# Assessing experimental silvicultural treatments enhancing structural complexity in a
Central European forest based on Sentinel-1 and -2

Patrick Kacic, PhD-Candidate

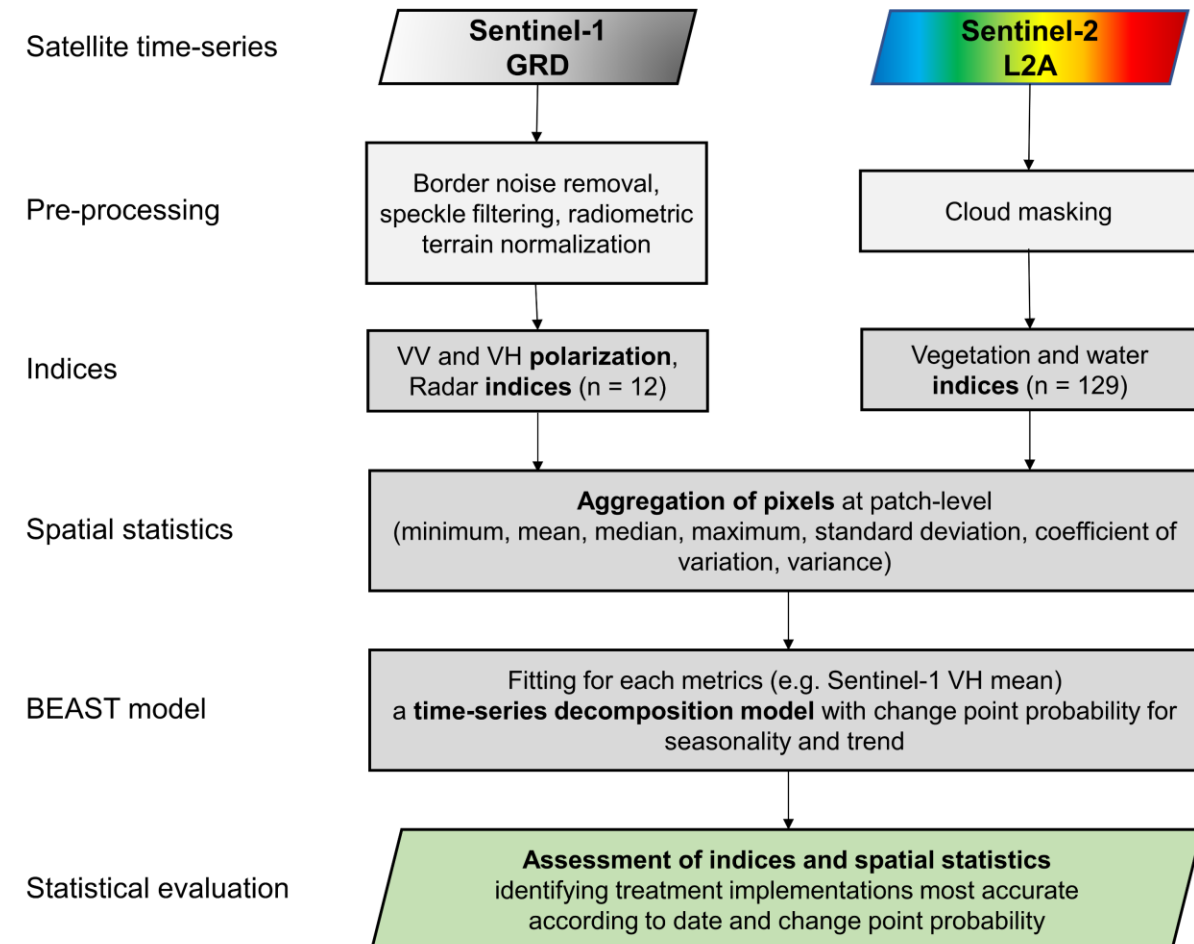Department of Remote Sensing, University of Würzburg, Germany

DFD-LAX, German Aerospace Center (DLR)

