Experimental Silvicultural Treatments and their Influence on Forest Structure-Biodiversity Relationships

using Multi-source Remote Sensing and Multi-taxa Biodiversity Data

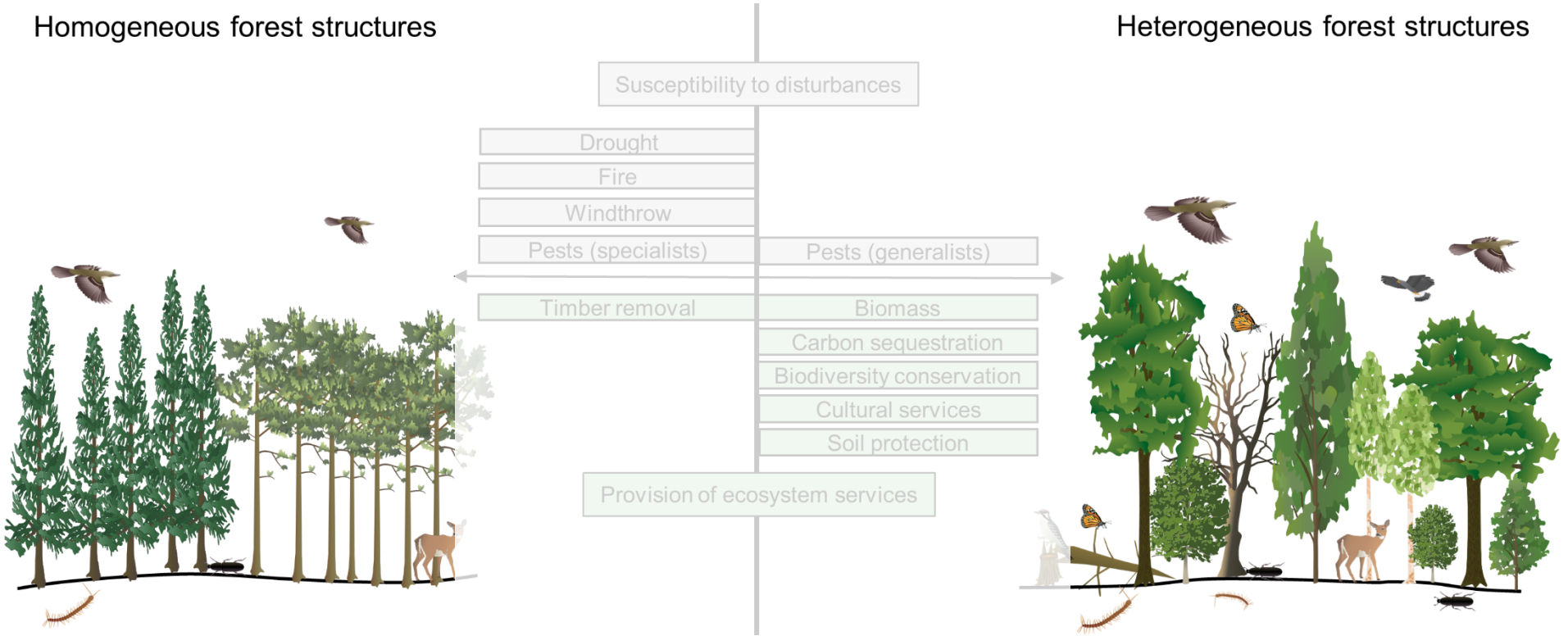
Patrick Kacic, Ursula Gessner, Christopher R. Hakkenberg, Stefanie Holzwarth, Jörg Müller, Kerstin Pierick, Dominik Seidel, Frank Thonfeld, Michele Torresani, Lisa Albrecht, Alice Claßen, Heike Feldhaar, Claudia Massó-Estaje, Julia Rothacher, Ingolf Steffen-Dewenter, Clara Wild, Claudia Künzer

Institute of Geography and Geology, Department of Remote Sensing

University of Würzburg

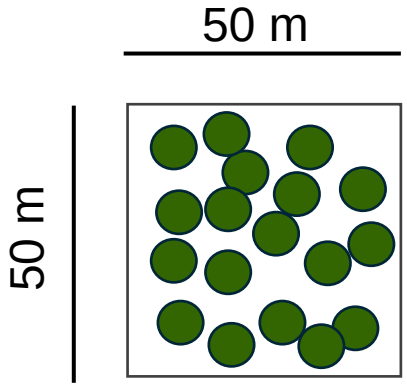
Forest Structure - Disturbances

Forest structure influences susceptibility to disturbances:



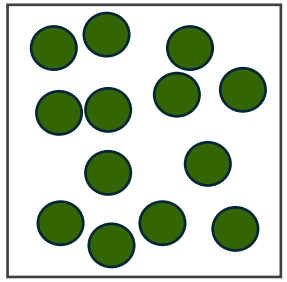
Adapted from Messier et al. 2021

Experimental Silvicultural Treatments Manipulate Forest Structure



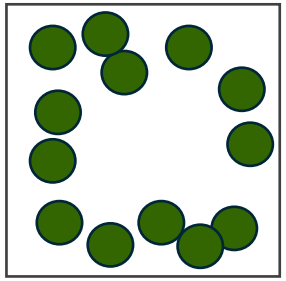
Control treatment

→ **No** tree removal



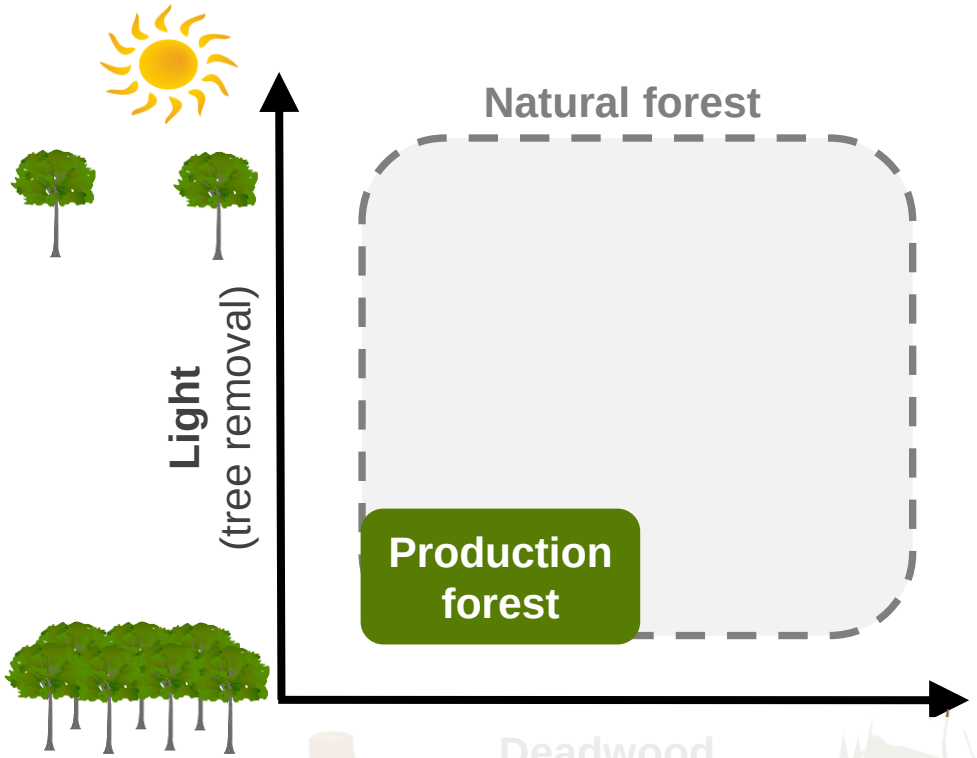
Distributed treatment

→ **Distributed** tree removal



Aggregated treatment

→ **Aggregated** tree removal

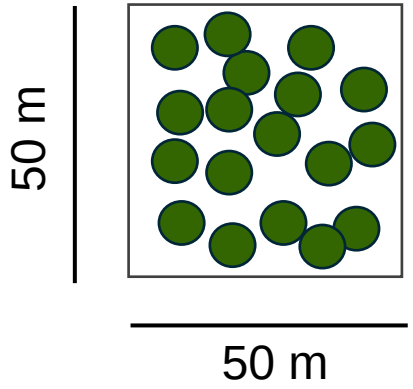


Multi-Source Remote Sensing Data

Platforms

Forest structural attribute	MLS (Mobile Laser Scanning)	TLS (Terrestrial Laser Scanning)	Spaceborne (Radar, Multispectral, Lidar)
Canopy cover / openness	Canopy cover	Canopy Openness Index (COI)	-
Structural complexity	Box dimension	Stand Structural Complexity Index (SSCI), Understory Complexity Index (UCI)	-
Structural heterogeneity	-	-	Sentinel-1 VH cv, Sentinel-2 NMDI cv, GEDI rh95 (canopy height) cv, GEDI cover cv, GEDI agbd cv

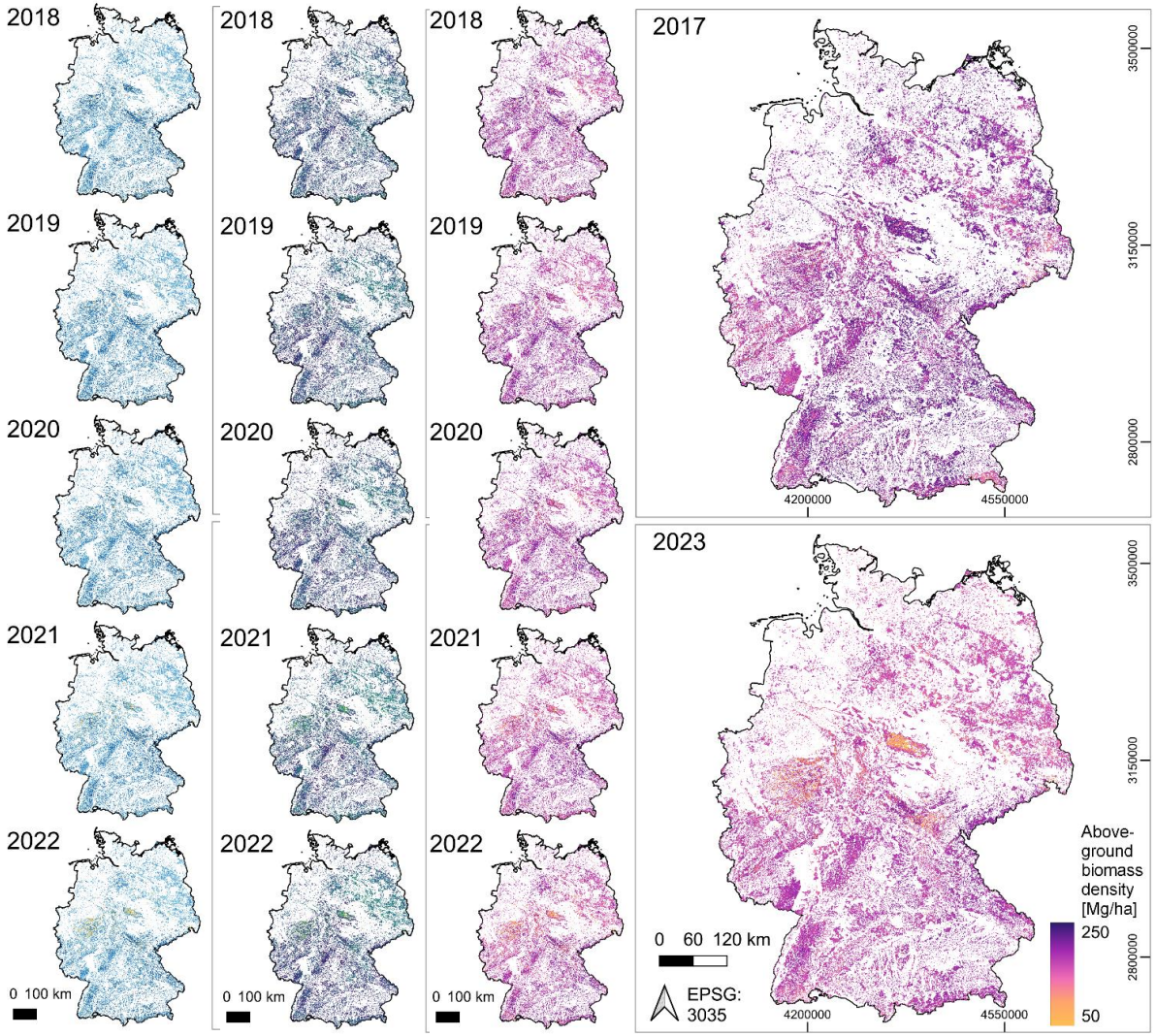
Patch-level:

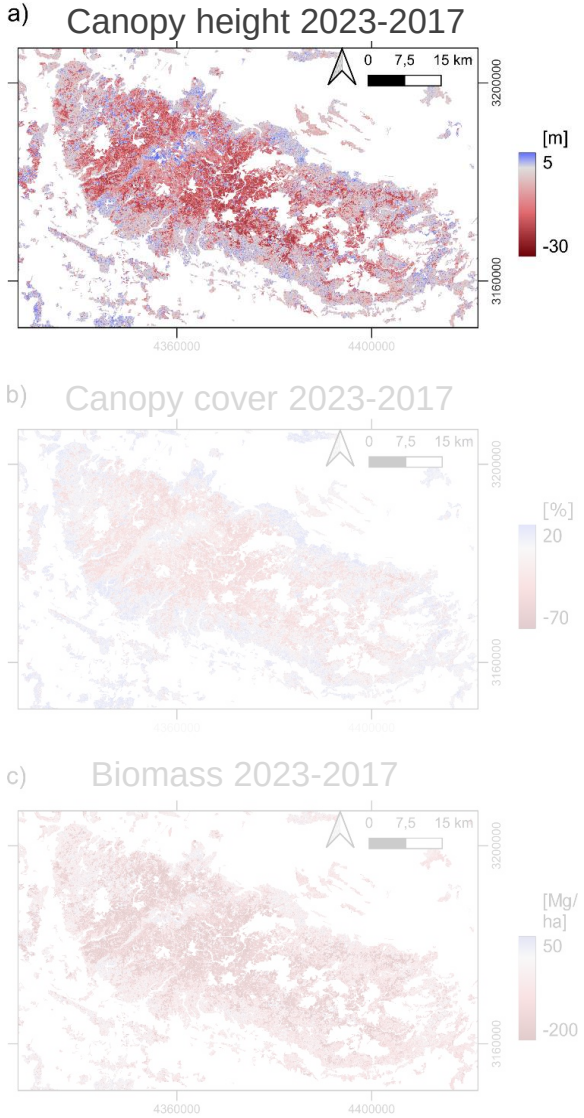


Kacic et al. 2025

Spaceborne Forest Structure Data for Germany

First German-wide products on **canopy height**,
total canopy cover and **above-ground biomass density**

