Latvian State Forest Research Institute “Silava”

Tree biomass changes over the last century in old–growth forest stands: case from Slītere National Park

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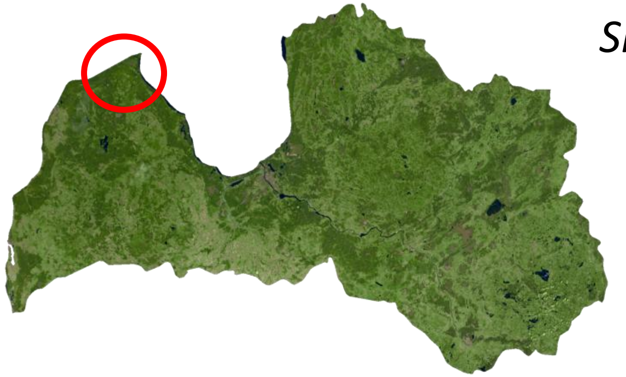
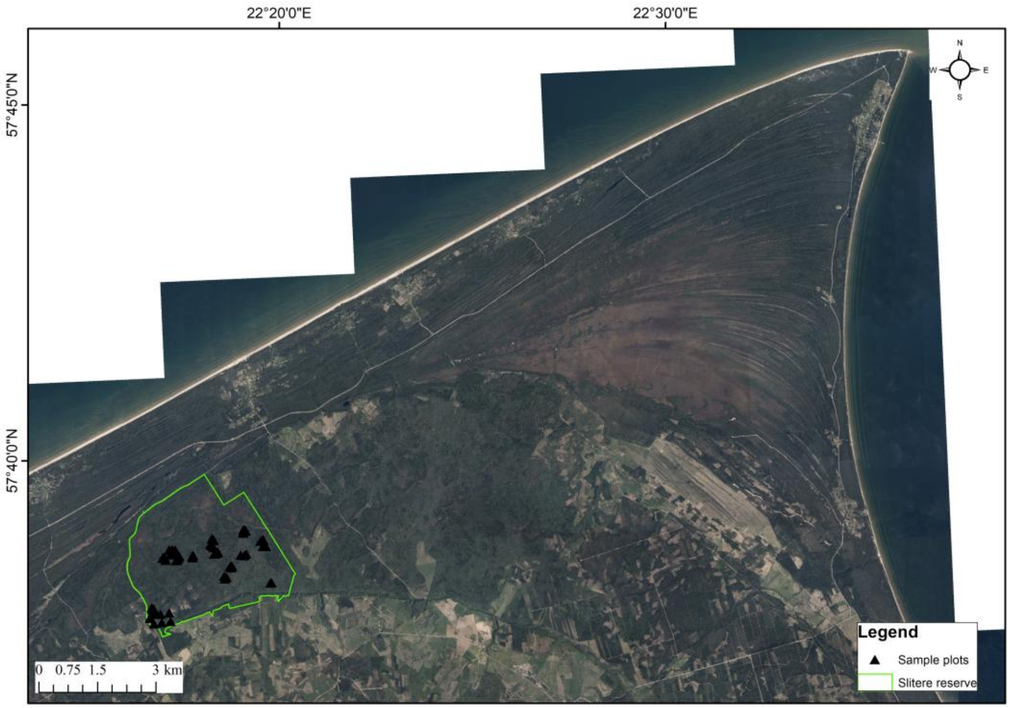
Slītere Nature Monument forest inventory from 1922



Slītere - high, forest-covered cliff –Livonian origin

Total area of Slītere National park – 16 360 ha

Old Monument – 1 100 ha



Key historical disturbances over the past centuries:

1824	Large wind storm
1838	Drainage of bog Baži
Mid-1800s	Charcoal production
1918	Forest fire
1967 and 1969	Large wind storm (~970 ha)
1992	Forst fire

Research aim

To **assess** the long-term changes in **tree biomass** (live and dead trees) over a last century with no human intervation in the forests of Slītere Nature Monument.