Implementation of Treatments: November to December 2018

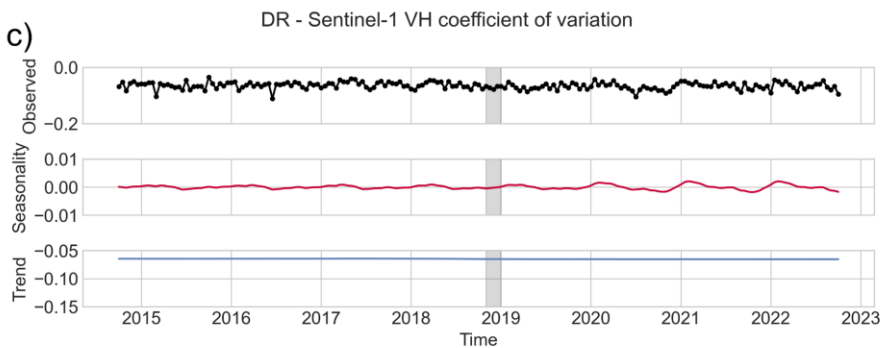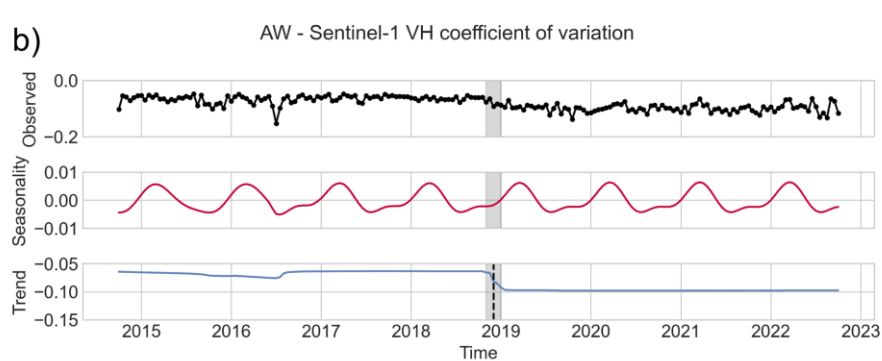