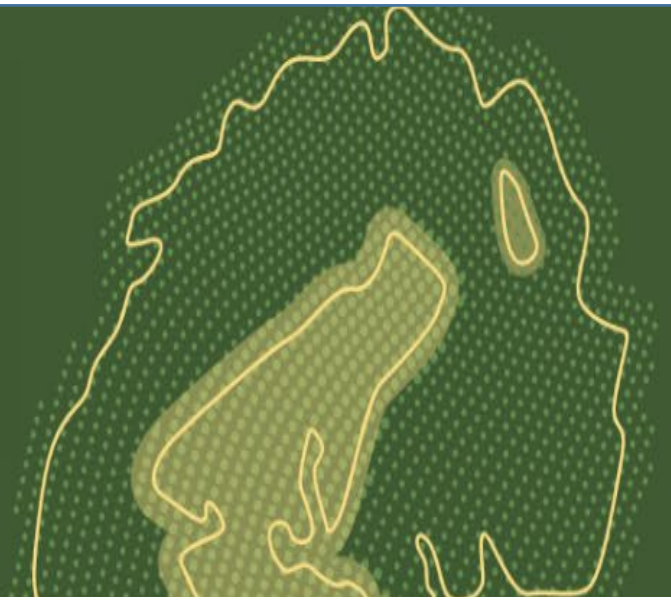
Forest Carbon Monitoring

Forest Carbon Monitoring – Key Findings

Jukka Miettinen VTT, Oleg Antropov VTT, Tuomas Häme VTT and Frank Martin Seifert ESA

EO FOR CARBON MARKETS FORUM, Frascati, 3-5 October 2023

We contribute to *climate change mitigation activities* by developing a platform for *forest carbon monitoring* with high accuracy, reach and frequency



VTT

AFRY ÅF PÖYRY

GAMMA REMOTE SENSING

Luke NATURAL RESOURCES INSTITUTE FINLAND

UNIVERSITY OF HELSINKI

EUROPEAN FOREST INSTITUTE

GFZ Helmholtz Centre Potsdam

JOANNEUM RESEARCH

Terramonitor

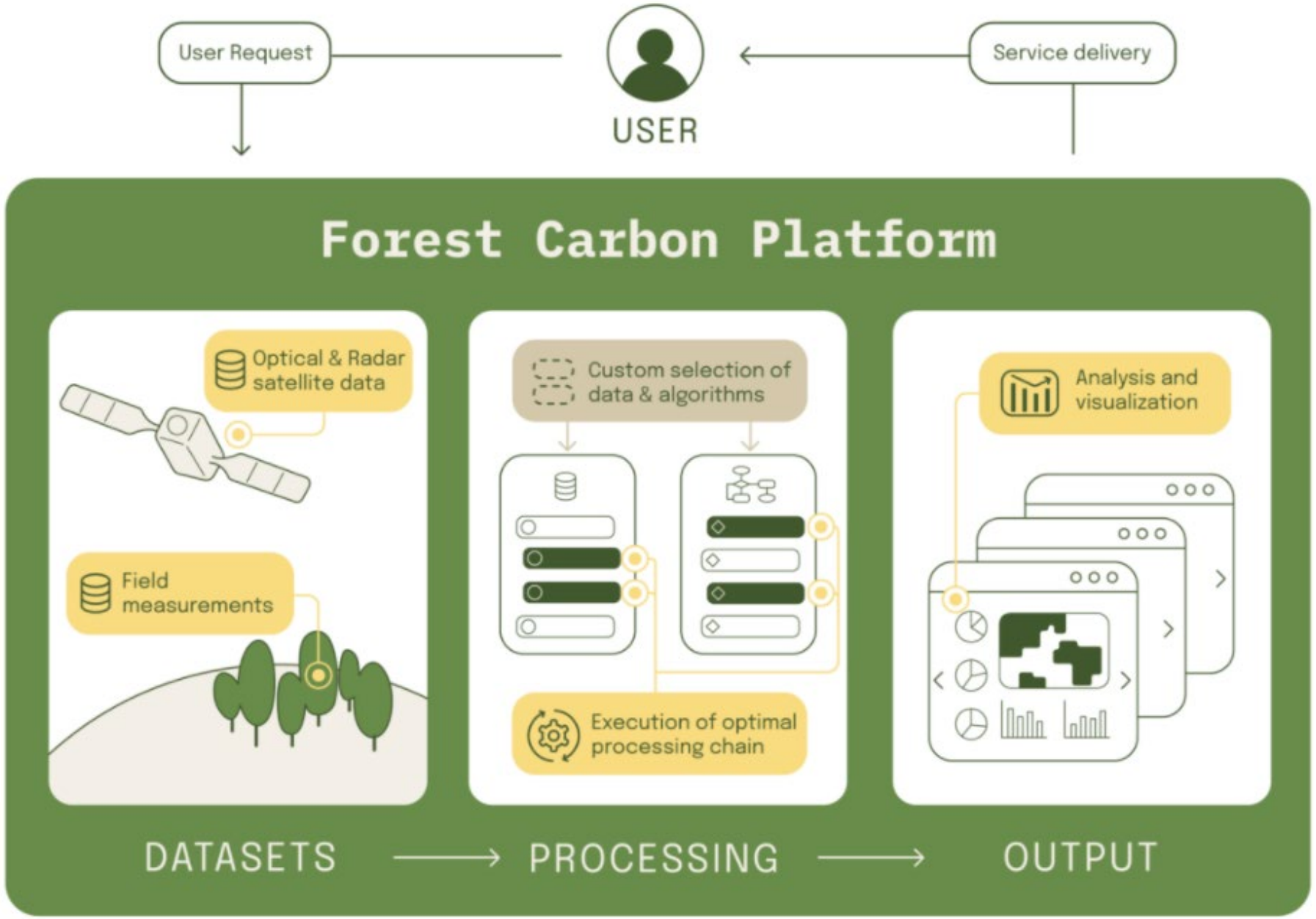
YUCA TROTE

Forest Carbon Platform Purpose

- Provision of products and information to support forest biomass and carbon monitoring:
  - Transparent approaches
  - Easily accessible cloud platform
  - Spatially explicit information using combination of in-situ and Earth observation data