1922 **1963** **1973** **2010** **2025**

Years

Materials and methods

Forest inventory map 1992

Forest inventory map 1992

- Wetland
- Scots pine (age group 5, 6 – mature/overmature stands)
- Norway spruce (age group 5 – mature stands)
- Birch (age group 1,2 – mature stands)
- Burned area
- Meadow
- Alder (age group 4 – mature stands)
- European ash (age group 4 – mature stands)

Forest inventory data 1963, 1973, 2010

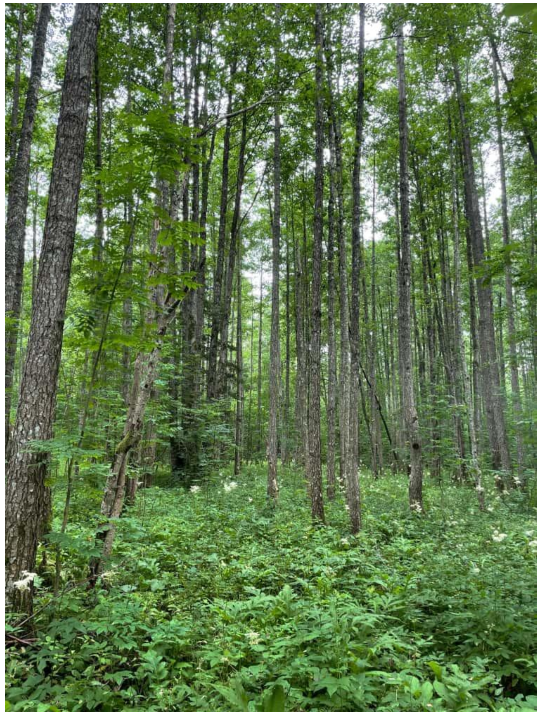
Before wind storm in 1969, forests in Old Monument dominated by Norway spruce (44%), followed by Scots pine (33%), birch (13%), black alder (7%).

Bāders et al. 2017. Natural succession of Norway spruce stands in hemiboreal forests: case study in Slitere National Park, Latvia. Baltic Forestry 23(2): 522-528.

Field work in 2025

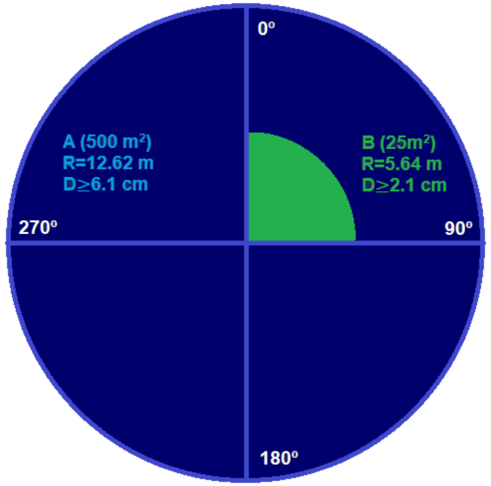
In total measured 65 sample plots in 11 forest stands in 5 groups.

Norway spruce forest stands on dry and wet mineral soils (Dm, Vr, Vrs, Dms).
Birch stands on dry and wet mineral soils (Dm, Vr, Dms, Vrs).
Black alder on wet mineral soils (Dms, Vrs).
Scots pine on wet mineral soils (Gs).



Sample plot: part A
R=12,62 m; 500 m^2
Tree dbh ≥ 6,1 cm

Sample plot: subplots B
R=5,64 m; 25 m^2
Tree dbh ≥ 2,1 cm



Field data collection in 2025 - deadwood

Decay class	Description
1	Raw wood. Trees that recently died, not yet dried up – with bark, branches - may be leaves/needles attached
2	Solid dead wood. Weakly decayed. The stem has a hard exterior surface, without bark.
3	Somewhat decayed wood. The volume of the stem consists to 10–25% of soft wood. Knife penetrates for 1-2 cm.
4	Decayed dead wood. The volume of the stem consists to 26–75% of soft or very soft wood
5	Very decayed dead wood. The volume of the stem consists to 76–100% soft or very soft wood.