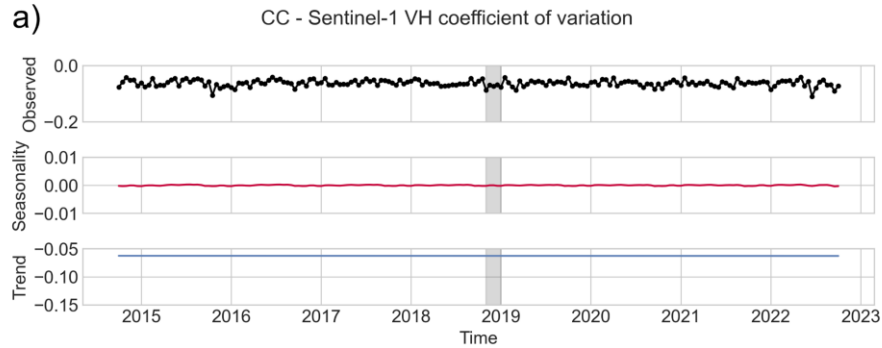Kacic, et al. (2024), Remote Sensing in Ecology and Conservation
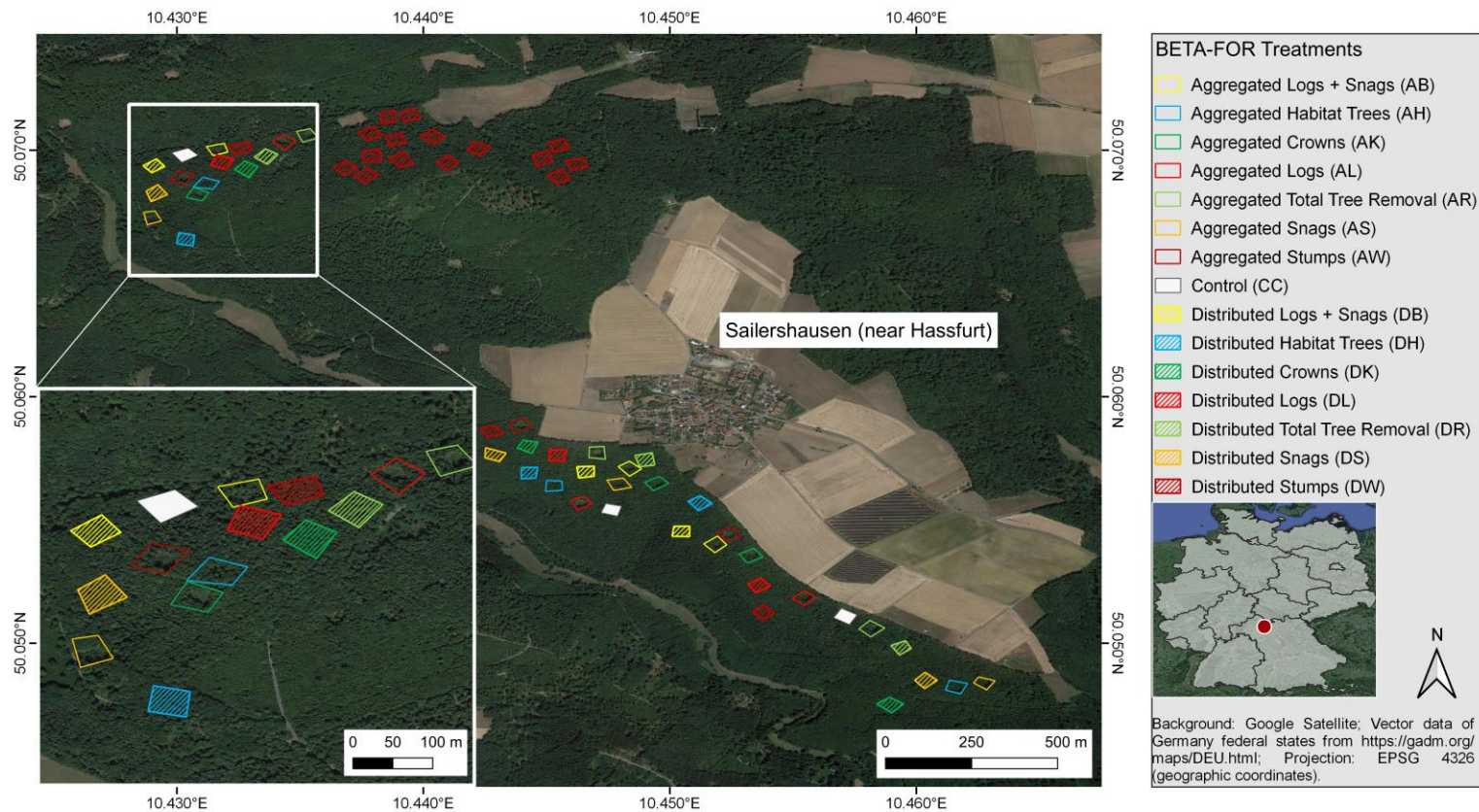
Methods and Data

