Analysing Multi-Temporal DESIS Data for Forest Health Monitoring Purposes – the Bavarian Forest National Park Case Study

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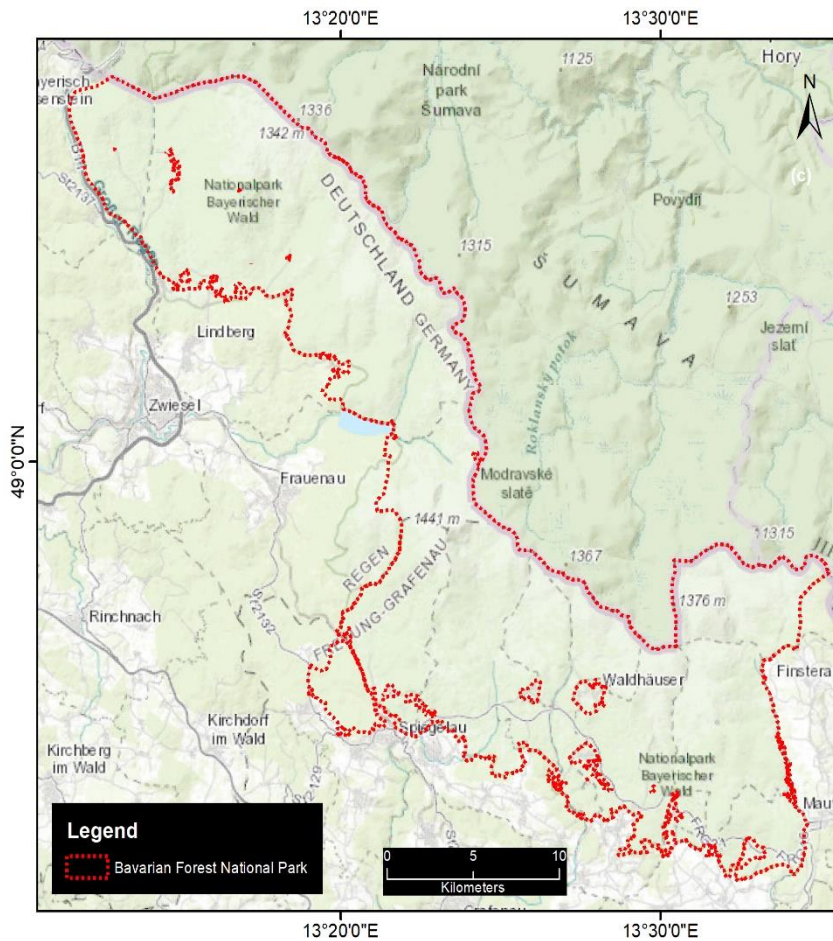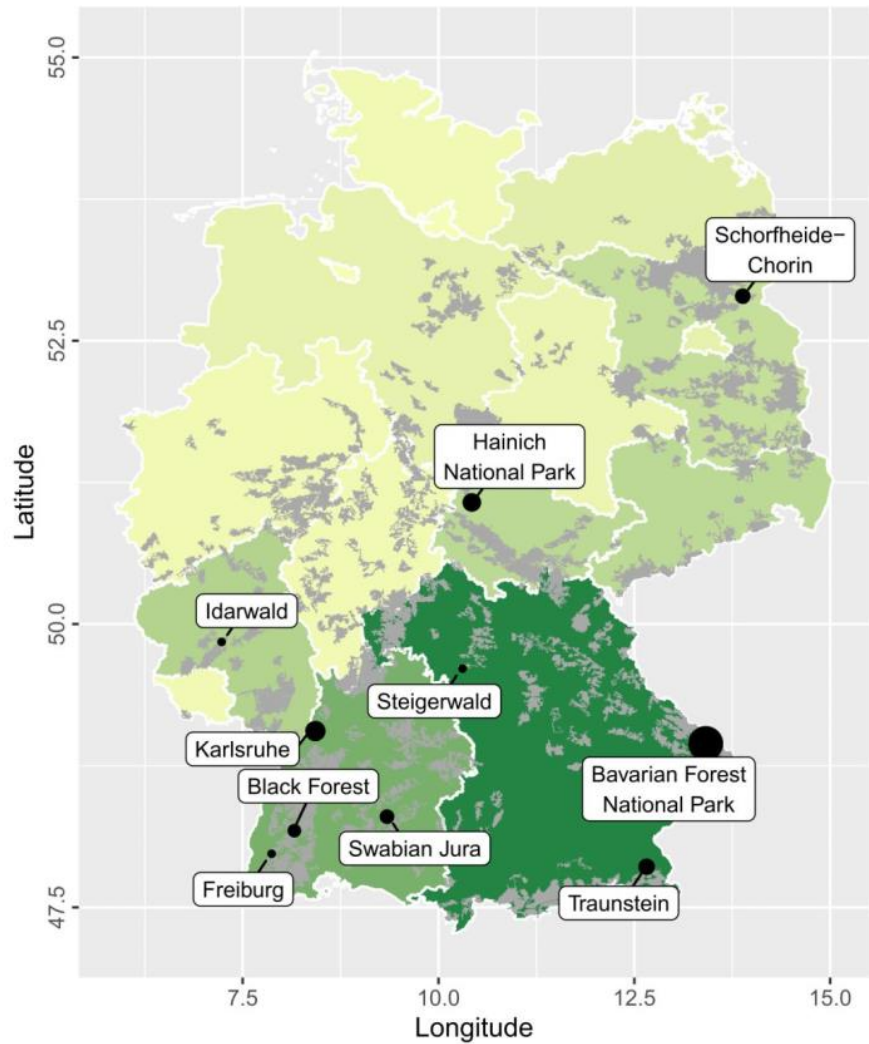
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[3] Bavarian Forest National Park

Knowledge for Tomorrow

Study Site: Bavarian Forest National Park (BFNP)

- mountainous forest
- Norway spruce dominant species
- 24,250 ha
- established 1970

(S. Holzwarth et al., 2020)

DLR Earth Sensing Imaging Spectrometer (DESIS) Mission

- Operated by DLR (scientific) and Teledyne Brown Engineering (commercial)

- Installed on the International Space Station (ISS)