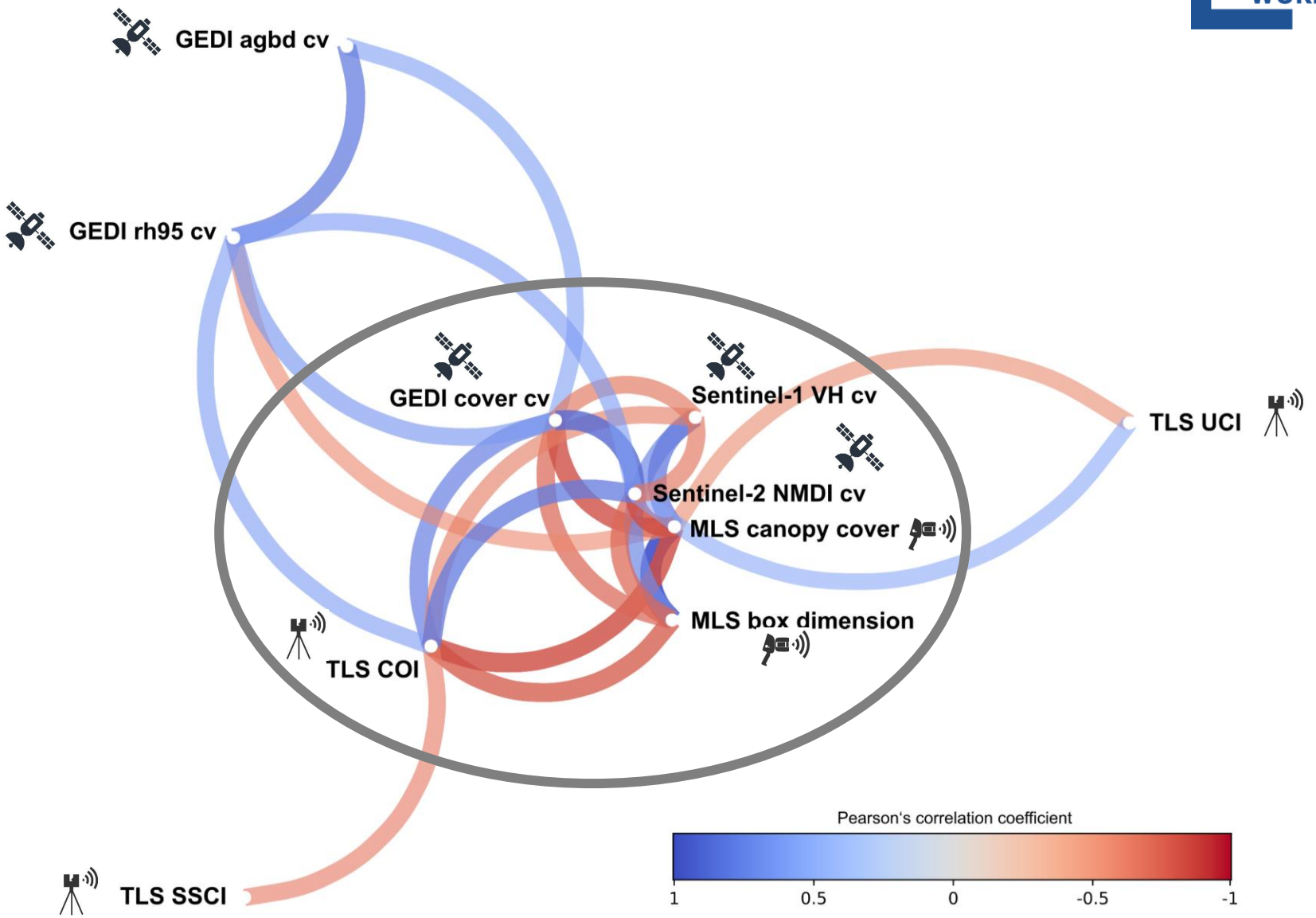




DLR Geoservice

Kacic et al. 2023

Correlation Network of Remotely Sensed Data



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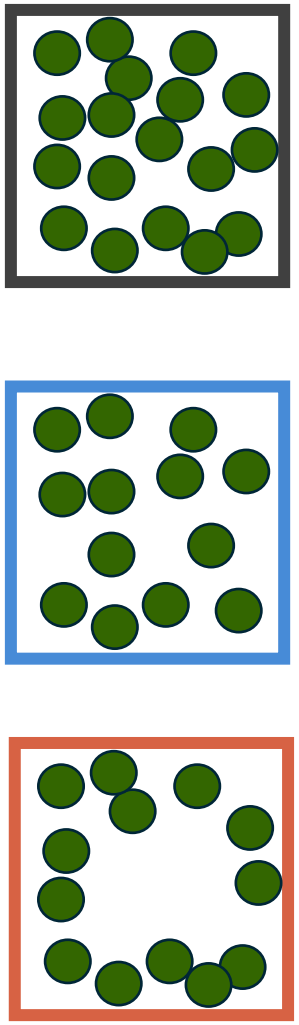
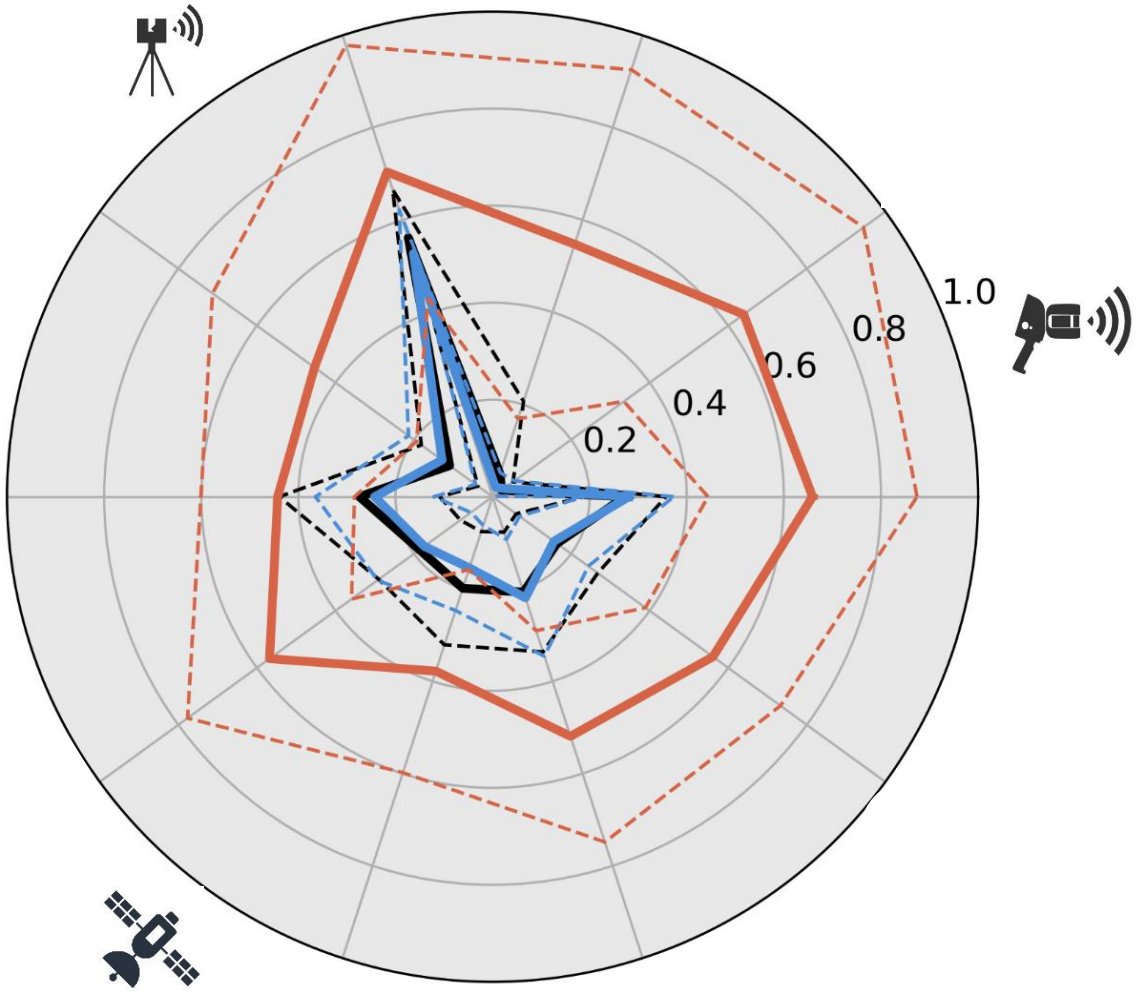
Comparative Analysis of Treatment Groups





Forest structure:

mean

standard deviation

0 — homogeneous

1 — heterogeneous

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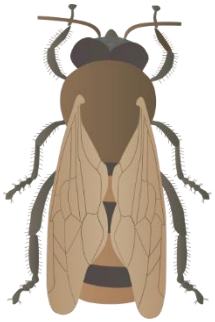
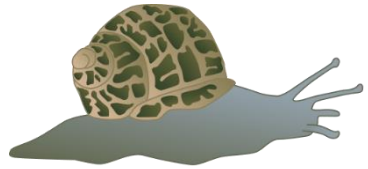
Assessing Forest Structure-Biodiversity Relationships