- Data Input:
  - Sentinel-1 (2014-2022) and Sentinel-2 time-series (2015-2022)
  - **Spectral indices** (n > 100) and **spatial statistics** (n = 7) at patch-level
  - Spectral indices based on a comprehensive catalogue (Montero et al. 2023)

- Model: **BEAST** = Bayesian Estimator of Abrupt change, Seasonal change, and Trend (Zhao et al. 2019)
  - **Bayesian probability** analysis
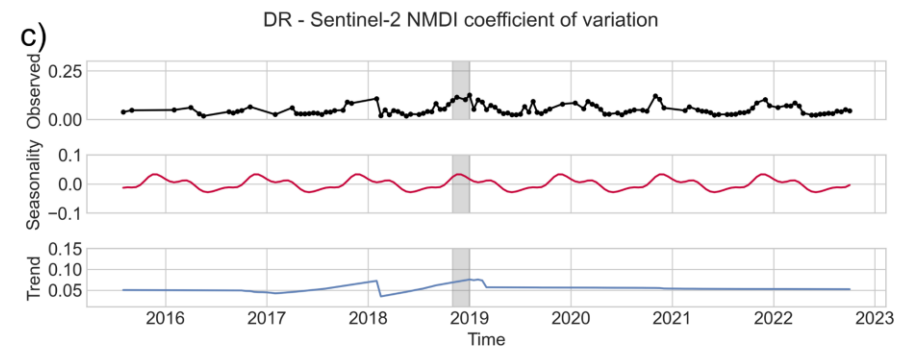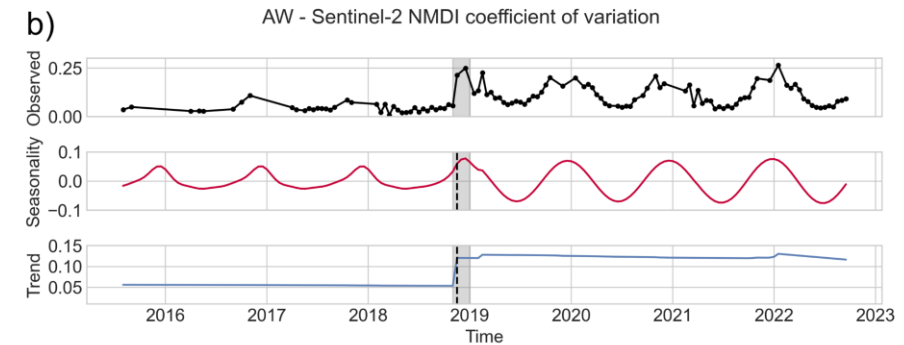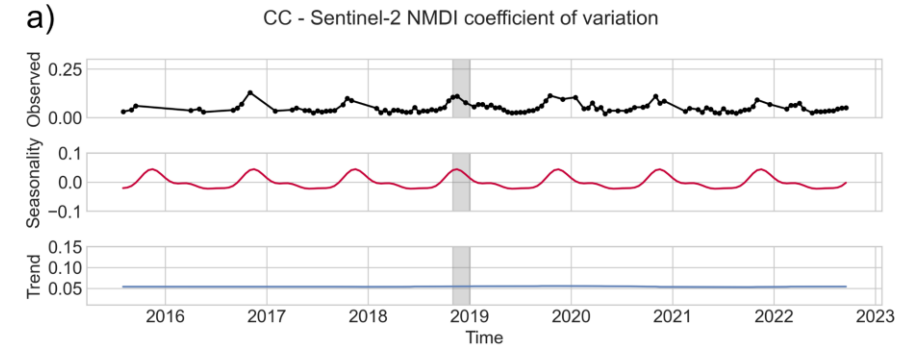 - Capable of **irregular time-series**, e.g. of Sentinel-2 due to atmospheric artefacts

Satellite time-series	Sentinel-1 GRD	Sentinel-2 L2A
Pre-processing	Border noise removal, speckle filtering, radiometric terrain normalization	Cloud masking
Indices	VV and VH **polarization**, Radar **indices** (n = 12)	Vegetation and water **indices** (n = 129)
Spatial statistics	**Aggregation of pixels** at patch-level (minimum, mean, median, maximum, standard deviation, coefficient of variation, variance)	
BEAST model	Fitting for each metrics (e.g. Sentinel-1 VH mean) a **time-series decomposition model** with change point probability for seasonality and trend	
Statistical evaluation	**Assessment of indices and spatial statistics** identifying treatment implementations most accurate according to date and change point probability	