Platform concept

1. Flexibility to user requirements
2. Integration of in-situ and EO data
3. Process-based forest ecosystem modelling



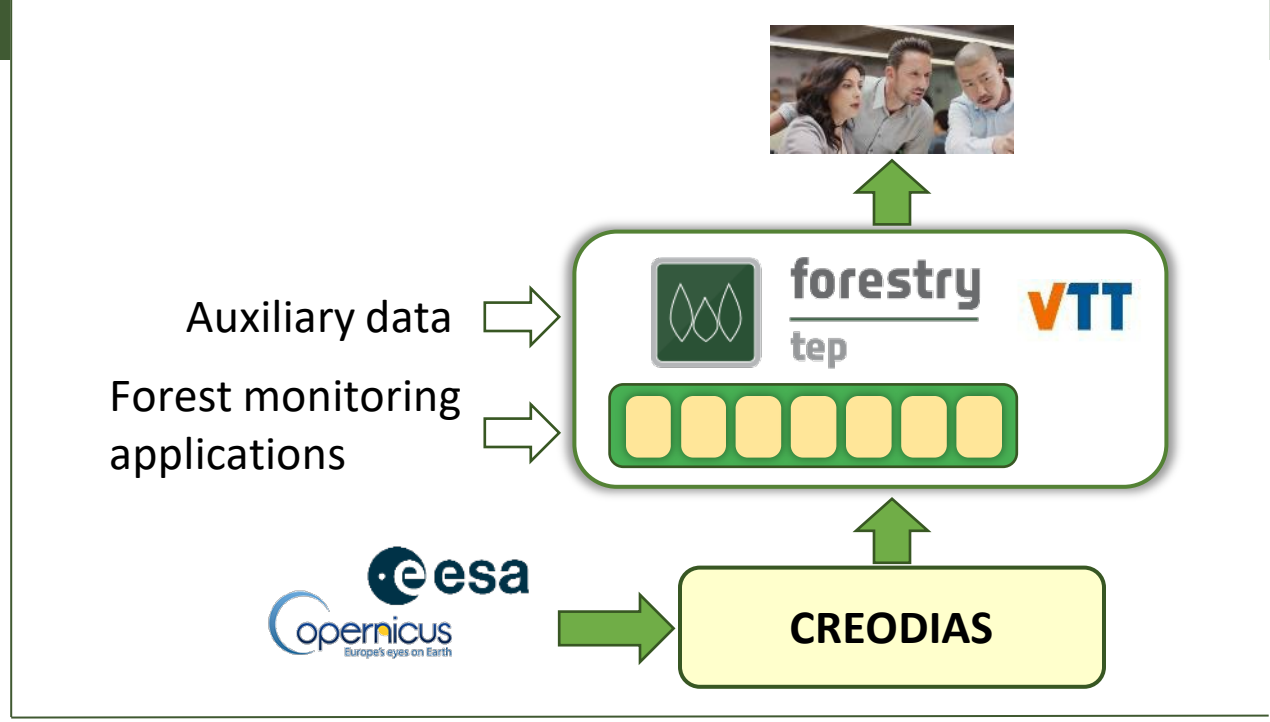
Forestry TEP

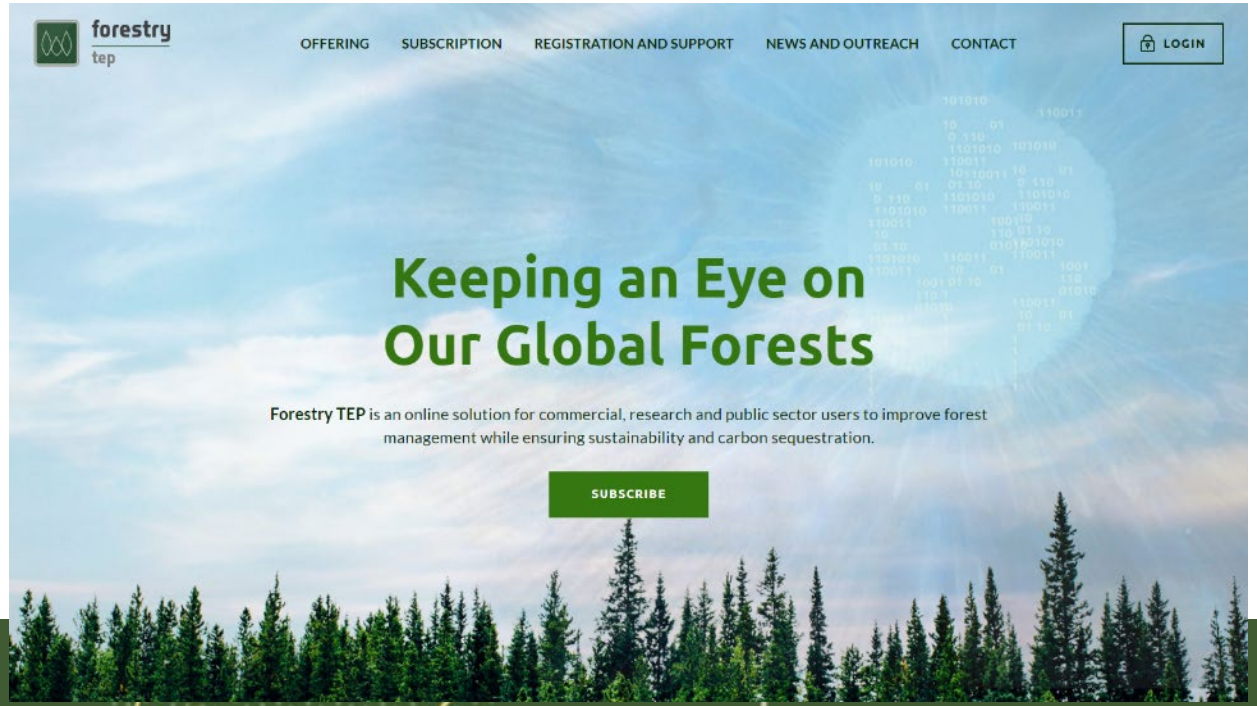
- **Platform demonstrations were implemented on Forestry TEP**