- Target lifetime from 2018 – 2023

- Average revisit frequency of 3 – 5 days, BUT no mapping mission

| Parameter	Value
Spectral coverage	402 nm – 1000 nm
Spectral sampling	2.55 nm (w/o binning) ~ 10.2 nm (binning 4)
Ground sampling distance (GSD) at nadir	~ 30 m (depends on the flight altitude of the ISS)
Swath at nadir	~ 30 km (depends on the flight altitude of the ISS)

(K. Alonso et al., 2019)

DESIS Data of the BFNP

Search Results

Products | Coverage Areas

				:: Name	:: Acquisition Date↓	:: Cloud Coverage Per	:: Acquisition Time	:: Quality Rating
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190611T	6/11/2019	From 50 to 75	15:32:56 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190611T	6/11/2019	From 75 to 100	15:33:01 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190612T	6/12/2019	From 0 to 25	11:29:42 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190612T	6/12/2019	Clear	11:29:47 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190618T	6/18/2019	From 50 to 75	12:59:32 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190618T	6/18/2019	From 25 to 50	12:59:37 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190623T(	6/23/2019	From 75 to 100	07:15:04 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190623T(	6/23/2019	From 75 to 100	07:15:09 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190626T(	6/26/2019	From 0 to 25	09:36:53 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190626T(	6/26/2019	From 0 to 25	09:36:57 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190627T(	6/27/2019	Clear	05:33:36 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190627T(	6/27/2019	Clear	05:33:41 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190629T(	6/29/2019	Clear	08:44:52 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20190629T(	6/29/2019	Clear	08:44:57 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20191027T(	10/27/2019	From 25 to 50	08:53:24 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20191027T(	10/27/2019	From 0 to 25	08:53:29 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20200422T	4/22/2020	Clear	10:35:05 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20200422T	4/22/2020	Clear	10:35:10 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20200612T	6/12/2020	From 25 to 50	10:53:58 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20200612T	6/12/2020	From 0 to 25	10:54:02 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20200623T	6/23/2020	From 50 to 75	10:11:49 GMT	Acceptable
☐	⊕	🛒	📄 🔍	DESIS-HSI-20200624T(	6/24/2020	From 0 to 25	06:09:58 GMT	Acceptable
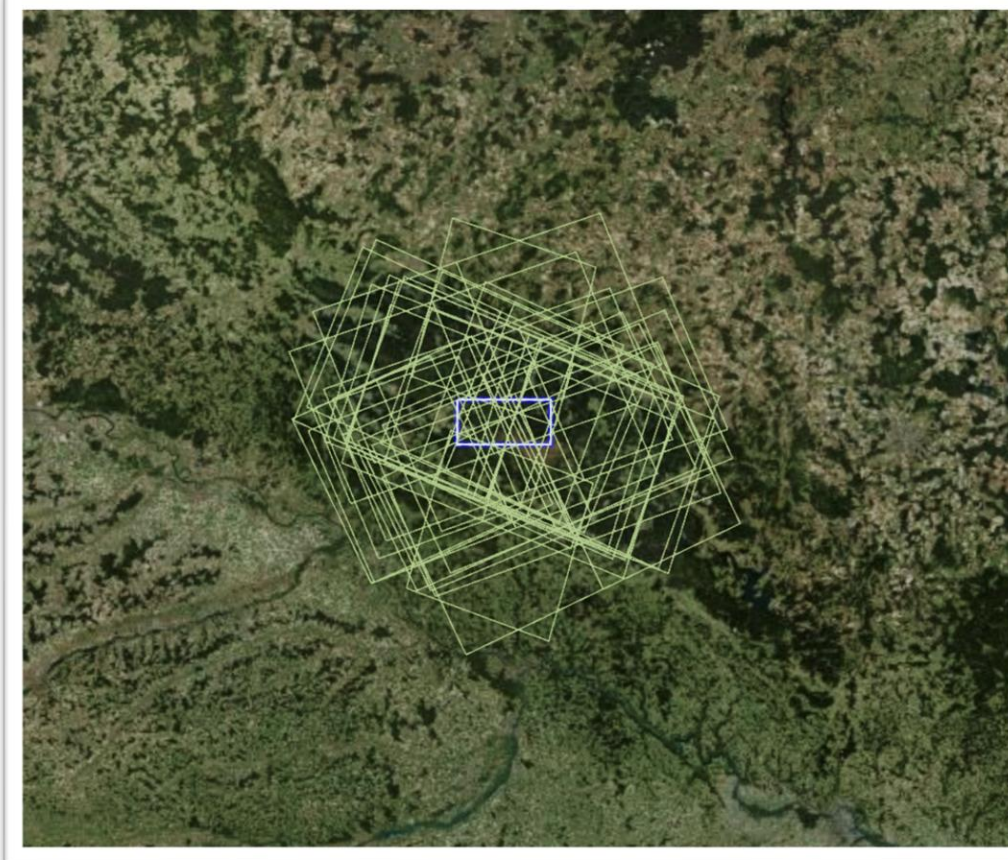
- 40 acquisitions from June 2019 – October 2021
- 12 data takes with clear condition
  (incl. no haze and no contrails)
- 8 scenes with solar zenith angles < 50 degree
- 6 tiles without snow
- 2 dates with full coverage: **29.06.19 & 17.06.21**

DLR

Observed Weather Extremes in the BFNP 2019-2021

2019:
- the third hottest year
- 350 millimeters less precipitation than average

2020:
- second lowest number of days with snow
- lowest number of days with sub-zero temperatures