Sentinel-1

Sentinel-2

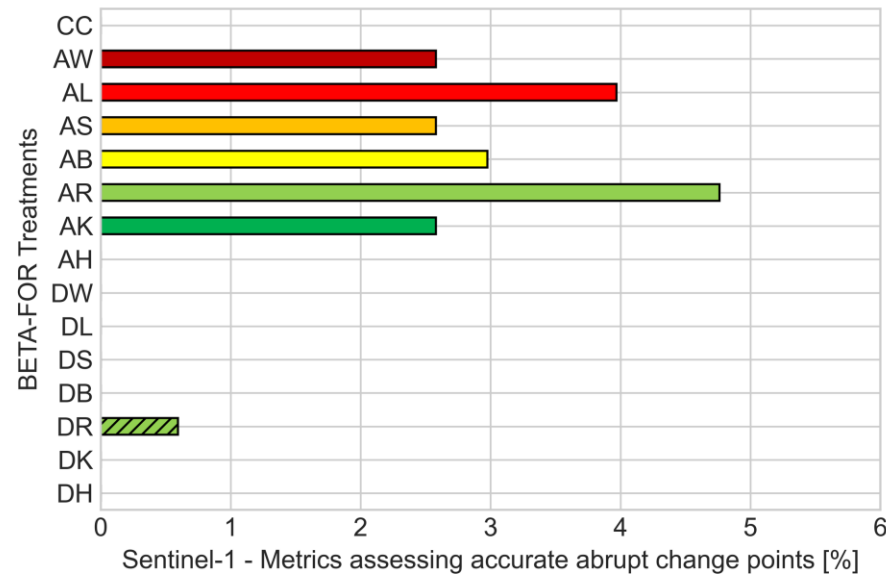treatment imple-mentation period
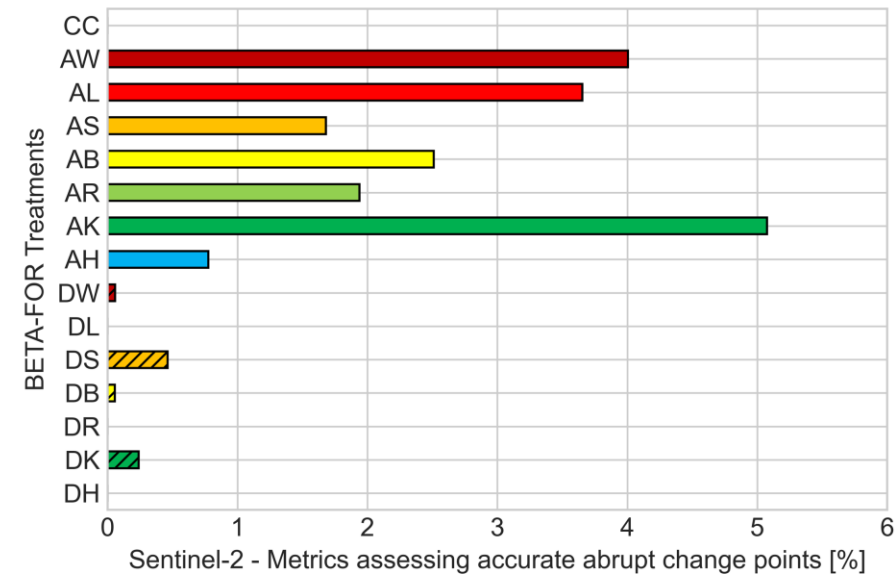
detected treatment imple-mentation

Results – Treatments

Assessment of individual treatments for which the **implementation event** was accurately identified:
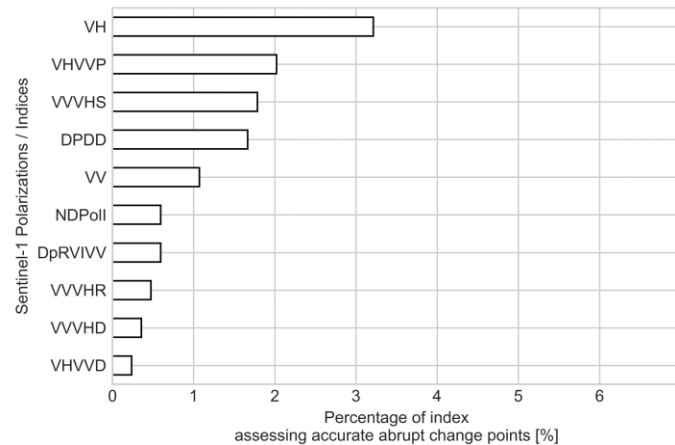
a) Sentinel-1

