NEURAL INFORMATION PROCESSING SYSTEMS

BioMassters: A Benchmark Dataset for Forest Biomass Estimation using Multi-modal Satellite Time-series

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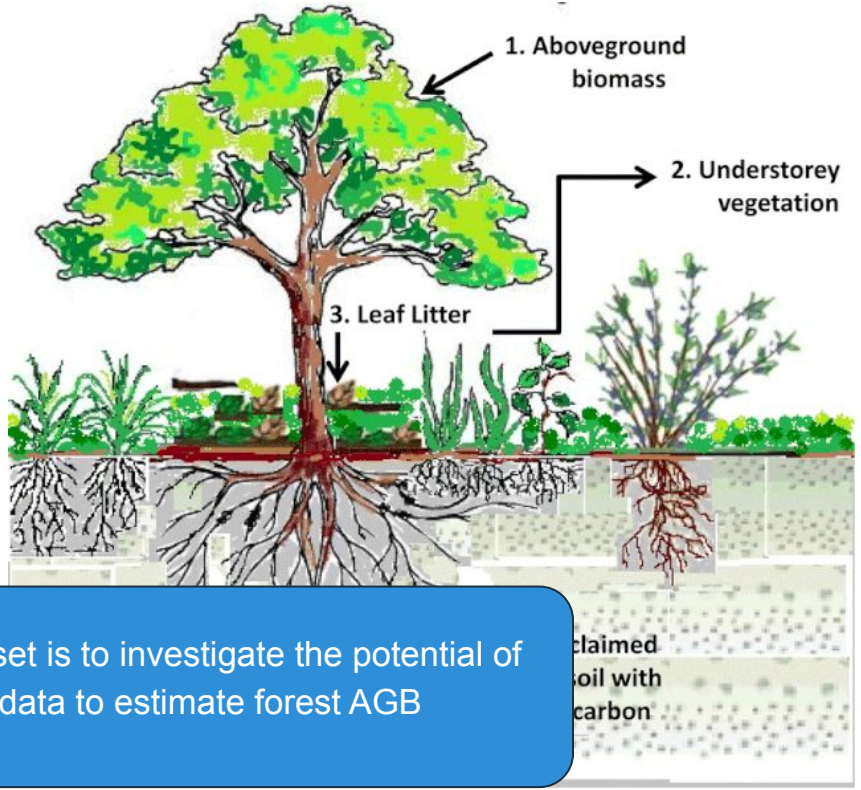
Problem Statement

- **AboveGround Biomass (AGB)** is a critical measure for understanding carbon sequestered in forests.
- Current airborne and terrestrial methods are expensive and time-consuming, with limited frequency.
- Satellite products are mainly based on physical based models and provide low spatial resolution AGB estimation.
- No deep-learning ready dataset available .