- **Ways to use Forestry TEP**
  - Use available applications that combine EO data and your own input datasets
  - Develop your own processing scripts
  - Share or license applications
  - Access or share output products

- **Two modes of usage**
  - Online web user interface
  - REST API for interconnecting between systems

- **All information available at: https://f-tep.com**





Expanding selection of methods available

Probability | *k-NN* | *Unet* *(in development)*

Forest structure variable products

Height	Diameter	Basal area
Growing stock volume	Species proportions	Site type

PREBAS
ecosystem modelling

Biomass and growth products

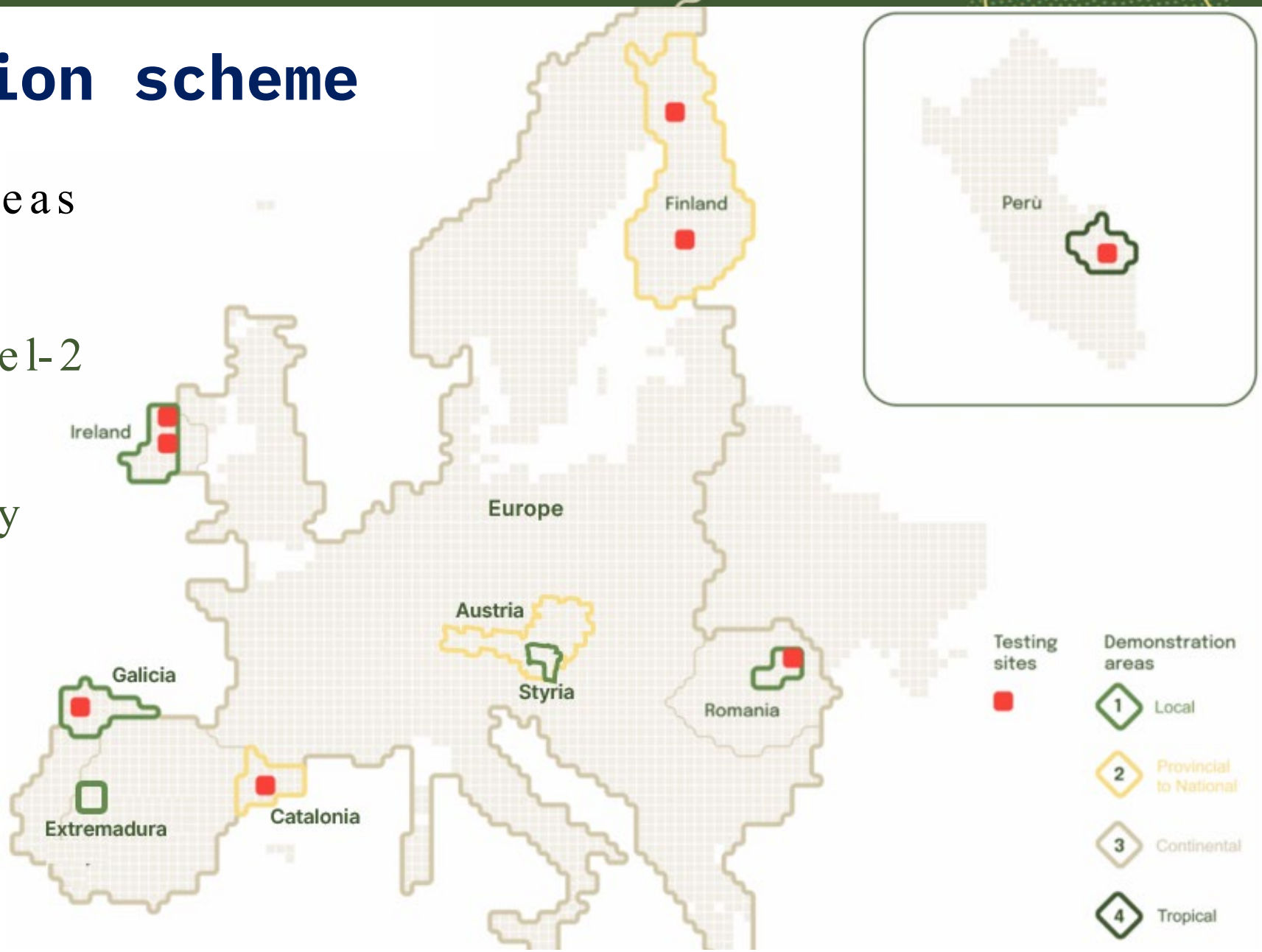
Above ground biomass	Below ground biomass	Stem volume increment

BIOMASAR

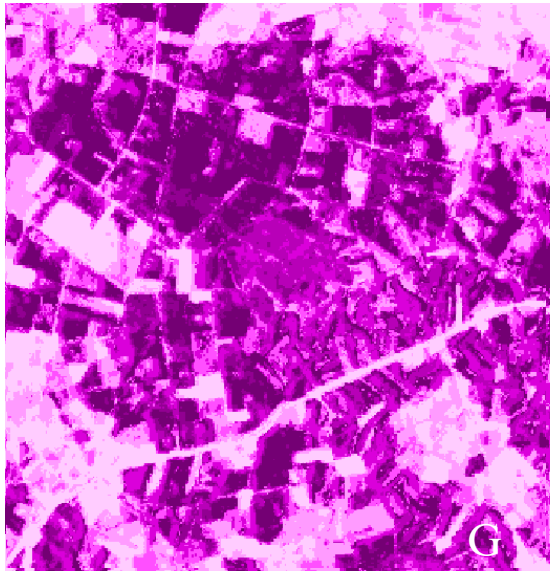
- Growing stock volume
- Above ground biomass
- Below ground biomass