b) Sentinel-2

→ Accurate detection of **aggregated treatments**

→ Low percentage values because only some indices and few spatial statistics identify the treatment implementation event accurately and consistently
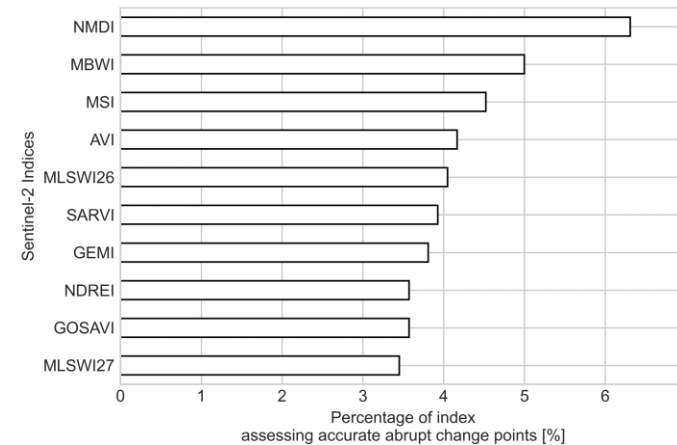
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Kacic, et al. (2024), Remote Sensing in Ecology and Conservation

Results – Spectral Indices and Spatial Statistics

Spectral indices:
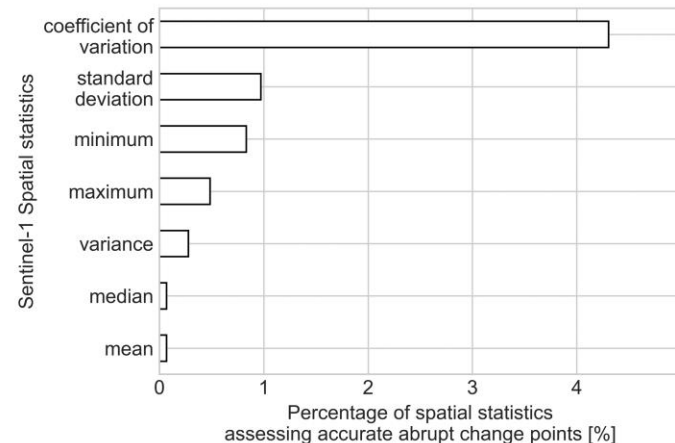

a) Sentinel-1

b) Sentinel-2

Sentinel-1:
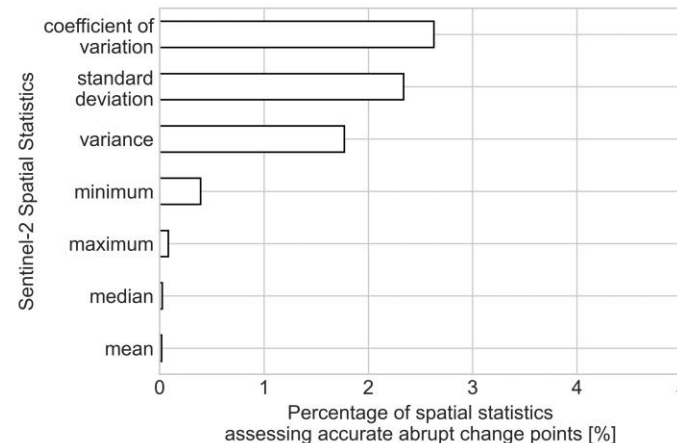**VH** = cross-polarized
VHVVP = VH-VV product

Sentinel-2:
NMDI = Normalized Multi-band Drought Index
MBWI = Multi-Band Water Index

Spatial statistics:

a) Sentinel-1

b) Sentinel-2

Results – Spectral Indices

Spectral indices **not** assessing treatment implementation:

Examples:

*The **Sentinel-2 index NDVI does not identify for any treatment an accurate abrupt change point** (= maximum change point probability; change point probability > 0.9) within the treatment implementation period (11 to 12/2018).*