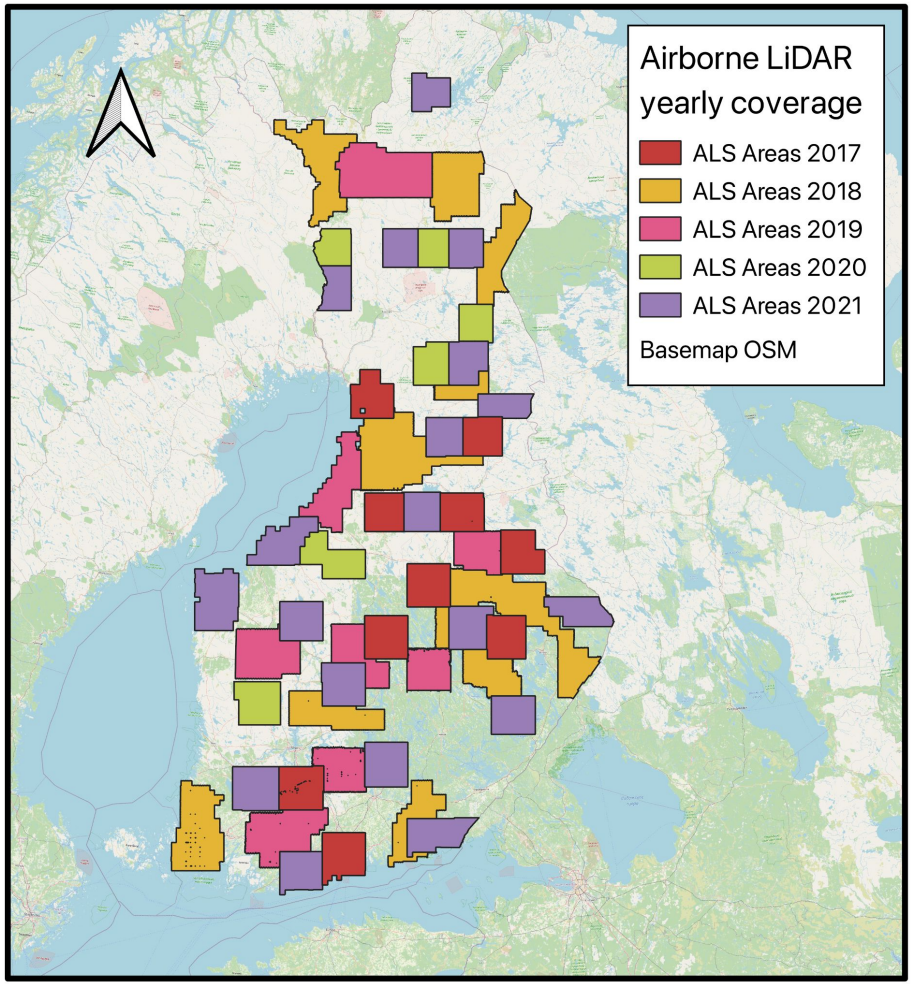
The aim of the "BioMassters" benchmark dataset is to investigate the potential of multi-modal and multi-temporal satellite data to estimate forest AGB

Carbon Stock Schematic by Rimi Das and Subodh Kumar Maiti is licensed under CC BY 4.0.

Biomasster Dataset:

Reference Airborne LiDAR data

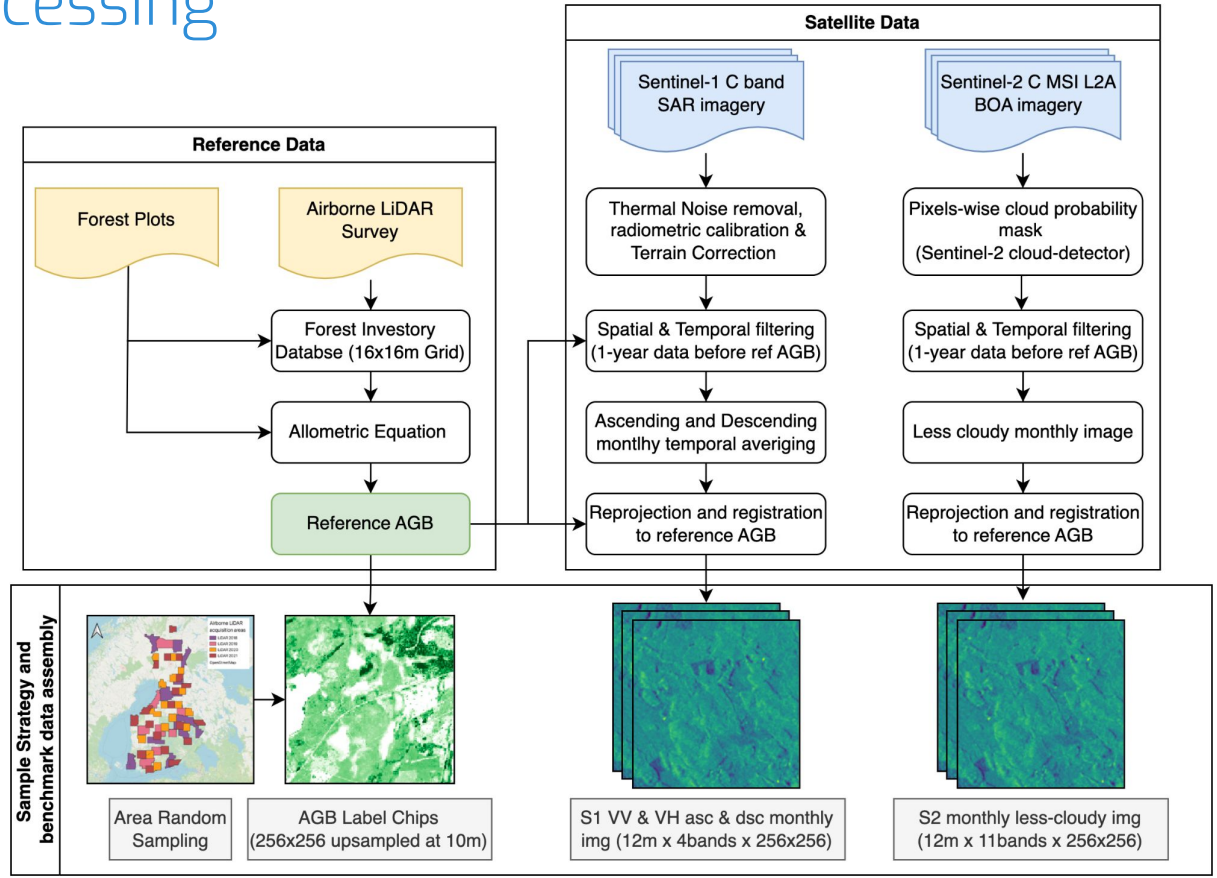
- LiDAR acquisition from 2017 to 2021 covering entire Finland
- Open Data by the Finland Forest Centre (CC-BY-4.0)
- Data in 16 m × 16 m regular grid including tree attributes e.g., tree species, number of trees, trunk diameter, tree height, and more
- Calibrated allometric equation to compute AGB
- **Approx 13000 patches,** with patch size 256 × 256 at 10 m resolution