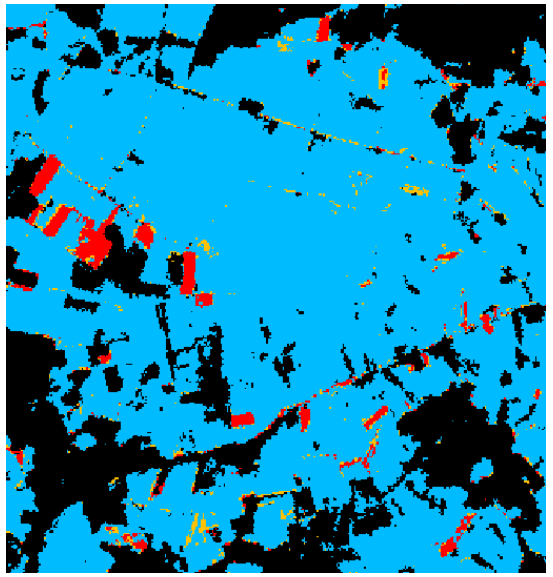
Wide demonstration scheme

- Nine demonstration areas
- Primary EO data:
  Sentinel-1 and Sentinel-2
- Coverage:
  From private company forests to European wide mapping
- Outputs:
  Over 90 products (times 2-3 years) delivered to users



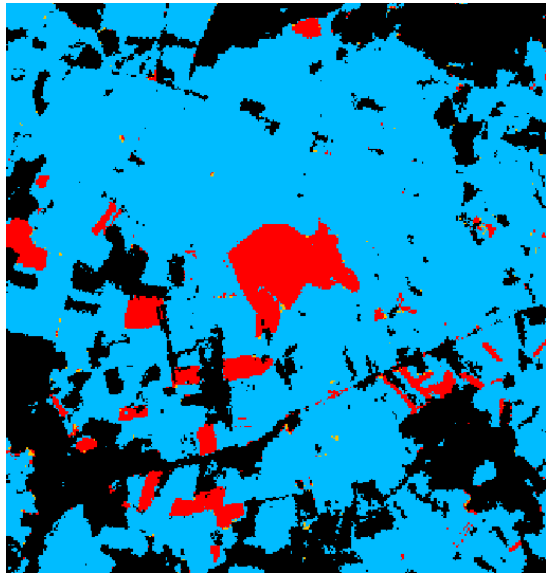
Highly detailed local data (Galicia) and…





2020

Basal area
No data (e.g. clouds)
Non-forest
Open forest
≤ 5 m^2/ha
6-10 m^2/ha
11-15 m^2/ha
16-20 m^2/ha
21-25 m^2/ha
25-30 m^2/ha
> 30 m^2/ha

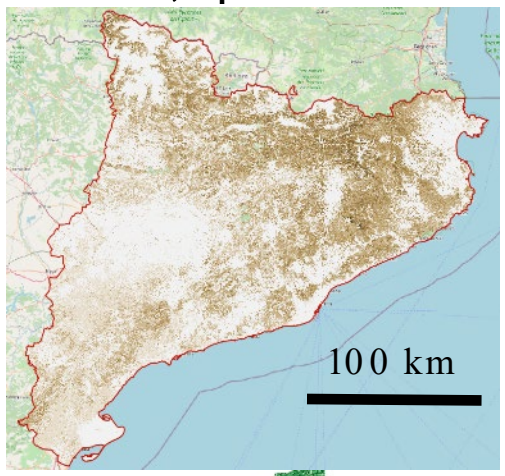


2021

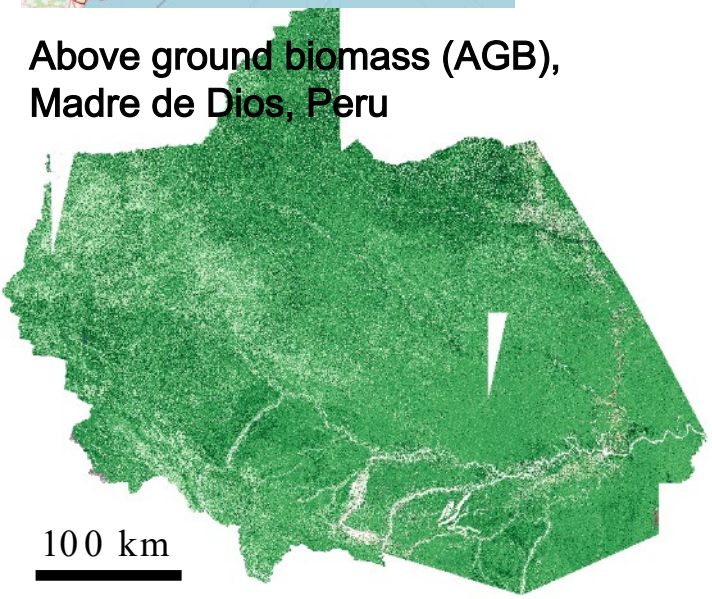
Above Ground Biomass
No data
Non-forest
0-25 t/ha
26-50 t/ha
51-75 t/ha
76-100 t/ha
101-125 t/ha
126-150 t/ha
151-175 t/ha
> 175 t/ha

…large area demonstrations.