Decay classification for deadwood modified from Sandström et al. (2007).

- Deadwood types:
  - Lying deadwood
  - Dead standing trees
  - Snags (dead trees with broken tops)

Sandström F., Petersson H., Kruys N., Ståhl G. 2007. Biomass conversion factors (density and carbon concentration) by decay classes for dead wood of Pinus sylvestris, Picea abies and Betula spp. in boreal forests of Sweden. Forest Ecology and Management, 243(1), 19-27.

Tree biomass and deadwood mass calculations

Live tree biomass for individual trees was calculated based on local biomass equations (dbh, tree height, tree species) according to Liepiņš et al. (2017, 2021).

Weighted means of C content for forest stands dominated by Norway spruce, Scots pine, birch or European aspen in Latvia (Bārdule et al. 2021). Carbon content 0,5 for other tree species (Eggleston et al. (2006)).

Values	Weighted Mean C Content for Forest Stands, $g \cdot kg^{-1}$			
	Stands Dominated by Norway Spruce	Stands Dominated by Scots Pine	Stands Dominated by Birch	Stands Dominated by European Aspen
Average ± S.E.	525.6 ± 0.1 [a]	531.3 ± 0.1 [b]	521.4 ± 0.1 [c]	512.7 ± 0.1 [d]
Median	526.4	532.1	521.4	512.0
Range	518.7–529.6	518.4–533.2	513.9–527.9	509.0–523.4

The individual deadwood mass and carbon stock were estimated from the volume, decay-class-specific density, and carbon content of the main tree species in hemiboreal forests, following Köster et al. (2015) and tested in Latvia (26 sample plots).

Liepiņš J. et al. (2017) Equation for estimating above- and belowground biomass of Norway spruce, Scots pine, birch spp. and European aspen in Latvia. *Scand J For Res* 33(1).
Liepiņš, J., Liepiņš, K., & Lazdiņš, A. (2021). Equations for estimating the above- and belowground biomass of grey alder (*Alnus incana* (L.) Moench.) and *common alder* (Alnus glutinosa L.) in Latvia. *Scand J For Res* 36(5), 389–400.

Bārdule A. et al. (2021) Variation in Carbon Content among the Major Tree Species in Hemiboreal Forests in Latvia. *Forests* 12.

Eggleston et al. (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories. *http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.*

Köster K. et al.. (2015) Dead wood basic density, and the concentration of carbon and nitrogen for main tree species in managed hemiboreal forests. *For Ecol Manage* 354.

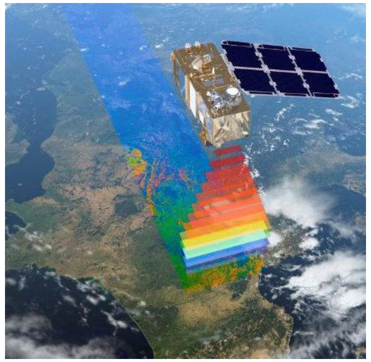
Above-ground biomass (AGB) estimation with remote sensing

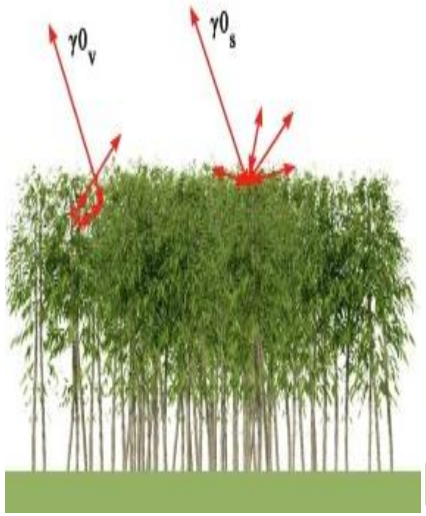
Remote sensing data pre-procesing with SNAP, ArcGIS and R