- **Integration of in-situ biodiversity data**
- Assessment of **best spaceborne forest structure indicator** per **species** and **taxonomic diversity level:**
  - Rare species (q = 0)
  - Common species (q = 1)
  - Dominant species (q = 2)





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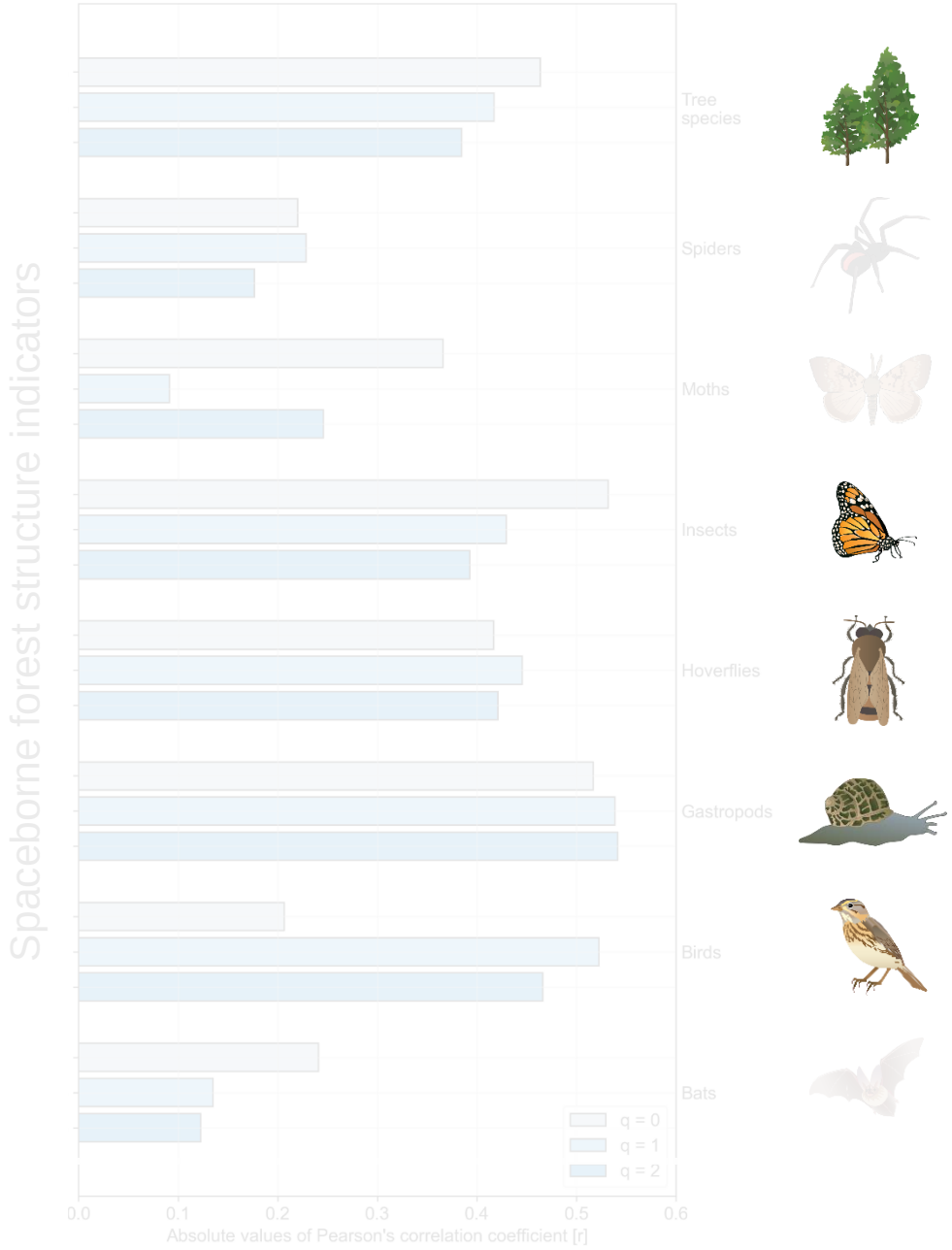


Overall Summary

- **Strong correlations of indicators on forest structure could be identified across sensors and platforms:**
  - MLS box dimension, MLS canopy cover,
  - TLS COI,
  - Sentinel-1 VH cv, Sentinel-2 NMDI cv, GEDI cover cv

- **Aggregated treatments** compared to control and distributed treatments can be **identified from all remote sensing platforms**

- **Spaceborne indicators of forest structure** from complementary sensors **hold similar capability to characterize experimental silvicultural treatments as close-range techniques**

- The **delineation of different forest structures** is essential to **characterize structure-biodiversity relationships**

Thank you very much for your attention!

remote sensing

MDPI

Article

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

Patrick Kacic [1,*], Frank Thonfeld [2], Ursula Gessner [2] and Claudia Kuenzer [1,2]

Remote Sensing in Ecology and Conservation — Open Access — ZSL

RESEARCH ARTICLE

Assessing experimental silvicultural treatments enhancing structural complexity in a central European forest – BEAST time-series analysis based on Sentinel-1 and Sentinel-2

Patrick Kacic[1], Ursula Gessner[2], Stefanie Holzwarth[2], Frank Thonfeld[2] & Claudia Kuenzer[1,2]

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original articles

Characterizing local forest structural complexity based on multi-platform and -sensor derived indicators

Patrick Kacic [a,*], Ursula Gessner [b], Christopher R. Hakkenberg [c], Stefanie Holzwarth [b], Jörg Müller [d,e], Kerstin Pierick [f,g], Dominik Seidel [f], Frank Thonfeld [b], Michele Torresani [h], Claudia Kuenzer [a,b]

SUPPLEMENTARY FILES

Foto: P. Kacic, Forest of University of Würzburg, Germany)