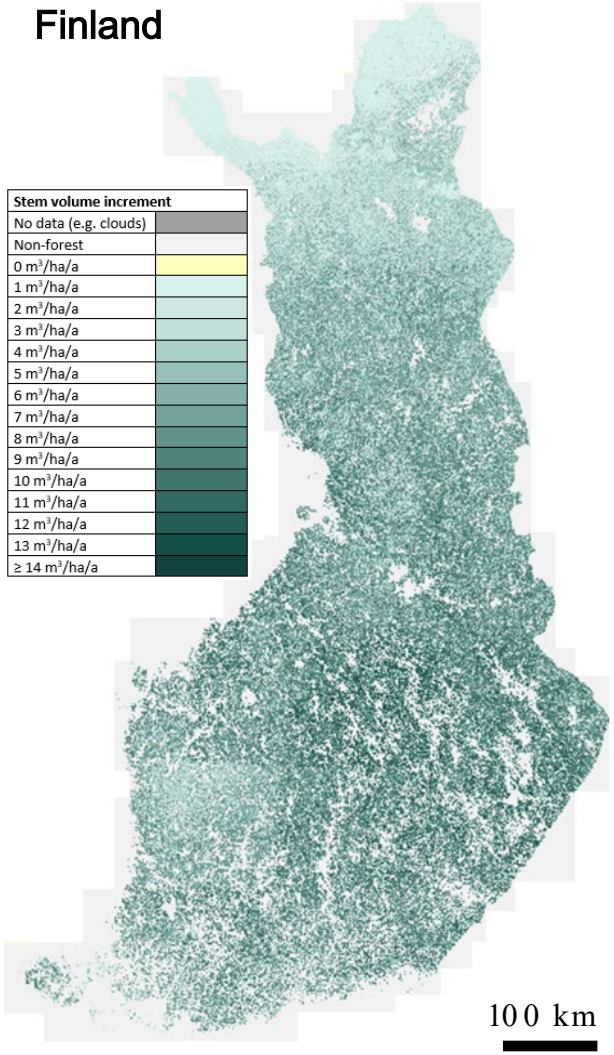
Growing stock volume (GSV), Catalonia, Spain



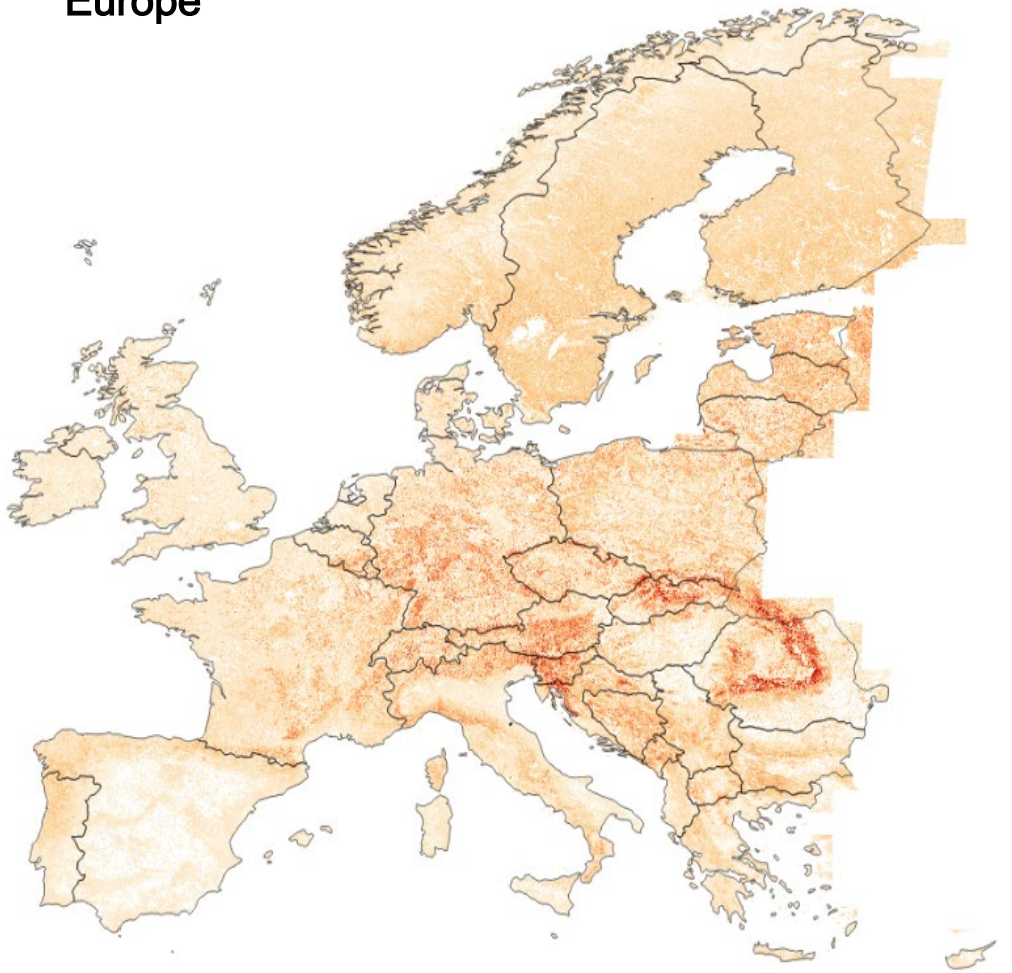
Above ground biomass (AGB), Madre de Dios, Peru