Satellite Data Pre-Processing

- Two Modalities:
  - Synthetic Aperture Radar (SAR) Sentinel-1
  - Multi-spectral Sentinel-2 (wavelengths from 400 to 2400 nm)

- Multi-temporal images:
  - Yearly time series
  - One image per month
  - Few missing images for some months (e.g. Dec. 2019)



The BioMassters Competition

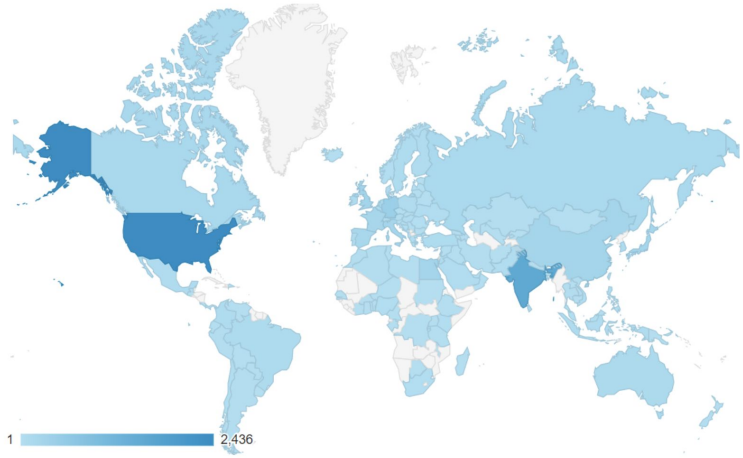
Hosted by Driven Data & supported by MathWorks

Quick facts:

- 976 participants
- 1049 submissions
- 90 active teams

Holdout test set, 30 % from 2018, 2020, and 2021, and 20 % from 2019 data

Metric: Average RMSE in tonnes per pixel

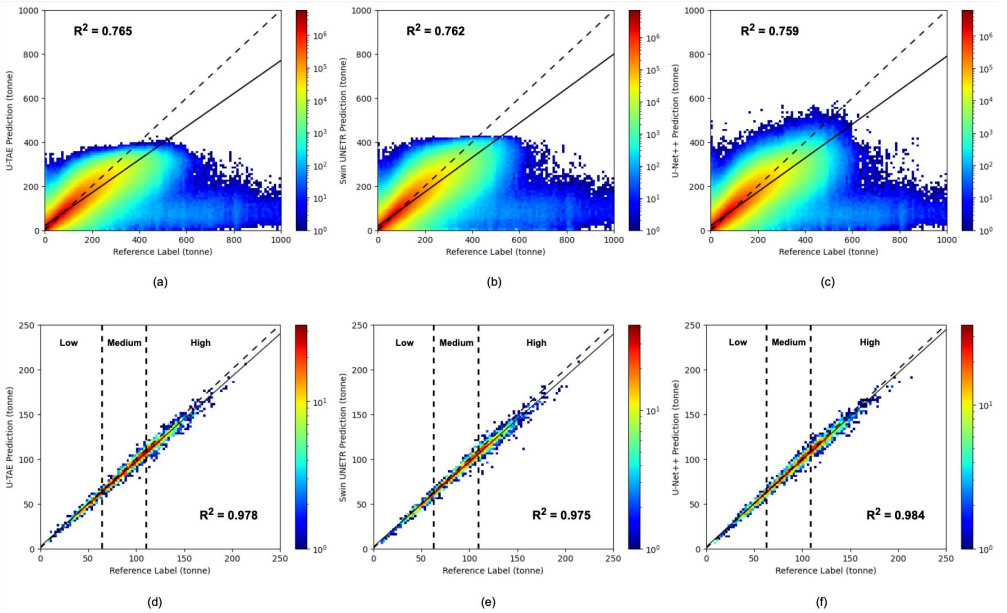


Top-Three Model Results

Top-three models are an adaptation of the following architectures:

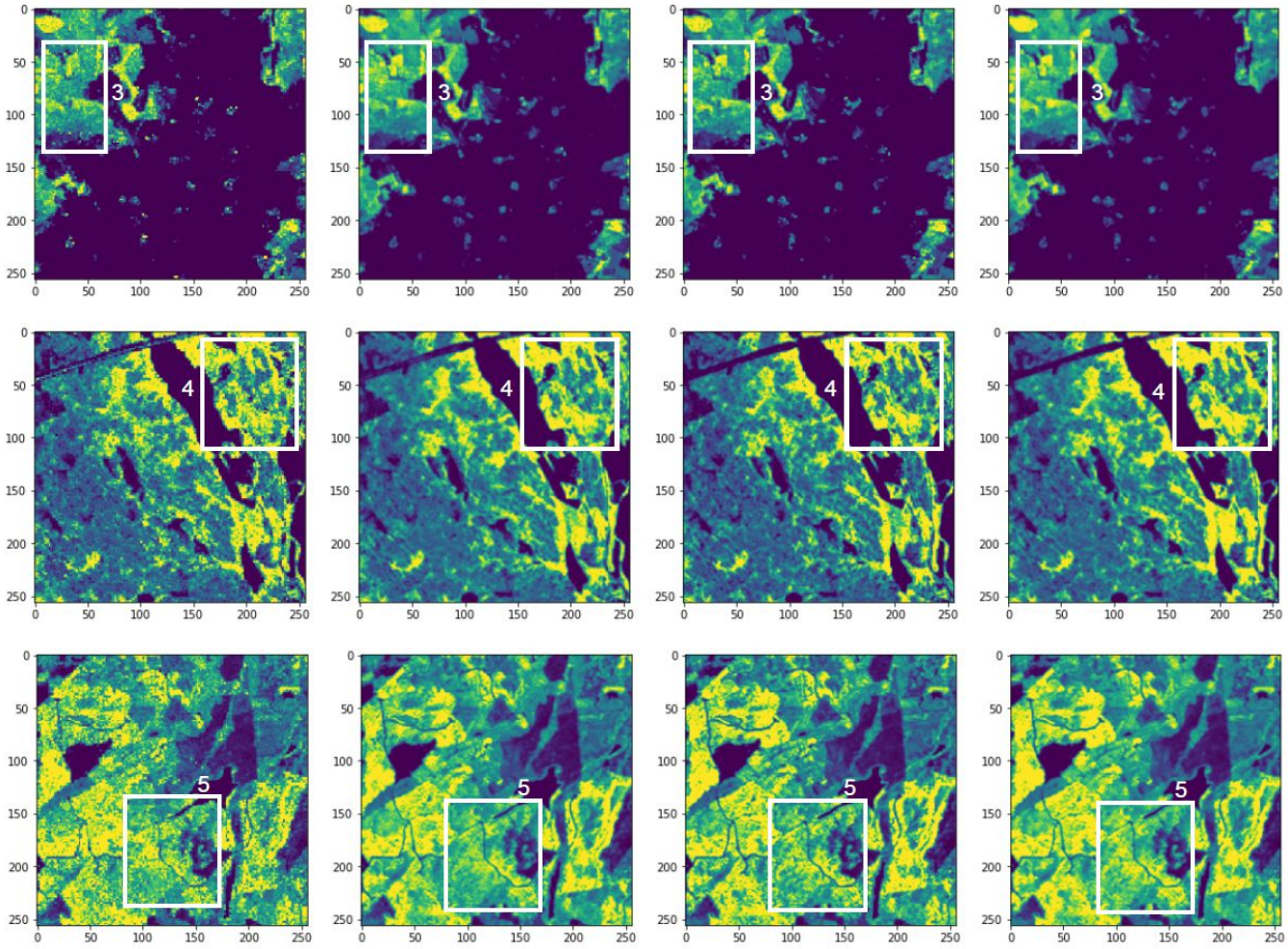
1. U-TAE (U-Net Temporal Attention Encoder)
2. Swin UNETR (Swin U-Net TRansformer)
3. U-Net++