BETA-FOR Project

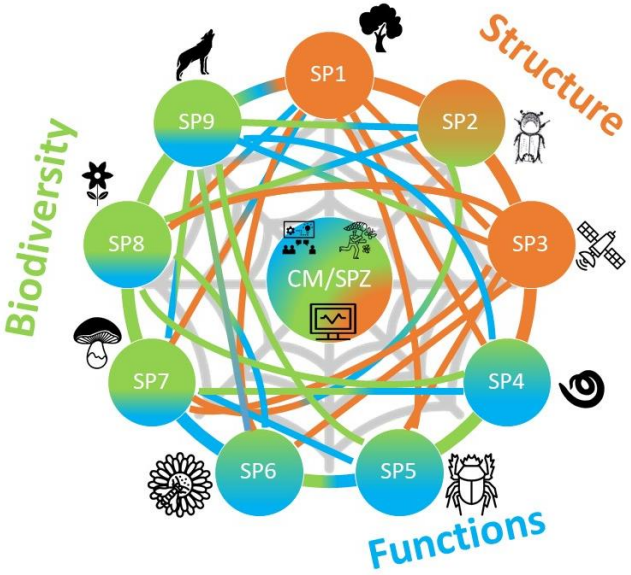
Assess the **effect of experimental silvicultural interventions on biodiversity based on a unique patch-network** in German broad-leaved forests

Current situation in German forests:

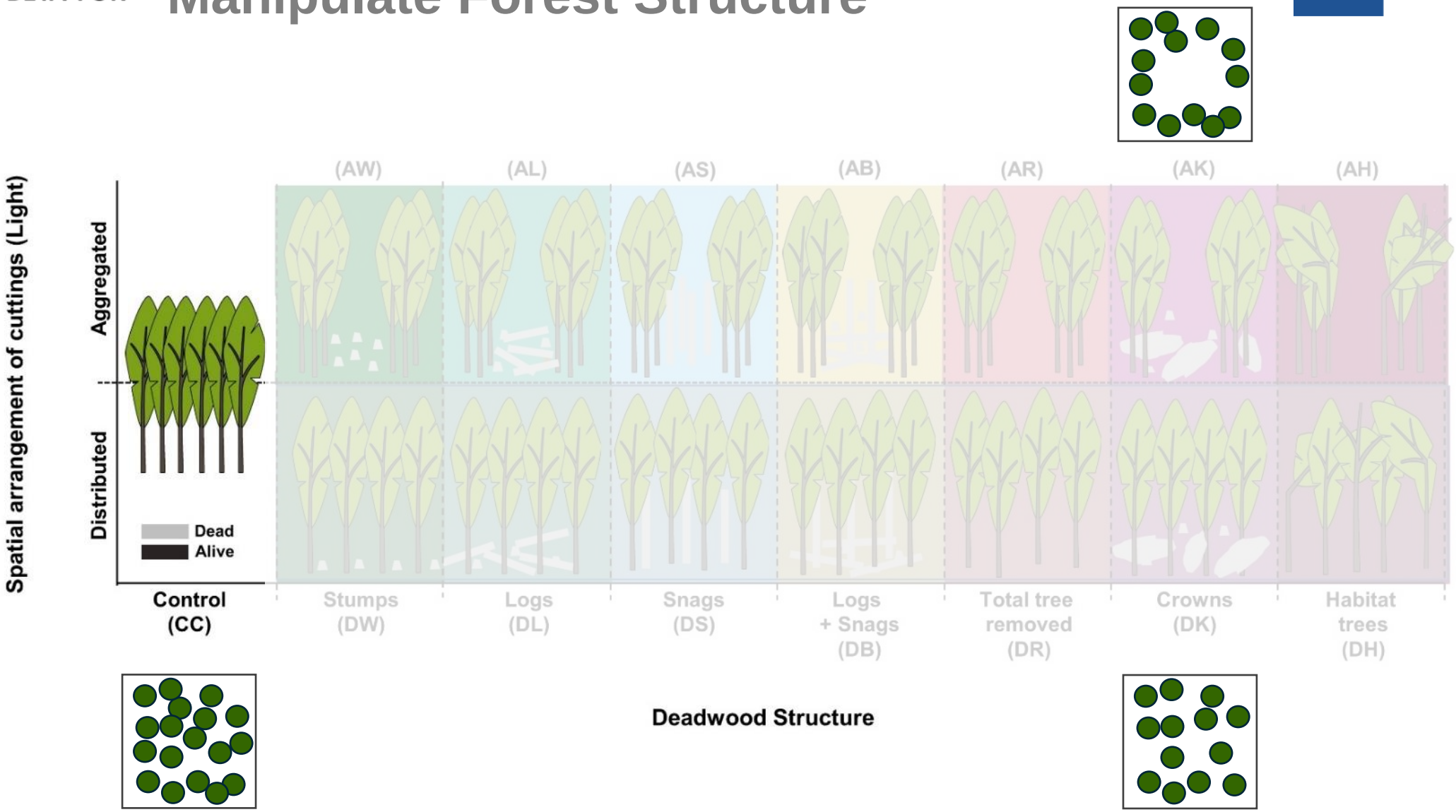
- homogeneity of **structures** (age, species, vertical and horizontal properties)
- low amount and diversity of **deadwood**

Motivation:

- **interdiscliplinary** analysis of forest structure and biodiversity
- assess **arrangements of cuttings** and **deadwood structures** that **enhance structural complexity** to **increase biodiversity**