2021
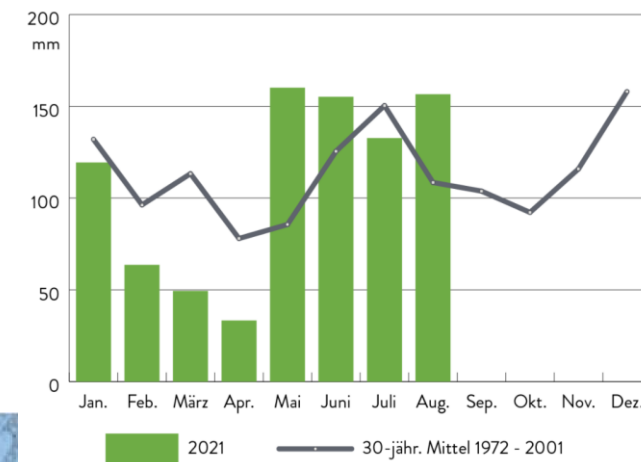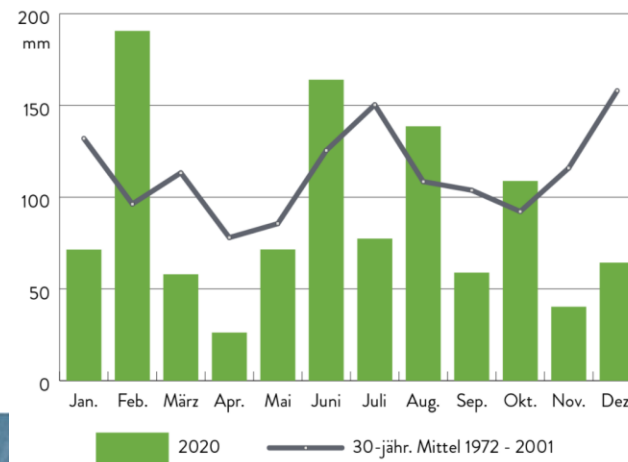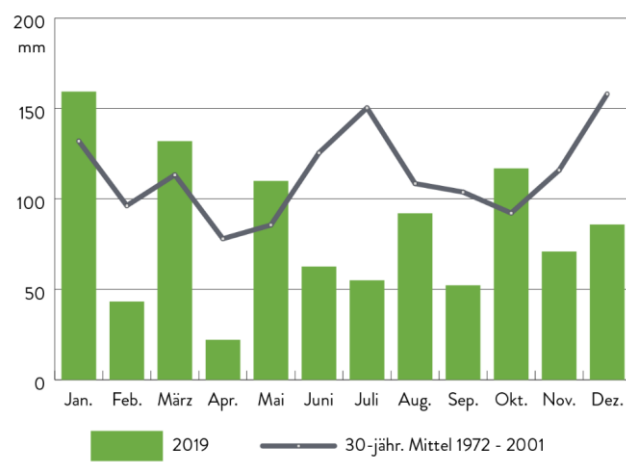- 20°C mark was exceeded in March for the first time

Effects on the National Park

→ increased emergence of bark beetle

→ infestation of native spruce trees

→ beech trees still cope with climate change

Monthly precipitation in BFNP (Jan 2019 – Aug 2021)

Research Questions

- How can DESIS data be used to observe changes in vegetation status over time?

- Which spectral index is most suitable to detect bark beetle infested trees in the National Park?

- Do the results add value compared to results obtained with Sentinel-2 data?