Implementations: https://github.com/drivendataorg/the-biomassters



Method	Low Density	Medium Density	High Density	Overall
Average RMSE ± Std.				
U-TAE [14]	**15.24** ±4.29	**28.55**±9.89	**37.59**±11.02	**27.49**± **12.14**
Swin UNETR [19]	15.25 ±4.41	28.61±9.85	37.64±11.09	27.53± 12.16
U-Net++ [50] Ensembled	15.60 ±4.35	29.01±9.80	38.04±10.93	27.92± 12.11
Average Bias ± Std.				
U-TAE [14]	0.054 ±15.84	0.37±30.22	1.76±39.14	0.64± 30.04
Swin UNETR [19]	0.43 ±15.88	0.92±30.25	2.37±39.17	1.16± 30.08
U-Net++ [50] Ensembled	-0.37 ±16.19	-0.62±30.62	0.49±39.58	-0.28± 30.43

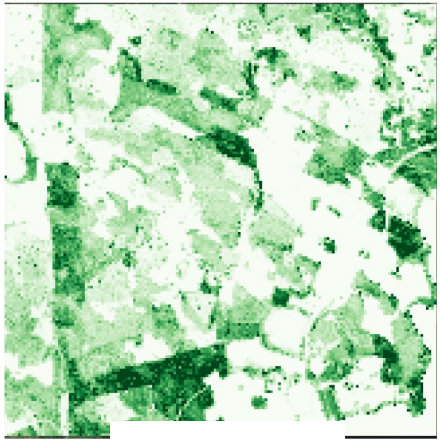
Result Samples



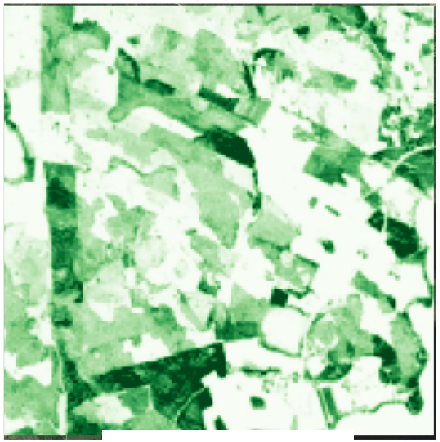
Conclusions & Future Prospects

- We released the first deep-learning ready dataset for AGB estimation from multi-modal and multi-temporal satellite time series
- We compare the obtained results with existing globally available satellite products derived from Sentinel images
- We show the potential of deep-learning model to obtained accurate estimation of the AGB at higher spatial resolution (10m vs 100m)
- The dataset could be extended to other regions to investigate the generalization capability of the model

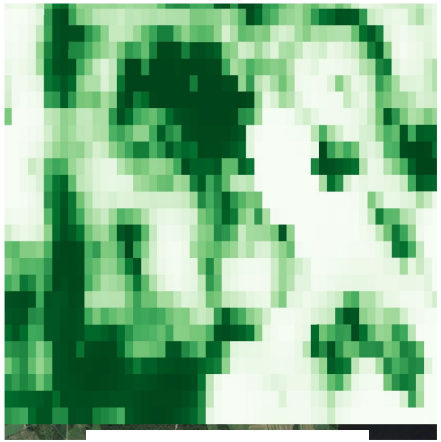
VHR Basemap



Reference AGB



U-TAE Prediction



ESA AGB Product