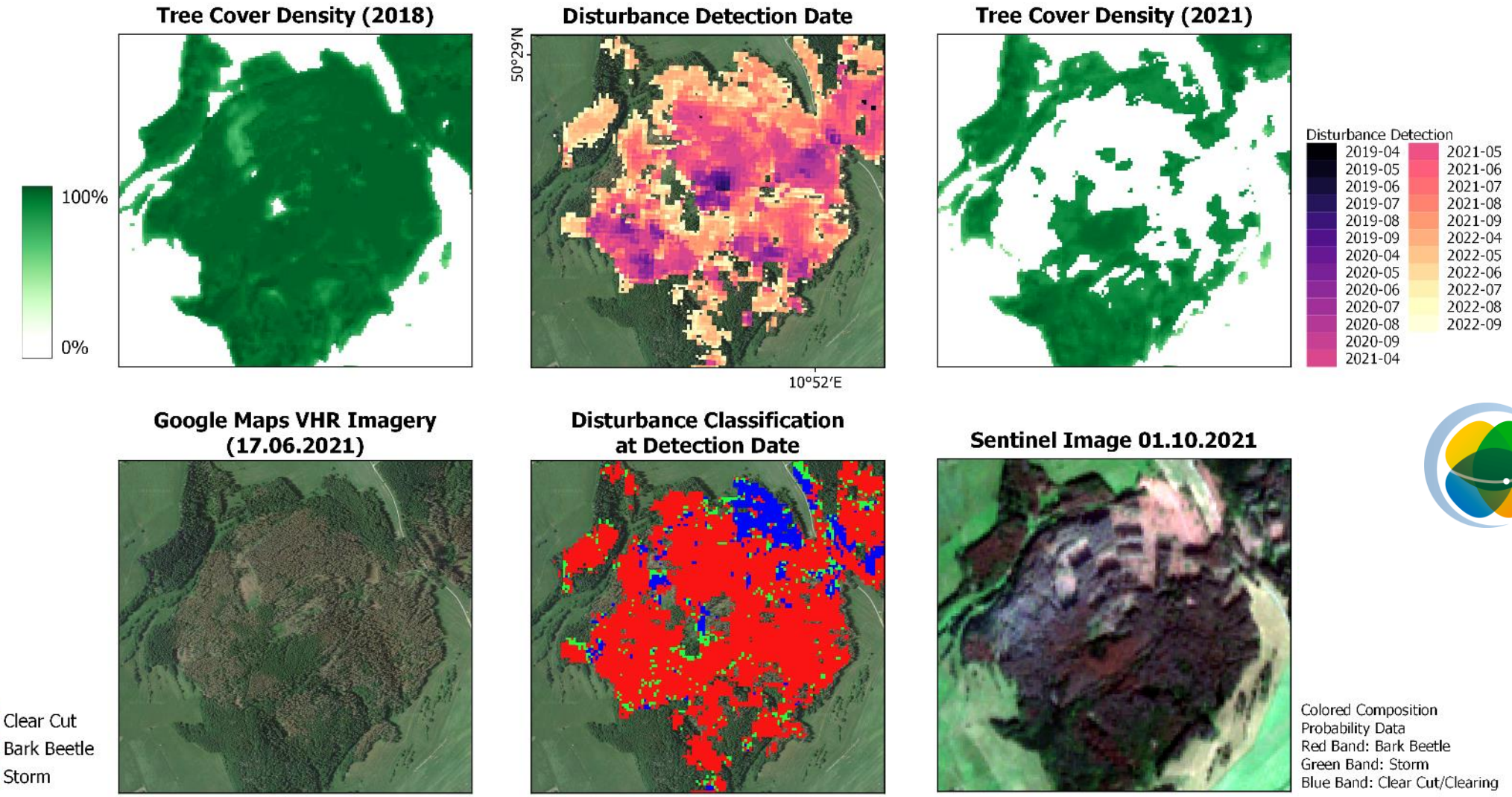


Sentinel-2 Based Forest Disturbance Data



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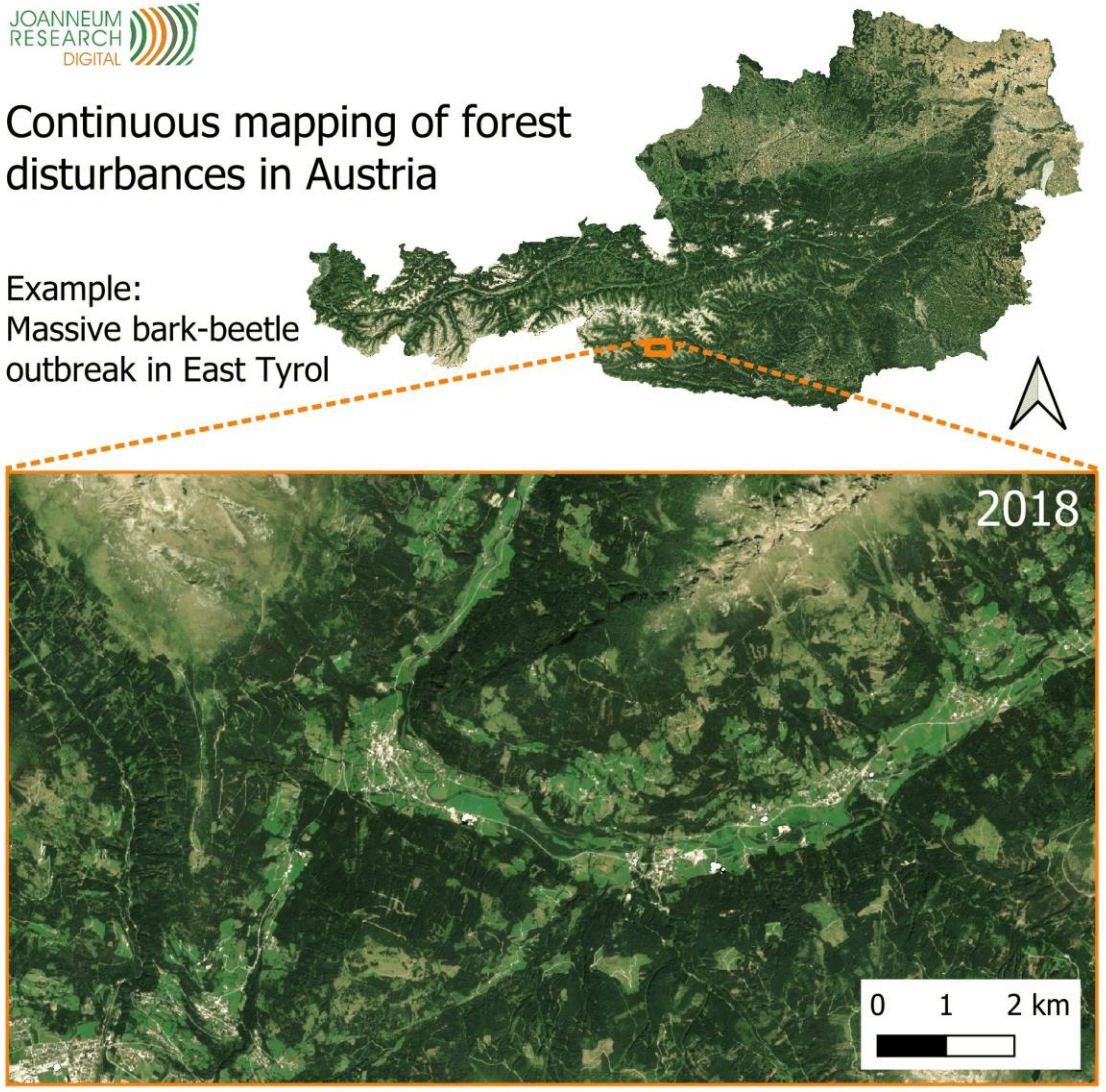
LAND MONITORING EVOLUTION

in collaboration with:

GAFAG
an e-GEOS (ASI / Telespazio) Company