- Does the combination of DESIS and Sentinel-2 improve the accuracy of detected changes?
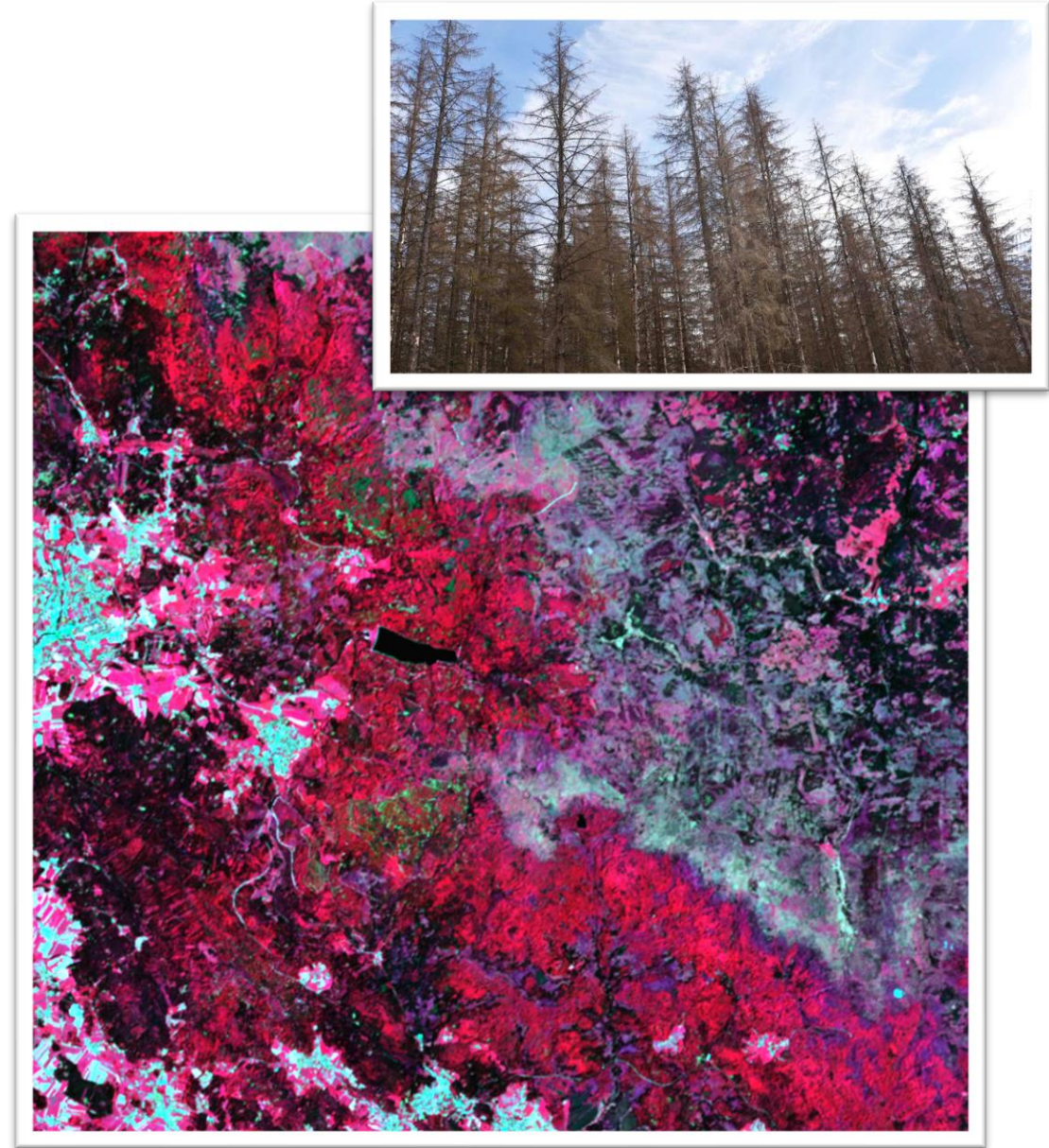
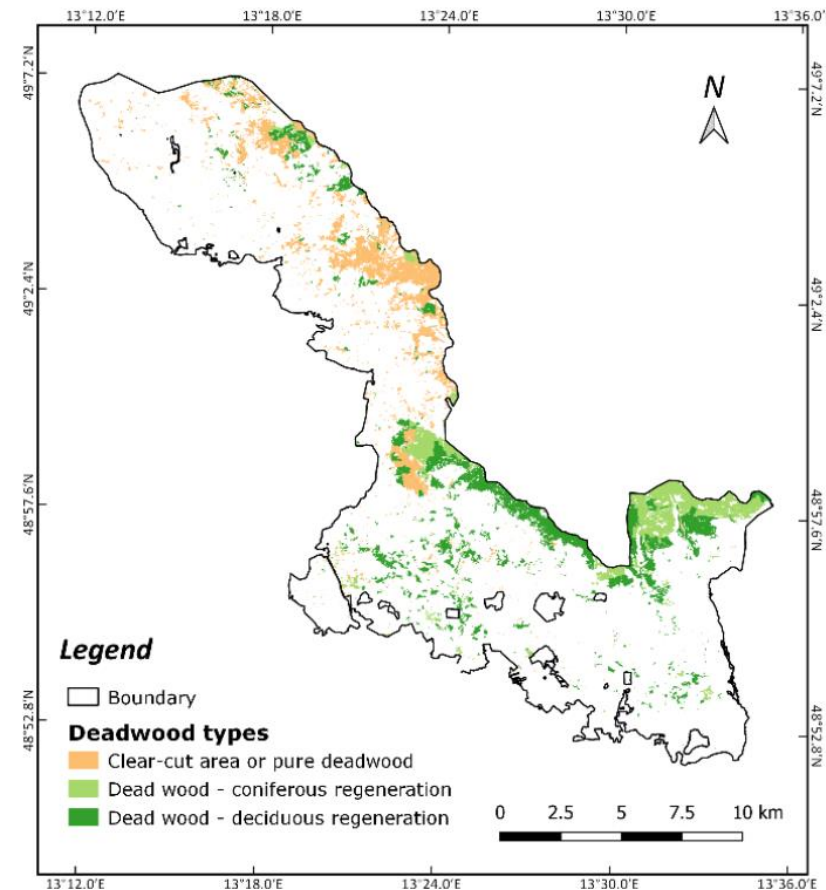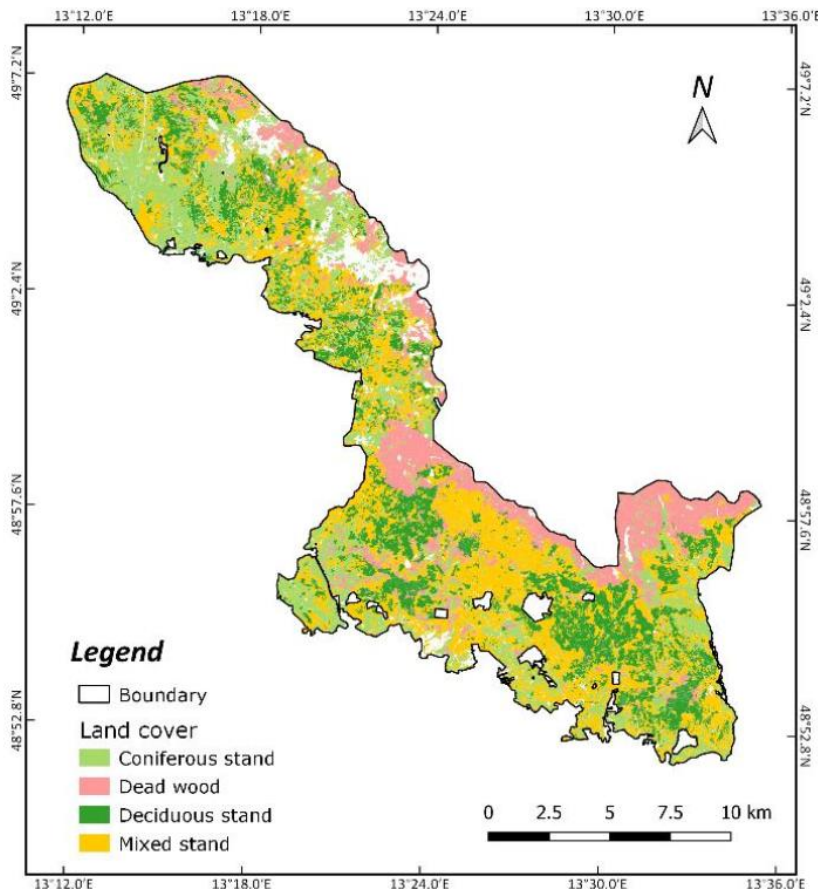# Supporting Data from the National Park