Experimental Silvicultural Treatments Manipulate Forest Structure



Kacic, et al. 2024, Müller et al. 2023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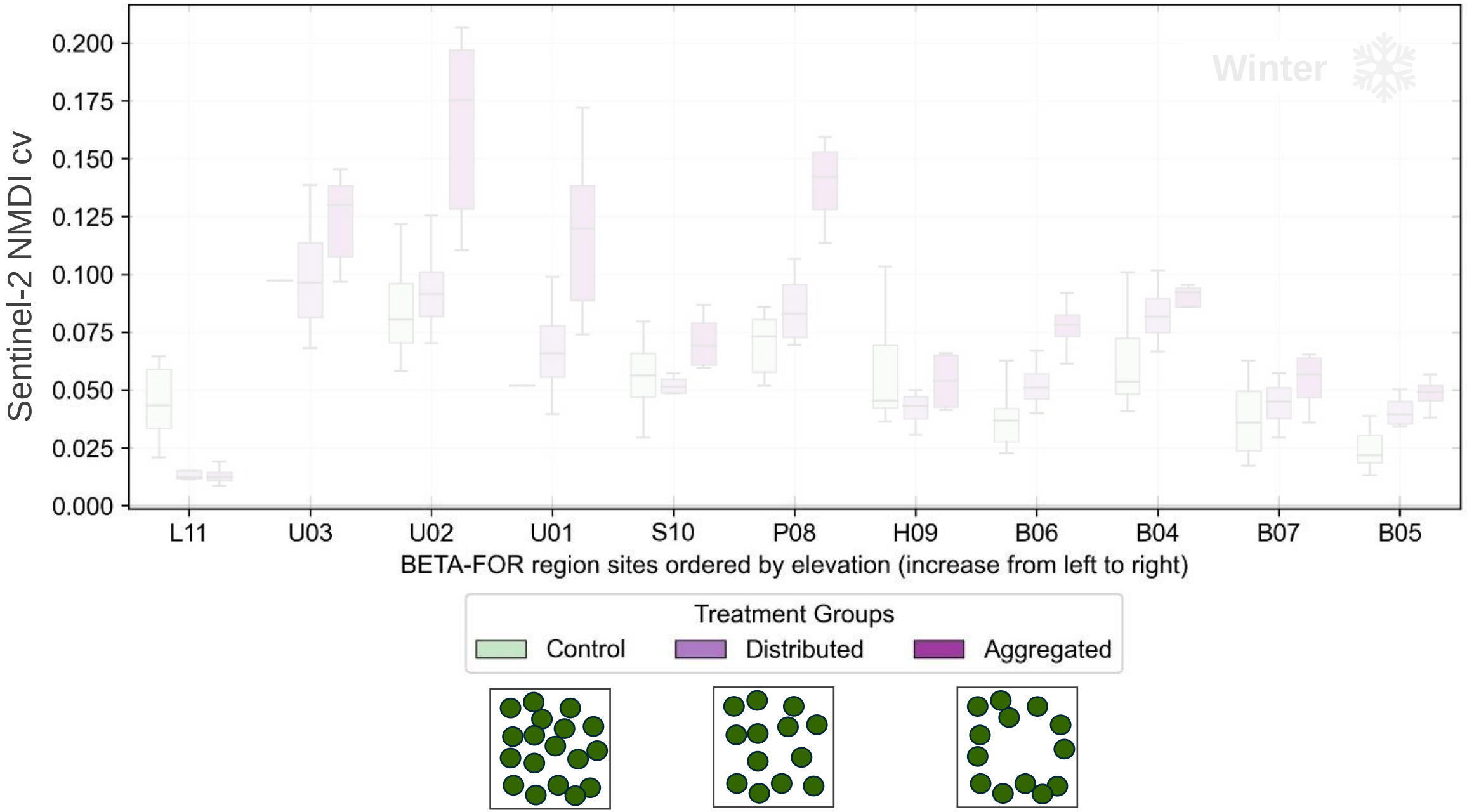
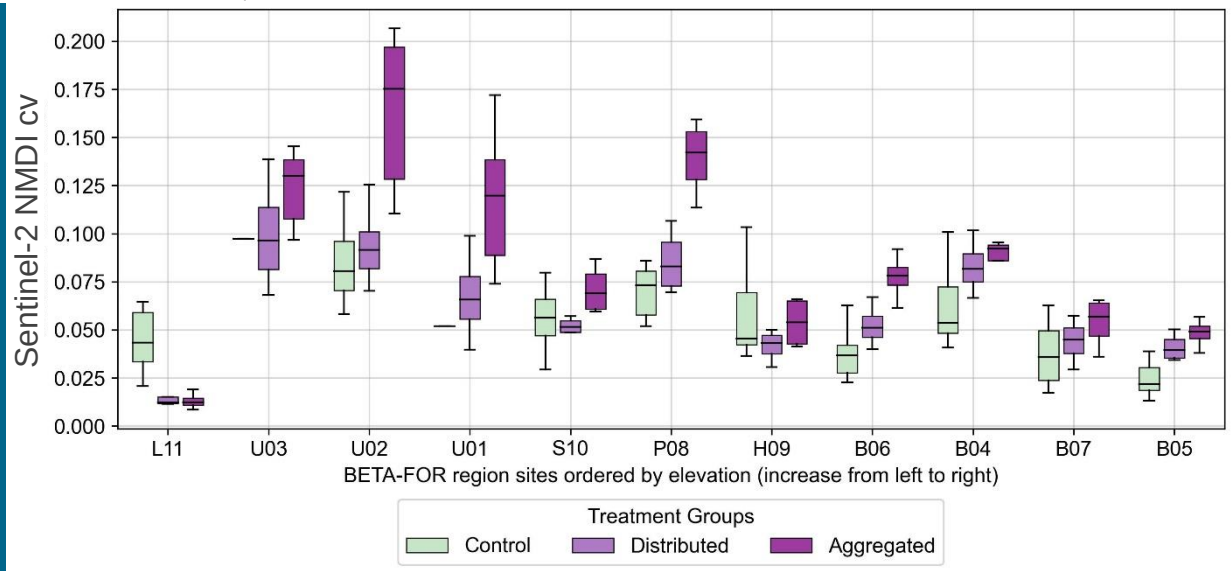
Assessment of Forest Structure