Continuously Mapping Forest Change and Disturbances

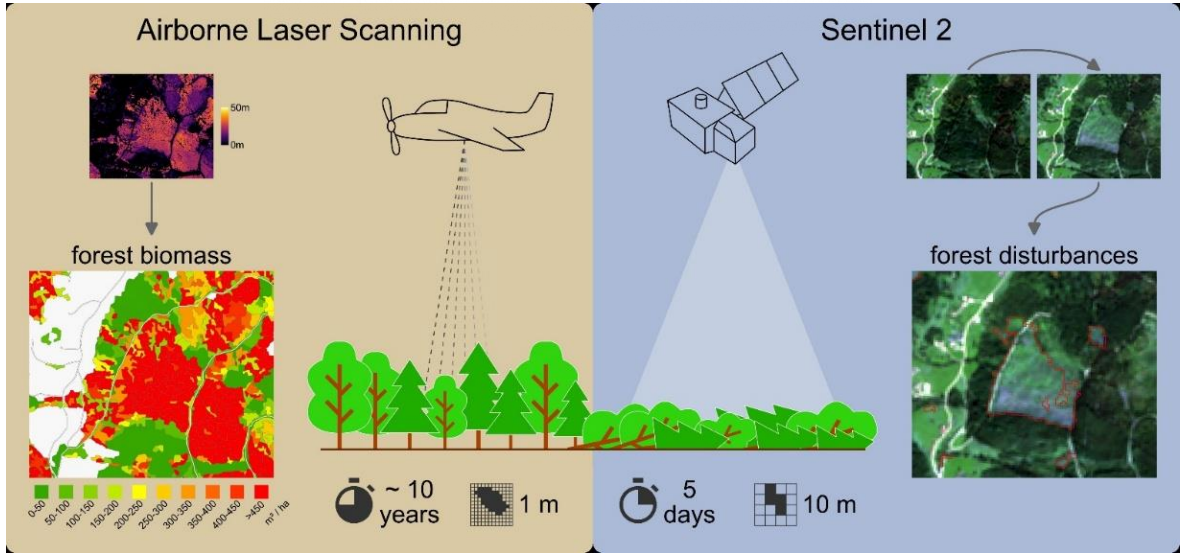
- Forest area change information
- GSV and biomass estimation (AGB) tools
- Forest type / tree species maps are available
- Number of trees in a forest stand