- Information on forest type
- Information on deadwood types
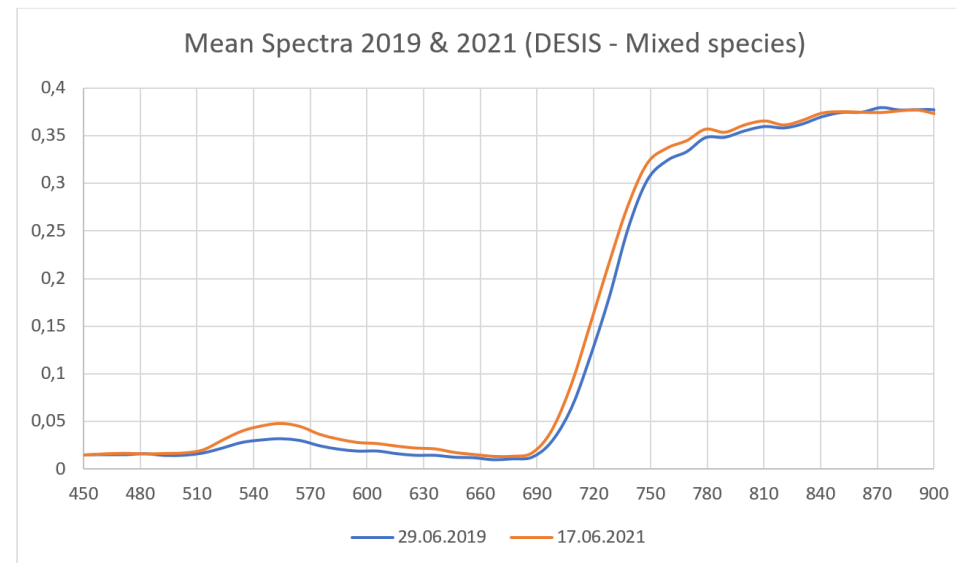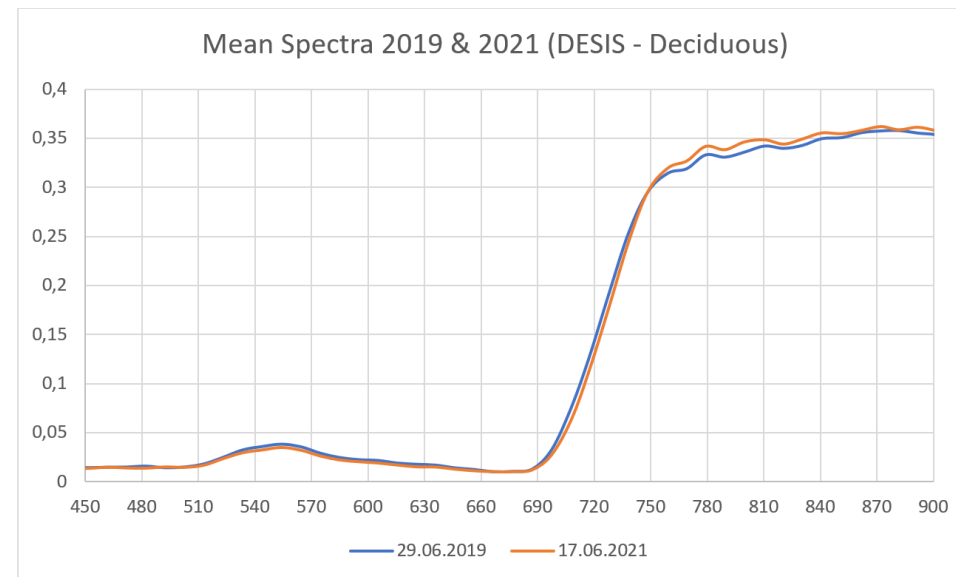- Information on infestation year
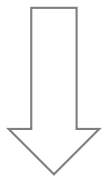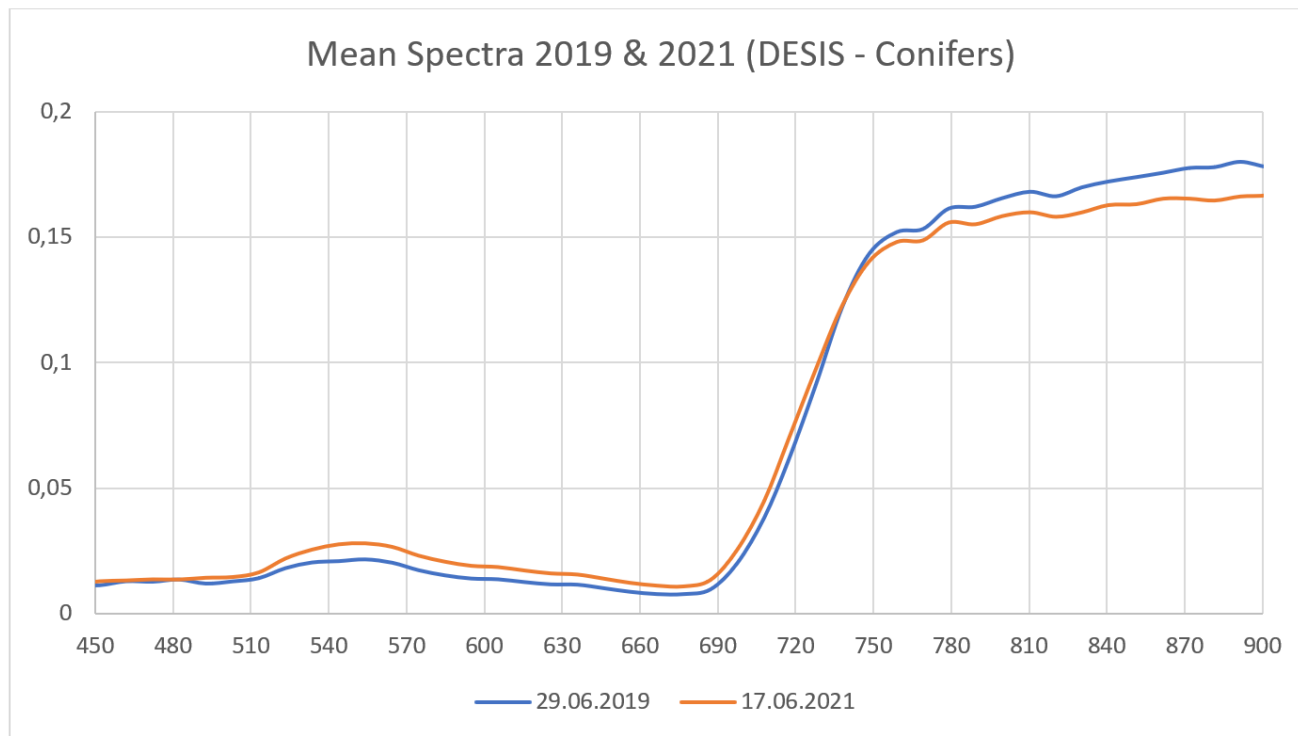
Concentrate analysis on coniferous areas
- ✓ Evergreen
- ✓ Less pronounced seasonal changes
- ✓ Link to bark beetle infestation