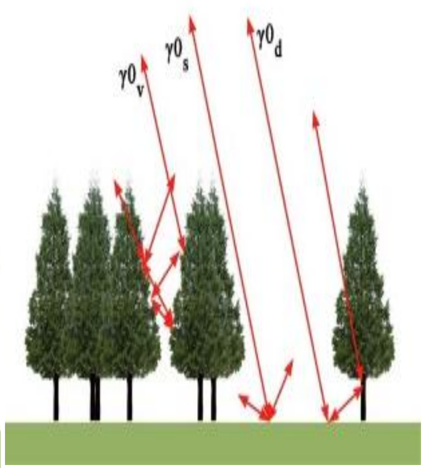
Optical data: Sentinel-2 (Bands B2–B4, B8)
Radar data: Sentinel-1 (VV & VH backscatter and
Derived indices and metrics:

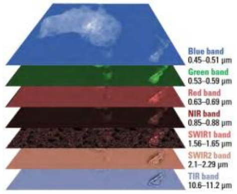
- **Vegetation indices:** NDVI, SAVI, ARVI, RARSc
- **GLCM texture metrics** (5×5 moving window) **:** contrast, homogeneity, entropy, correlation, variance, etc.

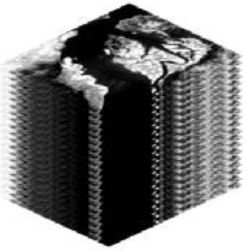
Feature matrix:
65 predictor variables (optical, radar, and texture features)
Target variable: **AGB field**







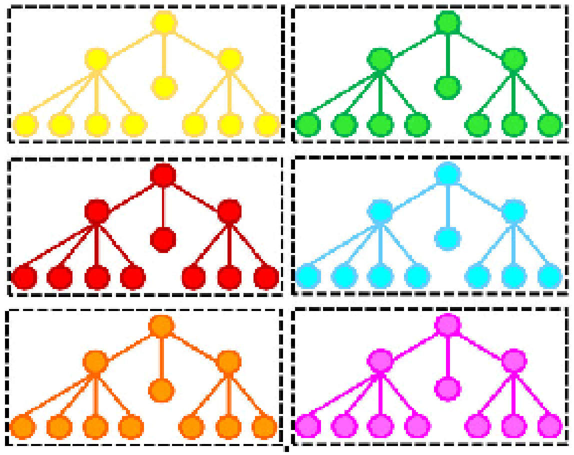


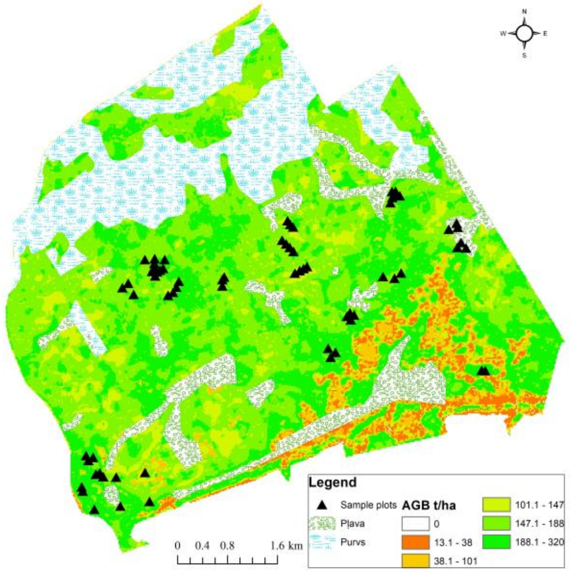


Above-ground biomass (AGB) Estimation with remote sensing (2)

Modeling Approach
Algorithm: Random Forest
Environment: Python / scikit-learn
Steps:

1. Split dataset into **training (80%)** and **testing (20%)** sets
2. Optimize hyperparameters using **GridSearchCV** with 5-fold cross-validation
    - max_depth: [3, 5, 10, 20, None]
    - n_estimators: [100, 200, 500]
    - max_features: ['sqrt', 'log2', '1']
    - min_samples_split: [2, 5, 10]
    - min_samples_leaf: [1, 2, 4]
3. Select the **best model** (lowest Mean Squared Error)
4. Evaluate model performance using:
    - **R^2, MSE, RMSE, RMSE %**
    - Scatter plot: *Observed vs Predicted AGB*





Data analysis

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lmer(AGB~Year+(1|Forest stand),data=Slitere)
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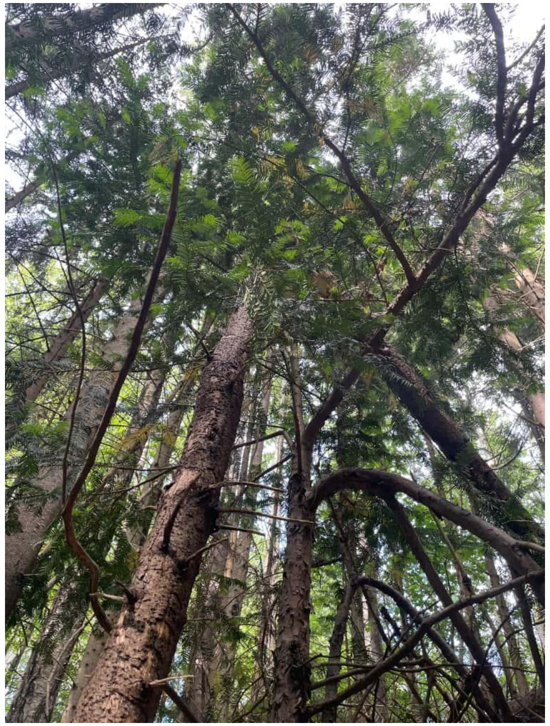
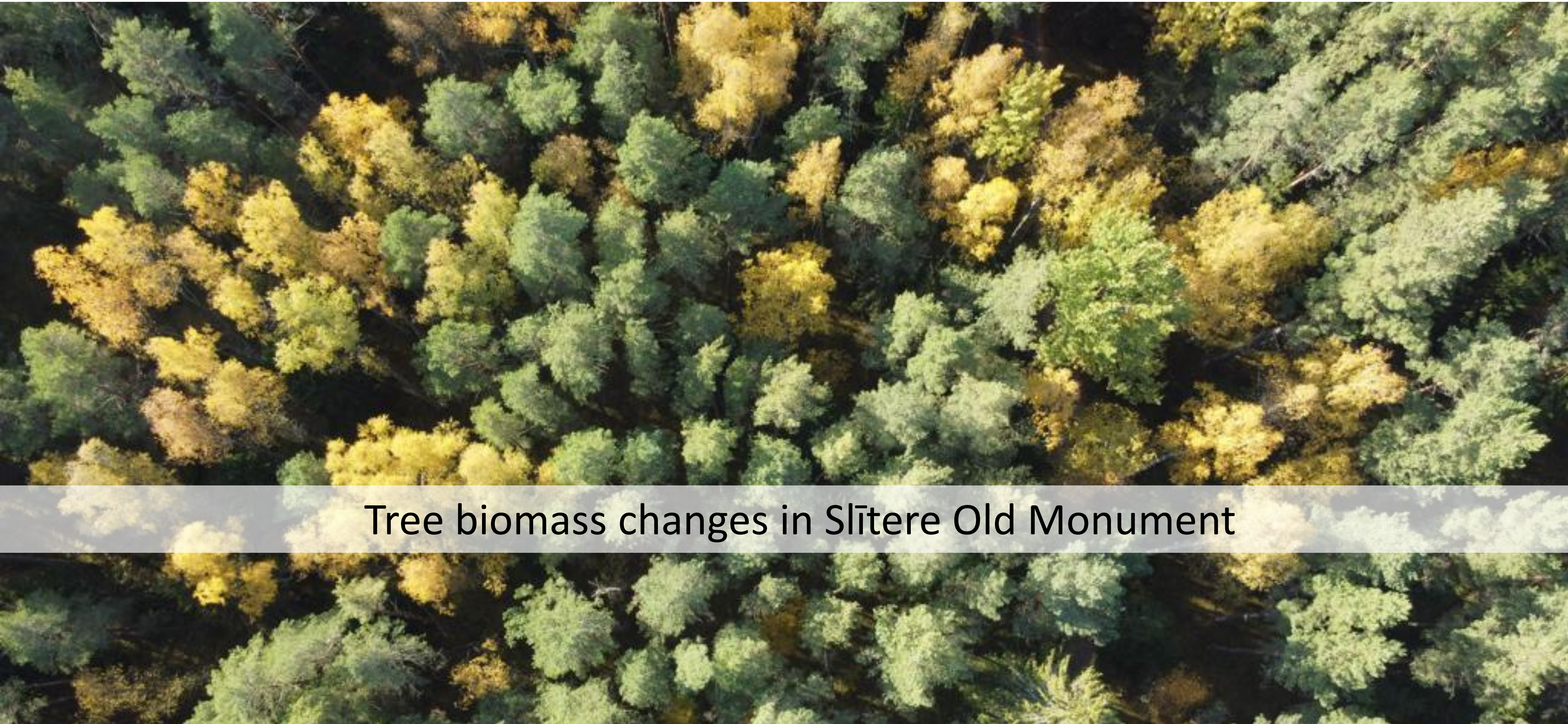
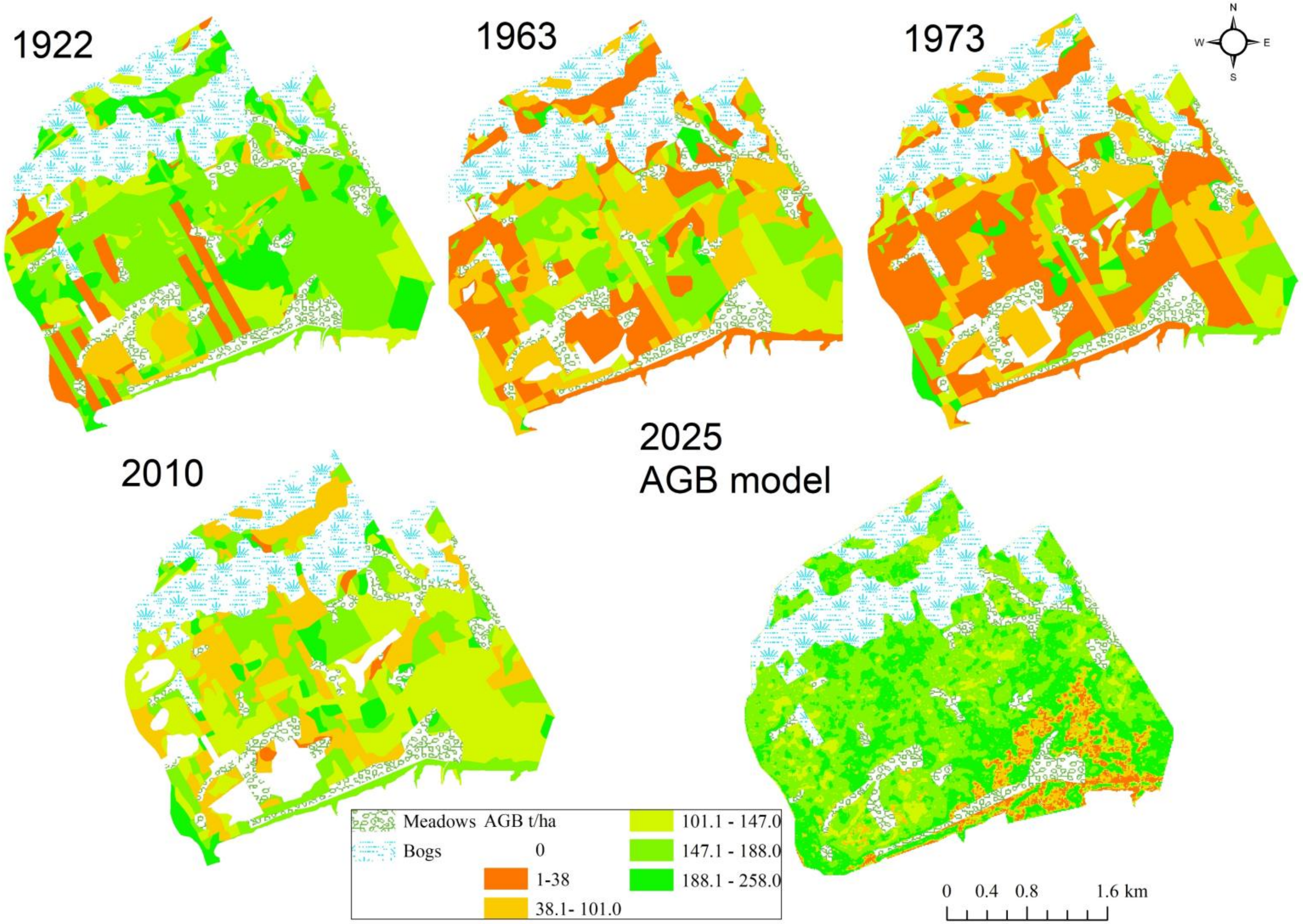