Stem volume increment, Finland

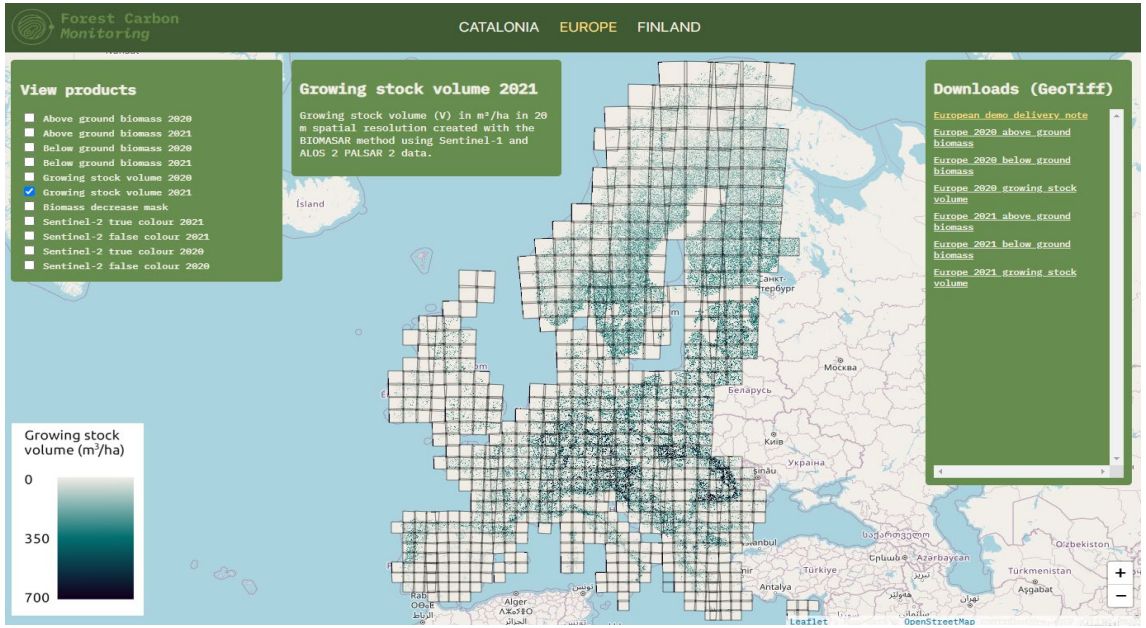


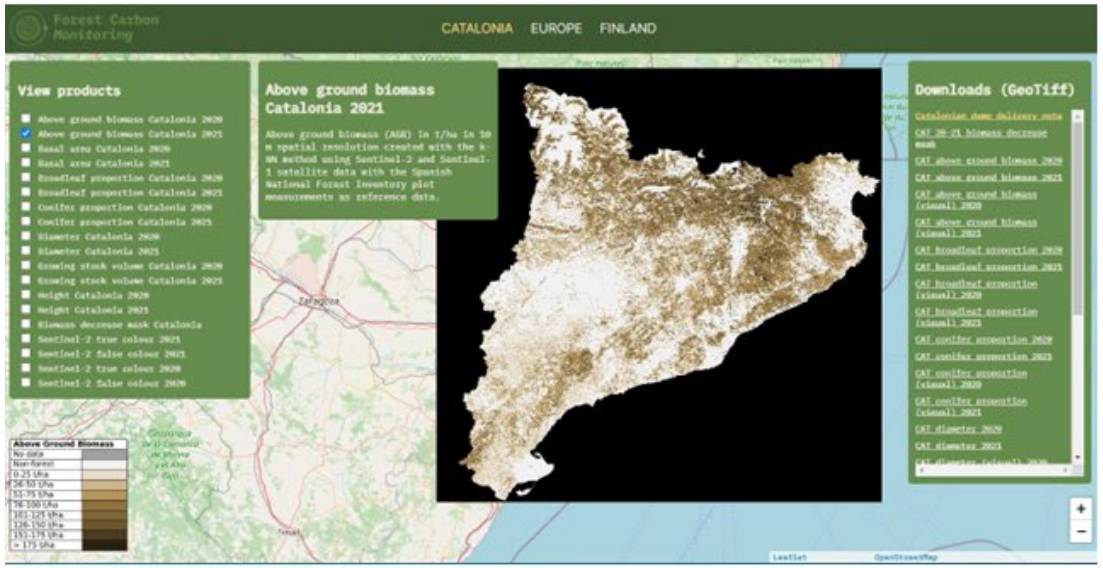
Growing stock volume, Europe



Product delivery portal

- Product viewing and downloading: https://portal.forestcarbonplatform.org/
- Austria products available at the GTIF portal: https://gtif.esa.int/





Nine user partners

DASOS CAPITAL

Generalitat de Catalunya

ence ENERGÍA & CELULOSA

Centre de la Propietat Forestal

Joint Research Centre JRC

TORNATOR

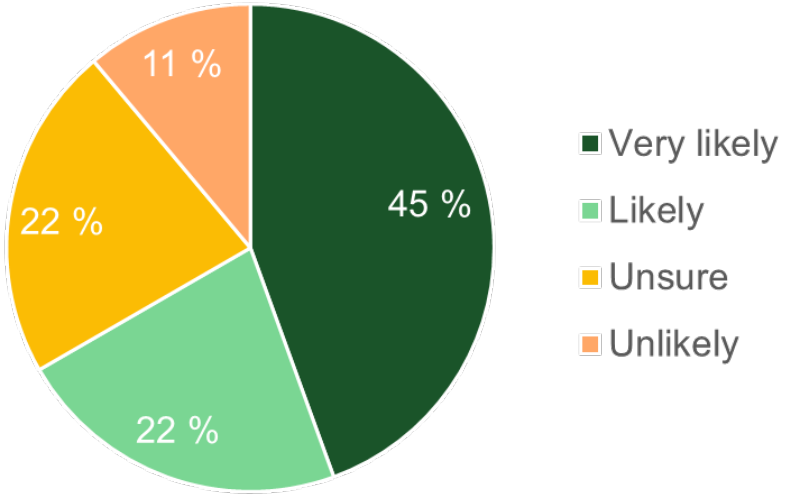
Luke NATURAL RESOURCES INSTITUTE FINLAND