Continuously Mapping Forest Change and Disturbances

- Biomass estimates for forest disturbance areas
- Biomass estimates for forest stand level

FUTUREFOR



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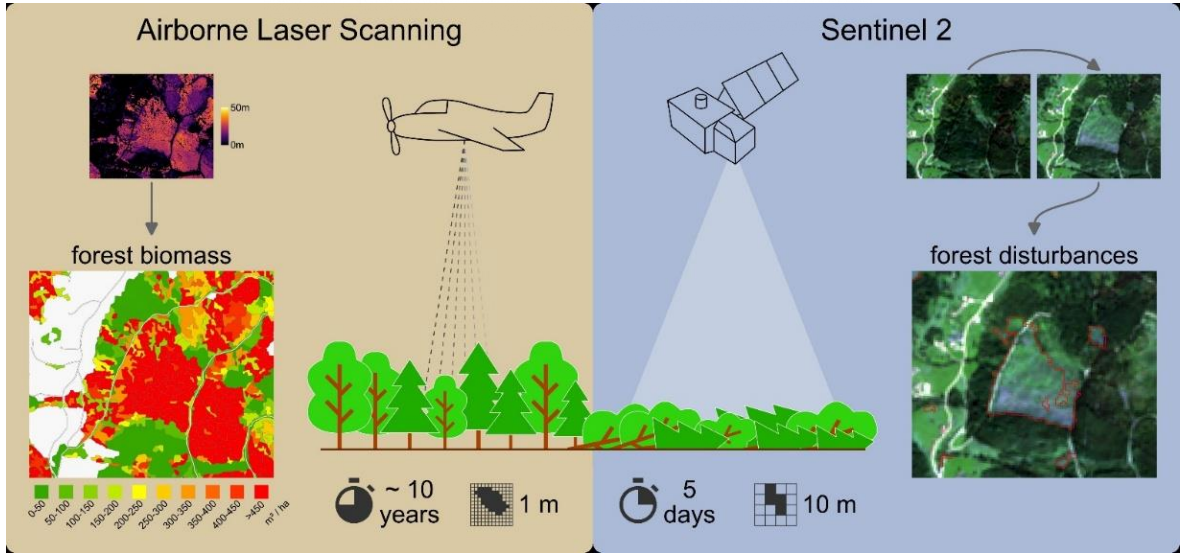
Continuous mapping of forest disturbances in Austria