*About **19 % of all calculated Sentinel-2 indices do not assess any accurate abrupt change point** (= maximum change point probability; change point probability > 0.9) within the treatment implementation period (11 to 12/2018).*
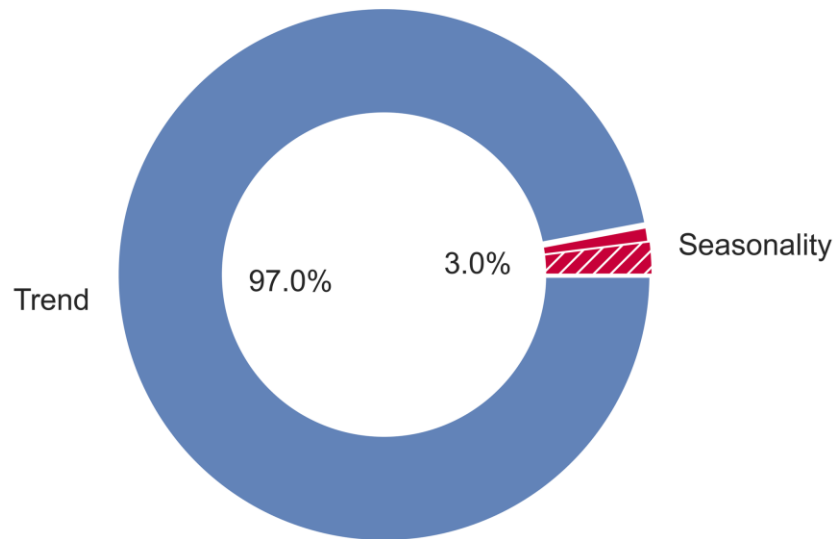
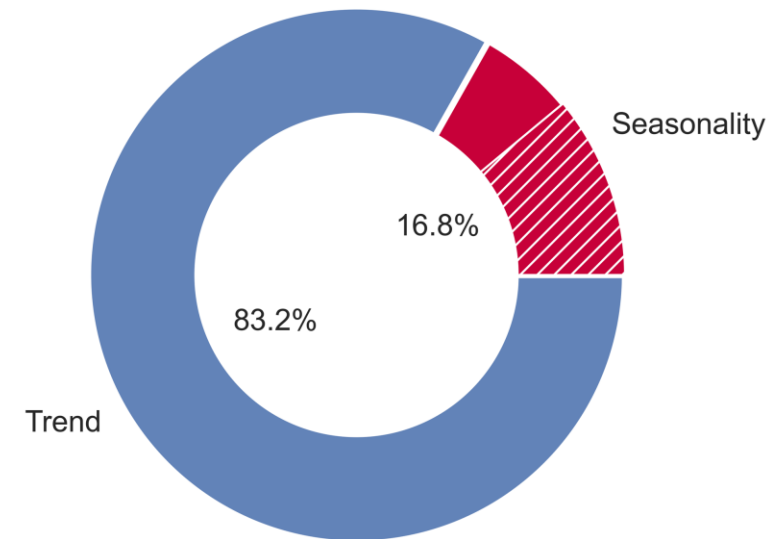| Sentinel-1 (n = 5; 42 %)	Sentinel-2 (n = 25; 19 %)
DpRVIHH, QpRVI, RFDI, VDDPI, VHVVR	BCC, GARI, GLI, GRNDVI, IKAW, IPVI, MCARI705, MGRVI, MNLI, MSR, **NDVI**, NDYI, NWI, RCC, REDSI, RGBVI, SAVI2, **SR,** **SR2,** SWM, TCARIOSAVI705, TTVI, VIG, WDRVI, WIR

Long names of spectral indices:

Results – Trend/Seasonal Component

a) Sentinel-1

b) Sentinel-2

Seasonality

Trend   97.0%   3.0%   Seasonality

16.8%

Trend   83.2%

→ Most change points of treatment implementations are detected in the **trend component**

→ About **2/3** of all detected **change points in the seasonal component are also detected in trend** (hashed area)

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Summary

- **Adaptive forest management** is needed in order to support future forest resilience through **enhanced structural complexity** (BETA-FOR treatments)

- The **BEAST** algorithm comes with the benefit to **assess the likelihood of changes** through change point probabilities for both **seasonal and trend components**

- We propose **specific bands/spectral indices** in combination with heterogeneity statistics for the monitoring of forest structure condition
    - Sentinel-1 **VH** (cross-polarised), **VHVVP** (VH-VV product)
    - Sentinel-2 **NMDI** (Normalized Multi-band Drought Index), **MBWI** (Multi-Band Water Index)

- **Comparative time-series analyses** demonstrate a **similar potential of Sentinel-1 to characterize changes in forest structure in comparison to Sentinel-2**

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

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