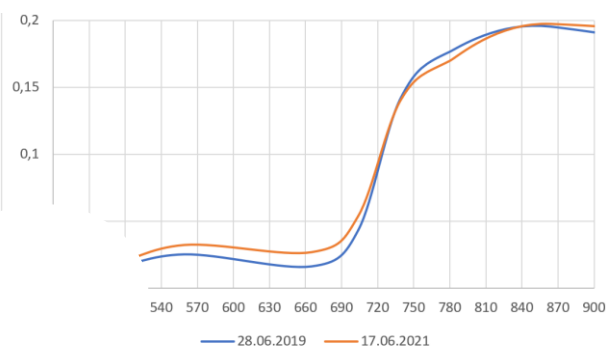Validation data of the years 2020 and 2021

Spectral Changes 2019-2021

Mean Spectra 2019 & 2021 (DESIS - Conifers)

Mean Spectra 2019 & 2021 (DESIS - Deciduous)

Mean Spectra 2019&2021 (S2 - Conifers)

Mean Spectra 2019 & 2021 (DESIS - Mixed species)

Spectral Indices Selection

Evaluation of DESIS derived indices
→ potential for mapping barkbeetle infested areas

Structural
- Normalized Difference Vegetation I̶n̶...
- Green Normalized Difference Veg̶...
- Specific Leaf Area Vegetation Index (S̶...

Chlorophyll & RedEdge
- Normalized Difference Red Edge Index (NDRE) - **D & S2**
- Photochemical Reflectance Index (PRI) - **D**
- Modified Chlorophyll Absorption Ratio Index (MCARI) - **D**
- Modified Red Edge Simple Ratio (MRESR) - **D**
- Vogelmann Red Edge Index 1 - **D**

Other Leaf Pigments
- Visible Atmospherically Resistant Indices Green (VIGreen) - **D & S2**
- Carotenoid Reflectance Index 2 (CRI) – **D**
- Anthocyanin Reflectance Index (ARI) – **D**

Used for further investigation:
- ... **S2**
- MCARI (DESIS)
- Combined Vegetation Index CVI (S2) [Hill et al. 2019]

Results: Structural
- Structural indices showed negligible differences
- Sensitive to background reflectance
- Difficult to interpret changes in conifers
- Potential for broadleaf canopy

Results: Chlorophyll & RedEdge
- ...nd indices that incorporates red edge range strongly
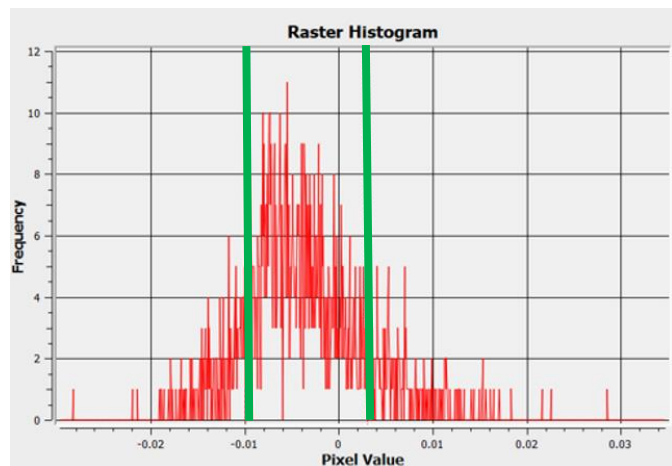- ...effected infested/deadwood areas
- ...s well

Results: Other Leaf Pigment
- Indices sparsely matched with the infested/dead regions
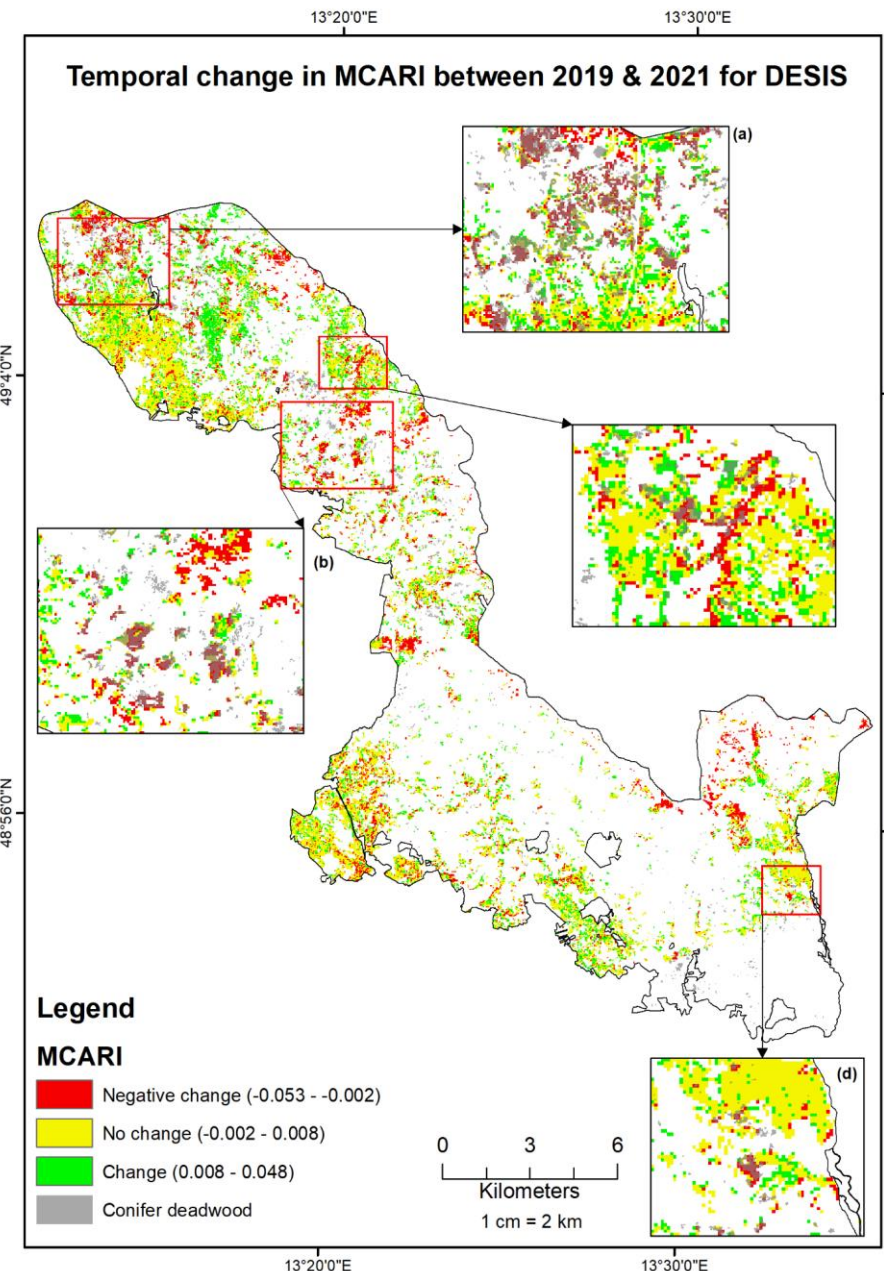- Needle like leaves of conifers shows minimal variation