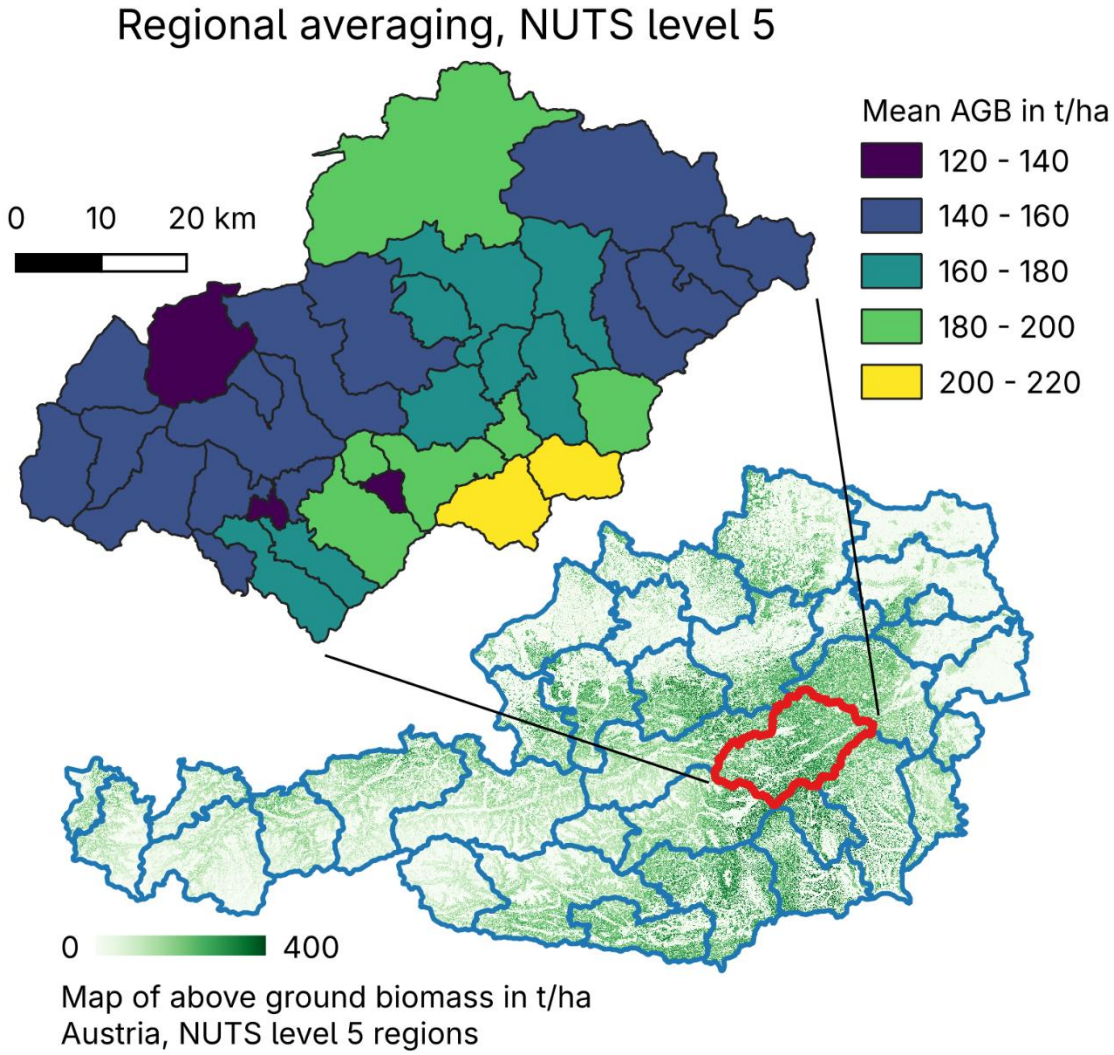
Example:
Massive bark-beetle outbreak in East Tyrol

Continuously Mapping Forest Change and Disturbances

- Biomass estimates for forest disturbance areas
- Biomass estimates for forest stand level
- Biomass estimates on regional/local level (NUTS 5)

FUTUREFOR





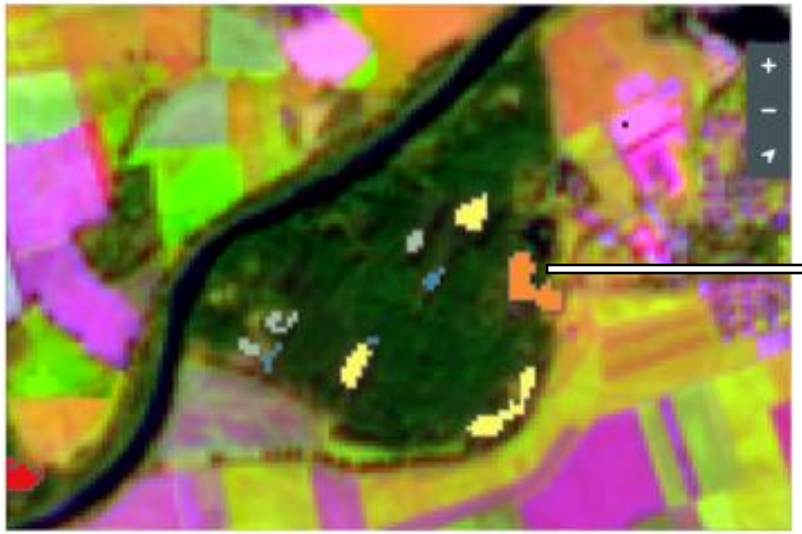
Example: Biomass in Windthrow Affected Forest Stands

Automated biomass calculation is available for windthrow-affected areas for the chosen event.

Click on polygon of area of interest in image below for biomass calculation (add change areas).

pre-storm (cloud-free mosaic) | post-storm (cloud-free mosaic)

add change areas | add biomass estimation



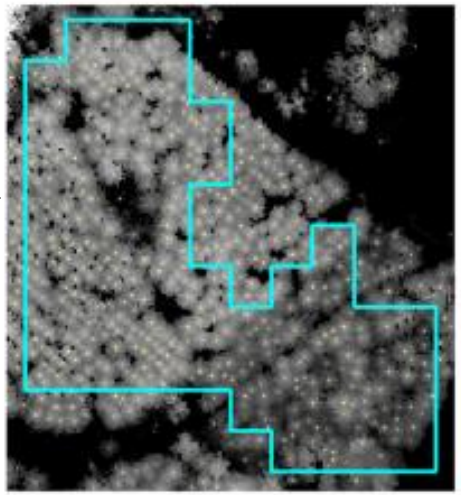
JR model image (12.09.2022)