Results



Tree biomass changes in Slītere Old Monument

Above-ground tree biomass, t / ha

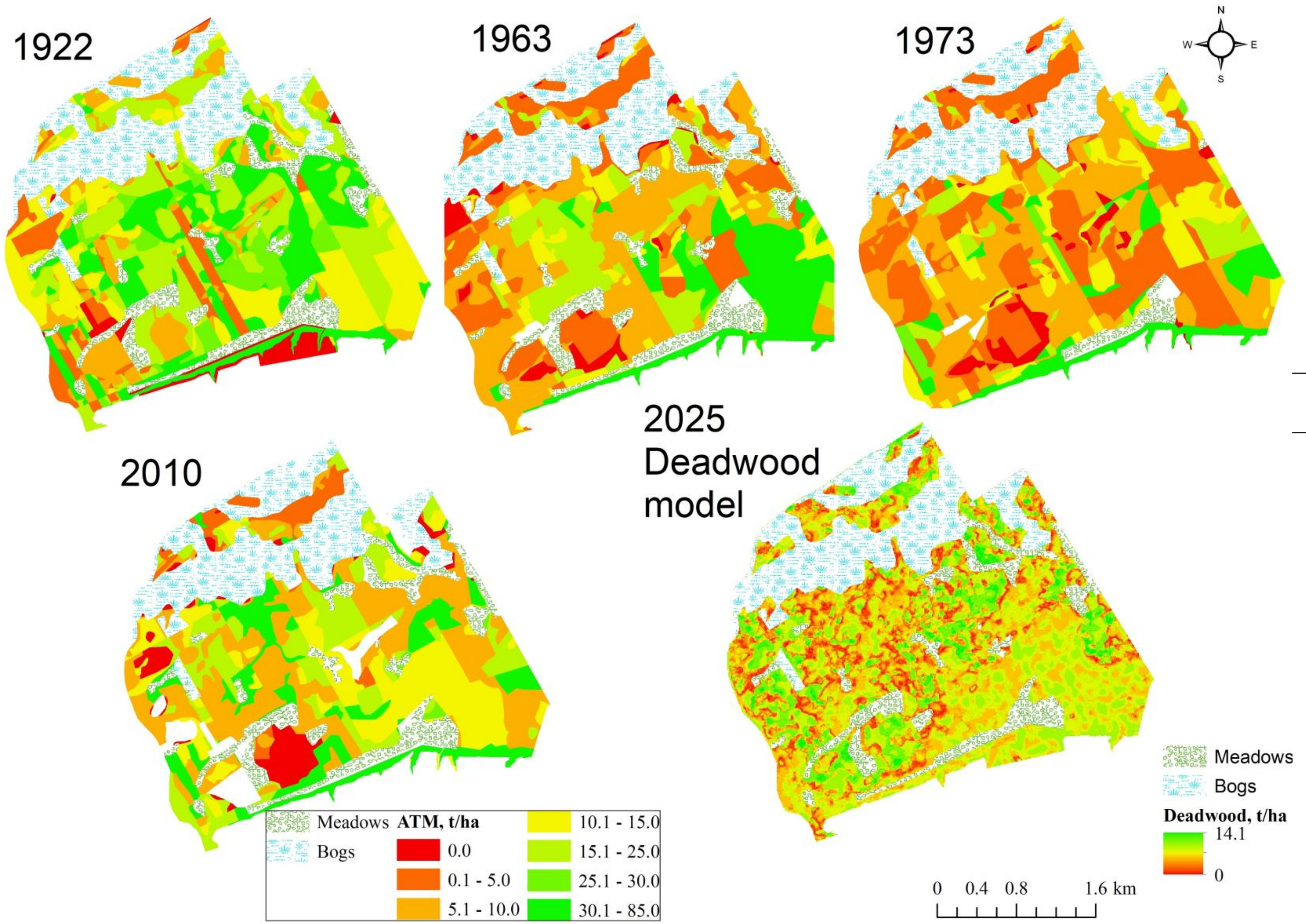


1963 – before wind storm
1973 – after wind damage

Above-ground biomass (AGB) estimates (1922-2025)

Year	Mean ABG	CI
1922	151	± 24.3
1963	112	± 24.3
1973	68	± 24.2
2010	150	± 24.4
2025	203	± 24.6

Deadwood (dead standing trees, snags) changes, t / ha



Deadwood mass estimates (1922-2025)

Year	mean	CI
1922	22.6	± 3.5
1963	13.5	± 3.6
1973	7.1	± 3.6
2010	17.1	± 3.6
2025	7.7	±3.7

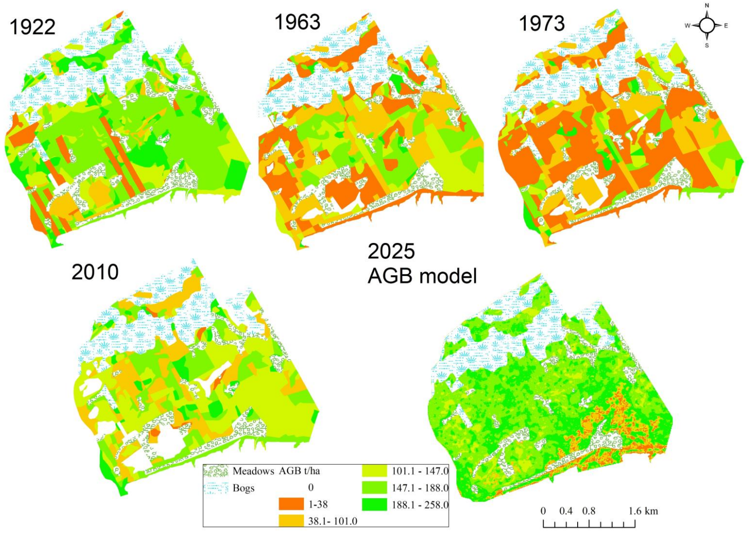
Field work estimations 2025: carbon stock, t C ha^{-1}

Mean carbon stock, t C ha^{-1}

Disturbance effect	Tree biomass	Deadwood
Inside windstorm area	125,5	8,8
Outside the damaged area	155,3	7,4

Summary

- Above-ground biomass (ABG) were significantly different between most of the inventory years – high variability.
- 1969 windstorm caused a major drop in AGB, but by 2010, the biomass was simalar to estimation from 1922.
- Deadwood assessment using remote sensing methods remains challenging and requires also ground-true data.



MEŽA ATTĪSTĪBAS FONDS

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Thank you!

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