Sylvestris NATURAL ENGINEERING

REPSOL Fundación

SERFOR Servicio Nacional Forestal y de Fauna Silvestre

70% of users found products potentially useful…

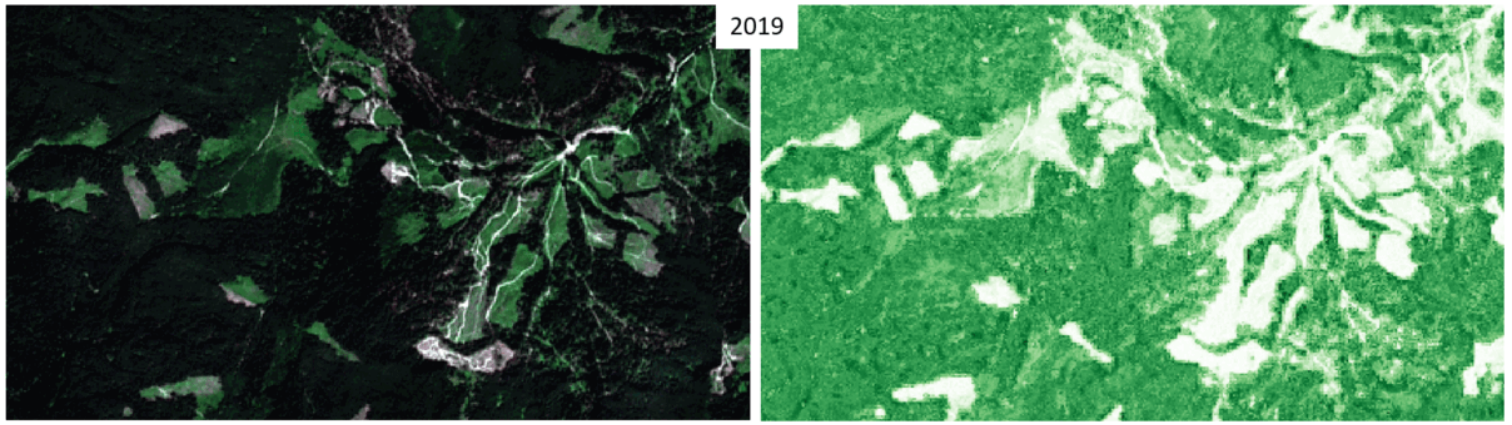


Mostly useful for…

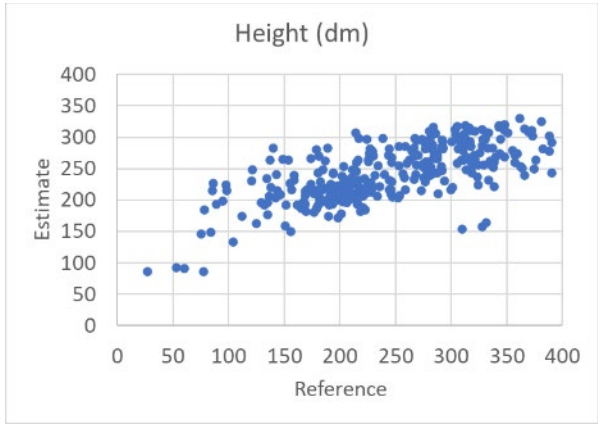
- Management planning
- Disturbance monitoring
- Voluntary carbon market reporting

Product evaluation

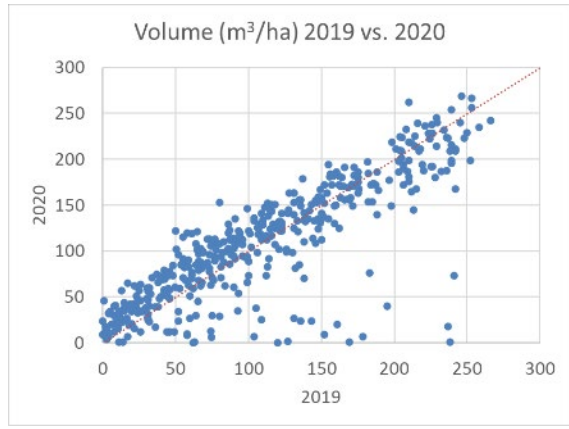
- Products evaluated with field sample plot measurements
- RMSE typically 20-60% of mean at 10 m resolution
- Systematic error typically < 4% of the mean
  - ➢ Unbiased estimation for forest holding level
- High potential for large area analysis
- Current accuracy not sufficient for stand level management decisions
- Inter-year consistency heavily dependent on the consistency of remotely sensed imagery



Annual time series of volume estimation in Romania



Height (in dm) uncertainty in Romania (plot level RMSE 22,2% of mean; Bias -0,7%)



Year-to-year consistency for growing stock volume in Galicia at stand level.

	Year	NFI plots (N)	NFI AGB mean (t/ha)	RMSE (t/ha)	RMSE (%)	Bias (t/ha)	Bias (%)
Finland	2017	7 646	62,8	37,3	59,3	-1,12	-1,78
	2019	7 295	60,7	36,8	60,6	0,52	0,86

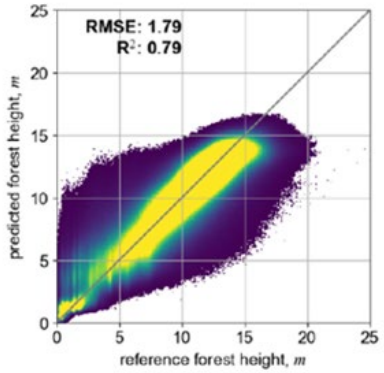
Accuracy assessment above ground biomass (AGB) maps in Finland

	D (cm)	G (m^2/ha)	H (dm)	V (m^3/ha)	BLP (%)	CP (%)	AGB (t/ha)
2020	18,5	18,5	86	92,7	61	38	82,2
2021	18,7	18,4	87	92,9	58	41	80,3

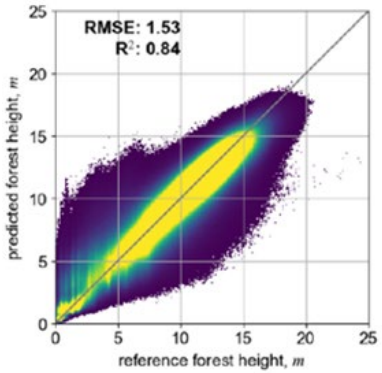
Average estimated forest parameters in 951 validation plots in Catalonia.