Timber volume estimates per damage area in solid cubic meters

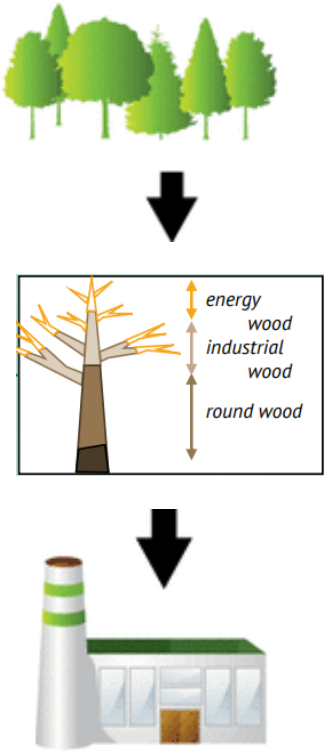
- 0 - 20,000000
- 20,000001 - 100,000000
- 100,000001 - 250,000000
- 250,000001 - 500,000000
- > 500,000001

FUTUREFOR

Choose polygon of interest for detailed biomass information.



Polygon ID	stmk90
Tree count	414
Mean tree height [m]	23,43
Top tree height [m]	32
Dominant tree species [%]:	
→ Spruce	85
→ Beech	15
Timber volume [m³]:	
→ from ALS	437,6
→ from CCI-Biomass	
Biomass for Bioenergy [m³]:	
→ Damaged primary wood	282,6
→ Harvest wastes	85
→ Sawmill residues	70



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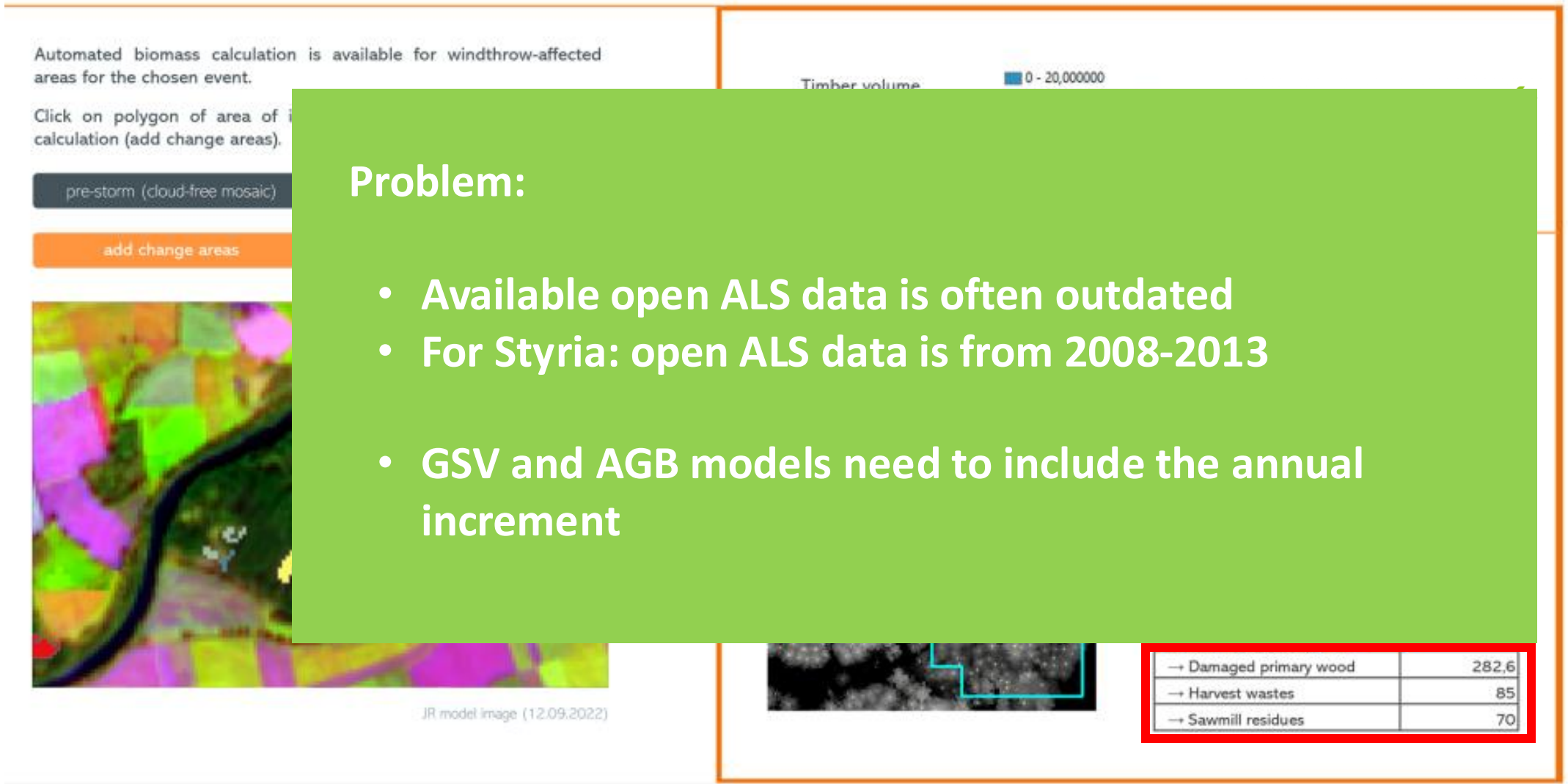
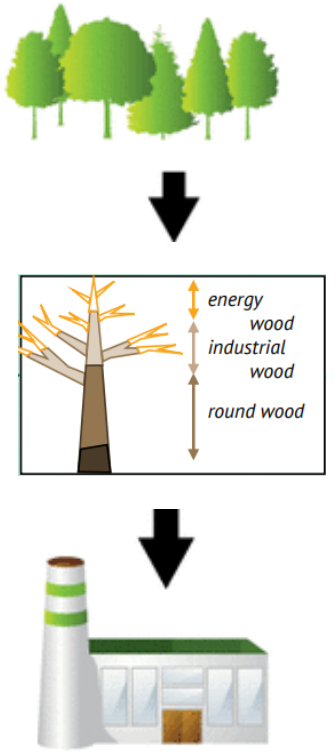