Temporal Changes

Differences in index values for infested regions

Raster Histogram

→ interactive threshold selection
→ aim: minimize false positives

Temporal change in CVI between 2019 & 2021 for S2

Legend

CVI Difference in S2 MSI

■ <= -0.35

■ Deadwood areas

1 cm = 2 km

Temporal change in MCARI between 2019 & 2021 for DESIS

Legend

MCARI

■ Negative change (-0.053 - -0.002)

■ No change (-0.002 - 0.008)

■ Change (0.008 - 0.048)

■ Conifer deadwood

1 cm = 2 km
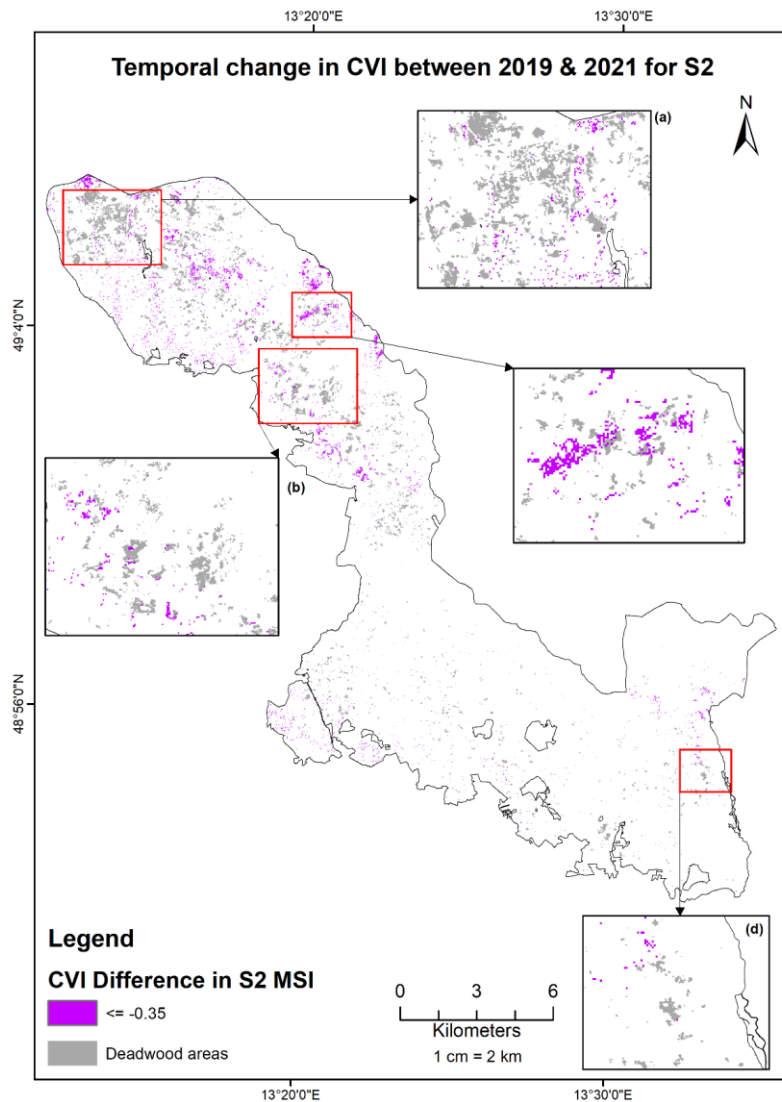
Comparison / Combination of Results
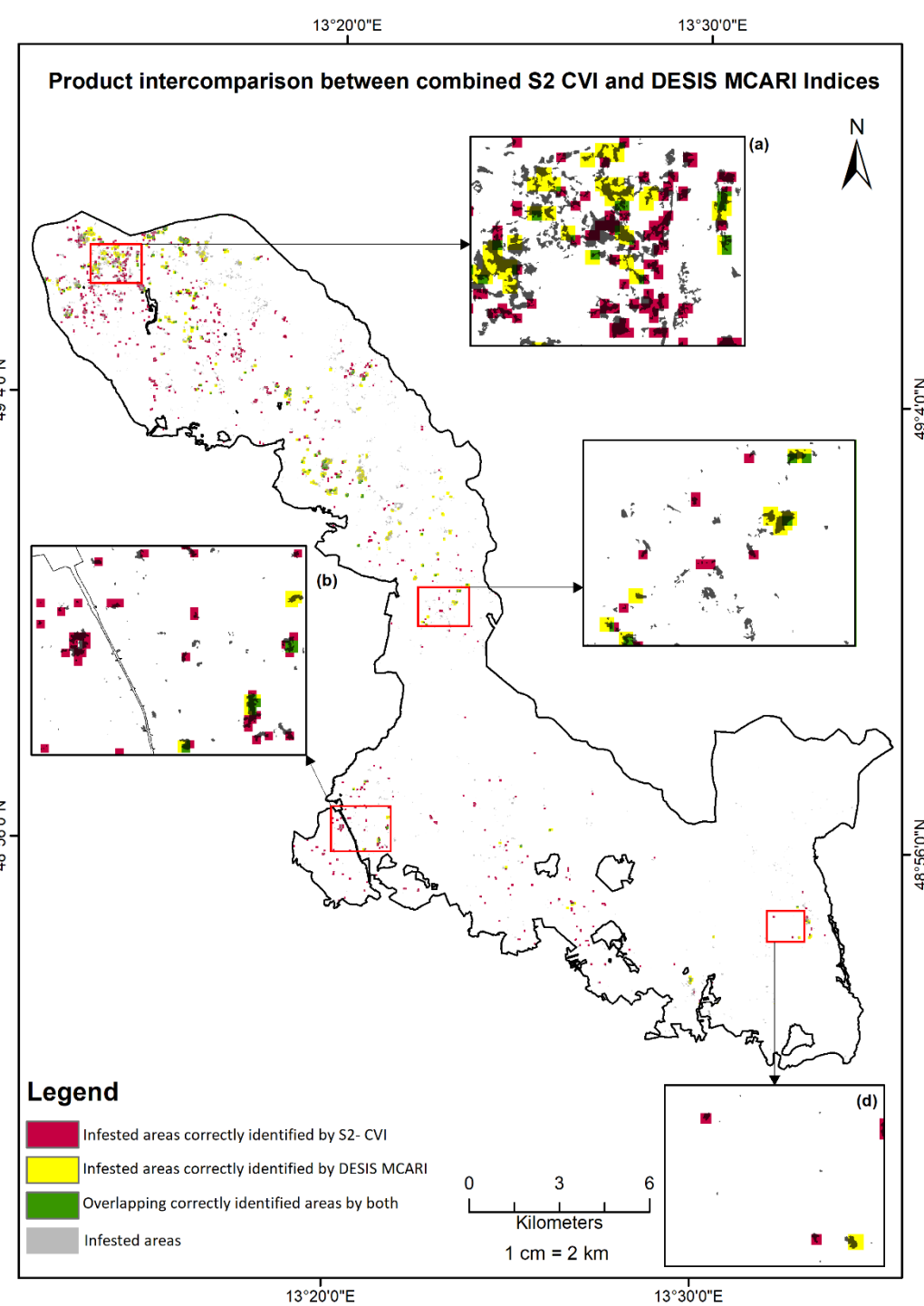
- Matching pixel size to 30m and apply buffering to reduce geometrical mismatches
- Apply morphological operator „clump" to cluster connectivity