Future development: Unet + model transfer

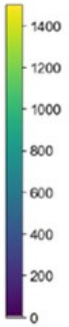
Pretraining using ALS as reference



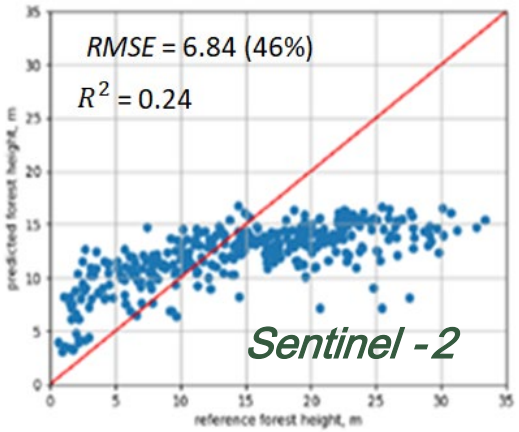
Sentinel -2

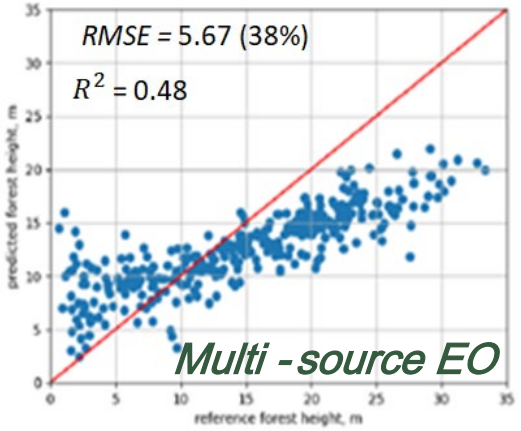


Multi -source EO

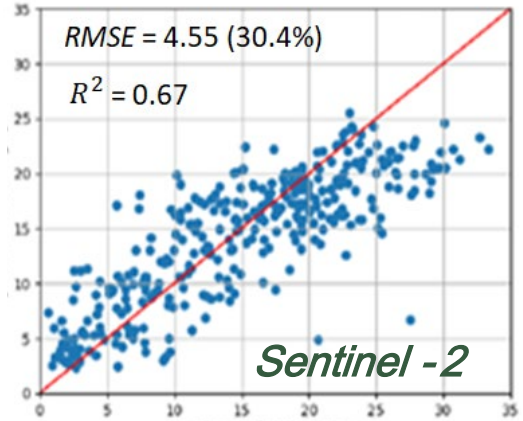


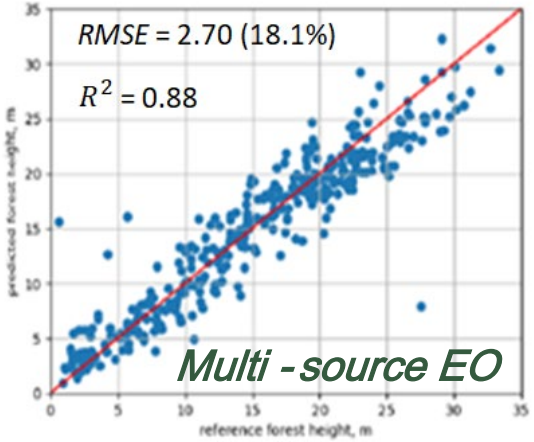
Non-finetuned model applied over target site





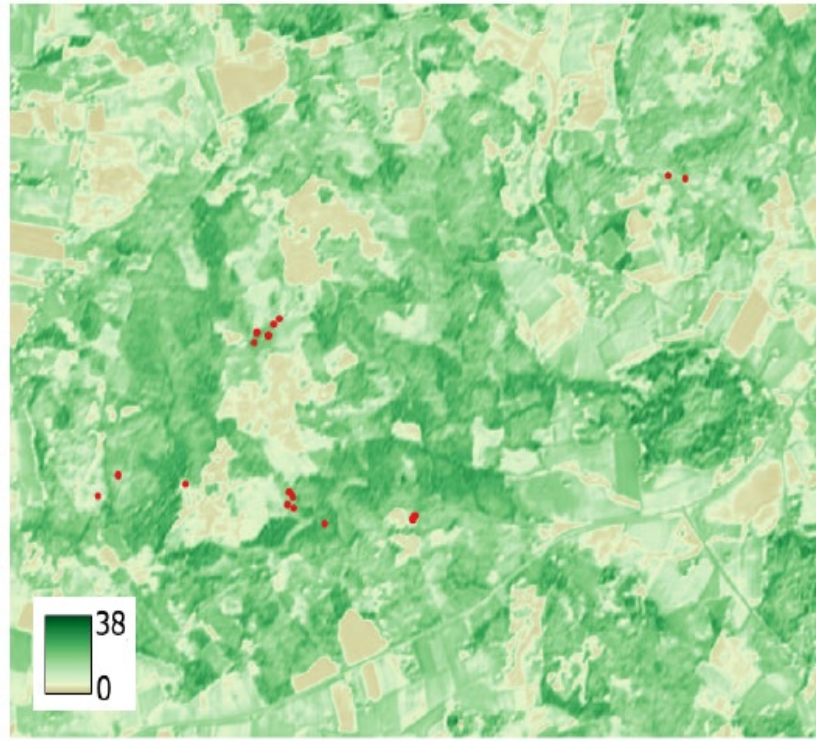
After fine -tuning with forest plots:





Multi -source EO:

Sentinel -2 & Sentinel -1 & ALOS-2 PALSAR-2 & TanDEM-X



Forest height map

Ge, Antropov, Häme, Miettinen et al. Deep learning models with transfer learning in boreal forest mapping using multi-source satellite SAR/InSAR and optical images, *Remote Sensing,* in review.

Conclusions

The platform allows effective forest structure and biomass monitoring

- Several methods for varying user needs implemented
- Unbiased estimation for large areas, with detailed information on distribution

Role of (field?) reference data is essential

- Multi-stage random sampling (incl. EO data) may alleviate work-load (see Häme et al. poster)
- Model transfer may reduce the amount of required reference data

Foreseen improvements

- Standard uncertainty derivation framework, including confidence intervals
- Improvement of pixel level accuracy (deep learning, new sensors, integration of LiDAR…)
- Data Assimilation and integration with digital twins
- Potential extension project with ESA

esa

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Thank you!

More information at:
https://www.forestcarbonplatform.org

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