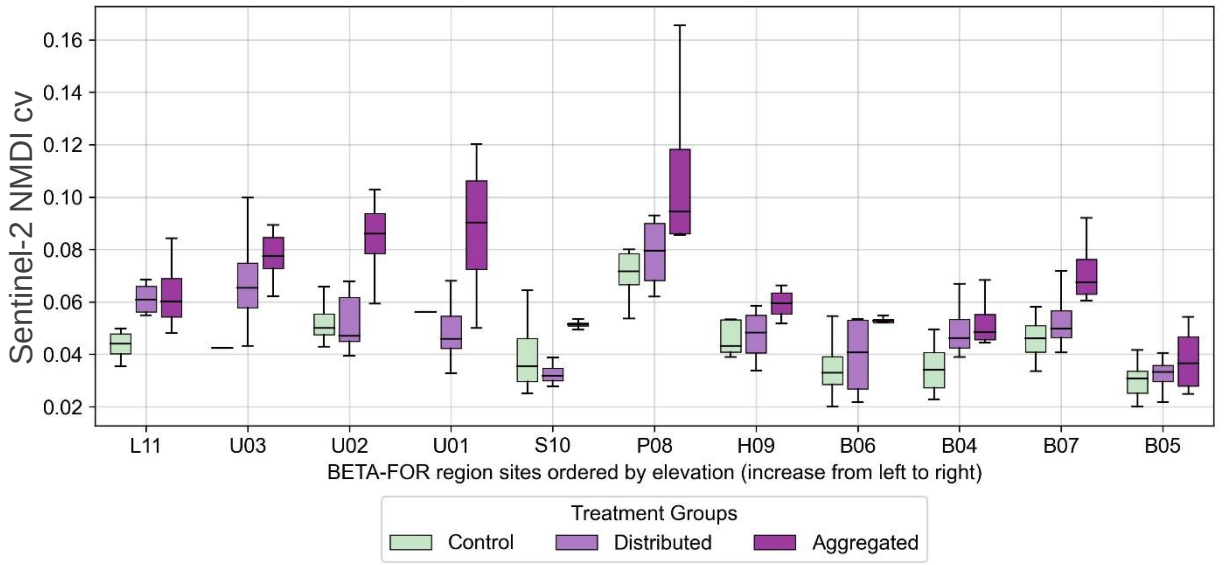


Assessment of Forest Structure

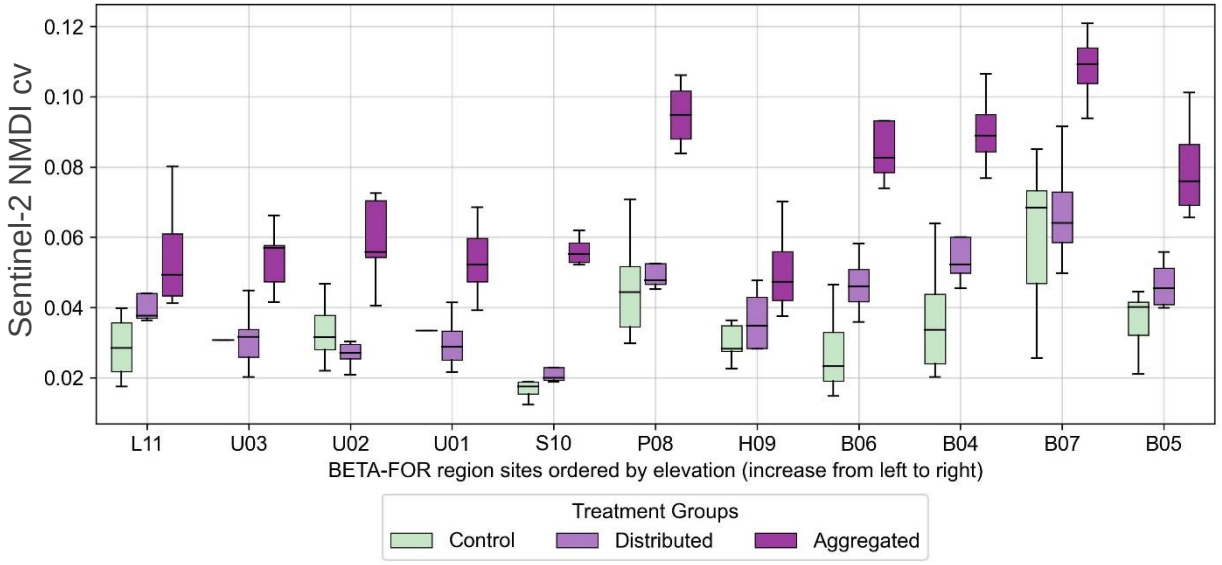
Winter



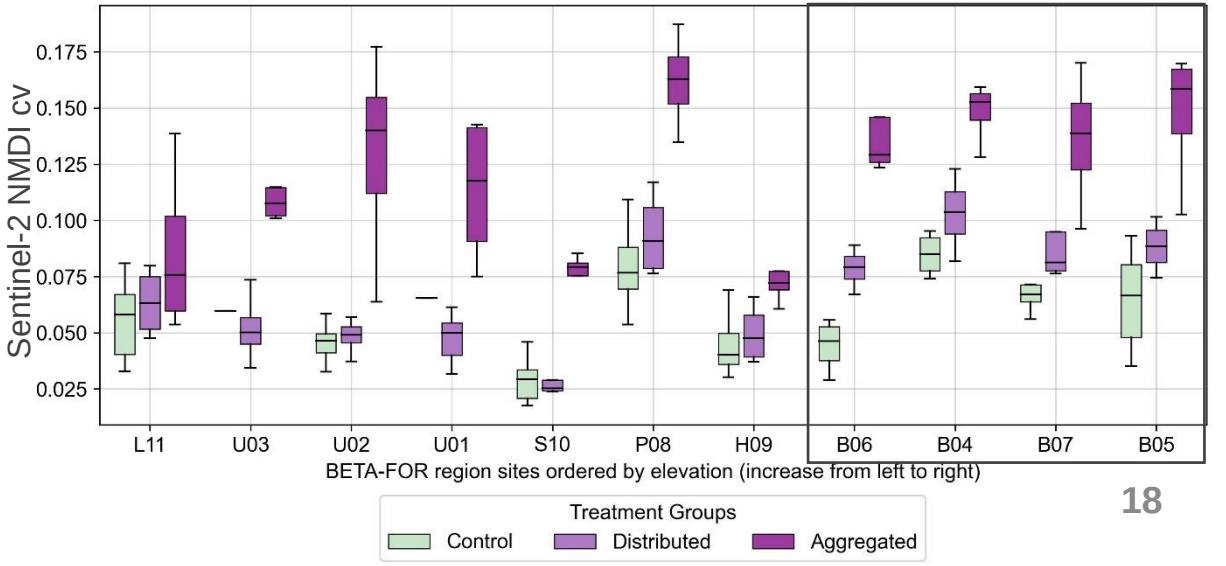
Spring



Summer



Autumn



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