Problem:

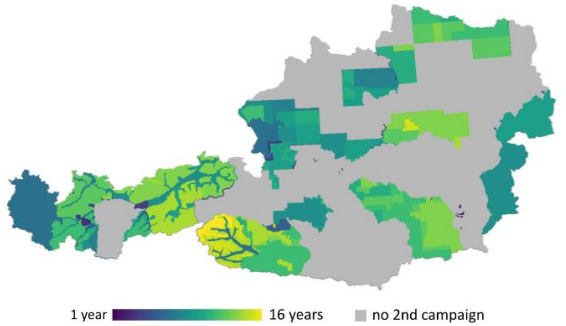
- **Available open ALS data is often outdated**
- **For Styria: open ALS data is from 2008-2013**

- **GSV and AGB models need to include the annual increment**

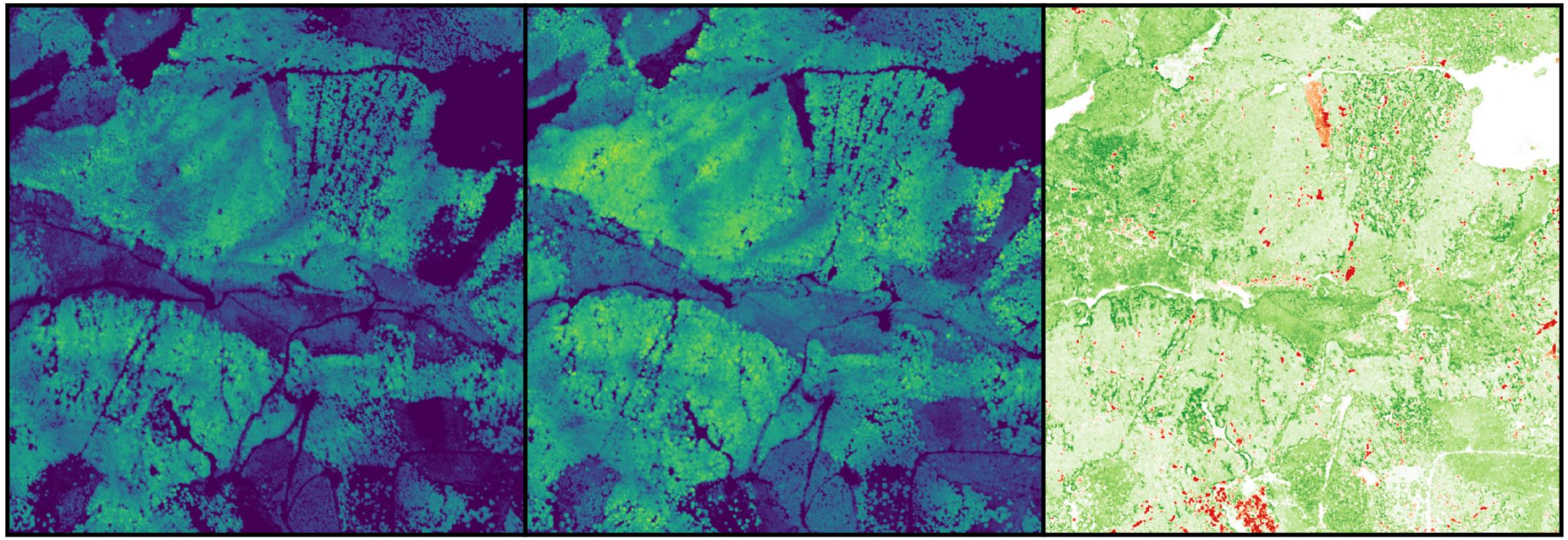


Multitemporal ALS: growth rates/increment at stand level?