	Infested areas (number of polygons)	Number of correctly identified polygons
All infested areas	3365	1269 / 38%
Areas > 225 m²	1439	685 / 48%
Areas > 900 m²	707	900 / 57%
Areas > 2025 m²	350	208 / 59%

	Correctly identified (DESIS)	Correctly identified (S2)	Correctly identified (DESIS ∩ S2)	Correctly identified (DESIS ∪ S2)
All infested areas	49 %	50 %	45 %	54 %

Product intercomparison between combined S2 CVI and DESIS MCARI Indices

Legend
- Infested areas correctly identified by S2- CVI
- Infested areas correctly identified by DESIS MCARI
- Overlapping correctly identified areas by both
- Infested areas

Conclusions

- DESIS data is suitable to detect changes in vegetation status over time also in **heterogeneous** natural forests

- Bark beetle infested areas can be detected with DESIS and Sentinel-2 (NO early warning!)

  ✓ Biophysical indices (esp. RedEdge parameters) reflect vegetation stress

- **Combined detection rate higher than individually**
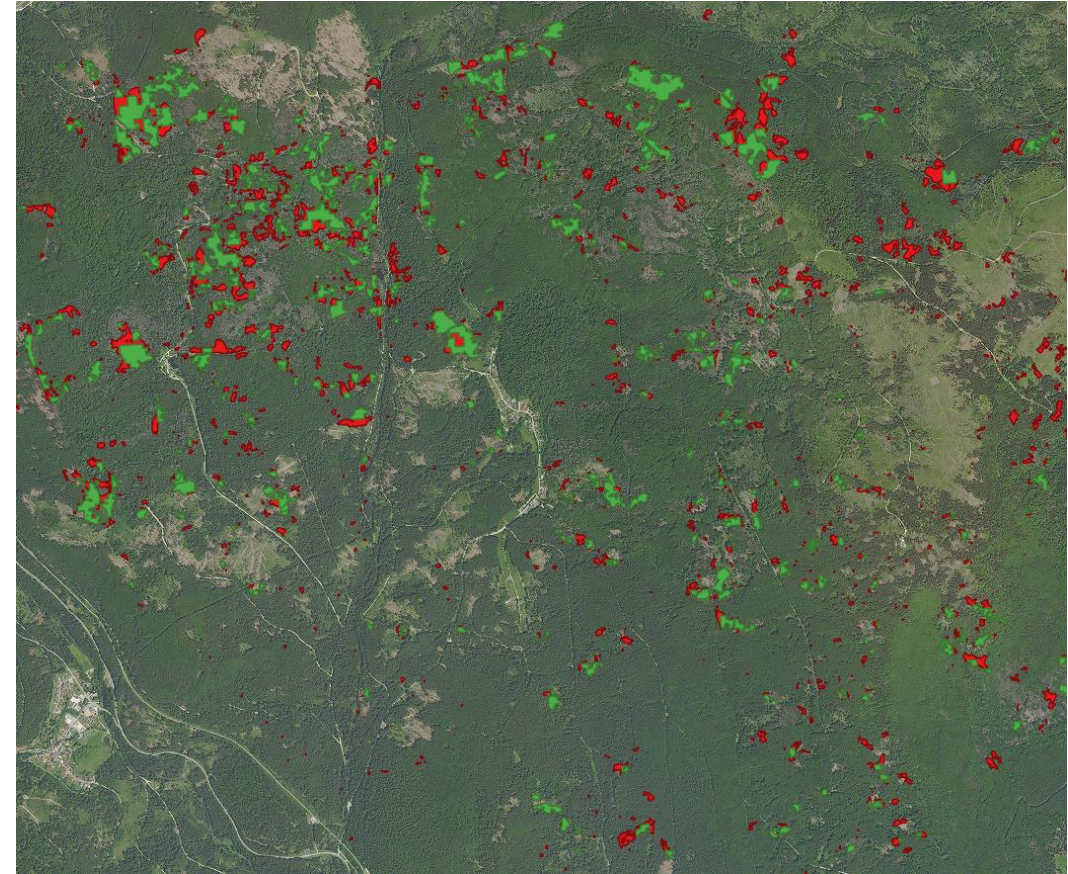
Barkbeetle infested area
Correctly identified by DESIS and Sentinel-2