- Growths rates at stand level will allow us to include the annual increment to the biomass models



ALS 2006 ***ALS 2021*** ***difference***



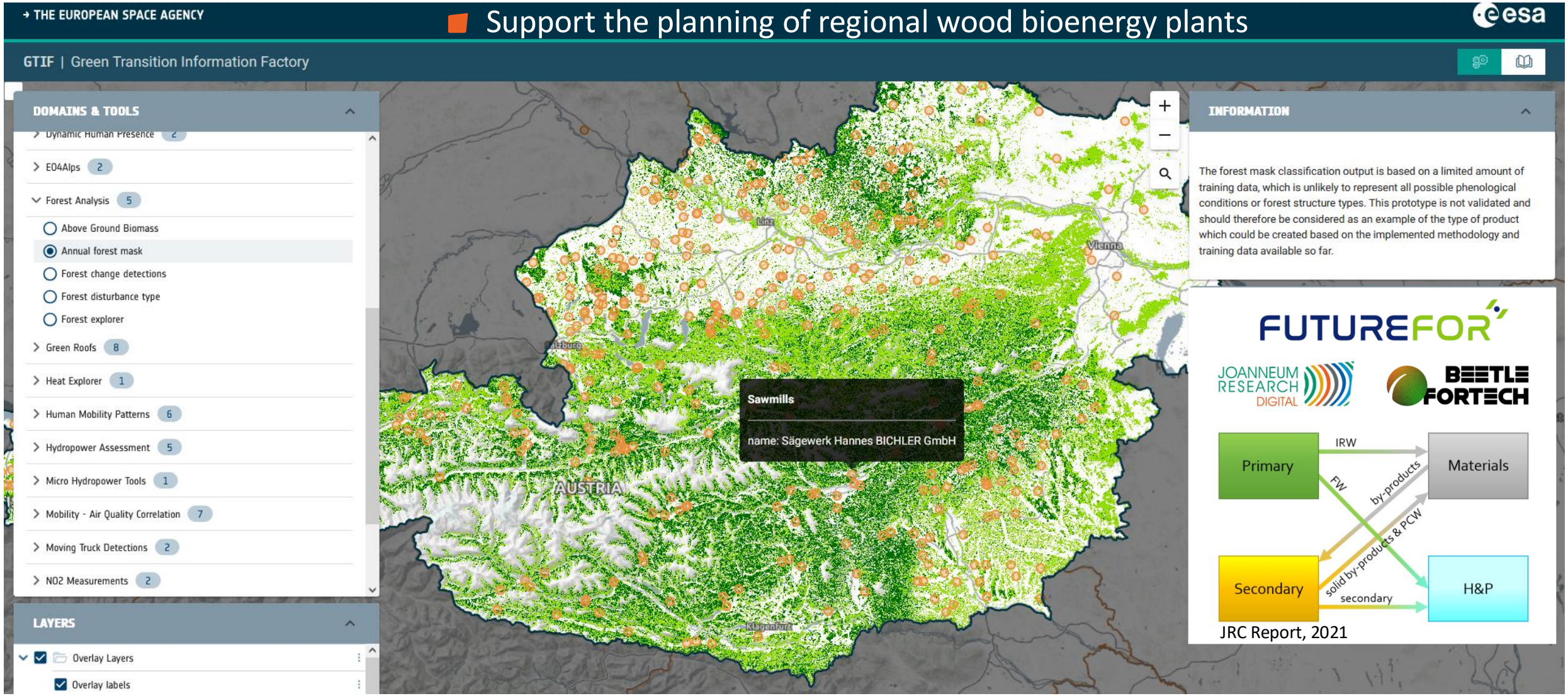
N
0 200 400 m

canopy height:
0 m 50 m

canopy height difference:
-20 m 20 m

ESA GTIF: Location of sawmills and biomass power plants

- Support the planning of regional wood bioenergy plants



JRC Report, 2021

Sustainability Apects

- Ensure forests remain a carbon sink
- Ensure forest habitat functions
- Ensure regional sourcing
- Ensure soil quality

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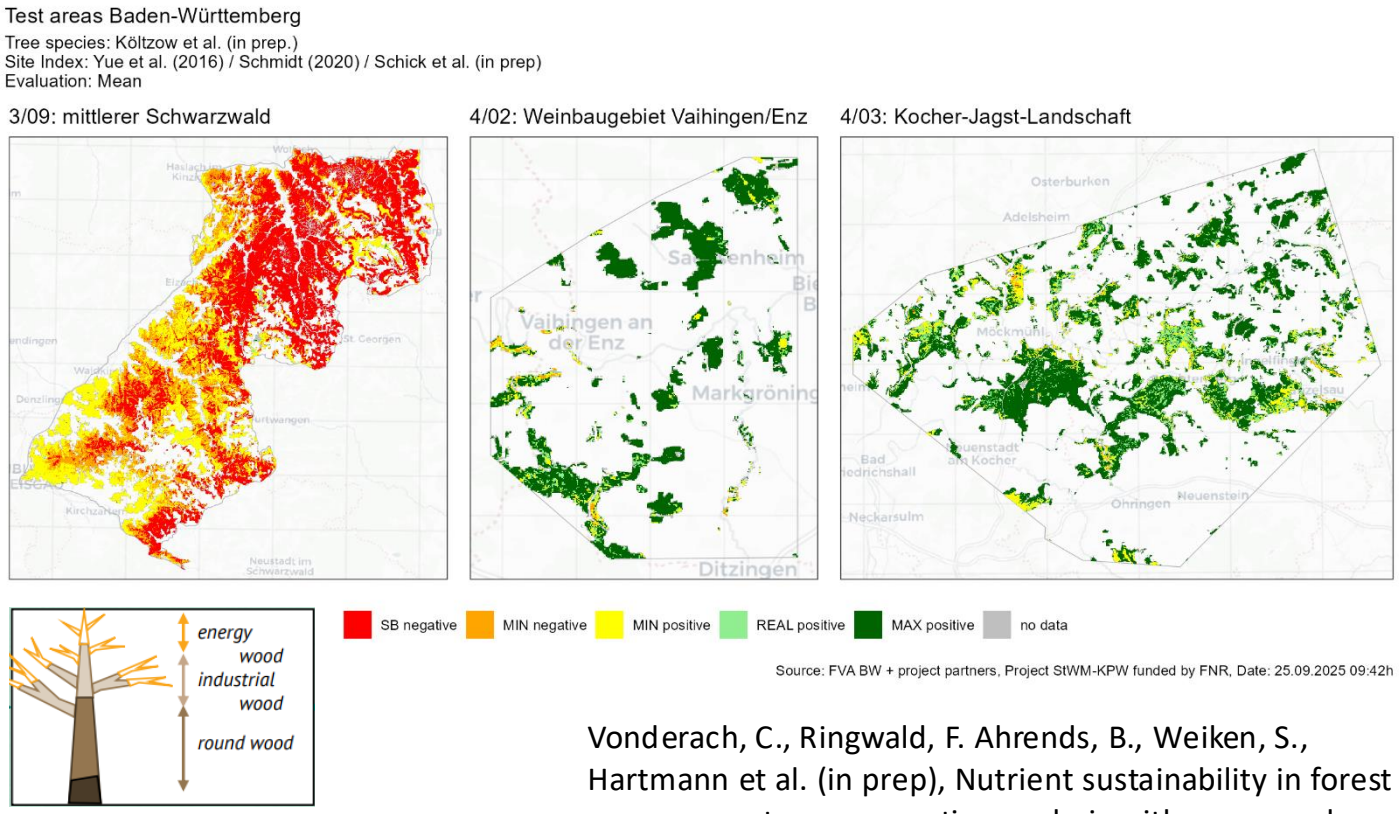
- Ensure forest habitat functions
- Ensure regional sourcing
- **Ensure soil quality**

Condition	Explanation	Management suggestions (nutrient perspective only!)
SB < 0	Soil balance without harvest is negative (loss of nutrients)	Only use stem wood (debarking if possible)
TB_{MIN} < 0	Soil balance without harvest slightly positive, but any harvest leads to a negative total balance	Only use stem wood (debarking if possible)
TB_{MIN} > 0	Total balance including extensive harvest is still positive	Only use merchantable wood (no crown; debarking if possible)
TB_{REAL} > 0	Total balance including common practice harvest is still positive	Use of merchantable wood parts of the crown possible
TB_{MAX} > 0	Total balance including intensive harvest is still positive	Intensive wood harvest possible

“Harvesting bioenergy - risking soil nutrient sustainability?”

presentation by Femke Ringwald, FowiTa, Freiburg, 2025



Vonderach, C., Ringwald, F. Ahrends, B., Weiken, S., Hartmann et al. (in prep), Nutrient sustainability in forest management: a comparative analysis with an example for Baden-Württemberg

Take Home Messages & Take Home Challenges

- Mapping accurate timber volume and AGB from ALS data is possible at stand level or disturbed areas
- ALS data is available for most European countries -> Open Data?
- National or regional field data (NFI) is required -> Open Data?
- Alternative forest biomass products already exists (ESA CCI Biomass, ESA Forest Carbon Monitoring), PathFinder project) for areas where ALS data is not available

Challenges:

- Wood residues: what are realistic wood residues by tree species (harvest, sawmill)?
- Timber market: volatile market prices for energy wood, industrial wood, round wood drive harvesting
- Sustainability: which forest biomass should stay in the forest (soil nutrients, deadwood for habitats, etc)?
- Technical challenges: huge datasets; varying ALS point densities; user access rights to sensitive data?

images: Vecteezy: K. Rafalia; sm wizzard

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